STRUCTURAL BEHAVIOUR OF WASHERLESS BOLTED CONNECTIONS LOADED IN SHEAR

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ABSTRACT

The general bearing mode of failure often controls the capacity of cold-formed steel bolted connections loaded in shear. Previous research has shown that the absence of washers can significantly lower the bearing resistance of these connections. Experimental studies have also revealed that the bearing capacity can be formulated with a gradated bearing coefficient that is governed by the ratio of fastener diameter to sheet thickness.

A gradated bearing coefficient method, which was based on an investigation of bolted connections composed of mild steel as well as thin high strength steel, has recently been proposed to cold-formed steel design code committees in North America, Australia and New Zealand. However, the new bearing method does not include provisions for the design of washerless bolted connections. For this reason a total of 168 bolted connection shear tests designed to fail by bearing were performed. The test program included connections with and without washers, which were divided into single and double shear, as well as high strength steel (Grade 550) and mild sheet steel (Grade 230) categories. The thickness of the sheet steel material ranged between 0.43 mm and 1.53 mm. In addition, data for 381 washerless bolted connection specimens from previous experimental investigations was included in an evaluation of current cold-formed steel design standards and specifications. Modifications to the connection design procedure contained in the 2001 North American Specification were proposed.

RÉSUMÉ

Le mode de rupture en pression diamétrale contrôle fréquemment la résistance des assemblages boulonnés d'éléments en acier formés à froid sollicités en cisaillement. Des recherches antérieures ont démontrées que l'absence de rondelles peut diminuer de façon significative la résistance à la pression diamétrale. Des recherches expérimentales ont aussi démontrées que la résistance à la pression diamétrale peut être déterminée à l'aide d'un coefficient de pression diamétrale variant en fonction du rapport du diamètre de boulon sur l'épaisseur de la feuille d'acier.

Une méthode basée sur un coefficient de pression diamétrale, établie à partir d'une étude d'assemblages boulonnés faits d'acier doux et d'acier mince à haute résistance, a été récemment proposé aux comités des normes d'acier formés à froid d'Amérique du Nord, d'Australie et de Nouvelle-Zélande. Toutefois, la nouvelle méthode de calcul de la pression diamétrale n'inclut pas de règles pour le design des assemblages boulonnés sans rondelles. Ainsi, 168 tests sur des assemblages boulonnés conçus pour briser par la pression diamétrale ont été faits. La série de tests incluait des assemblages avec et sans rondelles, en cisaillement simple ou double, en acier à haute résistance (Nuance 550) aussi bien qu'en acier doux (Nuance 230). L'épaissseur des feuilles d'acier variait de 0.43 à 1.53 mm. En plus, des données additionnelles de 381 tests sur des spécimens d'assemblages boulonnés sans rondelles provenant de recherches précédentes ont été utilisés dans l'évaluation des normes en vigueur de design de pièces en acier formés à froid. Des modifications au méthode de calcul des assemblages contenu dans la norme nord-américaine 2002 ont été proposées.

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CHAPTER 1 INTRODUCTION

1.1 General

Cold-formed steel products have been used in the building construction industry since the 1940s. Due to their high strength to weight ratio, ease of fabrication and uniform quality, these products have been widely used as primary structural members of buildings up to six stories and secondary structural members of high-rise buildings. Cold-formed structural members can be joined by various types of connections, including; welds, screws, rivets, clinches and bolts. The behaviour of bolted connections in cold-formed steel structures is different from that in hot-rolled steel structures due to the relatively higher ratio of bolt diameter to sheet thickness. The design of bolted connections for cold-formed steel can be based on applicable national design standards, which include the North American Specification (AISI, 2001a,b; CSA, 2001), AS/NZS 4600, 1996 (Australia and New Zealand) and Eurocode 3, 1996 (Europe).

The first study on the structural behaviour of bolted connections in cold-formed steel construction was made at the University of Michigan in 1946 (Cissel and Legatski, 1946). However, the fundamental research in this area was carried out by Winter at Cornell University in the 1950s (Cornell, 1954a,b,c, 1956, Winter, 1956a,b) From these experimental investigations four basic types of failure modes for bolted connections loaded in shear were initially observed. These failure modes included end pull-out, net section fracture, bearing and bolt shearing. Winter also proposed corresponding design equations for each type of failure. An overview of this systematic investigation can be found in Section 2.1.1. In the following years, additional research programs on bolted connections were carried out, *e.g.* Dhalla (1971), and Popowich (1969). However, only bolted connections with washers located under both the head and nut were included in these test programs. Essentially washers may not be installed in construction, although engineers typically stipulate that bolts with washers must be used. Two experimental investigations on the behaviour of washerless connections were performed by Chong and Matlock (1975) and Gilchrist and Chong (1979), which revealed that for mild sheet steels with thickness greater than 0.52 mm, the bearing resistance of a bolted connection is dependent on the presence of washers, where in all cases the lack of washers has a detrimental effect on the load carrying capacity.

With the improvement of manufacturing technology, thin ($t < 0.9$ mm) high strength ($F_y \approx 550$ MPa) sheet steels were recently introduced to the building construction industry. Due to the low ductility exhibited by this type of material, a result of the cold reduction manufacturing process, when designing with the North American Specification for the Design of Cold Formed Steel Structural Members (AISI, 2001a; CSA, 2001) engineers must use a yield stress and ultimate strength reduced to 75% of the minimum specified values. Rogers and Hancock carried out a series of experimental investigations on high strength Grade 550 sheet steels at the University of Sydney from 1996 to 1998 (Rogers and Hancock, 1997,1998a,b,c, 1999). The topics of these investigations included the mechanical properties and the structural behaviour of bolted and screwed connections made of thin high strength sheet steels. It was revealed that a need for a gradated bearing coefficient based on the ratio of fastener diameter to sheet thickness exists. This modification to the bearing design provisions for thin sheet steels is necessary to account for the reduced bearing resistance of the connected materials, because of the decrease in stability at the bolt hole edge. Proposals have been put forth to cold-formed steel design standard code committees in North America, Australia and New Zealand to revise the current bearing rules for thin sheet steels. However, these revisions need to be updated with information concerning the bearing behaviour of similar connections without washers. Wallace *et al.* (2000) carried out an experimental investigation of the behaviour of washerless bolted connections and studied the results from previous research programs on similar connections. The design recommendations from Rogers and Hancock and Wallace *et al.* have been adopted by the recently published North American Specification for the

Design of Cold-Formed Steel Structural Members (AISI, 2001a; CSA, 2001). However, the experimental research by Wallace *et al.* did not include connections made of thin, high strength sheet steels. Furthermore, most of the specimens (78 out 119) in the experiments by Wallace *et al.* were double shear connections with the thinner sheets placed outside. For this reason a systematic study of the structural behaviour of bolted washerless connections made of both mild and high strength steels was necessary.

1.2 Purpose Of Investigation

The objectives of this research project are as follows:

1. To observe the behaviour of bolted sheet steel connections that do not contain washers.
2. To determine the adequacy of current design methods in the prediction of load carrying capacity.
3. To revise the design equations for bearing resistance to account for the influence of sheet thickness and fastener diameter.
4. To provide guidelines for the design of sheet steel connections where bolts without washers are used.
5. To revisit all of the existing data for washerless bolted connections and to propose modifications to the current North American, Australian and New Zealand as well as European cold-formed steel design standards in the area of bolted connection design involving all possible failure modes.

1.3 Scope Of Investigation

In this research project, two types of sheet steel were selected to be tested, that is high strength ($F_y \approx 550$ MPa) and mild grade ($F_y \approx 230$ MPa) steel. The nominal thicknesses of the steel specimens ranged from 0.43 mm to 1.53 mm. The high strength steel included nominal thicknesses of 0.43, 0.64, and 0.76 mm; whereas the mild steel specimens were composed of 0.43, 0.64, 0.76, 0.91, 1.21, and 1.53 mm thick sheets. The bolt diameters were 1/4, 3/8, 1/2 and 5/8 in. (6.35, 9.53, 12.7 and 15.9 mm). The connection configurations were also varied with respect to the placement of the different sheet steels. Single shear loading was used for the mild steel specimens, which were composed of either two equal or two different thickness sheets. This steel type was also used in the composition of the double shear connections, where a thinner sheet was located on the inside of the connection. Only the single shear type of configuration with equal thickness sheets was used for the high strength steel connections. In total, 168 tests were carried out for this research investigation and an additional 381 tests from existing studies were utilized. Information from the following previous experimental investigations on washerless bolted connections is also contained in this thesis:

1. Chong and Matlock (1975)
2. Gilchrist and Chong (1979)
3. Yu and Mosby (1978)
4. Carril, LaBoube and Yu (1994)
5. Wallace, Schuster and LaBoube (2001)

A number of cold-formed steel design specifications are also reviewed and used in the analysis of test data:

1. North American Specification (AISI, 2001a; CSA, 2001)
2. AISI (1999)
3. CSA-S136 (1994)
4. AS / NZS 4600 (1996)
5. Eurocode 3 (1996)

CHAPTER 2 LITERATURE AND DESIGN STANDARD REVIEW

2.1 Previous Tests of Thin Sheet Steel Bolted Connections

The focus of this section is to summarize previous experimental works that pertain to the behaviour and capacity of cold-formed steel bolted connections, and to develop the background for the research that was undertaken for this thesis. Most of these studies were carried out on bolted connections with washers placed under both the nut and the head of the bolt, *e.g.* Cornell (1954a,b,c and 1956), Winter (1956a,b), Dhalla *et al.* (1971), Popowich (1969), and Rogers and Hancock (1997, 1998a,c and 1999). However, some tests of bolted connections without washers have been performed as well. Information on these tests can be found in Chong and Matlock (1975), Gilchrist and Chong (1979), Yu and Mosby (1976, 1978), Carril *et al.* (1994), as well as Wallace *et al.* (2001).

2.1.1 Winter (1950s and 1971)

In the 1950s, a systematic investigation of the behaviour of cold-formed sheet steel bolted connections was carried out at Cornell University (Cornell, 1954a,b,c and 1956; Winter, 1956a,b). The research project was divided into two phases, where for the first phase a total of 574 tests were completed. The majority of specimens, single bolt (526) and double bolt connections (48), were tested either in single shear (285), as well as double shear (289). Steels used in Phase 1 of the test program were normal strength with a yield value ranging from 26 to 36 ksi (179 to 248 MPa), and high strength with a yield value ranging from 46.7 to 56.5 ksi (322 to 389 MPa). The ratio of ultimate to yield strength, F_u/F_y, for the different materials was reported to be from 1.21 to 1.58. The sheet thickness ranged from 0.035 in. (0.89 mm) to 0.1644 in. (4.18 mm). The edge distance, e, measured from 1.25d to 9.0d, where d is the bolt diameter. The ratio d/s (where s is the spacing of bolts perpendicular to the direction of stress or the full specimen width for single bolts) was from1/16 to 6/16. Bolt diameters were 1/4, 3/8, 1/2, 5/8, 3/4 and 1 in (6.35, 9.53, 12.7, 19.1

and 25.4 mm). The torques applied to the bolts were as listed in Table 2.1

Table 2.1 Standard Torques (Winter, 1956a)

Bolt Diam. (in.)	Torque (ft.lb)	Torque (Nm)
1/4	5	6.78
3/8	14	19.0
1/2	40	54.2
5/8	50	67.8
3/4	110	149
1	250	339

Based on the results of the research program Winter classified all test specimens according to the four basic failure modes that were observed.

I. End Pull Out:

Longitudinal shearing of the sheet along two parallel lines. (Fig.2.1a)

II. Bearing:

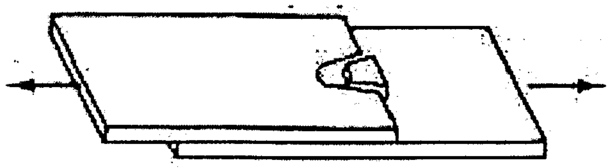
Bearing failure of the sheet. (Fig.2.1b)

III. Net Section Fracture:

Transverse tearing of the net section. (Fig.2.1c)

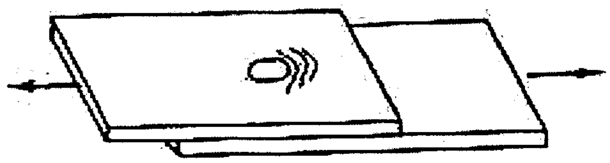
IV. Bolt shearing:

Shearing of the bolt. (Fig.2.1d)



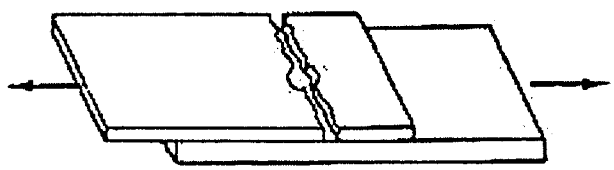
(a)

Type I. End Pull Out Failure



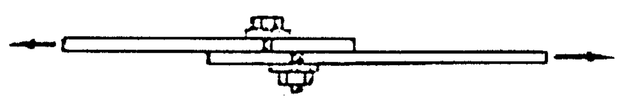
(b)

Type II. Bearing Failure



(c)

Type III. Net Section Fracture



(d)

Type IV. Bolt shearing

Figure 2.1 Failure Modes of Bolted Connections (Yu, 2000)

Design formulae for the prediction of the shear capacity of a bolted connection were proposed for the distinct failure modes, as shown below. However, Winter also indicated that a number of connections failed in a combined mode instead of one of the distinct modes show above. Specific design procedures were not developed for these combined modes of failure.

I. End Pull Out: when the e/d ratio does not exceed 3.5, this type of failure is often observed.

$$P_f = 1.40\ e\ t\ \sigma_y \qquad \text{Eq.2.1}$$

where, σ_y is the yield strength , e is the distance from the centre of the bolt hole to the end of the sheet, and t is the thickness of sheet steel.

II. Bearing: when the e/d ratio exceeds 3.5, Type II bearing failure tends to occur.

$$P_f = 4.9\ d\ t\ \sigma_y \qquad \text{Eq.2.2}$$

where d is bolt diameter.

III. Net Section Fracture:

$$P_f = (0.1 + 3.0\ d/s)\ \sigma_t\ A_{net} \leq \sigma_t\ A_{net} \qquad \text{Eq.2.3}$$

where A_{net} and σ_t are the net section area and the tensile strength, respectively, and s is the spacing of bolts perpendicular to the direction of stress or the full width of the sheet for a single bolt. It should be noted that Eq.2.3 was only recommended for connections with single or multiple bolts perpendicular to the direction of load.

IV. Bolt shearing:

$$P_f = 0.60\ \sigma_{tb}\ A_{root} \qquad \text{Eq.2.4}$$

where σ_{tb} is the bolt tensile strength and A_{root} is the cross-sectional area of the bolt at the root of the thread.

In the Phase 1 tests, most connections exhibited significant joint deformation at ultimate load, which included clearance slip between the bolt and the oversize hole, as well as plastic deformation of the sheet steels. Hence, Winter suggested that the deformation slip at the design load should not exceed 1/16 in (1.6 mm). Also, it should be noted that in these experimental works no significant behavioural difference was observed between double- and single-shear, as well as single and multiple bolts arranged in a line perpendicular to the applied force.

The second phase of the project consisted of 476 tests on similar connections composed of high strength, high torqued bolts (Cornell 1956, and Winter, 1956b). The purpose of these tests was to investigate the difference in behaviour between bolted connections with ordinary bolts and those made with high strength, high torqued bolts. Three types of faying surfaces; bare, galvanized and painted, were used to determine the influence of the coefficient of friction on connection performance. All specimens were fabricated with single high strength, high torqued bolts, in both the single and double shear configuration. Among the 476 specimens tested in total, 362 were made from normal and high strength bare steels, whose mechanical properties are as found for the Phase 1 specimens. The number of specimens fabricated from painted and galvanized steels were 54 and 60, respectively. The yield strength of the painted steels ranged from 36.5 ksi to 46.2 ksi (252 to 318 MPa), and for the galvanized steels from 41.3 ksi to 45.5 ksi (285 to 314 MPa). Sheet thicknesses ranged from 0.036 in. (0.91 mm) to 0.164 in. (4.17 mm). The ratios of F_u/F_y for all steels used in these tests varied from 1.21 to 1.58. Table 2.2 gives the torques for the high strength, high torqued bolts used in the Phase 2 tests.

The connection behaviour that was observed can be divided into two modes. Most tests progressed in a similar fashion to that observed in Phase 1, in which the connection slipped into bearing at a load lower than the ultimate strength. In contrast, about 10% of the total Phase 2 tests experienced a significantly high slip load followed by sheet failure at a reduced load level. This was an indication that the initial slip took place at a higher load level than the ultimate bearing capacity of the connection. Only those tests in which the connection slipped into bearing at a load lower than the ultimate strength were studied in Winter's report (Winter 1956b). The four failure modes from Phase 1 were again observed, for which equations 2.1 to 2.4 could be used to satisfactorily predict the tested shear capacity of the connections with high strength, high torqued bolts. The tests also showed that the slip load increases with bolt diameter, although the galvanized specimens slipped at lower loads than the painted specimens. In addition, the bare specimens showed more scattered results than the galvanized and painted sheets, which was attributed to their manufacturing history. Finally, two equations were proposed to predict the slip loads for connections with high strength, high torqued bolts.

For painted or bare steel

$$P_s = 25{,}000\ A_{root} \quad \text{(lb)} \qquad \text{Eq.2.5}$$

For galvanized steel

$$P_s = 21{,}500\ A_{root} \quad \text{(lb)} \qquad \text{Eq.2.6}$$

where A_{root} (in^2) is as defined in Eq. 2.4.

Table 2.2 Torques for High Strength, High Torqued Bolts (Winter 1956b).

Bolt Diam. (in.)	Torque (ft.lb)	Torque (Nm)
1/4	11	14.9
3/8	37.5	50.8
1/2	95	129
5/8	190	258
3/4	335	454

Dalla, Errera Winter (1971) and Dalla (1971) published the results of an experimental program on the structural behaviour of cold-formed members made from low ductility steel. As a part of the investigation, 59 single bolted, single shear connections were tested. The materials used for the connection specimens exhibited very limited uniform ductility but good local ductility, which means that although the steel did not possess a significant strain hardening range, considerable plastic deformation in a localized area could be expected. The elongation measured for the 2 in. (50 mm) and 1/4 in. (6.35 mm) gauge lengths ranged from 1.51% to 6.84% and from 6.09% to 35.2%, respectively. The average ratio of F_u/F_y was 1.03 and F_u varied from 72.8 to 99.8 ksi (502 to 688 MPa). The sheet thicknesses ranged from 0.038 in. (0.97 mm) to 0.183 in. (4.65 mm). The following variables were considered: bolt diameter from 3/16 to 7/8 in. (4.76 to 22.2 mm), e/d from 0.83 to 5.33; d/s from 0.09 to 0.50; and t/d from 0.051 to 0.488. The bolts were assembled with washers under both the nut and head; in addition most bolts were finger tightened, although 13 were hand torqued (no values provided). No significant difference in connection capacity was observed for the tests with the different bolt tightening methods. All specimens were designed to fail in the sheet by one of the three modes described previously (Figures 2.1a, b and c). Compared with the high ductility steels, the connections composed of low ductility sheet steel exhibited a lower end pull-out and bearing capacity, although a similar net section capacity was reached. From the test results, design equations for end pull out and bearing failure, similar to those given in Eqs. 2.1 and 2.2, were obtained:

For end pull out, when the e/d ratio is not larger than 3.33,

$$P_f = 0.9\ e\ t\ \sigma_y \qquad \text{Eq.2.7}$$

For bearing, when the e/d ratio exceeds 3.33,

$$P_f = 3.0\ d\ t\ \sigma_y \qquad \text{Eq.2.8}$$

An alternate formula for bearing and the combination of end pull-out, net section fracture and bearing was obtained provided $2.25 \le e/d \le 3.30$ and $3.33 \le s/d \le 6.00$:

$$P_c = (0.32(e/d + s/d + 1) - 0.04d/t)\ d\ t\ \sigma_t \qquad \text{Eq.2.9}$$

where s is the bolt distance perpendicular to the direction of load, or the width of the specimen for single bolt connections.

2.1.2 Popowich (1969)

Popowich carried out a total of 41 tests, divided into four groups, to investigate the tension capacity of shear loaded connections with multiple bolts parallel to the applied force (1969). The following variables were considered: bolt diameter, 1/4 to 1 1/8 in. (6.35 mm to 28.6 mm) sheet thickness, 0.0598 to 0.1793 in. (1.52 mm to 4.55 mm); edge distance, 2.3d to 6.8d; d/s ratio, 0.0834 to 0.281; yield strength, 29.6 to 86.3 ksi (204 to 595 MPa); tensile strength, 44.3 to 86.3 ksi (305 to 595 MPa); elongation for 2 in. (50 mm) gauge length, 4.91% to 50.1%.

All of the 25 specimens in Group 1 were made from a high ductility steel with a 2 in. gauge elongation from 26.2% to 49.2%, and were proportioned such that failure due to fracture at the net section would take place. Although the intent of testing the Group1 specimens was to determine the tensile capacity of two bolt connections with high ductility material, an additional 13 tests of single bolt connections were performed as well. In Group 1, 10 out of the 25 specimens were fabricated with a washer placed under the nut, although no washer was installed under the head of the bolt. The bolts for these 10 specimens were finger tightened, hence it can be assumed that no torque was applied. Washers were installed under both the nut and the head of the bolt for the remaining 15 specimens in Group 1, and a torque listed in Table 2.3 was applied. Group 3 comprised of four tests that were conducted to investigate the tensile capacity of two bolt connections with different sheet thickness. In order to compare the behaviour of connections with and without initial bearing, one of the four specimens in Group 3 was prepared such that the bolt would bear on the sheet steel and no slippage would occur. Group 2 (4 tests) and Group 4 (8 tests) were designed in order that the tensile capacity of three bolt connections made from high ductility steel and low ductility steel, respectively, could be determined. The nominal 2 in. (50mm) gauge length elongation of the sheet materials used for the Group 4 connections ranged from 5% to 9%. All bolts in Groups 2, 3 and 4 were torqued with the values shown in Table 2.3

In Group 1, the bolt head of finger tightened connections with only one washer under the nut dug into the sheet steel and caused failure to occur at approximately 80% of the load level of specimens with washers under both the nut and the head of bolts. Connections composed of sheets of different thickness did not show a significant difference, in terms of net section capacity, compared with equal thickness sheet specimens. Comparing the behaviour of one, two and three-bolt connections, Popowich found that as the number of bolts increased, the bolted connection exhibited much higher net section capacity. A universal equation was proposed to predict the net section capacity of either single or multiple bolted connections:

$$P_f = (1.0 - 0.9r + 3.0\, r\, d/s)\, \sigma_t\, A_{net} \leq \sigma_t\, A_{net} \qquad \text{Eq.2.10}$$

where r is the ratio of the force transmitted by the bolt or bolts at the section considered to the tension force in the member at the critical section. The test results also implied that connections comprised of low ductility steels performed better than those of high ductility steels. Popowich explained that the low ductility steel normally possesses higher tensile strength in comparison to high ductility steel and that only the coupon tensile strength was used rather than the complete strain-stress curve when the connection data was analyzed.

Table 2.3 Standard Torques (Popowich, 1969)

Bolt Diam.	Torque	
(in.)	(ft.lb)	(Nm)
1/4	5	6.78
3/8	14	19.0
1/2	40	54.2
5/8	50	67.8
3/4	110	149
1	250	339
1 1/8	275	373

2.1.3 Chong and Matlock (1975)

The purpose of this research was to investigate the behaviour of bolted connections without washers subjected to shear loading (Chong and Matlock, 1975). A total of 79 tests, among which 56 were bolted without washers, were performed for this experimental project. All specimens were fabricated as single shear connections with one, two or three bolts either perpendicular to or along the direction of load. Furthermore, five lapped joints with lips were tested to study the effect of free edge warping on connection capacity. The sheet thickness ranged from 0.037 in. (0.94 mm) to 0.104 in. (2.64 mm), with three types of surfaces, black, painted and galvanized. The yield strength varied from 40.6 to 59.3 ksi

(280 to 409MPa) and the tensile strength varied from 50.1 to 74.1 ksi (345 to 511 MPa). The F_u/F_y ratios of all sheet types were larger than 1.1. The bolt diameters used for the tests were 5/16, 1/2 and 3/4 in.. The edge distance ranged from 1.0d to 7.0d, and the ratio of s/d was varied from 2.0 to 13.2. The torques used in the tests were similar to those implemented by Winter (1956a) (Table 2.1), except that six bolts were torqued to a level 75% greater than that listed by Winter (1956a). The result of the tests showed that this variable did not affect the ultimate strength of the bolted connections.

Four failure modes, similar to those described by Winter (1956a) were reported. Also, significant bolt tilting and free edge warping was generally observed for connections with flat sheets when the load reached about 85% of its ultimate value. However, connections with lips did not show noticeable free edge warping, nor was a significant difference in the ultimate strength recorded. Three design equations, similar to Eqs. 2.1, 2.2 and 2.3 were proposed for bolted connections without washers:

For end pull out: $e/d \leq 2.5$:

$$P_f = 1.08\ e\ t\ \sigma_y \qquad \text{Eq.2.11}$$

For bearing: $e/d \geq 2.5$:

$$P_f = 2.7\ d\ t\ \sigma_y \qquad \text{Eq.2.12}$$

For net section fracture:

$$P_f = (0.6 - 0.66r + 2.92\ d/s)\ \sigma_t\ A_{net} \leq \sigma_t\ A_{net} \qquad \text{Eq.2.13}$$

Also, the authors indicated that Eq. 2.12 can be used for either single or multiple bolted connections regardless of the bolt pattern.

2.1.4 Gilchrist and Chong (1979)

A supplemental research program to that completed by Chong and Matlock (1975) was initiated by Gilchrist and Chong (1979). The objective was to study how bolted connections comprised of sheet steels thinner than those used by Chong and Matlock performed under shear loading when no washer was placed under the nut and the head of the bolt. All of the 30 specimens were fabricated as single shear, single bolted connections without washers. The sheet thicknesses ranged from 0.0204 in. (0.52 mm) to 0.0273 in. (0.69 mm), with yield strengths from 40.8 ksi to 56.5 ksi (281 to 389 MPa), and tensile strengths from 50.7 ksi to 59.7 ksi (349 to 411 MPa). The ratio of F_u/F_y varied from 1.06 to 1.24. Other pertinent variables were as follows: bolt diameter, 1/4, 3/8 and 1/2 in. (6.35, 9.53 and 12.7 mm); e/d, 2.0 to 4.0; s/d, 8.0 to 16.0; d/t, 9.16 to 18.38. All specimens failed by bearing or a combination of bearing and end pull-out accompanied by tears at 45° to the hole, or by a punch shear failure caused by bolt tilting. A lower bearing and end pull-out capacity was observed in these tests in comparison to the results obtained by Chong and Matlock (1975). Similar design equations were recommended:

For end pull out: $e/d \leq 2.5$:

$$P_f = 0.96\ e\ t\ \sigma_y \text{ or} \qquad \text{Eq.2.14}$$

$$P_f = 0.84\ e\ t\ \sigma_u \qquad \text{Eq.2.15}$$

For bearing: $e/d \geq 2.5$:

$$P_f = 2.4\ d\ t\ \sigma_y \text{ or} \qquad \text{Eq.2.16}$$

$$P_f = 2.1\ d\ t\ \sigma_u \qquad \text{Eq.2.17}$$

Also, the authors suggested that Eq. 2.13 be used to predict the net section capacity of bolted connections similar to those tested in the experimental investigation.

2.1.5 Yu and Mosby (1976 and 1978)

Two experimental projects on bolted connections were conducted by Yu and Mosby (1976 and 1978). In the first project, 50 tests were carried out to study the effects of torque and washers on the bearing and shear strength of single and double shear connections. The specimens were either not torqued or had values similar to those listed in Tables 2.1 and 2.2. Of the 50 specimens, 15 were double shear connections (3 with washers and 12 without washers) and 35 were single shear connections (13 with washers and 22 without washers). Other relevant test specimen characteristics were as follows: sheet thickness: 0.024 in. (0.61 mm) to 0.047 in. (1.19 mm); e/d ratio: 1.50 to 4.50; d/t ratio: 8.93 to 20; F_u / F_y: 1.16 to 1.27; and bolt diameter: 1/2 in. (12.7 mm), 3/8 in. (9.525 mm) and 1/4 in. (6.35 mm). Three types of failure modes were documented, including end pull-out, bearing and an additional mode which had not been documented before. This was defined by Yu and Mosby as tearing "due to excessive bolt rotation and warping of sheets" (Yu and Mosby, 1976). The newly defined failure mode occurred only for the single shear washerless connections with the sheet thickness no greater than 0.036 in. (0.91 mm). The resulting calculated bearing stress at failure was in the range of $1.5F_u$. Yu and Mosby also concluded that for those single shear connections with sheet thickness less than 0.036 in. (0.91 mm) the reduction in the bearing stress resulting from the elimination of washers is approximately 40%. For double shear connections without washers and single shear connections with washers that failed in bearing, Yu and Mosby indicated that the ratio of the bearing stress to the ultimate strength of the steel sheet were 2.2 and 3.0, respectively. The authors also suggested that for single shear connections, with or without washers, that failed in end pull-out failure the ratio of the bearing stress to the ultimate strength of the material approximately equals the ratio of e/d, although this relation is valid only when e/d does not exceed 3.0 for connections with washers and 2.2 for connections without washers. By comparing the differently torqued connections, the authors also concluded that the effect of torque has little effect on the bearing capacity of single shear connections without washers.

The second phase of the experimental investigation was conducted in 1978 and provided more in-depth information on the effect of torque on the bearing capacity of bolted connections (Yu and Mosby, 1978). A total of 370 specimens were prepared as single bolted connections either with or without washers. Amongst these specimens, 178 were single shear connections and 192 were double shear connections. Specimen dimensions were selected in order to prevent the possibility of cross-section tensile or bolt shearing failure. The e/d ratios were approximately 3.5 for the connections with washers and 2.2 for those without washers to ensure that longitudinal tear out would not occur before bearing failure. Hence, only bearing failures were expected for all of the tests. Included in each group were six to ten specimens of identical assembly, sheet thickness and bolt diameter, as well as similar e and s values. However, the torques applied to the bolts varied from finger tight (0 torque), to low torque (5 to 110 ft-lb or 5.78 to 149 Nm) to high torque (110 to 335 ft-lb or 149 to 454 Nm). The following variables were also selected for the test specimens: bolt diameters, 1/4, 1/2 and 3/4 in. (6.35, 12.7 and 19.1 mm); sheet thickness, 0.014 to 0.184 in. (0.36 to 4.67 mm); d/t ratio, 4.076 to 17.86; yield strength F_y, 39.0 to 70.6 ksi (269 to 486 MPa); tensile strength F_u, 46.9 to 80.8 ksi (323 to 557 MPa); and the ratio of F_u/F_y, 1.116 to 1.321.

Two ratios, $(\sigma_b)_O/(\sigma_b)_L$ and $(\sigma_b)_H/(\sigma_b)_L$, which were believed to represent the reduction of the bearing strength by using the finger tight condition and the increase of the bearing strength due to the use of high torque, were closely studied. The variables $(\sigma_b)_O$, $(\sigma_b)_L$ and $(\sigma_b)_H$ were defined as the average value of two identical tests with zero, low and high torque, respectively. The authors concluded that the effect of torque on the bearing strength of connections was dependent on the following three variables, d/t ratio, the use of washers and the type of connections (single or double shear). The following eight equations were obtained:

For single shear connection with washers

$$(\sigma_b)_O / (\sigma_b)_L = 1.044 - 0.0124\ (d/t) \qquad \text{Eq. 2.18}$$

$$(\sigma_b)_H / (\sigma_b)_L = 0.843 + 0.0249\ (d/t) \qquad \text{Eq. 2.19}$$

For double shear connection with washers

$$(\sigma_b)_O / (\sigma_b)_L = 0.966 - 0.0157\ (d/t) \qquad \text{Eq. 2.20}$$

$$(\sigma_b)_H / (\sigma_b)_L = 1.010 + 0.0050\ (d/t) \qquad \text{Eq. 2.21}$$

For single shear connection without washers

$$(\sigma_b)_O / (\sigma_b)_L = 0.989 - 0.0070\ (d/t) \qquad \text{Eq. 2.22}$$

$$(\sigma_b)_H / (\sigma_b)_L = 0.882 + 0.0193\ (d/t) \qquad \text{Eq. 2.23}$$

For double shear connection without washers

$$(\sigma_b)_O / (\sigma_b)_L = 0.994 - 0.0068\ (d/t) \qquad \text{Eq. 2.24}$$

$$(\sigma_b)_H / (\sigma_b)_L = 1.074 - 0.0029\ (d/t) \qquad \text{Eq. 2.25}$$

From the above equations, the authors concluded that the ratio of $(\sigma_b)_O / (\sigma_b)_L$ tends to decrease as the d/t ratio increases particularly for the single and double shear connections with washers and the ratio of $(\sigma_b)_H / (\sigma_b)_L$ increases as the d/t ratio increases particularly for single shear connections with and without washers.

As far as the effect of washers, the authors concluded that the use of washers could significantly increase the bearing capacity of single bolted connections because failure caused by extensive rotation of the bolts would be limited. However, the use of washers has a less significant impact on the bearing capacity of the inside sheet of double shear connections because bolt rotation does not occur due to the configuration of the sheets.

2.1.6 Carril, LaBoube and Yu (1994)

This experimental study was undertaken to investigate the bearing and tensile behaviour of bolted connections subjected to in-plane shear loads, along with their interaction. Furthermore, an evaluation of the bearing and net section capacity design procedures contained in the AISI (1986) and AISC (9^{th} Edition, 1989) Specifications was carried out. Finally a serviceability design criteria for bolted connections was developed (Carril *et al.*, 1994). The 75 single shear connections consisted of 5 different bolt patterns as shown in Figure 2.2. A total of 25 connections were fabricated with washers and 50 without washers. All tests were designed to fail by bearing, net section fracture or the combination of bearing and net section fracture. The ratios of d/s were 0.12, 0.15 and 0.31 for the three thickness sheet steels (0.04, 0.07 and 0.12 in. (1.016, 1.778 and 3.048 mm)). The e/d ratios of all specimens were set at approximately 4 to prevent the end pull-out failure mode from occurring. A single bolt type, 1/2 in. diameter A325T, and a consistent level of torque were used to achieve similar bolt tightness for all connection specimens. The following mechanical properties were measured for the sheet steels: yield strength, 32.1 to 36.6 ksi (221 to 252 MPa); tensile strength, 52.5 to 55.8 ksi (362 to 385 MPa); and F_u/F_y ratio, 1.45 to 1.64.

A bearing strength equation to limit the deformation around the bolt hole to about 1/4 in. (6.35 mm) was proposed:

$$P_n = 1.93\ d\ t\ F_u \qquad \text{Eq. 2.26}$$

The 9^{th} edition of the AISC Specification contains the following bearing and net section fracture resistance equations.

For bearing capacity:

$$P_n = 3\ d\ t\ F_u \qquad \text{Eq. 2.27}$$

For net section fracture capacity:

$$T_n = 0.5\ A_e\ F_u \qquad \text{Eq. 2.28}$$

where the A_e is the effective net cross section area, F_u is the ultimate strength of the material, the d and t are the bolt diameter and sheet thickness, respectively.

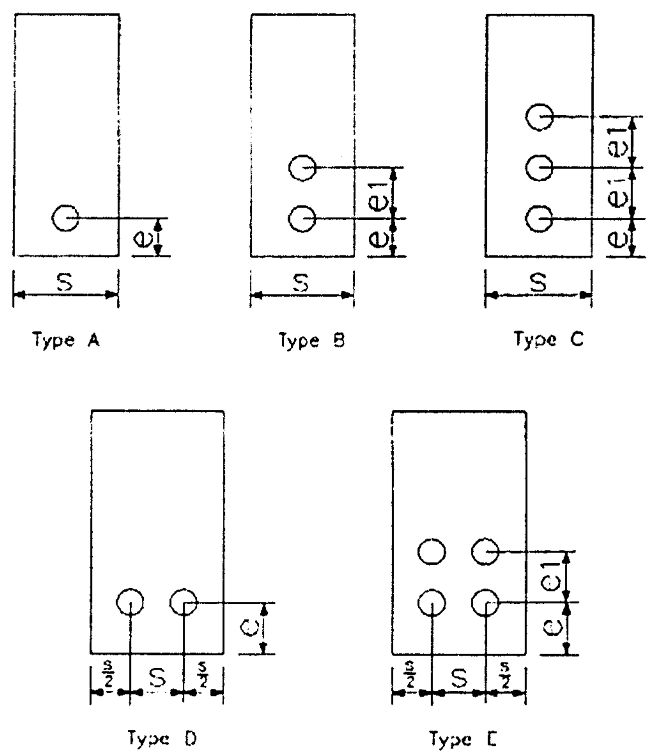


Figure 2.2. Bolt Pattern Configuration (Carril *et al*, 1994)

The methods to predict the bearing and net section fracture capacity in the AISI (1986) Specification are as detailed in Section 2.2.2 of this thesis. Comparing the test results with the predicted bearing and net section capacities using both the AISI (1986) and the AISC (9^{th} Edition) Specifications, Carril *et al.* concluded that the AISI was better than the AISC in terms of predicting the ultimate bearing capacity, however, both specifications provided satisfactory results when used to predict the net section failure capacity.

2.1.7 Rogers and Hancock (1997 and 1998a,b)

Rogers and Hancock carried out a series of experimental investigations on high strength G550 sheet steels at the University of Sydney from 1996 to 1998 (Rogers and Hancock, 1997,1998a,b). Only the test results that include the behaviour of bolted connections will be discussed herein. A total of 158 bolted connections were tested, involving three different sheet steels. This included two high strength G550 steels with thicknesses of 0.42 mm and 0.60 mm, as well as a mild grade 0.60 mm G300 sheet steel, which provided data for comparison with the then current design standards. The static tensile strength of the G550 steels ranged from 686 to 794 MPa and a F_u/F_y ratio of unity was typically measured. The static tensile strength and yield strength of the G300 steel was 410 MPa and 355 MPa, respectively, with a ratio of F_u/F_y of 1.15. In order to investigate the anisotropic effect of the sheet steels, blanks were cut from three different directions in the sheet with respect to rolling direction: longitudinal, transverse and diagonal. The various tests were designed to fail by end pull-out, bearing and net section fracture. Only M12 Grade 8.8 galvanized bolts (0.5 in.) having either integral or conventional washers were used. Of the 158 specimens, 60 were of the single-bolt configuration with varying e/d ratios (0.82 to 4.2) and s/d ratios of approximately 5.2. Fifty-six specimens were constructed with multiple-bolts for which the s/d ratio ranged from 3.8 to 6.6, the edge distance was 48 mm, and the bolt spacing was typically 36 mm. Forty-two winged single bolt connections (the common flat sheet had stiffening lips along its edges) with e/d values varying from 1.67 to 3.38 and an approximate s/d ratio of 5.24 were also tested. All multiple-bolted connections consisted of either two or three bolts in line with the applied load, including 39 specimens whose ends were secured with clips to prevent out of plane curling. The winged connections were included so that the restraining effect of the different elements in a structural profile could be simulated. Fourteen eccentrically loaded connections were also tested to determine the effect of load application point on behaviour and capacity. The torque applied to all bolts was less than 10 Nm (7.12 ft-lb), which allowed the connections to slip at relatively low loads.

Eighteen additional tests were completed in 1998 (Rogers and Hancock, 1998a) with the intent of determining the variation in bearing coefficient for the different connection configurations. All specimens contained either one or two bolts and were designed to fail by bearing of the sheet steel. Test components were cut from three directions in the sheet in a similar fashion to that noted above, although the materials used were high strength G550 steel with either a 0.8 or 1.0 mm thickness, and mild G300 steel with a 0.8 mm thickness. The mechanical properties of the steels were similar to those recorded for the previous tests, except that the F_u/F_y ratio of the 1.00 mm G550 steel was 1.04. For this second series of tests only the integral M12 Grade 8.8 galvanized bolts were used. The d/t ratios of all specimens were either 18.1 or 14.4 depending on the sheet thickness.

A type of failure mode named as localized tearing by authors was distinguished. The tears generally occur at bolt holes of mild steel connections, extend in a diagonal direction towards the end of test specimens, causing an extreme out-of-plane deformation and bearing distortion of sheets. The authors classified the localized tearing as bearing failure instead of net section fracture because it is caused by a combination of high bearing stress and through thickness shear stress.

Results from these tests revealed that in general the then current design standards could not correctly predict either failure modes or bearing capacity of bolted connections. A gradated bearing resistance equation similar to that found in the CSA-S136 Design Standard (1994) was proposed:

$$V_b = C\, d\, t\, F_u \qquad \text{Eq.2.29}$$

where C is the bearing factor as listed in Table 2.11, d is the diameter of the bolt and t is the sheet steel base metal thickness. The recommended design method for bolted connections is presented in detail in Section 2.2.6.

Equations in CSA-S136 (1994) and Eurocode 3 (1996) can be used as predictors of net section and end pull-out capacity, respectively. The inclusion of the reduced net section capacity approach in AS/NZS 4600 (1996), AISI (1997) and Eurocode 3 (1996) was attributed to the identification, in the evaluation of test data, of the bearing failure associated with localized tearing, end curling, end pull-out and block shear rupture as net section fracture. Some of the discoveries resulting from this experimental work are as follows: the load position had negligible effect on the behaviour of bolted connections; connections with conventional washers were able to carry higher load when end pull-out failure occurred; connections with integral washers showed higher elongations compared with those consisting of conventional washer; the load carrying capacity did not vary with the two types of washers; and the displacement of bolted connections in this experimental project was independent of the direction of blanks cut in the sheet and the types of sheet steel.

2.1.8 Wallace, Schuster and LaBoube (2001)

Sixty bolted connections with washers and fifty-nine bolted connections without washers were tested by *Wallace et al.* (2001). The intent of the experimental program was to compare the difference in the bearing capacity of bolted connections with and without washers. All specimens were dimensioned to fail in bearing with a d/t ratio that varied from 4.6 to 24.8. Two different sheet steels were used; 1) 0.64 mm with a yield stress of 350 MPa and an ultimate stress of 382 MPa, and 2) 1.38 mm thick steel with a yield stress of 356 MPa and an ultimate stress of 361 MPa. The connections were fabricated with either one or two bolts in line with the applied load. Of the 119 tests in total, 78 were for double shear loading with the thinner plates placed on the outside of the connection, and the remaining 41 were for single shear tests with either identical or different thickness plates. Six test specimens were torqued to 5 ft-lb (6.78 Nm) and an additional six were torqued to 15 ft-lb (20.3 Nm), whereas all of the other specimens had a 10 ft-lb (13.6 Nm) torque to facilitate the comparison of torque level on the connection behaviour.

Based on a study of results from this and previous experimental research, the authors confirmed the method used to predict the bearing failure capacity in Rogers and Hancock (1998a), and also recommended that for single shear or for the outside sheet of double shear connections without washers, the bearing factor in Table 2.11 should be multiplied by 0.75, and 1.33 in the case of the inside sheet of double shear connections either with or without washers.

2.1.9 Summary of Previous Experimental Investigations

The experimental investigations reviewed in the above sections involved the testing of bolted connections loaded in shear conducted before 2001. All of the most common failure modes, bolt shear, bearing, net section fracture and end pull-out, were reported to have occurred. However, only the research carried out by Chong and Matlock (1975), Gilchrist and Chong (1979), Yu and Mosby (1976 and 1978), Carril *et al.* (1994) and Wallace *et al.* (2001) contain information on bolted connections without washers. Hence, the results reported in these investigations on washerless bolted connections have been included in the data analysis documented in Chapter 4.

2.2 Design Standards

The majority of current design provisions for cold-formed steel bolted connections in North America, Australia, New Zealand and Europe are covered in this section. Furthermore, some proposed methods are introduced to reflect recent developments in the area of connection design. Chapter 4 contains a comparison of these various design methods with the results of the current and previous bolted connection investigations.

2.2.1 Canada

The previous Canadian design standard for cold-formed steel structures is S136-94 Cold Formed Steel Structural Members (CSA, 1994), and the associated commentary is S136.1-95 Commentary on CSA Standard S136-94 Cold Formed Steel Structural Members (CSA, 1995), both of which are published by the Canadian Standards Association. The current CSA S136 standard now follows the North American Specification for the Design of Cold-Formed Steel Structural Members (AISI, 2001a,b; CSA, 2001), which is discussed in Section 2.2.5. The 1994 version of the standard is based entirely on the limit states design philosophy.

2.2.1a Members in Tension

The factored tensile strength shall be the lesser of:

1. Gross Section Yielding:

$T_r = \phi A_g F_y$	(concentrically loaded members)	Eq. 2.30
$T_r = \phi F_y / (1/A_g + e/S_t)$	(eccentrically loaded members)	Eq.2.31

$\phi = 0.9$

where A_g is the gross section area, Fy is the yield strength, S_t is the tensile section modulus of the effective gross cross section area , and e is the eccentricity of the applied load.

2. Fracture at Net Section:

$T_r = \phi_u A_n F_u$	(concentrically loaded members)	Eq. 2.32
$T_r = \phi_u F_u / (1/A_n + e/S_{tn})$	(eccentrically loaded members)	Eq.2.33

$\phi_u = 0.75$

where S_{tn} is the tensile section modulus of effective gross cross section area, F_u is the ultimate strength, A_n is the critical net section area, which equals $L_t t$. L_t is the summation of critical path length along a potential failure path of minimum resistance and can be determined as follows:

$$L_t = L_n + L_i \quad \text{(for failure normal to force)} \qquad \text{Eq.2.34}$$

$$L_t = L_n + L_i + 0.6L_s \quad \text{(for failure of block tear-out at end of member)} \qquad \text{Eq.2.35}$$

where L_n and L_s are the failure path lengths normal and parallel to the force, respectively, L_i is the failure path length inclined to the force including the $s^2/4g$ allowance for staggered holes. In the CSA S136-94 Standard, the block and individual end tear out failure modes can be classified as fracture at the net section by choosing the appropriate failure path L_t. For details, refer to Figure C14 (a), (b) in the CSA S136-94 Commentary (CSA, 1995).

2.2.1b Bolted Connection

1. Bearing Strength:

$$B_r = \phi_u C\, d\, t\, F_u \qquad \text{Eq.2.36}$$

$$\phi_u = 0.75$$

where C is the bearing factor as listed in Table 2.4, d is the diameter of the bolt and t is the sheet steel base metal thickness.

Table2.4 Bearing Factor C (CSA, 1994)

Ratio of fastener Diameter to Member thickness, d/t	C
$d/t \leq 10$	3.00
$10 < d/t < 15$	$30t/d$
$d/t \geq 15$	2.00

It is assumed that the use or non-use of washers does not affect the bearing capacity of a bolted connection. For groups of fasteners where the force is perpendicular to the end of a member or where the group of fasteners is remote from the end of a member, the bearing resistance of the fastener group is equal to the sum of the individual bearing resistances, provided the centre to centre distance between fasteners is at least C d.

2. Shear and Tension in Bolt:

$V_r = \phi_c\, 0.6 A_b F_u^*$	(Shear)	Eq.2.37
$T_r = \phi_c\, 0.75 A_b F_u^*$	(Tension)	Eq.2.38
$T_r' = 1.25T_r - kV_f \leq T_r$	(Combined shear and tension)	Eq.2.39
$\phi_c = 0.67$		

where A_b is cross section area of a bolt based on the nominal diameter, F_u^* is the tensile strength of the bolt, and $k = 1.40$ if the bolt threads are not in the shear plane. When the threads are in the shear plane $k = 1.80$ and V_r shall be multiplied by 0.7.

2.2.2 USA

The previous version of the American Iron and Steel Institute (AISI) Specification for the Design of Cold- Formed Steel Structural Members can be used for the allowable stress or load and resistance factor design approaches (AISI, 1999). In this thesis, only the LRFD method is considered. The current AISI Specification now follows the North American Specification for the Design of Cold-Formed Steel Structural Members (AISI, 2001a; CSA, 2001), which is discussed in Section 2.2.5.

2.2.2a Members in Tension

The nominal tensile strength of axially loaded members shall be determined as follows.

1. Cross Section Yielding:

$$T_n = A_n F_y \qquad \text{Eq. 2.40}$$

$\phi_t = 0.95$

2.2.2b Bolted Connections

1. Fracture at the Connection (shear lag effect in bolted connections): the nominal tension strength, P_n, on the net section of connected part can be determined as follows.

For connections bolted with washers under both the bolt head and the nut

$$P_n = (1.0\text{-}0.9\ r\text{+}3\ r\ d\ /\ s)\ F_u\ A_n \leq F_u\ A_n \qquad \text{Eq. 2.41}$$

$\phi = 0.55$ for single shear connections

$\phi = 0.65$ for double shear connections

For washerless connections or connections bolted with only one washer under either the bolt head or the nut

$$P_n = (1.0\text{-}r\text{+}2.5\ r\ d\ /\ s)\ F_u\ A_n \leq F_u\ A_n \qquad \text{Eq. 2.42}$$

$\phi = 0.65$

where

A_n is the net area of the connected part, r is the ratio of the force transmitted by the bolt or bolts divided by the tensile force in the member at that section (if r is smaller than 0.2, it can be taken as 0), s is the spacing of the bolts perpendicular to the direction of load or the width of sheet for single bolted connections.

2. End Pull-Out:

$$P_n = t\, e\, F_u \qquad \text{Eq. 2.43}$$

$\phi = 0.70$ for $F_u/F_{sy} \geq 1.08$

$\phi = 0.60$ for $F_u/F_{sy} \leq 1.08$

where F_{sy} is the yield point of connected part.

The minimum distance between centres of bolt holes is 3d. For any standard hole, the minimum end distance is 1.5d.

3. Bearing Strength:

The nominal bearing strength is obtained from Tables 2.5 and 2.6

4. Shear and Tension in Bolts:

$$P_n = A_b\, F_n \qquad \text{Eq. 2.44}$$

$\phi = 0.75$ for tensile strength

$\phi = 0.65$ for shear strength

where A_b is the gross cross sectional area of a bolt, and F_n is F_{nv} and F_{nt} of the bolt for shear and tensile strength, respectively.

Table 2.5 Nominal Bearing Strength for Bolted Connections with Washers (AISI, 1999)

Thickness of Connected Part, t, in. (mm)	Type of Joint	F_u / F_y ratio of Connected Part	ϕ LRFD	Nominal Resistance P_n
$0.024 \le t < 3/16$ $(0.61 \le t < 4.76)$	Inside sheet of double shear connection	≥ 1.08	0.55	$3.33F_u dt$
		<1.08	0.65	$3.00F_u dt$
	Single shear and outside sheets of double shear connection	No limit	0.60	$3.00F_u dt$

Table 2.6 Nominal Bearing Strength for Bolted Connections without Washers (AISI, 1999)

Thickness of Connected Part, t, in. (mm)	Type of Joint	F_u / F_y ratio of Connected Part	ϕ LRFD	Nominal Resistance P_n
$0.024 \le t < 3/16$ $(0.61 \le t < 4.76)$	Inside sheet of double shear connection	≥ 1.08	0.65	$3.00F_u dt$
	Single shear and outside sheets of double shear connection	≥ 1.08	0.70	$2.22F_u dt$

2.2.3 Australia / New Zealand

The cold-formed steel design standard in Australia and New Zealand is AS/NZS 4600 (1996). The document was developed by the Joint Technical Committee BD/82 on Cold-Formed Structures and follows a limit states design approach.

2.2.3a Members in Tension

The design tensile force of an axially loaded member shall be no larger than the factored section capacity of the member in tension.

$$N^* \leq \phi_t N_t \qquad \text{Eq. 2.45}$$

$$\phi_t = 0.90$$

where N_t is the lesser of

1. Gross Section Yielding:

$$N_t = A_g f_y \qquad \text{Eq. 2.46}$$

2. Fracture at Net Section:

$$N_t = 0.85\, k_t A_n f_u \qquad \text{Eq. 2.47}$$

where A_g and A_n are the gross and net section area respectively, and k_t is a correction factor for the distribution of forces. For a uniform force distribution, k_t equals 1.0. For additional details, refer to clause 3.2.2 in *AS/NZS 4600 (1996)*.

2.2.3b Bolted Connection

1. Tearout:

The design shear force of the connected part shall be no larger than the factored tearout capacity.

$$V_f^* \leq \phi V_f \qquad \text{Eq.2.48}$$

$$\phi = 0.70 \qquad \text{for } f_u / f_y \geq 1.08$$

$$\phi = 0.60 \qquad \text{for } f_u / f_y < 1.08$$

where V_f, is the nominal tearout capacity, which is equal to $t\, e\, f_u$

2. Net section tension:

$$N_f^* \leq \phi N_f \qquad \text{Eq.2.49}$$

$\phi = 0.55$ (for single shear connection with washers)

$\phi = 0.65$ (for double shear connection with washers or connection without washers)

where N_f is the nominal tensile capacity of the connected part, which is equal to:

$$N_f = (1.0 - 0.9r_f + 3r_f d_f/s_f) f_u A_n \leq f_u A_n \quad \text{(for connection with washers)} \qquad \text{Eq.2.50}$$

$$N_f = (1.0 - r_f + 2.5r_f d_f/s_f) f_u A_n \leq f_u A_n \quad \text{(for connection without washers)} \qquad \text{Eq.2.52}$$

where r_f is the ratio of the force transmitted by the bolts divided by the tensile force in the member, and s_f is the spacing of bolts perpendicular to the line of the force or the width of sheet for single bolt connections.

3. Bearing:

The design bearing force shall be no larger than the factored bearing capacity of the connected part.

$$V_b^* \leq \phi V_b \qquad \text{Eq.2.53}$$

where V_b is the nominal bearing capacity as listed in Tables 2.7 and 2.8.

Table 2.7 Design bearing capacity for Bolted Connections with Washers (AS/NZS 4600, 1996)

Thickness of Connected Part (t) mm	Type of Joint	Ratio of Connected Part f_u / f_y	Capacity (Strength reduction) factor (ϕ)	Nominal Bearing capacity(V_b)
$0.6 \leq t < 3.0$	Inside sheet of double shear connection	≥ 1.08	0.55	$3.33 f_u d_f t$
		<1.08	0.65	$3.00 f_u d_f t$
	Single shear and outside sheets of double shear connection	No limit	0.60	$3.00 f_u d_f t$

Table 2.8 Design bearing capacity for Bolted Connections without Washers (AS/NZS 4600, 1996)

Thickness of Connected Part (t) mm	Type of Joint	Ratio of Connected Part f_u / f_y	Capacity (Strength reduction) factor (ϕ)	Nominal Bearing capacity(V_b)
$0.9 \leq t < 3.0$	Inside sheet of double shear Connection	≥ 1.08	0.65	$3.00 f_u d_f t$
	Single shear and outside sheets of double shear connection	≥ 1.08	0.70	$2.22 f_u d_f t$

4. Bolts in Tension and Shear:

The design shear force on a bolt shall be no larger than the factored shear capacity of a bolt.

$$V_{fv}^* \leq \phi V_{fv} \qquad \text{Eq. 2.54}$$

$$\phi = 0.80$$

$$V_{fv} = 0.62 f_{uf} (n_n A_c + n_x A_o) \qquad \text{Eq.2.55}$$

where f_{uf} is the minimum tensile strength of the bolt, A_c is minor diameter area of the bolt, A_o is plain shank area of the bolt, n_n and n_x are the number of shear planes with and without threads intercepting the shear plane, respectively.

The design tensile force on a bolt shall be no larger than the factored tensile capacity of a bolt.

$$N_{ft}^* \leq \phi N_{ft} \qquad \text{Eq.2.56}$$

$$\phi = 0.80$$

$$N_{ft} = A_s f_{uf} \qquad \text{Eq.2.57}$$

where A_s is the tensile stress area of a bolt.

When a bolt is subjected to combined shear and tension, the design shear force and the design tensile force on a bolt shall satisfy

$$(V^*_{fv} / \phi\ V_{fv})^2 + (N^*_{ft} / \phi\ N_{ft})^2 \leq 1.0 \qquad \text{Eq.2.58}$$

2.2.3c Block Shear Rupture

The design action effect at beam-end or tension connections shall be no larger than the factored block shear capacity of the beam-end or tension member connection.

$$S^* \leq \phi R_n \qquad \text{Eq.2.59}$$

$$\phi = 0.65 \qquad \text{(for bolt connection)}$$

$$R_n = 0.60 f_y A_{gv} + f_u A_{nt} \qquad (\text{for } f_u A_{nt} \geq 0.6 f_u A_{nv}) \qquad \text{Eq.2.60}$$

$$R_n = 0.60 f_u A_{nv} + f_y A_{gt} \qquad (\text{for } 0.6 f_u A_{nt} \geq f_u A_{gt}) \qquad \text{Eq.2.61}$$

where A_{nt} and A_{nv} are respectively the net area subjected to tension and the shear area in block shear rupture, A_{gt} and A_{gv} are the gross area subjected to tension and the shear area in block shear rupture, respectively.

2.2.4 Europe

The regulations concerning cold-formed steel structural design in Europe can be found in Eurocode 3 Design of steel structures, Part 1.3 Supplementary rules for cold formed thin gauge members and sheeting (1996). This document, which follows a limit states format, was developed by the European Committee for Standardisation.

2.2.4a Tensile Member Resistance:

The design tensile resistance of a cross section must satisfy:

$$N_{t,Rd} \leq F_{n,Rd} \quad \text{Eq.2.62}$$

$$N_{t,Rd} = f_{ya} A_g / \gamma_{MO} \quad \text{Eq.2.63}$$

$$F_{n,Rd} = f_u A_{net} / \gamma_{M2} \quad \text{Eq.2.64}$$

γ_{MO}=1.1 and γ_{M2}=1.25

where $N_{t,Rd}$ and $F_{n,Rd}$ are the design tensile resistance and the design net section fracture resistance, respectively.

2.2.4b Bolted Connection:

1. End pull-out resistance

$$F_{b,Rd} = f_u e_1 \, t / 1.2 / \gamma_{M2} \quad \text{Eq. 2.65}$$

$\gamma_{M2} = 1.25$

where e_1 is the edge distance in the direction of load.

2. Net Section Fracture:

$$F_{n,Rd} = (1+3r(d_o/u\text{-}0.3))f_u A_{net} / \gamma_{M2} \qquad \text{Eq.2.66}$$

$$\gamma_{M2} = 1.25$$

where r is the number of bolts at the cross section divided by the total number of bolts in the connection, d_o is the nominal diameter of the bolt hole, and u is the smaller of (1) the distance of the bolts perpendicular to the load direction, and (2) the summation of the edge distance in the direction perpendicular to the load.

3. Bearing:

$$F_{b,Rd} = 2.5 f_u d\, t / \gamma_{M2} \qquad \text{Eq.2.67}$$

$$\gamma_{M2} = 1.25$$

where d is the nominal diameter of the bolt.

4. Tension and Shear in Bolts:

$$F_{v,Rd} = 0.6 f_{ub}\, A_s / \gamma_{M2} \qquad (\text{for } f_{ub} \leq 800 \text{ MPa}) \qquad \text{Eq.2.68a}$$

$$F_{v,Rd} = 0.5 f_{ub}\, A_s / \gamma_{M2} \qquad (\text{for } f_{ub} > 800 \text{ MPa}) \qquad \text{Eq.2.68b}$$

$$F_{t,Rd} = 0.9 f_{ub}\, A_s / \gamma_{M2} \qquad \text{Eq.2.69}$$

$$\gamma_{M2} = 1.25$$

where $F_{v,Rd}$ and $F_{t,Rd}$ are the factored shear and tensile resistance, respectively, A_s is the tensile stress area of the bolt. Furthermore, the factored shear resistance must satisfy:

$$F_{v,Rd} \geq 1.2\ (F_{b,Rd}\ ;F_{n,Rd}) \qquad \text{Eq.2.70}$$

2.2.5 North American Cold-Formed Steel Specification

A uniform design specification for cold-formed steel structures has been approved for use in the United States, Canada and Mexico. The inaugural version of the North American Specification for the Design of Cold-Formed Steel Structural Members (AISI, 2001a; CSA, 2001) was made available in June of 2002. This document integrates the design provisions contained in the previous edition of the AISI Specification (1999) and the CSA-S136 Standard (1994). Additional amendments were introduced to reflect the latest developments of research in the cold-formed steel structures area. One of major changes from the previous national standards is found in the bolted connection approach, which now consists of a variable bearing coefficient similar to that suggested in Rogers and Hancock (1998a) (See Section 2.2.6).

2.2.5.1 USA and Mexico (AISI, 2001a,b)

2.2.5.1a Tension Members

The nominal tensile resistance of axially loaded tension members shall be the smallest of

1. Gross Section Yielding:

$$T_n = A_g F_y \qquad \text{Eq.2.71}$$

$$\phi_t = 0.90$$

2. Fracture of Net Section away from the Connection:

$$T_n = A_n F_u \qquad \text{Eq.2.72}$$

$\phi_t = 0.75$

where A_g and A_n are gross area and net area of the cross section, respectively.

3. Fracture at the Connection: the nominal tensile resistance is governed by the type of fastener, where for bolted connections:

$P_n = A_n F_t$	(flat sheet connections)	Eq.2.73
$P_n = A_e F_u$	(other than flat sheet connections)	Eq.2.74
$\phi = 0.55$	for single shear connection with washers and without staggered hole patterns	
$\phi = 0.65$	for other types of bolted connections	

where F_e is effective net area, for details, see Section E3.2 of Appendix A in the North American Specification(AISI, 2001a), and F_t can be determined as follows:

Multiple bolts in the line parallel to the force, with or without washers

$$F_t = F_u \qquad \text{Eq.2.75}$$

Single bolt or single row of bolts perpendicular to the force, with washers

$$F_t = (0.1 + 3\, d / s)\, F_u \leq F_u \qquad \text{Eq.2.76}$$

Single bolt or single row of bolts perpendicular to the force, without washers

$$F_t = (2.5\, d / s)\, F_u \leq F_u \qquad \text{Eq.2.77}$$

where s is the sheet width divided by the number of bolt holes in the cross section being considered.

2.2.5.1b Bolted Connection

1. End Pull-Out:

$P_n = t\,e\,F_u$ Eq.2.78

$\phi = 0.70$ for $F_u/F_{sy} \geq 1.08$

$\phi = 0.60$ for $F_u/F_{sy} \leq 1.08$

where F_{sy} is the yield point of the connected part.

The minimal distance between centres of bolt holes is 3d. For any standard hole, the minimal end distance is 1.5d.

2. Bearing Strength:

$P_n = m_f\,C\,d\,t\,F_u$ Eq.2.79

$\phi = 0.60$

where

C: Bearing factor, determined from Table 2.9

m_f: Modification factor for type of bearing connection from Table 2.10

Table 2.9: Bearing Factor C (AISI, 2001a)

Thickness of Connected Part, t, in. (mm)	Ratio of fastener Diameter to Member Thickness d/t	C
$0.024 \leq t < 0.1875$ ($0.61 \leq t < 4.76$)	$d/t < 10$	3.0
	$10 \leq d/t \leq 22$	$4-0.1(d/t)$
	$d/t > 22$	1.8

Table 2.10: Modification Factor, m_f (AISI, 2001a)

Type of Bearing Connection	m_f
Single Shear and Outside Sheets of Double Shear Connection With Washers Under Both Bolt Head and Nut	1.00
Single Shear and Outside Sheets of Double Shear Connection Without Washers Under Both Bolt Head and Nut, Or With Only One Washers	0.75
Inside Sheets of Double Shear Connection With or Without Washers	1.33

When the deformation around the bolt hole is a consideration:

$$P_n = (4.64\alpha t + 1.53)\ d\ t\ F_u \qquad \text{Eq.2.80}$$

$\phi = 0.65$

where α is the coefficient for the conversion of units. For details, see Section E3.3.2 of the North American Specification (AISI, 2001a)

3. Shear and Tension in Bolts:

$$P_n = A_b\ F_n \qquad \text{Eq.2.81}$$

ϕ=0.75 for tensile strength

ϕ=0.65 for shear strength

where A_b is gross cross sectional area of the bolt, F_n is F_{nv} and F_{nt} of the bolt for shear and tensile strength, respectively.

2.2.5.1c Block Shear Rupture

The block shear rupture strength at beam ends or tension connections shall satisfy:

$$R_n = 0.60F_y A_{gv} + F_uA_{nt} \quad (\text{for } F_u A_{nt} \geq 0.6F_uA_{nv}) \qquad \text{Eq. 2.82}$$

$$R_n = 0.60F_u A_{nv} + F_yA_{gt} \quad (\text{for } 0.6F_u A_{nt} \geq F_uA_{gt}) \qquad \text{Eq. 2.83}$$

$$\phi = 0.65 \quad (\text{for bolted connections})$$

where A_{nt} and A_{nv} are respectively the net area subjected to tension and shear, A_{gt} and A_{gv} are the gross area subjected to tension and shear, respectively.

2.2.5.2 CANADA

In the North American Specification, there are country specific clauses. This section refers to the Canadian approach to the design of bolted connections (CSA, 2001)

2.2.5.2a Tension Members

The nominal tensile resistance shall be the smallest of

1. Gross Section Yielding

$$T_n = A_g F_y \qquad \text{Eq.2.84}$$

$$\phi_t = 0.90$$

2. Fracture of Net Section

$$T_n = A_n F_u \qquad \text{Eq.2.85}$$

$$\phi_t = 0.75$$

where A_g is the gross area of cross section, and $A_n = L_ct$, L_c is the summation of the critical path length along a potential failure path of minimum strength.

2.2.5.2b Bolted Connection

1. Bearing Strength

$$P_n = m_f\, C\, d\, t\, F_u \qquad \text{Eq.2.86}$$

$\phi = 0.50$

where

C: Bearing factor, determined from Table 2.8

m_f: Modification factor for type of bearing connection from Table 2.9

When the deformation around the bolt hole is a consideration:

$$P_n = (4.64\alpha t + 1.53) d\, t\, F_u \qquad \text{Eq.2.87}$$

$\phi = 0.65$

where α is the coefficient for the conversion of units.

2. Shear and Tension in Bolts

$$P_n = A_b\, F_n \qquad \text{Eq.2.88}$$

$\phi = 0.65$ for tensile strength or a combination of shear and tension

$\phi = 0.55$ for shear strength

where A_b is gross cross sectional area of bolt and F_n is F_{nv}, F_{nt} and F'_{nt} of the bolt for shear, tensile and combined shear and tensile strength, respectively.

2.2.6 University of Sydney Method

Based on their experimental investigation at the University of Sydney and studies carried out by previous researchers, Rogers and Hancock (1998a, 1999) proposed a new method for bolted connections with washers.

1. Gross Yielding

$$N_t = A_g f_y \qquad \text{Eq.2.89}$$

where A_g is the gross section area and f_y is the yield stress or the 0.2% proof stress.

2. Net Section Fracture

$$N_t = A_n f_u \qquad \text{Eq.2.90}$$

where A_n is the net section area and f_u is the ultimate strength.

3. End Pull-Out

$$V_f = t\, e\, f_u \qquad \text{Eq.2.91}$$

where t is the thickness of the thinnest sheet, and e is the end distance or the distance between bolts parallel to the load direction.

4. Bearing

$$V_b = C\, t\, d\, f_u \qquad \text{Eq.2.92}$$

where C is a variable bearing coefficient determined from Table 2.10

Table 2.11:C Factors for Bearing Resistance (Rogers and Hancock, 1998a)

Ratio of fastener Diameter to Member thickness, d/t	C
$d/t \leq 10$	3.00
$10 < d/t < 22$	4.0-0.1d/t
$d/t \geq 22$	1.80

CHAPTER 3 PRESENT EXPERIMENTAL INVESTIGATION

As described in Chapter 2, research at the University of Sydney has revealed that current cold-formed steel design standards in North America, Australia/New Zealand and Europe cannot satisfactorily predict the bearing capacity of bolted connections with washers (Rogers and Hancock, 1997,1998a, b, c, 1999). A gradated bearing factor for bolted connections with washers under both the nut and the head of bolts was proposed by Rogers and Hancock (1998a). However, due to the lack of experimental data on high strength steel bolted connections without washers additional testing was required. To observe the bearing behaviour and to determine the bearing capacity of washerless bolted connections a total of 168 specimens (42 bolted with washers and 126 bolted without washers) were tested in the Materials Laboratory of the Department of Civil Engineering and Applied Mechanics at McGill University. Detailed information pertinent to this experimental work can be found in this chapter.

3.1 Test Program

The data from three previous experimental projects in which bolted connections without washers were tested, *i.e.* Chong and Matlock (1975), Gilchrist and Chong (1979) and Wallace *et al.* (2001), were closely studied before deciding on the range of specimens to test. Variables including material type, specimen size, bolt size, etc, were carefully chosen with the objective of yielding information that had not been forthcoming in previous tests. Two types of sheet steel were selected to be tested, that is high strength ($F_y \approx 550$ MPa) and mild grade ($F_y \approx 230$ MPa) steel. The nominal thicknesses of the steel, which ranged from 0.43 mm to 1.53 mm, were chosen to cover the common types of sheet steel available in North America. The high strength steel included nominal thicknesses of 0.43, 0.64, and 0.76 mm; whereas the mild steel specimens were composed of 0.43, 0.64, 0.76, 0.91, 1.21, and 1.53 mm thick sheets. To ensure that the bolt shearing mode of failure did not take place all bolts were specified as Grade 8 having either a diameter of 1/4, 3/8, 1/2 or 5/8 inch. Fifty test specimen configurations with d/t ratios varying from 4.1 to 45.4 were initially included in the test program. In order to obtain information on the behaviour and capacity of specimens both bolted connections with and without washers were included in this investigation. Four specimens were fabricated for each bolted connection configuration, including three tests without washers to obtain a statistically adequate number of washerless connections. One test specimen was assembled with washers under the bolt head and the nut such that a direct comparison could be made to determine the influence of washers on behaviour and capacity. The connection configurations were also varied with respect to the placement of the different sheet steels. Single shear loading was used for the mild steel specimens, which were composed of either two equal or different thickness sheets. This steel type was also used in the composition of the double shear connections, where a thinner sheet was located on the inside of the connection. Only the single shear type of configuration with equal thickness sheets were used for the high strength steel connections.

In order to establish a more efficient test program that could be carried out in a reasonable amount of time, fifty initial connection configurations were proposed, from which 42 connection types were selected for testing. The proposed single shear specimens composed of equal thickness sheets with similar d/t ratios to tests carried out by other researchers, *e.g.* Wallace *et al.* (2001); Chong and Matlock (1975); Gilchrist and Chong (1979), were not included in the final test program. The test results from these existing research programs were included in the database for this thesis, hence duplication of the specimen configurations was not necessary. A comparison of the proposed, selected, and existing d/t values for washerless bolted connection test specimens is presented in terms of the bearing coefficient, C, as proposed by Rogers and Hancock (1998a) in Figures 3.1a, b, c, d. (See Appendix A for a full listing – d = bolt diameter, t = sheet thickness). From these figures, one can observe that 18 configurations of mild grade, single shear, same sheet thickness were initially proposed. 8 out of these 18 configurations were finally eliminated because testing had been carried out by other researchers. There were 11 configurations for single shear, mild steel, different sheet thickness connections. Although a similar test configuration can be found in the previous research, this specimen was chosen because its d/t ratio is approximately 10, which is a critical point for determining the bearing factor C. For high strength single shear and mild double shear connections, there were 10 and 11 configurations respectively. The final scope of testing for this investigation included a total of 168 tests (42 configurations). The details on these 168 tests can be found in Appendix B.

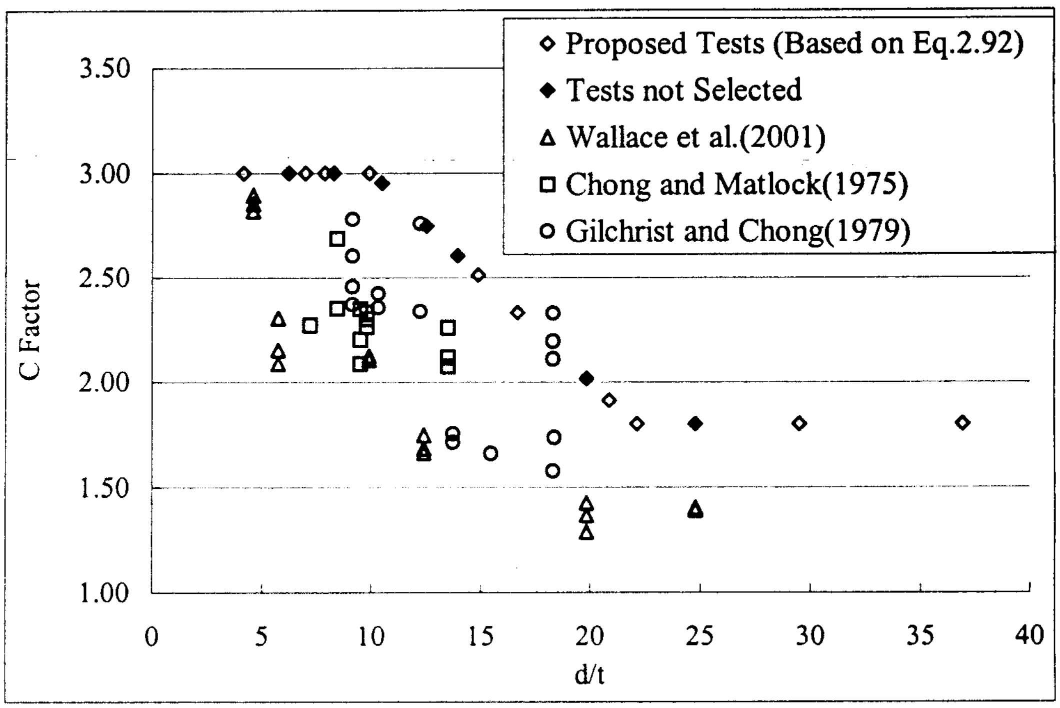


Figure 3.1a Washerless Bolted Connection Test Specimen Configurations Based on d/t and the Bearing Coefficient C (Mild grade steel, single shear, same thickness sheets)

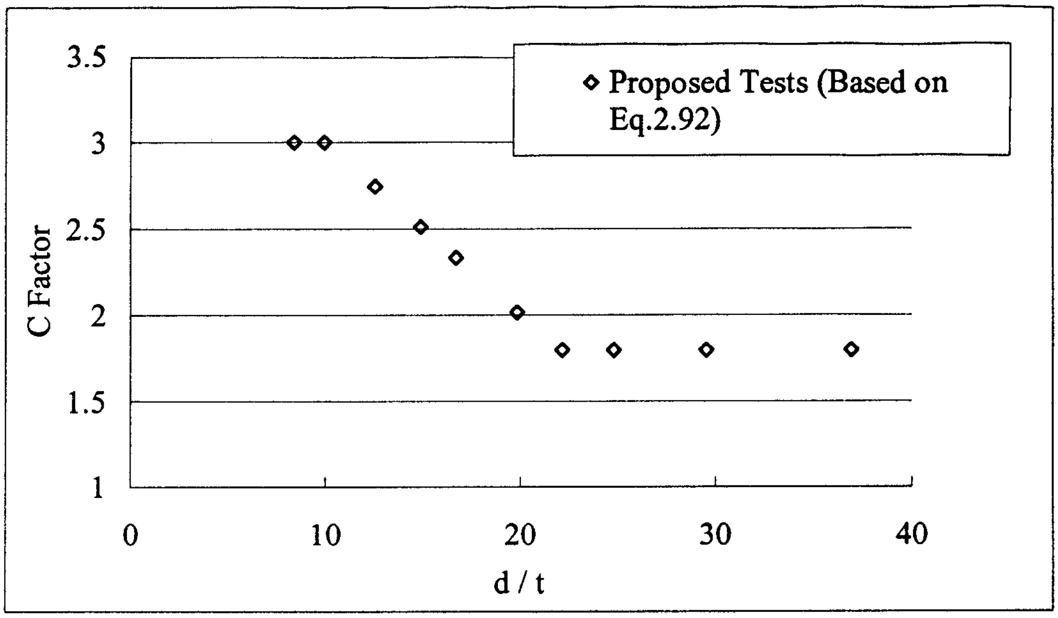


Figure 3.1b Washerless Bolted Connection Test Specimen Configurations Based on d/t and the Bearing Coefficient C (High strength steel, single shear, same thickness sheets)

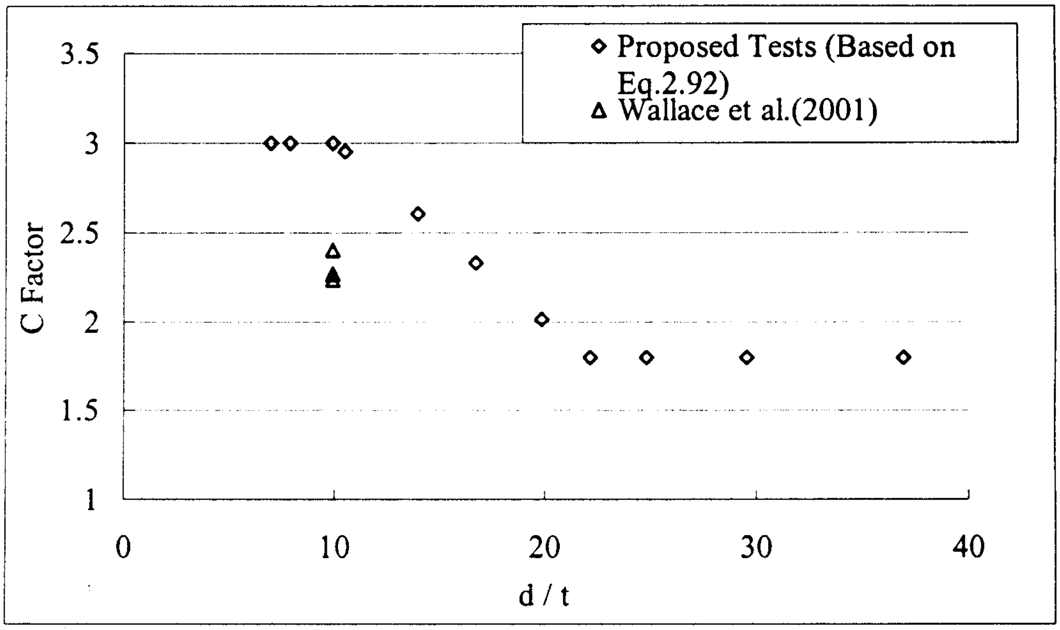


Figure3.1c Washerless Bolted Connection Test Specimen Configurations Based on d/t and the Bearing Coefficient C (Mild grade steel, single shear, different thickness sheets)

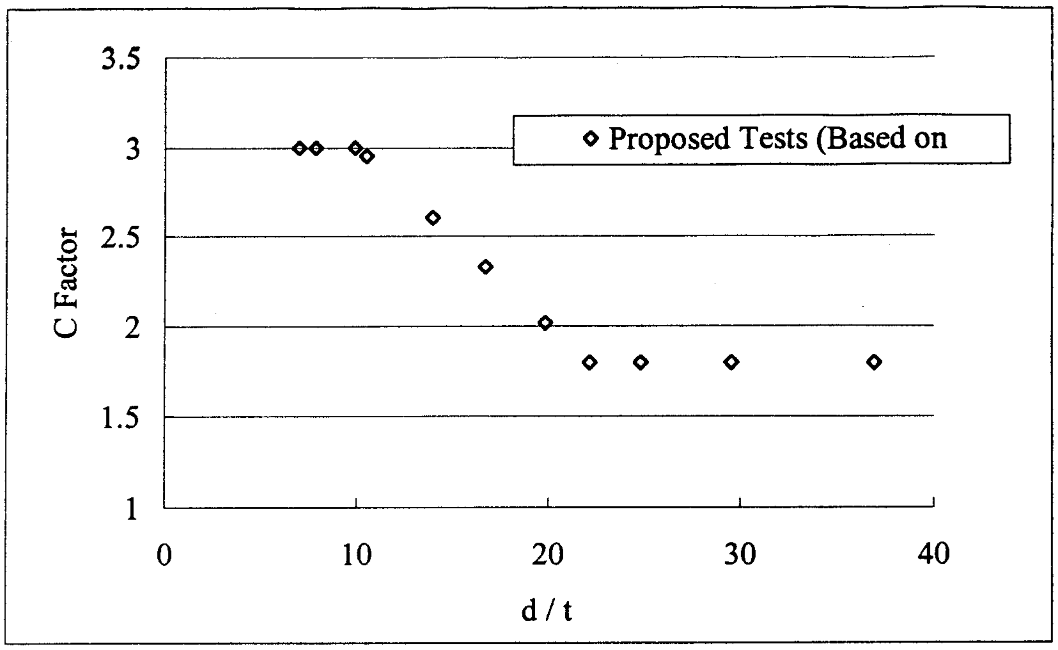


Figure3.1d Washerless Bolted Connection Test Specimen Configurations Based on d/t and the Bearing Coefficient C (Mild grade steel, double shear with thinner sheet placed inside)

All test specimens consisted of a single bolt and were sized based on S136-94 such that bearing failure of the connection would take place (nominal dimensions are shown in Figure 3.2). The bolt holes were drilled 1/16 inch (1.59 mm) larger than the nominal bolt diameter. The end distance, e, was chosen to be 60 mm, which corresponds to an e/d ratio of greater than 3.5 for all bolt sizes, and as such ensures that the pure end pull-out failure mode would not take place. All specimens were of 75 mm in width in order to eliminate the pure net section failure mode as determined using the CSA S136 (1994) design provisions. As stated previously, Grade 8 high strength bolts were used to avoid bolt shear failure. Hence, it was anticipated that failure modes other than bearing would not take place.

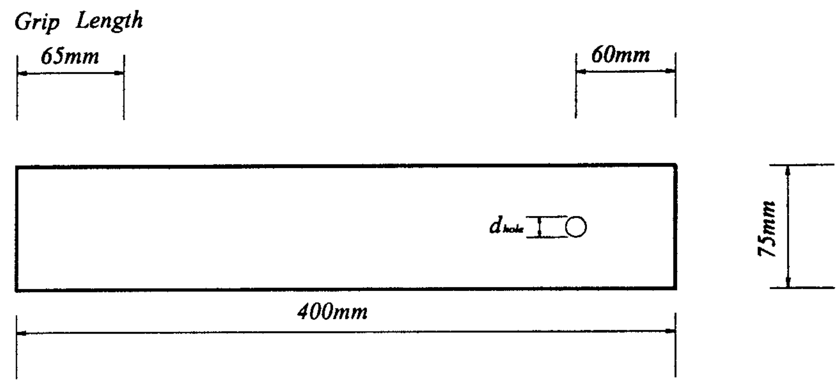


Figure 3.2 Nominal Dimensions of Test Specimens

3.2 Designation of Specimens

Each specimen was identified by an alphanumeric title in the form of XXX-YYY-A/B-ZZ-N, where:

XXX	: nominal thickness of thinner sheet steel (mm)
YYY	: type of steel, 550 for high strength steels and 230 for mild steels
A/B	: nominal diameter of bolts in inches.
ZZ	: type of connection, for single shear with equal sheet thickness, SS; for single shear with different sheet thickness, TTSS; for double shear, DS.
N	: individual connection in each configuration, for specimens without washers, A,B and C; for the specimen with washer, D

For double shear and single shear specimens with different sheet thickness, the nominal thickness of the thicker sheet was 1.53 mm. Table 3.1 lists detailed information concerning the nominal dimensions of all test specimens.

Table 3.1 Bolt Connection Test Dimensions

SPECIMEN	t_1 (mm)	t_2 (mm)	e (mm)	s (mm)	Washers	Single or Double Shear	Pitch of Bolt (mm)	d (mm)	d_{hole}	d/t
043-550-3/8-SS-A	0.35	0.35	60.0	75.0	No	1	1.60	9.53	11.1	27.2
043-550-3/8-SS-B	0.35	0.35	60.0	75.0	No	1	1.60	9.53	11.1	27.2
043-550-3/8-SS-C	0.35	0.35	60.0	75.0	No	1	1.60	9.53	11.1	27.2
043-550-3/8-SS-D	0.35	0.35	60.0	75.0	Yes	1	1.60	9.53	11.1	27.2
043-550-1/2-SS-A	0.35	0.35	60.0	75.0	No	1	2.00	12.7	14.3	36.3
043-550-1/2-SS-B	0.35	0.35	60.0	75.0	No	1	2.00	12.7	14.3	36.3
043-550-1/2-SS-C	0.35	0.35	60.0	75.0	No	1	2.00	12.7	14.3	36.3
043-550-1/2-SS-D	0.35	0.35	60.0	75.0	Yes	1	2.00	12.7	14.3	36.3
043-550-5/8-SS-A	0.35	0.35	60.0	75.0	No	1	2.33	15.9	17.5	45.4
043-550-5/8-SS-B	0.35	0.35	60.0	75.0	No	1	2.33	15.9	17.5	45.4
043-550-5/8-SS-C	0.35	0.35	60.0	75.0	No	1	2.33	15.9	17.5	45.4
043-550-5/8-SS-D	0.35	0.35	60.0	75.0	Yes	1	2.33	15.9	17.5	45.4
064-550-5/8-SS-A	0.63	0.63	60.0	75.0	No	1	2.33	15.9	17.5	25.2
064-550-5/8-SS-B	0.63	0.63	60.0	75.0	No	1	2.33	15.9	17.5	25.2
064-550-5/8-SS-C	0.63	0.63	60.0	75.0	No	1	2.33	15.9	17.5	25.2
064-550-5/8-SS-D	0.63	0.63	60.0	75.0	Yes	1	2.33	15.9	17.5	25.2
064-550-1/2-SS-A	0.63	0.63	60.0	75.0	No	1	2.00	12.7	14.3	20.2
064-550-1/2-SS-B	0.63	0.63	60.0	75.0	No	1	2.00	12.7	14.3	20.2
064-550-1/2-SS-C	0.63	0.63	60.0	75.0	No	1	2.00	12.7	14.3	20.2
064-550-1/2-SS-D	0.63	0.63	60.0	75.0	Yes	1	2.00	12.7	14.3	20.2
064-550-3/8-SS-A	0.63	0.63	60.0	75.0	No	1	1.60	9.53	11.1	15.1
064-550-3/8-SS-B	0.63	0.63	60.0	75.0	No	1	1.60	9.53	11.1	15.1
064-550-3/8-SS-C	0.63	0.63	60.0	75.0	No	1	1.60	9.53	11.1	15.1
064-550-3/8-SS-D	0.63	0.63	60.0	75.0	Yes	1	1.60	9.53	11.1	15.1

Table 3.1 Bolt Connection Test Dimensions (continued)

SPECIMEN	t_1 (mm)	t_2 (mm)	e (mm)	s (mm)	Washers	Single or Double Shear	Pitch of Bolt (mm)	d (mm)	d_{hole}	d/t
064-550-1/4-SS-A	0.63	0.63	60.0	75.0	No	1	1.30	6.35	7.94	10.1
064-550-1/4-SS-B	0.63	0.63	60.0	75.0	No	1	1.30	6.35	7.94	10.1
064-550-1/4-SS-C	0.63	0.63	60.0	75.0	No	1	1.30	6.35	7.94	10.1
064-550-1/4-SS-D	0.63	0.63	60.0	75.0	Yes	1	1.30	6.35	7.94	10.1
076-550-1/2-SS-A	0.76	0.76	60.0	75.0	No	1	2.00	12.7	14.3	16.7
076-550-1/2-SS-B	0.76	0.76	60.0	75.0	No	1	2.00	12.7	14.3	16.7
076-550-1/2-SS-C	0.76	0.76	60.0	75.0	No	1	2.00	12.7	14.3	16.7
076-550-1/2-SS-D	0.76	0.76	60.0	75.0	Yes	1	2.00	12.7	14.3	16.7
076-550-3/8-SS-A	0.76	0.76	60.0	75.0	No	1	1.60	9.53	11.1	12.5
076-550-3/8-SS-B	0.76	0.76	60.0	75.0	No	1	1.60	9.53	11.1	12.5
076-550-3/8-SS-C	0.76	0.76	60.0	75.0	No	1	1.60	9.53	11.1	12.5
076-550-3/8-SS-D	0.76	0.76	60.0	75.0	Yes	1	1.60	9.53	11.1	12.5
076-550-1/4-SS-A	0.76	0.76	60.0	75.0	No	1	1.30	6.35	7.94	8.36
076-550-1/4-SS-B	0.76	0.76	60.0	75.0	No	1	1.30	6.35	7.94	8.36
076-550-1/4-SS-C	0.76	0.76	60.0	75.0	No	1	1.30	6.35	7.94	8.36
076-550-1/4-SS-D	0.76	0.76	60.0	75.0	Yes	1	1.30	6.35	7.94	8.36
043-230-3/8-SS-A	0.41	0.41	60.0	75.0	No	1	1.60	9.53	11.1	23.2
043-230-3/8-SS-B	0.41	0.41	60.0	75.0	No	1	1.60	9.53	11.1	23.2
043-230-3/8-SS-C	0.41	0.41	60.0	75.0	No	1	1.60	9.53	11.1	23.2
043-230-3/8-SS-D	0.41	0.41	60.0	75.0	Yes	1	1.60	9.53	11.1	23.2
043-230-1/2-SS-A	0.41	0.41	60.0	75.0	No	1	2.00	12.7	14.3	31.0
043-230-1/2-SS-B	0.41	0.41	60.0	75.0	No	1	2.00	12.7	14.3	31.0
043-230-1/2-SS-C	0.41	0.41	60.0	75.0	No	1	2.00	12.7	14.3	31.0
043-230-1/2-SS-D	0.41	0.41	60.0	75.0	Yes	1	2.00	12.7	14.3	31.0

Table 3.1 Bolt Connection Test Dimensions (continued)

SPECIMEN	t_1 (mm)	t_2 (mm)	e (mm)	s (mm)	Washers	Single or Double Shear	Pitch of Bolt (mm)	d (mm)	d_{hole}	d/t
043-230-5/8-SS-A	0.41	0.41	60.0	75.0	No	1	2.33	15.9	17.5	38.7
043-230-5/8-SS-B	0.41	0.41	60.0	75.0	No	1	2.33	15.9	17.5	38.7
043-230-5/8-SS-C	0.41	0.41	60.0	75.0	No	1	2.33	15.9	17.5	38.7
043-230-5/8-SS-D	0.41	0.41	60.0	75.0	Yes	1	2.33	15.9	17.5	38.7
064-230-3/8-SS-A	0.63	0.63	60.0	75.0	No	1	1.60	9.53	11.1	15.1
064-230-3/8-SS-B	0.63	0.63	60.0	75.0	No	1	1.60	9.53	11.1	15.1
064-230-3/8-SS-C	0.63	0.63	60.0	75.0	No	1	1.60	9.53	11.1	15.1
064-230-3/8-SS-D	0.63	0.63	60.0	75.0	Yes	1	1.60	9.53	11.1	15.1
064-230-1/4-SS-A	0.63	0.63	60.0	75.0	No	1	1.30	6.35	7.94	10.1
064-230-1/4-SS-B	0.63	0.63	60.0	75.0	No	1	1.30	6.35	7.94	10.1
064-230-1/4-SS-C	0.63	0.63	60.0	75.0	No	1	1.30	6.35	7.94	10.1
064-230-1/4-SS-D	0.63	0.63	60.0	75.0	Yes	1	1.30	6.35	7.94	10.1
076-230-1/2-SS-A	0.72	0.72	60.0	75.0	No	1	2.00	12.7	14.3	17.6
076-230-1/2-SS-B	0.72	0.72	60.0	75.0	No	1	2.00	12.7	14.3	17.6
076-230-1/2-SS-C	0.72	0.72	60.0	75.0	No	1	2.00	12.7	14.3	17.6
076-230-1/2-SS-D	0.72	0.72	60.0	75.0	Yes	1	2.00	12.7	14.3	17.6
076-230-5/8-SS-A	0.72	0.72	60.0	75.0	No	1	2.33	15.9	17.5	22.0
076-230-5/8-SS-B	0.72	0.72	60.0	75.0	No	1	2.33	15.9	17.5	22.0
076-230-5/8-SS-C	0.72	0.72	60.0	75.0	No	1	2.33	15.9	17.5	22.0
076-230-5/8-SS-D	0.72	0.72	60.0	75.0	Yes	1	2.33	15.9	17.5	22.0
091-230-1/4-SS-A	0.91	0.91	60.0	75.0	No	1	1.30	6.35	7.94	6.98
091-230-1/4-SS-B	0.91	0.91	60.0	75.0	No	1	1.30	6.35	7.94	6.98
091-230-1/4-SS-C	0.91	0.91	60.0	75.0	No	1	1.30	6.35	7.94	6.98
091-230-1/4-SS-D	0.91	0.91	60.0	75.0	Yes	1	1.30	6.35	7.94	6.98

Table 3.1 Bolt Connection Test Dimensions (continued)

SPECIMEN	t_1 (mm)	t_2 (mm)	e (mm)	s (mm)	Washers	Single or Double Shear	Pitch of Bolt (mm)	d (mm)	d_{hole}	d/t
121-230-3/8-SS-A	1.34	1.34	60.0	75.0	No	1	1.60	9.53	11.1	7.1
121-230-3/8-SS-B	1.34	1.34	60.0	75.0	No	1	1.60	9.53	11.1	7.1
121-230-3/8-SS-C	1.34	1.34	60.0	75.0	No	1	1.60	9.53	11.1	7.1
121-230-3/8-SS-D	1.34	1.34	60.0	75.0	Yes	1	1.60	9.53	11.1	7.1
153-230-1/4-SS-A	1.51	1.51	60.0	75.0	No	1	1.30	6.35	7.94	4.2
153-230-1/4-SS-B	1.51	1.51	60.0	75.0	No	1	1.30	6.35	7.94	4.2
153-230-1/4-SS-C	1.51	1.51	60.0	75.0	No	1	1.30	6.35	7.94	4.2
153-230-1/4-SS-D	1.51	1.51	60.0	75.0	Yes	1	1.30	6.35	7.94	4.2
043-230-3/8-TTSS-A	0.41	1.51	60.0	75.0	No	1	1.60	9.53	11.1	23.2
043-230-3/8-TTSS-B	0.41	1.51	60.0	75.0	No	1	1.60	9.53	11.1	23.2
043-230-3/8-TTSS-C	0.41	1.51	60.0	75.0	No	1	1.60	9.53	11.1	23.2
043-230-3/8-TTSS-D	0.41	1.51	60.0	75.0	Yes	1	1.60	9.53	11.1	23.2
043-230-1/2-TTSS-A	0.41	1.51	60.0	75.0	No	1	2.00	12.7	14.3	31.0
043-230-1/2-TTSS-B	0.41	1.51	60.0	75.0	No	1	2.00	12.7	14.3	31.0
043-230-1/2-TTSS-C	0.41	1.51	60.0	75.0	No	1	2.00	12.7	14.3	31.0
043-230-1/2-TTSS-D	0.41	1.51	60.0	75.0	Yes	1	2.00	12.7	14.3	31.0
043-230-5/8-TTSS-A	0.41	1.51	60.0	75.0	No	1	2.33	15.9	17.5	38.7
043-230-5/8-TTSS-B	0.41	1.51	60.0	75.0	No	1	2.33	15.9	17.5	38.7
043-230-5/8-TTSS-C	0.41	1.51	60.0	75.0	No	1	2.33	15.9	17.5	38.7
043-230-5/8-TTSS-D	0.41	1.51	60.0	75.0	Yes	1	2.33	15.9	17.5	38.7
064-230-5/8-TTSS-A	0.63	1.51	60.0	75.0	No	1	2.33	15.9	17.5	25.2
064-230-5/8-TTSS-B	0.63	1.51	60.0	75.0	No	1	2.33	15.9	17.5	25.2
064-230-5/8-TTSS-C	0.63	1.51	60.0	75.0	No	1	2.33	15.9	17.5	25.2
064-230-5/8-TTSS-D	0.63	1.51	60.0	75.0	Yes	1	2.33	15.9	17.5	25.2

Table 3.1 Bolt Connection Test Dimensions (continued)

SPECIMEN	t_1 (mm)	t_2 (mm)	e (mm)	s (mm)	Washers	Single or Double Shear	Pitch of Bolt (mm)	d (mm)	d_{hole}	d/t
064-230-1/2-TTSS-A	0.63	1.51	60.0	75.0	No	1	2.00	12.7	14.3	20.2
064-230-1/2-TTSS-B	0.63	1.51	60.0	75.0	No	1	2.00	12.7	14.3	20.2
064-230-1/2-TTSS-C	0.63	1.51	60.0	75.0	No	1	2.00	12.7	14.3	20.2
064-230-1/2-TTSS-D	0.63	1.51	60.0	75.0	Yes	1	2.00	12.7	14.3	20.2
064-230-1/4-TTSS-A	0.63	1.51	60.0	75.0	No	1	1.30	6.35	7.94	10.1
064-230-1/4-TTSS-B	0.63	1.51	60.0	75.0	No	1	1.30	6.35	7.94	10.1
064-230-1/4-TTSS-C	0.63	1.51	60.0	75.0	No	1	1.30	6.35	7.94	10.1
064-230-1/4-TTSS-D	0.63	1.51	60.0	75.0	Yes	1	1.30	6.35	7.94	10.1
076-230-1/2-TTSS-A	0.72	1.51	60.0	75.0	No	1	2.00	12.7	14.3	17.6
076-230-1/2-TTSS-B	0.72	1.51	60.0	75.0	No	1	2.00	12.7	14.3	17.6
076-230-1/2-TTSS-C	0.72	1.51	60.0	75.0	No	1	2.00	12.7	14.3	17.6
076-230-1/2-TTSS-D	0.72	1.51	60.0	75.0	Yes	1	2.00	12.7	14.3	17.6
091-230-1/4-TTSS-A	0.91	1.51	60.0	75.0	No	1	1.30	6.35	7.94	6.98
091-230-1/4-TTSS-B	0.91	1.51	60.0	75.0	No	1	1.30	6.35	7.94	6.98
091-230-1/4-TTSS-C	0.91	1.51	60.0	75.0	No	1	1.30	6.35	7.94	6.98
091-230-1/4-TTSS-D	0.91	1.51	60.0	75.0	Yes	1	1.30	6.35	7.94	6.98
091-230-1/2-TTSS-A	0.91	1.51	60.0	75.0	No	1	2.00	12.7	14.3	14.0
091-230-1/2-TTSS-B	0.91	1.51	60.0	75.0	No	1	2.00	12.7	14.3	14.0
091-230-1/2-TTSS-C	0.91	1.51	60.0	75.0	No	1	2.00	12.7	14.3	14.0
091-230-1/2-TTSS-D	0.91	1.51	60.0	75.0	Yes	1	2.00	12.7	14.3	14.0
121-230-1/2-TTSS-A	1.34	1.51	60.0	75.0	No	1	2.00	12.7	14.3	9.48
121-230-1/2-TTSS-B	1.34	1.51	60.0	75.0	No	1	2.00	12.7	14.3	9.48
121-230-1/2-TTSS-C	1.34	1.51	60.0	75.0	No	1	2.00	12.7	14.3	9.48
121-230-1/2-TTSS-D	1.34	1.51	60.0	75.0	Yes	1	2.00	12.7	14.3	9.48

Table 3.1 Bolt Connection Test Dimensions (continued)

SPECIMEN	t_1 (mm)	t_2 (mm)	e (mm)	s (mm)	Washers	Single or Double Shear	Pitch of Bolt (mm)	d (mm)	d_{hole}	d/t
121-230-3/8-TTSS-A	1.34	1.51	60.0	75.0	No	1	1.60	9.53	11.1	7.11
121-230-3/8-TTSS-B	1.34	1.51	60.0	75.0	No	1	1.60	9.53	11.1	7.11
121-230-3/8-TTSS-C	1.34	1.51	60.0	75.0	No	1	1.60	9.53	11.1	7.11
121-230-3/8-TTSS-D	1.34	1.51	60.0	75.0	Yes	1	1.60	9.53	11.1	7.11
043-230-3/8-DS-A	0.41	1.51	60.0	75.0	No	2	1.60	9.53	11.1	23.2
043-230-3/8-DS-B	0.41	1.51	60.0	75.0	No	2	1.60	9.53	11.1	23.2
043-230-3/8-DS-C	0.41	1.51	60.0	75.0	No	2	1.60	9.53	11.1	23.2
043-230-3/8-DS-D	0.41	1.51	60.0	75.0	Yes	2	1.60	9.53	11.1	23.2
043-230-1/2-DS-A	0.41	1.51	60.0	75.0	No	2	2.00	12.7	14.3	31.0
043-230-1/2-DS-B	0.41	1.51	60.0	75.0	No	2	2.00	12.7	14.3	31.0
043-230-1/2-DS-C	0.41	1.51	60.0	75.0	No	2	2.00	12.7	14.3	31.0
043-230-1/2-DS-D	0.41	1.51	60.0	75.0	Yes	2	2.00	12.7	14.3	31.0
043-230-5/8-DS-A	0.41	1.51	60.0	75.0	No	2	2.33	15.9	17.5	38.7
043-230-5/8-DS-B	0.41	1.51	60.0	75.0	No	2	2.33	15.9	17.5	38.7
043-230-5/8-DS-C	0.41	1.51	60.0	75.0	No	2	2.33	15.9	17.5	38.7
043-230-5/8-DS-D	0.41	1.51	60.0	75.0	Yes	2	2.33	15.9	17.5	38.7
064-230-5/8-DS-A	0.63	1.51	60.0	75.0	No	2	2.33	15.9	17.5	25.2
064-230-5/8-DS-B	0.63	1.51	60.0	75.0	No	2	2.33	15.9	17.5	25.2
064-230-5/8-DS-C	0.63	1.51	60.0	75.0	No	2	2.33	15.9	17.5	25.2
064-230-5/8-DS-D	0.63	1.51	60.0	75.0	Yes	2	2.33	15.9	17.5	25.2
064-230-1/2-DS-A	0.63	1.51	60.0	75.0	No	2	2.00	12.7	14.3	20.2
064-230-1/2-DS-B	0.63	1.51	60.0	75.0	No	2	2.00	12.7	14.3	20.2
064-230-1/2-DS-C	0.63	1.51	60.0	75.0	No	2	2.00	12.7	14.3	20.2
064-230-1/2-DS-D	0.63	1.51	60.0	75.0	Yes	2	2.00	12.7	14.3	20.2

Table 3.1 Bolt Connection Test Dimensions (continued)

SPECIMEN	t_1 (mm)	t_2 (mm)	e (mm)	s (mm)	Washers	Single or Double Shear	Pitch of Bolt (mm)	d (mm)	d_{hole}	d/t
064-230-1/4-DS-A	0.63	1.51	60.0	75.0	No	2	1.30	6.35	7.94	10.1
064-230-1/4-DS-B	0.63	1.51	60.0	75.0	No	2	1.30	6.35	7.94	10.1
064-230-1/4-DS-C	0.63	1.51	60.0	75.0	No	2	1.30	6.35	7.94	10.1
064-230-1/4-DS-D	0.63	1.51	60.0	75.0	Yes	2	1.30	6.35	7.94	10.1
076-230-1/2-DS-A	0.72	1.51	60.0	75.0	No	2	2.00	12.7	14.3	17.6
076-230-1/2-DS-B	0.72	1.51	60.0	75.0	No	2	2.00	12.7	14.3	17.6
076-230-1/2-DS-C	0.72	1.51	60.0	75.0	No	2	2.00	12.7	14.3	17.6
076-230-1/2-DS-D	0.72	1.51	60.0	75.0	Yes	2	2.00	12.7	14.3	17.6
091-230-1/4-DS-A	0.91	1.51	60.0	75.0	No	2	1.30	6.35	7.94	6.98
091-230-1/4-DS-B	0.91	1.51	60.0	75.0	No	2	1.30	6.35	7.94	6.98
091-230-1/4-DS-C	0.91	1.51	60.0	75.0	No	2	1.30	6.35	7.94	6.98
091-230-1/4-DS-D	0.91	1.51	60.0	75.0	Yes	2	1.30	6.35	7.94	6.98
091-230-1/2-DS-A	0.91	1.51	60.0	75.0	No	2	2.00	12.7	14.3	14.0
091-230-1/2-DS-B	0.91	1.51	60.0	75.0	No	2	2.00	12.7	14.3	14.0
091-230-1/2-DS-C	0.91	1.51	60.0	75.0	No	2	2.00	12.7	14.3	14.0
091-230-1/2-DS-D	0.91	1.51	60.0	75.0	Yes	2	2.00	12.7	14.3	14.0
121-230-1/2-DS-A	1.34	1.51	60.0	75.0	No	2	2.00	12.7	14.3	9.48
121-230-1/2-DS-B	1.34	1.51	60.0	75.0	No	2	2.00	12.7	14.3	9.48
121-230-1/2-DS-C	1.34	1.51	60.0	75.0	No	2	2.00	12.7	14.3	9.48
121-230-1/2-DS-D	1.34	1.51	60.0	75.0	Yes	2	2.00	12.7	14.3	9.48
121-230-3/8-DS-A	1.34	1.51	60.0	75.0	No	2	1.60	9.53	11.1	7.11
121-230-3/8-DS-B	1.34	1.51	60.0	75.0	No	2	1.60	9.53	11.1	7.11
121-230-3/8-DS-C	1.34	1.51	60.0	75.0	No	2	1.60	9.53	11.1	7.11
121-230-3/8-DS-D	1.34	1.51	60.0	75.0	Yes	2	1.60	9.53	11.1	7.11

3.3 Fabrication of Specimens

Sheet steel samples were obtained from the rolling mill at Dofasco Inc. in Hamilton, Ontario, and then shipped to McGill University. From these samples blanks that were positioned in the longitudinal (rolling direction) were cut. This operation was carried out on a shear machine located in the Mechanical Tools Lab in the Department of Mechanical Engineering at McGill University. Consistent and accurate fabrication procedures were applied to all operations in an attempt to fabricate near identical size and shape test specimens. The centres of bolt holes were positioned using a spring punch. All bolt holes were drilled and any resulting burrs were carefully removed with a file.

Although the 0.64 mm mild grade steels were included in the test program, they were not at the time available from Dofasco Inc.. It was necessary to utilize a 0.64 mm high strength steel, shear the appropriate blanks, and then anneal the specimens in an electric furnace located in the McGill Metals Processing Centre in the Department of Mining, Metals and Materials Engineering. In order to determine an appropriate treatment process, six coupons were machined, with three subsequently annealed in the furnace at a temperature of 700°C for two, five and ten minutes, respectively. Standard tensile coupon tests similar to that described in Section 3.4 were performed (ASTM A370, 2002) and the stress-strain curves were recorded. The material behaviour indicated by the stress-strain curve for the coupon that underwent the ten minute annealing was determined to be most similar to that typical of mild sheet steels. However, after all of the prepared blanks, as well as the three additional coupons were annealed simultaneously for ten minutes at 700°C, it was found from a coupon test that the stress-strain curve did not change significantly as had been observed for the ten minute test coupon. This was likely due to the increase in the quantity of steel specimens placed in the furnace at one time, which resulted in an actual decrease in the furnace temperature compared with the previous procedures. All materials were then subjected to a further twenty minutes in the furnace, and again a satisfactory result was not obtained. A stress-strain curve exhibiting mild steel characteristics was finally obtained after the blanks and coupons were annealed for an additional 30 minutes at 700°C (total annealing time = 60 minutes).

The bolts for most specimens were consistently torqued to a nominal value of 30 Nm with a torque wrench. However, in order to avoid a slip load higher than the ultimate load of a connection, the specimens made from the 0.43 mm mild grade steel sheets were assembled by hand to a torque less than 10 Nm. Due to the use of oversized bolt holes and the placement of bolts in the centre of the bolt holes, slippage between the sheets would normally occur during the initial stages of loading. In some cases the rolling process and the storage of the sheets in coils resulted in residual curvature of the test specimens. These specimens were assembled such that the curvature of the sheets faced one another in an attempt to limit out of plane bending of the steel near the bolt. Schematic drawings of the typical test assemblies are shown in Figure 3.3

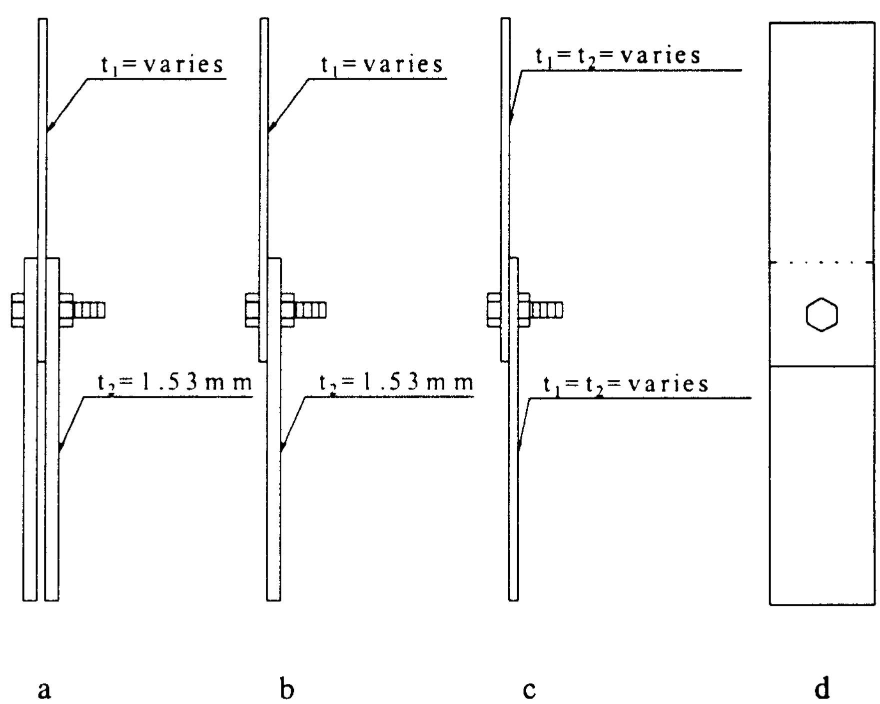


Figure 3.3 Side View (a: DS, b: TTSS, c: SS) and Front View (d) of Test Specimens

3.4 Material Properties

High strength and mild steels used in this investigation can be categorized into the SQ grade 550 and SQ grade 230 ASTM A653 (2002) sheet types. The material properties of the sheet steels were obtained from standard tensile coupon tests according to ASTM A370 (2002) recommendations. All steel sheets were cold reduced in thickness and galvanized with a zinc coating during manufacturing before being shipped to the laboratory. Three coupons for each type of steel were cut from the longitudinal direction of the supplied sheets when the test specimens were prepared. Coupons for the 0.64 mm mild sheet steel were annealed simultaneously with test specimens in the McGill Metals Processing Centre as discussed previously. The crosshead speed for the high strength coupons was 0.1 mm/minute, whereas 0.5 mm/minute was utilized for mild steel coupons due to their greater ability to elongate. The strength for the steels could be measured directly from each coupon test. In order to obtain the static strength of the materials, the crosshead of the test machine was stopped for five one-minute intervals (two in the yielding region and three in the strain hardening region) during testing. The static load was considered to be that measured at the end of the stoppage time. After testing, the coupons were bathed in an hydrochloric acid solution to remove the zinc coating such that the base metal thickness could be measured. The mechanical properties provided in Table 3.2 were obtained by using the base metal thickness in calculations.

Most coupons for the mild sheet steels, including the annealed 0.64 mm steel, exhibited a typical sharp-yielding stress-strain curve, which can be identified by the sharp yielding point, followed by a yield plateau, and then a significant strain hardening region, and finally necking. However, a gradual-yielding stress-strain relationship was recorded for the 0.43 mm mild sheet steel. The corresponding yield strength was obtained per the 0.2% strain offset method. All of the mild steels possessed adequate ductility to meet the requirements of the North American Specification (AISI, 2001a; CSA, 2001) based on the 2 in. (50mm) gauge length elongation ($\varepsilon \geq 10\%$), which ranged from 24% to 42%. These steels also met the minimum ratio of tensile strength to yield strength (F_u / $F_y \geq 1.08$). However, all high strength steels that were tested for this investigation did not meet the gauge length ductility or F_u / F_y requirements. Of the three types of high strength sheet steels, the 0.76 mm and 0.64 mm displayed a sharp yield point, which was followed by a very flat plateau with no observable strain-hardening region. Compared with the limited ductility of the 0.76 mm and 0.64 mm grade 550 steels, the 0.43 mm grade 550 steel showed approximately zero ductility. Fracture of these coupons took place suddenly in the elastic range, and hence, it was not possible to measure an elongation over the 2 in. (50mm) gauge length

Table 3.2 Material Properties of Sheet Steel

Specimen Type	Total Thickness (mm)	Base Thickness (mm)	F_u (MPa) Dyn. / Sta.	F_y (MPa) Dyn. / Sta	F_u / F_y Dyn. / Sta	2 in. (50mm) Elongation (%)
1.53 Mild	1.55	1.51	361/344	295/278	1.22/1.24	42
1.21 Mild	1.39	1.34	375/357	300/282	1.25/1.27	30
0.91 Mild	0.93	0.91	354/334	293/273	1.21/1.22	34
0.76 Mild	0.76	0.72	398/379	342/323	1.16/1.17	34
0.64 Mild	0.69	0.63	348/323	303/278	1.15/1.16	27
0.43 Mild	0.46	0.41	377/360	261/244	1.44/1.48	24
0.76 High Strength	0.81	0.76	674/654	674/654	1.00/1.00	8
0.64 High Strength	0.69	0.63	704/679	704/679	1.00/1.00	*
0.43 High Strength	0.39	0.35	734/698	734/698	1.00/1.00	0

* Coupon specimens broke outside of the 50 mm gauge length, similar ductility to 0.76 mm high strength observed.

3.5 Test Procedure

All tests in this study were performed on an MTS SINTEC 30/G 150 kN universal testing machine located in the Materials Laboratory of the Department of Civil

Engineering and Applied Mechanics at McGill University. A special grip apparatus was fabricated to connect the test specimens to the test machine such that eccentric load conditions and hence applied moments, would not occur, as shown in Figs. 3.5 and 3.6. Before each test, the specimen was aligned with the grips to ensure that the connection was concentrically loaded. Aluminum angles were attached to each side of the test specimen (200 mm apart) by using wing nuts. A total of four displacement transducers were used to measure the connection elongation. These transducers were placed on both sides of each aluminum angle such that the effect of the specimen's rotation on the connection elongation measurement could be minimized. The displacement transducers, along with the 150 kN load cell were connected to a Vishay System 5000 data acquisition system, which allowed for all load and displacement readings to be recorded at one-second intervals during testing (see Fig 3.7). All tests were run at a crosshead speed of 1.0 mm/min.

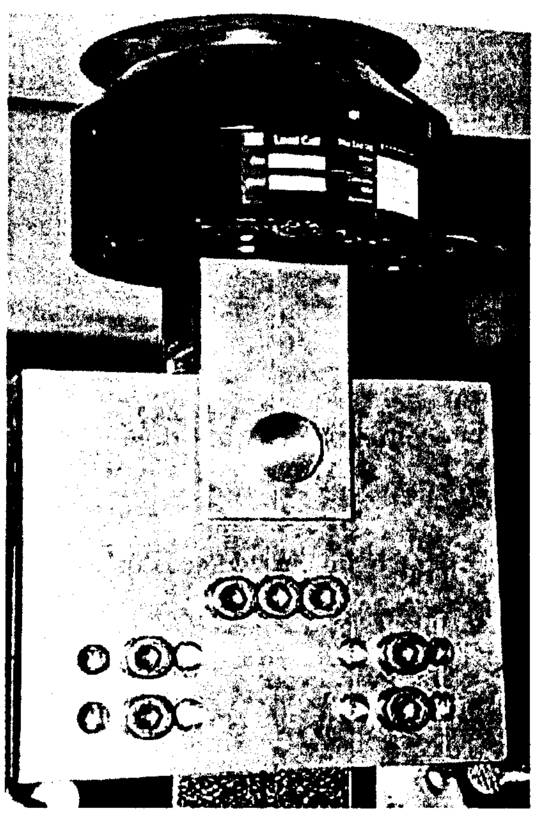


Figure 3.5 Grip Apparatus

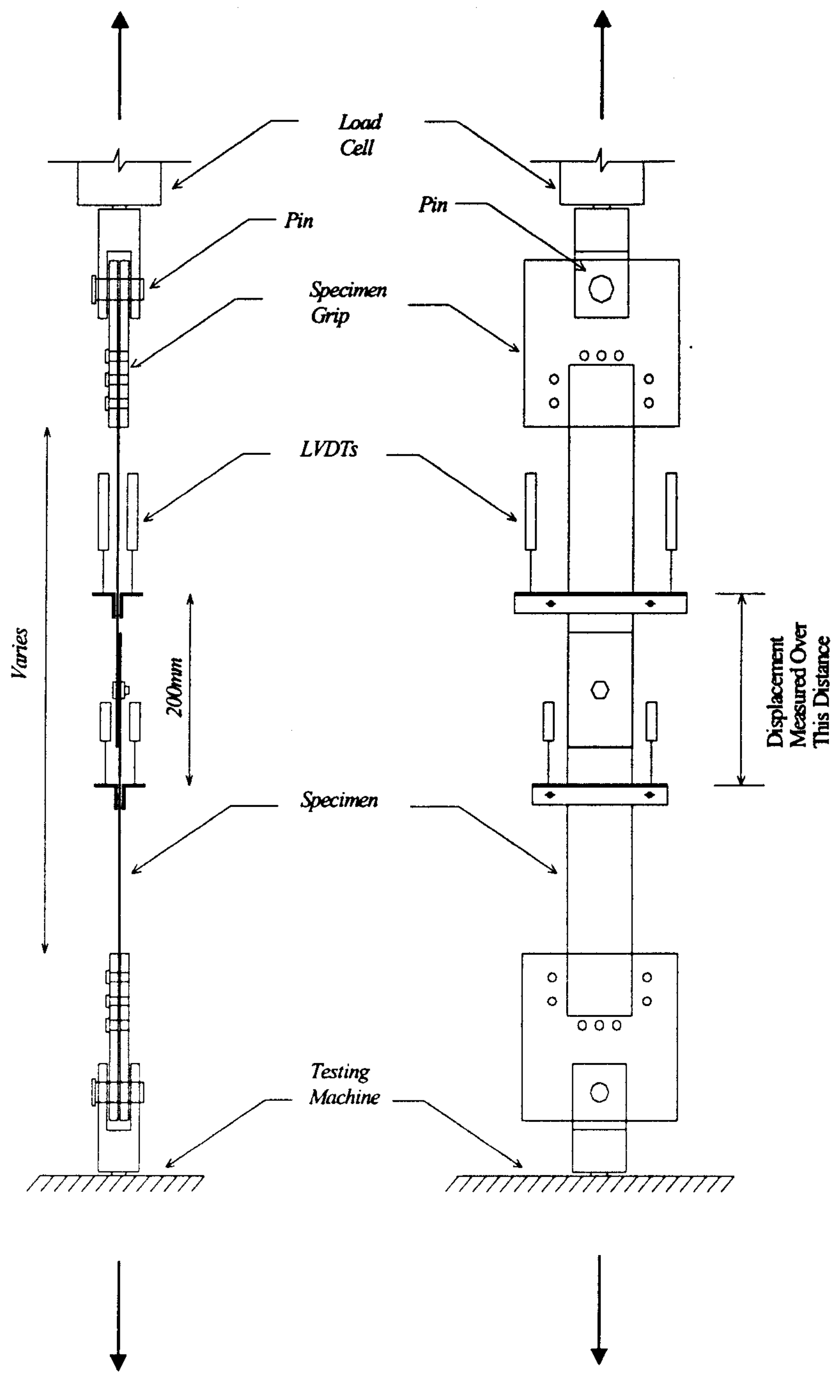


Figure 3.6 Schematic Drawing of Bolted Connection Set-Up

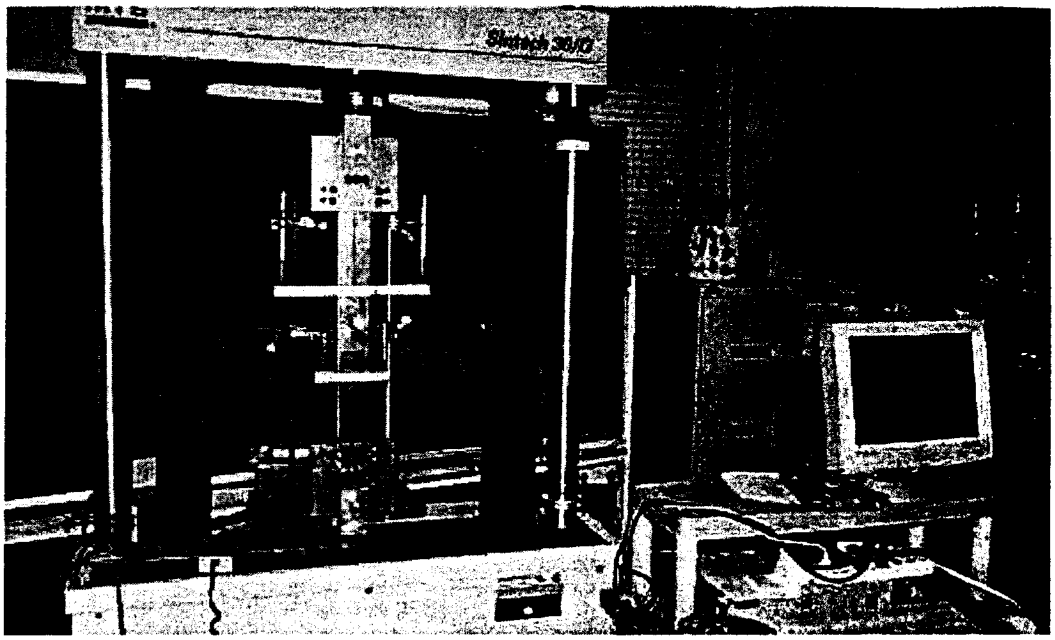


Figure 3.7 Test Machine and Data Acquisition System

3.6 Behaviour of Bolted Connections

Typical load *vs.* elongation curves for different configurations of the washerless bolted connections are presented in Figures 3.8 to 3.11. Test curves for each individual connection can be found in Appendix B. The load elongation graphs in Appendix B and those presented in this section indicate that the different types of connections exhibited similar shear behaviour. In general, at initial load application, bolt slippage was experienced due to the oversize holes, followed by bearing contact of the bolt shank against the bolt hole edge, then elastic deformation of the test specimen and gripping assembly and localized plastic bearing deformation in the sheet steel around the connector. It was in the plastic range that the ultimate shear load was reached; hence large deformations after slip, typically 8 to 13 mm, were observed at peak load. The connections were also able to carry load in the post-ultimate range. Additional aspects of the connection shear behaviour, which involve bolt tilting (rotation) and sheet tearing, are discussed on the following pages.

Deformation limits for bolted connections have been suggested by the Research Council on Structural Connections (AISC, 1988) and the American Institute of Steel Construction (AISC, 1989, 1993). A relative displacement based capacity upon reaching 6.35 mm deformation was introduced in the North American Specification (AISI, 2001a; CSA, 2001) as well. Hence, the maximum load reached prior to the AISC connection displacement limit of 6.35 mm was recorded for all test specimens. The connection displacement measured after bearing had commenced was utilized. Of the 148 tests without washers, 27 tests reached the ultimate load before 6.35 mm elongation. A more detailed comparison of the displacement based load limit, $P_{6.35}$, between bolted connections with and without washers will be discussed in Chapter 4.

In general, the deformation around the holes of washerless connections was less severe than that of connections bolted with washers. The washers acted in a bracing role on the connection, such that the connections with washers were able to resist a larger ultimate load and experienced greater displacement compared with nominally identical washerless connection. (The use of a washer provided a greater contact area between the sheet steel and the bolt assembly, which decreased the degree of fastener rotation compared with the situation where a washer was not installed.) As expected, the mode of failure for all tests was established as bearing. However, it is important to note that distinctions must be made within the bearing type of failure mode. Three types of bearing failure were observed for the washerless connections during the experiment.

Type A: bearing failure with bolt tilting, with associated end curling and localized tearing of the sheet steel.

Type B: bearing failure with bolt tilting and localized dishing of the sheet steel adjacent to the bolt.

Type C: bearing failure with material piling up in front of the bolt and significant longitudinal shearing along two parallel lines.

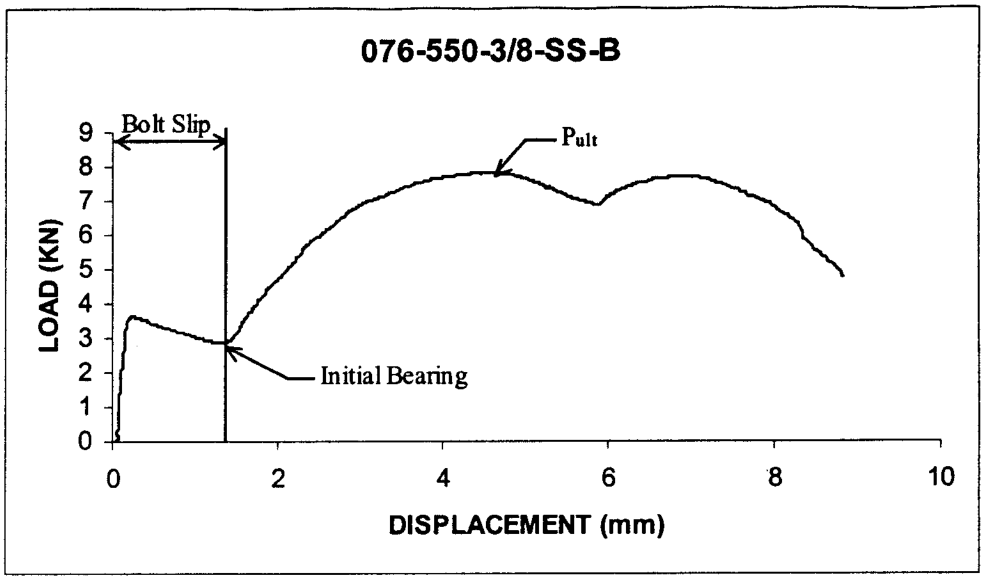


Figure 3.8 Typical Load Elongation Curve for High Strength Single Shear Washerless Connections With Equal Sheet Thickness

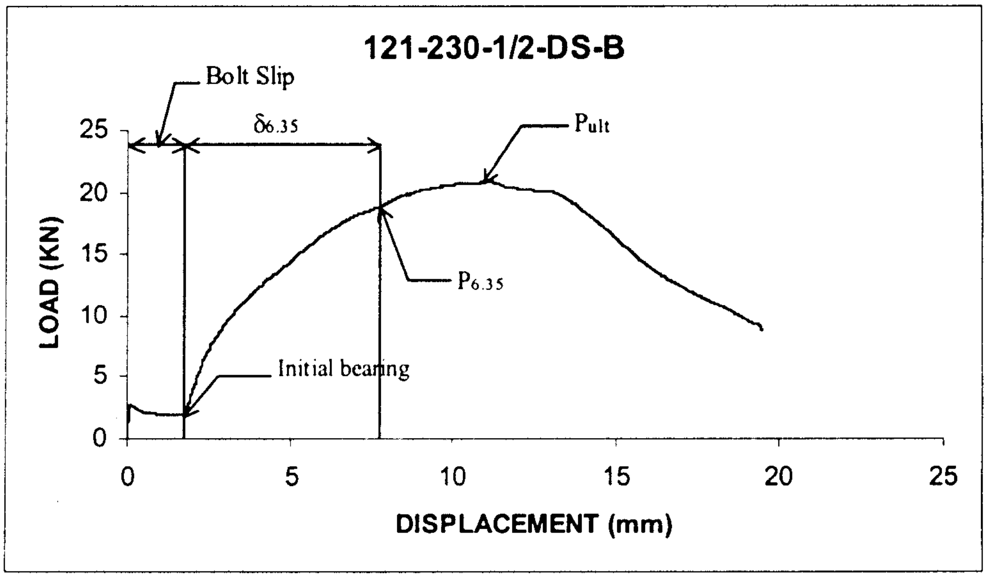


Figure 3.9 Typical Load Elongation Curve for Double Shear Washerless Connections With Thinner Sheet Inside.

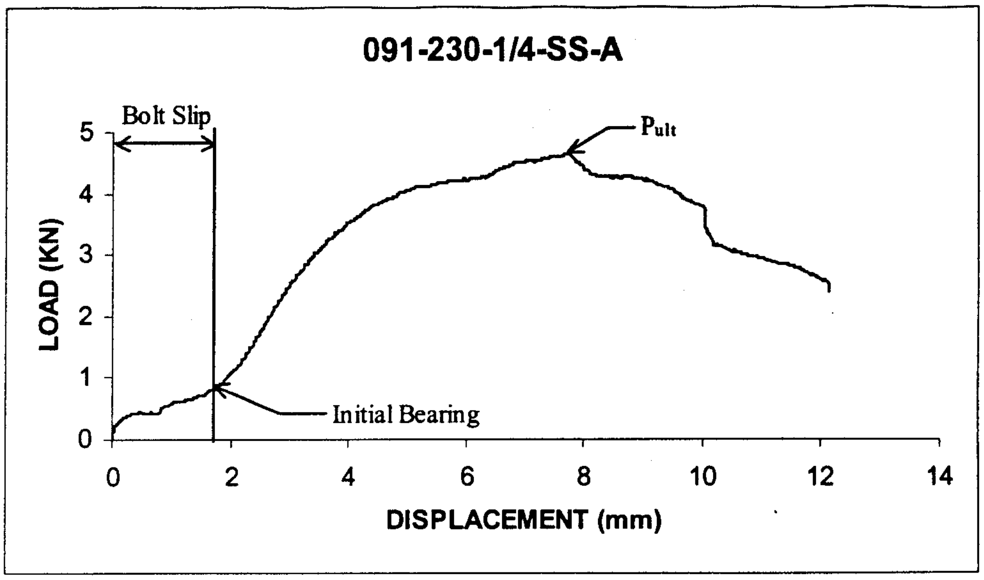


Figure 3.10 Typical Load Elongation Curve for Mild Strength Single Shear Washerless Connections With Equal Sheet Thickness.

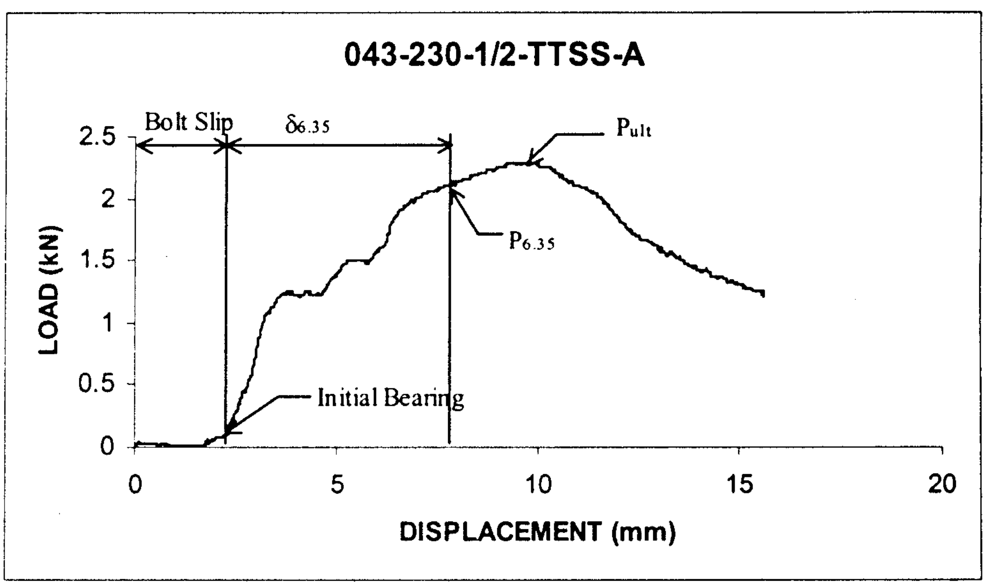


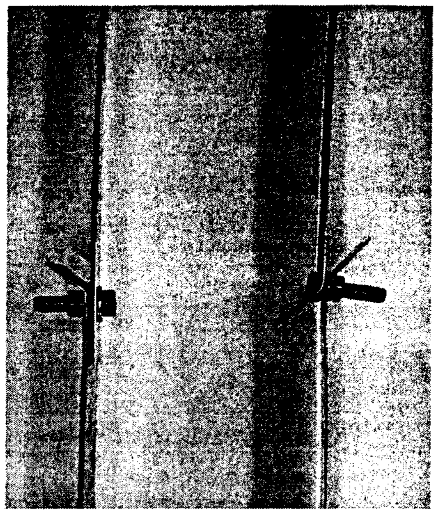
Figure 3.11 Typical Load Elongation Curve for Mild Strength Single Shear Washerless Connections With Different Sheet Thickness.

After initial slip had taken place and bearing stresses had developed in the sheet steel around the bolt the different connections would experience various types of behaviour. The three types of bearing failure will be discussed in detail in the following paragraphs.

Type A: A majority of single shear connection tests (excluding some mild steel connections with bolt diameter smaller than 1/4 in) failed in the Type A mode. Once initial bearing contact between the bolt and sheet had been established, the steel sheets would in some cases curl outward and the bolt would tilt (Figures 3.12a and b present these types of connections after failure). The magnitude of this bolt tilting and sheet curling depended on the presence of washers, where those connections without washers experienced somewhat more extensive tilting and curling. Although the curling of the steel sheet and bolt tilting typically could be observed after the initial bearing had begun, these out-of-plane actions were not significant until the load elongation curve had progressed into the plastic region. At this time the bolt would start to tilt severely and to punch into the steel. In the cases where curling of the sheets was observed, it would typically manifest into localized tears in the sheet steel at the edge of the bolt or bolt washer. Tears of this type can be seen in Figures 3.13 to 3.15. As described in Rogers and Hancock (1998b, 2000), the localized tears were most likely caused by the bearing stress and through thickness shear stress concentrated at the edge of the bolt hole due to the out-of- plane curling of steel sheet. Most of these tears originated at the end of holes and developed in a diagonal direction for a short distance. Hence, these tears were considered to be not very significant and in some instance they could be observed only when the test specimens were disassembled.

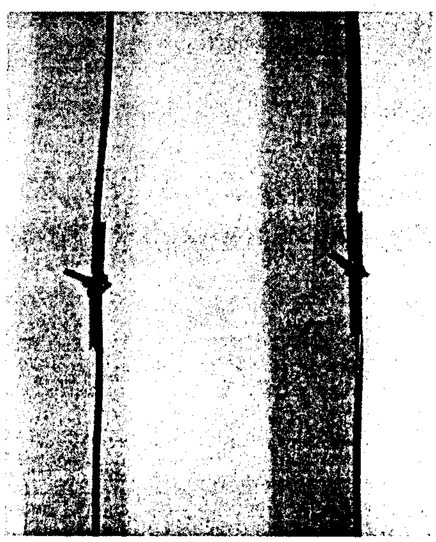
Type B: Type B failure only occurred in mild strength single shear connections with 1/4-inch bolts. Although not all of these connections failed in Type B bearing. Among a total of 20 connections of this type, one connection with washers exhibited significant end curling and three connections without washers experienced slight end curling at the end of the test. For Type B bearing failure, as shown in Figure 3.12c, the bolts tilted severely, and the head as well as the nut dished into the steel sheet. No localized tears nor significant out-of-plane curling occurred in the sheet even at the ultimate load. (See Figure 3.16) This phenomenon can be attributed to the relative higher out-of-plane punching shear stress caused by the bolt rotation. In part, this behaviour may also have been traced to the use of bolt holes that were 1/16 in (1.59 mm). larger than the bolt diameter. In the AISI Specification (1999), the standard hole diameter is given as 1/32 in. (0.79 mm) larger than the bolt diameter for bolts smaller than 1/2 in. (12.7 mm)

Type C: Type C failure took place in the double shear connections only. There was no significant bolt rotation was observed for double shear connections either with or without washers during the tests. The typical double shear connection at failure is shown in Figure 3.12d. The outside sheets of the connection prevented the inside sheet from curling out-of-plane, thus increasing the load carrying capacity and prolonging the longitudinal bolt displacement. This behaviour was caused by the outside sheets which were larger in thickness, and which provided a symmetrical support and bracing to the inner sheet and bolt. The bearing stress at the bolt sheet interface was associated with a shearing stress that was responsible for the diagonal tearing toward the specimen edge (See Figure 3.18). However, these tears typically occurred with the thinner sheets, *e.g.* 0.64 and 0.43 mm sheet steel. For the thicker steels (0.76, 0.91, 1.21 mm) as shown in Figure 3.17, the longitudinal shear stress did not cause tears to occur before the connections reached the ultimate load.

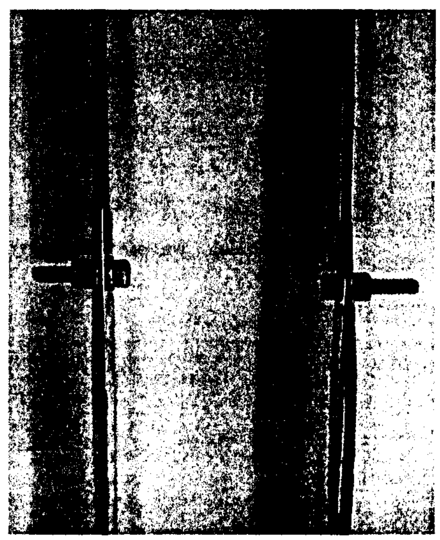


(a). Single shear, equal sheet thickness, with the bolt diameter larger than ¼ inch

(b). Single shear, different sheet thickness, with the bolt diameter larger than ¼ inch



(c). Single shear, equal sheet thickness, with the bolt diameter equaling to ¼ inch



(d). Double shear connections

Figure 3.12 Typical Connections at failure (In the picture, the left is the connection with washer and the right is washerless connection)

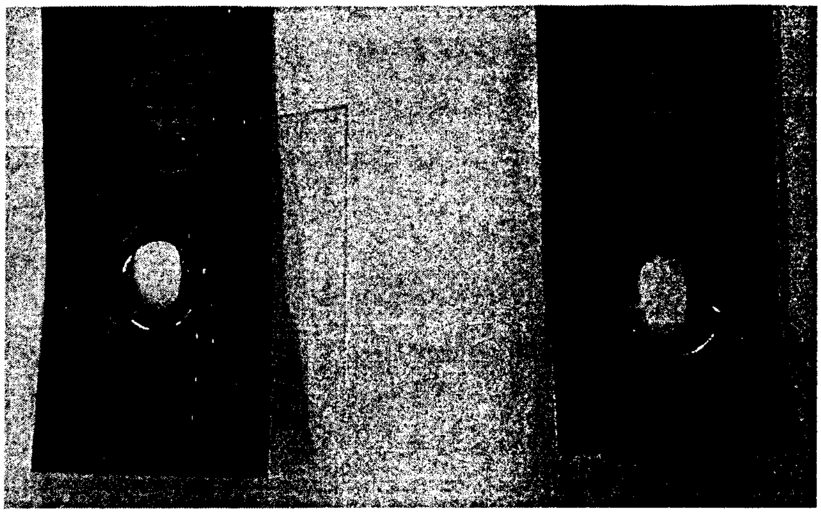


Figure 3.13 Type A Bearing Failure: 043-230-5/8-SS-C (left) and 043-230-5/8-SS-D (right)

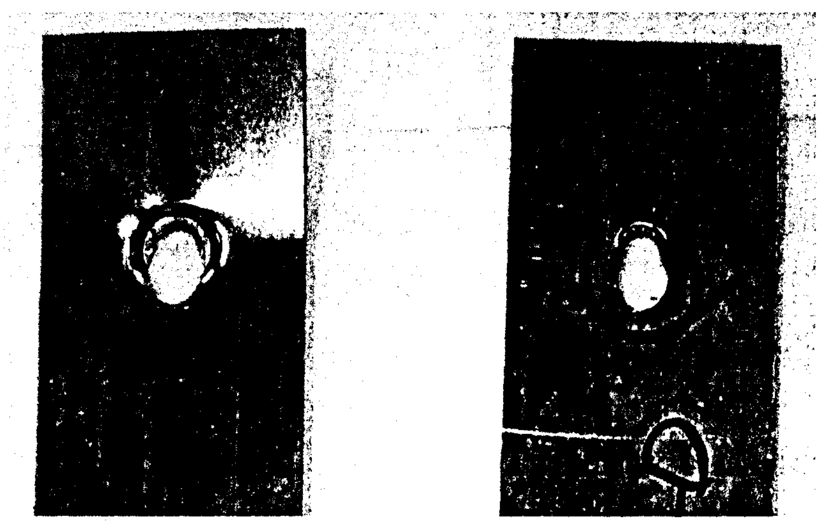


Figure 3.14 Type A Bearing Failure: 064-550-1/2-SS-C (left) and 064-550-1/2-SS-D (right)

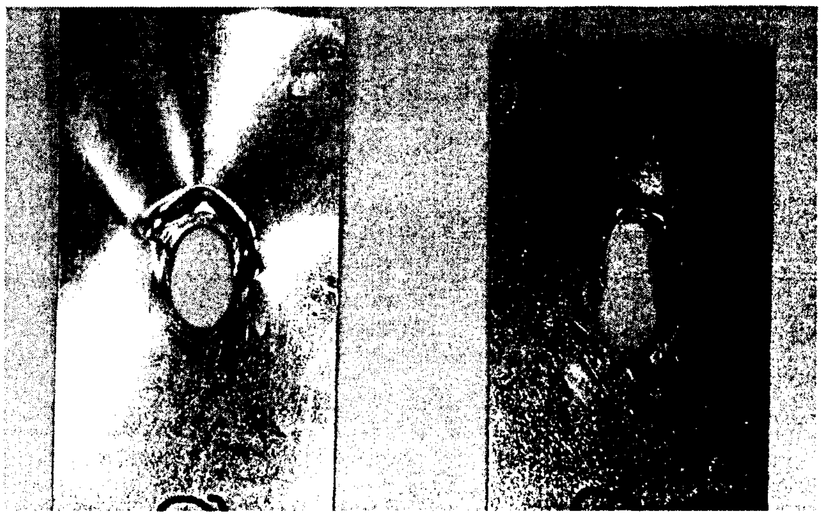


Figure 3.15 Type A Bearing Failure:043-550-5/8-SS-A (left) and 043-550-5/8-SS-D (right).

Figure 3.16 Type B Bearing Failure: 091-230-1/4-SS-C (left) and 091-230-1/4-SS-D (right).

Figure 3.17 Type C Bearing Failure: 091-230-1/4-DS-A (left) and 091-230-1/4-DS-D (right)

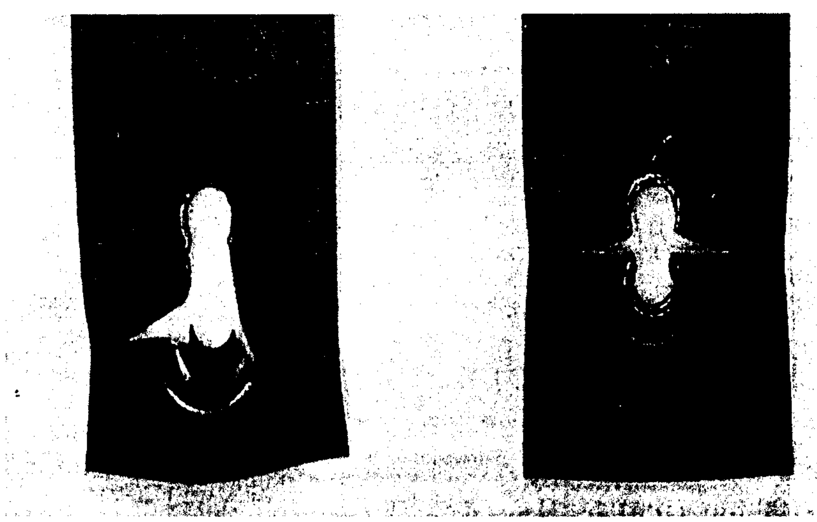


Figure 3.18 Type C Bearing Failure: 043-230-1/2-DS-A (left) and 043-230-1/2-DS-D (right)

CHAPTER 4 EVALUATION OF TEST DATA AND DESIGN METHODS

4.1 Evaluation of Test Data

In this section the results from the experimental investigation at McGill University are presented in detail. This presentation focuses on the comparison of ultimate load and elongation between the various connection specimens. The design methods for ultimate load in this section include the North American Specification (AISI, 2001a; CSA, 2001), CSA (1994), AISI (1999), AS/NZS 4600 (1996) and Eurocode (1996). In the North American Specification (AISI, 2001a,b; CSA, 2001), a relative displacement based capacity was introduced when deformation around the bolt hole is a design consideration. The capacity is based on an acceptable deformation limit of 0.25 in. (6.35 mm). Hence, the loads at 6.35 mm extension after the initial bearing were recorded as well.

Due to the use of bolt holes which were 1/16 in. (1.59 mm) larger than the bolts themselves, slip of the connection before initial bearing was normally experienced. As shown in Figure 4.1, the elongation at ultimate, δ_{ult}, for each test specimen was obtained from the difference between the total elongation at ultimate and the slip length. The displacement based capacity at 6.35 mm extension, $P_{6.35}$, was also obtained by measuring from the initial bearing point. In some tests, the measured elongation at ultimate was less than 6.35 mm, hence, the maximum load and the $P_{6.35}$ load were equal. The ultimate load, P_t, and the corresponding elongation at ultimate, δ_{ult}, for each test as well as the displacement based capacity, $P_{6.35}$ can be found in Table B1 of Appendix "B".

A comparison of ultimate load and elongation at ultimate for the bolted connection tests with and without washers is documented in Tables 4.1a to 4.1d. In these tables, P_t and δ_{ult} for connections without washers are the average of three identical samples within one group. In contrast, for bolted connections with washers P_t and δ_{ult} were determined from

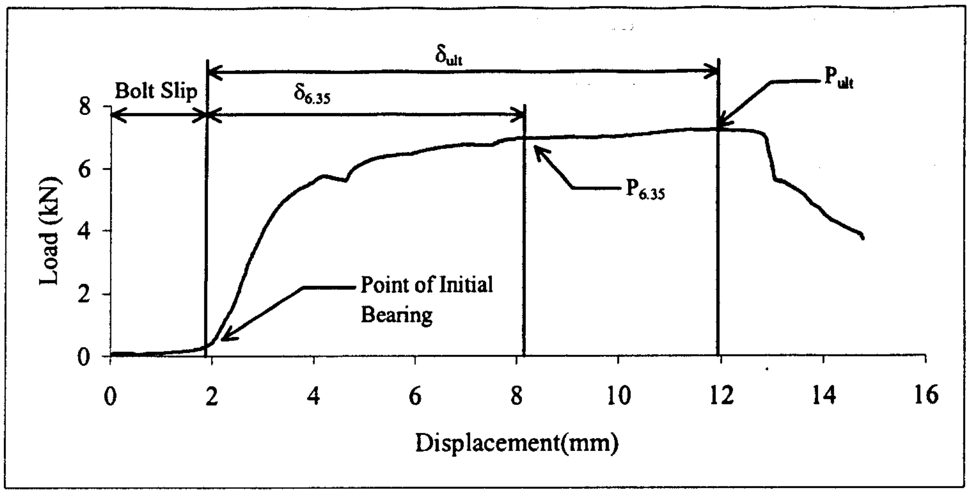


Figure 4.1 Definition of $P_{6.35}$ and δ_{ult}

only one sample, *i.e.* the forth sample identified with a "D" in each group. In Section 3.5 the differences between the physical behaviour of single shear and double shear connections have been discussed. From the test results presented in Tables 4.1a to 4.1d, it can also be concluded that the behavioural differences between single shear and double shear connections are quite significant. For the single shear connections with equal sheet thickness, regardless of the types of steel used, the ratios of ultimate load ($P_{t,\text{Without Washers}}$/ $P_{t,\text{With Washers}}$) and corresponding displacement ($\delta_{t,\text{Without Washers}}/\delta_{t,\text{With Washers}}$) between tests with and without washers are almost 70%. However, in the case of double shear and single shear connections with different sheet thickness, the ratios are close to 85% and 100% for ultimate load and corresponding elongation, respectively. This can be attributed to the rotational support provided to the bolt by the thicker sheets, which is similar to that provided by washers. This support reduces the degree of fastener rotation and hence increases the load carrying ability of the connection. In general, the greater the difference in thickness between the two sheets that are connected, the more significant the effect of this support, in the context of the sheet thicknesses that were used in this study. Figures 4.2a and 4.2b illustrate the relationship between the ratios of sheet thicknesses and the ratios of ultimate load with and without washers. It can be observed from these figures that the ratios of $P_{t,\text{ Without Washers}}$ / $P_{t,\text{ With Washers}}$ decrease with an increase in the ratio of t_1/t_2. Similarly, this tendency was found in the relationship between t_1/t_2 and $\delta_{t,\ Without\ Washers}/\delta_{t,\ With\ Washers}$ (Figures 4.3a and 4.3b). However, it is unusual that both ratios ($P_{t,\ Without\ Washers}$ / $P_{t,\ With\ Washers}$ and $\delta_{t,Without\ Washers}/\delta_{t,With\ Washers}$) for single shear connections with different sheet thickness are closer to unity than those of double shear connections. This is considered unusual because in the double shear case fastener rotation is eliminated due to the connection configuration, and hence the use of washers should not have a significant a role as found for the single shear case. In all likelihood this trend was probably due to the lack of data for connections with washers in this investigation, where for every three washerless connections only a single washer connection was tested. For single shear connections with different sheet thickness, the coefficient of variation for the ratio of ultimate load is 0.14, which is 55% higher than that of double shear connections. Compared with the ratios of ultimate load, the coefficient of variation for the ratios of elongation at ultimate, regardless of the type of connection, are approximately 1~2 times higher than those of ultimate load. This can be partially attributed to the difficulty in accurately determining the initial point of bearing on the load *vs.* displacement graphs, which may have introduced an error into the estimation of connection slip.

Tables 4.2a to 4.2d provide a comparison of the displacement based capacity at initial 6.35 mm extension, $P_{6.35}$, for different types of connections. As found in Table 4.1, all data for the tests without washers is based on the average of three samples in one group, and the data for specimens with washers was determined from a single connection test in the same group. Similarly, there is an approximate decrease of 80% for the relative displacement based capacity for washerless connections from that measured for the connections with washers. Compared with the data of ultimate load and corresponding elongation in Table 4.1, the relative displacement based capacities for connections with and without washers do not significantly vary with the type of connection. Only the average ratio of $P_{6.35,\ without\ washers}$ / $P_{6.35,with\ washers}$ for mild steel, single shear connections with equal sheet thickness is slightly lower than the counterparts of the other three connection types.

Table 4.1a: Connection Elongation and Ultimate Load Comparison: Mild Strength Steel, Double Shear

SPECIMEN	t_1 / t_2	$P_{t,\text{Without Washers}}$[1] (kN)	$P_{t,\text{With Washers}}$[2] (kN)	$P_{t,\text{Without Washers}} / P_{t,\text{With Washers}}$	$\delta_{t,\text{Without Washers}}$[1] (mm)	$\delta_{t,\text{With Washers}}$[2] (mm)	$\delta_{t,\text{Without Washers}} / \delta_{t,\text{With Washers}}$
043-230-3/8-DS	0.27	3.46	4.51	0.77	12.2	15.3	0.80
043-230-1/2-DS	0.27	5.65	6.98	0.81	14.3	11.5	1.24
043-230-5/8-DS	0.27	7.30	7.50	0.97	13.3	8.91	1.50
064-230-5/8-DS	0.42	11.5	12.5	0.92	12.3	10.6	1.17
064-230-1/2-DS	0.42	9.14	10.7	0.86	8.56	9.07	0.94
064-230-1/4-DS	0.42	6.60	8.98	0.74	9.30	10.5	0.88
076-230-1/2-DS	0.48	11.1	14.4	0.77	11.0	16.3	0.68
091-230-1/4-DS	0.60	12.1	14.6	0.83	10.7	11.9	0.90
091-230-1/2-DS	0.60	13. 8	15.4	0.90	10.7	10.5	1.01
121-230-1/2-DS	0.89	19.3	24.9	0.77	10.9	16.0	0.68
121-230-3/8-DS	0.89	18.4	23.2	0.79	10.7	12.0	0.89
			Mean	**0.83**		**Mean**	**0.97**
			S.D.	**0.07**		**S.D.**	**0.25**
			C.O.V.	**0.09**		**C.O.V.**	**0.25**

[1]Values based on average of three test specimens.

[2]Values based on single test specimen.

Table 4.1b: Connection Elongation and Ultimate Load Comparison: High Strength Steel, Single Shear with Equal Sheet Thickness

SPECIMEN	t_1 / t_2	$P_{t,\text{Without Washers}}$ (kN)	$P_{t,\text{With Washers}}$ (kN)	$P_{t,\text{Without Washers}}$ / $P_{t,\text{With Washers}}$	$\delta_{t,\text{Without Washers}}$ (mm)	$\delta_{t,\text{With Washers}}$ (mm)	$\delta_{t,\text{Without Washers}}$ / $\delta_{t,\text{With Washers}}$
043-550-3/8-SS	1.0	2.61	4.44	0.59	6.87	10.6	0.65
043-550-1/2-SS	1.0	3.36	4.52	0.74	8.59	8.90	0.97
043-550-5/8-SS	1.0	3.85	4.85	0.79	8.74	21.7	0.40
064-550-5/8-SS	1.0	8.63	11.2	0.77	10.3	15.9	0.65
064-550-1/2-SS	1.0	7.08	9.63	0.74	8.55	10.1	0.84
064-550-3/8-SS	1.0	6.03	9.39	0.64	4.73	7.79	0.61
064-550-1/4-SS	1.0	5.71	7.42	0.77	5.55	7.17	0.77
076-550-1/2-SS	1.0	8.46	12.5	0.68	7.29	8.38	0.87
076-550-3/8-SS	1.0	7.53	10.1	0.75	3.71	7.66	0.48
076-550-1/4-SS	1.0	6.79	9.26	0.73	5.23	5.92	0.88
			Mean	**0.72**		**Mean**	**0.71**
			S.D	**0.06**		**S.D.**	**0.18**
			C.O.V.	**0.08**		**C.O.V.**	**0.26**

Table 4.1c: Connection Elongation and Ultimate Load Comparison: Mild Strength Steel, Single Shear with Equal Sheet Thickness

SPECIMEN	t_1 / t_2	$P_{t,\text{Without Washers}}$ (kN)	$P_{t,\text{With Washers}}$ (kN)	$P_{t,\text{Without Washers}} / P_{t,\text{With Washers}}$	$\delta_{t,\text{Without Washers}}$ (mm)	$\delta_{t,\text{With Washers}}$ (mm)	$\delta_{t,\text{Without Washers}} / \delta_{t,\text{With Washers}}$
043-230-3/8-SS	1.0	1.71	2.94	0.58	6.75	9.40	0.72
043-230-1/2-SS	1.0	2.15	2.50	0.86	9.48	11.9	0.80
043-230-5/8-SS	1.0	2.87	3.85	0.75	*	*	*
064-230-3/8-SS	1.0	2.86	3.85	0.74	5.02	6.58	0.76
064-230-1/4-SS	1.0	3.00	5.56	0.54	4.87	9.76	0.50
076-230-1/2-SS	1.0	4.73	7.21	0.66	7.94	12.5	0.64
076-230-5/8-SS	1.0	6.08	8.62	0.71	13.2	13.2	1.00
091-230-1/4-SS	1.0	4.87	6.41	0.76	6.14	11.9	0.52
121-230-3/8-SS	1.0	8.61	14.7	0.59	5.66	13.7	0.41
153-230-1/4-SS	1.0	9.76	15.2	0.64	6.97	13.2	0.53
			Mean	**0.68**		**Mean**	**0.65**
			S.D.	**0.10**		**S.D.**	**0.18**
			C.O.V.	**0.14**		**C.O.V.**	**0.28**

*: Due to the disturbance of the load-elongation curves, the point of initial bearing could not be determined.

Table 4.1d: Connection Elongation and Ultimate Load Comparison: Mild Strength Steel, Single Shear with Different Sheet Thickness

SPECIMEN	t_1 / t_2	$P_{t,\text{Without Washers}}$ (kN)	$P_{t,\text{With Washers}}$ (kN)	$P_{t,\text{Without Washers}} / P_{t,\text{With Washers}}$	$\delta_{t,\text{Without Washers}}$ (mm)	$\delta_{t,\text{With Washers}}$ (mm)	$\delta_{t,\text{Without Washers}} / \delta_{t,\text{With Washers}}$
043-230-3/8-TTSS	0.27	1.93	2.04	0.95	4.68	5.26	0.89
043-230-1/2-TTSS	0.27	2.33	2.28	1.02	6.96	7.78	0.90
043-230-5/8-TTSS	0.27	3.22	3.75	0.86	8.34	7.28	1.15
064-230-5/8-TTSS	0.42	5.19	6.10	0.85	9.04	7.00	1.29
064-230-1/2-TTSS	0.42	4.37	4.92	0.89	5.80	6.50	0.89
064-230-1/4-TTSS	0.42	3.35	4.29	0.78	4.80	5.00	0.96
076-230-1/2-TTSS	0.48	5.51	9.80	0.56	7.95	5.41	1.47
091-230-1/4-TTSS	0.60	7.64	7.19	1.06	8.26	7.88	1.05
091-230-1/2-TTSS	0.60	6.95	7.64	0.91	8.43	9.23	0.91
121-230-1/2-TTSS	0.89	10.9	12.2	0.89	8.45	9.29	0.91
121-230-3/8-TTSS	0.89	9.34	12.5	0.75	6.41	11.0	0.58
			Mean	**0.86**		**Mean**	**1.00**
			S.D.	**0.14**		**S.D.**	**0.24**
			C.O.V.	**0.16**		**C.O.V.**	**0.24**

Table 4.2a: Comparison of Maximum Load at Initial 6.35mm Extension: Mild Strength Steel, Single Shear with Equal Sheet Thickness

SPECIMEN	t_1 / t_2	$P_{6.35,\text{Without Washers}}$ (kN)	$P_{6.35,\text{With Washers}}$ (kN)	$P_{6.35,\text{Without Washers}}$ / $P_{6.35,\text{With Washers}}$
043-230-3/8-SS	1.0	1.65	2.50	0.66
043-230-1/2-SS	1.0	1.81	2.00	0.90
043-230-5/8-SS	1.0	*	*	*
064-230-3/8-SS	1.0	2.86	3.80	0.75
064-230-1/4-SS	1.0	3.00	4.20	0.71
076-230-1/2-SS	1.0	4.57	6.50	0.70
076-230-5/8-SS	1.0	4.97	7.65	0.65
091-230-1/4-SS	1.0	4.82	6.30	0.77
121-230-3/8-SS	1.0	8.58	12.9	0.66
153-230-1/4-SS	1.0	9.63	11.9	0.81
			Mean	**0.74**
			S.D	**0.08**
			C.O.V.	**0.11**

*: Due to the disturbance of the load-elongation curves, the point of initial bearing could not be determined.

Table 4.2b: Comparison of Maximum Load at Initial 6.35mm Extension: High Strength Steel, Single Shear with Equal Sheet Thickness

SPECIMEN	t_1 / t_2	$P_{6.35,\text{Without Washers}}$ (kN)	$P_{6.35,\text{With Washers}}$ (kN)	$P_{6.35,\text{Without Washers}}$ / $P_{6.35,\text{With Washers}}$
043-550-3/8-SS	1.0	2.60	3.30	0.79
043-550-1/2-SS	1.0	3.03	3.30	0.92
043-550-5/8-SS	1.0	3.40	3.50	0.97
064-550-5/8-SS	1.0	9.97	12.1	0.82
064-550-1/2-SS	1.0	6.90	8.75	0.79
064-550-3/8-SS	1.0	6.03	8.13	0.74
064-550-1/4-SS	1.0	5.71	6.60	0.87
076-550-1/2-SS	1.0	8.21	11.6	0.71
076-550-3/8-SS	1.0	7.53	9.70	0.78
076-550-1/4-SS	1.0	6.79	9.20	0.74
			Mean	**0.81**
			S.D	**0.08**
			C.O.V.	**0.10**

Table 4.2c: Comparison of Maximum Load at Initial 6.35mm Extension: Normal Strength Steel, Single Shear with Different Sheet Thickness

SPECIMEN	t_1 / t_2	$P_{6.35,\text{Without Washers}}$ (kN)	$P_{6.35,\text{With Washers}}$ (kN)	$P_{6.35,\text{Without Washers}} / P_{6.35,\text{With Washers}}$
043-230-3/8-TTSS	0.27	1.93	2.04	0.95
043-230-1/2-TTSS	0.27	2.26	2.20	1.03
043-230-5/8-TTSS	0.27	2.90	3.60	0.81
064-230-5/8-TTSS	0.42	4.50	6.00	0.75
064-230-1/2-TTSS	0.42	4.29	4.90	0.87
064-230-1/4-TTSS	0.42	3.25	4.30	0.76
076-230-1/2-TTSS	0.48	5.17	9.80	0.53
091-230-1/4-TTSS	0.60	7.05	6.90	1.02
091-230-1/2-TTSS	0.60	6.40	7.30	0.88
121-230-1/2-TTSS	0.89	10.6	11.7	0.90
121-230-3/8-TTSS	0.89	8.94	12.0	0.75
			Mean	**0.84**
			S.D	**0.14**
			C.O.V.	**0.17**

Table 4.2d: Comparison of Maximum Load at Initial 6.35mm Extension: Mild Strength Steel, Double Shear

SPECIMEN	t_1 / t_2	$P_{6.35,\text{Without Washers}}$ (kN)	$P_{6.35,\text{With Washers}}$ (kN)	$P_{6.35,\text{Without Washers}} / P_{6.35,\text{With Washers}}$
043-230-3/8-DS	0.27	2.13	1.60	1.33
043-230-1/2-DS	0.27	3.53	5.10	0.69
043-230-5/8-DS	0.27	5.33	7.00	0.76
064-230-5/8-DS	0.42	9.95	12.0	0.83
064-230-1/2-DS	0.42	8.28	9.30	0.89
064-230-1/4-DS	0.42	5.66	7.00	0.81
076-230-1/2-DS	0.48	9.40	10.1	0.93
091-230-1/4-DS	0.60	8.93	9.90	0.90
091-230-1/2-DS	0.60	11.5	13.7	0.84
121-230-1/2-DS	0.89	17.2	18.2	0.95
121-230-3/8-DS	0.89	15.6	17.6	0.89
			Mean	**0.89**
			S.D	**0.16**
			C.O.V.	**0.18**

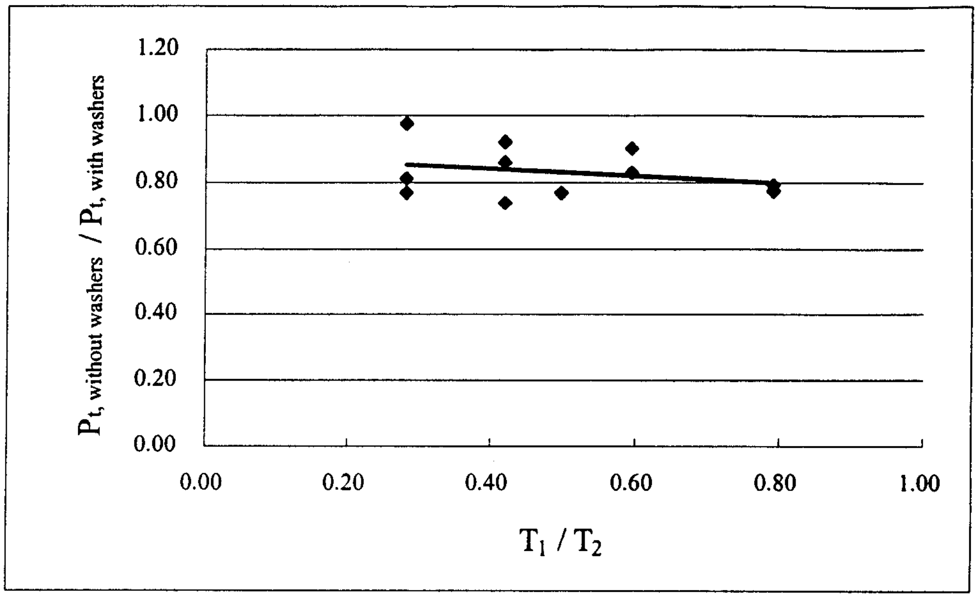


Figure 4.2a Sheet Thickness Ratios vs. Test Load Ratios: Double Shear Connections

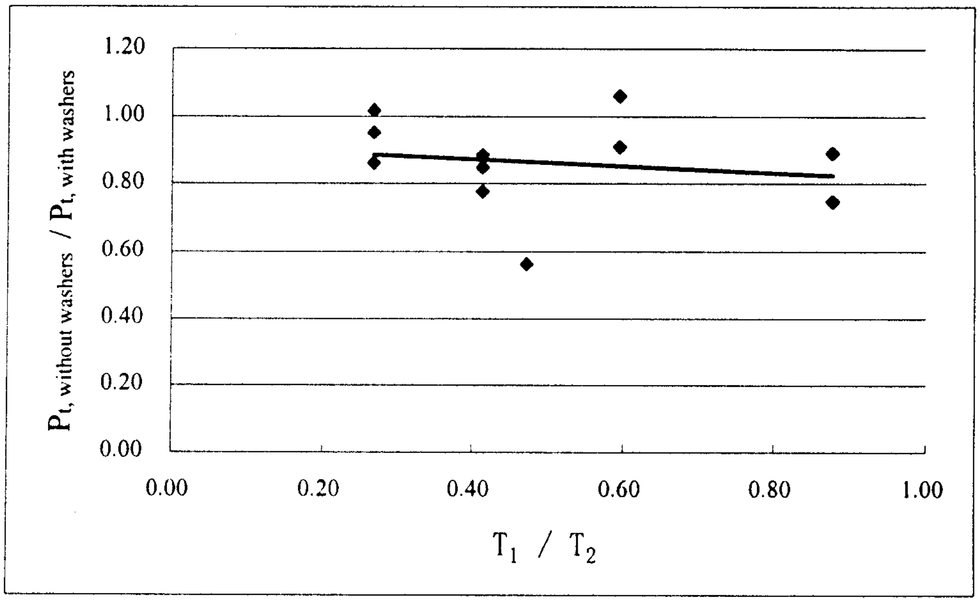


Figure 4.2b Sheet Thickness Ratios vs. Test Load Ratios: Single Shear Connections with Different Sheet Thickness

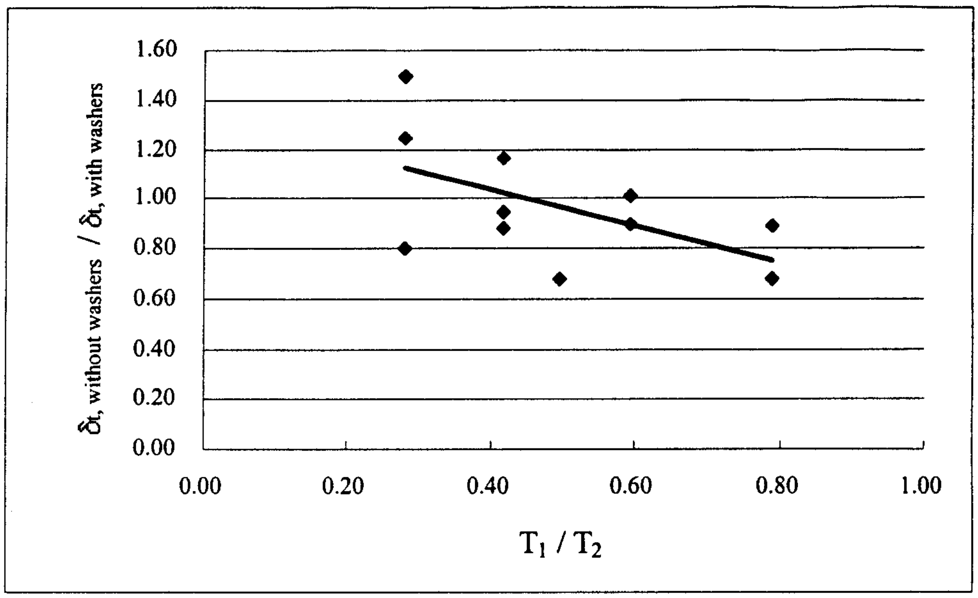


Figure 4.3a Sheet Thickness Ratios vs. Elongation Ratios: Double Shear Connections

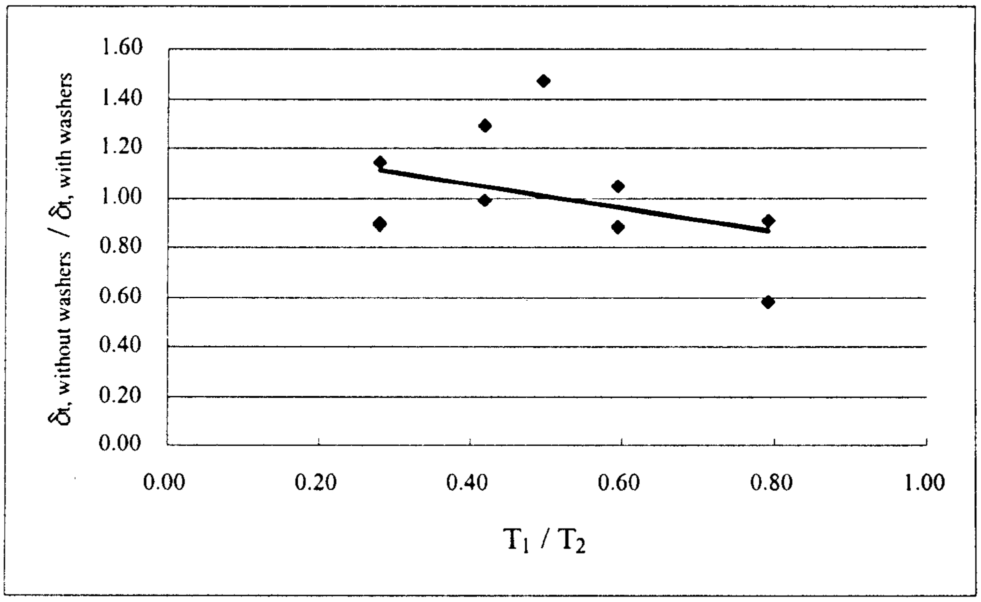


Figure 4.3b Sheet Thickness Ratios vs. Elongation Ratios: Single Shear Connections with Different Sheet Thickness

4.2 Comparison of Design Specifications

A comparison of five different bolted connection design methods, including those prescribed by the AISI (1999), AS/NZS 4600 (1996), CSA (1994), Eurocode (1996) and the North American Specification (AISI, 2001a,b; CSA, 2001), is provided in this section. The comparison is based on the accuracy of failure mode prediction and the ratio of ultimate test load to the predicted resistance. Furthermore, test data from the experimental investigation at McGill University, as well as five previous research programs in which bolted connections were studied is utilized. The data consists of test results of washerless bolted connections from Wallace *et al.* (2001), Carril *et al.* (1994), Yu and Mosby (1978), Gilchrist and Chong (1979) and Chong and Matlock (1975). The tables also contain results for two proposed methods which will be discussed in Section 4.3

4.2.1 Prediction of Failure Modes

A total of 507 test results of washerless bolted connections were utilized from the previous and the present experimental investigations. Background information concerning each of the existing test programs is presented in Section 2.1. The specimen dimensions, observed failure modes and calculated details for each test can be found in Tables C1 and C2 to C8 of Appendix C, respectively. A large number of tests from the existing research programs were observed to have failed in a combined mode, in which bearing and end pull-out or bearing and net section fracture took place, instead of an individual failure mode. Chong and Matlock (1975) and Gilchrist and Chong (1979) suggested that for bolted connections without washers, if the e/d ratio is larger than 2.5, then bearing failure had likely occurred. Hence, in order to match the predicted failure modes with the observed failure modes, for this thesis those tests that were reported to have failed in the combination of bearing and end pull-out were classified as bearing failure specimens if the e/d ratios were greater than 2.5. Furthermore, the rotation failure mode in Yu and Mosby (1978) and

Carril *et al.* (1994) were also classified as bearing failure in this thesis, because they have a similar failure mechanism with those defined as localized tearing in Rogers and Hancock (1998b). Bolt tilting for the single shear specimens can be attributed to the eccentric shear forces on the fastener. Additional out-of-plane distortion of the sheet steel in the vicinity of the bolt hole most likely resulted from the relative thinness of the steel (Figure 4.4).

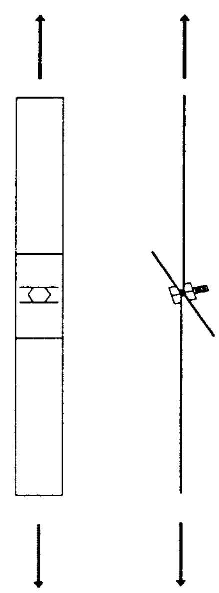


Figure 4.4 Failure by Bolt Rotation and Sheet Warping. (Yu and Mosby, 1976)

It should be noted that there are still 21 tests that failed in a combination of either bearing and end pull out or bearing and net section fracture for which it was not possible to match any of the predicted failure modes, because only one type of failure mode could be predicted for each test. For these 21 tests the results of the observed failure modes to predicted failure modes would not change with the different design methods. Considering that all of the tests included in the analysis were designed such that bolt shearing failure would not take place, only the following four failure modes were included; that is gross section yielding, net section fracture, end pull-out and bearing. Theoretically the predicted failure mode can be defined as that which provides the lowest resistance for the connection. However, gross yielding of the cross section is not a failure mode as one considers net section, bearing, *etc*. Rather gross yielding can be thought of as a limiting displacement beyond which the member that relies on the bolted connection will not be useful. One may have predicted gross yielding as the controlling mode but it would be almost impossible to see this in a test unless displacement limits were put into place, or if the remaining failure modes were at such an increased force level that actual necking of the gross cross section took place. In most cases the test specimen would simply elongate extensively with its entire length reaching the yield stress. Strain hardening would occur over the reduced section and either net section fracture or bearing failure would take place. When gross yielding is predicted it was not possible to match the observed failure mode because only the ultimate limit states had been recorded. Hence, although gross section yielding was included in Table C2 to C8 of Appendix "C", it was not taken into account in terms of predicting the governing failure mode and the ultimate capacity.

For tests from the experimental program at McGill University, the base material thickness and the average dynamic ultimate strengths obtained from the coupon tests were used in the shear capacity and failure mode predictions. The recorded material properties were utilized for specimens from the existing research programs.

Table 4.3 presents the number of correctly and incorrectly predicted tests according to the different design standards. The design methods from the CSA (1994), Eurocode (1996) and North American Specification (CSA, 2001) have better result than those from the AISI (1999), AS/NZS 4600 (1996) and North American Specification (AISI, 2001a,b), e.g. the ratios of correct to incorrect prediction are 398/109 and 359/148 for the CSA (1994) and Eurocode (1996), respectively. In contrast, the ratio of correct to incorrect prediction is 89/418 for the AISI (1999) and AS/NZS 4600 (1996). Much of the error in the AISI (1999), AS/NZS 4600 (1996) and North American Specification (AISI, 2001a,b) failure modes can be attributed to the identification of bearing failure as net section fracture. The net section stress reduction equations were used to predict the net section fracture capacity in the AISI (1999), AS/NZS 4600 (1996) and North American Specification (AISI, 2001a,b). These equations were obtained from the experimental work conducted by Popowich (1969).

However, Rogers and Hancock (1998b, 2000) closely studied the results and found that most tests that were identified by Popowich as having failed by net section fracture essentially were localized tearing caused by bearing stress. Of the tests whose failure modes were incorrectly predicted, at total of 370 by the AISI (1999) and the AS/NZS 4600 (1996) Specifications, as well as 269 by the North American Specification (AISI, 2001a) were predicted to fail by net section fracture when bearing failure was observed. In terms of the CSA Standard (1994), Eurocode (1996) and the North American Specification (CSA, 2001) the incorrect failure mode predictions occurred when end pull out failure was expected, although bearing failure occurred. This was most likely due to the difficulty in differentiating between the end pull-out and bearing failure modes because of the extensive shear displacement that was subjected to the connection specimens.

Table 4.3 Comparison of Predicted Failure Modes and Actual Failure Modes

Design Specification	Total Tests	No.of Correct	No.of Incorrect
AISI (1999) and AS/NZS 4600 (1996)	507	89	418
CSA (1994)	507	398	109
EUROCODE (1996)	507	359	148
North American (AISI, 2001a)	507	208	299
North American (CSA, 2001)	507	364	143
Proposed Method 1*	507	424	83
Proposed Method 2*	507	369	138

* Details and comments on the proposed methods will be provided in Section 4.3

4.2.2 Comparison of Ultimate Test-to-Failure Criterion Predicted Loads

Of the 507 tests, 451 were observed to have failed by bearing or by a combination of bearing with either end pull-out or net section fracture, 44 had net section fracture as the recorded failure mode and 12 were evaluated as failing by end pull out. Among the 451 bearing failure-involved tests, four specimens that failed in the combination of end pull out and bearing were excluded from the bearing resistance analysis because their e/d ratios are almost equal to unity, which indicates the high possibility of end pull-out failure.

Tables 4.4a to 4.4e list the statistical results in the comparison of predicted bearing resistance according to the different design methods. These statistical results include all the specimens that were observed to have failed by bearing. The test-to-predicted ratios were obtained from the calculated bearing capacity, although if all failure mode equations were used for each design method in some cases the bearing failure mode would not control. Compared with design equations prescribed in the other standards and specifications, the North American Design Specification (AISI, 2001a,b; CSA, 2001) provided a much better prediction of the bearing capacity for those specimens deemed to have failed by bearing. However, some minor modifications to this method are still necessary because of unconservative results, especially for the double shear connections with thinner sheets placed on the inside.

The specimens that failed in either the end pull out or the net section fracture modes were tested by Chong and Matlock (1975) or Carril *et al.* (1994). As described in Section 2.1.4 and 2.1.6, only single shear connections composed of Mild strength steel with equal sheet thickness were involved in these two research programs. Thus the specimens from Chong and Matlock and Carril *et al.* were utilized to provide information on the predicted end pull out and net section capacity. Tables 4.5 and 4.6 present the statistical data for end pull out failure and net section fracture failure, respectively. The standard deviation and coefficient of variation in Table 4.6 are very high regardless of the specification used, ranging from 0.37 to 0.95 and 0.41 to 0.74, respectively. These high statistical values may be attributed to the low sample size (11 specimens for end pull out) and the possibility that the specimens identified as having failed by end pull out may have experienced bearing failure. This comment arises because if one calculates the bearing or net section capacity, one will often be near the predicted end pull out capacity. For net section fracture failure, Table 4.6 seems to suggest that methods in the AISI (1999) and AS/NZS 4600 (1996) or the Eurocode (1996) can be more precise than other methods in the prediction of net section failure. The stress reduction equations, Eq 2.42, 2.52 and 2.66, were used to predict the net section fracture for these three specifications, respectively. However, it should be noted that most of the net section fracture failure tests (37 out of 47) studied in this report are multiple bolted connections with the bolts arranged along the direction of load. Hence, there is a lack of data for other connection configurations that may fail by net section fracture. Therefore, additional test data would be required before making the general conclusion that the stress reduced equations provide appropriate results for net section fracture.

Table 4.4a Test-To-Predicted Bearing Resistance Statistical Data: Single Shear Connections with Equal Sheet Thickness

Design Specification	No. of Tests	Mean	S.D.	C.o.V.	C / I [1]
AISI (1999) and AS/NZS 4600 (1996)	242	0.88	0.23	0.26	36/206
CSA (1994)	242	0.78	0.18	0.23	148/94
EUROCODE (1996)	242	0.78	0.20	0.26	109/133
North American (AISI, 2001a)	242	0.99	0.19	0.19	122/120
North American (CSA, 2001)	242	0.99	0.19	0.19	171/71
Proposed Method 1	242	1.06	0.20	0.19	225/17
Proposed Method 2	242	0.99	0.19	0.19	188/54

[1]. Number of correctly predicted failure mode / number of incorrectly predicted failure mode.

Table 4.4b Test-To-Predicted Bearing Resistance Statistical Data: Single Shear Connections with Different Sheet Thickness

Design Specification	No. of Tests	Mean	S.D.	C.o.V	C / I
AISI (1999) and AS/NZS 4600 (1996)	36	0.88	0.33	0.38	6/30
CSA (1994)	36	0.79	0.19	0.24	36/0
EUROCODE (1996)	36	0.74	0.28	0.37	36/0
North American (AISI, 2001a)	36	1.07	0.25	0.23	21/15
North American (CSA, 2001)	36	1.07	0.25	0.23	36/0
Proposed Method 1	36	1.15	0.26	0.23	36/0
Proposed Method 2	36	1.07	0.25	0.23	36/0

Table 4.4c Test-To-Predicted Bearing Resistance Statistical Data: Double Shear Connections with Thinner Sheet Outside

Design Specification	No. of Tests	Mean	S.D.	C.o.V.	C / I
AISI (1999) and AS/NZS 4600 (1996)	39	0.90	0.15	0.17	0/39
CSA (1994)	39	0.74	0.06	0.08	39/0
EUROCODE (1996)	39	0.80	0.14	0.17	36/3
North American (AISI, 2001a)	39	0.96	0.08	0.08	18/21
North American (CSA, 2001)	39	0.96	0.08	0.08	39/0
Proposed Method 1	39	1.03	0.08	0.08	39/0
Proposed Method 2	39	0.96	0.08	0.08	39/0

Table 4.4d Test-To-Predicted Bearing Resistance Statistical Data: All Single Shear Connections and Double Shear Connections with Thinner Sheet Outside

Design Specification	No. of Tests	Mean	S.D.	C.o.V.	C / I
AISI (1999) and AS/NZS 4600 (1996)	317	0.88	0.23	0.26	42/275
CSA (1994)	317	0.77	0.17	0.22	223/94
EUROCODE (1996)	317	0.78	0.21	0.26	181/136
North American (AISI, 2001a)	317	0.99	0.19	0.19	161/156
North American (CSA, 2001)	317	0.99	0.19	0.19	246/71
Proposed Method 1	317	1.07	0.20	0.19	300/17
Proposed Method 2	317	0.99	0.19	0.19	263/54

Table 4.4e Test-To-Predicted Bearing Resistance Statistical Data: Double Shear Connections with Thinner Sheet Inside

Design Specification	No.of Tests	Mean	S.D.	C.o.V.	C / I
AISI (1999) and AS/NZS 4600 (1996)	130	1.04	0.20	0.20	0/130
CSA (1994)	130	1.25	0.19	0.15	130/0
EUROCODE (1996)	130	1.25	0.25	0.20	130/0
North American (AISI, 2001a)	130	0.89	0.15	0.17	0/130
North American (CSA, 2001)	130	0.89	0.15	0.17	73/57
Proposed Method 1	130	1.06	0.20	0.19	82/48
Proposed Method 2	130	1.06	0.20	0.19	130/0

Table 4.5 Test-To-Predicted End Pull-Out Resistance Statistical Data

Design Specification	No. of Tests	Mean	S.D.	C.o.V.	C / I
AISI (1999), AS/NZS 4600 (1996) and North American (AISI, 2001a)	12	0.89	0.37	0.42	4/8
CSA (1994) and North American (CSA, 2001)	12	1.29	0.95	0.74	4/8
EUROCODE (1996)	12	1.07	0.45	0.41	7/5
Proposed Method 1	12	0.89	0.37	0.42	4/8
Proposed Method 2	12	0.89	0.37	0.42	4/8

Table 4.6 Test-To-Predicted Net Section Fracture Resistance Statistical Data

Design Specification	No. of Tests	Mean	S.D.	C.o.V.	C / I
AISI (1999) and AS/NZS 4600 (1996)	44	1.20	0.15	0.12	43/1
CSA (1994) and North American (CSA, 2001)	44	1.10	0.24	0.22	41/3
EUROCODE (1996)	44	0.99	0.15	0.15	41/3
North American (AISI, 2001a)	44	1.17	0.35	0.30	43/1
Proposed Method 1	44	1.10	0.24	0.22	35/6
Proposed Method 2	44	1.10	0.24	0.22	41/3

In summary, the current design specifications do not satisfactorily predict the failure modes of washerless bolted connections loaded in shear. Especially in the case of the AISI (1999) and AS/NZS 4600 (1996) Specifications, use of the stress reduction formulation (Eq.2.42 and 2.52) resulted in a significant number of incorrect failure mode predictions, *i.e.* 418 of 507 (Table 4.3). Furthermore, many of the current design methods are not able to precisely predict the bearing capacity of bolted connections without washers. However, the method for the calculation of bearing resistance found in the North American Specification (AISI, 2001a,b; CSA, 2001) provides a reasonable estimate of the test obtained values. Only minor modifications to the North American Specification are recommended, as detailed in the following section.

4.3 Proposed Design Methods

4.3.1 Basis of the Proposed Methods

As stated in previous sections, the majority of current design standards and specifications cannot be used to precisely predict either the failure modes or the ultimate load of washerless bolted connections loaded in shear. Although the North American Specification (AISI, 2001a,b; CSA, 2001) provides an improved method to predict the bearing capacity of bolted connections without washers, it still remains unconservative for double shear connections with thinner sheet inside (the average test-to-predicted value = 0.89). Furthermore, the failure modes of bolted connections without washers cannot be satisfactorily determined by the North American Specification (AISI, 2001a,b; CSA, 2001) (see Table 4.3).

Based on the findings of this research two proposed methods for the calculation of bolted connection shear capacity have been provided. The proposed methods include provisions from the North American Specification for gross section yielding, net section fracture, end pull out and bearing as shown below. The m_f factor for bearing capacity was modified to obtain more satisfactory results for the single shear case, and an additional category was added to address the bearing behaviour of inside sheets of double shear connections without washers. Furthermore, the stress reduction term for net section fracture following the US and Mexico clauses was not utilized. However, the US and Mexico end pull out formulation was incorporated into the proposed design methods.

1. Gross Section Yielding:

$$T_n = A_g f_y \qquad \text{Eq. 4.1}$$

where the A_g is the gross section area and f_y is the yield strength or the 0.2% offset proof stress. (Eq. C2-1 and Eq. C2.1-1 in the North American Specification (AISI, 2001a; CSA, 2001))

2. Net Section Fracture

$$T_n = A_n\, f_u \qquad \text{Eq. 4.2}$$

where the A_n is the net section area and f_u is the ultimate strength. (Eq.2.2-1 in the North American Specification (AISI, 2001a; CSA, 2001))

3. End Pull-Out

$$V_f = t\, e\, f_u \qquad \text{Eq. 4.3}$$

where t is the thickness of the thinnest connected part and e is the distance measured in line of force from center of a standard hole to nearest edge of adjacent hole or to end of connected part. (Eq. 3.1-1 in the North American Specification (AISI, 2001a; CSA, 2001))

4. Bearing

$$V_b = m_f\, C\, d\, t\, f_u \qquad \text{Eq. 4.4}$$

where

C: Bearing factor, determined from Table 4.7

m_f: Modification factor for type of bearing connection from Table 4.8

(Eq. E3.3.1-1 in the North American Specification (AISI, 2001a,b; CSA, 2001))

Table 4.7: C Factor for Bearing Resistance (Table E3.3.1-1 in the North American Specification (AISI, 2001a; CSA, 2001))

Ratio of fastener Diameter to Member thickness, d/t	C
$d/t \leq 10$	3.00
$10 < d/t < 22$	4.0-0.1d/t
$d/t \geq 22$	1.80

Table 4.8: Modification Factor, m_f

Type of Bearing Connection	m_f
Single Shear and Outside Sheets of Double Shear Connection With Washers Under Both Bolt Head and Nut	1.00
Single Shear and Outside Sheets of Double Shear Connection Without Washers Under Both Bolt Head and Nut, Or With Only One Washer	0.75[a] 0.70[b]
Inside Sheets of Double Shear Connection Without Washers	1.20
Inside Sheets of Double Shear Connection With Washers	1.33

[a] proposed method 2

[b] proposed method 1

4.3.2 Test-to Predicted Values using Proposed Methods

The statistical data for the two proposed methods for different types of connections is presented in Table 4.10. The test-to-predicted ratio for bearing resistance is improved when the proposed method 1 for the double shear connections without washers is implemented. Concerning the single shear connection bearing resistance, it appears that modification of the m_f factor provides a slightly conservative prediction of the shear capacity. The ratio of correct-to-incorrect failure mode prediction was significantly improved to 424 / 83. Of the

83 tests whose failure modes were not successfully predicted by the proposed method, 21 tests were predicted to fail in bearing, although they were reported to have failed in a combination of bearing with either end pull-out or net section fracture. An additional 48 tests were predicted to fail by end pull-out while bearing failure actually occurred. If one takes a more detailed look at the predicted results for these 48 tests, it becomes apparent that the predicted bearing and end pull-out strengths are very close. This can be supported by statistical data: the average ratio of predicted bearing to end pull-out capacity for these 48 tests is 1.03 and both the standard deviation and coefficient of variation are 0.02. Hence, it was most likely difficult for the various researchers to differentiate between the two failure modes when recording their test observations. Method 2 has a similar statistical result compared with method 1. However, the ratio of correct-to-incorrect failure mode prediction by using method 2 was 369 / 138. Of the 138 tests whose failure modes were not successfully predicted by the proposed method 2, 95 tests were predicted to fail in end pull-out, but they were reported to have failed in a bearing failure. The proposed method 2 is not as accurate as method 1 in the prediction of failure mode.

Table 4.9 provides the statistical data of test-to-predicted ratios when the specimens are not divided into observed failure mode categories. The mean value and C.o.V. for method 1 are 1.07 and 0.19, respectively, for method 2 they are 1.01 and 0.23, respectively. It is apparent that both proposed methods can provide a satisfactory prediction of ultimate load capacity.

Table 4.9 Statistical Data for Two Proposed Methods When the Specimens Are not Divided into Observed Failure Mode Categories.

	No. of Tests	Mean	S.D.	C.o.V.
Method 1	507	1.07	0.20	0.19
Method 2	507	1.01	0.23	0.23

Table 4.10 Summary of Test-To-Predicted Resistance by Using Proposed Methods

Failure Modes	Method	No. of Tests	Mean	S.D.	C.o.V.
Bearing (SS[1])	1	242	1.06	0.20	0.19
	2	242	0.99	0.19	0.19
Bearing (TTSS[2])	1	36	1.15	0.26	0.23
	2	36	1.07	0.25	0.23
Bearing (DDSS[3])	1	39	1.03	0.08	0.08
	2	39	0.96	0.08	0.08
Bearing (SS, TTSS, DDSS)	1	317	1.07	0.20	0.19
	2	317	0.99	0.19	0.19
Bearing (DS[4])	1	130	1.06	0.20	0.19
	2	130	1.06	0.20	0.19
Bearing (All)	1	447	1.07	0.20	0.19
	2	447	1.04	0.27	0.26
Net Section Fracture	1,2	44	1.10	0.24	0.22
End Pull-Out	1,2	12	0.89	0.37	0.42

1. Single shear connections with equal sheet thickness

2. Single shear connections with different sheet thickness

3. Double shear connections with thinner sheet outside

4. Double shear connections with thinner sheet inside

4.4 Reliability Study

A reliability study was carried out for the proposed bearing resistance methods following the procedure outlined in Chapter F of the North American Specification (AISI, 2001a; CSA, 2001). As shown in Eq 4.5, limit states design methods require that the factored resistance of the member be greater than or equal to the sum of the factored loads applied to the member.

$$\phi R_n \geq \Sigma \gamma_i Q_i \qquad \text{Eq. 4.5}$$

where R_n is the nominal resistance, ϕ is the resistance factor, and γ_i and Q_i are the load factor and the load effect .

The resistance factor, ϕ, is correlated with the target reliability index, β_0, which is defined for connections as 3.5 in the US and 4.0 in Canada . (Chapter F in the North American Specification (AISI, 2001a; CSA, 2001)).

$$\phi = C_\phi \left(M_m F_m P_m\right) e^{-\beta_0 \sqrt{V_M^2 + V_F^2 + CPV_P^2 + V_Q^2}} \qquad \text{Eq. 4.6}$$

C_ϕ is the calibration coefficient 1.42 for Canada and 1.52 for the US

where

M_m: mean value of the material factor

F_m: mean value of the fabrication factor

P_m: mean value of the professional factor

V_M: coefficient of variation of the material factor

V_F: coefficient of variation of the fabrication factor

V_P: coefficient of variation of the test results

V_Q: coefficient of variation of the load effect

C_p: Correction factor

= $(1+1/n)\ m / (m-2)$ for $n \geq 4$, and 5.7 for $n=3$

m: degree of freedom

= n-1

n: number of tests

Among the above variables, the values of M_m, V_M, F_m and V_F for bearing failure of bolted connections can be found in the Table F1 in the North American Specification (AISI, 2001a; CSA, 2001). Chapter F of the North American Specification (AISI, 2001a; CSA, 2001) defines the value of V_Q as 0.21 as well. P_m can be obtained by calculating the mean ratio of test capacities to predicted capacities using the nominal strength of the sheet steels. Details on the calculation of ϕ factors are presented in Tables 4.11a and b.

Table 4.11a Calculation of ϕ Factors for Method 1 Bearing Resistance

	SS[1]	TTSS[2]	DDSS[3]	DS[4]	SS, TTSS, DDSS	ALL
M_m	1.10	1.10	1.10	1.10	1.10	1.10
V_M	0.08	0.08	0.08	0.08	0.08	0.08
F_m	1.00	1.00	1.00	1.00	1.00	1.00
V_F	0.05	0.05	0.05	0.05	0.05	0.05
P_m	1.35	1.28	1.27	1.45	1.33	1.32
V_Q	0.21	0.21	0.21	0.21	0.21	0.21
V_P	0.19	0.23	0.08	0.19	0.19	0.19
n	242	36	39	130	317	447
C_P	1.01	1.09	1.08	1.02	1.01	1.01
Mean	1.06	1.15	1.03	1.06	1.07	1.07
ϕ (U.S.)	0.79	0.67	0.90	0.85	0.78	0.77
ϕ (Canada)	0.68	0.57	0.80	0.73	0.67	0.67

1. Single shear connections with equal sheet thickness
2. Single shear connections with different sheet thickness
3. Double shear connections with thinner sheet outside
4. Double shear connections with thinner sheet inside

Table 4.11b Calculation of ϕ Factors for Method 2 Bearing Resistance

	SS[1]	TTSS[2]	DDSS[3]	DS[4]	SS, TTSS, DDSS	ALL
M_m	1.10	1.10	1.10	1.10	1.10	1.10
V_M	0.08	0.08	0.08	0.08	0.08	0.08
F_m	1.00	1.00	1.00	1.00	1.00	1.00
V_F	0.05	0.05	0.05	0.05	0.05	0.05
P_m	1.26	1.20	1.19	1.45	1.24	1.27
V_Q	0.21	0.21	0.21	0.21	0.21	0.21
V_P	0.19	0.23	0.08	0.19	0.19	0.26
n	242	36	39	130	317	447
C_P	1.01	1.09	1.08	1.02	1.01	1.01
Mean	0.99	1.07	0.96	1.06	0.99	1.04
ϕ (U.S.)	0.74	0.63	0.84	0.85	0.73	0.75
ϕ (Canada)	0.64	0.53	0.75	0.73	0.63	0.64

In the North American Specification (AISI, 2001a; CSA, 2001), the ϕ factors for bolted connection bearing design are 0.6 and 0.5 for the USA and Canada, respectively. Compared with the data in Tables 11a and b, the current ϕ factors in the North American Specification are on the conservative side, and therefore can be used with the proposed design procedure.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

A total of 168 bolted connection tests (126 washerless and 42 bolted with washers) were carried out in the Materials Laboratory of the Department of Civil Engineering and Applied Mechanics at McGill University. The results from these tests along with data of 381 washerless bolted connection tests from five existing research programs (Wallace *et al.*, 2001, Carril *et al.*, 1994, Yu and Mosby, 1978, Gilchrist and Chong, 1979 and Chong and Matlock, 1975) were analyzed with respect to failure mode and ultimate capacity predictions according to a number of design standards (AISI, 1999; AS/NZS 4600, 1996; CSA-S136, 1994; Eurocode 3, 1996 and the North American Specification (AISI, 2001a; CSA, 2001)). The existing design method for the bearing capacity of bolted connections in the North American Specification (AISI, 2001a; CSA, 2001) was modified to account for the change in behaviour of washerless bolted connections. More detailed conclusions and recommendations can be found below.

5.1 Behaviour of washerless bolted connections

From the results of 126 washerless connection tests and 42 washer connection tests performed at McGill University, it can be concluded that the behavioural differences between single shear and double shear connections without washers are quite significant. For the single shear connections with equal sheet thickness, regardless of the types of steel used, the ratios of ultimate load ($P_{t,\text{Without Washers}}$ / $P_{t,\text{With Washers}}$) and corresponding displacement ($\delta_{t,\text{Without Washers}}/\delta_{t,\text{With Washers}}$) between tests with and without washers are almost 70%. However, in the case of double shear and single shear connections with different sheet thickness, the ratios are closer to 85% and 100% for ultimate load and corresponding elongation, respectively. In general, the greater the difference in thickness between the two sheets that are connected, the more significant the effect of the support in terms of resistance to bolt tilting, in the context of the sheet thicknesses that were used in this study. The ratios of $P_{t, \text{Without Washers}} / P_{t, \text{With Washers}}$ decrease with an increase in the ratio of t_1 / t_2. Similarly, this tendency was found in the relationship between t_1 / t_2 and $\delta_{t, \text{Without Washers}}/\delta_{t, \text{With Washers}}$.

There is an approximate decrease of 20% for the relative displacement based capacity ($P_{6.35}$) of washerless connections from that measured for the connections with washers. This decrease in capacity for the washerless connections was observed for the different connection configurations, *e.g.* single shear, single shear with different thickness sheets, and double shear.

5.2 Comparison of current design specifications

Five design methods to determine the ultimate load of washerless bolted connections were compared in this thesis, including the North American Specification (AISI, 2001a; CSA, 2001), CSA-S136 (1994), AISI (1999), AS/NZS 4600 (1996) and Eurocode (1996). In general, the current design specifications do not satisfactorily predict the failure modes of washerless bolted connections loaded in shear. However, the design methods from the CSA, Eurocode and North American Specification (CSA, 2001) have better results than those from the AISI, AS/NZS 4600 and North American Specification (AISI, 2001a), in which use of the stress reduction formulation (Eq.2.42 and 2.52) resulted in a significant number of incorrect failure modes.

Furthermore, many of the current design methods are not able to precisely predict the bearing capacity of bolted connections without washers. Compared with design equations prescribed in the other standards and specifications, the North American Design Specification (AISI, 2001a; CSA, 2001) provided a more reasonable estimate of the bearing capacity for those washerless connections deemed to have failed by bearing. However, some minor modifications to this method are still necessary because of unconservative test-to-predicted results, especially for the double shear connections with thinner sheets placed on the inside.

5.3 Recommended Methods

Based on the findings of this research two proposed methods for the calculation of bolted connection shear capacity have been provided. Both methods include provisions from the North American Specification for gross section yielding, net section fracture, end pull out and bearing as shown in Section 4.3. The m_f factor for bearing capacity of single shear washerless connections was modified to 0.7 in method 1 and remained at 0.75 in method 2. An additional category was added to the m_f factor to address the bearing behaviour of inside sheets of double shear connections without washers. For this case, the m_f factor was proposed as 1.2. Furthermore, the stress reduction term for net section fracture following the US and Mexico clauses was not utilized. However, the US and Mexico end pull out formulation was incorporated into the proposed design methods.

5.4 Recommendations for future research

The effect of torque was not taken into account in the investigation. Yu and Mosby have concluded that the effect of torque on the bearing strength of mild steel connections was dependent on the following three variables, d/t ratio, the use of washers and the type of connections (single or double shear) (Yu and Mosby, 1978). For future research, investigations concerning the effect of torque on thin, high strength bolted connections either with or without washers should be performed.

The scatter of results for the single shear connections with different sheet thickness in the investigation suggests that additional tests of this type, using both mild and high strength steel connections, are necessary to provide more information for an indepth understanding of the structural behaviour of bolted connections.

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APPENDIX A

Dimensions and Mechanical Properties of Initially Proposed Test Specimens

Table A1 Proposed Test Specimen Dimensions

SPECIMEN	t_1 (mm)	t_2 (mm)	e (mm)	s (mm)	Washers	Single or Double Shear	d (mm)	d/t
043-550-3/8-SS-A	0.35	0.35	60.0	75.0	No	1	9.53	27.2
043-550-3/8-SS-B	0.35	0.35	60.0	75.0	No	1	9.53	27.2
043-550-3/8-SS-C	0.35	0.35	60.0	75.0	No	1	9.53	27.2
043-550-3/8-SS-D	0.35	0.35	60.0	75.0	Yes	1	9.53	27.2
043-550-1/2-SS-A	0.35	0.35	60.0	75.0	No	1	12.7	36.3
043-550-1/2-SS-B	0.35	0.35	60.0	75.0	No	1	12.7	36.3
043-550-1/2-SS-C	0.35	0.35	60.0	75.0	No	1	12.7	36.3
043-550-1/2-SS-D	0.35	0.35	60.0	75.0	Yes	1	12.7	36.3
043-550-5/8-SS-A	0.35	0.35	60.0	75.0	No	1	15.9	45.4
043-550-5/8-SS-B	0.35	0.35	60.0	75.0	No	1	15.9	45.4
043-550-5/8-SS-C	0.35	0.35	60.0	75.0	No	1	15.9	45.4
043-550-5/8-SS-D	0.35	0.35	60.0	75.0	Yes	1	15.9	45.4
064-550-5/8-SS-A	0.63	0.63	60.0	75.0	No	1	15.9	25.2
064-550-5/8-SS-B	0.63	0.63	60.0	75.0	No	1	15.9	25.2
064-550-5/8-SS-C	0.63	0.63	60.0	75.0	No	1	15.9	25.2
064-550-5/8-SS-D	0.63	0.63	60.0	75.0	Yes	1	15.9	25.2
064-550-1/2-SS-A	0.63	0.63	60.0	75.0	No	1	12.7	20.2
064-550-1/2-SS-B	0.63	0.63	60.0	75.0	No	1	12.7	20.2
064-550-1/2-SS-C	0.63	0.63	60.0	75.0	No	1	12.7	20.2
064-550-1/2-SS-D	0.63	0.63	60.0	75.0	Yes	1	12.7	20.2
064-550-3/8-SS-A	0.63	0.63	60.0	75.0	No	1	9.53	15.1
064-550-3/8-SS-B	0.63	0.63	60.0	75.0	No	1	9.53	15.1
064-550-3/8-SS-C	0.63	0.63	60.0	75.0	No	1	9.53	15.1
064-550-3/8-SS-D	0.63	0.63	60.0	75.0	Yes	1	9.53	15.1
064-550-1/4-SS-A	0.63	0.63	60.0	75.0	No	1	6.35	10.1
064-550-1/4-SS-B	0.63	0.63	60.0	75.0	No	1	6.35	10.1
064-550-1/4-SS-C	0.63	0.63	60.0	75.0	No	1	6.35	10.1
064-550-1/4-SS-D	0.63	0.63	60.0	75.0	Yes	1	6.35	10.1
076-550-1/2-SS-A	0.76	0.76	60.0	75.0	No	1	12.7	16.7
076-550-1/2-SS-B	0.76	0.76	60.0	75.0	No	1	12.7	16.7
076-550-1/2-SS-C	0.76	0.76	60.0	75.0	No	1	12.7	16.7
076-550-1/2-SS-D	0.76	0.76	60.0	75.0	Yes	1	12.7	16.7
076-550-3/8-SS-A	0.76	0.76	60.0	75.0	No	1	9.53	12.5
076-550-3/8-SS-B	0.76	0.76	60.0	75.0	No	1	9.53	12.5
076-550-3/8-SS-C	0.76	0.76	60.0	75.0	No	1	9.53	12.5
076-550-3/8-SS-D	0.76	0.76	60.0	75.0	Yes	1	9.53	12.5
076-550-1/4-SS-A	0.76	0.76	60.0	75.0	No	1	6.35	8.36
076-550-1/4-SS-B	0.76	0.76	60.0	75.0	No	1	6.35	8.36

Table A1 Proposed Test Specimen Dimensions (continued)

SPECIMEN	t_1 (mm)	t_2 (mm)	e (mm)	s (mm)	Washers	Single or Double Shear	d (mm)	d/t
076-550-1/4-SS-C	0.76	0.76	60.0	75.0	No	1	6.35	8.36
076-550-1/4-SS-D	0.76	0.76	60.0	75.0	Yes	1	6.35	8.36
043-230-3/8-SS-A	0.41	0.41	60.0	75.0	No	1	9.53	23.2
043-230-3/8-SS-B	0.41	0.41	60.0	75.0	No	1	9.53	23.2
043-230-3/8-SS-C	0.41	0.41	60.0	75.0	No	1	9.53	23.2
043-230-3/8-SS-D	0.41	0.41	60.0	75.0	Yes	1	9.53	23.2
043-230-1/2-SS-A	0.41	0.41	60.0	75.0	No	1	12.7	31.0
043-230-1/2-SS-B	0.41	0.41	60.0	75.0	No	1	12.7	31.0
043-230-1/2-SS-C	0.41	0.41	60.0	75.0	No	1	12.7	31.0
043-230-1/2-SS-D	0.41	0.41	60.0	75.0	Yes	1	12.7	31.0
043-230-5/8-SS-A	0.41	0.41	60.0	75.0	No	1	15.9	38.7
043-230-5/8-SS-B	0.41	0.41	60.0	75.0	No	1	15.9	38.7
043-230-5/8-SS-C	0.41	0.41	60.0	75.0	No	1	15.9	38.7
043-230-5/8-SS-D	0.41	0.41	60.0	75.0	Yes	1	15.9	38.7
064-230-3/8-SS-A	0.63	0.63	60.0	75.0	No	1	9.53	15.1
064-230-3/8-SS-B	0.63	0.63	60.0	75.0	No	1	9.53	15.1
064-230-3/8-SS-C	0.63	0.63	60.0	75.0	No	1	9.53	15.1
064-230-3/8-SS-D	0.63	0.63	60.0	75.0	Yes	1	9.53	15.1
064-230-1/2-SS-A[1]	0.63	0.63	60.0	75.0	No	1	12.70	20.2
064-230-1/2-SS-B[1]	0.63	0.63	60.0	75.0	No	1	12.70	20.2
064-230-1/2-SS-C[1]	0.63	0.63	60.0	75.0	No	1	12.70	20.2
064-230-1/2-SS-D[1]	0.63	0.63	60.0	75.0	Yes	1	12.70	20.2
064-230-5/8-SS-A[1]	0.63	0.63	60.0	75.0	No	1	15.90	10.1
064-230-5/8-SS-B[1]	0.63	0.63	60.0	75.0	No	1	15.90	10.1
064-230-5/8-SS-C[1]	0.63	0.63	60.0	75.0	No	1	15.90	10.1
064-230-5/8-SS-D[1]	0.63	0.63	60.0	75.0	Yes	1	15.90	10.1
064-230-1/4-SS-A	0.63	0.63	60.0	75.0	No	1	6.35	25.2
064-230-1/4-SS-B	0.63	0.63	60.0	75.0	No	1	6.35	25.2
064-230-1/4-SS-C	0.63	0.63	60.0	75.0	No	1	6.35	25.2
064-230-1/4-SS-D	0.63	0.63	60.0	75.0	Yes	1	6.35	25.2
076-230-1/2-SS-A	0.72	0.72	60.0	75.0	No	1	12.7	17.6
076-230-1/2-SS-B	0.72	0.72	60.0	75.0	No	1	12.7	17.6
076-230-1/2-SS-C	0.72	0.72	60.0	75.0	No	1	12.7	17.6
076-230-1/2-SS-D	0.72	0.72	60.0	75.0	Yes	1	12.7	17.6
076-230-3/8-SS-A[1]	0.72	0.72	60.0	75.0	No	1	9.53	12.5
076-230-3/8-SS-B[1]	0.72	0.72	60.0	75.0	No	1	9.53	12.5
076-230-3/8-SS-C[1]	0.72	0.72	60.0	75.0	No	1	9.53	12.5
076-230-3/8-SS-D[1]	0.72	0.72	60.0	75.0	Yes	1	9.53	12.5

Table A1 Proposed Test Specimen Dimensions (continued)

SPECIMEN	t_1 (mm)	t_2 (mm)	e (mm)	s (mm)	Washers	Single or Double Shear	d (mm)	d/t
076-230-5/8-SS-A	0.72	0.72	60.0	75.0	No	1	15.9	22.0
076-230-5/8-SS-B	0.72	0.72	60.0	75.0	No	1	15.9	22.0
076-230-5/8-SS-C	0.72	0.72	60.0	75.0	No	1	15.9	22.0
076-230-5/8-SS-D	0.72	0.72	60.0	75.0	Yes	1	15.9	22.0
091-230-3/8-SS-A[1]	0.91	0.91	60.0	75.0	No	1	9.53	10.50
091-230-3/8-SS-B[1]	0.91	0.91	60.0	75.0	No	1	9.53	10.50
091-230-3/8-SS-C[1]	0.91	0.91	60.0	75.0	No	1	9.53	10.50
091-230-3/8-SS-D[1]	0.91	0.91	60.0	75.0	Yes	1	9.53	10.50
091-230-1/2-SS-A[1]	0.91	0.91	60.0	75.0	No	1	12.70	14.00
091-230-1/2-SS-B[1]	0.91	0.91	60.0	75.0	No	1	12.70	14.00
091-230-1/2-SS-C[1]	0.91	0.91	60.0	75.0	No	1	12.70	14.00
091-230-1/2-SS-D[1]	0.91	0.91	60.0	75.0	Yes	1	12.70	14.00
091-230-1/4-SS-A	0.91	0.91	60.0	75.0	No	1	6.35	6.98
091-230-1/4-SS-B	0.91	0.91	60.0	75.0	No	1	6.35	6.98
091-230-1/4-SS-C	0.91	0.91	60.0	75.0	No	1	6.35	6.98
091-230-1/4-SS-D	0.91	0.91	60.0	75.0	Yes	1	6.35	6.98
121-230-1/2-SS-A[1]	1.34	1.34	60.0	75.0	No	1	12.70	9.48
121-230-1/2-SS-B[1]	1.34	1.34	60.0	75.0	No	1	12.70	9.48
121-230-1/2-SS-C[1]	1.34	1.34	60.0	75.0	No	1	12.70	9.48
121-230-1/2-SS-D[1]	1.34	1.34	60.0	75.0	Yes	1	12.70	9.48
121-230-3/8-SS-A	1.34	1.34	60.0	75.0	No	1	9.53	7.11
121-230-3/8-SS-B	1.34	1.34	60.0	75.0	No	1	9.53	7.11
121-230-3/8-SS-C	1.34	1.34	60.0	75.0	No	1	9.53	7.11
121-230-3/8-SS-D	1.34	1.34	60.0	75.0	Yes	1	9.53	7.11
153-230-1/4-SS-A	1.51	1.51	60.0	75.0	No	1	6.35	4.21
153-230-1/4-SS-B	1.51	1.51	60.0	75.0	No	1	6.35	4.21
153-230-1/4-SS-C	1.51	1.51	60.0	75.0	No	1	6.35	4.21
153-230-1/4-SS-D	1.51	1.51	60.0	75.0	Yes	1	6.35	4.21
153-230-3/8-SS-A[1]	1.51	1.51	60.0	75.0	No	1	9.53	6.22
153-230-3/8-SS-B[1]	1.51	1.51	60.0	75.0	No	1	9.53	6.20
153-230-3/8-SS-C[1]	1.51	1.51	60.0	75.0	No	1	9.53	6.20
153-230-3/8-SS-D[1]	1.51	1.51	60.0	75.0	Yes	1	9.53	6.20
153-230-1/2-SS-A[1]	1.51	1.51	60.0	75.0	No	1	12.7	8.30
153-230-1/2-SS-B[1]	1.51	1.51	60.0	75.0	No	1	12.7	8.30
153-230-1/2-SS-C[1]	1.51	1.51	60.0	75.0	No	1	12.7	8.30
153-230-1/2-SS-D[1]	1.51	1.51	60.0	75.0	Yes	1	12.7	8.30
043-230-3/8-TTSS-A	0.41	1.51	60.0	75.0	No	1	9.53	23.2
043-230-3/8-TTSS-B	0.41	1.51	60.0	75.0	No	1	9.53	23.2

Table A1 Proposed Test Specimen Dimensions (continued)

SPECIMEN	t_1 (mm)	t_2 (mm)	e (mm)	s (mm)	Washers	Single or Double Shear	d (mm)	d/t
043-230-3/8-TTSS-C	0.41	1.51	60.0	75.0	No	1	9.53	23.2
043-230-3/8-TTSS-D	0.41	1.51	60.0	75.0	Yes	1	9.53	23.2
043-230-1/2-TTSS-A	0.41	1.51	60.0	75.0	No	1	12.7	31.0
043-230-1/2-TTSS-B	0.41	1.51	60.0	75.0	No	1	12.7	31.0
043-230-1/2-TTSS-C	0.41	1.51	60.0	75.0	No	1	12.7	31.0
043-230-1/2-TTSS-D	0.41	1.51	60.0	75.0	Yes	1	12.7	31.0
043-230-5/8-TTSS-A	0.41	1.51	60.0	75.0	No	1	15.9	38.7
043-230-5/8-TTSS-B	0.41	1.51	60.0	75.0	No	1	15.9	38.7
043-230-5/8-TTSS-C	0.41	1.51	60.0	75.0	No	1	15.9	38.7
043-230-5/8-TTSS-D	0.41	1.51	60.0	75.0	Yes	1	15.9	38.7
064-230-5/8-TTSS-A	0.63	1.51	60.0	75.0	No	1	15.9	25.2
064-230-5/8-TTSS-B	0.63	1.51	60.0	75.0	No	1	15.9	25.2
064-230-5/8-TTSS-C	0.63	1.51	60.0	75.0	No	1	15.9	25.2
064-230-5/8-TTSS-D	0.63	1.51	60.0	75.0	Yes	1	15.9	25.2
064-230-1/2-TTSS-A	0.63	1.51	60.0	75.0	No	1	12.7	20.2
064-230-1/2-TTSS-B	0.63	1.51	60.0	75.0	No	1	12.7	20.2
064-230-1/2-TTSS-C	0.63	1.51	60.0	75.0	No	1	12.7	20.2
064-230-1/2-TTSS-D	0.63	1.51	60.0	75.0	Yes	1	12.7	20.2
064-230-1/4-TTSS-A	0.63	1.51	60.0	75.0	No	1	6.35	10.1
064-230-1/4-TTSS-B	0.63	1.51	60.0	75.0	No	1	6.35	10.1
064-230-1/4-TTSS-C	0.63	1.51	60.0	75.0	No	1	6.35	10.1
064-230-1/4-TTSS-D	0.63	1.51	60.0	75.0	Yes	1	6.35	10.1
076-230-1/2-TTSS-A	0.72	1.51	60.0	75.0	No	1	12.7	17.6
076-230-1/2-TTSS-B	0.72	1.51	60.0	75.0	No	1	12.7	17.6
076-230-1/2-TTSS-C	0.72	1.51	60.0	75.0	No	1	12.7	17.6
076-230-1/2-TTSS-D	0.72	1.51	60.0	75.0	Yes	1	12.7	17.6
091-230-1/4-TTSS-A	0.91	1.51	60.0	75.0	No	1	6.35	6.98
091-230-1/4-TTSS-B	0.91	1.51	60.0	75.0	No	1	6.35	6.98
091-230-1/4-TTSS-C	0.91	1.51	60.0	75.0	No	1	6.35	6.98
091-230-1/4-TTSS-D	0.91	1.51	60.0	75.0	Yes	1	6.35	6.98
091-230-1/2-TTSS-A	0.91	1.51	60.0	75.0	No	1	12.7	14.0
091-230-1/2-TTSS-B	0.91	1.51	60.0	75.0	No	1	12.7	14.0
091-230-1/2-TTSS-C	0.91	1.51	60.0	75.0	No	1	12.7	14.0
091-230-1/2-TTSS-D	0.91	1.51	60.0	75.0	Yes	1	12.7	14.0
121-230-1/2-TTSS-A	1.34	1.51	60.0	75.0	No	1	12.7	9.48
121-230-1/2-TTSS-B	1.34	1.51	60.0	75.0	No	1	12.7	9.48
121-230-1/2-TTSS-C	1.34	1.51	60.0	75.0	No	1	12.7	9.48
121-230-1/2-TTSS-D	1.34	1.51	60.0	75.0	Yes	1	12.7	9.48

Table A1 Proposed Test Specimen Dimensions (continued)

SPECIMEN	t_1 (mm)	t_2 (mm)	e (mm)	s (mm)	Washers	Single or Double Shear	d (mm)	d/t
121-230-3/8-TTSS-A	1.34	1.51	60.0	75.0	No	1	9.53	7.11
121-230-3/8-TTSS-B	1.34	1.51	60.0	75.0	No	1	9.53	7.11
121-230-3/8-TTSS-C	1.34	1.51	60.0	75.0	No	1	9.53	7.11
121-230-3/8-TTSS-D	1.34	1.51	60.0	75.0	Yes	1	9.53	7.11
043-230-3/8-DS-A	0.41	1.51	60.0	75.0	No	2	9.53	23.2
043-230-3/8-DS-B	0.41	1.51	60.0	75.0	No	2	9.53	23.2
043-230-3/8-DS-C	0.41	1.51	60.0	75.0	No	2	9.53	23.2
043-230-3/8-DS-D	0.41	1.51	60.0	75.0	Yes	2	9.53	23.2
043-230-1/2-DS-A	0.41	1.51	60.0	75.0	No	2	12.7	31.0
043-230-1/2-DS-B	0.41	1.51	60.0	75.0	No	2	12.7	31.0
043-230-1/2-DS-C	0.41	1.51	60.0	75.0	No	2	12.7	31.0
043-230-1/2-DS-D	0.41	1.51	60.0	75.0	Yes	2	12.7	31.0
043-230-5/8-DS-A	0.41	1.51	60.0	75.0	No	2	15.9	38.7
043-230-5/8-DS-B	0.41	1.51	60.0	75.0	No	2	15.9	38.7
043-230-5/8-DS-C	0.41	1.51	60.0	75.0	No	2	15.9	38.7
043-230-5/8-DS-D	0.41	1.51	60.0	75.0	Yes	2	15.9	38.7
064-230-5/8-DS-A	0.63	1.51	60.0	75.0	No	2	15.9	25.2
064-230-5/8-DS-B	0.63	1.51	60.0	75.0	No	2	15.9	25.2
064-230-5/8-DS-C	0.63	1.51	60.0	75.0	No	2	15.9	25.2
064-230-5/8-DS-D	0.63	1.51	60.0	75.0	Yes	2	15.9	25.2
064-230-1/2-DS-A	0.63	1.51	60.0	75.0	No	2	12.7	20.2
064-230-1/2-DS-B	0.63	1.51	60.0	75.0	No	2	12.7	20.2
064-230-1/2-DS-C	0.63	1.51	60.0	75.0	No	2	12.7	20.2
064-230-1/2-DS-D	0.63	1.51	60.0	75.0	Yes	2	12.7	20.2
064-230-1/4-DS-A	0.63	1.51	60.0	75.0	No	2	6.35	10.1
064-230-1/4-DS-B	0.63	1.51	60.0	75.0	No	2	6.35	10.1
064-230-1/4-DS-C	0.63	1.51	60.0	75.0	No	2	6.35	10.1
064-230-1/4-DS-D	0.63	1.51	60.0	75.0	Yes	2	6.35	10.1
076-230-1/2-DS-A	0.72	1.51	60.0	75.0	No	2	12.7	17.6
076-230-1/2-DS-B	0.72	1.51	60.0	75.0	No	2	12.7	17.6
076-230-1/2-DS-C	0.72	1.51	60.0	75.0	No	2	12.7	17.6
076-230-1/2-DS-D	0.72	1.51	60.0	75.0	Yes	2	12.7	17.6
091-230-1/4-DS-A	0.91	1.51	60.0	75.0	No	2	6.35	6.98
091-230-1/4-DS-B	0.91	1.51	60.0	75.0	No	2	6.35	6.98
091-230-1/4-DS-C	0.91	1.51	60.0	75.0	No	2	6.35	6.98
091-230-1/4-DS-D	0.91	1.51	60.0	75.0	Yes	2	6.35	6.98
091-230-1/2-DS-A	0.91	1.51	60.0	75.0	No	2	12.7	14.0
091-230-1/2-DS-B	0.91	1.51	60.0	75.0	No	2	12.7	14.0

Table A1 Proposed Test Specimen Dimensions (continued)

SPECIMEN	t_1 (mm)	t_2 (mm)	e (mm)	s (mm)	Washers	Single or Double Shear	d (mm)	d/t
091-230-1/2-DS-C	0.91	1.51	60.0	75.0	No	2	12.7	14.0
091-230-1/2-DS-D	0.91	1.51	60.0	75.0	Yes	2	12.7	14.0
121-230-1/2-DS-A	1.34	1.51	60.0	75.0	No	2	12.7	9.48
121-230-1/2-DS-B	1.34	1.51	60.0	75.0	No	2	12.7	9.48
121-230-1/2-DS-C	1.34	1.51	60.0	75.0	No	2	12.7	9.48
121-230-1/2-DS-D	1.34	1.51	60.0	75.0	Yes	2	12.7	9.48
121-230-3/8-DS-A	1.34	1.51	60.0	75.0	No	2	9.53	7.11
121-230-3/8-DS-B	1.34	1.51	60.0	75.0	No	2	9.53	7.11
121-230-3/8-DS-C	1.34	1.51	60.0	75.0	No	2	9.53	7.11
121-230-3/8-DS-D	1.34	1.51	60.0	75.0	Yes	2	9.53	7.11

[1.] Tests not Selected

APPENDIX B

McGill Test Data

Table B1 Results of Present Test Program

SPECIMEN	P_t (kN)	δ_{ult} (mm)	$P_{6.35}$ (kN)	Actual Failure Mode
043-230-3/8-SS-A	1.69	6.48	1.60	Bearing(A)
043-230-3/8-SS-B	1.77	5.66	1.77	Bearing(A)
043-230-3/8-SS-C	1.67	8.12	1.57	Bearing(A)
043-230-3/8-SS-D	2.94	9.40	2.50	Bearing(A)
043-230-3/8-TTSS-A	1.87	5.27	1.87	Bearing(A)
043-230-3/8-TTSS-B	1.77	3.65	1.77	Bearing(A)
043-230-3/8-TTSS-C	2.16	5.12	2.16	Bearing(A)
043-230-3/8-TTSS-D	2.04	5.26	2.04	Bearing(A)
043-230-3/8-DS-A	3.65	10.6	2.60	Bearing(C)
043-230-3/8-DS-B	3.46	11.1	2.20	Bearing(C)
043-230-3/8-DS-C	3.26	14.8	1.60	Bearing(C)
043-230-3/8-DS-D	4.51	15.2	1.60	Bearing(C)
043-550-3/8-SS-A	2.62	6.74	2.60	Bearing(A)
043-550-3/8-SS-B	2.73	7.24	2.70	Bearing(A)
043-550-3/8-SS-C	2.49	6.63	2.50	Bearing(A)
043-550-3/8-SS-D	4.44	10.6	3.30	Bearing(A)
043-230-1/2-SS-A	2.14	9.93	1.72	Bearing(A)
043-230-1/2-SS-B	2.13	8.57	1.90	Bearing(A)
043-230-1/2-SS-C	2.18	9.94	1.80	Bearing(A)
043-230-1/2-SS-D	2.50	11.9	2.00	Bearing(A)
043-230-1/2-TTSS-A	2.29	7.68	2.18	Bearing(A)
043-230-1/2-TTSS-B	2.24	6.67	2.20	Bearing(A)
043-230-1/2-TTSS-C	2.46	6.54	2.40	Bearing(A)
043-230-1/2-TTSS-D	2.28	7.78	2.20	Bearing(A)
043-230-1/2-DS-A	5.43	14.3	3.50	Bearing(C)
043-230-1/2-DS-B	5.80	13.3	3.30	Bearing(C)
043-230-1/2-DS-C	5.72	15.2	3.80	Bearing(C)
043-230-1/2-DS-D	6.98	11.5	5.10	Bearing(C)
043-550-1/2-SS-A	3.37	7.67	3.20	Bearing(A)
043-550-1/2-SS-B	3.36	8.10	2.90	Bearing(A)
043-550-1/2-SS-C	3.36	10.0	3.00	Bearing(A)
043-550-1/2-SS-D	4.52	8.90	3.30	Bearing(A)
043-230-5/8-SS-A	2.99	12.6	2.20	Bearing(A)
043-230-5/8-SS-B	2.84	10.9	2.50	Bearing(A)
043-230-5/8-SS-C	2.78	*	*	Bearing(A)
043-230-5/8-SS-D	3.85	*	*	Bearing(A)
043-230-5/8-TTSS-A	3.09	8.35	2.70	Bearing(A)

Table B1 Results of Present Test Program(continued)

SPECIMEN	P_t (kN)	δ_{ult} (mm)	$P_{6.35}$ (kN)	Actual Failure Mode
043-230-5/8-TTSS-B	3.22	7.86	3.00	Bearing(A)
043-230-5/8-TTSS-C	3.36	8.81	3.00	Bearing(A)
043-230-5/8-TTSS-D	3.75	7.28	3.60	Bearing(A)
043-230-5/8-DS-A	7.05	8.83	6.60	Bearing(C)
043-230-5/8-DS-B	7.49	14.2	5.20	Bearing(C)
043-230-5/8-DS-C	7.35	17.0	4.20	Bearing(C)
043-230-5/8-DS-D	7.50	8.91	7.00	Bearing(C)
043-550-5/8-SS-A	3.71	8.15	3.30	Bearing(A)
043-550-5/8-SS-B	3.93	9.07	3.50	Bearing(A)
043-550-5/8-SS-C	3.92	8.99	3.40	Bearing(A)
043-550-5/8-SS-D	4.85	21.7	3.50	Bearing(A)
064-230-5/8-TTSS-A	5.22	9.15	4.40	Bearing(A)
064-230-5/8-TTSS-B	4.88	6.47	4.88	Bearing(A)
064-230-5/8-TTSS-C	5.47	11.5	4.20	Bearing(A)
064-230-5/8-TTSS-D	6.10	7.00	6.00	Bearing(A)
064-230-5/8-DS-A	11.8	14.2	9.50	Bearing(C)
064-230-5/8-DS-B	11.0	9.67	10.3	Bearing(C)
064-230-5/8-DS-C	11.7	13.0	10.1	Bearing(C)
064-230-5/8-DS-D	12.5	10.5	12.0	Bearing(C)
064-550-5/8-SS-A	8.64	8.91	10.8	Bearing(A)
064-550-5/8-SS-B	8.91	12.2	10.1	Bearing(A)
064-550-5/8-SS-C	8.34	9.81	9.00	Bearing(A)
064-550-5/8-SS-D	11.2	15.9	12.1	Bearing(A)
064-230-1/2-TTSS-A	4.56	5.23	4.56	Bearing(A)
064-230-1/2-TTSS-B	4.44	7.67	4.20	Bearing(A)
064-230-1/2-TTSS-C	4.10	4.50	4.10	Bearing(A)
064-230-1/2-TTSS-D	4.92	6.50	4.90	Bearing(A)
064-230-1/2-DS-A	8.91	7.53	8.35	Bearing(C)
064-230-1/2-DS-B	9.28	10.0	7.30	Bearing(C)
064-230-1/2-DS-C	9.23	8.12	9.20	Bearing(C)
064-230-1/2-DS-D	10.7	9.07	9.30	Bearing(C)
064-550-1/2-SS-A	6.94	6.68	6.90	Bearing(A)
064-550-1/2-SS-B	7.26	10.0	7.00	Bearing(A)
064-550-1/2-SS-C	7.04	8.96	6.80	Bearing(A)
064-550-1/2-SS-D	9.63	10.1	8.75	Bearing(A)
064-230-3/8-SS-A	3.05	6.20	3.05	Bearing(A)
064-230-3/8-SS-B	2.75	5.70	2.75	Bearing(A)
064-230-3/8-SS-C	2.77	3.17	2.77	Bearing(A)

Table B1 Results of Present Test Program(continued)

SPECIMEN	P_t (kN)	δ_{ult} (mm)	$P_{6.35}$ (kN)	Actual Failure Mode
064-230-3/8-SS-D	3.85	6.58	3.80	Bearing(A)
064-550-3/8-SS-A	5.83	5.33	5.83	Bearing(A)
064-550-3/8-SS-B	6.43	3.65	6.43	Bearing(A)
064-550-3/8-SS-C	5.82	5.22	5.82	Bearing(A)
064-550-3/8-SS-D	9.39	7.79	8.13	Bearing(A)
064-230-1/4-DS-A	6.76	9.32	5.88	Bearing(B)
064-230-1/4-DS-B	6.67	8.60	5.90	Bearing(B)
064-230-1/4-DS-C	6.38	9.98	5.20	Bearing(B)
064-230-1/4-DS-D	8.98	10.5	7.00	Bearing(B)
064-550-1/4-SS-A	5.68	5.77	5.68	Bearing(B)
064-550-1/4-SS-B	5.55	6.24	5.55	Bearing(B)
064-550-1/4-SS-C	5.90	4.65	5.90	Bearing(B)
064-550-1/4-SS-D	7.42	7.17	6.60	Bearing(B)
064-230-1/4-SS-A	2.92	3.77	2.92	Bearing(A)
064-230-1/4-SS-B	3.07	4.83	3.07	Bearing(A)
064-230-1/4-SS-C	3.00	6.02	3.00	Bearing(A)
064-230-1/4-SS-D	5.56	9.76	4.20	Bearing(B)
064-230-1/4-TTSS-A	2.95	2.40	2.95	Bearing(B)
064-230-1/4-TTSS-B	3.29	5.80	3.29	Bearing(B)
064-230-1/4-TTSS-C	3.80	6.20	3.50	Bearing(B)
064-230-1/4-TTSS-D	4.29	5.00	4.30	Bearing(B)
076-230-1/2-SS-A	4.77	8.79	4.50	Bearing(A)
076-230-1/2-SS-B	4.53	6.58	4.50	Bearing(A)
076-230-1/2-SS-C	4.90	8.45	4.70	Bearing(A)
076-230-1/2-SS-D	7.21	12.5	6.50	Bearing(A)
076-230-1/2-TTSS-A	5.22	8.47	4.80	Bearing(A)
076-230-1/2-TTSS-B	5.90	8.09	5.40	Bearing(A)
076-230-1/2-TTSS-C	5.41	7.29	5.30	Bearing(A)
076-230-1/2-TTSS-D	9.80	5.41	9.80	Bearing(A)
076-230-1/2-DS-A	10.8	11.2	8.30	Bearing(A)
076-230-1/2-DS-B	11.8	8.49	10.8	Bearing(A)
076-230-1/2-DS-C	10.5	13.2	9.10	Bearing(A)
076-230-1/2-DS-D	14.4	16.3	10.1	Bearing(A)
076-550-1/2-SS-A	8.50	7.79	8.30	Bearing(A)
076-550-1/2-SS-B	8.06	6.53	8.02	Bearing(A)
076-550-1/2-SS-C	8.50	7.54	8.30	Bearing(A)
076-550-1/2-SS-D	11.7	8.38	11.6	Bearing(A)
076-230-5/8-SS-A	6.17	15.5	4.60	Bearing(A)

Table B1 Results of Present Test Program(continued)

SPECIMEN	P_t (kN)	δ_{ult} (mm)	$P_{6.35}$ (kN)	Actual Failure Mode
076-230-5/8-SS-B	6.04	10.6	5.30	Bearing$^{(A)}$
076-230-5/8-SS-C	6.04	13.4	5.00	Bearing$^{(A)}$
076-230-5/8-SS-D	8.62	13.2	7.65	Bearing$^{(A)}$
076-550-3/8-SS-A	8.19	4.13	8.19	Bearing$^{(A)}$
076-550-3/8-SS-B	7.80	3.07	7.80	Bearing$^{(A)}$
076-550-3/8-SS-C	6.61	3.93	6.61	Bearing$^{(A)}$
076-550-3/8-SS-D	10.1	7.66	9.70	Bearing$^{(A)}$
076-550-1/4-SS-A	7.01	5.55	7.01	Bearing$^{(B)}$
076-550-1/4-SS-B	6.80	5.86	6.80	Bearing$^{(B)}$
076-550-1/4-SS-C	6.55	4.27	6.55	Bearing$^{(B)}$
076-550-1/4-SS-D	9.26	5.92	9.20	Bearing$^{(B)}$
091-230-1/4-SS-A	4.65	6.88	4.50	Bearing$^{(B)}$
091-230-1/4-SS-B	5.14	5.49	5.14	Bearing$^{(B)}$
091-230-1/4-SS-C	4.83	6.06	4.83	Bearing$^{(B)}$
091-230-1/4-SS-D	6.41	11.9	6.30	Bearing$^{(B)}$
091-230-1/4-TTSS-A	7.94	7.30	7.50	Bearing$^{(B)}$
091-230-1/4-TTSS-B	7.46	9.00	6.62	Bearing$^{(B)}$
091-230-1/4-TTSS-C	7.51	8.48	7.02	Bearing$^{(B)}$
091-230-1/4-TTSS-D	7.19	7.88	6.90	Bearing$^{(A)}$
091-230-1/4-DS-A	12.7	11.7	8.50	Bearing$^{(C)}$
091-230-1/4-DS-B	12.4	9.02	9.50	Bearing$^{(C)}$
091-230-1/4-DS-C	11.2	11.5	8.80	Bearing$^{(C)}$
091-230-1/4-DS-D	14.6	11.9	9.90	Bearing$^{(C)}$
091-230-1/2-TTSS-A	6.91	8.49	6.20	Bearing$^{(A)}$
091-230-1/2-TTSS-B	6.94	7.80	6.50	Bearing$^{(A)}$
091-230-1/2-TTSS-C	7.00	9.00	6.50	Bearing$^{(A)}$
091-230-1/2-TTSS-D	7.64	9.23	7.30	Bearing$^{(A)}$
091-230-1/2-DS-A	14.3	13.4	10.6	Bearing$^{(C)}$
091-230-1/2-DS-B	13.6	6.76	13.4	Bearing$^{(C)}$
091-230-1/2-DS-C	13.4	11.9	10.5	Bearing$^{(C)}$
091-230-1/2-DS-D	15.4	10.5	13.7	Bearing$^{(C)}$
121-230-1/2-TTSS-A	10.3	8.29	9.60	Bearing$^{(A)}$
121-230-1/2-TTSS-B	10.3	6.73	10.2	Bearing$^{(A)}$
121-230-1/2-TTSS-C	12.0	10.3	11.9	Bearing$^{(A)}$
121-230-1/2-TTSS-D	12.2	9.29	11.7	Bearing$^{(A)}$
121-230-1/2-DS-A	18.6	13.1	15.9	Bearing$^{(C)}$
121-230-1/2-DS-B	20.9	9.26	19.5	Bearing$^{(C)}$
121-230-1/2-DS-C	18.3	10.4	16.3	Bearing$^{(C)}$

Table B1 Results of Present Test Program(continued)

SPECIMEN	P_t (kN)	δ_{ult} (mm)	$P_{6.35}$ (kN)	Actual Failure Mode
121-230-1/2-DS-D	24.9	16.0	18.2	Bearing(C)
121-230-3/8-SS-A	8.39	7.49	8.30	Bearing(A)
121-230-3/8-SS-B	8.54	5.92	8.54	Bearing(A)
121-230-3/8-SS-C	8.89	3.57	8.89	Bearing(A)
121-230-3/8-SS-D	14.7	13.6	12.9	Bearing(A)
121-230-3/8-TTSS-A	9.28	3.44	9.12	Bearing(A)
121-230-3/8-TTSS-B	9.03	9.24	8.00	Bearing(A)
121-230-3/8-TTSS-C	9.70	6.55	9.70	Bearing(A)
121-230-3/8-TTSS-D	12.5	11.0	12.0	Bearing(A)
121-230-3/8-DS-A	20.5	9.98	17.4	Bearing(A)
121-230-3/8-DS-B	18.4	10.7	14.6	Bearing(A)
121-230-3/8-DS-C	16.4	11.3	14.8	Bearing(A)
121-230-3/8-DS-D	23.2	12.0	17.6	Bearing(A)
153-230-1/4-SS-A	9.99	7.04	9.90	Bearing(B)
153-230-1/4-SS-B	9.80	7.24	9.40	Bearing(B)
153-230-1/4-SS-C	9.49	6.62	9.60	Bearing(B)
153-230-1/4-SS-D	15.2	13.2	11.9	Bearing(B)

(A). Type A Bearing Failure (Definition can be found in Section 3.6)

(B). Type B Bearing Failure (Definition can be found in Section 3.6)

(C). Type C Bearing Failure (Definition can be found in Section 3.6)

*. Due to the disturbance of the load-elongation curves, the point of initial bearing could not be determined

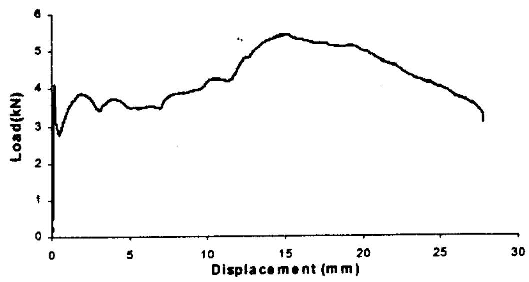


Figure B1 043-230-1/2-DS-A

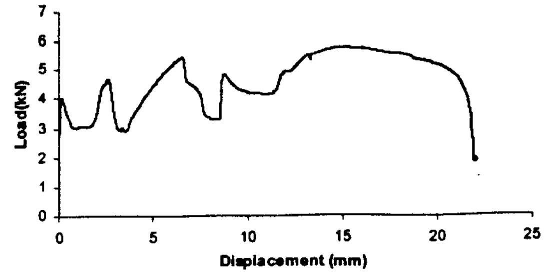


Figure B2 043-230-1/2-DS-B

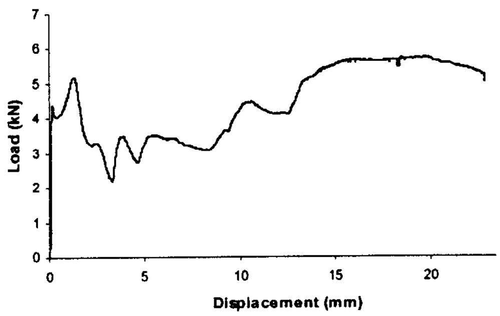


Figure B3 043-230-1/2-DS-C

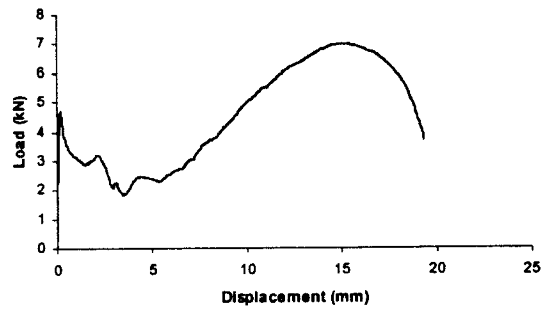


Figure B4 043-230-1/2-DS-D

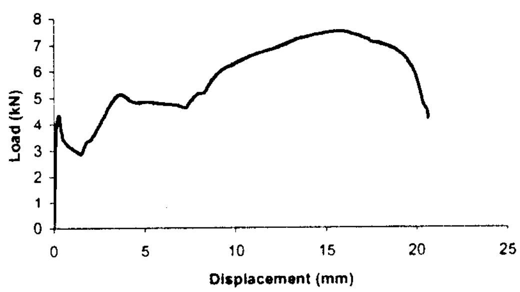


Figure B5 043-230-5/8-DS-A

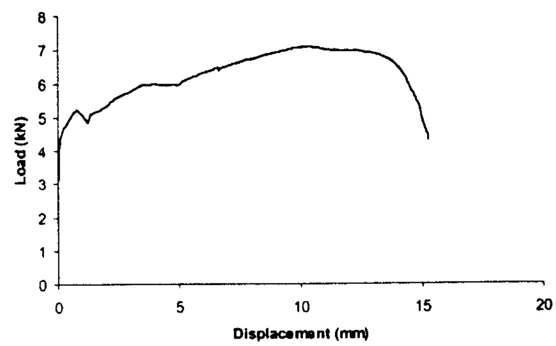


Figure B6 043-230-5/8-DS-B

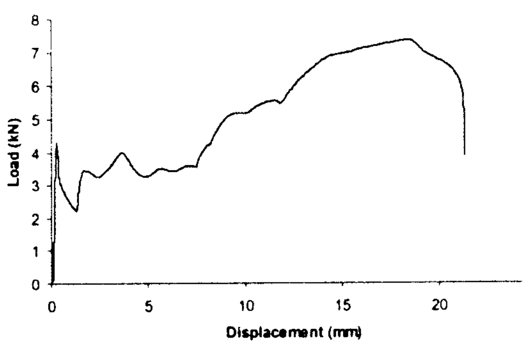


Figure B7 043-230-5/8-DS-C

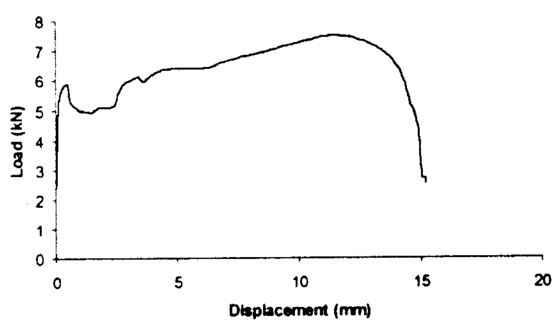
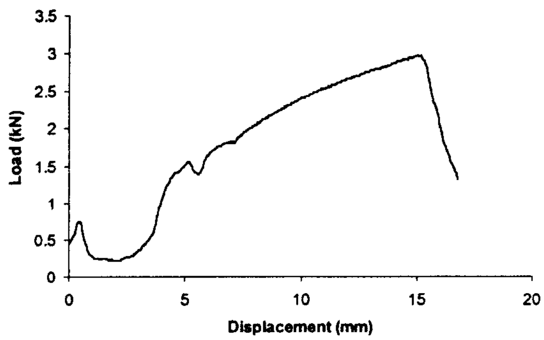


Figure B8 043-230-5/8-DS-D



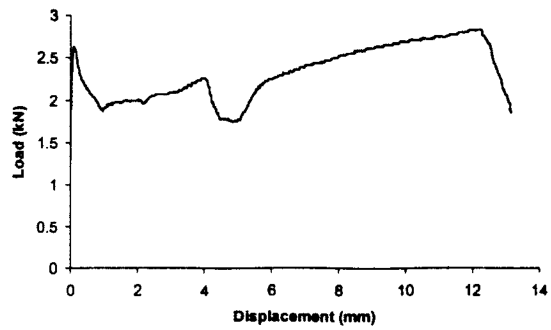
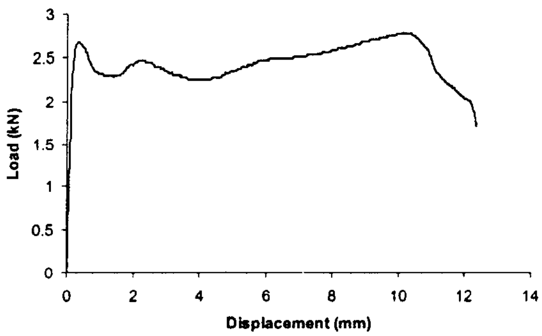


Figure B9 043-230-5/8-SS-A

Figure B10 043-230-5/8-SS-B



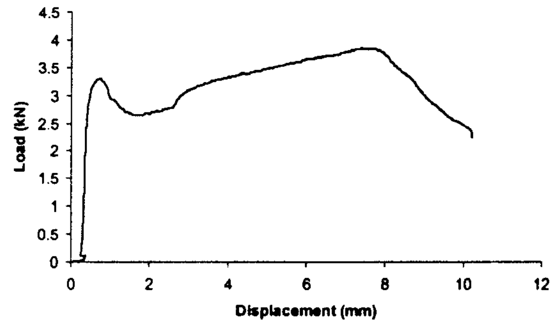
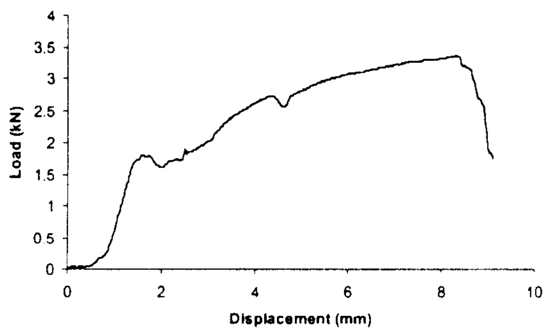


Figure B11 043-230-5/8-SS-C

Figure B12 043-230-5/8-SS-D



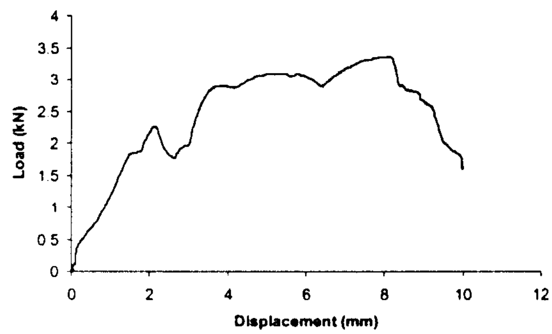
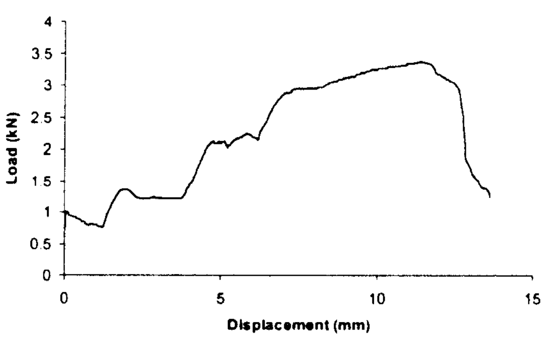


Figure B13 043-550-1/2-SS-A

Figure B14 043-550-1/2-SS-B



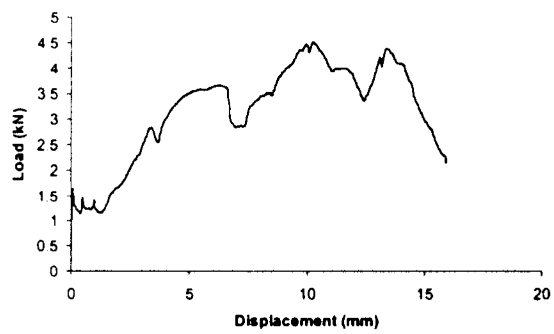


Figure B15 043-550-1/2-SS-C

Figure B16 043-550-1/2-SS-D

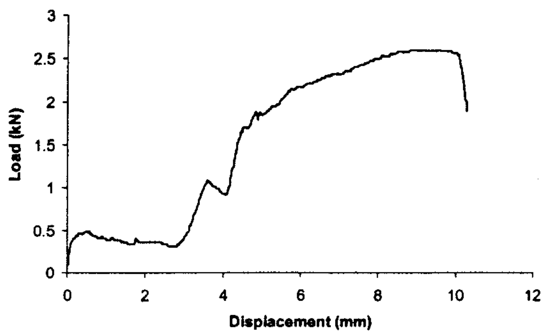


Figure B17 043-550-3/8-SS-A

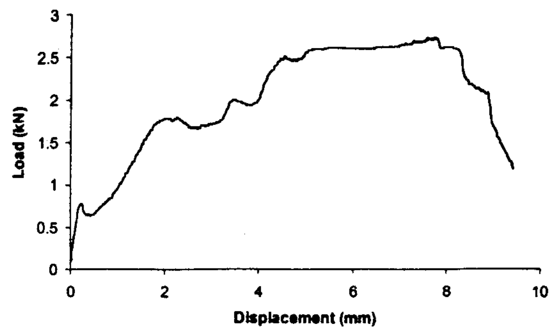


Figure B18 043-550-3/8-SS-B

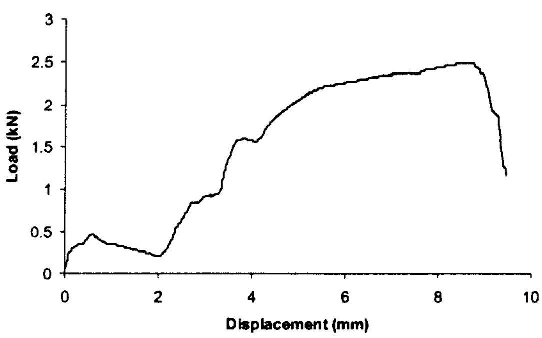


Figure B19 043-550-3/8-SS-C

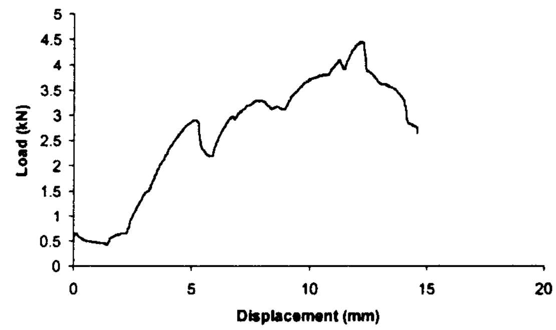


Figure B20 043-550-3/8-SS-D

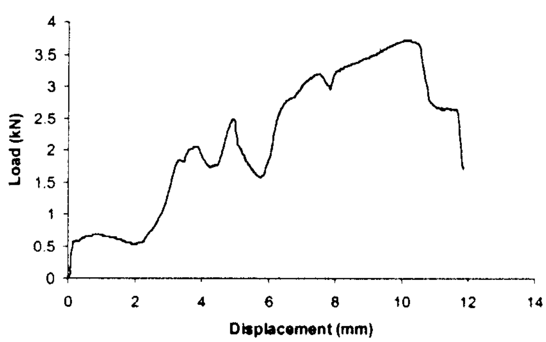


Figure B21 043-550-5/8-SS-A

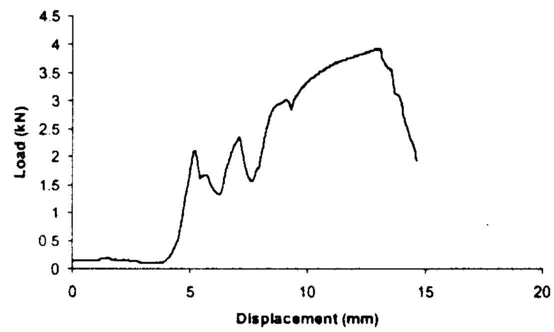


Figure B22 043-550-5/8-SS-B

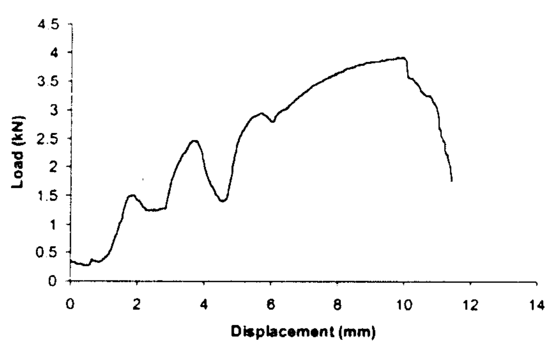


Figure B22 043-550-5/8-SS-C

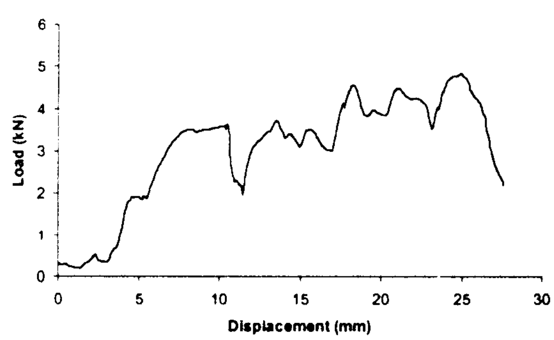


Figure B24 043-550-5/8-SS-D

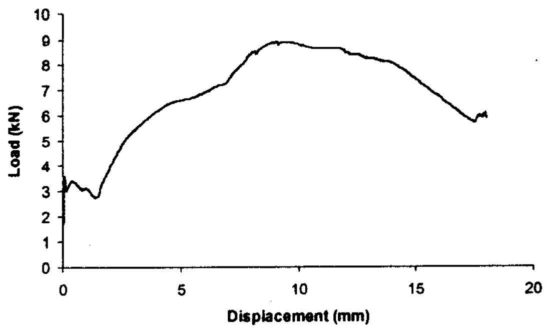


Figure B25 064-230-1/2-DS-A

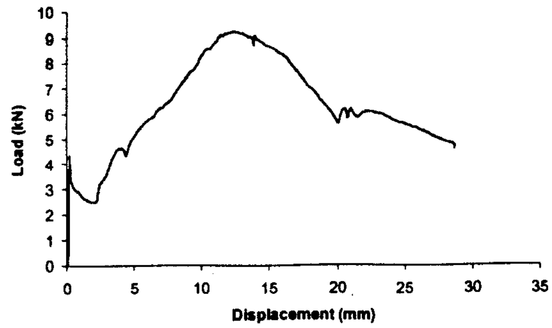


Figure B26 064-230-1/2-DS-B

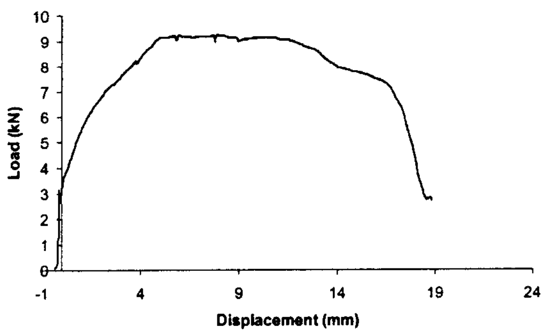


Figure B27 064-230-1/2-DS-C

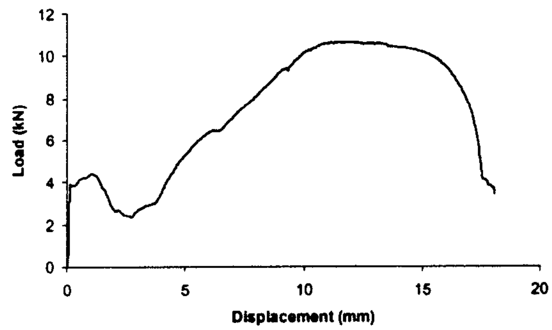


Figure B28 064-230-1/2-DS-D

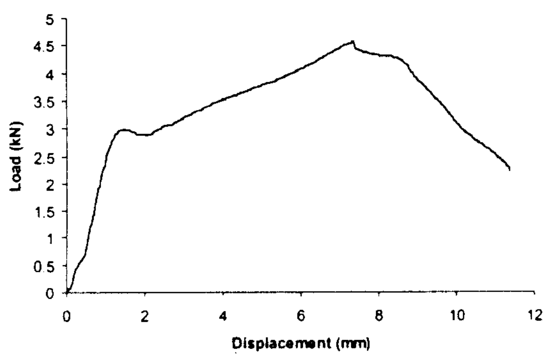


Figure B29 064-230-1/2-TTSS-A

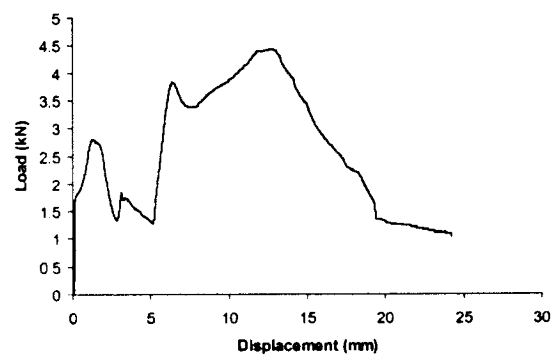


Figure B30 064-230-1/2-TTSS-B

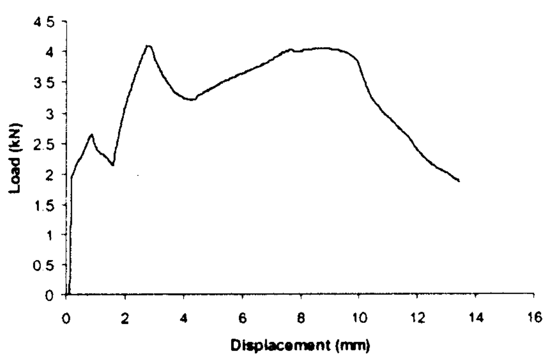


Figure B31 064-230-1/2-TTSS-C

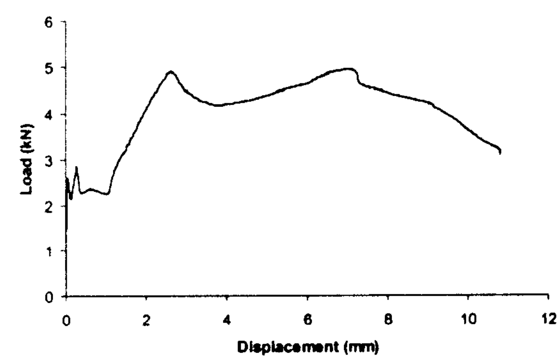


Figure B32 064-230-1/2-TTSS-D

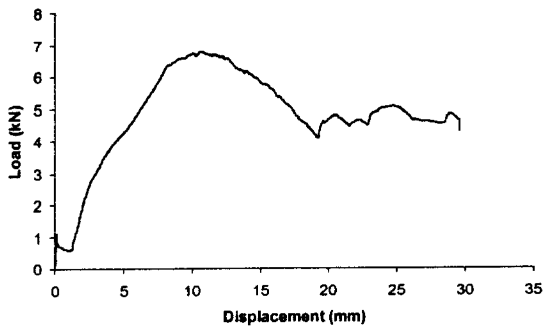


Figure B33 064-230-1/4-DS-A

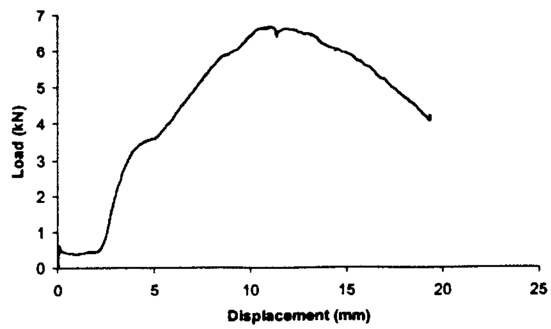


Figure B34 064-230-1/4-DS-B

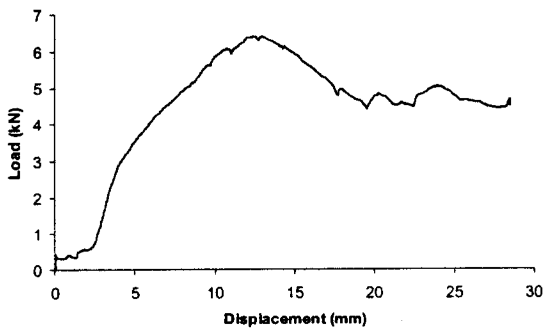


Figure B35 064-230-1/4-DS-C

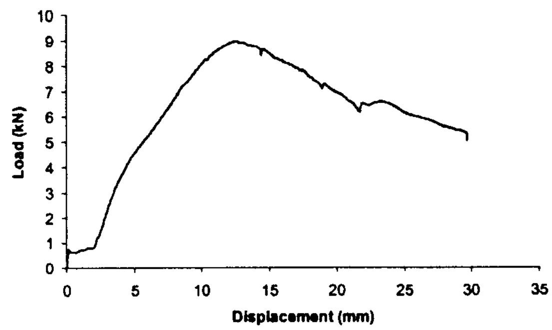


Figure B36 064-230-1/4-DS-D

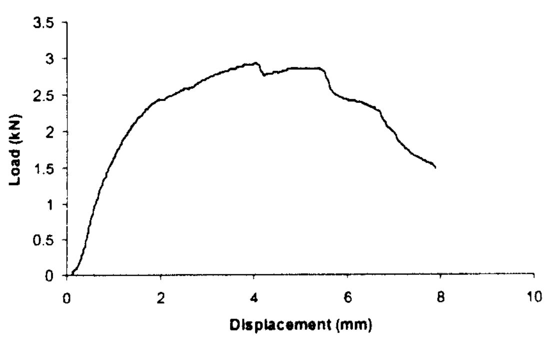


Figure B37 064-230-1/4-SS-A

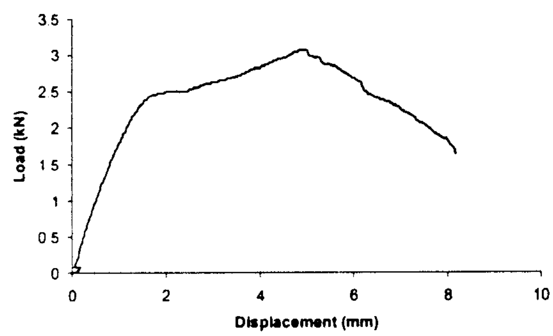


Figure B38 064-230-1/4-SS-B

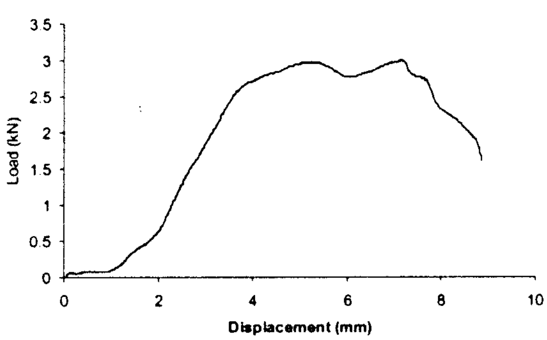


Figure B39 064-230-1/4-SS-C

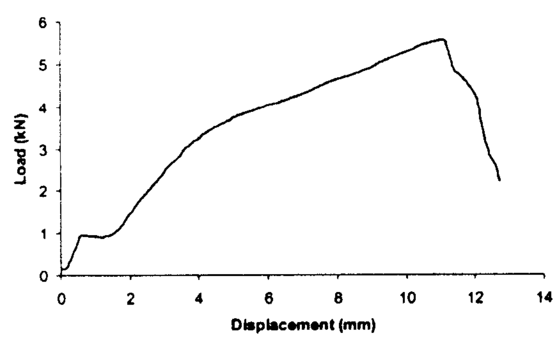


Figure B40 064-230-1/4-SS-D

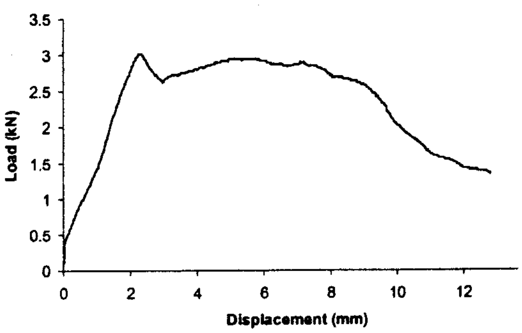


Figure B41 064-230-1/4-TTSS-A

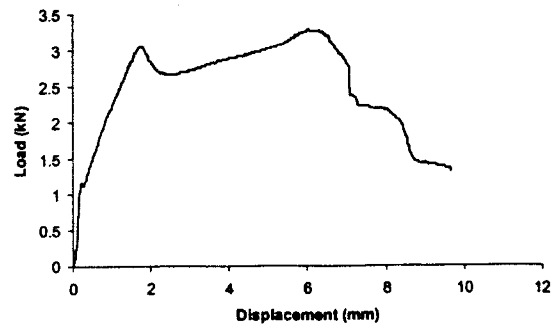


Figure B42 064-230-1/4-TTSS-B

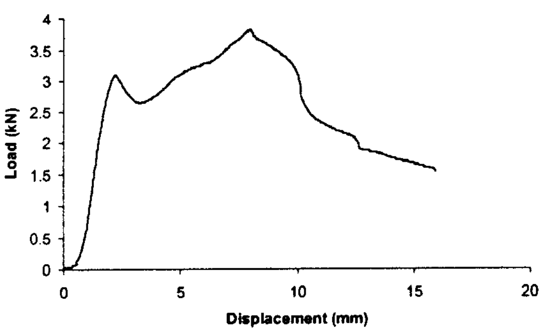


Figure B43 064-230-1/4-TTSS-C

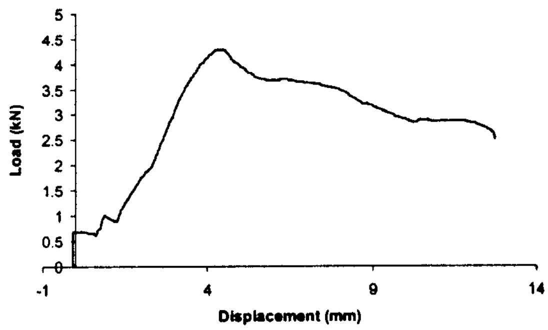


Figure B44 064-230-1/4-TTSS-D

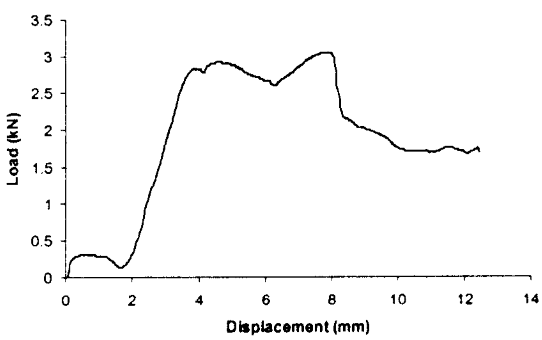


Figure B45 064-230-3/8-SS-A

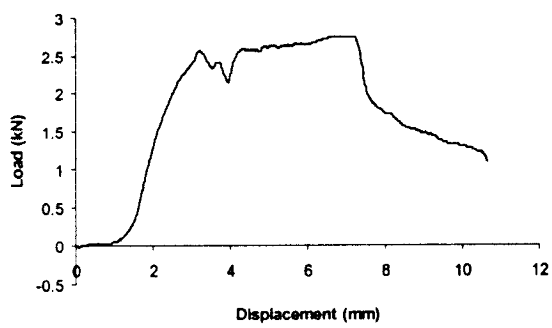


Figure B46 064-230-3/8-SS-B

Figure B47 064-230-3/8-SS-C

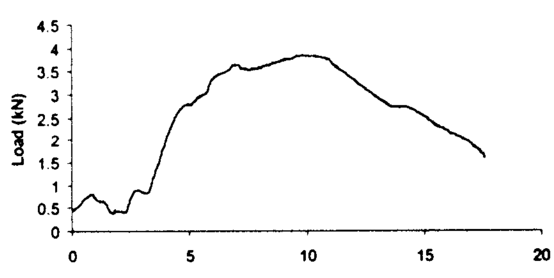


Figure B48 064-230-3/8-SS-D

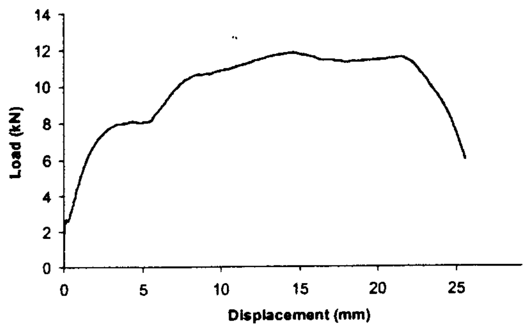


Figure B49 064-230-5/8-DS-A

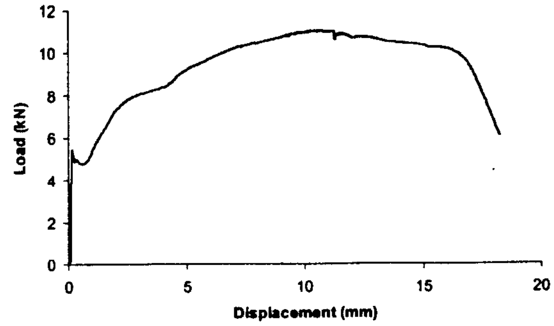


Figure B50 064-230-5/8-DS-B

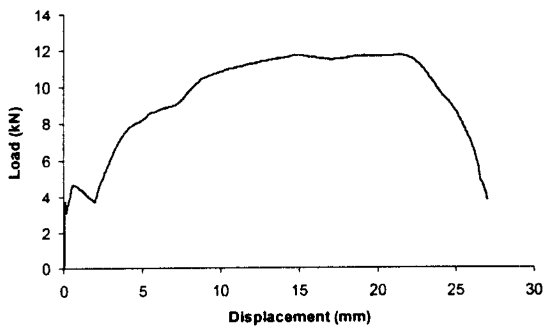


Figure B51 064-230-5/8-DS-C

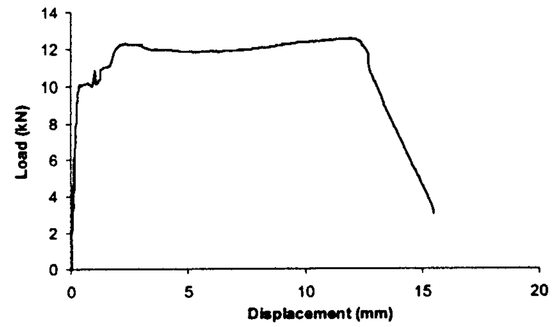


Figure B52 064-230-5/8-DS-D

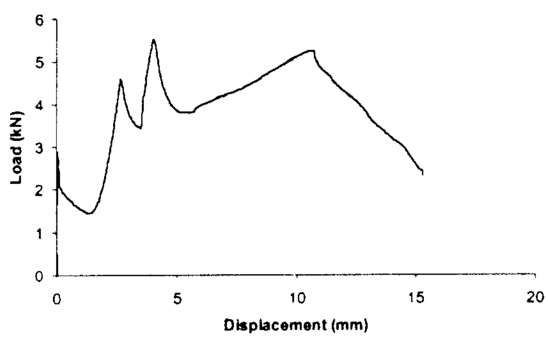


Figure B53 064-230-5/8-TTSS-A

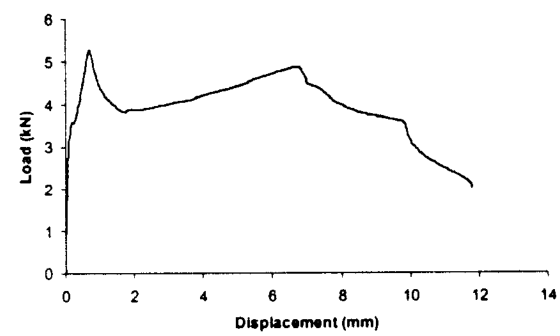


Figure B54 064-230-5/8-TTSS-B

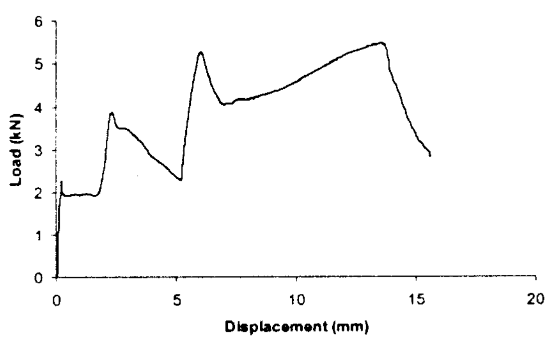


Figure B55 064-230-5/8-TTSS-C

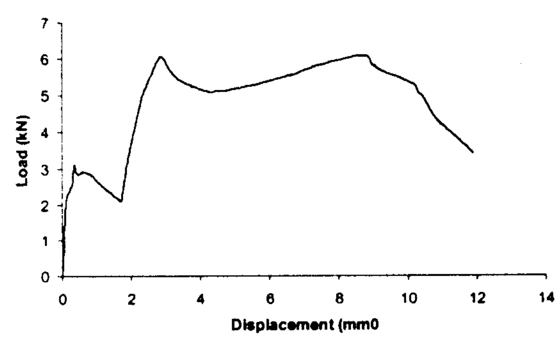


Figure B56 064-230-5/8-TTSS-D

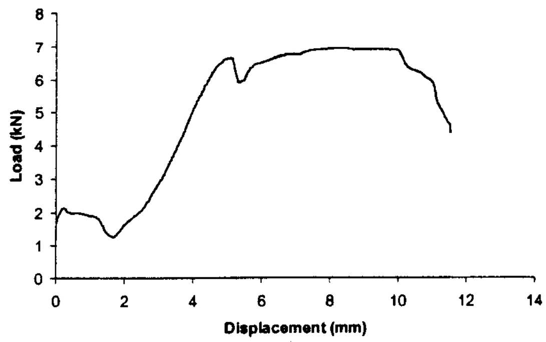


Figure B57 064-550-1/2-SS-A

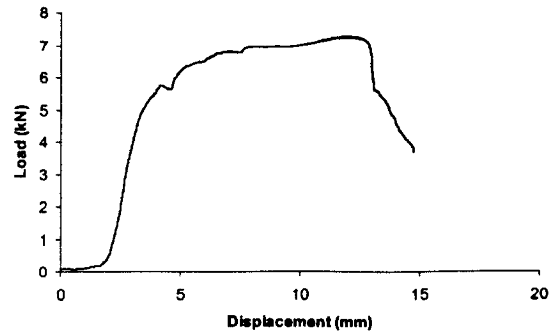


Figure B58 064-550-1/2-SS-B

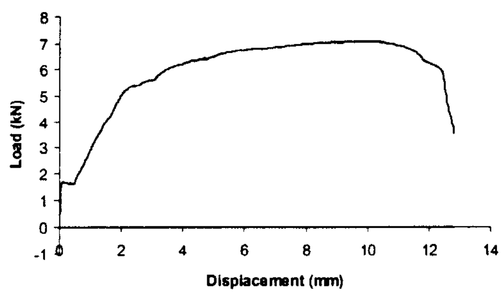


Figure B59 064-550-1/2-SS-C

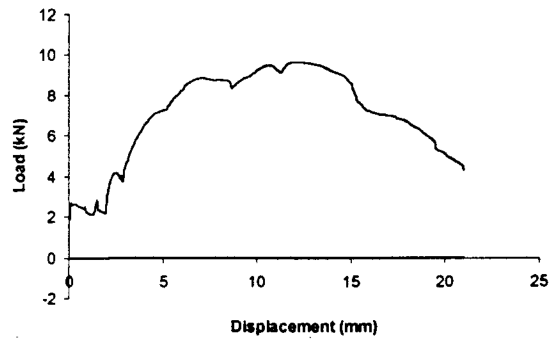


Figure B60 064-550-1/2-SS-D

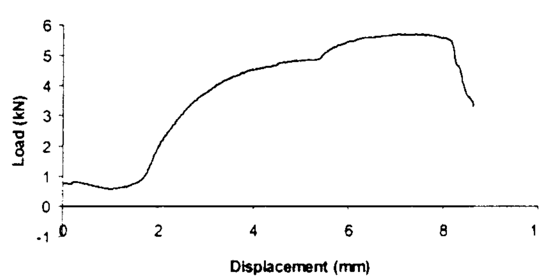


Figure B61 064-550-1/4-SS-A

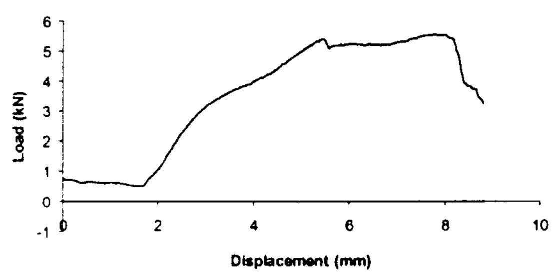


Figure B62 064-550-1/4-SS-B

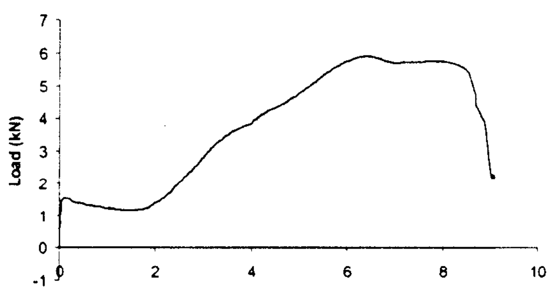


Figure B63 064-550-1/4-SS-C

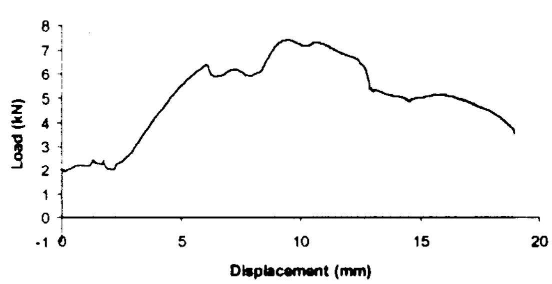


Figure B64 064-550-1/4-SS-D

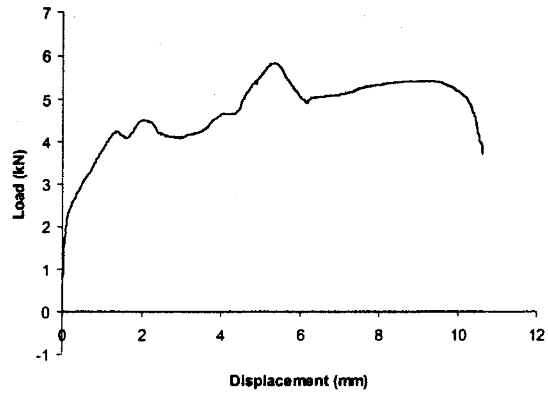


Figure B65 064-550-3/8-SS-A

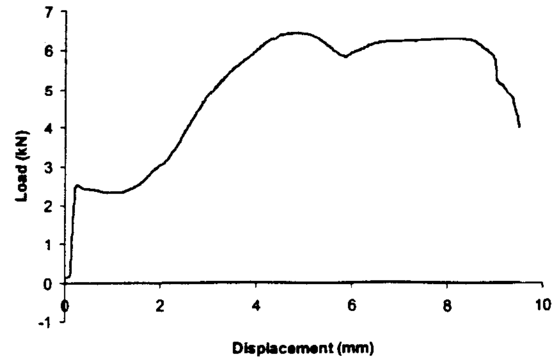


Figure B66 064-550-3/8-SS-B

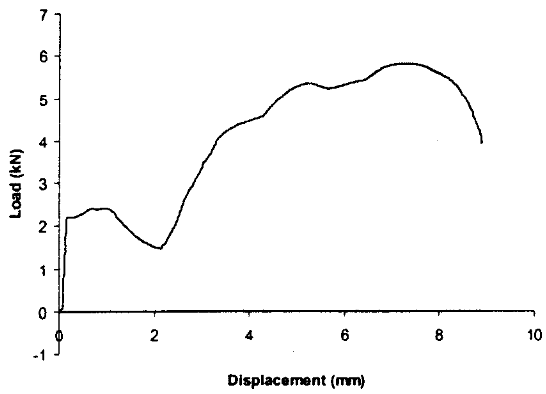


Figure B67 064-550-3/8-SS-C

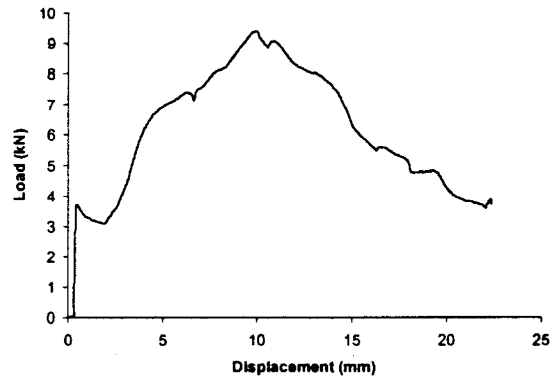


Figure B68 064-550-3/8-SS-D

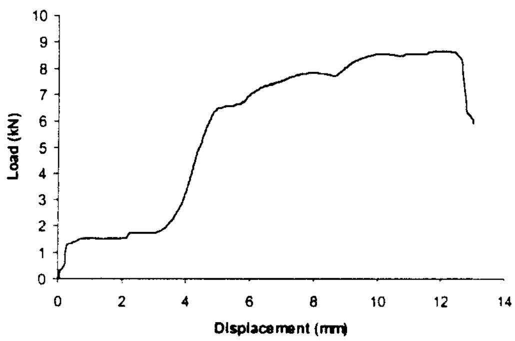


Figure B69 064-550-5/8-SS-A

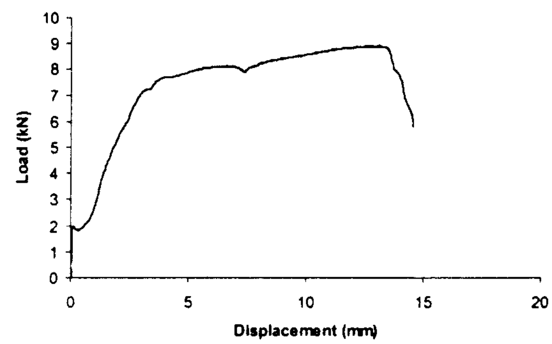


Figure B70 064-550-5/8-SS-B

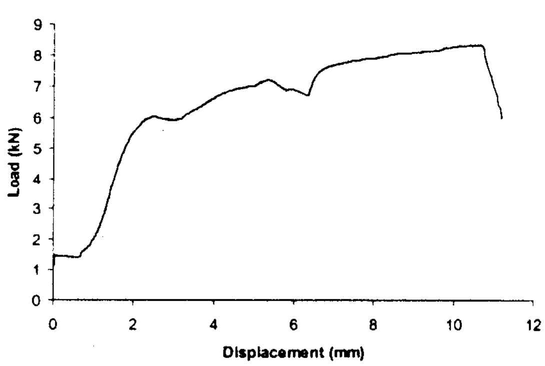


Figure B71 064-550-5/8-SS-C

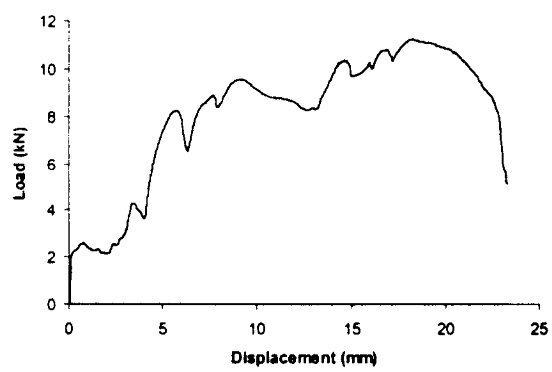


Figure B72 064-550-5/8-SS-D

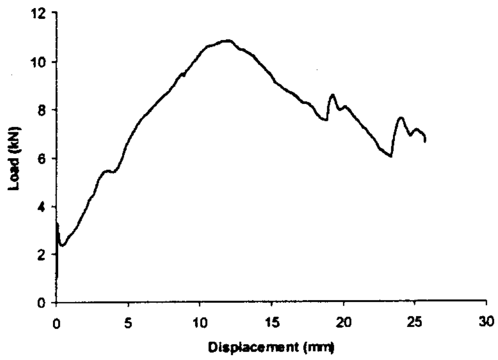


Figure B73 064-230-1/2-DS-A

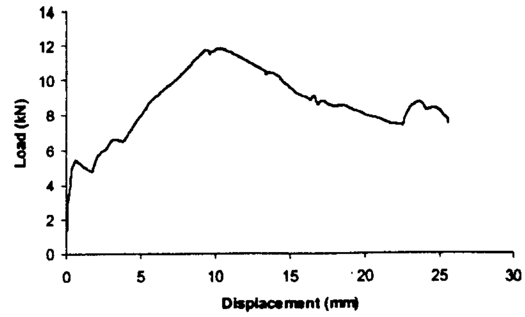


Figure B74 064-230-1/2-DS-B

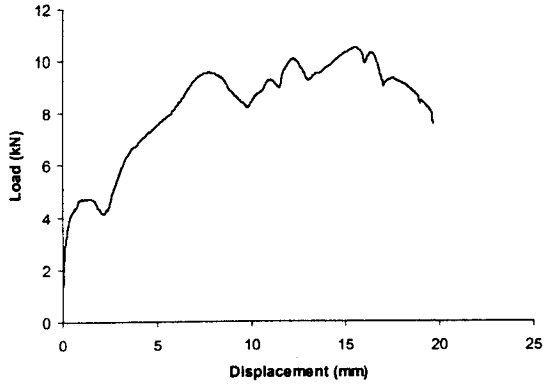


Figure B76 064-230-1/2-DS-C

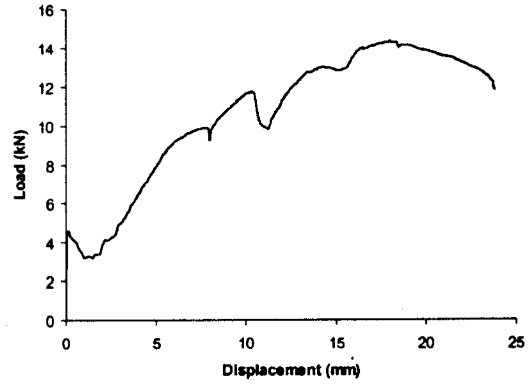


Figure B76 064-230-1/2-DS-D

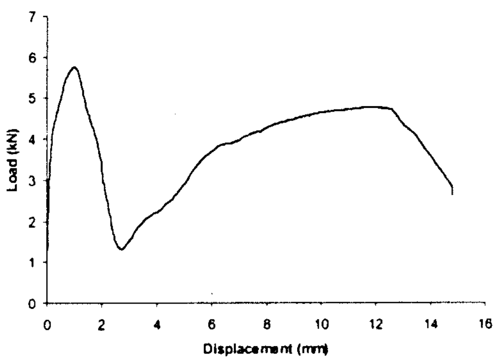


Figure B77 064-230-1/2-SS-A

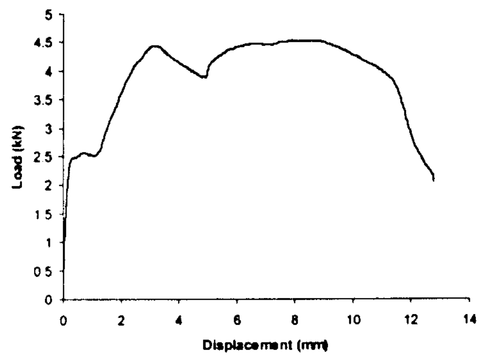


Figure B78 064-230-1/2-SS-B

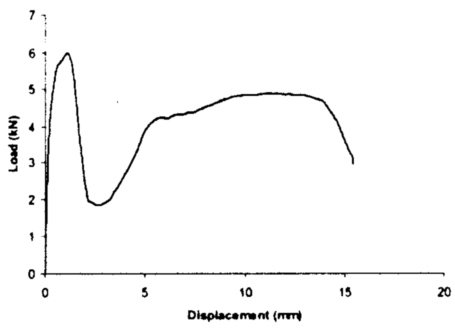


Figure B79 064-230-1/2-SS-C

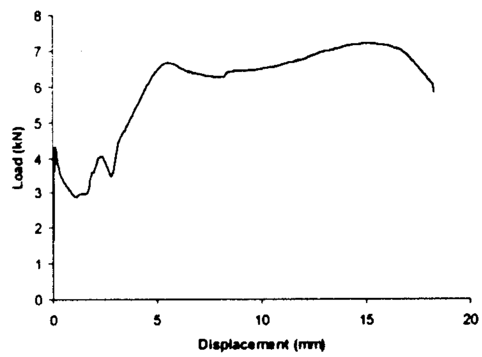


Figure B80 064-230-1/2-SS-D

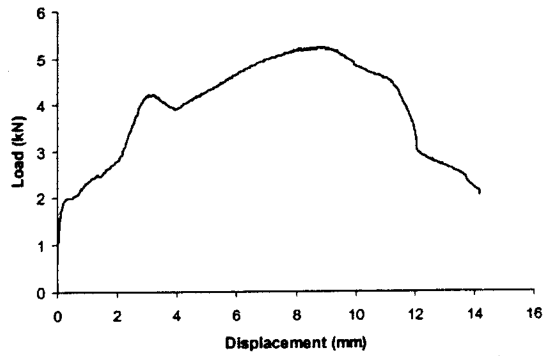


Figure B81 064-230-1/2-TTSS-A

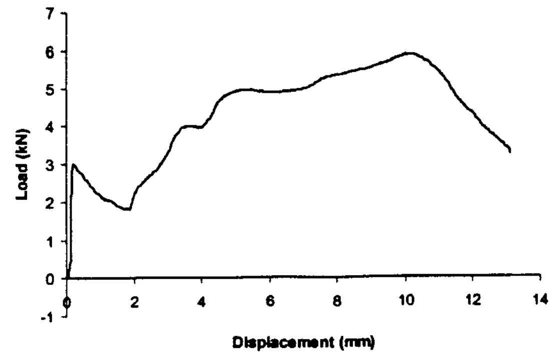


Figure B82 064-230-1/2-TTSS-B

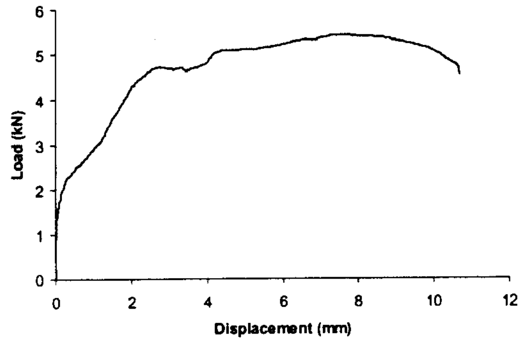


Figure B83 064-230-1/2-TTSS-C

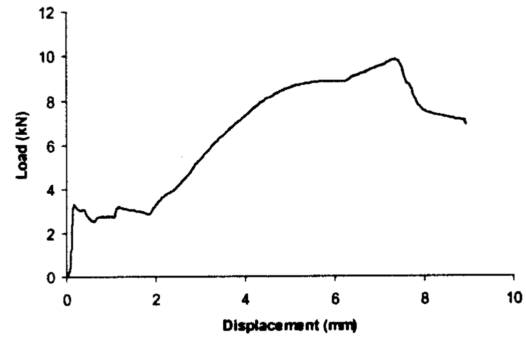


Figure B84 064-230-1/2-TTSS-D

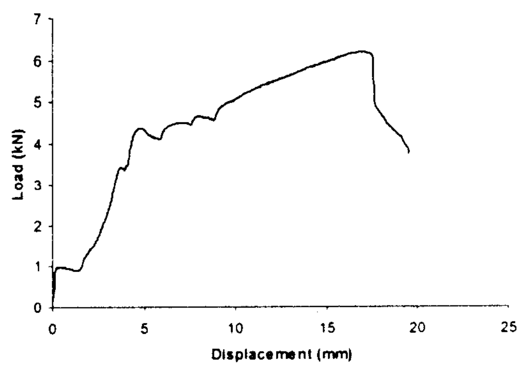


Figure B85 064-230-5/8-SS-A

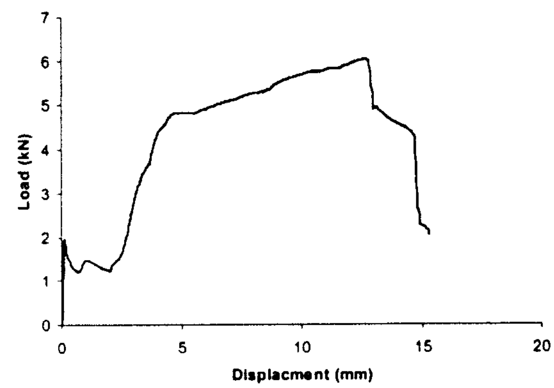


Figure B86 064-230-5/8-SS-B

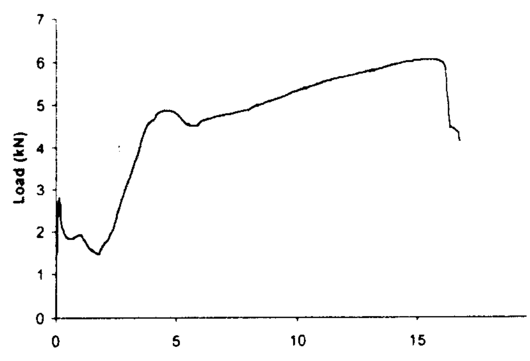


Figure B87 064-230-5/8-SS-C

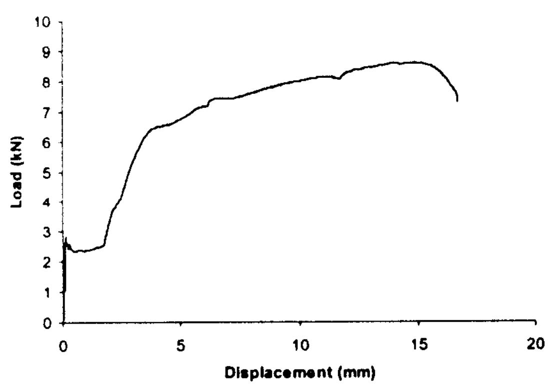


Figure B88 064-230-5/8-SS-D

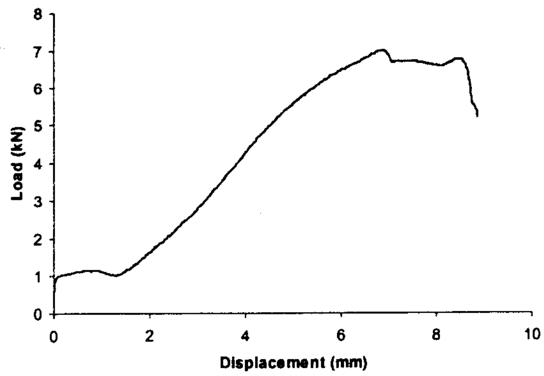


Figure B89 064-550-1/4-SS-A

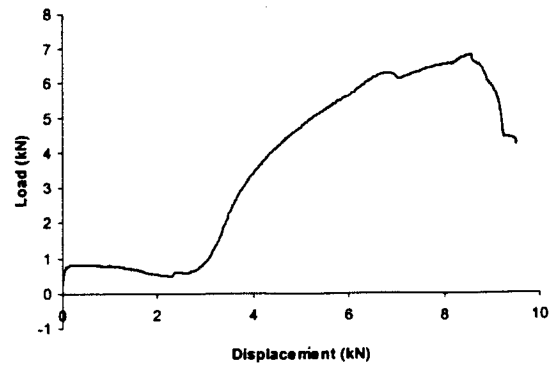


Figure B90 064-550-1/4-SS-B

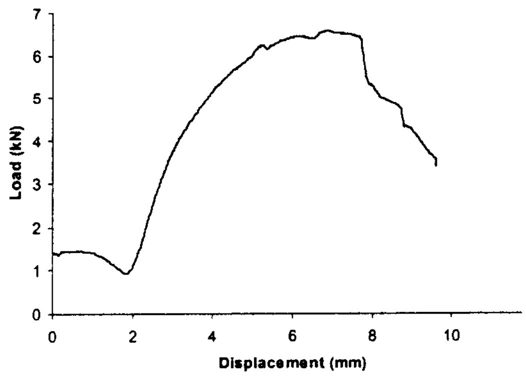


Figure B91 064-550-1/4-SS-C

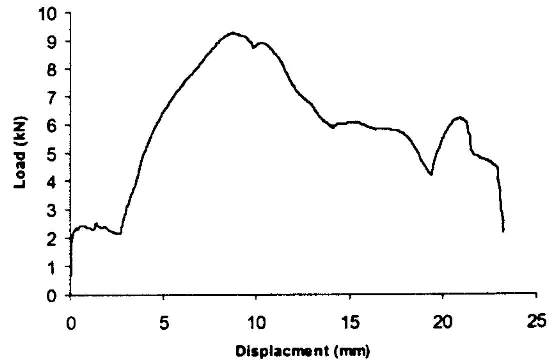


Figure B92 064-550-1/4-SS-D

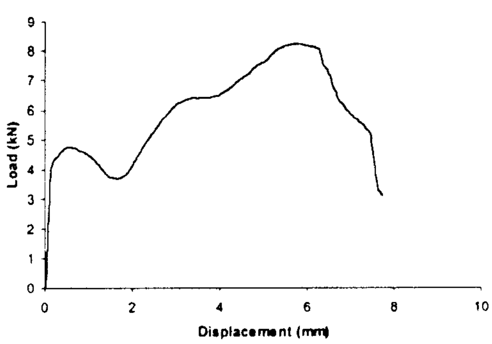


Figure B93 064-550-3/8-SS-A

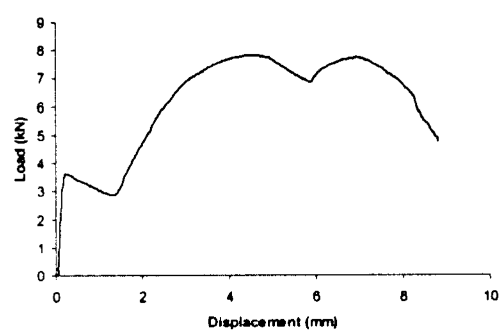


Figure B94 064-550-3/8-SS-B

Figure B95 064-550-3/8-SS-C

Figure B96 064-550-3/8-SS-D

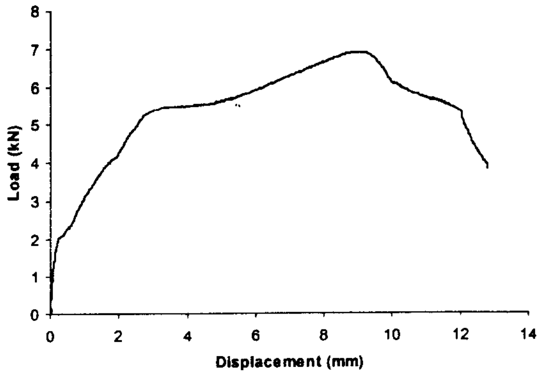


Figure B97 064-230-1/2-TTSS-A

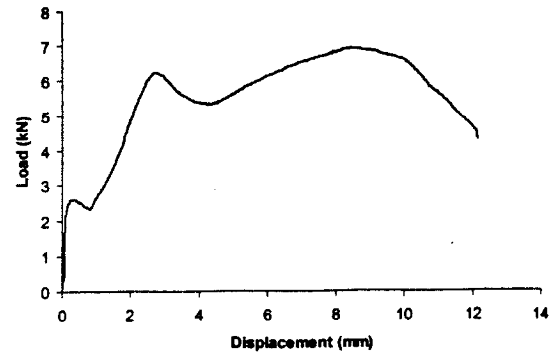


Figure B98 064-230-1/2-TTSS-B

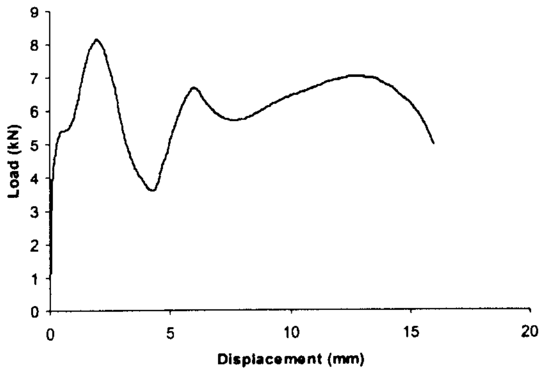


Figure B99 064-230-1/2-TTSS-C

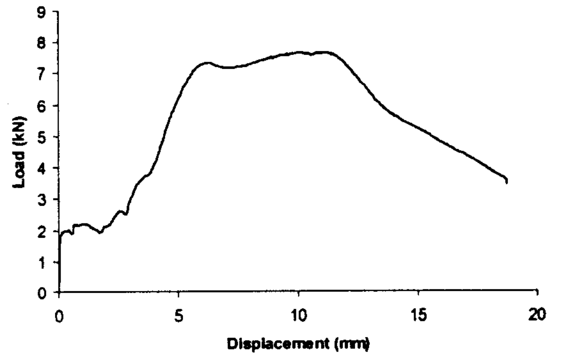


Figure B100 064-230-1/2-TTSS-D

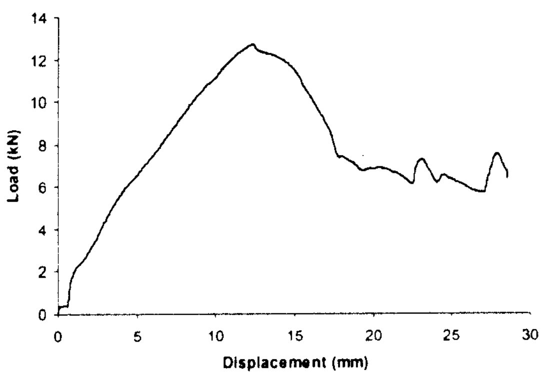


Figure B101 064-230-1/4-DS-A

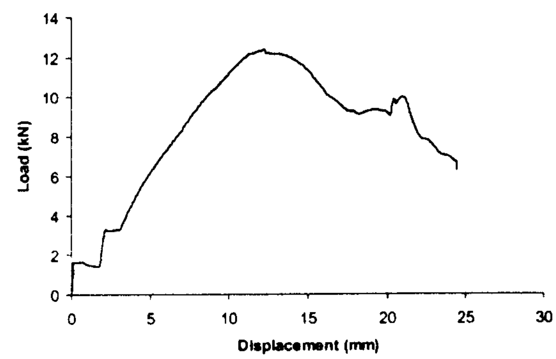


Figure B102 064-230-1/4-DS-B

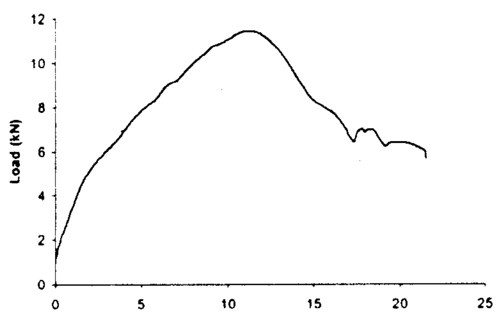


Figure B103 064-230-1/4-DS-C

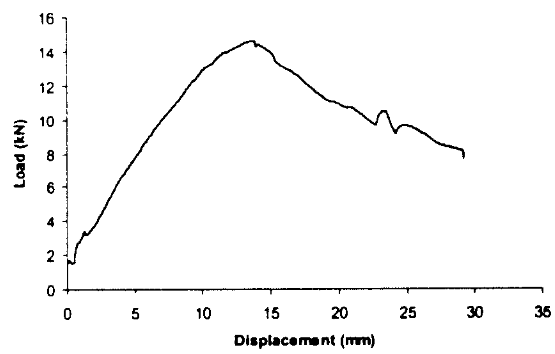


Figure B104 064-230-1/4-DS-D

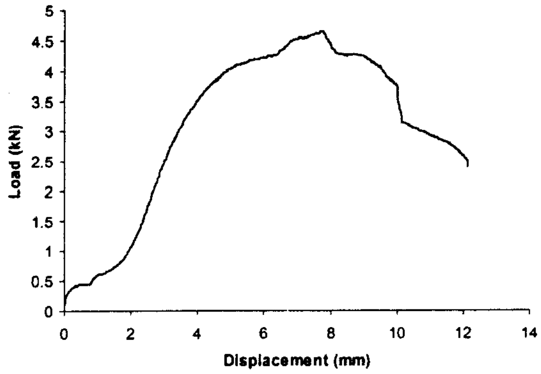


Figure B105 064-230-1/4-SS-A

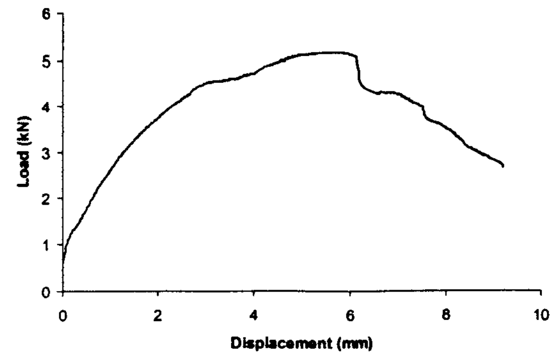


Figure B106 064-230-1/4-SS-B

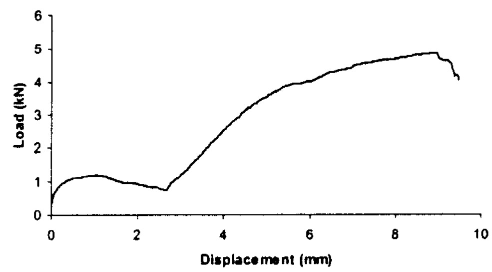


Figure B107 064-230-1/4-SS-C

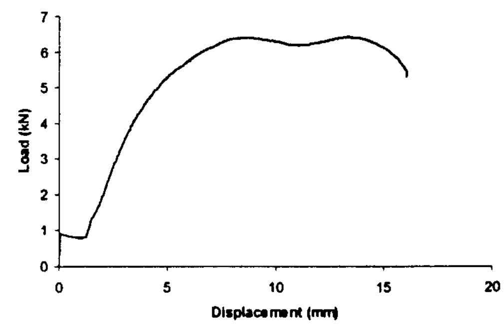


Figure B108 064-230-1/4-SS-D

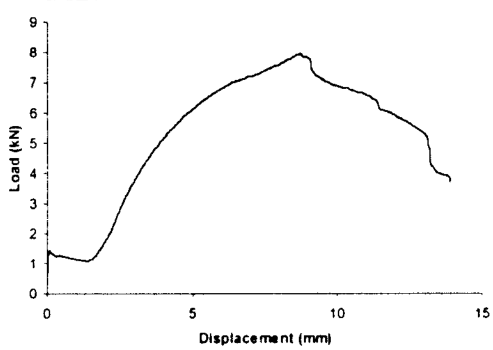


Figure B109 064-230-1/4-TTSS-A

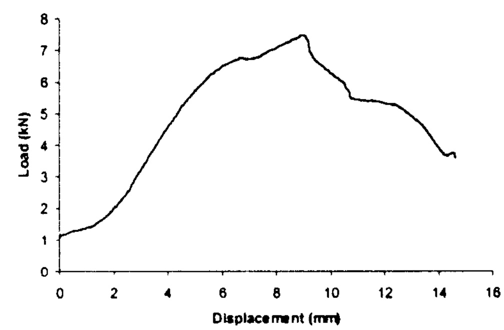


Figure B110 064-230-1/4-TTSS-B

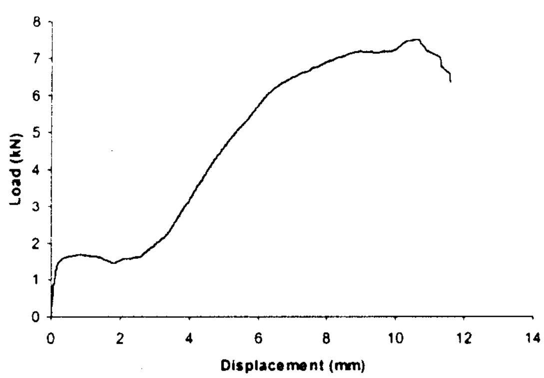


Figure B111 064-230-1/4-TTSS-C

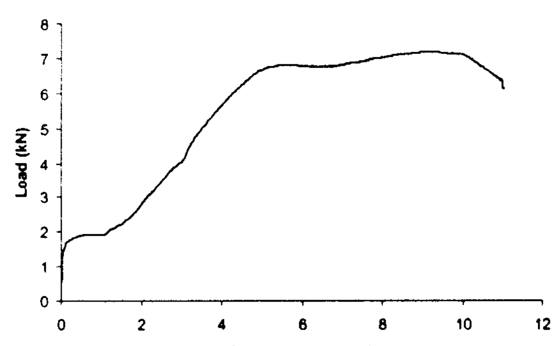


Figure B112 064-230-1/4-TTSS-D

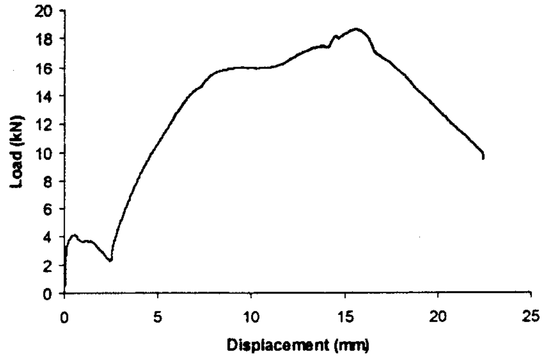


Figure B113 064-230-1/2-DS-A

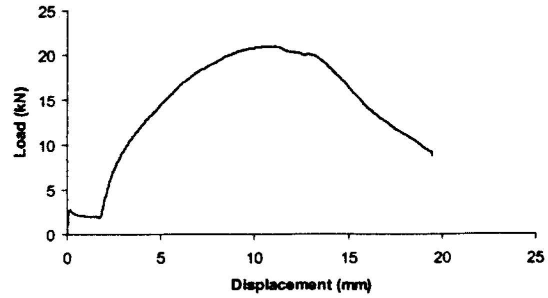


Figure B114 064-230-1/2-DS-B

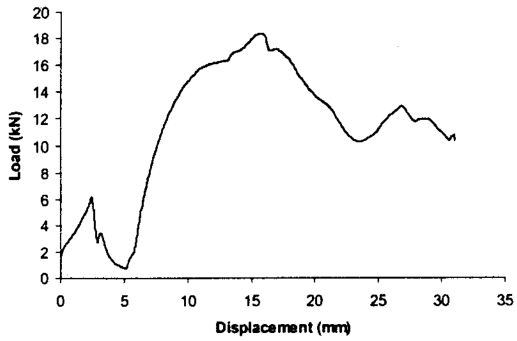


Figure B115 064-230-1/2-DS-C

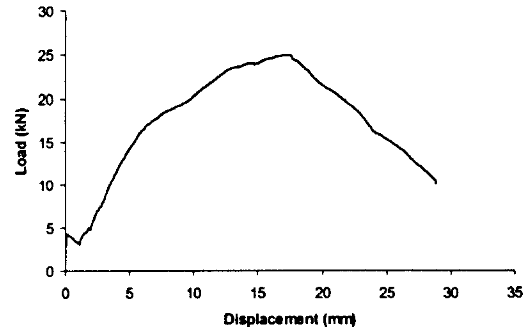


Figure B116 064-230-1/2-DS-D

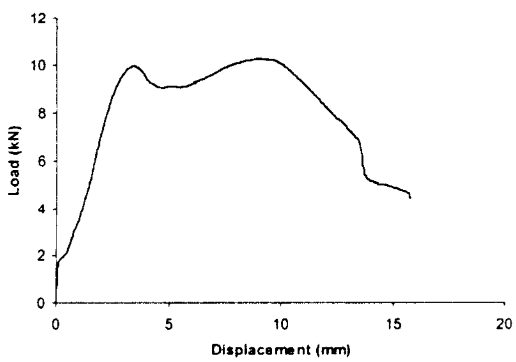


Figure B117 064-230-1/2-TTSS-A

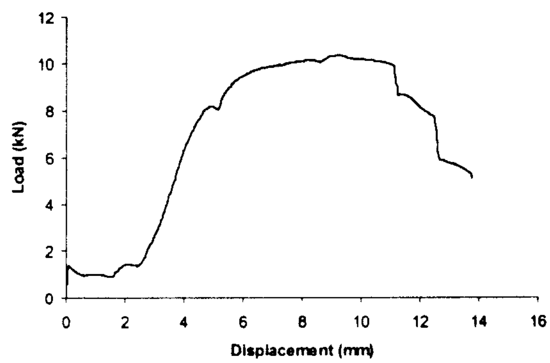


Figure B118 064-230-1/2-TTSS-B

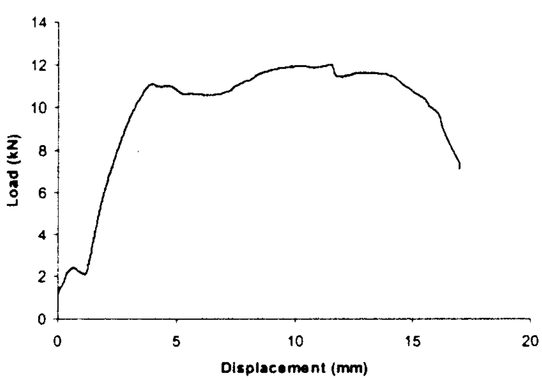


Figure B119 064-230-1/2-TTSS-C

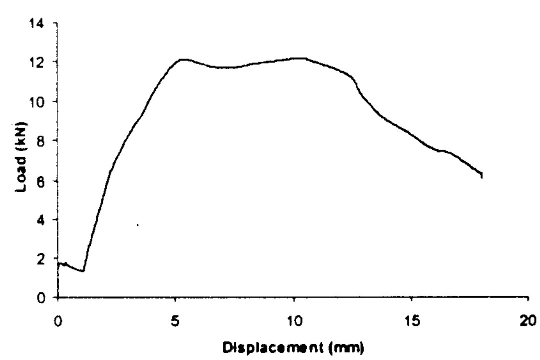


Figure B120 064-230-1/2-TTSS-D

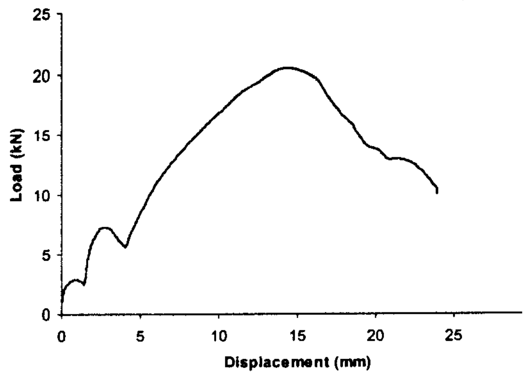


Figure B121 064-230-3/8-DS-A

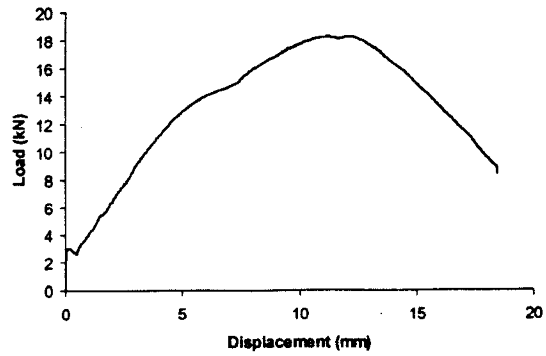


Figure B122 064-230-3/8-DS-B

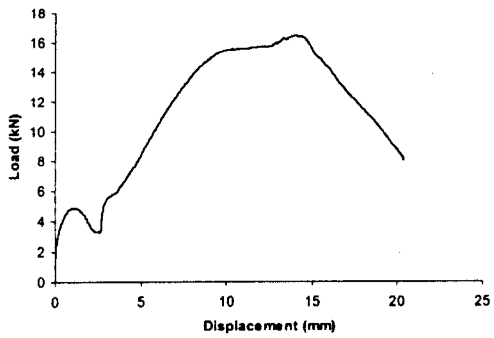


Figure B123 064-230-3/8-DS-C

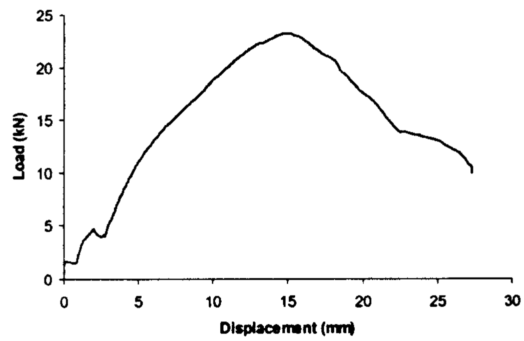


Figure B124 064-230-3/8-DS-D

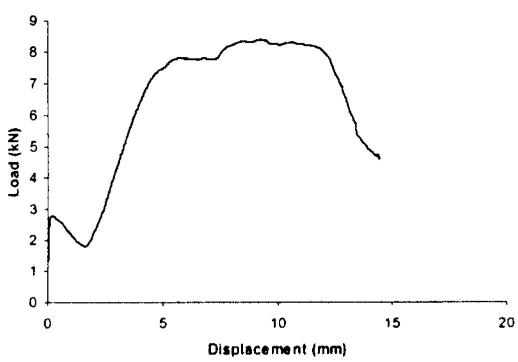


Figure B125 064-230-3/8-SS-A

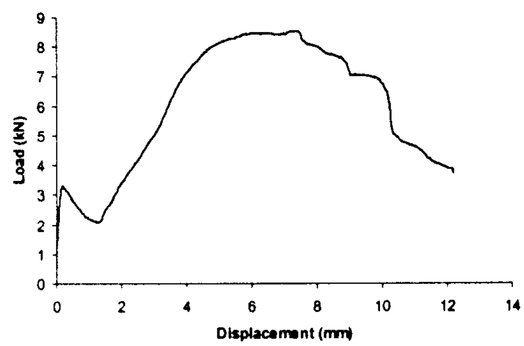


Figure B126 064-230-3/8-SS-B

Figure B127 064-230-3/8-SS-C

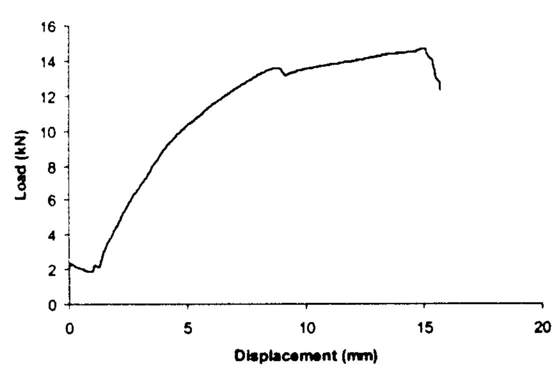


Figure B128 064-230-3/8-SS-D

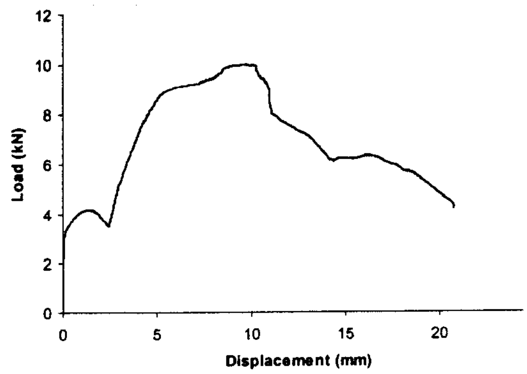


Figure B129 064-230-1/4-SS-A

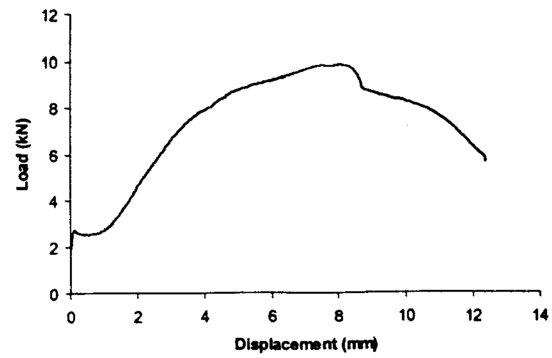


Figure B130 064-230-1/4-SS-B

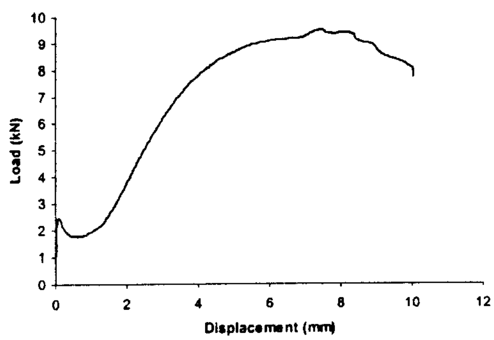


Figure B131 064-230-1/4-SS-C

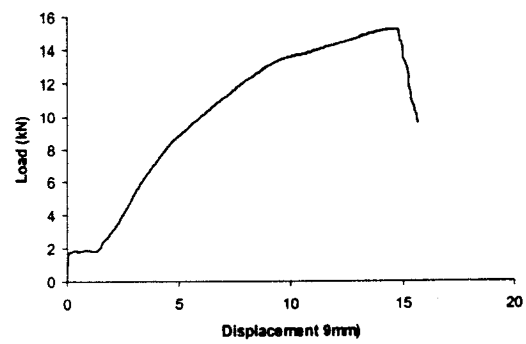


Figure B132 064-230-1/4-SS-D

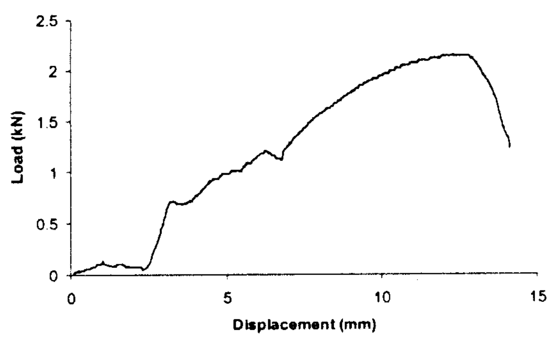


Figure B133 064-230-1/2-SS-A

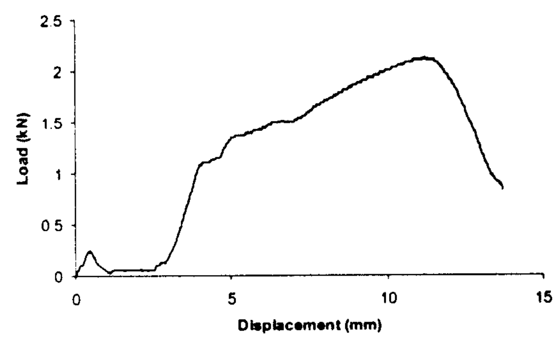


Figure B134 064-230-1/2-SS-B

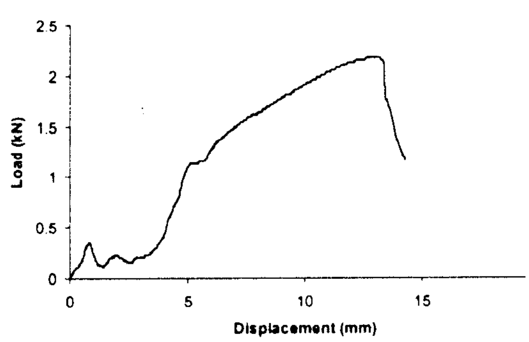


Figure B135 064-230-1/2-SS-C

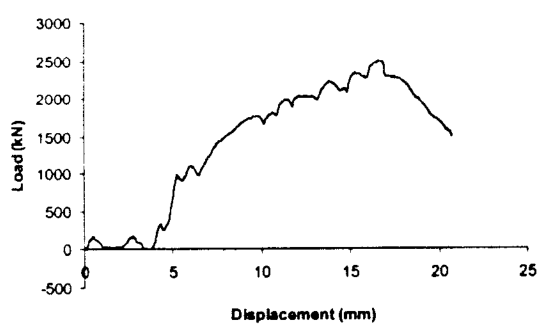


Figure B136 064-230-1/2-SS-D

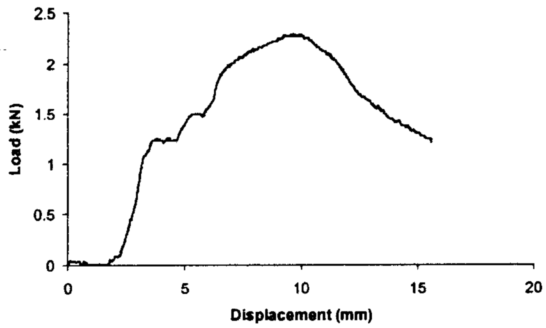


Figure B137 064-230-1/2-TTSS-A

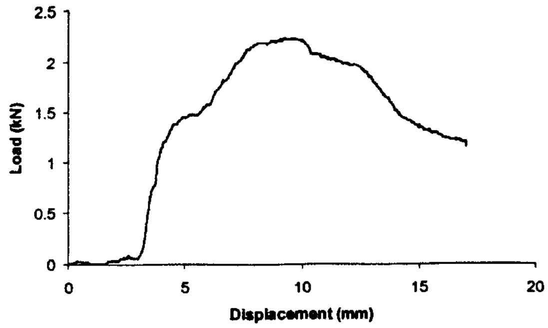


Figure B138 064-230-1/2-TTSS-B

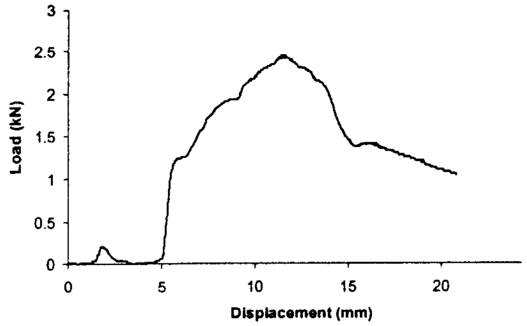


Figure B139 064-230-1/2-TTSS-C

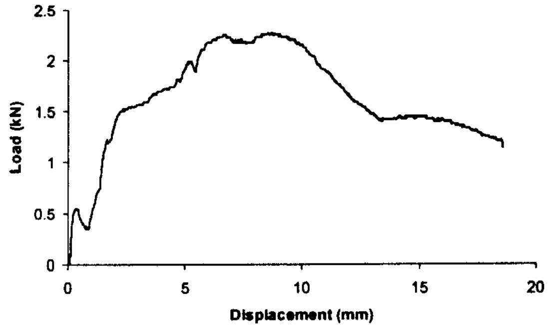


Figure B140 064-230-1/2-TTSS-D

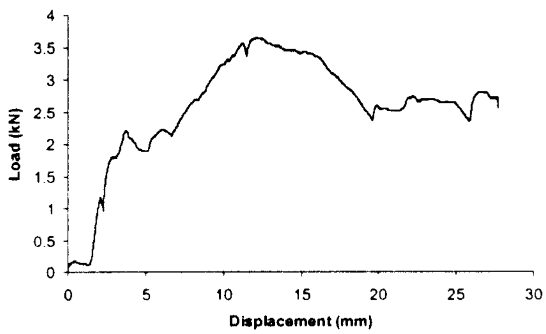


Figure B141 064-230-3/8-DS-A

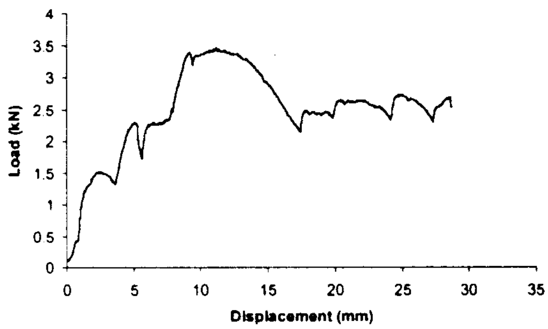


Figure B142 064-230-3/8-DS-B

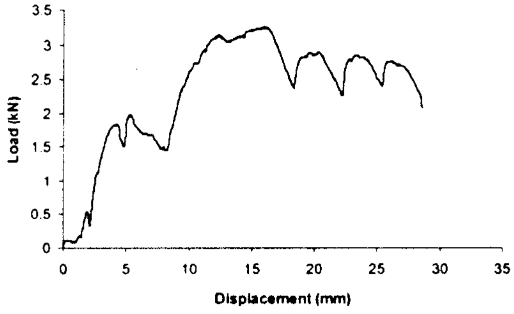


Figure B143 064-230-3/8-DS-C

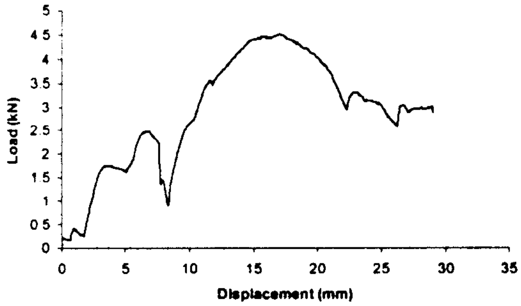


Figure B144 064-230-3/8-DS-D

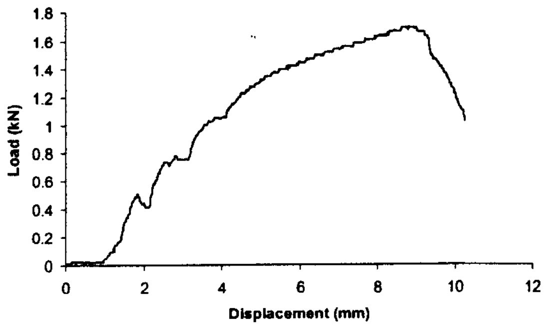


Figure B145 064-230-3/8-SS-A

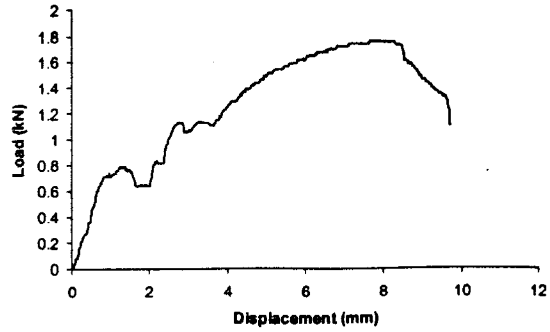


Figure B146 064-230-3/8-SS-B

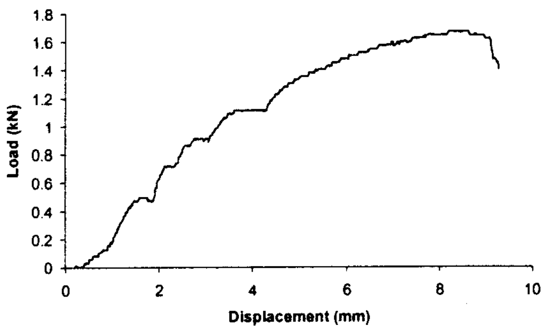


Figure B147 064-230-3/8-SS-C

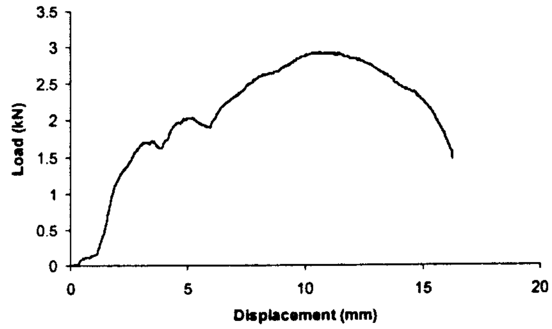


Figure B148 064-230-3/8-SS-D

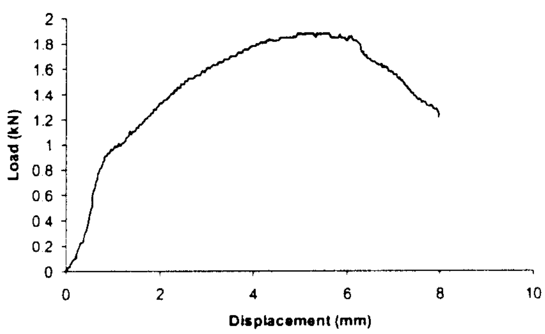


Figure B149 064-230-3/8-TTSS-A

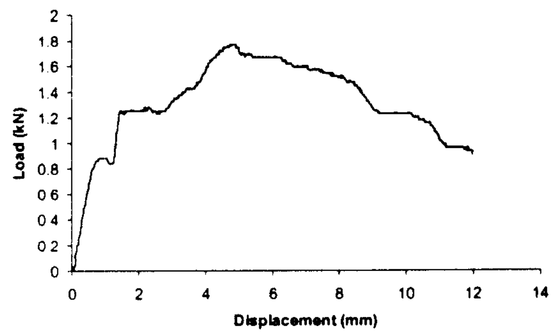


Figure B150 064-230-3/8-TTSS-B

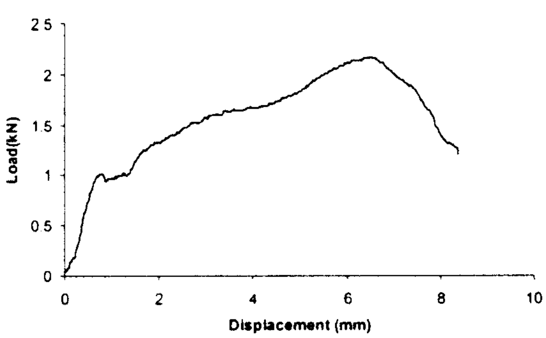


Figure B151 064-230-3/8-TTSS-C

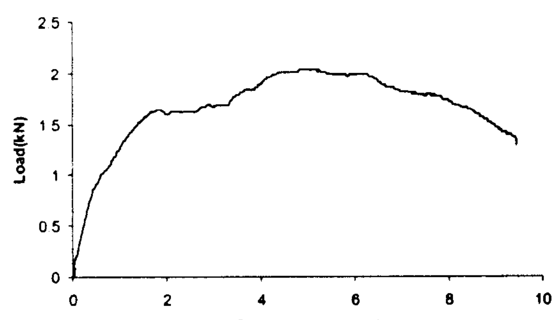


Figure B152 064-230-3/8-TTSS-D

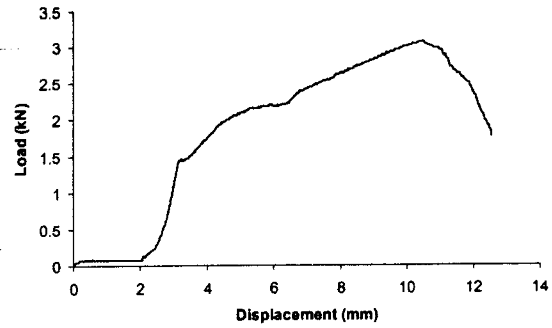


Figure B153 064-230-5/8-TTSS-A

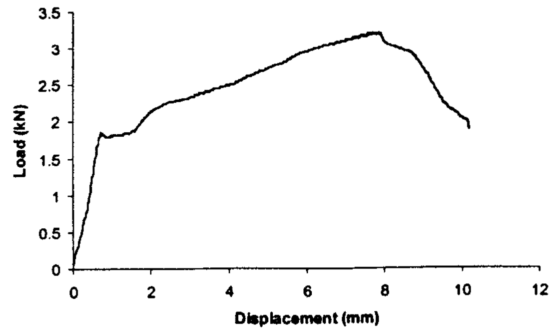


Figure B154 064-230-5/8-TTSS-B

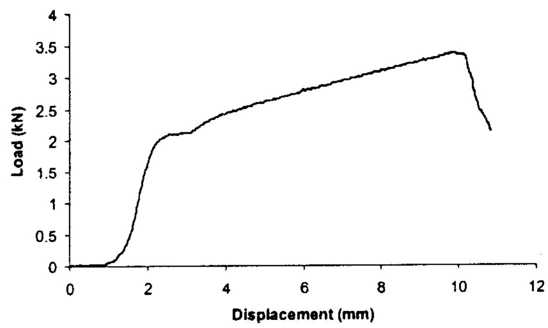


Figure B155 064-230-5/8-TTSS-C

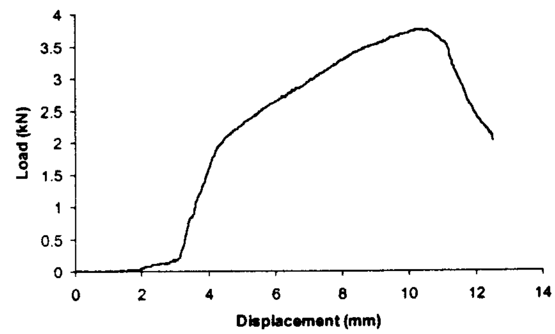


Figure B156 064-230-5/8-TTSS-D

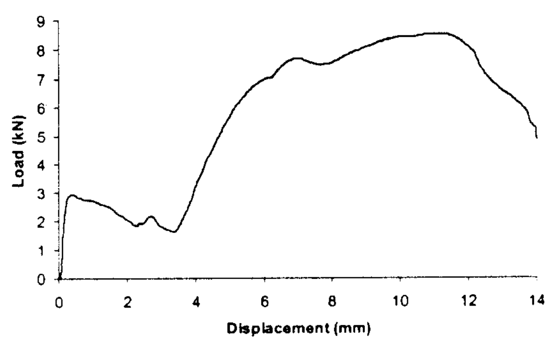


Figure B157 064-230-1/2-SS-A

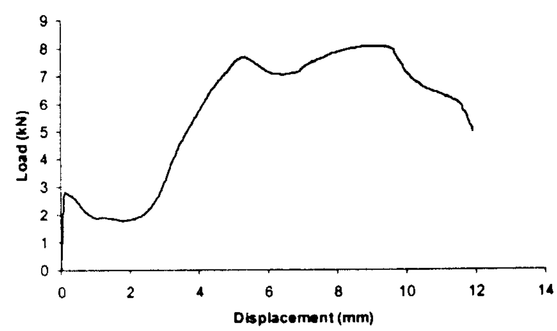


Figure B158 064-230-1/2-SS-B

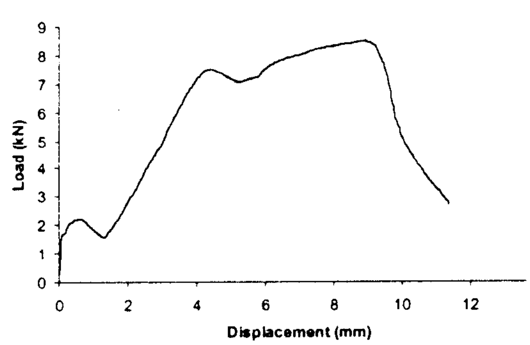


Figure B159 064-230-1/2-SS-C

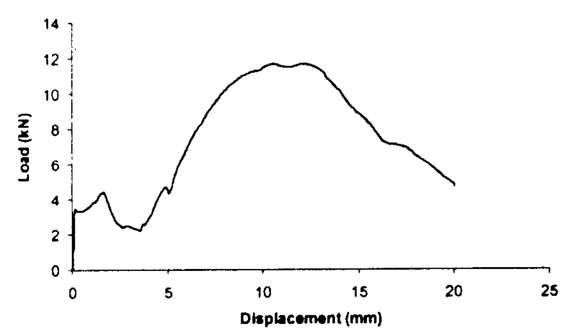


Figure B160 064-230-1/2-SS-D

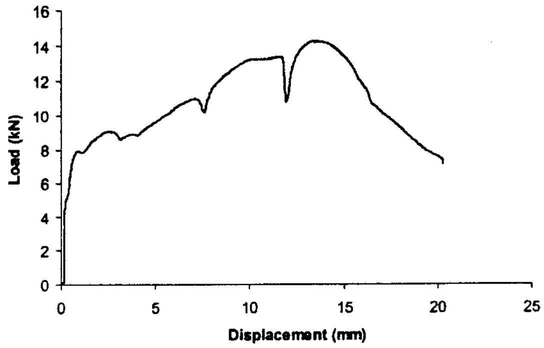


Figure B161 064-230-1/2-DS-A

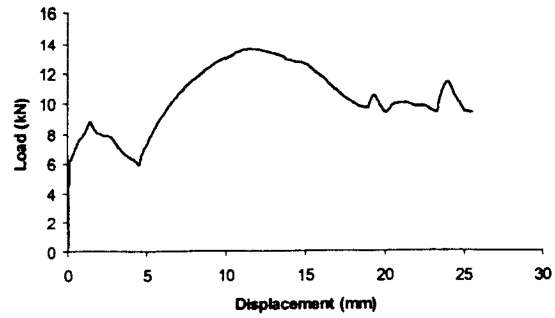


Figure B162 064-230-1/2-DS-B

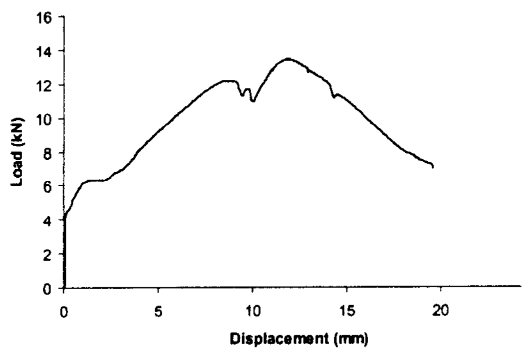


Figure B163 064-230-1/2-DS-C

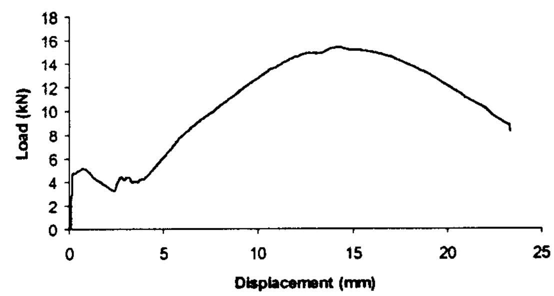


Figure B164 064-230-1/2-DS-D

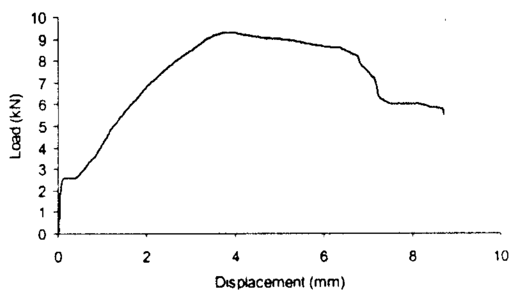


Figure B165 064-230-3/8-TTSS-A

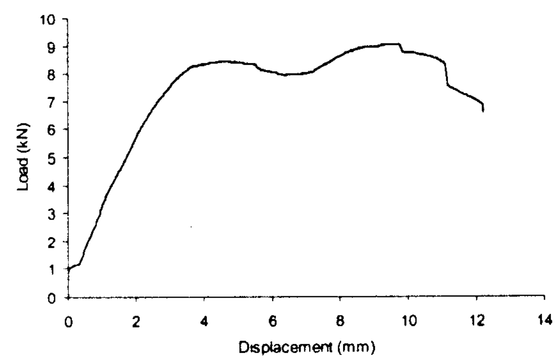


Figure B166 064-230-3/8-TTSS-B

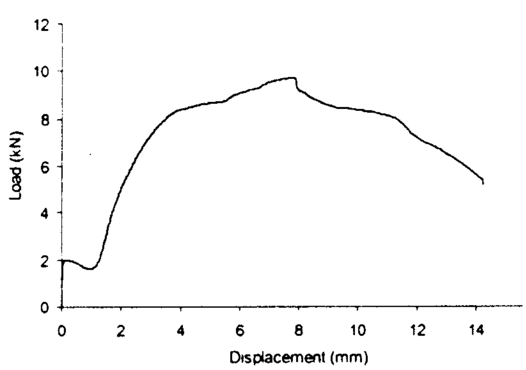


Figure B167 064-230-3/8-TTSS-C

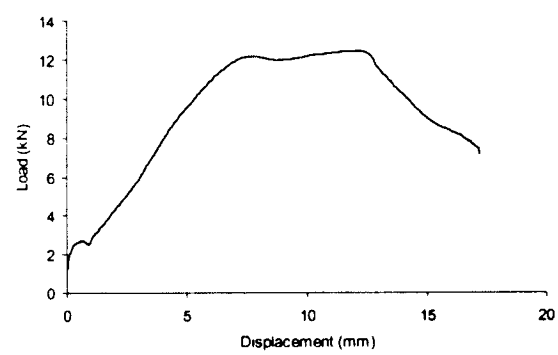


Figure B168 064-230-3/8-TTSS-D

APPENDIX C

Database of Test Results

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Carril,1994	AN32-1	3.00	3.00	253	366	No	1	1	50.9	0.00	83.0	12.7	14.3	4.24
Carril,1994	AN32-2	2.95	2.95	253	366	No	1	1	50.8	0.00	82.8	12.7	14.3	4.31
Carril,1994	AN33-1	3.00	3.00	253	366	No	1	1	50.8	0.00	102	12.7	14.3	4.24
Carril,1994	AN33-2	3.05	3.05	253	366	No	1	1	50.9	0.00	102	12.7	14.3	4.17
Carril,1994	BN33-1	3.02	3.02	253	366	No	1	2	50.9	50.8	102	12.7	14.3	4.20
Carril,1994	BN33-2	3.02	3.02	253	366	No	1	2	50.9	50.9	102	12.7	14.3	4.20
Carril,1994	DN12-2	1.09	1.09	247	385	No	1	2	50.7	0.00	82.7	12.7	14.3	11.6
Carril,1994	DN12-3	1.07	1.07	247	385	No	1	2	50.7	0.00	82.7	12.7	14.3	11.9
Carril,1994	DN22-1	1.78	1.78	221	362	No	1	2	50.8	0.00	82.8	12.7	14.3	7.14
Carril,1994	DN22-2	1.80	1.80	221	362	No	1	2	50.7	0.00	82.8	12.7	14.3	7.04
Carril,1994	BN32-1	3.00	3.00	253	366	No	1	2	50.8	50.8	82.9	12.7	14.3	4.24
Carril,1994	BN32-2	2.97	2.97	253	366	No	1	2	50.9	50.9	82.7	12.7	14.3	4.27
Carril,1994	DN32-1	3.05	3.05	253	366	No	1	2	50.8	0.00	82.9	12.7	14.3	4.17
Carril,1994	DN32-2	3.00	3.00	253	366	No	1	2	50.8	0.00	82.8	12.7	14.3	4.24
Carril,1994	EN12-1	1.09	1.09	247	385	No	1	4	50.9	50.8	82.7	12.7	14.3	11.6
Carril,1994	EN12-2	1.09	1.09	247	385	No	1	4	50.8	50.8	82.7	12.7	14.3	11.6
Carril,1994	EN22-1	1.80	1.80	221	362	No	1	4	50.9	50.7	82.8	12.7	14.3	7.04
Carril,1994	EN22-2	1.83	1.83	221	362	No	1	4	50.8	50.8	82.6	12.7	14.3	6.94
Carril,1994	EN32-1	3.00	3.00	253	366	No	1	4	50.7	50.7	82.9	12.7	14.3	4.24

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Carril,1994	EN32-2	2.97	2.97	253	366	No	1	4	50.7	50.7	82.8	12.7	14.3	4.27
Carril,1994	AN31-2	2.95	2.95	253	366	No	1	1	50.7	0.00	41.8	12.7	14.3	4.31
Carril,1994	AN31-3	2.97	2.97	253	366	No	1	1	50.7	0.00	41.5	12.7	14.3	4.27
Carril,1994	BN31-1	3.00	3.00	253	366	No	1	2	50.8	50.9	41.4	12.7	14.3	4.24
Carril,1994	BN31-2	3.00	3.00	253	366	No	1	2	50.7	50.9	41.3	12.7	14.3	4.24
Carril,1994	CN11-1	1.09	1.09	247	385	No	1	3	50.8	50.7	40.9	12.7	14.3	11.6
Carril,1994	CN11-2	1.09	1.09	247	385	No	1	3	50.9	50.7	40.9	12.7	14.3	11.6
Carril,1994	CN12-1	1.09	1.09	247	385	No	1	3	50.9	50.7	82.3	12.7	14.3	11.6
Carril,1994	CN12-2	1.09	1.09	247	385	No	1	3	50.9	50.8	82.3	12.7	14.3	11.6
Carril,1994	CN21-1	1.80	1.80	221	362	No	1	3	50.7	50.7	41.8	12.7	14.3	7.04
Carril,1994	CN21-2	1.83	1.83	221	362	No	1	3	50.7	50.7	41.7	12.7	14.3	6.94
Carril,1994	CN21-3	1.83	1.83	221	362	No	1	3	50.7	50.7	41.7	12.7	14.3	6.94
Carril,1994	CN22-1	1.80	1.80	221	362	No	1	3	50.9	50.7	82.9	12.7	14.3	7.04
Carril,1994	CN22-2	1.83	1.83	221	362	No	1	3	50.9	50.7	83.0	12.7	14.3	6.94
Carril,1994	CN22-3	1.80	1.80	221	362	No	1	3	50.9	50.7	83.0	12.7	14.3	7.04
Carril,1994	CN31-2	3.05	3.05	253	366	No	1	3	50.8	50.7	41.6	12.7	14.3	4.17
Carril,1994	CN31-3	3.07	3.07	253	366	No	1	3	50.6	50.7	41.6	12.7	14.3	4.13
Carril,1994	CN32-1	3.07	3.07	253	366	No	1	3	50.9	50.7	82.9	12.7	14.3	4.13
Carril,1994	CN32-2	3.05	3.05	253	366	No	1	3	50.9	50.7	82.7	12.7	14.3	4.17

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Carril,1994	DN31-1	3.05	3.05	253	366	No	1	2	50.8	0.00	41.4	12.7	14.3	4.17
Carril,1994	DN31-2	2.95	2.95	253	366	No	1	2	50.8	0.00	41.4	12.7	14.3	4.31
Carril,1994	EN11-1	1.12	1.12	247	385	No	1	4	50.7	50.9	41.1	12.7	14.3	11.4
Carril,1994	EN11-2	1.09	1.09	247	385	No	1	4	50.6	50.9	41.2	12.7	14.3	11.6
Carril,1994	EN21-1	1.83	1.83	221	362	No	1	4	50.7	50.8	41.5	12.7	14.3	6.94
Carril,1994	EN21-2	1.83	1.83	221	362	No	1	4	50.8	50.9	41.5	12.7	14.3	6.94
Carril,1994	EN31-1	2.97	2.97	253	366	No	1	4	50.8	50.9	41.4	12.7	14.3	4.27
Carril,1994	EN31-2	3.00	3.00	253	366	No	1	4	50.6	51.1	41.4	12.7	14.3	4.24
Carril,1994	DN11-1	1.04	1.04	247	385	No	1	2	50.8	0.00	41.2	12.7	14.3	12.2
Carril,1994	DN11-2	1.07	1.07	247	385	No	1	2	50.7	0.00	41.1	12.7	14.3	11.9
Carril,1994	DN21-1	1.83	1.83	221	362	No	1	2	50.8	0.00	41.5	12.7	14.3	6.94
Carril,1994	DN21-2	1.80	1.80	221	362	No	1	2	50.8	0.00	41.5	12.7	14.3	7.04
Chong,1975	1	0.94	0.94	369	406	No	1	1	52.3	0.00	103	12.7	14.3	13.5
Chong,1975	2	0.94	0.94	369	406	No	1	1	51.8	0.00	102	7.94	8.73	8.45
Chong,1975	3	0.94	0.94	369	406	No	1	1	52.3	0.00	105	7.94	8.73	8.45
Chong,1975	4	0.94	0.94	369	406	No	1	1	51.6	0.00	103	12.7	14.3	13.5
Chong,1975	5	0.94	0.94	369	406	No	1	1	52.6	0.00	103	12.7	14.3	13.5
Chong,1975	6	0.94	0.94	369	406	No	1	1	25.4	0.00	102	12.7	14.3	13.5
Chong,1975	7	0.94	0.94	369	406	No	1	1	38.1	0.00	102	12.7	14.3	13.5
Chong,1975	8	0.94	0.94	369	406	No	1	1	44.5	0.00	102	12.7	14:3	13.5

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Chong,1975	9	0.94	0.94	369	406	No	1	1	63.5	0.00	102	12.7	14.3	13.5
Chong,1975	11	0.94	0.94	369	406	No	1	1	63.5	0.00	102	12.7	14.3	13.5
Chong,1975	12	0.94	0.94	369	406	No	1	1	38.1	0.00	102	12.7	14.3	13.5
Chong,1975	13	0.94	0.94	369	406	No	1	1	25.4	0.00	102	12.7	14.3	13.5
Chong,1975	14	0.94	0.94	369	406	No	1	1	12.7	0.00	102	12.7	14.3	13.5
Chong,1975	15	0.94	0.94	369	406	No	1	1	12.7	0.00	102	12.7	14.3	13.5
Chong,1975	32	1.30	1.30	280	346	No	1	1	52.3	0.00	102	12.7	14.3	9.80
Chong,1975	33	1.30	1.30	280	346	No	1	1	51.1	0.00	102	12.7	14.3	9.80
Chong,1975	34	1.30	1.30	280	346	No	1	1	51.1	0.00	102	12.7	14.3	9.80
Chong,1975	41	1.55	1.55	348	511	No	1	1	13.0	0.00	102	12.7	14.3	8.20
Chong,1975	42	1.55	1.55	348	511	No	1	1	13.2	0.00	102	12.7	14.3	8.20
Chong,1975	49	1.55	1.55	348	511	No	1	1	50.8	0.00	25.7	12.7	14.3	8.20
Chong,1975	50	1.55	1.55	348	511	No	1	1	50.8	0.00	25.7	12.7	14.3	8.20
Chong,1975	51	1.55	1.55	348	511	No	1	1	50.8	0.00	25.7	12.7	14.3	8.20
Chong,1975	52	2.01	2.01	364	455	No	1	1	76.2	0.00	102	19.1	20.6	9.49
Chong,1975	53	2.01	2.01	364	455	No	1	1	76.5	0.00	102	19.1	20.6	9.49
Chong,1975	54	2.01	2.01	364	455	No	1	1	76.2	0.00	102	19.1	20.6	9.49
Chong,1975	55	2.64	2.64	409	487	No	1	1	77.0	0.00	103	19.1	20.6	7.21
Chong,1975	16(3b)	0.94	0.94	369	406	No	1	2	26.2	0.00	38.4	12.7	14.3	13.5
Chong,1975	17(3b)	0.94	0.94	369	406	No	1	2	25.4	0.00	38.9	12.7	14.3	13.5

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Chong,1975	37(3b)	1.30	1.30	280	346	No	1	2	50.0	0.00	51.3	12.7	14.3	9.80
Chong,1975	40(3b)	1.55	1.55	348	511	No	1	2	50.0	0.00	50.8	12.7	14.3	8.20
Chong,1975	56(3b)	2.64	2.64	409	487	No	1	2	76.2	0.00	51.3	19.1	20.6	7.21
Chong,1975	35(3c)	1.30	1.30	280	346	No	1	3	52.1	0.00	34.3	7.94	8.73	6.13
Chong,1975	36(3c)	1.30	1.30	280	346	No	1	3	52.6	0.00	34.3	7.94	8.73	6.13
Chong,1975	18(3d)	0.94	0.94	369	406	No	1	2	25.4	50.8	25.4	12.7	14.3	13.5
Chong,1975	19(3d)	0.94	0.94	369	406	No	1	2	25.4	50.8	25.4	12.7	14.3	13.5
Chong,1975	22(3d)	0.94	0.94	369	406	No	1	2	25.4	50.8	50.8	12.7	14.3	13.5
Chong,1975	23(3d)	0.94	0.94	369	406	No	1	2	25.4	50.8	50.8	12.7	14.3	13.5
Chong,1975	28(3d)	0.94	0.94	369	406	No	1	2	25.4	50.8	102	12.7	14.3	13.5
Chong,1975	29(3d)	0.94	0.94	369	406	No	1	2	25.4	50.8	102	12.7	14.3	13.5
Chong,1975	45(3d)	1.55	1.55	348	511	No	1	2	25.4	50.8	50.8	12.7	14.3	8.20
Chong,1975	46(3d)	1.55	1.55	348	511	No	1	2	25.4	50.8	50.8	12.7	14.3	8.20
Chong,1975	20(3e)	0.94	0.94	369	406	No	1	3	25.4	50.8	25.4	12.7	14.3	13.5
Chong,1975	21(3e)	0.94	0.94	369	406	No	1	3	25.4	50.8	25.4	12.7	14.3	13.5
Chong,1975	24(3e)	0.94	0.94	369	406	No	1	3	25.4	50.8	50.8	12.7	14.3	13.5
Chong,1975	25(3e)	0.94	0.94	369	406	No	1	3	25.4	50.8	50.8	12.7	14.3	13.5
Chong,1975	26(3e)	0.94	0.94	369	406	No	1	3	25.4	50.8	100	12.7	14.3	13.5
Chong,1975	27(3e)	0.94	0.94	369	406	No	1	3	25.4	50.8	100	12.7	14.3	13.5
Chong,1975	43(3e)	1.55	1.55	348	511	No	1	3	25.4	50.8	102	12.7	14.3	8.20

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Chong,1975	44(3e)	1.55	1.55	348	511	No	1	3	25.4	50.8	103	12.7	14.3	8.20
Chong,1975	47(3e)	1.55	1.55	348	511	No	1	3	25.4	50.8	25.4	12.7	14.3	8.20
Chong,1975	48(3e)	1.55	1.55	348	511	No	1	3	25.4	50.8	25.4	12.7	14.3	8.20
Gilchrist, 1979	1	0.52	0.52	322	353	No	1	1	25.4	0.00	102	6.35	7.14	12.3
Gilchrist, 1979	2	0.52	0.52	322	353	No	1	1	19.1	0.00	102	6.35	7.14	12.3
Gilchrist, 1979	3	0.52	0.52	322	353	No	1	1	15.2	0.00	102	6.35	7.14	12.3
Gilchrist, 1979	4	0.52	0.52	322	353	No	1	1	38.1	0.00	102	9.53	10.3	18.4
Gilchrist, 1979	5	0.52	0.52	322	353	No	1	1	25.4	0.00	102	9.53	10.3	18.4
Gilchrist, 1979	6	0.52	0.52	322	353	No	1	1	19.1	0.00	102	9.53	10.3	18.4
Gilchrist, 1979	7	0.61	0.61	390	412	No	1	1	25.4	0.00	102	6.35	7.14	10.3
Gilchrist, 1979	8	0.61	0.61	390	412	No	1	1	19.1	0.00	102	6.35	7.14	10.3
Gilchrist, 1979	9	0.61	0.61	390	412	No	1	1	15.2	0.00	102	6.35	7.14	10.3
Gilchrist, 1979	10	0.61	0.61	390	412	No	1	1	38.1	0.00	102	9.53	10.3	15.5
Gilchrist, 1979	11	0.61	0.61	390	412	No	1	1	25.4	0.00	102	9.53	10.3	15.5
Gilchrist, 1979	12	0.61	0.61	390	412	No	1	1	19.1	0.00	102	9.53	10.3	15.5
Gilchrist, 1979	13	0.69	0.69	353	375	No	1	1	25.4	0.00	102	6.35	7.14	9.16
Gilchrist, 1979	14	0.69	0.69	353	375	No	1	1	19.1	0.00	102	6.35	7.14	9.16
Gilchrist, 1979	15	0.69	0.69	353	375	No	1	1	15.2	0.00	102	6.35	7.14	9.16
Gilchrist, 1979	16	0.69	0.69	353	375	No	1	1	38.1	0.00	102	9.53	10.3	13.7
Gilchrist, 1979	17	0.69	0.69	353	375	No	1	1	25.4	0.00	102	9.53	10.3	13.7

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Gilchrist, 1979	18	0.69	0.69	353	375	No	1	1	19.1	0.00	102	9.53	10.3	13.7
Gilchrist, 1979	19	0.69	0.69	353	375	No	1	1	50.8	0.00	102	12.7	14.3	18.3
Gilchrist, 1979	20	0.69	0.69	353	375	No	1	1	38.1	0.00	102	12.7	14.3	18.3
Gilchrist, 1979	21	0.69	0.69	353	375	No	1	1	25.4	0.00	102	12.7	14.3	18.3
Gilchrist, 1979	22	0.69	0.69	282	350	No	1	1	25.4	0.00	102	6.35	7.14	9.16
Gilchrist, 1979	23	0.69	0.69	282	350	No	1	1	19.1	0.00	102	6.35	7.14	9.16
Gilchrist, 1979	24	0.69	0.69	282	350	No	1	1	15.2	0.00	102	6.35	7.14	9.16
Gilchrist, 1979	25	0.69	0.69	282	350	No	1	1	38.1	0.00	102	9.53	10.3	13.7
Gilchrist, 1979	26	0.69	0.69	282	350	No	1	1	25.4	0.00	102	9.53	10.3	13.7
Gilchrist, 1979	27	0.69	0.69	282	350	No	1	1	19.1	0.00	102	9.53	10.3	13.7
Gilchrist, 1979	28	0.69	0.69	282	350	No	1	1	50.8	0.00	102	12.7	14.3	18.3
Gilchrist, 1979	29	0.69	0.69	282	350	No	1	1	38.1	0.00	102	12.7	14.3	18.3
Gilchrist, 1979	30	0.69	0.69	282	350	No	1	1	25.4	0.00	102	12.7	14.3	18.3
Wallace,2000	1-wo-50	0.64	1.38	350	382	No	2	1	50.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	2-wo-50	0.64	1.38	350	382	No	2	1	50.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	3-wo-50	0.64	1.38	350	382	No	2	1	50.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	1-wo-40	0.64	1.38	350	382	No	2	1	40.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	2-wo-40	0.64	1.38	350	382	No	2	1	40.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	3-wo-40	0.64	1.38	350	382	No	2	1	40.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	1-wo-30	0.64	1.38	350	382	No	2	1	30.0	0.00	50.0	6.35	7.94	9.92

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Wallace,2000	2-wo-30	0.64	1.38	350	382	No	2	1	30.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	3-wo-30	0.64	1.38	350	382	No	2	1	30.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	1-wo-20	0.64	1.38	350	382	No	2	1	20.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	2-wo-20	0.64	1.38	350	382	No	2	1	20.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	3-wo-20	0.64	1.38	350	382	No	2	1	20.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	1-wo-20-t5	0.64	1.38	350	382	No	2	1	20.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	2-wo-20-t5	0.64	1.38	350	382	No	2	1	20.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	3-wo-20-t5	0.64	1.38	350	382	No	2	1	20.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	1-wo-20-t15	0.64	1.38	350	382	No	2	1	20.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	2-wo-20-t15	0.64	1.38	350	382	No	2	1	20.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	3-wo-20-t15	0.64	1.38	350	382	No	2	1	20.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	1-wo-30-50	0.64	1.38	350	382	No	2	2	30.0	50.0	50.0	6.35	7.94	9.92
Wallace,2000	2-wo-30-50	0.64	1.38	350	382	No	2	2	30.0	50.0	50.0	6.35	7.94	9.92
Wallace,2000	3-wo-30-50	0.64	1.38	350	382	No	2	2	30.0	50.0	50.0	6.35	7.94	9.92
Wallace,2000	1-wo-30-40	0.64	1.38	350	382	No	2	2	30.0	40.0	50.0	6.35	7.94	9.92
Wallace,2000	2-wo-30-40	0.64	1.38	350	382	No	2	2	30.0	40.0	50.0	6.35	7.94	9.92
Wallace,2000	3-wo-30-40	0.64	1.38	350	382	No	2	2	30.0	40.0	50.0	6.35	7.94	9.92
Wallace,2000	1-wo-30-30	0.64	1.38	350	382	No	2	2	30.0	30.0	50.0	6.35	7.94	9.92
Wallace,2000	2-wo-30-30	0.64	1.38	350	382	No	2	2	30.0	30.0	50.0	6.35	7.94	9.92
Wallace,2000	3-wo-30-30	0.64	1.38	350	382	No	2	2	30.0	30.0	50.0	6.35	7.94	9.92

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Wallace,2000	1-wo-40-3/8	0.64	1.38	350	382	No	2	1	40.0	0.00	50.0	9.53	11.1	14.9
Wallace,2000	2-wo-40-3/8	0.64	1.38	350	382	No	2	1	40.0	0.00	50.0	9.53	11.1	14.9
Wallace,2000	3-wo-40-3/8	0.64	1.38	350	382	No	2	1	40.0	0.00	50.0	9.53	11.1	14.9
Wallace,2000	1-wo-30-5/16	0.64	1.38	350	382	No	2	1	30.0	0.00	50.0	7.94	9.53	12.4
Wallace,2000	2-wo-30-5/16	0.64	1.38	350	382	No	2	1	30.0	0.00	50.0	7.94	9.53	12.4
Wallace,2000	3-wo-30-5/16	0.64	1.38	350	382	No	2	1	30.0	0.00	50.0	7.94	9.53	12.4
Wallace,2000	1-wo-50-1/2	0.64	1.38	350	382	No	2	1	50.0	0.00	50.0	12.7	14.3	19.8
Wallace,2000	2-wo-50-1/2	0.64	1.38	350	382	No	2	1	50.0	0.00	50.0	12.7	14.3	19.8
Wallace,2000	3-wo-50-1/2	0.64	1.38	350	382	No	2	1	50.0	0.00	50.0	12.7	14.3	19.8
Wallace,2000	1-wo-50-5/8	0.64	1.38	350	382	No	2	1	50.0	0.00	50.0	15.9	17.5	24.8
Wallace,2000	2-wo-50-5/8	0.64	1.38	350	382	No	2	1	50.0	0.00	50.0	15.9	17.5	24.8
Wallace,2000	3-wo-50-5/8	0.64	1.38	350	382	No	2	1	50.0	0.00	50.0	15.9	17.5	24.8
Wallace,2000	1-wo-ss-5/16	0.64	0.64	350	382	No	1	1	30.0	0.00	50.0	7.94	9.53	12.4
Wallace,2000	2-wo-ss-5/16	0.64	0.64	350	382	No	1	1	30.0	0.00	50.0	7.94	9.53	12.4
Wallace,2000	3-wo-ss-5/16	0.64	0.64	350	382	No	1	1	30.0	0.00	50.0	7.94	9.53	12.4
Wallace,2000	1-wo-sst-5/16	1.38	1.38	356	361	No	1	1	30.0	0.00	50.0	7.94	9.53	5.75
Wallace,2000	2-wo-sst-5/16	1.38	1.38	356	361	No	1	1	30.0	0.00	50.0	7.94	9.53	5.75
Wallace,2000	3-wo-sst-5/16	1.38	1.38	356	361	No	1	1	30.0	0.00	50.0	7.94	9.53	5.75
Wallace,2000	1-wo-sst-1/4	1.38	1.38	356	361	No	1	1	30.0	0.00	50.0	6.35	7.94	4.60
Wallace,2000	2-wo-sst-1/4	1.38	1.38	356	361	No	1	1	30.0	0.00	50.0	6.35	7.94	4.60

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Wallace,2000	3-wo-sst-1/4	1.38	1.38	356	361	No	1	1	30.0	0.00	50.0	6.35	7.94	4.60
Wallace,2000	1-wo-mix-1/4	0.64	1.38	350	382	No	1	1	30.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	2-wo-mix-1/4	0.64	1.38	350	382	No	1	1	30.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	3-wo-mix-1/4	0.64	1.38	350	382	No	1	1	30.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	1-wo-ss-1/4	0.64	0.64	350	382	No	1	1	30.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	2-wo-ss-1/4	0.64	0.64	350	382	No	1	1	30.0	0.00	50.0	6.35	7.94	9.92
Wallace,2000	1-wo-ss-1/2	0.64	0.64	350	382	No	1	1	30.0	0.00	50.0	12.7	14.3	19.8
Wallace,2000	2-wo-ss-1/2	0.64	0.64	350	382	No	1	1	30.0	0.00	50.0	12.7	14.3	19.8
Wallace,2000	3-wo-ss-1/2	0.64	0.64	350	382	No	1	1	30.0	0.00	50.0	12.7	14.3	19.8
Wallace,2000	1-wo-ss-5/8	0.64	0.64	350	382	No	1	1	30.0	0.00	50.0	15.9	17.5	24.8
Wallace,2000	2-wo-ss-5/8	0.64	0.64	350	382	No	1	1	30.0	0.00	50.0	15.9	17.5	24.8
Wallace,2000	3-wo-ss-5/8	0.64	0.64	350	382	No	1	1	30.0	0.00	50.0	15.9	17.5	24.8
Yu,1978	B-0-12-1-0-SS	0.36	0.36	269	324	No	1	1	13.9	0.00	50.0	6.35	7.14	17.9
Yu,1978	B-0-12-2-0-SS	0.36	0.36	269	324	No	1	1	13.9	0.00	50.0	6.35	7.14	17.9
Yu,1978	B-0-12-3-L-SS	0.36	0.36	269	324	No	1	1	14.3	0.00	50.0	6.35	7.14	17.9
Yu,1978	B-0-12-4-L-SS	0.36	0.36	269	324	No	1	1	14.3	0.00	50.0	6.35	7.14	17.9
Yu,1978	B-0-12-5-0-SS	0.36	0.36	269	324	No	1	1	13.9	0.00	50.0	6.35	7.14	17.9
Yu,1978	B-0-12-6-0-SS	0.36	0.36	269	324	No	1	1	14.3	0.00	50.0	6.35	7.14	17.9
Yu,1978	B-0-12-7-L-SS	0.36	0.36	269	324	No	1	1	13.9	0.00	50.0	6.35	7.14	17.9
Yu,1978	B-0-12-8-L-SS	0.36	0.36	269	324	No	1	1	14.1	0.00	48.8	6.35	7.14	17.9

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Yu,1978	B-0-12-9-H-SS	0.36	0.36	269	324	No	1	1	14.1	0.00	49.3	6.35	7.14	17.9
Yu,1978	B-0-12-10-H-SS	0.36	0.36	269	324	No	1	1	14.3	0.00	50.0	6.35	7.14	17.9
Yu,1978	B-0-14-1-0-DS	0.36	0.36	269	324	No	2	1	22.2	0.00	82.6	6.35	7.14	17.9
Yu,1978	B-0-14-2-0-DS	0.36	0.36	269	324	No	2	1	22.2	0.00	82.6	6.35	7.14	17.9
Yu,1978	B-0-14-3-L-DS	0.36	0.36	269	324	No	2	1	22.2	0.00	82.6	6.35	7.14	17.9
Yu,1978	B-0-14-4-L-DS	0.36	0.36	269	324	No	2	1	22.2	0.00	82.6	6.35	7.14	17.9
Yu,1978	B-0-14-5-0-DS	0.36	0.36	269	324	No	2	1	22.2	0.00	82.6	6.35	7.14	17.9
Yu,1978	B-0-14-6-0-DS	0.36	0.36	269	324	No	2	1	22.2	0.00	82.6	6.35	7.14	17.9
Yu,1978	B-0-14-7-L-DS	0.36	0.36	269	324	No	2	1	22.2	0.00	82.6	6.35	7.14	17.9
Yu,1978	B-0-14-8-L-DS	0.36	0.36	269	324	No	2	1	22.2	0.00	82.6	6.35	7.14	17.9
Yu,1978	B-0-14-9-H-DS	0.36	0.36	269	324	No	2	1	22.2	0.00	82.6	6.35	7.14	17.9
Yu,1978	B-0-14-10-H-DS	0.36	0.36	269	324	No	2	1	22.2	0.00	82.6	6.35	7.14	17.9
Yu,1978	B-0-17-1-0-SS	0.91	0.91	273	337	No	1	1	14.3	0.00	50.0	6.35	7.14	6.94
Yu,1978	B-0-17-2-0-SS	0.91	0.91	273	337	No	1	1	14.3	0.00	50.0	6.35	7.14	6.94
Yu,1978	B-0-17-3-L-SS	0.91	0.91	273	337	No	1	1	14.3	0.00	50.8	6.35	7.14	6.94
Yu,1978	B-0-17-4-L-SS	0.91	0.91	273	337	No	1	1	14.3	0.00	50.0	6.35	7.14	6.94
Yu,1978	B-0-17-5-0-SS	0.91	0.91	273	337	No	1	1	14.3	0.00	50.0	6.35	7.14	6.94
Yu,1978	B-0-17-6-0-SS	0.91	0.91	273	337	No	1	1	13.9	0.00	50.0	6.35	7.14	6.94
Yu,1978	B-0-17-7-L-SS	0.91	0.91	273	337	No	1	1	14.3	0.00	50.0	6.35	7.14	6.94
Yu,1978	B-0-17-8-L-SS	0.91	0.91	273	337	No	1	1	14.3	0.00	50.0	6.35	7.14	6.94

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Yu,1978	B-0-17-9-H-SS	0.91	0.91	273	337	No	1	1	14.3	0.00	50.8	6.35	7.14	6.94
Yu,1978	B-0-17-10-H-SS	0.91	0.91	273	337	No	1	1	14.0	0.00	50.0	6.35	7.14	6.94
Yu,1978	B-0-18-1-0-SS	0.91	0.91	273	337	No	1	1	27.8	0.00	76.2	12.7	14.3	13.9
Yu,1978	B-0-18-2-0-SS	0.91	0.91	273	337	No	1	1	27.9	0.00	76.2	12.7	14.3	13.9
Yu,1978	B-0-18-3-L-SS	0.91	0.91	273	337	No	1	1	27.9	0.00	76.2	12.7	14.3	13.9
Yu,1978	B-0-18-4-L-SS	0.91	0.91	273	337	No	1	1	27.9	0.00	76.2	12.7	14.3	13.9
Yu,1978	B-0-18-5-0-SS	0.91	0.91	273	337	No	1	1	27.9	0.00	76.2	12.7	14.3	13.9
Yu,1978	B-0-18-6-0-SS	0.91	0.91	273	337	No	1	1	27.9	0.00	76.2	12.7	14.3	13.9
Yu,1978	B-0-18-7-L-SS	0.91	0.91	273	337	No	1	1	27.9	0.00	76.2	12.7	14.3	13.9
Yu,1978	B-0-18-8-L-SS	0.91	0.91	273	337	No	1	1	28.6	0.00	76.2	12.7	14.3	13.9
Yu,1978	B-0-18-9-H-SS	0.91	0.91	273	337	No	1	1	27.9	0.00	76.2	12.7	14.3	13.9
Yu,1978	B-0-18-10-H-SS	0.91	0.91	273	337	No	1	1	27.9	0.00	76.2	12.7	14.3	13.9
Yu,1978	B-0-21-1-0-DS	0.91	0.91	273	337	No	2	1	21.4	0.00	82.6	6.35	7.14	6.94
Yu,1978	B-0-21-2-0-DS	0.91	0.91	273	337	No	2	1	22.2	0.00	82.6	6.35	7.14	6.94
Yu,1978	B-0-21-3-L-DS	0.91	0.91	273	337	No	2	1	22.6	0.00	82.6	6.35	7.14	6.94
Yu,1978	B-0-21-4-L-DS	0.91	0.91	273	337	No	2	1	22.2	0.00	82.6	6.35	7.14	6.94
Yu,1978	B-0-21-5-0-DS	0.91	0.91	273	337	No	2	1	22.2	0.00	82.6	6.35	7.14	6.94
Yu,1978	B-0-21-6-0-DS	0.91	0.91	273	337	No	2	1	23.0	0.00	82.6	6.35	7.14	6.94
Yu,1978	B-0-21-7-L-DS	0.91	0.91	273	337	No	2	1	22.2	0.00	82.6	6.35	7.14	6.94
Yu,1978	B-0-21-8-L-DS	0.91	0.91	273	337	No	2	1	22.2	0.00	82.6	6.35	7.14	6.94

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Yu,1978	B-0-21-9-H-DS	0.91	0.91	273	337	No	2	1	22.2	0.00	82.6	6.35	7.14	6.94
Yu,1978	B-0-21-10-H-DS	0.91	0.91	273	337	No	2	1	22.2	0.00	82.6	6.35	7.14	6.94
Yu,1978	B-0-22-1-0-DS	0.91	0.91	273	337	No	2	1	44.5	0.00	159	12.7	14.3	13.9
Yu,1978	B-0-22-2-0-DS	0.91	0.91	273	337	No	2	1	44.5	0.00	159	12.7	14.3	13.9
Yu,1978	B-0-22-3-L-DS	0.91	0.91	273	337	No	2	1	44.5	0.00	159	12.7	14.3	13.9
Yu,1978	B-0-22-4-L-DS	0.91	0.91	273	337	No	2	1	44.5	0.00	159	12.7	14.3	13.9
Yu,1978	B-0-22-5-0-DS	0.91	0.91	273	337	No	2	1	44.5	0.00	159	12.7	14.3	13.9
Yu,1978	B-0-22-6-0-DS	0.91	0.91	273	337	No	2	1	44.5	0.00	159	12.7	14.3	13.9
Yu,1978	B-0-22-7-L-DS	0.91	0.91	273	337	No	2	1	44.5	0.00	159	12.7	14.3	13.9
Yu,1978	B-0-22-8-L-DS	0.91	0.91	273	337	No	2	1	44.5	0.00	159	12.7	14.3	13.9
Yu,1978	B-0-22-9-H-DS	0.91	0.91	273	337	No	2	1	44.5	0.00	159	12.7	14.3	13.9
Yu,1978	B-0-22-10-H-DS	0.91	0.91	273	337	No	2	1	45.2	0.00	159	12.7	14.3	13.9
Yu,1978	B-0-25-1-0-SS	1.88	1.88	332	371	No	1	1	27.9	0.00	76.2	12.7	14.3	6.76
Yu,1978	B-0-25-2-0-SS	1.88	1.88	332	371	No	1	1	27.9	0.00	76.2	12.7	14.3	6.76
Yu,1978	B-0-25-3-L-SS	1.88	1.88	332	371	No	1	1	27.9	0.00	76.2	12.7	14.3	6.76
Yu,1978	B-0-25-4-L-SS	1.88	1.88	332	371	No	1	1	27.9	0.00	76.2	12.7	14.3	6.76
Yu,1978	B-0-25-5-H-SS	1.88	1.88	332	371	No	1	1	27.9	0.00	76.2	12.7	14.3	6.76
Yu,1978	B-0-25-6-H-SS	1.88	1.88	332	371	No	1	1	27.9	0.00	76.2	12.7	14.3	6.76
Yu,1978	B-0-26-1-0-SS	1.88	1.88	332	371	No	1	1	41.9	0.00	107	19.1	20.6	10.1
Yu,1978	B-0-26-2-0-SS	1.88	1.88	332	371	No	1	1	41.9	0.00	107	19.1	20.6	10.1

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Yu,1978	B-0-26-3-L-SS	1.88	1.88	332	371	No	1	1	41.9	0.00	107	19.1	20.6	10.1
Yu,1978	B-0-26-4-L-SS	1.88	1.88	332	371	No	1	1	41.9	0.00	107	19.1	20.6	10.1
Yu,1978	B-0-26-5-0-SS	1.88	1.88	332	371	No	1	1	41.9	0.00	107	19.1	20.6	10.1
Yu,1978	B-0-26-6-0-SS	1.88	1.88	332	371	No	1	1	41.9	0.00	107	19.1	20.6	10.1
Yu,1978	B-0-26-7-L-SS	1.88	1.88	332	371	No	1	1	41.9	0.00	107	19.1	20.6	10.1
Yu,1978	B-0-26-8-L-SS	1.88	1.88	332	371	No	1	1	41.9	0.00	107	19.1	20.6	10.1
Yu,1978	B-0-26-9-H-SS	1.88	1.88	332	371	No	1	1	41.9	0.00	107	19.1	20.6	10.1
Yu,1978	B-0-26-10-H-SS	1.88	1.88	332	371	No	1	1	41.9	0.00	107	19.1	20.6	10.1
Yu,1978	B-0-29-1-0-DS	1.88	1.88	332	371	No	2	1	46.1	0.00	165	12.7	14.3	6.76
Yu,1978	B-0-29-2-0-DS	1.88	1.88	332	371	No	2	1	45.2	0.00	165	12.7	14.3	6.76
Yu,1978	B-0-29-3-L-DS	1.88	1.88	332	371	No	2	1	44.5	0.00	165	12.7	14.3	6.76
Yu,1978	B-0-29-4-L-DS	1.88	1.88	332	371	No	2	1	46.1	0.00	165	12.7	14.3	6.76
Yu,1978	B-0-29-5-0-DS	1.88	1.88	332	371	No	2	1	46.8	0.00	165	12.7	14.3	6.76
Yu,1978	B-0-29-6-0-DS	1.88	1.88	332	371	No	2	1	46.8	0.00	165	12.7	14.3	6.76
Yu,1978	B-0-29-7-L-DS	1.88	1.88	332	371	No	2	1	45.2	0.00	165	12.7	14.3	6.76
Yu,1978	B-0-29-8-L-DS	1.88	1.88	332	371	No	2	1	46.8	0.00	165	12.7	14.3	6.76
Yu,1978	B-0-29-9-H-DS	1.88	1.88	332	371	No	2	1	46.8	0.00	165	12.7	14.3	6.76
Yu,1978	B-0-29-10-H-DS	1.88	1.88	332	371	No	2	1	46.8	0.00	165	12.7	14.3	6.76
Yu,1978	B-0-30-1-0-DS	1.88	1.88	332	371	No	2	1	62.7	0.00	254	19.1	20.6	10.1
Yu,1978	B-0-30-2-0-DS	1.88	1.88	332	371	No	2	1	65.1	0.00	254	19.1	20.6	10.1

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Yu,1978	B-0-30-3-L-DS	1.88	1.88	332	371	No	2	1	65.1	0.00	254	19.1	20.6	10.1
Yu,1978	B-0-30-4-L-DS	1.88	1.88	332	371	No	2	1	65.1	0.00	254	19.1	20.6	10.1
Yu,1978	B-0-30-5-0-DS	1.88	1.88	332	371	No	2	1	65.1	0.00	254	19.1	20.6	10.1
Yu,1978	B-0-30-6-0-DS	1.88	1.88	332	371	No	2	1	64.3	0.00	254	19.1	20.6	10.1
Yu,1978	B-0-30-7-L-DS	1.88	1.88	332	371	No	2	1	65.1	0.00	254	19.1	20.6	10.1
Yu,1978	B-0-30-8-L-DS	1.88	1.88	332	371	No	2	1	65.1	0.00	254	19.1	20.6	10.1
Yu,1978	B-0-30-9-H-DS	1.88	1.88	332	371	No	2	1	62.7	0.00	254	19.1	20.6	10.1
Yu,1978	B-0-30-10-H-DS	1.88	1.88	332	371	No	2	1	62.7	0.00	254	19.1	20.6	10.1
Yu,1978	B-0-32-1-0-SS	0.39	0.39	487	558	No	1	1	14.0	0.00	50.8	6.35	7.14	16.2
Yu,1978	B-0-32-2-0-SS	0.39	0.39	487	558	No	1	1	13.5	0.00	50.8	6.35	7.14	16.2
Yu,1978	B-0-32-3-L-SS	0.39	0.39	487	558	No	1	1	14.0	0.00	50.8	6.35	7.14	16.2
Yu,1978	B-0-32-4-L-SS	0.39	0.39	487	558	No	1	1	14.0	0.00	50.8	6.35	7.14	16.2
Yu,1978	B-0-32-5-0-SS	0.39	0.39	487	558	No	1	1	14.0	0.00	50.8	6.35	7.14	16.2
Yu,1978	B-0-32-6-0-SS	0.39	0.39	487	558	No	1	1	14.2	0.00	50.8	6.35	7.14	16.2
Yu,1978	B-0-32-7-L-SS	0.39	0.39	487	558	No	1	1	14.0	0.00	50.8	6.35	7.14	16.2
Yu,1978	B-0-32-8-L-SS	0.39	0.39	487	558	No	1	1	14.2	0.00	50.8	6.35	7.14	16.2
Yu,1978	B-0-32-9-H-SS	0.39	0.39	487	558	No	1	1	14.2	0.00	50.8	6.35	7.14	16.2
Yu,1978	B-0-32-10-H-SS	0.39	0.39	487	558	No	1	1	14.0	0.00	50.8	6.35	7.14	16.2
Yu,1978	B-0-34-1-0-DS	0.39	0.39	487	558	No	2	1	22.2	0.00	82.6	6.35	7.14	16.2
Yu,1978	B-0-34-2-0-DS	0.39	0.39	487	558	No	2	1	22.2	0.00	82.6	6.35	7.14	16.2

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Yu,1978	B-0-34-3-L-DS	0.39	0.39	487	558	No	2	1	22.2	0.00	82.6	6.35	7.14	16.2
Yu,1978	B-0-34-4-L-DS	0.39	0.39	487	558	No	2	1	22.2	0.00	82.6	6.35	7.14	16.2
Yu,1978	B-0-34-5-0-DS	0.39	0.39	487	558	No	2	1	22.2	0.00	82.6	6.35	7.14	16.2
Yu,1978	B-0-34-6-0-DS	0.39	0.39	487	558	No	2	1	22.2	0.00	82.6	6.35	7.14	16.2
Yu,1978	B-0-34-7-L-DS	0.39	0.39	487	558	No	2	1	22.2	0.00	82.6	6.35	7.14	16.2
Yu,1978	B-0-34-8-L-DS	0.39	0.39	487	558	No	2	1	22.2	0.00	82.6	6.35	7.14	16.2
Yu,1978	B-0-34-9-H-DS	0.39	0.39	487	558	No	2	1	22.2	0.00	82.6	6.35	7.14	16.2
Yu,1978	B-0-34-10-H-DS	0.39	0.39	487	558	No	2	1	22.2	0.00	82.6	6.35	7.14	16.2
Yu,1978	B-0-37-1-0-SS	0.79	0.79	409	514	No	1	1	14.0	0.00	57.2	6.35	7.14	8.06
Yu,1978	B-0-37-2-0-SS	0.79	0.79	409	514	No	1	1	14.0	0.00	57.2	6.35	7.14	8.06
Yu,1978	B-0-37-3-L-SS	0.79	0.79	409	514	No	1	1	14.0	0.00	57.2	6.35	7.14	8.06
Yu,1978	B-0-37-4-L-SS	0.79	0.79	409	514	No	1	1	14.0	0.00	57.2	6.35	7.14	8.06
Yu,1978	B-0-37-5-H-SS	0.79	0.79	409	514	No	1	1	14.0	0.00	57.2	6.35	7.14	8.06
Yu,1978	B-0-37-6-H-SS	0.79	0.79	409	514	No	1	1	14.0	0.00	57.2	6.35	7.14	8.06
Yu,1978	B-0-38-1-0-SS	0.79	0.79	409	514	No	1	1	27.9	0.00	76.2	12.7	14.3	16.1
Yu,1978	B-0-38-2-0-SS	0.79	0.79	409	514	No	1	1	27.9	0.00	76.2	12.7	14.3	16.1
Yu,1978	B-0-38-3-L-SS	0.79	0.79	409	514	No	1	1	27.9	0.00	76.2	12.7	14.3	16.1
Yu,1978	B-0-38-4-L-SS	0.79	0.79	409	514	No	1	1	27.9	0.00	76.2	12.7	14.3	16.1
Yu,1978	B-0-38-5-0-SS	0.79	0.79	409	514	No	1	1	27.9	0.00	76.2	12.7	14.3	16.1
Yu,1978	B-0-38-6-0-SS	0.79	0.79	409	514	No	1	1	27.9	0.00	76.2	12.7	14.3	16.1

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Yu,1978	B-0-38-7-L-SS	0.79	0.79	409	514	No	1	1	27.9	0.00	76.2	12.7	14.3	16.1
Yu,1978	B-0-38-8-L-SS	0.79	0.79	409	514	No	1	1	27.9	0.00	76.2	12.7	14.3	16.1
Yu,1978	B-0-38-9-H-SS	0.79	0.79	409	514	No	1	1	27.9	0.00	76.2	12.7	14.3	16.1
Yu,1978	B-0-38-10-H-SS	0.79	0.79	409	514	No	1	1	27.9	0.00	76.2	12.7	14.3	16.1
Yu,1978	B-0-41-1-0-DS	0.79	0.79	409	514	No	2	1	22.2	0.00	82.6	6.35	7.14	8.06
Yu,1978	B-0-41-2-0-DS	0.79	0.79	409	514	No	2	1	22.2	0.00	82.6	6.35	7.14	8.06
Yu,1978	B-0-41-3-L-DS	0.79	0.79	409	514	No	2	1	22.2	0.00	82.6	6.35	7.14	8.06
Yu,1978	B-0-41-4-L-DS	0.79	0.79	409	514	No	2	1	22.2	0.00	82.6	6.35	7.14	8.06
Yu,1978	B-0-41-5-H-DS	0.79	0.79	409	514	No	2	1	22.2	0.00	82.6	6.35	7.14	8.06
Yu,1978	B-0-41-6-H-DS	0.79	0.79	409	514	No	2	1	22.2	0.00	82.6	6.35	7.14	8.06
Yu,1978	B-0-42-1-0-DS	0.79	0.79	409	514	No	2	1	44.5	0.00	165	12.7	14.3	16.1
Yu,1978	B-0-42-2-0-DS	0.79	0.79	409	514	No	2	1	44.5	0.00	165	12.7	14.3	16.1
Yu,1978	B-0-42-3-L-DS	0.79	0.79	409	514	No	2	1	44.5	0.00	165	12.7	14.3	16.1
Yu,1978	B-0-42-4-L-DS	0.79	0.79	409	514	No	2	1	44.5	0.00	165	12.7	14.3	16.1
Yu,1978	B-0-42-5-0-DS	0.79	0.79	409	514	No	2	1	44.5	0.00	165	12.7	14.3	16.1
Yu,1978	B-0-42-6-0-DS	0.79	0.79	409	514	No	2	1	44.5	0.00	165	12.7	14.3	16.1
Yu,1978	B-0-42-7-L-DS	0.79	0.79	409	514	No	2	1	44.5	0.00	165	12.7	14.3	16.1
Yu,1978	B-0-42-8-L-DS	0.79	0.79	409	514	No	2	1	44.5	0.00	165	12.7	14.3	16.1
Yu,1978	B-0-42-9-H-DS	0.79	0.79	409	514	No	2	1	44.5	0.00	165	12.7	14.3	16.1
Yu,1978	B-0-42-10-H-DS	0.79	0.79	409	514	No	2	1	44.5	0.00	165	12.7	14.3	16.1

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Yu,1978	B-0-45-1-0-SS	1.80	1.80	362	478	No	1	1	30.2	0.00	76.2	12.7	14.3	7.04
Yu,1978	B-0-45-2-0-SS	1.80	1.80	362	478	No	1	1	27.9	0.00	76.2	12.7	14.3	7.04
Yu,1978	B-0-45-3-L-SS	1.80	1.80	362	478	No	1	1	27.9	0.00	76.2	12.7	14.3	7.04
Yu,1978	B-0-45-4-L-SS	1.80	1.80	362	478	No	1	1	29.2	0.00	76.2	12.7	14.3	7.04
Yu,1978	B-0-45-5-H-SS	1.80	1.80	362	478	No	1	1	29.2	0.00	76.2	12.7	14.3	7.04
Yu,1978	B-0-45-6-H-SS	1.80	1.80	362	478	No	1	1	27.9	0.00	76.2	12.7	14.3	7.04
Yu,1978	B-0-46-1-0-SS	1.80	1.80	362	478	No	1	1	41.9	0.00	108	19.1	20.6	10.6
Yu,1978	B-0-46-2-0-SS	1.80	1.80	362	478	No	1	1	41.9	0.00	108	19.1	20.6	10.6
Yu,1978	B-0-46-3-L-SS	1.80	1.80	362	478	No	1	1	41.9	0.00	108	19.1	20.6	10.6
Yu,1978	B-0-46-4-L-SS	1.80	1.80	362	478	No	1	1	41.9	0.00	108	19.1	20.6	10.6
Yu,1978	B-0-46-5-0-SS	1.80	1.80	362	478	No	1	1	41.9	0.00	108	19.1	20.6	10.6
Yu,1978	B-0-46-6-0-SS	1.80	1.80	362	478	No	1	1	41.9	0.00	108	19.1	20.6	10.6
Yu,1978	B-0-46-7-L-SS	1.80	1.80	362	478	No	1	1	41.9	0.00	108	19.1	20.6	10.6
Yu,1978	B-0-46-8-L-SS	1.80	1.80	362	478	No	1	1	41.9	0.00	108	19.1	20.6	10.6
Yu,1978	B-0-46-9-H-SS	1.80	1.80	362	478	No	1	1	41.9	0.00	108	19.1	20.6	10.6
Yu,1978	B-0-46-10-H-SS	1.80	1.80	362	478	No	1	1	41.9	0.00	108	19.1	20.6	10.6
Yu,1978	B-0-49-1-0-DS	1.80	1.80	362	478	No	2	1	45.2	0.00	170	12.7	14.3	7.04
Yu,1978	B-0-49-2-0-DS	1.80	1.80	362	478	No	2	1	46.1	0.00	170	12.7	14.3	7.04
Yu,1978	B-0-49-3-L-DS	1.80	1.80	362	478	No	2	1	45.2	0.00	170	12.7	14.3	7.04
Yu,1978	B-0-49-4-L-DS	1.80	1.80	362	478	No	2	1	45.2	0.00	170	12.7	14.3	7.04

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Yu,1978	B-0-49-5-H-DS	1.80	1.80	362	478	No	2	1	45.2	0.00	170	12.7	14.3	7.04
Yu,1978	B-0-49-6-H-DS	1.80	1.80	362	478	No	2	1	45.2	0.00	170	12.7	14.3	7.04
Yu,1978	B-0-50-1-0-DS	1.80	1.80	362	478	No	2	1	66.7	0.00	254	19.1	20.6	10.6
Yu,1978	B-0-50-2-0-DS	1.80	1.80	362	478	No	2	1	66.7	0.00	254	19.1	20.6	10.6
Yu,1978	B-0-50-3-L-DS	1.80	1.80	362	478	No	2	1	66.7	0.00	254	19.1	20.6	10.6
Yu,1978	B-0-50-4-L-DS	1.80	1.80	362	478	No	2	1	66.7	0.00	254	19.1	20.6	10.6
Yu,1978	B-0-50-5-0-DS	1.80	1.80	362	478	No	2	1	66.7	0.00	254	19.1	20.6	10.6
Yu,1978	B-0-50-6-0-DS	1.80	1.80	362	478	No	2	1	66.7	0.00	254	19.1	20.6	10.6
Yu,1978	B-0-50-7-L-DS	1.80	1.80	362	478	No	2	1	66.7	0.00	254	19.1	20.6	10.6
Yu,1978	B-0-50-8-L-DS	1.80	1.80	362	478	No	2	1	66.7	0.00	254	19.1	20.6	10.6
Yu,1978	B-0-50-9-H-DS	1.80	1.80	362	478	No	2	1	66.7	0.00	254	19.1	20.6	10.6
Yu,1978	B-0-50-10-H-DS	1.80	1.80	362	478	No	2	1	66.7	0.00	254	19.1	20.6	10.6
Yu,1978	B-0-51-1-0-SS	4.67	4.67	374	488	No	1	1	42.9	0.00	108	19.1	20.6	4.08
Yu,1978	B-0-51-2-0-SS	4.67	4.67	374	488	No	1	1	42.9	0.00	108	19.1	20.6	4.08
Yu,1978	B-0-51-3-L-SS	4.67	4.67	374	488	No	1	1	43.7	0.00	108	19.1	20.6	4.08
Yu,1978	B-0-51-4-L-SS	4.67	4.67	374	488	No	1	1	42.9	0.00	108	19.1	20.6	4.08
Yu,1978	B-0-51-5-H-SS	4.67	4.67	374	488	No	1	1	42.9	0.00	108	19.1	20.6	4.08
Yu,1978	B-0-51-6-H-SS	4.67	4.67	374	488	No	1	1	42.9	0.00	108	19.1	20.6	4.08
Yu,1978	B-0-53-1-0-DS	4.67	4.67	374	488	No	2	1	66.7	0.00	254	19.1	20.6	4.08
Yu,1978	B-0-53-2-0-DS	4.67	4.67	374	488	No	2	1	68.3	0.00	254	19.1	20.6	4.08

Table C1 Dimension and Mechanical Properties of Washerless Connections Tests in Previous Investigations(continued)

SOURCE	SPECIMEN	t_1 (mm)	t_2 (mm)	f_y (MPa)	f_u (MPa)	Washers	Single or Double Shear	No. Of Bolt	e (mm)	e_1 (mm)	s (mm)	d (mm)	d_{hole} (mm)	d/t
Yu,1978	B-0-53-3-L-DS	4.67	4.67	374	488	No	2	1	66.7	0.00	254	19.1	20.6	4.08
Yu,1978	B-0-53-4-L-DS	4.67	4.67	374	488	No	2	1	67.5	0.00	254	19.1	20.6	4.08
Yu,1978	B-0-53-5-H-DS	4.67	4.67	374	488	No	2	1	65.1	0.00	254	19.1	20.6	4.08

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
Carril,1994	AN32-1	62.8	28.8	55.8	30.9	N.S	B	36.0	1.249
Carril,1994	AN32-2	61.6	28.3	54.8	30.4	N.S	B	36.5	1.289
Carril,1994	AN33-1	77.2	29.9	55.7	30.9	N.S	B	40.1	1.338
Carril,1994	AN33-2	78.5	30.4	56.7	31.4	N.S	B	39.8	1.308
Carril,1994	BN33-1	77.9	63.6	105	62.4	B	B	65.0	1.042
Carril,1994	BN33-2	77.9	63.6	105	62.4	B	B	64.0	1.026
Carril,1994	DN12-2	44.6	22.1	42.7	23.7	N.S	B	21.1	0.954
Carril,1994	DN12-3	43.6	21.6	41.7	23.2	N.S	B	21.1	0.977
Carril,1994	DN22-1	65.1	33.8	65.4	36.3	N.S	B	37.5	1.109
Carril,1994	DN22-2	66.0	34.3	66.2	36.8	N.S	B	37.8	1.103
Carril,1994	BN32-1	62.7	52.0	104	61.8	N.S	B&N.S	64.3	1.238
Carril,1994	BN32-2	62.0	51.4	103	61.3	N.S	B&N.S	65.4	1.271
Carril,1994	DN32-1	128	58.6	113	62.9	N.S	B&R	70.1	1.196
Carril,1994	DN32-2	125	57.6	111	61.8	N.S	B&R	71.6	1.242
Carril,1994	EN12-1	44.6	39.8	79.6	47.5	N.S	B&R	38.5	0.966
Carril,1994	EN12-2	44.6	39.9	79.5	47.5	N.S	B&R	38.7	0.971
Carril,1994	EN22-1	66.0	61.9	123	73.6	N.S	B&R	70.2	1.135
Carril,1994	EN22-2	66.9	62.6	125	74.7	N.S	B&R	70.0	1.118
Carril,1994	EN32-1	125	104	207	124	N.S	B&R	128	1.231
Carril,1994	EN32-2	124	103	205	123	N.S	B&R	129	1.252
Carril,1994	AN31-2	31.1	22.5	54.7	30.4	N.S	N.S	29.3	1.301
Carril,1994	AN31-3	31.1	22.6	55.2	30.7	N.S	N.S	29.1	1.286
Carril,1994	BN31-1	31.3	26.3	104	61.8	N.S	N.S	29.4	1.118
Carril,1994	BN31-2	31.3	26.2	104	61.8	N.S	N.S	29.4	1.120
Carril,1994	CN11-1	11.0	10.4	58.1	35.6	N.S	N.S	10.2	0.983
Carril,1994	CN11-2	11.0	10.4	58.1	35.6	N.S	N.S	10.4	0.999
Carril,1994	CN12-1	22.2	22.8	58.1	35.6	N.S	N.S	25.5	1.122
Carril,1994	CN12-2	22.2	22.8	58.1	35.6	N.S	N.S	25.5	1.122
Carril,1994	CN21-1	16.7	16.5	90.0	55.2	N.S	N.S	18.2	1.100
Carril,1994	CN21-2	16.9	16.7	91.3	56.0	N.S	N.S	18.1	1.083
Carril,1994	CN21-3	16.9	16.7	91.3	56.0	N.S	N.S	17.9	1.074
Carril,1994	CN22-1	33.1	35.6	90.1	55.2	N.S	N.S	42.7	1.201
Carril,1994	CN22-2	33.6	36.1	91.4	56.0	N.S	N.S	42.9	1.186
Carril,1994	CN22-3	33.1	35.6	90.0	55.2	N.S	N.S	42.9	1.203
Carril,1994	CN31-2	32.0	28.0	154	94.3	N.S	N.S	30.8	1.099
Carril,1994	CN31-3	32.3	28.2	155	95.1	N.S	N.S	30.0	1.063
Carril,1994	CN32-1	64.4	61.3	155	95.1	N.S	N.S	71.2	1.162

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
Carril,1994	CN32-2	63.6	60.6	154	94.3	N.S	N.S	70.4	1.162
Carril,1994	DN31-1	63.7	46.3	113	62.9	N.S	N.S	55.2	1.191
Carril,1994	DN31-2	61.7	44.8	110	60.8	N.S	N.S	53.4	1.191
Carril,1994	EN11-1	22.7	20.5	81.3	48.6	N.S	N.S	21.4	1.046
Carril,1994	EN11-2	22.2	20.1	79.5	47.5	N.S	N.S	21.5	1.072
Carril,1994	EN21-1	33.6	31.8	125	74.7	N.S	N.S	37.4	1.176
Carril,1994	EN21-2	33.5	31.8	125	74.7	N.S	N.S	37.4	1.178
Carril,1994	EN31-1	62.2	52.1	206	123	N.S	N.S	58.9	1.130
Carril,1994	EN31-2	62.7	52.5	207	124	N.S	N.S	60.3	1.147
Carril,1994	DN11-1	21.2	16.6	40.8	22.6	N.S	N&R	18.1	1.088
Carril,1994	DN11-2	21.7	17.0	41.7	23.2	N.S	N&R	18.7	1.100
Carril,1994	DN21-1	33.6	27.6	67.3	37.3	N.S	N&R	32.0	1.161
Carril,1994	DN21-2	33.1	27.2	66.3	36.8	N.S	N&R	31.5	1.159
Chong,1975	1	35.8	10.4	20.0	10.8	N.S	B&E	10.9	1.048
Chong,1975	2	35.5	6.93	19.8	6.73	B	B	8.14	1.210
Chong,1975	3	36.3	6.95	20.0	6.73	B	B&E	7.12	1.058
Chong,1975	4	35.8	10.4	19.7	10.8	N.S	E	9.92	0.950
Chong,1975	5	35.8	10.4	20.1	10.8	N.S	E	10.8	1.035
Chong,1975	6	35.2	10.4	9.70	10.8	E	B&E	10.6	1.096
Chong,1975	7	35.2	10.4	14.6	10.8	N.S	E	11.0	1.059
Chong,1975	8	35.2	10.4	17.0	10.8	N.S	E	10.0	0.961
Chong,1975	9	35.2	10.4	24.3	10.8	N.S	B	10.1	0.965
Chong,1975	11	35.2	10.4	24.3	10.8	N.S	B	10.3	0.986
Chong,1975	12	35.2	10.4	14.6	10.8	N.S	E	10.7	1.029
Chong,1975	13	35.2	10.4	9.70	10.8	E	E&B	10.5	1.083
Chong,1975	14	35.2	10.4	4.85	10.8	E	E	7.48	1.541
Chong,1975	15	35.2	10.4	4.85	10.8	E	E	6.76	1.394
Chong,1975	32	37.1	12.2	23.4	12.6	N.S	E&B	12.9	1.051
Chong,1975	33	37.1	12.2	22.9	12.6	N.S	B&E	13.3	1.084
Chong,1975	34	37.1	12.2	22.9	12.6	N.S	B&E	13.1	1.069
Chong,1975	41	54.9	21.6	10.3	22.3	E	E&B	12.3	1.201
Chong,1975	42	54.9	21.6	10.5	22.3	E	E&B	13.8	1.314
Chong,1975	49	13.9	11.1	40.2	22.3	N.S	N.S	13.5	1.210
Chong,1975	50	13.9	11.1	40.2	22.3	N.S	N.S	12.9	1.162
Chong,1975	51	13.9	11.1	40.2	22.3	N.S	N.S	11.9	1.066
Chong,1975	52	74.3	34.6	69.5	38.6	N.S	B&E	38.3	1.105
Chong,1975	53	74.3	34.6	69.8	38.6	N.S	B&E	36.3	1.047
Chong,1975	54	74.3	34.6	69.5	38.6	N.S	B&E	40.8	1.178

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
Chong,1975	55	111	49.0	99.0	54.4	N.S	B&E	55.6	1.135
Chong,1975	16(3b)	26.6	15.2	20.0	21.5	N.S	N.S	18.1	1.187
Chong,1975	17(3b)	27.0	15.3	19.4	21.5	N.S	N.S	18.4	1.198
Chong,1975	37(3b)	37.2	20.5	44.8	25.3	N.S	E&B	24.8	1.208
Chong,1975	40(3b)	54.9	36.2	79.3	44.7	N.S	B	40.0	1.105
Chong,1975	56(3b)	111	73.3	196	109	N.S	E&N	88.3	1.206
Chong,1975	35(3c)	37.3	19.9	70.0	23.7	N.S	B	23.3	1.174
Chong,1975	36(3c)	37.3	19.9	70.6	23.7	N.S	B	24.0	1.207
Chong,1975	18(3d)	8.81	4.77	26.4	21.5	N.S	N.S	7.57	1.584
Chong,1975	19(3d)	8.81	4.77	26.4	21.5	N.S	N.S	6.72	1.407
Chong,1975	22(3d)	17.6	11.3	26.4	21.5	N.S	N.S	14.9	1.312
Chong,1975	23(3d)	17.6	11.3	26.4	21.5	N.S	N.S	15.9	1.402
Chong,1975	28(3d)	35.2	21.9	26.4	21.5	B	E	19.5	0.905
Chong,1975	29(3d)	35.2	21.9	26.4	21.5	B	B&E	19.2	0.893
Chong,1975	45(3d)	27.4	23.5	54.7	44.7	N.S	N.S	30.7	1.308
Chong,1975	46(3d)	27.4	23.5	54.7	44.7	N.S	N.S	31.9	1.358
Chong,1975	20(3e)	8.81	4.60	43.0	32.3	N.S	N.S	7.83	1.703
Chong,1975	21(3e)	8.81	4.60	43.0	32.3	N.S	N.S	4.76	1.036
Chong,1975	24(3e)	17.6	12.2	43.0	32.3	N.S	N.S	15.7	1.287
Chong,1975	25(3e)	17.6	12.2	43.0	32.3	N.S	N.S	15.2	1.243
Chong,1975	26(3e)	34.7	25.3	43.0	32.3	N.S	E	28.8	1.137
Chong,1975	27(3e)	34.7	25.3	43.0	32.3	N.S	E	28.8	1.139
Chong,1975	43(3e)	55.3	53.7	89.3	67.0	N.S	E&B	58.3	1.085
Chong,1975	44(3e)	55.7	54.2	89.3	67.0	N.S	E&B	60.1	1.109
Chong,1975	47(3e)	13.7	9.54	89.3	67.0	N.S	N.S	13.0	1.363
Chong,1975	48(3e)	13.7	9.54	89.3	67.0	N.S	N.S	13.5	1.414
Gilchrist, 1979	1	16.9	2.70	4.65	2.58	B	B&E	3.20	1.242
Gilchrist, 1979	2	16.9	2.70	3.49	2.58	B	B&E	2.71	1.052
Gilchrist, 1979	3	16.9	2.70	2.79	2.58	B	B&E	2.60	1.009
Gilchrist, 1979	4	16.9	3.92	6.97	3.87	B	B&E	3.03	0.782
Gilchrist, 1979	5	16.9	3.92	4.65	3.87	B	B	3.00	0.776
Gilchrist, 1979	6	16.9	3.92	3.49	3.87	E	B&E	3.16	0.906
Gilchrist, 1979	7	24.3	3.74	6.43	3.57	B	B&E	3.78	1.060
Gilchrist, 1979	8	24.3	3.74	4.82	3.57	B	B&E	3.89	1.091
Gilchrist, 1979	9	24.3	3.74	3.86	3.57	B	B&E	3.69	1.035
Gilchrist, 1979	10	24.3	5.42	9.65	5.35	B	B&E	4.01	0.748
Gilchrist, 1979	11	24.3	5.42	6.43	5.35	B	B	3.56	0.665
Gilchrist, 1979	12	24.3	5.42	4.82	5.35	E	B&E	4.34	0.899

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
Gilchrist, 1979	13	24.8	3.83	6.60	3.66	B	B&E	4.58	1.251
Gilchrist, 1979	14	24.8	3.83	4.95	3.66	B	B&E	4.29	1.173
Gilchrist, 1979	15	24.8	3.83	3.96	3.66	B	B&E	4.18	1.142
Gilchrist, 1979	16	24.8	5.56	9.90	5.49	B	B&E	4.34	0.790
Gilchrist, 1979	17	24.8	5.56	6.60	5.49	B	B&E	4.36	0.794
Gilchrist, 1979	18	24.8	5.56	4.95	5.49	E	B&E	4.05	0.818
Gilchrist, 1979	19	24.8	7.09	13.2	7.32	N.S	B&E	7.23	1.020
Gilchrist, 1979	20	24.8	7.09	9.90	7.32	N.S	B	5.21	0.734
Gilchrist, 1979	21	24.8	7.09	6.60	7.32	E	B	5.45	0.826
Gilchrist, 1979	22	19.8	3.58	6.16	3.42	B	B&E	3.78	1.106
Gilchrist, 1979	23	19.8	3.58	4.62	3.42	B	B&E	3.65	1.067
Gilchrist, 1979	24	19.8	3.58	3.70	3.42	B	B&E	4.01	1.171
Gilchrist, 1979	25	19.8	5.19	9.24	5.13	B	B&E	4.41	0.859
Gilchrist, 1979	26	19.8	5.19	6.16	5.13	B	B&E	4.21	0.820
Gilchrist, 1979	27	19.8	5.19	4.62	5.13	E	B&E	4.12	0.891
Gilchrist, 1979	28	19.8	6.62	12.3	6.84	N.S	B	7.16	1.082
Gilchrist, 1979	29	19.8	6.62	9.24	6.84	N.S	B	6.50	0.982
Gilchrist, 1979	30	19.8	6.62	6.16	6.84	E	B	5.01	0.813
McGill,2002	043-230-3/8-SS-A	8.03	3.14	9.27	3.27	N.S	B	1.69	0.539
McGill,2002	043-230-3/8-SS-B	8.03	3.14	9.27	3.27	N.S	B	1.77	0.565
McGill,2002	043-230-3/8-SS-C	8.03	3.14	9.27	3.27	N.S	B	1.67	0.533
McGill,2002	043-230-3/8-TTSS-A	8.03	3.14	9.27	3.27	N.S	B	1.87	0.596
McGill,2002	043-230-3/8-TTSS-B	8.03	3.14	9.27	3.27	N.S	B	1.77	0.565
McGill,2002	043-230-3/8-TTSS-C	8.03	3.14	9.27	3.27	N.S	B	2.16	0.689
McGill,2002	043-230-3/8-DS-A	8.03	3.14	9.27	4.42	N.S	B	3.65	1.164
McGill,2002	043-230-3/8-DS-B	8.03	3.14	9.27	4.42	N.S	B	3.46	1.104
McGill,2002	043-230-3/8-DS-C	8.03	3.14	9.27	4.42	N.S	B	3.26	1.040
McGill,2002	043-550-3/8-SS-A	19.3	5.21	15.4	5.43	N.S	B	2.62	0.503
McGill,2002	043-550-3/8-SS-B	19.3	5.21	15.4	5.43	N.S	B	2.73	0.524
McGill,2002	043-550-3/8-SS-C	19.3	5.21	15.4	5.43	N.S	B	2.49	0.478
McGill,2002	043-230-1/2-SS-A	8.03	3.97	9.27	4.36	N.S	B	2.14	0.539
McGill,2002	043-230-1/2-SS-B	8.03	3.97	9.27	4.36	N.S	B	2.13	0.536
McGill,2002	043-230-1/2-SS-C	8.03	3.97	9.27	4.36	N.S	B	2.18	0.549
McGill,2002	043-230-1/2-TTSS-A	8.03	3.97	9.27	4.36	N.S	B	2.29	0.576
McGill,2002	043-230-1/2-TTSS-B	8.03	3.97	9.27	4.36	N.S	B	2.24	0.564
McGill,2002	043-230-1/2-TTSS-C	8.03	3.97	9.27	4.36	N.S	B	2.46	0.619
McGill,2002	043-230-1/2-DS-A	8.03	3.97	9.27	5.89	N.S	B	5.43	1.367
McGill,2002	043-230-1/2-DS-B	8.03	3.97	9.27	5.89	N.S	B	5.80	1.460

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
McGill,2002	043-230-1/2-DS-C	8.03	3.97	9.27	5.89	N.S	B	5.72	1.440
McGill,2002	043-550-1/2-SS-A	19.3	6.60	15.4	7.24	N.S	B	3.37	0.510
McGill,2002	043-550-1/2-SS-B	19.3	6.60	15.4	7.24	N.S	B	3.36	0.509
McGill,2002	043-550-1/2-SS-C	19.3	6.60	15.4	7.24	N.S	B	3.36	0.509
McGill,2002	043-230-5/8-SS-A	8.03	4.71	9.27	5.45	N.S	B	2.99	0.635
McGill,2002	043-230-5/8-SS-B	8.03	4.71	9.27	5.45	N.S	B	2.84	0.603
McGill,2002	043-230-5/8-SS-C	8.03	4.71	9.27	5.45	N.S	B	2.78	0.591
McGill,2002	043-230-5/8-TTSS-A	8.03	4.71	9.27	5.45	N.S	B	3.09	0.657
McGill,2002	043-230-5/8-TTSS-B	8.03	4.71	9.27	5.45	N.S	B	3.22	0.684
McGill,2002	043-230-5/8-TTSS-C	8.03	4.71	9.27	5.45	N.S	B	3.36	0.714
McGill,2002	043-230-5/8-DS-A	8.03	4.71	9.27	7.36	N.S	B	7.05	1.498
McGill,2002	043-230-5/8-DS-B	8.03	4.71	9.27	7.36	N.S	B	7.49	1.592
McGill,2002	043-230-5/8-DS-C	8.03	4.71	9.27	7.36	N.S	B	7.35	1.562
McGill,2002	043-550-5/8-SS-A	19.3	7.82	15.4	9.05	N.S	B	3.71	0.474
McGill,2002	043-550-5/8-SS-B	19.3	7.82	15.4	9.05	N.S	B	3.93	0.502
McGill,2002	043-550-5/8-SS-C	19.3	7.82	15.4	9.05	N.S	B	3.92	0.501
McGill,2002	064-230-5/8-TTSS-A	14.3	6.68	13.2	7.73	N.S	B	5.22	0.782
McGill,2002	064-230-5/8-TTSS-B	14.3	6.68	13.2	7.73	N.S	B	4.88	0.731
McGill,2002	064-230-5/8-TTSS-C	14.3	6.68	13.2	7.73	N.S	B	5.47	0.819
McGill,2002	064-230-5/8-DS-A	14.3	6.68	13.2	10.4	N.S	B	11.8	1.774
McGill,2002	064-230-5/8-DS-B	14.3	6.68	13.2	10.4	N.S	B	11.0	1.651
McGill,2002	064-230-5/8-DS-C	14.3	6.68	13.2	10.4	N.S	B	11.7	1.753
McGill,2002	064-550-5/8-SS-A	33.3	13.5	26.6	15.6	N.S	B	8.64	0.640
McGill,2002	064-550-5/8-SS-B	33.3	13.5	26.6	15.6	N.S	B	8.91	0.660
McGill,2002	064-550-5/8-SS-C	33.3	13.5	26.6	15.6	N.S	B	8.34	0.618
McGill,2002	064-230-1/2-TTSS-A	14.3	5.63	13.2	6.18	N.S	B	4.56	0.809
McGill,2002	064-230-1/2-TTSS-B	14.3	5.63	13.2	6.18	N.S	B	4.44	0.788
McGill,2002	064-230-1/2-TTSS-C	14.3	5.63	13.2	6.18	N.S	B	4.10	0.728
McGill,2002	064-230-1/2-DS-A	14.3	5.63	13.2	8.35	N.S	B	8.91	1.581
McGill,2002	064-230-1/2-DS-B	14.3	5.63	13.2	8.35	N.S	B	9.28	1.647
McGill,2002	064-230-1/2-DS-C	14.3	5.63	13.2	8.35	N.S	B	9.23	1.638
McGill,2002	064-550-1/2-SS-A	33.3	11.4	26.6	12.5	N.S	B	6.94	0.609
McGill,2002	064-550-1/2-SS-B	33.3	11.4	26.6	12.5	N.S	B	7.26	0.637
McGill,2002	064-550-1/2-SS-C	33.3	11.4	26.6	12.5	N.S	B	7.04	0.618
McGill,2002	064-230-3/8-SS-A	14.3	4.45	13.2	4.64	N.S	B	3.05	0.686
McGill,2002	064-230-3/8-SS-B	14.3	4.45	13.2	4.64	N.S	B	2.75	0.618
McGill,2002	064-230-3/8-SS-C	14.3	4.45	13.2	4.64	N.S	B	2.77	0.623
McGill,2002	064-550-3/8-SS-A	33.3	9.00	26.6	9.38	N.S	B	5.83	0.648

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
McGill,2002	064-550-3/8-SS-B	33.3	9.00	26.6	9.38	N.S	B	6.43	0.715
McGill,2002	064-550-3/8-SS-C	33.3	9.00	26.6	9.38	N.S	B	5.82	0.647
McGill,2002	064-230-1/4-DS-A	14.3	3.11	13.2	4.18	N.S	B	6.76	2.172
McGill,2002	064-230-1/4-DS-B	14.3	3.11	13.2	4.18	N.S	B	6.67	2.143
McGill,2002	064-230-1/4-DS-C	14.3	3.11	13.2	4.18	N.S	B	6.38	2.050
McGill,2002	064-550-1/4-SS-A	33.3	6.30	26.6	6.25	B	B	5.68	0.908
McGill,2002	064-550-1/4-SS-B	33.3	6.30	26.6	6.25	B	B	5.55	0.888
McGill,2002	064-550-1/4-SS-C	33.3	6.30	26.6	6.25	B	B	5.90	0.944
McGill,2002	064-230-1/4-SS-A	14.3	3.11	13.2	3.09	B	B	2.92	0.945
McGill,2002	064-230-1/4-SS-B	14.3	3.11	13.2	3.09	B	B	3.07	0.993
McGill,2002	064-230-1/4-SS-C	14.3	3.11	13.2	3.09	B	B	3.00	0.971
McGill,2002	064-230-1/4-TTSS-A	14.3	3.11	13.2	3.09	B	B	2.95	0.954
McGill,2002	064-230-1/4-TTSS-B	14.3	3.11	13.2	3.09	B	B	3.29	1.065
McGill,2002	064-230-1/4-TTSS-C	14.3	3.11	13.2	3.09	B	B	3.80	1.230
McGill,2002	076-230-1/2-SS-A	18.5	7.37	17.2	8.08	N.S	B	4.77	0.647
McGill,2002	076-230-1/2-SS-B	18.5	7.37	17.2	8.08	N.S	B	4.53	0.615
McGill,2002	076-230-1/2-SS-C	18.5	7.37	17.2	8.08	N.S	B	4.90	0.665
McGill,2002	076-230-1/2-TTSS-A	18.5	7.37	17.2	8.08	N.S	B	5.22	0.709
McGill,2002	076-230-1/2-TTSS-B	18.5	7.37	17.2	8.08	N.S	B	5.90	0.801
McGill,2002	076-230-1/2-TTSS-C	18.5	7.37	17.2	8.08	N.S	B	5.41	0.735
McGill,2002	076-230-1/2-DS-A	18.5	7.37	17.2	10.9	N.S	B	10.8	1.470
McGill,2002	076-230-1/2-DS-B	18.5	7.37	17.2	10.9	N.S	B	11.8	1.606
McGill,2002	076-230-1/2-DS-C	18.5	7.37	17.2	10.9	N.S	B	10.5	1.430
McGill,2002	076-550-1/2-SS-A	38.4	13.2	30.7	14.4	N.S	B	8.50	0.646
McGill,2002	076-550-1/2-SS-B	38.4	13.2	30.7	14.4	N.S	B	8.06	0.612
McGill,2002	076-550-1/2-SS-C	38.4	13.2	30.7	14.4	N.S	B	8.50	0.646
McGill,2002	076-230-5/8-SS-A	18.5	8.72	17.2	10.1	N.S	B	6.17	0.707
McGill,2002	076-230-5/8-SS-B	18.5	8.72	17.2	10.1	N.S	B	6.04	0.692
McGill,2002	076-230-5/8-SS-C	18.5	8.72	17.2	10.1	N.S	B	6.04	0.692
McGill,2002	076-550-3/8-SS-A	38.4	10.4	30.7	10.8	N.S	B	8.19	0.788
McGill,2002	076-550-3/8-SS-B	38.4	10.4	30.7	10.8	N.S	B	7.80	0.751
McGill,2002	076-550-3/8-SS-C	38.4	10.4	30.7	10.8	N.S	B	6.61	0.636
McGill,2002	076-550-1/4-SS-A	38.4	7.27	30.7	7.22	B	B	7.01	0.971
McGill,2002	076-550-1/4-SS-B	38.4	7.27	30.7	7.22	B	B	6.80	0.941
McGill,2002	076-550-1/4-SS-C	38.4	7.27	30.7	7.22	B	B	6.55	0.907
McGill,2002	091-230-1/4-SS-A	20.0	4.57	19.3	4.54	B	B	4.65	1.024
McGill,2002	091-230-1/4-SS-B	20.0	4.57	19.3	4.54	B	B	5.14	1.132
McGill,2002	091-230-1/4-SS-C	20.0	4.57	19.3	4.54	B	B	4.83	1.064

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
McGill,2002	091-230-1/4-TTSS-A	20.0	4.57	19.3	4.54	B	B	7.94	1.748
McGill,2002	091-230-1/4-TTSS-B	20.0	4.57	19.3	4.54	B	B	7.46	1.643
McGill,2002	091-230-1/4-TTSS-C	20.0	4.57	19.3	4.54	B	B	7.51	1.654
McGill,2002	091-230-1/4-DS-A	20.0	4.57	19.3	6.14	N.S	B	12.7	2.775
McGill,2002	091-230-1/4-DS-B	20.0	4.57	19.3	6.14	N.S	B	12.4	2.703
McGill,2002	091-230-1/4-DS-C	20.0	4.57	19.3	6.14	N.S	B	11.2	2.458
McGill,2002	091-230-1/2-TTSS-A	20.0	8.28	19.3	9.08	N.S	B	6.91	0.835
McGill,2002	091-230-1/2-TTSS-B	20.0	8.28	19.3	9.08	N.S	B	6.94	0.838
McGill,2002	091-230-1/2-TTSS-C	20.0	8.28	19.3	9.08	N.S	B	7.00	0.845
McGill,2002	091-230-1/2-DS-A	20.0	8.28	19.3	12.3	N.S	B	14.3	1.727
McGill,2002	091-230-1/2-DS-B	20.0	8.28	19.3	12.3	N.S	B	13.6	1.643
McGill,2002	091-230-1/2-DS-C	20.0	8.28	19.3	12.3	N.S	B	13.4	1.623
McGill,2002	121-230-1/2-TTSS-A	30.2	12.9	30.2	14.2	N.S	B	10.3	0.794
McGill,2002	121-230-1/2-TTSS-B	30.2	12.9	30.2	14.2	N.S	B	10.3	0.801
McGill,2002	121-230-1/2-TTSS-C	30.2	12.9	30.2	14.2	N.S	B	12.0	0.929
McGill,2002	121-230-1/2-DS-A	30.2	12.9	30.2	19.1	N.S	B	18.6	1.440
McGill,2002	121-230-1/2-DS-B	30.2	12.9	30.2	19.1	N.S	B	20.9	1.617
McGill,2002	121-230-1/2-DS-C	30.2	12.9	30.2	19.1	N.S	B	18.3	1.414
McGill,2002	121-230-3/8-SS-A	30.2	10.2	30.2	10.6	N.S	B	8.39	0.823
McGill,2002	121-230-3/8-SS-B	30.2	10.2	30.2	10.6	N.S	B	8.54	0.838
McGill,2002	121-230-3/8-SS-C	30.2	10.2	30.2	10.6	N.S	B	8.89	0.872
McGill,2002	121-230-3/8-TTSS-A	30.2	10.2	30.2	10.6	N.S	B	9.28	0.910
McGill,2002	121-230-3/8-TTSS-B	30.2	10.2	30.2	10.6	N.S	B	9.03	0.886
McGill,2002	121-230-3/8-TTSS-C	30.2	10.2	30.2	10.6	N.S	B	9.70	0.952
McGill,2002	121-230-3/8-DS-A	30.2	10.2	30.2	14.4	N.S	B	20.5	2.007
McGill,2002	121-230-3/8-DS-B	30.2	10.2	30.2	14.4	N.S	B	18.4	1.800
McGill,2002	121-230-3/8-DS-C	30.2	10.2	30.2	14.4	N.S	B	16.4	1.607
McGill,2002	153-230-1/4-SS-A	33.3	7.72	32.6	7.67	B	B	10.0	1.303
McGill,2002	153-230-1/4-SS-B	33.3	7.72	32.6	7.67	B	B	9.80	1.278
McGill,2002	153-230-1/4-SS-C	33.3	7.72	32.6	7.67	B	B	9.49	1.237
Wallace,2000	1-wo-50	22.4	6.53	24.4	6.89	N.S	B	6.29	0.963
Wallace,2000	2-wo-50	22.4	6.53	24.4	6.89	N.S	B	6.95	1.064
Wallace,2000	3-wo-50	22.4	6.53	24.4	6.89	N.S	B	6.53	1.000
Wallace,2000	1-wo-40	22.4	6.53	19.6	6.89	N.S	B	6.64	1.017
Wallace,2000	2-wo-40	22.4	6.53	19.6	6.89	N.S	B	6.12	0.937
Wallace,2000	3-wo-40	22.4	6.53	19.6	6.89	N.S	B	6.70	1.026
Wallace,2000	1-wo-30	22.4	6.53	14.7	6.89	N.S	B	6.38	0.977
Wallace,2000	2-wo-30	22.4	6.53	14.7	6.89	N.S	B	6.41	0.982

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
Wallace,2000	3-wo-30	22.4	6.53	14.7	6.89	N.S	B	6.24	0.956
Wallace,2000	1-wo-20	22.4	6.53	9.78	6.89	N.S	B	5.89	0.902
Wallace,2000	2-wo-20	22.4	6.53	9.78	6.89	N.S	B	6.20	0.949
Wallace,2000	3-wo-20	22.4	6.53	9.78	6.89	N.S	B	6.60	1.011
Wallace,2000	1-wo-20-t5	22.4	6.53	9.78	6.89	N.S	B	7.24	1.109
Wallace,2000	2-wo-20-t5	22.4	6.53	9.78	6.89	N.S	B	6.63	1.015
Wallace,2000	3-wo-20-t5	22.4	6.53	9.78	6.89	N.S	B	6.45	0.988
Wallace,2000	1-wo-20-t15	22.4	6.53	9.78	6.89	N.S	B	7.11	1.089
Wallace,2000	2-wo-20-t15	22.4	6.53	9.78	6.89	N.S	B	6.50	0.995
Wallace,2000	3-wo-20-t15	22.4	6.53	9.78	6.89	N.S	B	7.71	1.181
Wallace,2000	1-wo-30-50	22.4	13.5	37.2	13.8	N.S	B	14.5	1.067
Wallace,2000	2-wo-30-50	22.4	13.5	37.2	13.8	N.S	B	15.3	1.128
Wallace,2000	3-wo-30-50	22.4	13.5	37.2	13.8	N.S	B	14.2	1.045
Wallace,2000	1-wo-30-40	22.4	13.5	32.3	13.8	N.S	B	14.1	1.044
Wallace,2000	2-wo-30-40	22.4	13.5	32.3	13.8	N.S	B	14.6	1.075
Wallace,2000	3-wo-30-40	22.4	13.5	32.3	13.8	N.S	B	14.2	1.047
Wallace,2000	1-wo-30-30	22.4	13.5	27.4	13.8	N.S	B	15.1	1.115
Wallace,2000	2-wo-30-30	22.4	13.5	27.4	13.8	N.S	B	15.3	1.132
Wallace,2000	3-wo-30-30	22.4	13.5	27.4	13.8	N.S	B	14.0	1.030
Wallace,2000	1-wo-40-3/8	22.4	9.06	19.6	10.3	N.S	B	7.26	0.802
Wallace,2000	2-wo-40-3/8	22.4	9.06	19.6	10.3	N.S	B	7.52	0.830
Wallace,2000	3-wo-40-3/8	22.4	9.06	19.6	10.3	N.S	B	7.65	0.845
Wallace,2000	1-wo-30-5/16	22.4	7.85	14.7	8.62	N.S	B	7.82	0.996
Wallace,2000	2-wo-30-5/16	22.4	7.85	14.7	8.62	N.S	B	6.58	0.838
Wallace,2000	3-wo-30-5/16	22.4	7.85	14.7	8.62	N.S	B	6.98	0.889
Wallace,2000	1-wo-50-1/2	22.4	11.1	24.4	13.8	N.S	B	9.80	0.884
Wallace,2000	2-wo-50-1/2	22.4	11.1	24.4	13.8	N.S	B	9.62	0.868
Wallace,2000	3-wo-50-1/2	22.4	11.1	24.4	13.8	N.S	B	9.16	0.826
Wallace,2000	1-wo-50-5/8	22.4	12.6	24.4	17.2	N.S	B	10.3	0.816
Wallace,2000	2-wo-50-5/8	22.4	12.6	24.4	17.2	N.S	B	10.3	0.818
Wallace,2000	3-wo-50-5/8	22.4	12.6	24.4	17.2	N.S	B	10.3	0.812
Wallace,2000	1-wo-ss-5/16	11.2	3.93	7.33	4.31	N.S	B	3.23	0.822
Wallace,2000	2-wo-ss-5/16	11.2	3.93	7.33	4.31	N.S	B	3.27	0.833
Wallace,2000	3-wo-ss-5/16	11.2	3.93	7.33	4.31	N.S	B	3.39	0.863
Wallace,2000	1-wo-sst-5/16	24.6	8.00	14.9	8.78	N.S	B	9.12	1.140
Wallace,2000	2-wo-sst-5/16	24.6	8.00	14.9	8.78	N.S	B	8.51	1.063
Wallace,2000	3-wo-sst-5/16	24.6	8.00	14.9	8.78	N.S	B	8.26	1.032
Wallace,2000	1-wo-sst-1/4	24.6	6.65	14.9	7.02	N.S	B	9.16	1.377

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
Wallace,2000	2-wo-sst-1/4	24.6	6.65	14.9	7.02	N.S	B	8.92	1.341
Wallace,2000	3-wo-sst-1/4	24.6	6.65	14.9	7.02	N.S	B	9.03	1.357
Wallace,2000	1-wo-mix-1/4	11.2	3.26	7.33	3.45	N.S	B	3.52	1.078
Wallace,2000	2-wo-mix-1/4	11.2	3.26	7.33	3.45	N.S	B	3.47	1.063
Wallace,2000	3-wo-mix-1/4	11.2	3.26	7.33	3.45	N.S	B	3.73	1.142
Wallace,2000	1-wo-ss-1/4	11.2	3.26	7.33	3.45	N.S	B	3.27	1.002
Wallace,2000	2-wo-ss-1/4	11.2	3.26	7.33	3.45	N.S	B	3.30	1.011
Wallace,2000	1-wo-ss-1/2	11.2	5.54	7.33	6.89	N.S	B	4.25	0.767
Wallace,2000	2-wo-ss-1/2	11.2	5.54	7.33	6.89	N.S	B	4.43	0.799
Wallace,2000	3-wo-ss-1/2	11.2	5.54	7.33	6.89	N.S	B	4.00	0.721
Wallace,2000	1-wo-ss-5/8	11.2	6.31	7.33	8.62	N.S	B	5.45	0.863
Wallace,2000	2-wo-ss-5/8	11.2	6.31	7.33	8.62	N.S	B	5.43	0.860
Wallace,2000	3-wo-ss-5/8	11.2	6.31	7.33	8.62	N.S	B	5.41	0.857
Yu,1978	B-0-12-1-0-SS	4.78	1.57	1.60	1.62	N.S	R	1.73	1.101
Yu,1978	B-0-12-2-0-SS	4.78	1.57	1.60	1.62	N.S	R	1.40	0.894
Yu,1978	B-0-12-3-L-SS	4.78	1.57	1.65	1.62	N.S	R	1.40	0.894
Yu,1978	B-0-12-4-L-SS	4.78	1.57	1.65	1.62	N.S	R	1.50	0.959
Yu,1978	B-0-12-5-0-SS	4.78	1.57	1.60	1.62	N.S	R	1.36	0.866
Yu,1978	B-0-12-6-0-SS	4.78	1.57	1.65	1.62	N.S	R	1.44	0.917
Yu,1978	B-0-12-7-L-SS	4.78	1.57	1.60	1.62	N.S	R	1.58	1.011
Yu,1978	B-0-12-8-L-SS	4.66	1.56	1.62	1.62	N.S	R	1.45	0.929
Yu,1978	B-0-12-9-H-SS	4.71	1.56	1.62	1.62	N.S	R	1.70	1.090
Yu,1978	B-0-12-10-H-SS	4.78	1.57	1.65	1.62	N.S	R	2.25	1.433
Yu,1978	B-0-14-1-0-DS	7.89	1.67	2.56	2.19	N.S	B&E	2.42	1.446
Yu,1978	B-0-14-2-0-DS	7.89	1.67	2.56	2.19	N.S	B&E	2.13	1.273
Yu,1978	B-0-14-3-L-DS	7.89	1.67	2.56	2.19	N.S	B&E	2.55	1.529
Yu,1978	B-0-14-4-L-DS	7.89	1.67	2.56	2.19	N.S	B&E	2.36	1.412
Yu,1978	B-0-14-5-0-DS	7.89	1.67	2.56	2.19	N.S	B&E	2.33	1.393
Yu,1978	B-0-14-6-0-DS	7.89	1.67	2.56	2.19	N.S	B&E	2.14	1.284
Yu,1978	B-0-14-7-L-DS	7.89	1.67	2.56	2.19	N.S	B&E	3.06	1.833
Yu,1978	B-0-14-8-L-DS	7.89	1.67	2.56	2.19	N.S	B&E	3.15	1.886
Yu,1978	B-0-14-9-H-DS	7.89	1.67	2.56	2.19	N.S	B&E	2.46	1.470
Yu,1978	B-0-14-10-H-DS	7.89	1.67	2.56	2.19	N.S	B&E	2.41	1.444
Yu,1978	B-0-17-1-0-SS	12.5	4.19	4.41	4.34	N.S	R	5.42	1.291
Yu,1978	B-0-17-2-0-SS	12.5	4.19	4.41	4.34	N.S	R	4.96	1.183
Yu,1978	B-0-17-3-L-SS	12.7	4.20	4.41	4.34	N.S	R	5.36	1.274
Yu,1978	B-0-17-4-L-SS	12.5	4.19	4.41	4.34	N.S	R	5.75	1.371
Yu,1978	B-0-17-5-0-SS	12.5	4.19	4.41	4.34	N.S	R	5.28	1.259

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
Yu,1978	B-0-17-6-0-SS	12.5	4.19	4.28	4.34	N.S	R	5.31	1.267
Yu,1978	B-0-17-7-L-SS	12.5	4.19	4.41	4.34	N.S	R	5.32	1.268
Yu,1978	B-0-17-8-L-SS	12.5	4.19	4.41	4.34	N.S	R	5.45	1.300
Yu,1978	B-0-17-9-H-SS	12.7	4.20	4.41	4.34	N.S	R	5.33	1.268
Yu,1978	B-0-17-10-H-SS	12.5	4.19	4.31	4.34	N.S	R	5.40	1.288
Yu,1978	B-0-18-1-0-SS	19.0	7.95	8.56	8.69	N.S	R	6.30	0.792
Yu,1978	B-0-18-2-0-SS	19.0	7.95	8.61	8.69	N.S	R	6.32	0.795
Yu,1978	B-0-18-3-L-SS	19.0	7.95	8.61	8.69	N.S	R	9.08	1.142
Yu,1978	B-0-18-4-L-SS	19.0	7.95	8.61	8.69	N.S	R	6.63	0.834
Yu,1978	B-0-18-5-0-SS	19.0	7.95	8.61	8.69	N.S	R	6.32	0.795
Yu,1978	B-0-18-6-0-SS	19.0	7.95	8.61	8.69	N.S	R	7.10	0.893
Yu,1978	B-0-18-7-L-SS	19.0	7.95	8.61	8.69	N.S	R	12.2	1.531
Yu,1978	B-0-18-8-L-SS	19.0	7.95	8.81	8.69	N.S	R	11.5	1.444
Yu,1978	B-0-18-9-H-SS	19.0	7.95	8.61	8.69	N.S	R	11.6	1.461
Yu,1978	B-0-18-10-H-SS	19.0	7.95	8.61	8.69	N.S	R	10.4	1.310
Yu,1978	B-0-21-1-0-DS	20.6	4.47	6.61	5.87	N.S	B&E	8.37	1.872
Yu,1978	B-0-21-2-0-DS	20.6	4.47	6.85	5.87	N.S	B&E	8.46	1.892
Yu,1978	B-0-21-3-L-DS	20.6	4.47	6.98	5.87	N.S	B&E	8.46	1.892
Yu,1978	B-0-21-4-L-DS	20.6	4.47	6.85	5.87	N.S	B&E	8.52	1.907
Yu,1978	B-0-21-5-0-DS	20.6	4.47	6.85	5.87	N.S	B&E	8.63	1.932
Yu,1978	B-0-21-6-0-DS	20.6	4.47	7.09	5.87	N.S	B&E	9.03	2.021
Yu,1978	B-0-21-7-L-DS	20.6	4.47	6.85	5.87	N.S	B&E	9.68	2.166
Yu,1978	B-0-21-8-L-DS	20.6	4.47	6.85	5.87	N.S	B&E	9.12	2.041
Yu,1978	B-0-21-9-H-DS	20.6	4.47	6.85	5.87	N.S	B&E	9.95	2.225
Yu,1978	B-0-21-10-H-DS	20.6	4.47	6.85	5.87	N.S	B&E	8.90	1.991
Yu,1978	B-0-22-1-0-DS	39.6	8.91	13.7	11.7	N.S	B&E	11.4	1.279
Yu,1978	B-0-22-2-0-DS	39.6	8.91	13.7	11.7	N.S	B&E	11.1	1.242
Yu,1978	B-0-22-3-L-DS	39.6	8.91	13.7	11.7	N.S	B&E	12.8	1.437
Yu,1978	B-0-22-4-L-DS	39.6	8.91	13.7	11.7	N.S	B&E	10.8	1.212
Yu,1978	B-0-22-5-0-DS	39.6	8.91	13.7	11.7	N.S	B&R	10.8	1.212
Yu,1978	B-0-22-6-0-DS	39.6	8.91	13.7	11.7	N.S	B&R	9.79	1.099
Yu,1978	B-0-22-7-L-DS	39.6	8.91	13.7	11.7	N.S	B&E	12.0	1.349
Yu,1978	B-0-22-8-L-DS	39.6	8.91	13.7	11.7	N.S	B&E	12.1	1.359
Yu,1978	B-0-22-9-H-DS	39.6	8.91	13.7	11.7	N.S	B&E	11.8	1.324
Yu,1978	B-0-22-10-H-DS	39.6	8.91	13.9	11.7	N.S	B&E	12.7	1.429
Yu,1978	B-0-25-1-0-SS	47.5	18.0	19.5	19.6	N.S	R	18.2	1.013
Yu,1978	B-0-25-2-0-SS	47.5	18.0	19.5	19.6	N.S	R	19.0	1.058
Yu,1978	B-0-25-3-L-SS	47.5	18.0	19.5	19.6	N.S	R	20.2	1.125

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
Yu,1978	B-0-25-4-L-SS	47.5	18.0	19.5	19.6	N.S	R	21.0	1.172
Yu,1978	B-0-25-5-H-SS	47.5	18.0	19.5	19.6	N.S	R	20.4	1.137
Yu,1978	B-0-25-6-H-SS	47.5	18.0	19.5	19.6	N.S	R	19.4	1.077
Yu,1978	B-0-26-1-0-SS	66.6	26.8	29.2	29.5	N.S	R	24.4	0.912
Yu,1978	B-0-26-2-0-SS	66.6	26.8	29.2	29.5	N.S	R	24.7	0.924
Yu,1978	B-0-26-3-L-SS	66.6	26.8	29.2	29.5	N.S	R	25.3	0.946
Yu,1978	B-0-26-4-L-SS	66.6	26.8	29.2	29.5	N.S	R	24.7	0.922
Yu,1978	B-0-26-5-0-SS	66.6	26.8	29.2	29.5	N.S	R	24.7	0.923
Yu,1978	B-0-26-6-0-SS	66.6	26.8	29.2	29.5	N.S	R	23.1	0.862
Yu,1978	B-0-26-7-L-SS	66.6	26.8	29.2	29.5	N.S	R	25.0	0.935
Yu,1978	B-0-26-8-L-SS	66.6	26.8	29.2	29.5	N.S	R	24.9	0.932
Yu,1978	B-0-26-9-H-SS	66.6	26.8	29.2	29.5	N.S	R	31.2	1.164
Yu,1978	B-0-26-10-H-SS	66.6	26.8	29.2	29.5	N.S	R	32.7	1.223
Yu,1978	B-0-29-1-0-DS	103	20.2	32.1	26.5	N.S	B&E	30.9	1.528
Yu,1978	B-0-29-2-0-DS	103	20.2	31.5	26.5	N.S	B&E	35.6	1.760
Yu,1978	B-0-29-3-L-DS	103	20.2	31.0	26.5	N.S	B&E	38.3	1.895
Yu,1978	B-0-29-4-L-DS	103	20.2	32.1	26.5	N.S	B&E	38.5	1.906
Yu,1978	B-0-29-5-0-DS	103	20.2	32.6	26.5	N.S	B&E	37.0	1.832
Yu,1978	B-0-29-6-0-DS	103	20.2	32.6	26.5	N.S	B&E	31.4	1.555
Yu,1978	B-0-29-7-L-DS	103	20.2	31.5	26.5	N.S	B&E	40.9	2.027
Yu,1978	B-0-29-8-L-DS	103	20.2	32.6	26.5	N.S	B&E	41.4	2.049
Yu,1978	B-0-29-9-H-DS	103	20.2	32.6	26.5	N.S	B&E	41.2	2.038
Yu,1978	B-0-29-10-H-DS	103	20.2	32.6	26.5	N.S	B&E	40.7	2.016
Yu,1978	B-0-30-1-0-DS	158	30.5	43.7	39.8	N.S	B&E	44.3	1.453
Yu,1978	B-0-30-2-0-DS	158	30.5	45.3	39.8	N.S	B&E	46.7	1.533
Yu,1978	B-0-30-3-L-DS	158	30.5	45.3	39.8	N.S	B&E	51.2	1.679
Yu,1978	B-0-30-4-L-DS	158	30.5	45.3	39.8	N.S	B&E	48.1	1.577
Yu,1978	B-0-30-5-0-DS	158	30.5	45.3	39.8	N.S	B&E	46.2	1.515
Yu,1978	B-0-30-6-0-DS	158	30.5	44.8	39.8	N.S	B&E	43.7	1.435
Yu,1978	B-0-30-7-L-DS	158	30.5	45.3	39.8	N.S	B&E	49.5	1.624
Yu,1978	B-0-30-8-L-DS	158	30.5	45.3	39.8	N.S	B&E	48.1	1.580
Yu,1978	B-0-30-9-H-DS	158	30.5	43.7	39.8	N.S	B&E	50.3	1.650
Yu,1978	B-0-30-10-H-DS	158	30.5	43.7	39.8	N.S	B&E	51.6	1.694
Yu,1978	B-0-32-1-0-SS	9.69	2.98	3.05	3.08	N.S	B&R	2.45	0.822
Yu,1978	B-0-32-2-0-SS	9.69	2.98	2.94	3.08	E	B&R	2.58	0.879
Yu,1978	B-0-32-3-L-SS	9.69	2.98	3.05	3.08	N.S	B&R	2.72	0.915
Yu,1978	B-0-32-4-L-SS	9.69	2.98	3.05	3.08	N.S	B&R	3.14	1.055
Yu,1978	B-0-32-5-0-SS	9.69	2.98	3.05	3.08	N.S	B&R	2.67	0.897

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
Yu,1978	B-0-32-6-0-SS	9.69	2.98	3.10	3.08	N.S	B&R	2.41	0.810
Yu,1978	B-0-32-7-L-SS	9.69	2.98	3.05	3.08	N.S	B&R	2.49	0.837
Yu,1978	B-0-32-8-L-SS	9.69	2.98	3.10	3.08	N.S	B&R	2.39	0.803
Yu,1978	B-0-32-9-H-SS	9.69	2.98	3.10	3.08	N.S	B&N.S	3.61	1.214
Yu,1978	B-0-32-10-H-SS	9.69	2.98	3.05	3.08	N.S	B&N.S	2.89	0.972
Yu,1978	B-0-34-1-0-DS	15.7	3.16	4.85	4.16	N.S	B&E	3.78	1.195
Yu,1978	B-0-34-2-0-DS	15.7	3.16	4.85	4.16	N.S	B&E	3.81	1.205
Yu,1978	B-0-34-3-L-DS	15.7	3.16	4.85	4.16	N.S	B&E	4.25	1.345
Yu,1978	B-0-34-4-L-DS	15.7	3.16	4.85	4.16	N.S	B&E	4.43	1.401
Yu,1978	B-0-34-5-0-DS	15.7	3.16	4.85	4.16	N.S	B&E	3.07	0.970
Yu,1978	B-0-34-6-0-DS	15.7	3.16	4.85	4.16	N.S	B&E	3.63	1.146
Yu,1978	B-0-34-7-L-DS	15.7	3.16	4.85	4.16	N.S	B&E	3.87	1.224
Yu,1978	B-0-34-8-L-DS	15.7	3.16	4.85	4.16	N.S	B&E	4.62	1.460
Yu,1978	B-0-34-9-H-DS	15.7	3.16	4.85	4.16	N.S	B&E	5.03	1.589
Yu,1978	B-0-34-10-H-DS	15.7	3.16	4.85	4.16	N.S	B&E	4.04	1.276
Yu,1978	B-0-37-1-0-SS	18.4	5.62	5.66	5.71	N.S	R	5.37	0.955
Yu,1978	B-0-37-2-0-SS	18.4	5.62	5.66	5.71	N.S	R	5.36	0.953
Yu,1978	B-0-37-3-L-SS	18.4	5.62	5.66	5.71	N.S	R	5.62	0.999
Yu,1978	B-0-37-4-L-SS	18.4	5.62	5.66	5.71	N.S	R	5.55	0.988
Yu,1978	B-0-37-5-H-SS	18.4	5.62	5.66	5.71	N.S	R	5.52	0.982
Yu,1978	B-0-37-6-H-SS	18.4	5.62	5.66	5.71	N.S	R	8.88	1.579
Yu,1978	B-0-38-1-0-SS	24.5	10.4	11.3	11.4	N.S	R	7.01	0.671
Yu,1978	B-0-38-2-0-SS	24.5	10.4	11.3	11.4	N.S	R	7.28	0.697
Yu,1978	B-0-38-3-L-SS	24.5	10.4	11.3	11.4	N.S	R	10.1	0.963
Yu,1978	B-0-38-4-L-SS	24.5	10.4	11.3	11.4	N.S	R	8.68	0.831
Yu,1978	B-0-38-5-0-SS	24.5	10.4	11.3	11.4	N.S	R	7.19	0.688
Yu,1978	B-0-38-6-0-SS	24.5	10.4	11.3	11.4	N.S	R	7.45	0.714
Yu,1978	B-0-38-7-L-SS	24.5	10.4	11.3	11.4	N.S	R	10.4	0.999
Yu,1978	B-0-38-8-L-SS	24.5	10.4	11.3	11.4	N.S	R	8.19	0.784
Yu,1978	B-0-38-9-H-SS	24.5	10.4	11.3	11.4	N.S	R	9.35	0.895
Yu,1978	B-0-38-10-H-SS	24.5	10.4	11.3	11.4	N.S	R	10.4	0.993
Yu,1978	B-0-41-1-0-DS	26.6	5.87	9.00	7.71	N.S	B&E	8.81	1.501
Yu,1978	B-0-41-2-0-DS	26.6	5.87	9.00	7.71	N.S	B&E	9.63	1.641
Yu,1978	B-0-41-3-L-DS	26.6	5.87	9.00	7.71	N.S	B&E	10.6	1.812
Yu,1978	B-0-41-4-L-DS	26.6	5.87	9.00	7.71	N.S	B&E	9.48	1.615
Yu,1978	B-0-41-5-H-DS	26.6	5.87	9.00	7.71	N.S	B&E	10.3	1.759
Yu,1978	B-0-41-6-H-DS	26.6	5.87	9.00	7.71	N.S	B&E	10.7	1.819
Yu,1978	B-0-42-1-0-DS	53.1	11.7	18.0	15.4	N.S	B&E	13.1	1.116

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
Yu,1978	B-0-42-2-0-DS	53.1	11.7	18.0	15.4	N.S	B&E	12.1	1.027
Yu,1978	B-0-42-3-L-DS	53.1	11.7	18.0	15.4	N.S	B&E	12.8	1.092
Yu,1978	B-0-42-4-L-DS	53.1	11.7	18.0	15.4	N.S	B&E	12.1	1.035
Yu,1978	B-0-42-5-0-DS	53.1	11.7	18.0	15.4	N.S	B&E	13.4	1.141
Yu,1978	B-0-42-6-0-DS	53.1	11.7	18.0	15.4	N.S	B&E	13.4	1.141
Yu,1978	B-0-42-7-L-DS	53.1	11.7	18.0	15.4	N.S	B&E	16.8	1.433
Yu,1978	B-0-42-8-L-DS	53.1	11.7	18.0	15.4	N.S	B&E	12.7	1.080
Yu,1978	B-0-42-9-H-DS	53.1	11.7	18.0	15.4	N.S	B&E	17.2	1.469
Yu,1978	B-0-42-10-H-DS	53.1	11.7	18.0	15.4	N.S	B&E	19.3	1.645
Yu,1978	B-0-45-1-0-SS	49.7	22.2	26.0	24.3	N.S	R	18.0	0.808
Yu,1978	B-0-45-2-0-SS	49.7	22.2	24.1	24.3	N.S	R	18.2	0.816
Yu,1978	B-0-45-3-L-SS	49.7	22.2	24.1	24.3	N.S	R	19.3	0.867
Yu,1978	B-0-45-4-L-SS	49.7	22.2	25.2	24.3	N.S	R	19.2	0.865
Yu,1978	B-0-45-5-H-SS	49.7	22.2	25.2	24.3	N.S	R	19.8	0.892
Yu,1978	B-0-45-6-H-SS	49.7	22.2	24.1	24.3	N.S	R	19.8	0.890
Yu,1978	B-0-46-1-0-SS	70.4	33.2	36.1	36.5	N.S	B&R	25.9	0.781
Yu,1978	B-0-46-2-0-SS	70.4	33.2	36.1	36.5	N.S	B&R	24.3	0.733
Yu,1978	B-0-46-3-L-SS	70.4	33.2	36.1	36.5	N.S	B&R	26.7	0.804
Yu,1978	B-0-46-4-L-SS	70.4	33.2	36.1	36.5	N.S	B&R	26.5	0.799
Yu,1978	B-0-46-5-0-SS	70.4	33.2	36.1	36.5	N.S	B&R	26.1	0.787
Yu,1978	B-0-46-6-0-SS	70.4	33.2	36.1	36.5	N.S	B&R	25.9	0.780
Yu,1978	B-0-46-7-L-SS	70.4	33.2	36.1	36.5	N.S	B&R	29.8	0.896
Yu,1978	B-0-46-8-L-SS	70.4	33.2	36.1	36.5	N.S	B&R	26.1	0.787
Yu,1978	B-0-46-9-H-SS	70.4	33.2	36.1	36.5	N.S	B&R	33.4	1.005
Yu,1978	B-0-46-10-H-SS	70.4	33.2	36.1	36.5	N.S	B&R	29.2	0.879
Yu,1978	B-0-49-1-0-DS	111	25.1	39.0	32.8	N.S	B&E	42.6	1.699
Yu,1978	B-0-49-2-0-DS	111	25.1	39.7	32.8	N.S	B&E	37.4	1.491
Yu,1978	B-0-49-3-L-DS	111	25.1	39.0	32.8	N.S	B&E	39.2	1.565
Yu,1978	B-0-49-4-L-DS	111	25.1	39.0	32.8	N.S	B&E	39.8	1.588
Yu,1978	B-0-49-5-H-DS	111	25.1	39.0	32.8	N.S	B&E	40.9	1.633
Yu,1978	B-0-49-6-H-DS	111	25.1	39.0	32.8	N.S	B&E	42.3	1.686
Yu,1978	B-0-50-1-0-DS	166	37.7	57.5	49.3	N.S	B&E	54.5	1.445
Yu,1978	B-0-50-2-0-DS	166	37.7	57.5	49.3	N.S	B&E	53.0	1.404
Yu,1978	B-0-50-3-L-DS	166	37.7	57.5	49.3	N.S	B&E	55.4	1.469
Yu,1978	B-0-50-4-L-DS	166	37.7	57.5	49.3	N.S	B&E	51.8	1.374
Yu,1978	B-0-50-5-0-DS	166	37.7	57.5	49.3	N.S	B&E	50.5	1.339
Yu,1978	B-0-50-6-0-DS	166	37.7	57.5	49.3	N.S	B&E	48.3	1.280
Yu,1978	B-0-50-7-L-DS	166	37.7	57.5	49.3	N.S	B&E	53.4	1.416

Table C2 Test-To-Predicted Values (AISI, 1999 & AS/NZS 4600, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (kN)	Net Section (kN)	End Pull-Out (kN)	Bearing (kN)	Predicted Failure Mode	Actual Failure Mode	Pt (kN)	P_t / P_p
Yu,1978	B-0-50-8-L-DS	166	37.7	57.5	49.3	N.S	B&E	44.9	1.189
Yu,1978	B-0-50-9-H-DS	166	37.7	57.5	49.3	N.S	B&E	62.3	1.652
Yu,1978	B-0-50-10-H-DS	166	37.7	57.5	49.3	N.S	B&E	53.5	1.419
Yu,1978	B-0-51-1-0-SS	189	87.8	97.7	96.4	N.S	R	97.7	1.112
Yu,1978	B-0-51-2-0-SS	189	87.8	97.7	96.4	N.S	R	96.3	1.097
Yu,1978	B-0-51-3-L-SS	189	87.8	99.5	96.4	N.S	R	94.1	1.072
Yu,1978	B-0-51-4-L-SS	189	87.8	97.7	96.4	N.S	R	102	1.161
Yu,1978	B-0-51-5-H-SS	189	87.8	97.7	96.4	N.S	R	95.0	1.082
Yu,1978	B-0-51-6-H-SS	189	87.8	97.7	96.4	N.S	R	97.9	1.115
Yu,1978	B-0-53-1-0-DS	444	99.7	152	130	N.S	B&E	158	1.584
Yu,1978	B-0-53-2-0-DS	444	99.7	156	130	N.S	B&E	155	1.557
Yu,1978	B-0-53-3-L-DS	444	99.7	152	130	N.S	B&E	162	1.624
Yu,1978	B-0-53-4-L-DS	444	99.7	154	130	N.S	B&E	161	1.613
Yu,1978	B-0-53-5-H-DS	444	99.7	148	130	N.S	B&E	161	1.611

Table C3 Test-To-Predicted Values (CSA-S136, 1994)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Carril,1994	AN32-1	62.8	75.3	57.5	41.8	B	B	36.0	0.862
Carril,1994	AN32-2	61.6	73.9	56.5	41.1	B	B	36.5	0.889
Carril,1994	AN33-1	77.2	96.1	57.5	41.8	B	B	40.1	0.959
Carril,1994	AN33-2	78.5	97.7	58.5	42.5	B	B	39.8	0.937
Carril,1994	BN33-1	77.9	97.1	106	84.3	B	B	65.0	0.771
Carril,1994	BN33-2	77.9	97.1	107	84.3	B	B	64.0	0.759
Carril,1994	DN12-2	44.6	57.6	44.0	27.6	B	B	21.1	0.765
Carril,1994	DN12-3	43.6	56.2	43.0	26.3	B	B	21.1	0.802
Carril,1994	DN22-1	65.1	88.2	67.5	49.1	B	B	37.5	0.765
Carril,1994	DN22-2	66.0	89.4	68.2	49.8	B	B	37.8	0.760
Carril,1994	BN32-1	62.7	75.2	106	83.6	N.S	B&N.S	64.3	0.856
Carril,1994	BN32-2	62.0	74.3	105	82.8	N.S	B&N.S	65.4	0.880
Carril,1994	DN32-1	128	153	117	85.0	B	B&R	70.1	0.825
Carril,1994	DN32-2	125	150	115	83.6	B	B&R	71.6	0.856
Carril,1994	EN12-1	44.6	57.6	81.0	55.2	B	B&R	38.5	0.698
Carril,1994	EN12-2	44.6	57.6	81.0	55.2	B	B&R	38.7	0.702
Carril,1994	EN22-1	66.0	89.4	126	99.5	N.S	B&R	70.2	0.785
Carril,1994	EN22-2	66.9	90.5	127	101	N.S	B&R	70.0	0.774
Carril,1994	EN32-1	125	150	211	167	N.S	B&R	128	0.853
Carril,1994	EN32-2	124	149	209	166	N.S	B&R	129	0.866
Carril,1994	AN31-2	31.1	29.6	56.4	41.1	N.S	N.S	29.3	0.989
Carril,1994	AN31-3	31.1	29.6	56.9	41.4	N.S	N.S	29.1	0.984
Carril,1994	BN31-1	31.3	29.7	106	83.6	N.S	N.S	29.4	0.988
Carril,1994	BN31-2	31.3	29.6	106	83.6	N.S	N.S	29.4	0.991
Carril,1994	CN11-1	11.0	11.2	58.8	41.4	N.S	N.S	10.2	0.909
Carril,1994	CN11-2	11.0	11.2	58.9	41.4	N.S	N.S	10.4	0.924
Carril,1994	CN12-1	22.2	28.6	58.9	41.4	N.S	N.S	25.5	0.893
Carril,1994	CN12-2	22.2	28.6	58.9	41.4	N.S	N.S	25.5	0.893
Carril,1994	CN21-1	16.7	18.0	91.2	74.6	N.S	N.S	18.2	1.012
Carril,1994	CN21-2	16.9	18.1	92.5	75.7	N.S	N.S	18.1	0.997
Carril,1994	CN21-3	16.9	18.1	92.5	75.7	N.S	N.S	17.9	0.989
Carril,1994	CN22-1	33.1	44.8	91.4	74.6	N.S	N.S	42.7	0.954
Carril,1994	CN22-2	33.6	45.5	92.6	75.7	N.S	N.S	42.9	0.943
Carril,1994	CN22-3	33.1	44.8	91.3	74.6	N.S	N.S	42.9	0.956
Carril,1994	CN31-2	32.0	30.4	156	127	N.S	N.S	30.8	1.013
Carril,1994	CN31-3	32.3	30.7	157	129	N.S	N.S	30.0	0.980
Carril,1994	CN32-1	64.4	77.2	157	129	N.S	N.S	71.2	0.923

Table C3 Test-To-Predicted Values (CSA-S136, 1994)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Carril,1994	CN32-2	63.6	76.2	156	127	N.S	N.S	70.4	0.924
Carril,1994	DN31-1	63.7	60.4	117	85.0	N.S	N.S	55.2	0.914
Carril,1994	DN31-2	61.7	58.5	113	82.1	N.S	N.S	53.4	0.913
Carril,1994	EN11-1	22.7	23.1	82.8	57.7	N.S	N.S	21.4	0.927
Carril,1994	EN11-2	22.2	22.6	80.9	55.2	N.S	N.S	21.5	0.949
Carril,1994	EN21-1	33.6	36.1	127	101	N.S	N.S	37.4	1.037
Carril,1994	EN21-2	33.5	36.0	127	101	N.S	N.S	37.4	1.040
Carril,1994	EN31-1	62.2	59.0	209	166	N.S	N.S	58.9	0.999
Carril,1994	EN31-2	62.7	59.5	211	167	N.S	N.S	60.3	1.013
Carril,1994	DN11-1	21.2	21.6	42.1	25.1	N.S	N&R	18.1	0.839
Carril,1994	DN11-2	21.7	22.1	42.9	26.3	N.S	N&R	18.7	0.848
Carril,1994	DN21-1	33.6	36.0	69.4	50.5	N.S	N&R	32.0	0.889
Carril,1994	DN21-2	33.1	35.5	68.4	49.8	N.S	N&R	31.5	0.887
Chong,1975	1	35.8	33.9	20.7	10.8	B	B&E	10.9	1.017
Chong,1975	2	35.5	35.8	21.7	9.10	B	B	8.14	0.895
Chong,1975	3	36.3	36.6	22.0	9.10	B	B&E	7.12	0.783
Chong,1975	4	35.8	33.9	20.4	10.8	B	E	9.92	0.922
Chong,1975	5	35.8	33.9	20.8	10.8	B	E	10.8	1.004
Chong,1975	6	35.2	33.3	8.37	10.8	E	B&E	10.6	1.271
Chong,1975	7	35.2	33.3	14.2	10.8	B	E	11.0	1.025
Chong,1975	8	35.2	33.3	17.1	10.8	B	E	10.0	0.930
Chong,1975	9	35.2	33.3	25.8	10.8	B	B	10.1	0.934
Chong,1975	11	35.2	33.3	25.8	10.8	B	B	10.3	0.955
Chong,1975	12	35.2	33.3	14.2	10.8	B	E	10.7	0.996
Chong,1975	13	35.2	33.3	8.37	10.8	E	E&B	10.5	1.255
Chong,1975	14	35.2	33.3	2.55	10.8	E	E	7.48	2.936
Chong,1975	15	35.2	33.3	2.55	10.8	E	E	6.76	2.656
Chong,1975	32	37.1	39.4	24.3	17.1	B	E&B	12.9	0.754
Chong,1975	33	37.1	39.4	23.6	17.1	B	B&E	13.3	0.777
Chong,1975	34	37.1	39.4	23.6	17.1	B	B&E	13.1	0.767
Chong,1975	41	54.9	69.2	5.52	30.2	E	E&B	12.3	2.232
Chong,1975	42	54.9	69.2	5.76	30.2	E	E&B	13.8	2.385
Chong,1975	49	13.9	9.00	41.5	30.2	N.S	N.S	13.5	1.497
Chong,1975	50	13.9	9.00	41.5	30.2	N.S	N.S	12.9	1.438
Chong,1975	51	13.9	9.00	41.5	30.2	N.S	N.S	11.9	1.320
Chong,1975	52	74.3	73.9	72.1	52.1	B	B&E	38.3	0.734
Chong,1975	53	74.3	73.9	72.4	52.1	B	B&E	36.3	0.696
Chong,1975	54	74.3	73.9	72.1	52.1	B	B&E	40.8	0.783

Table C3 Test-To-Predicted Values (CSA-S136, 1994)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Chong,1975	55	111	106	103	73.5	B	B&E	55.6	0.756
Chong,1975	16(3b)	26.6	18.4	17.4	21.5	E	N.S	18.1	1.036
Chong,1975	17(3b)	27.0	18.8	16.7	21.5	E	N.S	18.4	1.098
Chong,1975	37(3b)	37.2	33.2	46.1	34.1	N.S	E&B	24.8	0.748
Chong,1975	40(3b)	54.9	57.8	81.6	60.4	N.S	B	40.0	0.691
Chong,1975	56(3b)	111	78.9	203	147	N.S	E&N	88.3	1.119
Chong,1975	35(3c)	37.3	34.3	76.9	32.0	B	B	23.3	0.729
Chong,1975	36(3c)	37.3	34.3	77.7	32.0	B	B	24.0	0.750
Chong,1975	18(3d)	8.81	4.24	25.1	21.5	N.S	N.S	7.57	1.782
Chong,1975	19(3d)	8.81	4.24	25.1	21.5	N.S	N.S	6.72	1.583
Chong,1975	22(3d)	17.6	13.9	25.1	21.5	N.S	N.S	14.9	1.066
Chong,1975	23(3d)	17.6	13.9	25.1	21.5	N.S	N.S	15.9	1.139
Chong,1975	28(3d)	35.2	33.3	25.1	21.5	B	E	19.5	0.905
Chong,1975	29(3d)	35.2	33.3	25.1	21.5	B	B&E	19.2	0.893
Chong,1975	45(3d)	27.4	28.9	52.1	60.4	N.S	N.S	30.7	1.063
Chong,1975	46(3d)	27.4	28.9	52.1	60.4	N.S	N.S	31.9	1.103
Chong,1975	20(3e)	8.81	4.24	41.8	32.3	N.S	N.S	7.83	1.845
Chong,1975	21(3e)	8.81	4.24	41.8	32.3	N.S	N.S	4.76	1.122
Chong,1975	24(3e)	17.6	13.9	41.8	32.3	N.S	N.S	15.7	1.126
Chong,1975	25(3e)	17.6	13.9	41.8	32.3	N.S	N.S	15.2	1.088
Chong,1975	26(3e)	34.7	32.8	41.8	32.3	B	E	28.8	0.891
Chong,1975	27(3e)	34.7	32.8	41.8	32.3	B	E	28.8	0.893
Chong,1975	43(3e)	55.3	69.8	86.8	90.5	N.S	E&B	58.3	0.836
Chong,1975	44(3e)	55.7	70.4	86.8	90.5	N.S	E&B	60.1	0.854
Chong,1975	47(3e)	13.7	8.80	86.8	90.5	N.S	N.S	13.0	1.476
Chong,1975	48(3e)	13.7	8.80	86.8	90.5	N.S	N.S	13.5	1.532
Gilchrist,1979	1	16.9	17.3	4.79	2.85	B	B&E	3.20	1.126
Gilchrist,1979	2	16.9	17.3	3.40	2.85	B	B&E	2.71	0.954
Gilchrist,1979	3	16.9	17.3	2.56	2.85	E	B&E	2.60	1.016
Gilchrist,1979	4	16.9	16.7	7.24	3.49	B	B&E	3.03	0.868
Gilchrist,1979	5	16.9	16.7	4.45	3.49	B	B	3.00	0.861
Gilchrist,1979	6	16.9	16.7	3.05	3.49	E	B&E	3.16	1.035
Gilchrist,1979	7	24.3	23.9	6.63	4.67	B	B&E	3.78	0.810
Gilchrist,1979	8	24.3	23.9	4.70	4.67	B	B&E	3.89	0.834
Gilchrist,1979	9	24.3	23.9	3.55	4.67	E	B&E	3.69	1.042
Gilchrist,1979	10	24.3	23.1	10.0	4.67	B	B&E	4.01	0.858
Gilchrist,1979	11	24.3	23.1	6.15	4.67	B	B	3.56	0.762
Gilchrist,1979	12	24.3	23.1	4.22	4.67	E	B&E	4.34	1.028

Table C3 Test-To-Predicted Values (CSA-S136, 1994)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Gilchrist,1979	13	24.8	24.5	6.81	4.95	B	B&E	4.58	0.926
Gilchrist,1979	14	24.8	24.5	4.83	4.95	E	B&E	4.29	0.890
Gilchrist,1979	15	24.8	24.5	3.64	4.95	E	B&E	4.18	1.150
Gilchrist,1979	16	24.8	23.7	10.3	5.40	B	B&E	4.34	0.803
Gilchrist,1979	17	24.8	23.7	6.31	5.40	B	B&E	4.36	0.807
Gilchrist,1979	18	24.8	23.7	4.33	5.40	E	B&E	4.05	0.935
Gilchrist,1979	19	24.8	22.7	13.6	6.60	B	B&E	7.23	1.096
Gilchrist,1979	20	24.8	22.7	9.65	6.60	B	B	5.21	0.789
Gilchrist,1979	21	24.8	22.7	5.69	6.60	E	B	5.45	0.958
Gilchrist,1979	22	19.8	22.9	6.35	4.62	B	B&E	3.78	0.819
Gilchrist,1979	23	19.8	22.9	4.51	4.62	E	B&E	3.65	0.810
Gilchrist,1979	24	19.8	22.9	3.40	4.62	E	B&E	4.01	1.179
Gilchrist,1979	25	19.8	22.1	9.59	5.05	B	B&E	4.41	0.873
Gilchrist,1979	26	19.8	22.1	5.89	5.05	B	B&E	4.21	0.833
Gilchrist,1979	27	19.8	22.1	4.04	5.05	E	B&E	4.12	1.018
Gilchrist,1979	28	19.8	21.2	12.7	6.16	B	B	7.16	1.163
Gilchrist,1979	29	19.8	21.2	9.01	6.16	B	B	6.50	1.054
Gilchrist,1979	30	19.8	21.2	5.31	6.16	E	B	5.01	0.942
McGill,2002	043-230-3/8-SS-A	8.03	9.88	10.1	2.94	B	B	1.69	0.574
McGill,2002	043-230-3/8-SS-B	8.03	9.88	10.1	2.94	B	B	1.77	0.601
McGill,2002	043-230-3/8-SS-C	8.03	9.88	10.1	2.94	B	B	1.67	0.567
McGill,2002	043-230-3/8-TTSS-A	8.03	9.88	10.1	2.94	B	B	1.87	0.635
McGill,2002	043-230-3/8-TTSS-B	8.03	9.88	10.1	2.94	B	B	1.77	0.601
McGill,2002	043-230-3/8-TTSS-C	8.03	9.88	10.1	2.94	B	B	2.16	0.734
McGill,2002	043-230-3/8-DS-A	8.03	9.88	10.1	2.94	B	B	3.65	1.240
McGill,2002	043-230-3/8-DS-B	8.03	9.88	10.1	2.94	B	B	3.46	1.175
McGill,2002	043-230-3/8-DS-C	8.03	9.88	10.1	2.94	B	B	3.26	1.107
McGill,2002	043-550-3/8-SS-A	19.3	16.4	16.8	4.89	B	B	2.62	0.535
McGill,2002	043-550-3/8-SS-B	19.3	16.4	16.8	4.89	B	B	2.73	0.558
McGill,2002	043-550-3/8-SS-C	19.3	16.4	16.8	4.89	B	B	2.49	0.509
McGill,2002	043-230-1/2-SS-A	8.03	9.38	9.80	3.93	B	B	2.14	0.545
McGill,2002	043-230-1/2-SS-B	8.03	9.38	9.80	3.93	B	B	2.13	0.543
McGill,2002	043-230-1/2-SS-C	8.03	9.38	9.80	3.93	B	B	2.18	0.555
McGill,2002	043-230-1/2-TTSS-A	8.03	9.38	9.80	3.93	B	B	2.29	0.583
McGill,2002	043-230-1/2-TTSS-B	8.03	9.38	9.80	3.93	B	B	2.24	0.571
McGill,2002	043-230-1/2-TTSS-C	8.03	9.38	9.80	3.93	B	B	2.46	0.627
McGill,2002	043-230-1/2-DS-A	8.03	9.38	9.80	3.93	B	B	5.43	1.383
McGill,2002	043-230-1/2-DS-B	8.03	9.38	9.80	3.93	B	B	5.80	1.477

Table C3 Test-To-Predicted Values (CSA-S136, 1994)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	043-230-1/2-DS-C	8.03	9.38	9.80	3.93	B	B	5.72	1.457
McGill,2002	043-550-1/2-SS-A	19.3	15.6	16.3	6.53	B	B	3.37	0.516
McGill,2002	043-550-1/2-SS-B	19.3	15.6	16.3	6.53	B	B	3.36	0.515
McGill,2002	043-550-1/2-SS-C	19.3	15.6	16.3	6.53	B	B	3.36	0.515
McGill,2002	043-230-5/8-SS-A	8.03	8.89	9.51	4.91	B	B	2.99	0.609
McGill,2002	043-230-5/8-SS-B	8.03	8.89	9.51	4.91	B	B	2.84	0.579
McGill,2002	043-230-5/8-SS-C	8.03	8.89	9.51	4.91	B	B	2.78	0.566
McGill,2002	043-230-5/8-TTSS-A	8.03	8.89	9.51	4.91	B	B	3.09	0.630
McGill,2002	043-230-5/8-TTSS-B	8.03	8.89	9.51	4.91	B	B	3.22	0.656
McGill,2002	043-230-5/8-TTSS-C	8.03	8.89	9.51	4.91	B	B	3.36	0.685
McGill,2002	043-230-5/8-DS-A	8.03	8.89	9.51	4.91	B	B	7.05	1.437
McGill,2002	043-230-5/8-DS-B	8.03	8.89	9.51	4.91	B	B	7.49	1.526
McGill,2002	043-230-5/8-DS-C	8.03	8.89	9.51	4.91	B	B	7.35	1.498
McGill,2002	043-550-5/8-SS-A	19.3	14.8	15.8	8.16	B	B	3.71	0.455
McGill,2002	043-550-5/8-SS-B	19.3	14.8	15.8	8.16	B	B	3.93	0.482
McGill,2002	043-550-5/8-SS-C	19.3	14.8	15.8	8.16	B	B	3.92	0.481
McGill,2002	064-230-5/8-TTSS-A	14.3	12.6	13.5	6.96	B	B	5.22	0.750
McGill,2002	064-230-5/8-TTSS-B	14.3	12.6	13.5	6.96	B	B	4.88	0.701
McGill,2002	064-230-5/8-TTSS-C	14.3	12.6	13.5	6.96	B	B	5.47	0.786
McGill,2002	064-230-5/8-DS-A	14.3	12.6	13.5	6.96	B	B	11.8	1.701
McGill,2002	064-230-5/8-DS-B	14.3	12.6	13.5	6.96	B	B	11.0	1.583
McGill,2002	064-230-5/8-DS-C	14.3	12.6	13.5	6.96	B	B	11.7	1.681
McGill,2002	064-550-5/8-SS-A	33.3	25.5	27.3	14.1	B	B	8.64	0.614
McGill,2002	064-550-5/8-SS-B	33.3	25.5	27.3	14.1	B	B	8.91	0.633
McGill,2002	064-550-5/8-SS-C	33.3	25.5	27.3	14.1	B	B	8.34	0.592
McGill,2002	064-230-1/2-TTSS-A	14.3	13.3	13.9	5.57	B	B	4.56	0.819
McGill,2002	064-230-1/2-TTSS-B	14.3	13.3	13.9	5.57	B	B	4.44	0.797
McGill,2002	064-230-1/2-TTSS-C	14.3	13.3	13.9	5.57	B	B	4.10	0.736
McGill,2002	064-230-1/2-DS-A	14.3	13.3	13.9	5.57	B	B	8.91	1.600
McGill,2002	064-230-1/2-DS-B	14.3	13.3	13.9	5.57	B	B	9.28	1.666
McGill,2002	064-230-1/2-DS-C	14.3	13.3	13.9	5.57	B	B	9.23	1.657
McGill,2002	064-550-1/2-SS-A	33.3	26.9	28.1	11.3	B	B	6.94	0.616
McGill,2002	064-550-1/2-SS-B	33.3	26.9	28.1	11.3	B	B	7.26	0.644
McGill,2002	064-550-1/2-SS-C	33.3	26.9	28.1	11.3	B	B	7.04	0.625
McGill,2002	064-230-3/8-SS-A	14.3	14.0	14.3	4.14	B	B	3.05	0.736
McGill,2002	064-230-3/8-SS-B	14.3	14.0	14.3	4.14	B	B	2.75	0.664
McGill,2002	064-230-3/8-SS-C	14.3	14.0	14.3	4.14	B	B	2.77	0.668
McGill,2002	064-550-3/8-SS-A	33.3	28.3	29.0	8.38	B	B	5.83	0.695

Table C3 Test-To-Predicted Values (CSA-S136, 1994)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	064-550-3/8-SS-B	33.3	28.3	29.0	8.38	B	B	6.43	0.767
McGill,2002	064-550-3/8-SS-C	33.3	28.3	29.0	8.38	B	B	5.82	0.694
McGill,2002	064-230-1/4-DS-A	14.3	14.7	14.7	4.14	B	B	6.76	1.631
McGill,2002	064-230-1/4-DS-B	14.3	14.7	14.7	4.14	B	B	6.67	1.610
McGill,2002	064-230-1/4-DS-C	14.3	14.7	14.7	4.14	B	B	6.38	1.540
McGill,2002	064-550-1/4-SS-A	33.3	29.7	29.8	8.38	B	B	5.68	0.678
McGill,2002	064-550-1/4-SS-B	33.3	29.7	29.8	8.38	B	B	5.55	0.662
McGill,2002	064-550-1/4-SS-C	33.3	29.7	29.8	8.38	B	B	5.90	0.704
McGill,2002	064-230-1/4-SS-A	14.3	14.7	14.7	4.14	B	B	2.92	0.705
McGill,2002	064-230-1/4-SS-B	14.3	14.7	14.7	4.14	B	B	3.07	0.741
McGill,2002	064-230-1/4-SS-C	14.3	14.7	14.7	4.14	B	B	3.00	0.724
McGill,2002	064-230-1/4-TTSS-A	14.3	14.7	14.7	4.14	B	B	2.95	0.712
McGill,2002	064-230-1/4-TTSS-B	14.3	14.7	14.7	4.14	B	B	3.29	0.794
McGill,2002	064-230-1/4-TTSS-C	14.3	14.7	14.7	4.14	B	B	3.80	0.917
McGill,2002	076-230-1/2-SS-A	18.5	17.4	18.2	6.19	B	B	4.77	0.770
McGill,2002	076-230-1/2-SS-B	18.5	17.4	18.2	6.19	B	B	4.53	0.732
McGill,2002	076-230-1/2-SS-C	18.5	17.4	18.2	6.19	B	B	4.90	0.791
McGill,2002	076-230-1/2-TTSS-A	18.5	17.4	18.2	6.19	B	B	5.22	0.843
McGill,2002	076-230-1/2-TTSS-B	18.5	17.4	18.2	6.19	B	B	5.90	0.953
McGill,2002	076-230-1/2-TTSS-C	18.5	17.4	18.2	6.19	B	B	5.41	0.874
McGill,2002	076-230-1/2-DS-A	18.5	17.4	18.2	6.19	B	B	10.8	1.750
McGill,2002	076-230-1/2-DS-B	18.5	17.4	18.2	6.19	B	B	11.8	1.911
McGill,2002	076-230-1/2-DS-C	18.5	17.4	18.2	6.19	B	B	10.5	1.701
McGill,2002	076-550-1/2-SS-A	38.4	31.1	32.5	11.7	B	B	8.50	0.728
McGill,2002	076-550-1/2-SS-B	38.4	31.1	32.5	11.7	B	B	8.06	0.690
McGill,2002	076-550-1/2-SS-C	38.4	31.1	32.5	11.7	B	B	8.50	0.728
McGill,2002	076-230-5/8-SS-A	18.5	16.5	17.6	9.10	B	B	6.17	0.678
McGill,2002	076-230-5/8-SS-B	18.5	16.5	17.6	9.10	B	B	6.04	0.664
McGill,2002	076-230-5/8-SS-C	18.5	16.5	17.6	9.10	B	B	6.04	0.664
McGill,2002	076-550-3/8-SS-A	38.4	32.7	33.5	11.7	B	B	8.19	0.701
McGill,2002	076-550-3/8-SS-B	38.4	32.7	33.5	11.7	B	B	7.80	0.668
McGill,2002	076-550-3/8-SS-C	38.4	32.7	33.5	11.7	B	B	6.61	0.566
McGill,2002	076-550-1/4-SS-A	38.4	34.4	34.4	9.76	B	B	7.01	0.718
McGill,2002	076-550-1/4-SS-B	38.4	34.4	34.4	9.76	B	B	6.80	0.697
McGill,2002	076-550-1/4-SS-C	38.4	34.4	34.4	9.76	B	B	6.55	0.671
McGill,2002	091-230-1/4-SS-A	20.0	21.6	21.7	6.14	B	B	4.65	0.758
McGill,2002	091-230-1/4-SS-B	20.0	21.6	21.7	6.14	B	B	5.14	0.838
McGill,2002	091-230-1/4-SS-C	20.0	21.6	21.7	6.14	B	B	4.83	0.787

Table C3 Test-To-Predicted Values (CSA-S136, 1994)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	091-230-1/4-TTSS-A	20.0	21.6	21.7	6.14	B	B	7.94	1.294
McGill,2002	091-230-1/4-TTSS-B	20.0	21.6	21.7	6.14	B	B	7.46	1.216
McGill,2002	091-230-1/4-TTSS-C	20.0	21.6	21.7	6.14	B	B	7.51	1.224
McGill,2002	091-230-1/4-DS-A	20.0	21.6	21.7	6.14	B	B	12.7	2.068
McGill,2002	091-230-1/4-DS-B	20.0	21.6	21.7	6.14	B	B	12.4	2.014
McGill,2002	091-230-1/4-DS-C	20.0	21.6	21.7	6.14	B	B	11.2	1.832
McGill,2002	091-230-1/2-TTSS-A	20.0	19.6	20.4	8.79	B	B	6.91	0.786
McGill,2002	091-230-1/2-TTSS-B	20.0	19.6	20.4	8.79	B	B	6.94	0.789
McGill,2002	091-230-1/2-TTSS-C	20.0	19.6	20.4	8.79	B	B	7.00	0.796
McGill,2002	091-230-1/2-DS-A	20.0	19.6	20.4	8.79	B	B	14.3	1.626
McGill,2002	091-230-1/2-DS-B	20.0	19.6	20.4	8.79	B	B	13.6	1.546
McGill,2002	091-230-1/2-DS-C	20.0	19.6	20.4	8.79	B	B	13.4	1.528
McGill,2002	121-230-1/2-TTSS-A	30.2	30.5	31.9	19.1	B	B	10.3	0.535
McGill,2002	121-230-1/2-TTSS-B	30.2	30.5	31.9	19.1	B	B	10.3	0.540
McGill,2002	121-230-1/2-TTSS-C	30.2	30.5	31.9	19.1	B	B	12.0	0.627
McGill,2002	121-230-1/2-DS-A	30.2	30.5	31.9	19.1	B	B	18.6	0.972
McGill,2002	121-230-1/2-DS-B	30.2	30.5	31.9	19.1	B	B	20.9	1.091
McGill,2002	121-230-1/2-DS-C	30.2	30.5	31.9	19.1	B	B	18.3	0.954
McGill,2002	121-230-3/8-SS-A	30.2	32.1	32.8	14.4	B	B	8.39	0.584
McGill,2002	121-230-3/8-SS-B	30.2	32.1	32.8	14.4	B	B	8.54	0.595
McGill,2002	121-230-3/8-SS-C	30.2	32.1	32.8	14.4	B	B	8.89	0.619
McGill,2002	121-230-3/8-TTSS-A	30.2	32.1	32.8	14.4	B	B	9.28	0.646
McGill,2002	121-230-3/8-TTSS-B	30.2	32.1	32.8	14.4	B	B	9.03	0.629
McGill,2002	121-230-3/8-TTSS-C	30.2	32.1	32.8	14.4	B	B	9.70	0.676
McGill,2002	121-230-3/8-DS-A	30.2	32.1	32.8	14.4	B	B	20.5	1.425
McGill,2002	121-230-3/8-DS-B	30.2	32.1	32.8	14.4	B	B	18.4	1.278
McGill,2002	121-230-3/8-DS-C	30.2	32.1	32.8	14.4	B	B	16.4	1.141
McGill,2002	153-230-1/4-SS-A	33.3	36.5	36.6	10.4	B	B	10.0	0.964
McGill,2002	153-230-1/4-SS-B	33.3	36.5	36.6	10.4	B	B	9.80	0.946
McGill,2002	153-230-1/4-SS-C	33.3	36.5	36.6	10.4	B	B	9.49	0.916
Wallace,2000	1-wo-50	22.4	20.6	27.0	9.31	B	B	6.29	0.675
Wallace,2000	2-wo-50	22.4	20.6	27.0	9.31	B	B	6.95	0.746
Wallace,2000	3-wo-50	22.4	20.6	27.0	9.31	B	B	6.53	0.701
Wallace,2000	1-wo-40	22.4	20.6	21.1	9.31	B	B	6.64	0.713
Wallace,2000	2-wo-40	22.4	20.6	21.1	9.31	B	B	6.12	0.657
Wallace,2000	3-wo-40	22.4	20.6	21.1	9.31	B	B	6.70	0.719
Wallace,2000	1-wo-30	22.4	20.6	15.3	9.31	B	B	6.38	0.685
Wallace,2000	2-wo-30	22.4	20.6	15.3	9.31	B	B	6.41	0.688

Table C3 Test-To-Predicted Values (CSA-S136, 1994)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Wallace,2000	3-wo-30	22.4	20.6	15.3	9.31	B	B	6.24	0.670
Wallace,2000	1-wo-20	22.4	20.6	9.41	9.31	B	B	5.89	0.632
Wallace,2000	2-wo-20	22.4	20.6	9.41	9.31	B	B	6.20	0.666
Wallace,2000	3-wo-20	22.4	20.6	9.41	9.31	B	B	6.60	0.709
Wallace,2000	1-wo-20-t5	22.4	20.6	9.41	9.31	B	B	7.24	0.777
Wallace,2000	2-wo-20-t5	22.4	20.6	9.41	9.31	B	B	6.63	0.712
Wallace,2000	3-wo-20-t5	22.4	20.6	9.41	9.31	B	B	6.45	0.692
Wallace,2000	1-wo-20-t15	22.4	20.6	9.41	9.31	B	B	7.11	0.763
Wallace,2000	2-wo-20-t15	22.4	20.6	9.41	9.31	B	B	6.50	0.698
Wallace,2000	3-wo-20-t15	22.4	20.6	9.41	9.31	B	B	7.71	0.828
Wallace,2000	1-wo-30-50	22.4	20.6	40.0	18.6	B	B	14.5	0.776
Wallace,2000	2-wo-30-50	22.4	20.6	40.0	18.6	B	B	15.3	0.820
Wallace,2000	3-wo-30-50	22.4	20.6	40.0	18.6	B	B	14.2	0.760
Wallace,2000	1-wo-30-40	22.4	20.6	34.1	18.6	B	B	14.1	0.759
Wallace,2000	2-wo-30-40	22.4	20.6	34.1	18.6	B	B	14.6	0.782
Wallace,2000	3-wo-30-40	22.4	20.6	34.1	18.6	B	B	14.2	0.761
Wallace,2000	1-wo-30-30	22.4	20.6	28.2	18.6	B	B	15.1	0.811
Wallace,2000	2-wo-30-30	22.4	20.6	28.2	18.6	B	B	15.3	0.823
Wallace,2000	3-wo-30-30	22.4	20.6	28.2	18.6	B	B	14.0	0.749
Wallace,2000	1-wo-40-3/8	22.4	19.0	20.2	9.39	B	B	7.26	0.773
Wallace,2000	2-wo-40-3/8	22.4	19.0	20.2	9.39	B	B	7.52	0.801
Wallace,2000	3-wo-40-3/8	22.4	19.0	20.2	9.39	B	B	7.65	0.815
Wallace,2000	1-wo-30-5/16	22.4	19.8	14.8	9.39	B	B	7.82	0.833
Wallace,2000	2-wo-30-5/16	22.4	19.8	14.8	9.39	B	B	6.58	0.701
Wallace,2000	3-wo-30-5/16	22.4	19.8	14.8	9.39	B	B	6.98	0.743
Wallace,2000	1-wo-50-1/2	22.4	17.5	25.1	12.4	B	B	9.80	0.789
Wallace,2000	2-wo-50-1/2	22.4	17.5	25.1	12.4	B	B	9.62	0.775
Wallace,2000	3-wo-50-1/2	22.4	17.5	25.1	12.4	B	B	9.16	0.738
Wallace,2000	1-wo-50-5/8	22.4	15.9	24.2	15.5	B	B	10.3	0.664
Wallace,2000	2-wo-50-5/8	22.4	15.9	24.2	15.5	B	B	10.3	0.665
Wallace,2000	3-wo-50-5/8	22.4	15.9	24.2	15.5	B	B	10.3	0.661
Wallace,2000	1-wo-ss-5/16	11.2	9.90	7.40	4.69	B	B	3.23	0.688
Wallace,2000	2-wo-ss-5/16	11.2	9.90	7.40	4.69	B	B	3.27	0.697
Wallace,2000	3-wo-ss-5/16	11.2	9.90	7.40	4.69	B	B	3.39	0.722
Wallace,2000	1-wo-sst-5/16	24.6	20.2	15.1	11.9	B	B	9.12	0.769
Wallace,2000	2-wo-sst-5/16	24.6	20.2	15.1	11.9	B	B	8.51	0.717
Wallace,2000	3-wo-sst-5/16	24.6	20.2	15.1	11.9	B	B	8.26	0.696
Wallace,2000	1-wo-sst-1/4	24.6	21.0	15.6	9.49	B	B	9.16	0.965

Table C3 Test-To-Predicted Values (CSA-S136, 1994)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Wallace,2000	2-wo-sst-1/4	24.6	21.0	15.6	9.49	B	B	8.92	0.940
Wallace,2000	3-wo-sst-1/4	24.6	21.0	15.6	9.49	B	B	9.03	0.951
Wallace,2000	1-wo-mix-1/4	11.2	10.3	7.64	4.66	B	B	3.52	0.756
Wallace,2000	2-wo-mix-1/4	11.2	10.3	7.64	4.66	B	B	3.47	0.745
Wallace,2000	3-wo-mix-1/4	11.2	10.3	7.64	4.66	B	B	3.73	0.801
Wallace,2000	1-wo-ss-1/4	11.2	10.3	7.64	4.66	B	B	3.27	0.702
Wallace,2000	2-wo-ss-1/4	11.2	10.3	7.64	4.66	B	B	3.30	0.709
Wallace,2000	1-wo-ss-1/2	11.2	8.73	6.71	6.21	B	B	4.25	0.684
Wallace,2000	2-wo-ss-1/2	11.2	8.73	6.71	6.21	B	B	4.43	0.713
Wallace,2000	3-wo-ss-1/2	11.2	8.73	6.71	6.21	B	B	4.00	0.644
Wallace,2000	1-wo-ss-5/8	11.2	7.95	6.24	7.76	E	B	5.45	0.873
Wallace,2000	2-wo-ss-5/8	11.2	7.95	6.24	7.76	E	B	5.43	0.870
Wallace,2000	3-wo-ss-5/8	11.2	7.95	6.24	7.76	E	B	5.41	0.867
Yu,1978	B-0-12-1-0-SS	4.78	4.94	1.43	1.23	B	R	1.73	1.405
Yu,1978	B-0-12-2-0-SS	4.78	4.94	1.43	1.23	B	R	1.40	1.141
Yu,1978	B-0-12-3-L-SS	4.78	4.94	1.48	1.23	B	R	1.40	1.141
Yu,1978	B-0-12-4-L-SS	4.78	4.94	1.48	1.23	B	R	1.50	1.224
Yu,1978	B-0-12-5-0-SS	4.78	4.94	1.43	1.23	B	R	1.36	1.104
Yu,1978	B-0-12-6-0-SS	4.78	4.94	1.48	1.23	B	R	1.44	1.170
Yu,1978	B-0-12-7-L-SS	4.78	4.94	1.43	1.23	B	R	1.58	1.289
Yu,1978	B-0-12-8-L-SS	4.66	4.80	1.45	1.23	B	R	1.45	1.180
Yu,1978	B-0-12-9-H-SS	4.71	4.85	1.45	1.23	B	R	1.70	1.387
Yu,1978	B-0-12-10-H-SS	4.78	4.94	1.48	1.23	B	R	2.25	1.829
Yu,1978	B-0-14-1-0-DS	7.89	8.69	2.58	1.23	B	B&E	2.42	1.966
Yu,1978	B-0-14-2-0-DS	7.89	8.69	2.58	1.23	B	B&E	2.13	1.731
Yu,1978	B-0-14-3-L-DS	7.89	8.69	2.58	1.23	B	B&E	2.55	2.078
Yu,1978	B-0-14-4-L-DS	7.89	8.69	2.58	1.23	B	B&E	2.36	1.919
Yu,1978	B-0-14-5-0-DS	7.89	8.69	2.58	1.23	B	B&E	2.33	1.894
Yu,1978	B-0-14-6-0-DS	7.89	8.69	2.58	1.23	B	B&E	2.14	1.745
Yu,1978	B-0-14-7-L-DS	7.89	8.69	2.58	1.23	B	B&E	3.06	2.491
Yu,1978	B-0-14-8-L-DS	7.89	8.69	2.58	1.23	B	B&E	3.15	2.564
Yu,1978	B-0-14-9-H-DS	7.89	8.69	2.58	1.23	B	B&E	2.46	1.999
Yu,1978	B-0-14-10-H-DS	7.89	8.69	2.58	1.23	B	B&E	2.41	1.963
Yu,1978	B-0-17-1-0-SS	12.5	13.2	3.97	5.87	E	R	5.42	1.365
Yu,1978	B-0-17-2-0-SS	12.5	13.2	3.97	5.87	E	R	4.96	1.250
Yu,1978	B-0-17-3-L-SS	12.7	13.5	3.97	5.87	E	R	5.36	1.350
Yu,1978	B-0-17-4-L-SS	12.5	13.2	3.97	5.87	E	R	5.75	1.449
Yu,1978	B-0-17-5-0-SS	12.5	13.2	3.97	5.87	E	R	5.28	1.331

Table C3 Test-To-Predicted Values (CSA-S136, 1994)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-17-6-0-SS	12.5	13.2	3.82	5.87	E	R	5.31	1.392
Yu,1978	B-0-17-7-L-SS	12.5	13.2	3.97	5.87	E	R	5.32	1.340
Yu,1978	B-0-17-8-L-SS	12.5	13.2	3.97	5.87	E	R	5.45	1.374
Yu,1978	B-0-17-9-H-SS	12.7	13.5	3.97	5.87	E	R	5.33	1.344
Yu,1978	B-0-17-10-H-SS	12.5	13.2	3.85	5.87	E	R	5.40	1.405
Yu,1978	B-0-18-1-0-SS	19.0	19.1	7.64	8.45	E	R	6.30	0.825
Yu,1978	B-0-18-2-0-SS	19.0	19.1	7.69	8.45	E	R	6.32	0.822
Yu,1978	B-0-18-3-L-SS	19.0	19.1	7.69	8.45	E	R	9.08	1.180
Yu,1978	B-0-18-4-L-SS	19.0	19.1	7.69	8.45	E	R	6.63	0.862
Yu,1978	B-0-18-5-0-SS	19.0	19.1	7.69	8.45	E	R	6.32	0.822
Yu,1978	B-0-18-6-0-SS	19.0	19.1	7.69	8.45	E	R	7.10	0.923
Yu,1978	B-0-18-7-L-SS	19.0	19.1	7.69	8.45	E	R	12.2	1.582
Yu,1978	B-0-18-8-L-SS	19.0	19.1	7.93	8.45	E	R	11.5	1.448
Yu,1978	B-0-18-9-H-SS	19.0	19.1	7.69	8.45	E	R	11.6	1.510
Yu,1978	B-0-18-10-H-SS	19.0	19.1	7.69	8.45	E	R	10.4	1.354
Yu,1978	B-0-21-1-0-DS	20.6	23.2	6.61	5.87	B	B&E	8.37	1.425
Yu,1978	B-0-21-2-0-DS	20.6	23.2	6.90	5.87	B	B&E	8.46	1.440
Yu,1978	B-0-21-3-L-DS	20.6	23.2	7.05	5.87	B	B&E	8.46	1.440
Yu,1978	B-0-21-4-L-DS	20.6	23.2	6.90	5.87	B	B&E	8.52	1.451
Yu,1978	B-0-21-5-0-DS	20.6	23.2	6.90	5.87	B	B&E	8.63	1.470
Yu,1978	B-0-21-6-0-DS	20.6	23.2	7.19	5.87	B	B&E	9.03	1.539
Yu,1978	B-0-21-7-L-DS	20.6	23.2	6.90	5.87	B	B&E	9.68	1.648
Yu,1978	B-0-21-8-L-DS	20.6	23.2	6.90	5.87	B	B&E	9.12	1.554
Yu,1978	B-0-21-9-H-DS	20.6	23.2	6.90	5.87	B	B&E	9.95	1.694
Yu,1978	B-0-21-10-H-DS	20.6	23.2	6.90	5.87	B	B&E	8.90	1.516
Yu,1978	B-0-22-1-0-DS	39.6	44.5	13.8	8.45	B	B&E	11.4	1.347
Yu,1978	B-0-22-2-0-DS	39.6	44.5	13.8	8.45	B	B&E	11.1	1.308
Yu,1978	B-0-22-3-L-DS	39.6	44.5	13.8	8.45	B	B&E	12.8	1.513
Yu,1978	B-0-22-4-L-DS	39.6	44.5	13.8	8.45	B	B&E	10.8	1.276
Yu,1978	B-0-22-5-0-DS	39.6	44.5	13.8	8.45	B	B&R	10.8	1.276
Yu,1978	B-0-22-6-0-DS	39.6	44.5	13.8	8.45	B	B&R	9.79	1.158
Yu,1978	B-0-22-7-L-DS	39.6	44.5	13.8	8.45	B	B&E	12.0	1.421
Yu,1978	B-0-22-8-L-DS	39.6	44.5	13.8	8.45	B	B&E	12.1	1.432
Yu,1978	B-0-22-9-H-DS	39.6	44.5	13.8	8.45	B	B&E	11.8	1.395
Yu,1978	B-0-22-10-H-DS	39.6	44.5	14.1	8.45	B	B&E	12.7	1.505
Yu,1978	B-0-25-1-0-SS	47.5	43.1	17.4	26.5	E	R	18.2	1.047
Yu,1978	B-0-25-2-0-SS	47.5	43.1	17.4	26.5	E	R	19.0	1.093
Yu,1978	B-0-25-3-L-SS	47.5	43.1	17.4	26.5	E	R	20.2	1.162

Table C3 Test-To-Predicted Values (CSA-S136, 1994)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-25-4-L-SS	47.5	43.1	17.4	26.5	E	R	21.0	1.211
Yu,1978	B-0-25-5-H-SS	47.5	43.1	17.4	26.5	E	R	20.4	1.175
Yu,1978	B-0-25-6-H-SS	47.5	43.1	17.4	26.5	E	R	19.4	1.114
Yu,1978	B-0-26-1-0-SS	66.6	59.9	26.4	39.3	E	R	24.4	0.924
Yu,1978	B-0-26-2-0-SS	66.6	59.9	26.4	39.3	E	R	24.7	0.936
Yu,1978	B-0-26-3-L-SS	66.6	59.9	26.4	39.3	E	R	25.3	0.959
Yu,1978	B-0-26-4-L-SS	66.6	59.9	26.4	39.3	E	R	24.7	0.934
Yu,1978	B-0-26-5-0-SS	66.6	59.9	26.4	39.3	E	R	24.7	0.935
Yu,1978	B-0-26-6-0-SS	66.6	59.9	26.4	39.3	E	R	23.1	0.873
Yu,1978	B-0-26-7-L-SS	66.6	59.9	26.4	39.3	E	R	25.0	0.947
Yu,1978	B-0-26-8-L-SS	66.6	59.9	26.4	39.3	E	R	24.9	0.944
Yu,1978	B-0-26-9-H-SS	66.6	59.9	26.4	39.3	E	R	31.2	1.180
Yu,1978	B-0-26-10-H-SS	66.6	59.9	26.4	39.3	E	R	32.7	1.239
Yu,1978	B-0-29-1-0-DS	103	105	32.5	26.5	B	B&E	30.9	1.163
Yu,1978	B-0-29-2-0-DS	103	105	31.8	26.5	B	B&E	35.6	1.340
Yu,1978	B-0-29-3-L-DS	103	105	31.2	26.5	B	B&E	38.3	1.442
Yu,1978	B-0-29-4-L-DS	103	105	32.5	26.5	B	B&E	38.5	1.451
Yu,1978	B-0-29-5-0-DS	103	105	33.2	26.5	B	B&E	37.0	1.394
Yu,1978	B-0-29-6-0-DS	103	105	33.2	26.5	B	B&E	31.4	1.184
Yu,1978	B-0-29-7-L-DS	103	105	31.8	26.5	B	B&E	40.9	1.543
Yu,1978	B-0-29-8-L-DS	103	105	33.2	26.5	B	B&E	41.4	1.560
Yu,1978	B-0-29-9-H-DS	103	105	33.2	26.5	B	B&E	41.2	1.551
Yu,1978	B-0-29-10-H-DS	103	105	33.2	26.5	B	B&E	40.7	1.535
Yu,1978	B-0-30-1-0-DS	158	163	43.8	39.3	B	B&E	44.3	1.127
Yu,1978	B-0-30-2-0-DS	158	163	45.8	39.3	B	B&E	46.7	1.190
Yu,1978	B-0-30-3-L-DS	158	163	45.8	39.3	B	B&E	51.2	1.303
Yu,1978	B-0-30-4-L-DS	158	163	45.8	39.3	B	B&E	48.1	1.224
Yu,1978	B-0-30-5-0-DS	158	163	45.8	39.3	B	B&E	46.2	1.176
Yu,1978	B-0-30-6-0-DS	158	163	45.1	39.3	B	B&E	43.7	1.114
Yu,1978	B-0-30-7-L-DS	158	163	45.8	39.3	B	B&E	49.5	1.260
Yu,1978	B-0-30-8-L-DS	158	163	45.8	39.3	B	B&E	48.1	1.226
Yu,1978	B-0-30-9-H-DS	158	163	43.8	39.3	B	B&E	50.3	1.280
Yu,1978	B-0-30-10-H-DS	158	163	43.8	39.3	B	B&E	51.6	1.314
Yu,1978	B-0-32-1-0-SS	9.69	9.53	2.72	2.56	B	B&R	2.45	0.956
Yu,1978	B-0-32-2-0-SS	9.69	9.53	2.59	2.56	B	B&R	2.58	1.008
Yu,1978	B-0-32-3-L-SS	9.69	9.53	2.72	2.56	B	B&R	2.72	1.064
Yu,1978	B-0-32-4-L-SS	9.69	9.53	2.72	2.56	B	B&R	3.14	1.227
Yu,1978	B-0-32-5-0-SS	9.69	9.53	2.72	2.56	B	B&R	2.67	1.043

Table C3 Test-To-Predicted Values (CSA-S136, 1994)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-32-6-0-SS	9.69	9.53	2.79	2.56	B	B&R	2.41	0.942
Yu,1978	B-0-32-7-L-SS	9.69	9.53	2.72	2.56	B	B&R	2.49	0.973
Yu,1978	B-0-32-8-L-SS	9.69	9.53	2.79	2.56	B	B&R	2.39	0.933
Yu,1978	B-0-32-9-H-SS	9.69	9.53	2.79	2.56	B	B&N.S	3.61	1.411
Yu,1978	B-0-32-10-H-SS	9.69	9.53	2.72	2.56	B	B&N.S	2.89	1.130
Yu,1978	B-0-34-1-0-DS	15.7	16.5	4.88	2.56	B	B&E	3.78	1.477
Yu,1978	B-0-34-2-0-DS	15.7	16.5	4.88	2.56	B	B&E	3.81	1.489
Yu,1978	B-0-34-3-L-DS	15.7	16.5	4.88	2.56	B	B&E	4.25	1.662
Yu,1978	B-0-34-4-L-DS	15.7	16.5	4.88	2.56	B	B&E	4.43	1.731
Yu,1978	B-0-34-5-0-DS	15.7	16.5	4.88	2.56	B	B&E	3.07	1.199
Yu,1978	B-0-34-6-0-DS	15.7	16.5	4.88	2.56	B	B&E	3.63	1.416
Yu,1978	B-0-34-7-L-DS	15.7	16.5	4.88	2.56	B	B&E	3.87	1.512
Yu,1978	B-0-34-8-L-DS	15.7	16.5	4.88	2.56	B	B&E	4.62	1.804
Yu,1978	B-0-34-9-H-DS	15.7	16.5	4.88	2.56	B	B&E	5.03	1.964
Yu,1978	B-0-34-10-H-DS	15.7	16.5	4.88	2.56	B	B&E	4.04	1.576
Yu,1978	B-0-37-1-0-SS	18.4	20.2	5.05	7.71	E	R	5.37	1.063
Yu,1978	B-0-37-2-0-SS	18.4	20.2	5.05	7.71	E	R	5.36	1.061
Yu,1978	B-0-37-3-L-SS	18.4	20.2	5.05	7.71	E	R	5.62	1.112
Yu,1978	B-0-37-4-L-SS	18.4	20.2	5.05	7.71	E	R	5.55	1.099
Yu,1978	B-0-37-5-H-SS	18.4	20.2	5.05	7.71	E	R	5.52	1.093
Yu,1978	B-0-37-6-H-SS	18.4	20.2	5.05	7.71	E	R	8.88	1.758
Yu,1978	B-0-38-1-0-SS	24.5	25.1	10.1	9.56	B	R	7.01	0.733
Yu,1978	B-0-38-2-0-SS	24.5	25.1	10.1	9.56	B	R	7.28	0.761
Yu,1978	B-0-38-3-L-SS	24.5	25.1	10.1	9.56	B	R	10.1	1.052
Yu,1978	B-0-38-4-L-SS	24.5	25.1	10.1	9.56	B	R	8.68	0.907
Yu,1978	B-0-38-5-0-SS	24.5	25.1	10.1	9.56	B	R	7.19	0.752
Yu,1978	B-0-38-6-0-SS	24.5	25.1	10.1	9.56	B	R	7.45	0.779
Yu,1978	B-0-38-7-L-SS	24.5	25.1	10.1	9.56	B	R	10.4	1.091
Yu,1978	B-0-38-8-L-SS	24.5	25.1	10.1	9.56	B	R	8.19	0.856
Yu,1978	B-0-38-9-H-SS	24.5	25.1	10.1	9.56	B	R	9.35	0.977
Yu,1978	B-0-38-10-H-SS	24.5	25.1	10.1	9.56	B	R	10.4	1.084
Yu,1978	B-0-41-1-0-DS	26.6	30.5	9.06	7.71	B	B&E	8.81	1.143
Yu,1978	B-0-41-2-0-DS	26.6	30.5	9.06	7.71	B	B&E	9.63	1.249
Yu,1978	B-0-41-3-L-DS	26.6	30.5	9.06	7.71	B	B&E	10.6	1.379
Yu,1978	B-0-41-4-L-DS	26.6	30.5	9.06	7.71	B	B&E	9.48	1.229
Yu,1978	B-0-41-5-H-DS	26.6	30.5	9.06	7.71	B	B&E	10.3	1.339
Yu,1978	B-0-41-6-H-DS	26.6	30.5	9.06	7.71	B	B&E	10.7	1.385
Yu,1978	B-0-42-1-0-DS	53.1	61.1	18.1	9.56	B	B&E	13.1	1.370

Table C3 Test-To-Predicted Values (CSA-S136, 1994)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-42-2-0-DS	53.1	61.1	18.1	9.56	B	B&E	12.1	1.261
Yu,1978	B-0-42-3-L-DS	53.1	61.1	18.1	9.56	B	B&E	12.8	1.340
Yu,1978	B-0-42-4-L-DS	53.1	61.1	18.1	9.56	B	B&E	12.1	1.270
Yu,1978	B-0-42-5-0-DS	53.1	61.1	18.1	9.56	B	B&E	13.4	1.401
Yu,1978	B-0-42-6-0-DS	53.1	61.1	18.1	9.56	B	B&E	13.4	1.401
Yu,1978	B-0-42-7-L-DS	53.1	61.1	18.1	9.56	B	B&E	16.8	1.759
Yu,1978	B-0-42-8-L-DS	53.1	61.1	18.1	9.56	B	B&E	12.7	1.326
Yu,1978	B-0-42-9-H-DS	53.1	61.1	18.1	9.56	B	B&E	17.2	1.803
Yu,1978	B-0-42-10-H-DS	53.1	61.1	18.1	9.56	B	B&E	19.3	2.020
Yu,1978	B-0-45-1-0-SS	49.7	53.4	23.8	32.8	E	R	18.0	0.755
Yu,1978	B-0-45-2-0-SS	49.7	53.4	21.5	32.8	E	R	18.2	0.844
Yu,1978	B-0-45-3-L-SS	49.7	53.4	21.5	32.8	E	R	19.3	0.897
Yu,1978	B-0-45-4-L-SS	49.7	53.4	22.8	32.8	E	R	19.2	0.843
Yu,1978	B-0-45-5-H-SS	49.7	53.4	22.8	32.8	E	R	19.8	0.869
Yu,1978	B-0-45-6-H-SS	49.7	53.4	21.5	32.8	E	R	19.8	0.920
Yu,1978	B-0-46-1-0-SS	70.4	75.3	32.7	46.6	E	B&R	25.9	0.793
Yu,1978	B-0-46-2-0-SS	70.4	75.3	32.7	46.6	E	B&R	24.3	0.745
Yu,1978	B-0-46-3-L-SS	70.4	75.3	32.7	46.6	E	B&R	26.7	0.817
Yu,1978	B-0-46-4-L-SS	70.4	75.3	32.7	46.6	E	B&R	26.5	0.812
Yu,1978	B-0-46-5-0-SS	70.4	75.3	32.7	46.6	E	B&R	26.1	0.799
Yu,1978	B-0-46-6-0-SS	70.4	75.3	32.7	46.6	E	B&R	25.9	0.792
Yu,1978	B-0-46-7-L-SS	70.4	75.3	32.7	46.6	E	B&R	29.8	0.911
Yu,1978	B-0-46-8-L-SS	70.4	75.3	32.7	46.6	E	B&R	26.1	0.800
Yu,1978	B-0-46-9-H-SS	70.4	75.3	32.7	46.6	E	B&R	33.4	1.021
Yu,1978	B-0-46-10-H-SS	70.4	75.3	32.7	46.6	E	B&R	29.2	0.893
Yu,1978	B-0-49-1-0-DS	111	134	39.4	32.8	B	B&E	42.6	1.297
Yu,1978	B-0-49-2-0-DS	111	134	40.2	32.8	B	B&E	37.4	1.138
Yu,1978	B-0-49-3-L-DS	111	134	39.4	32.8	B	B&E	39.2	1.195
Yu,1978	B-0-49-4-L-DS	111	134	39.4	32.8	B	B&E	39.8	1.213
Yu,1978	B-0-49-5-H-DS	111	134	39.4	32.8	B	B&E	40.9	1.246
Yu,1978	B-0-49-6-H-DS	111	134	39.4	32.8	B	B&E	42.3	1.287
Yu,1978	B-0-50-1-0-DS	166	201	58.3	46.6	B	B&E	54.5	1.169
Yu,1978	B-0-50-2-0-DS	166	201	58.3	46.6	B	B&E	53.0	1.135
Yu,1978	B-0-50-3-L-DS	166	201	58.3	46.6	B	B&E	55.4	1.188
Yu,1978	B-0-50-4-L-DS	166	201	58.3	46.6	B	B&E	51.8	1.112
Yu,1978	B-0-50-5-0-DS	166	201	58.3	46.6	B	B&E	50.5	1.083
Yu,1978	B-0-50-6-0-DS	166	201	58.3	46.6	B	B&E	48.3	1.035
Yu,1978	B-0-50-7-L-DS	166	201	58.3	46.6	B	B&E	53.4	1.145

Table C3 Test-To-Predicted Values (CSA-S136, 1994)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-50-8-L-DS	166	201	58.3	46.6	B	B&E	44.9	0.962
Yu,1978	B-0-50-9-H-DS	166	201	58.3	46.6	B	B&E	62.3	1.336
Yu,1978	B-0-50-10-H-DS	166	201	58.3	46.6	B	B&E	53.5	1.147
Yu,1978	B-0-51-1-0-SS	189	199	89.1	130	E	R	97.7	1.097
Yu,1978	B-0-51-2-0-SS	189	199	89.1	130	E	R	96.3	1.082
Yu,1978	B-0-51-3-L-SS	189	199	91.2	130	E	R	94.1	1.032
Yu,1978	B-0-51-4-L-SS	189	199	89.1	130	E	R	102	1.144
Yu,1978	B-0-51-5-H-SS	189	199	89.1	130	E	R	95.0	1.067
Yu,1978	B-0-51-6-H-SS	189	199	89.1	130	E	R	97.9	1.099
Yu,1978	B-0-53-1-0-DS	444	532	154	130	B	B&E	158	1.213
Yu,1978	B-0-53-2-0-DS	444	532	159	130	B	B&E	155	1.192
Yu,1978	B-0-53-3-L-DS	444	532	154	130	B	B&E	162	1.243
Yu,1978	B-0-53-4-L-DS	444	532	156	130	B	B&E	161	1.235
Yu,1978	B-0-53-5-H-DS	444	532	150	130	B	B&E	161	1.233

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
Carril,1994	AN32-1	62.8	46.4	46.5	34.8	B	B	36.0	1.034
Carril,1994	AN32-2	61.6	45.6	45.6	34.2	B	B	36.5	1.066
Carril,1994	AN33-1	77.2	50.0	46.4	34.8	B	B	40.1	1.150
Carril,1994	AN33-2	78.5	50.9	47.3	35.4	B	B	39.8	1.125
Carril,1994	BN33-1	77.9	73.8	87.1	70.2	B	B	65.0	0.925
Carril,1994	BN33-2	77.9	73.8	87.2	70.2	B	B	64.0	0.911
Carril,1994	DN12-2	44.6	35.6	35.6	26.7	B	B	21.1	0.789
Carril,1994	DN12-3	43.6	34.8	34.8	26.1	B	B	21.1	0.808
Carril,1994	DN22-1	65.1	54.5	54.5	40.9	B	B	37.5	0.918
Carril,1994	DN22-2	66.0	55.2	55.2	41.5	B	B	37.8	0.912
Carril,1994	BN32-1	62.7	60.8	86.4	69.6	N.S	B&N.S	64.3	1.058
Carril,1994	BN32-2	62.0	60.2	85.7	69.0	N.S	B&N.S	65.4	1.087
Carril,1994	DN32-1	128	94.4	94.5	70.8	B	B&R	70.1	0.990
Carril,1994	DN32-2	125	92.8	92.9	69.6	B	B&R	71.6	1.028
Carril,1994	EN12-1	44.6	46.6	66.3	53.4	N.S	B&R	38.5	0.826
Carril,1994	EN12-2	44.6	46.6	66.3	53.4	N.S	B&R	38.7	0.831
Carril,1994	EN22-1	66.0	72.3	103	82.9	N.S	B&R	70.2	0.970
Carril,1994	EN22-2	66.9	73.2	104	84.1	N.S	B&R	70.0	0.956
Carril,1994	EN32-1	125	122	172	139	N.S	B&R	128	1.055
Carril,1994	EN32-2	124	121	171	138	N.S	B&R	129	1.071
Carril,1994	AN31-2	31.1	33.4	45.6	34.2	N.S	N.S	29.3	0.878
Carril,1994	AN31-3	31.1	33.5	46.0	34.5	N.S	N.S	29.1	0.869
Carril,1994	BN31-1	31.3	31.7	86.4	69.6	N.S	N.S	29.4	0.925
Carril,1994	BN31-2	31.3	31.7	86.4	69.6	N.S	N.S	29.4	0.927
Carril,1994	CN11-1	11.0	11.8	48.4	40.1	N.S	N.S	10.2	0.867
Carril,1994	CN11-2	11.0	11.8	48.4	40.1	N.S	N.S	10.4	0.881
Carril,1994	CN12-1	22.2	25.0	48.4	40.1	N.S	N.S	25.5	1.021
Carril,1994	CN12-2	22.2	25.0	48.5	40.1	N.S	N.S	25.5	1.022
Carril,1994	CN21-1	16.7	18.7	75.0	62.2	N.S	N.S	18.2	0.972
Carril,1994	CN21-2	16.9	18.9	76.1	63.1	N.S	N.S	18.1	0.956
Carril,1994	CN21-3	16.9	18.9	76.1	63.1	N.S	N.S	17.9	0.948
Carril,1994	CN22-1	33.1	39.1	75.1	62.2	N.S	N.S	42.7	1.094
Carril,1994	CN22-2	33.6	39.7	76.1	63.1	N.S	N.S	42.9	1.080
Carril,1994	CN22-3	33.1	39.1	75.0	62.2	N.S	N.S	42.9	1.096
Carril,1994	CN31-2	32.0	31.7	128	106	N.S	N.S	30.8	0.970
Carril,1994	CN31-3	32.3	32.0	129	107	N.S	N.S	30.0	0.939
Carril,1994	CN32-1	64.4	67.3	129	107	N.S	N.S	71.2	1.058

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
Carril,1994	CN32-2	63.6	66.5	128	106	N.S	N.S	70.4	1.059
Carril,1994	DN31-1	63.7	68.6	94.5	70.8	N.S	N.S	55.2	0.804
Carril,1994	DN31-2	61.7	66.4	91.3	68.4	N.S	N.S	53.4	0.804
Carril,1994	EN11-1	22.7	24.7	67.8	54.7	N.S	N.S	21.4	0.865
Carril,1994	EN11-2	22.2	24.2	66.2	53.4	N.S	N.S	21.5	0.887
Carril,1994	EN21-1	33.6	38.5	104	84.1	N.S	N.S	37.4	0.973
Carril,1994	EN21-2	33.5	38.4	104	84.1	N.S	N.S	37.4	0.975
Carril,1994	EN31-1	62.2	62.9	171	138	N.S	N.S	58.9	0.935
Carril,1994	EN31-2	62.7	63.5	173	139	N.S	N.S	60.3	0.949
Carril,1994	DN11-1	21.2	24.6	34.0	25.5	N.S	N&R	18.1	0.735
Carril,1994	DN11-2	21.7	25.2	34.7	26.1	N.S	N&R	18.7	0.743
Carril,1994	DN21-1	33.6	40.8	56.1	42.0	N.S	N&R	32.0	0.784
Carril,1994	DN21-2	33.1	40.2	55.3	41.5	N.S	N&R	31.5	0.783
Chong,1975	1	35.8	17.5	16.7	12.1	B	B&E	10.9	0.903
Chong,1975	2	35.5	12.7	16.5	7.58	B	B	8.14	1.074
Chong,1975	3	36.3	12.8	16.7	7.58	B	B&E	7.12	0.939
Chong,1975	4	35.8	17.5	16.4	12.1	B	E	9.92	0.818
Chong,1975	5	35.8	17.5	16.7	12.1	B	E	10.8	0.892
Chong,1975	6	35.2	17.4	8.08	12.1	E	B&E	10.6	1.316
Chong,1975	7	35.2	17.4	12.1	12.1	E	E	11.0	0.910
Chong,1975	8	35.2	17.4	14.1	12.1	B	E	10.0	0.826
Chong,1975	9	35.2	17.4	20.2	12.1	B	B	10.1	0.829
Chong,1975	11	35.2	17.4	20.2	12.1	B	B	10.3	0.848
Chong,1975	12	35.2	17.4	12.1	12.1	E	E	10.7	0.884
Chong,1975	13	35.2	17.4	8.08	12.1	E	E&B	10.5	1.299
Chong,1975	14	35.2	17.4	4.04	12.1	E	E	7.48	1.849
Chong,1975	15	35.2	17.4	4.04	12.1	E	E	6.76	1.673
Chong,1975	32	37.1	20.5	19.5	14.2	B	E&B	12.9	0.905
Chong,1975	33	37.1	20.5	19.1	14.2	B	B&E	13.3	0.933
Chong,1975	34	37.1	20.5	19.1	14.2	B	B&E	13.1	0.920
Chong,1975	41	54.9	36.1	8.55	25.2	E	E&B	12.3	1.441
Chong,1975	42	54.9	36.1	8.72	25.2	E	E&B	13.8	1.577
Chong,1975	49	13.9	15.9	33.5	25.2	N.S	N.S	13.5	0.846
Chong,1975	50	13.9	15.9	33.5	25.2	N.S	N.S	12.9	0.812
Chong,1975	51	13.9	15.9	33.5	25.2	N.S	N.S	11.9	0.745
Chong,1975	52	74.3	52.4	57.9	43.5	B	B&E	38.3	0.881
Chong,1975	53	74.3	52.4	58.1	43.5	B	B&E	36.3	0.835
Chong,1975	54	74.3	52.4	57.9	43.5	B	B&E	40.8	0.939

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
Chong,1975	55	111	74.3	82.5	61.3	B	B&E	55.6	0.908
Chong,1975	16(3b)	26.6	22.4	16.7	24.3	E	N.S	18.1	1.085
Chong,1975	17(3b)	27.0	22.6	16.2	24.3	E	N.S	18.4	1.137
Chong,1975	37(3b)	37.2	31.0	37.3	28.4	B	E&B	24.8	0.872
Chong,1975	40(3b)	54.9	54.6	66.1	50.3	B	B	40.0	0.794
Chong,1975	56(3b)	111	103	163	123	N.S	E&N	88.3	0.856
Chong,1975	35(3c)	37.3	29.7	58.3	26.7	B	B	23.3	0.875
Chong,1975	36(3c)	37.3	29.7	58.9	26.7	B	B	24.0	0.900
Chong,1975	18(3d)	8.81	5.92	22.0	24.3	N.S	N.S	7.57	1.279
Chong,1975	19(3d)	8.81	5.92	22.0	24.3	N.S	N.S	6.72	1.136
Chong,1975	22(3d)	17.6	13.6	22.0	24.3	N.S	N.S	14.9	1.097
Chong,1975	23(3d)	17.6	13.6	22.0	24.3	N.S	N.S	15.9	1.172
Chong,1975	28(3d)	35.2	25.4	22.0	24.3	E	E	19.5	0.887
Chong,1975	29(3d)	35.2	25.4	22.0	24.3	E	B&E	19.2	0.875
Chong,1975	45(3d)	27.4	28.1	45.6	50.3	N.S	N.S	30.7	1.094
Chong,1975	46(3d)	27.4	28.1	45.6	50.3	N.S	N.S	31.9	1.135
Chong,1975	20(3e)	8.81	5.36	35.9	36.4	N.S	N.S	7.83	1.462
Chong,1975	21(3e)	8.81	5.36	35.9	36.4	N.S	N.S	4.76	0.889
Chong,1975	24(3e)	17.6	13.7	35.9	36.4	N.S	N.S	15.7	1.148
Chong,1975	25(3e)	17.6	13.7	35.9	36.4	N.S	N.S	15.2	1.109
Chong,1975	26(3e)	34.7	27.6	35.9	36.4	N.S	E	28.8	1.042
Chong,1975	27(3e)	34.7	27.6	35.9	36.4	N.S	E	28.8	1.044
Chong,1975	43(3e)	55.3	58.6	74.4	75.5	N.S	E&B	58.3	0.995
Chong,1975	44(3e)	55.7	59.0	74.4	75.5	N.S	E&B	60.1	1.018
Chong,1975	47(3e)	13.7	11.1	74.4	75.5	N.S	N.S	13.0	1.169
Chong,1975	48(3e)	13.7	11.1	74.4	75.5	N.S	N.S	13.5	1.213
Gilchrist, 1979	1	16.9	5.38	3.87	2.91	B	B&E	3.20	1.103
Gilchrist, 1979	2	16.9	5.38	2.91	2.91	E	B&E	2.71	0.934
Gilchrist, 1979	3	16.9	5.38	2.32	2.91	E	B&E	2.60	1.120
Gilchrist, 1979	4	16.9	6.76	5.81	4.36	B	B&E	3.03	0.694
Gilchrist, 1979	5	16.9	6.76	3.87	4.36	E	B	3.00	0.775
Gilchrist, 1979	6	16.9	6.76	2.91	4.36	E	B&E	3.16	1.087
Gilchrist, 1979	7	24.3	7.44	5.36	4.02	B	B&E	3.78	0.941
Gilchrist, 1979	8	24.3	7.44	4.02	4.02	E	B&E	3.89	0.969
Gilchrist, 1979	9	24.3	7.44	3.22	4.02	E	B&E	3.69	1.149
Gilchrist, 1979	10	24.3	9.35	8.04	6.03	B	B&E	4.01	0.664
Gilchrist, 1979	11	24.3	9.35	5.36	6.03	E	B	3.56	0.664
Gilchrist, 1979	12	24.3	9.35	4.02	6.03	E	B&E	4.34	1.079

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
Gilchrist, 1979	13	24.8	7.63	5.50	4.12	B	B&E	4.58	1.111
Gilchrist, 1979	14	24.8	7.63	4.12	4.12	E	B&E	4.29	1.041
Gilchrist, 1979	15	24.8	7.63	3.30	4.12	E	B&E	4.18	1.268
Gilchrist, 1979	16	24.8	9.60	8.25	6.19	B	B&E	4.34	0.701
Gilchrist, 1979	17	24.8	9.60	5.50	6.19	E	B&E	4.36	0.793
Gilchrist, 1979	18	24.8	9.60	4.12	6.19	E	B&E	4.05	0.982
Gilchrist, 1979	19	24.8	11.8	11.0	8.25	B	B&E	7.23	0.877
Gilchrist, 1979	20	24.8	11.8	8.25	8.25	E	B	5.21	0.631
Gilchrist, 1979	21	24.8	11.8	5.50	8.25	E	B	5.45	0.991
Gilchrist, 1979	22	19.8	7.12	5.13	3.85	B	B&E	3.78	0.982
Gilchrist, 1979	23	19.8	7.12	3.85	3.85	E	B&E	3.65	0.948
Gilchrist, 1979	24	19.8	7.12	3.08	3.85	E	B&E	4.01	1.300
Gilchrist, 1979	25	19.8	8.96	7.70	5.78	B	B&E	4.41	0.763
Gilchrist, 1979	26	19.8	8.96	5.13	5.78	E	B&E	4.21	0.819
Gilchrist, 1979	27	19.8	8.96	3.85	5.78	E	B&E	4.12	1.069
Gilchrist, 1979	28	19.8	11.1	10.3	7.70	B	B	7.16	0.930
Gilchrist, 1979	29	19.8	11.1	7.70	7.70	E	B	6.50	0.844
Gilchrist, 1979	30	19.8	11.1	5.13	7.70	E	B	5.01	0.975
McGill,2002	043-230-3/8-SS-A	8.03	14.3	7.73	3.68	B	B	1.69	0.459
McGill,2002	043-230-3/8-SS-B	8.03	14.3	7.73	3.68	B	B	1.77	0.481
McGill,2002	043-230-3/8-SS-C	8.03	14.3	7.73	3.68	B	B	1.67	0.454
McGill,2002	043-230-3/8-TTSS-A	8.03	14.3	7.73	3.68	B	B	1.87	0.508
McGill,2002	043-230-3/8-TTSS-B	8.03	14.3	7.73	3.68	B	B	1.77	0.481
McGill,2002	043-230-3/8-TTSS-C	8.03	14.3	7.73	3.68	B	B	2.16	0.587
McGill,2002	043-230-3/8-DS-A	8.03	14.3	7.73	3.68	B	B	3.65	0.992
McGill,2002	043-230-3/8-DS-B	8.03	14.3	7.73	3.68	B	B	3.46	0.940
McGill,2002	043-230-3/8-DS-C	8.03	14.3	7.73	3.68	B	B	3.26	0.886
McGill,2002	043-550-3/8-SS-A	19.3	23.7	12.8	6.12	B	B	2.62	0.428
McGill,2002	043-550-3/8-SS-B	19.3	23.7	12.8	6.12	B	B	2.73	0.446
McGill,2002	043-550-3/8-SS-C	19.3	23.7	12.8	6.12	B	B	2.49	0.407
McGill,2002	043-230-1/2-SS-A	8.03	14.7	7.73	4.91	B	B	2.14	0.436
McGill,2002	043-230-1/2-SS-B	8.03	14.7	7.73	4.91	B	B	2.13	0.434
McGill,2002	043-230-1/2-SS-C	8.03	14.7	7.73	4.91	B	B	2.18	0.444
McGill,2002	043-230-1/2-TTSS-A	8.03	14.7	7.73	4.91	B	B	2.29	0.467
McGill,2002	043-230-1/2-TTSS-B	8.03	14.7	7.73	4.91	B	B	2.24	0.456
McGill,2002	043-230-1/2-TTSS-C	8.03	14.7	7.73	4.91	B	B	2.46	0.501
McGill,2002	043-230-1/2-DS-A	8.03	14.7	7.73	4.91	B	B	5.43	1.107
McGill,2002	043-230-1/2-DS-B	8.03	14.7	7.73	4.91	B	B	5.80	1.182

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
McGill,2002	043-230-1/2-DS-C	8.03	14.7	7.73	4.91	B	B	5.72	1.166
McGill,2002	043-550-1/2-SS-A	19.3	24.5	12.8	8.16	B	B	3.37	0.413
McGill,2002	043-550-1/2-SS-B	19.3	24.5	12.8	8.16	B	B	3.36	0.412
McGill,2002	043-550-1/2-SS-C	19.3	24.5	12.8	8.16	B	B	3.36	0.412
McGill,2002	043-230-5/8-SS-A	8.03	15.1	7.73	6.13	B	B	2.99	0.487
McGill,2002	043-230-5/8-SS-B	8.03	15.1	7.73	6.13	B	B	2.84	0.463
McGill,2002	043-230-5/8-SS-C	8.03	15.1	7.73	6.13	B	B	2.78	0.453
McGill,2002	043-230-5/8-TTSS-A	8.03	15.1	7.73	6.13	B	B	3.09	0.504
McGill,2002	043-230-5/8-TTSS-B	8.03	15.1	7.73	6.13	B	B	3.22	0.525
McGill,2002	043-230-5/8-TTSS-C	8.03	15.1	7.73	6.13	B	B	3.36	0.548
McGill,2002	043-230-5/8-DS-A	8.03	15.1	7.73	6.13	B	B	7.05	1.149
McGill,2002	043-230-5/8-DS-B	8.03	15.1	7.73	6.13	B	B	7.49	1.221
McGill,2002	043-230-5/8-DS-C	8.03	15.1	7.73	6.13	B	B	7.35	1.198
McGill,2002	043-550-5/8-SS-A	19.3	25.1	12.8	10.2	B	B	3.71	0.364
McGill,2002	043-550-5/8-SS-B	19.3	25.1	12.8	10.2	B	B	3.93	0.385
McGill,2002	043-550-5/8-SS-C	19.3	25.1	12.8	10.2	B	B	3.92	0.384
McGill,2002	064-230-5/8-TTSS-A	14.3	21.4	11.0	8.70	B	B	5.22	0.600
McGill,2002	064-230-5/8-TTSS-B	14.3	21.4	11.0	8.70	B	B	4.88	0.561
McGill,2002	064-230-5/8-TTSS-C	14.3	21.4	11.0	8.70	B	B	5.47	0.629
McGill,2002	064-230-5/8-DS-A	14.3	21.4	11.0	8.70	B	B	11.8	1.361
McGill,2002	064-230-5/8-DS-B	14.3	21.4	11.0	8.70	B	B	11.0	1.267
McGill,2002	064-230-5/8-DS-C	14.3	21.4	11.0	8.70	B	B	11.7	1.345
McGill,2002	064-550-5/8-SS-A	33.3	43.3	22.2	17.6	B	B	8.64	0.491
McGill,2002	064-550-5/8-SS-B	33.3	43.3	22.2	17.6	B	B	8.91	0.506
McGill,2002	064-550-5/8-SS-C	33.3	43.3	22.2	17.6	B	B	8.34	0.474
McGill,2002	064-230-1/2-TTSS-A	14.3	20.9	11.0	6.96	B	B	4.56	0.655
McGill,2002	064-230-1/2-TTSS-B	14.3	20.9	11.0	6.96	B	B	4.44	0.638
McGill,2002	064-230-1/2-TTSS-C	14.3	20.9	11.0	6.96	B	B	4.10	0.589
McGill,2002	064-230-1/2-DS-A	14.3	20.9	11.0	6.96	B	B	8.91	1.280
McGill,2002	064-230-1/2-DS-B	14.3	20.9	11.0	6.96	B	B	9.28	1.333
McGill,2002	064-230-1/2-DS-C	14.3	20.9	11.0	6.96	B	B	9.23	1.326
McGill,2002	064-550-1/2-SS-A	33.3	42.3	22.2	14.1	B	B	6.94	0.493
McGill,2002	064-550-1/2-SS-B	33.3	42.3	22.2	14.1	B	B	7.26	0.516
McGill,2002	064-550-1/2-SS-C	33.3	42.3	22.2	14.1	B	B	7.04	0.500
McGill,2002	064-230-3/8-SS-A	14.3	20.2	11.0	5.22	B	B	3.05	0.584
McGill,2002	064-230-3/8-SS-B	14.3	20.2	11.0	5.22	B	B	2.75	0.527
McGill,2002	064-230-3/8-SS-C	14.3	20.2	11.0	5.22	B	B	2.77	0.531
McGill,2002	064-550-3/8-SS-A	33.3	40.9	22.2	10.6	B	B	5.83	0.552

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
McGill,2002	064-550-3/8-SS-B	33.3	40.9	22.2	10.6	B	B	6.43	0.609
McGill,2002	064-550-3/8-SS-C	33.3	40.9	22.2	10.6	B	B	5.82	0.551
McGill,2002	064-230-1/4-DS-A	14.3	19.4	11.0	3.48	B	B	6.76	1.942
McGill,2002	064-230-1/4-DS-B	14.3	19.4	11.0	3.48	B	B	6.67	1.916
McGill,2002	064-230-1/4-DS-C	14.3	19.4	11.0	3.48	B	B	6.38	1.833
McGill,2002	064-550-1/4-SS-A	33.3	39.2	22.2	7.04	B	B	5.68	0.807
McGill,2002	064-550-1/4-SS-B	33.3	39.2	22.2	7.04	B	B	5.55	0.788
McGill,2002	064-550-1/4-SS-C	33.3	39.2	22.2	7.04	B	B	5.90	0.838
McGill,2002	064-230-1/4-SS-A	14.3	19.4	11.0	3.48	B	B	2.92	0.839
McGill,2002	064-230-1/4-SS-B	14.3	19.4	11.0	3.48	B	B	3.07	0.882
McGill,2002	064-230-1/4-SS-C	14.3	19.4	11.0	3.48	B	B	3.00	0.862
McGill,2002	064-230-1/4-TTSS-A	14.3	19.4	11.0	3.48	B	B	2.95	0.848
McGill,2002	064-230-1/4-TTSS-B	14.3	19.4	11.0	3.48	B	B	3.29	0.945
McGill,2002	064-230-1/4-TTSS-C	14.3	19.4	11.0	3.48	B	B	3.80	1.092
McGill,2002	076-230-1/2-SS-A	18.5	27.3	14.3	9.10	B	B	4.77	0.524
McGill,2002	076-230-1/2-SS-B	18.5	27.3	14.3	9.10	B	B	4.53	0.498
McGill,2002	076-230-1/2-SS-C	18.5	27.3	14.3	9.10	B	B	4.90	0.538
McGill,2002	076-230-1/2-TTSS-A	18.5	27.3	14.3	9.10	B	B	5.22	0.574
McGill,2002	076-230-1/2-TTSS-B	18.5	27.3	14.3	9.10	B	B	5.90	0.648
McGill,2002	076-230-1/2-TTSS-C	18.5	27.3	14.3	9.10	B	B	5.41	0.595
McGill,2002	076-230-1/2-DS-A	18.5	27.3	14.3	9.10	B	B	10.8	1.190
McGill,2002	076-230-1/2-DS-B	18.5	27.3	14.3	9.10	B	B	11.8	1.300
McGill,2002	076-230-1/2-DS-C	18.5	27.3	14.3	9.10	B	B	10.5	1.157
McGill,2002	N076-550-1/2-SS-A	38.4	48.9	25.6	16.3	B	B	8.50	0.523
McGill,2002	N076-550-1/2-SS-B	38.4	48.9	25.6	16.3	B	B	8.06	0.496
McGill,2002	N076-550-1/2-SS-C	38.4	48.9	25.6	16.3	B	B	8.50	0.523
McGill,2002	076-230-5/8-SS-A	18.5	28.0	14.3	11.4	B	B	6.17	0.543
McGill,2002	076-230-5/8-SS-B	18.5	28.0	14.3	11.4	B	B	6.04	0.531
McGill,2002	076-230-5/8-SS-C	18.5	28.0	14.3	11.4	B	B	6.04	0.531
McGill,2002	076-550-3/8-SS-A	38.4	47.3	25.6	12.2	B	B	8.19	0.671
McGill,2002	076-550-3/8-SS-B	38.4	47.3	25.6	12.2	B	B	7.80	0.639
McGill,2002	076-550-3/8-SS-C	38.4	47.3	25.6	12.2	B	B	6.61	0.542
McGill,2002	076-550-1/4-SS-A	38.4	45.3	25.6	8.13	B	B	7.01	0.862
McGill,2002	076-550-1/4-SS-B	38.4	45.3	25.6	8.13	B	B	6.80	0.836
McGill,2002	076-550-1/4-SS-C	38.4	45.3	25.6	8.13	B	B	6.55	0.805
McGill,2002	091-230-1/4-SS-A	20.0	28.5	16.1	5.11	B	B	4.65	0.909
McGill,2002	091-230-1/4-SS-B	20.0	28.5	16.1	5.11	B	B	5.14	1.005
McGill,2002	091-230-1/4-SS-C	20.0	28.5	16.1	5.11	B	B	4.83	0.944

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
McGill,2002	091-230-1/4-TTSS-A	20.0	28.5	16.1	5.11	B	B	7.94	1.553
McGill,2002	091-230-1/4-TTSS-B	20.0	28.5	16.1	5.11	B	B	7.46	1.459
McGill,2002	091-230-1/4-TTSS-C	20.0	28.5	16.1	5.11	B	B	7.51	1.469
McGill,2002	091-230-1/4-DS-A	20.0	28.5	16.1	5.11	B	B	12.7	2.481
McGill,2002	091-230-1/4-DS-B	20.0	28.5	16.1	5.11	B	B	12.4	2.417
McGill,2002	091-230-1/4-DS-C	20.0	28.5	16.1	5.11	B	B	11.2	2.198
McGill,2002	091-230-1/2-TTSS-A	20.0	30.7	16.1	10.2	B	B	6.91	0.676
McGill,2002	091-230-1/2-TTSS-B	20.0	30.7	16.1	10.2	B	B	6.94	0.679
McGill,2002	091-230-1/2-TTSS-C	20.0	30.7	16.1	10.2	B	B	7.00	0.684
McGill,2002	091-230-1/2-DS-A	20.0	30.7	16.1	10.2	B	B	14.3	1.398
McGill,2002	091-230-1/2-DS-B	20.0	30.7	16.1	10.2	B	B	13.6	1.330
McGill,2002	091-230-1/2-DS-C	20.0	30.7	16.1	10.2	B	B	13.4	1.314
McGill,2002	121-230-1/2-TTSS-A	30.2	47.9	25.1	16.0	B	B	10.3	0.642
McGill,2002	121-230-1/2-TTSS-B	30.2	47.9	25.1	16.0	B	B	10.3	0.648
McGill,2002	121-230-1/2-TTSS-C	30.2	47.9	25.1	16.0	B	B	12.0	0.752
McGill,2002	121-230-1/2-DS-A	30.2	47.9	25.1	16.0	B	B	18.6	1.166
McGill,2002	121-230-1/2-DS-B	30.2	47.9	25.1	16.0	B	B	20.9	1.309
McGill,2002	121-230-1/2-DS-C	30.2	47.9	25.1	16.0	B	B	18.3	1.145
McGill,2002	121-230-3/8-SS-A	30.2	46.4	25.1	12.0	B	B	8.39	0.701
McGill,2002	121-230-3/8-SS-B	30.2	46.4	25.1	12.0	B	B	8.54	0.714
McGill,2002	121-230-3/8-SS-C	30.2	46.4	25.1	12.0	B	B	8.89	0.743
McGill,2002	121-230-3/8-TTSS-A	30.2	46.4	25.1	12.0	B	B	9.28	0.776
McGill,2002	121-230-3/8-TTSS-B	30.2	46.4	25.1	12.0	B	B	9.03	0.755
McGill,2002	121-230-3/8-TTSS-C	30.2	46.4	25.1	12.0	B	B	9.70	0.811
McGill,2002	121-230-3/8-DS-A	30.2	46.4	25.1	12.0	B	B	20.5	1.710
McGill,2002	121-230-3/8-DS-B	30.2	46.4	25.1	12.0	B	B	18.4	1.534
McGill,2002	121-230-3/8-DS-C	30.2	46.4	25.1	12.0	B	B	16.4	1.369
McGill,2002	153-230-1/4-SS-A	33.3	48.1	27.2	8.64	B	B	10.0	1.157
McGill,2002	153-230-1/4-SS-B	33.3	48.1	27.2	8.64	B	B	9.80	1.135
McGill,2002	153-230-1/4-SS-C	33.3	48.1	27.2	8.64	B	B	9.49	1.099
Wallace,2000	1-wo-50	22.4	11.9	20.4	7.76	B	B	6.29	0.810
Wallace,2000	2-wo-50	22.4	11.9	20.4	7.76	B	B	6.95	0.895
Wallace,2000	3-wo-50	22.4	11.9	20.4	7.76	B	B	6.53	0.841
Wallace,2000	1-wo-40	22.4	11.9	16.3	7.76	B	B	6.64	0.855
Wallace,2000	2-wo-40	22.4	11.9	16.3	7.76	B	B	6.12	0.788
Wallace,2000	3-wo-40	22.4	11.9	16.3	7.76	B	B	6.70	0.863
Wallace,2000	1-wo-30	22.4	11.9	12.2	7.76	B	B	6.38	0.822
Wallace,2000	2-wo-30	22.4	11.9	12.2	7.76	B	B	6.41	0.826

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
Wallace,2000	3-wo-30	22.4	11.9	12.2	7.76	B	B	6.24	0.804
Wallace,2000	1-wo-20	22.4	11.9	8.15	7.76	B	B	5.89	0.759
Wallace,2000	2-wo-20	22.4	11.9	8.15	7.76	B	B	6.20	0.799
Wallace,2000	3-wo-20	22.4	11.9	8.15	7.76	B	B	6.60	0.850
Wallace,2000	1-wo-20-t5	22.4	11.9	8.15	7.76	B	B	7.24	0.933
Wallace,2000	2-wo-20-t5	22.4	11.9	8.15	7.76	B	B	6.63	0.854
Wallace,2000	3-wo-20-t5	22.4	11.9	8.15	7.76	B	B	6.45	0.831
Wallace,2000	1-wo-20-t15	22.4	11.9	8.15	7.76	B	B	7.11	0.916
Wallace,2000	2-wo-20-t15	22.4	11.9	8.15	7.76	B	B	6.50	0.837
Wallace,2000	3-wo-20-t15	22.4	11.9	8.15	7.76	B	B	7.71	0.993
Wallace,2000	1-wo-30-50	22.4	16.2	31.0	15.5	B	B	14.5	0.931
Wallace,2000	2-wo-30-50	22.4	16.2	31.0	15.5	B	B	15.3	0.984
Wallace,2000	3-wo-30-50	22.4	16.2	31.0	15.5	B	B	14.2	0.912
Wallace,2000	1-wo-30-40	22.4	16.2	26.9	15.5	B	B	14.1	0.911
Wallace,2000	2-wo-30-40	22.4	16.2	26.9	15.5	B	B	14.6	0.938
Wallace,2000	3-wo-30-40	22.4	16.2	26.9	15.5	B	B	14.2	0.913
Wallace,2000	1-wo-30-30	22.4	16.2	22.8	15.5	B	B	15.1	0.973
Wallace,2000	2-wo-30-30	22.4	16.2	22.8	15.5	B	B	15.3	0.988
Wallace,2000	3-wo-30-30	22.4	16.2	22.8	15.5	B	B	14.0	0.899
Wallace,2000	1-wo-40-3/8	22.4	14.6	16.3	11.6	B	B	7.26	0.624
Wallace,2000	2-wo-40-3/8	22.4	14.6	16.3	11.6	B	B	7.52	0.646
Wallace,2000	3-wo-40-3/8	22.4	14.6	16.3	11.6	B	B	7.65	0.657
Wallace,2000	1-wo-30-5/16	22.4	13.3	12.2	9.70	B	B	7.82	0.806
Wallace,2000	2-wo-30-5/16	22.4	13.3	12.2	9.70	B	B	6.58	0.678
Wallace,2000	3-wo-30-5/16	22.4	13.3	12.2	9.70	B	B	6.98	0.719
Wallace,2000	1-wo-50-1/2	22.4	16.7	20.4	15.5	B	B	9.80	0.631
Wallace,2000	2-wo-50-1/2	22.4	16.7	20.4	15.5	B	B	9.62	0.620
Wallace,2000	3-wo-50-1/2	22.4	16.7	20.4	15.5	B	B	9.16	0.590
Wallace,2000	1-wo-50-5/8	22.4	18.3	20.4	19.4	N.S	B	10.3	0.565
Wallace,2000	2-wo-50-5/8	22.4	18.3	20.4	19.4	N.S	B	10.3	0.566
Wallace,2000	3-wo-50-5/8	22.4	18.3	20.4	19.4	N.S	B	10.3	0.562
Wallace,2000	1-wo-ss-5/16	11.2	6.64	6.11	4.85	B	B	3.23	0.666
Wallace,2000	2-wo-ss-5/16	11.2	6.64	6.11	4.85	B	B	3.27	0.674
Wallace,2000	3-wo-ss-5/16	11.2	6.64	6.11	4.85	B	B	3.39	0.699
Wallace,2000	1-wo-sst-5/16	24.6	13.5	12.5	9.89	B	B	9.12	0.923
Wallace,2000	2-wo-sst-5/16	24.6	13.5	12.5	9.89	B	B	8.51	0.861
Wallace,2000	3-wo-sst-5/16	24.6	13.5	12.5	9.89	B	B	8.26	0.836
Wallace,2000	1-wo-sst-1/4	24.6	12.1	12.5	7.91	B	B	9.16	1.158

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
Wallace,2000	2-wo-sst-1/4	24.6	12.1	12.5	7.91	B	B	8.92	1.128
Wallace,2000	3-wo-sst-1/4	24.6	12.1	12.5	7.91	B	B	9.03	1.142
Wallace,2000	1-wo-mix-1/4	11.2	5.93	6.11	3.88	B	B	3.52	0.907
Wallace,2000	2-wo-mix-1/4	11.2	5.93	6.11	3.88	B	B	3.47	0.894
Wallace,2000	3-wo-mix-1/4	11.2	5.93	6.11	3.88	B	B	3.73	0.961
Wallace,2000	1-wo-ss-1/4	11.2	5.93	6.11	3.88	B	B	3.27	0.843
Wallace,2000	2-wo-ss-1/4	11.2	5.93	6.11	3.88	B	B	3.30	0.850
Wallace,2000	1-wo-ss-1/2	11.2	8.36	6.11	7.76	E	B	4.25	0.695
Wallace,2000	2-wo-ss-1/2	11.2	8.36	6.11	7.76	E	B	4.43	0.725
Wallace,2000	3-wo-ss-1/2	11.2	8.36	6.11	7.76	E	B	4.00	0.654
Wallace,2000	1-wo-ss-5/8	11.2	9.13	6.11	9.70	E	B	5.45	0.892
Wallace,2000	2-wo-ss-5/8	11.2	9.13	6.11	9.70	E	B	5.43	0.888
Wallace,2000	3-wo-ss-5/8	11.2	9.13	6.11	9.70	E	B	5.41	0.885
Yu,1978	B-0-12-1-0-SS	4.78	2.61	1.33	1.83	E	R	1.73	1.295
Yu,1978	B-0-12-2-0-SS	4.78	2.61	1.33	1.83	E	R	1.40	1.051
Yu,1978	B-0-12-3-L-SS	4.78	2.61	1.37	1.83	E	R	1.40	1.021
Yu,1978	B-0-12-4-L-SS	4.78	2.61	1.37	1.83	E	R	1.50	1.096
Yu,1978	B-0-12-5-0-SS	4.78	2.61	1.33	1.83	E	R	1.36	1.018
Yu,1978	B-0-12-6-0-SS	4.78	2.61	1.37	1.83	E	R	1.44	1.047
Yu,1978	B-0-12-7-L-SS	4.78	2.61	1.33	1.83	E	R	1.58	1.188
Yu,1978	B-0-12-8-L-SS	4.66	2.59	1.35	1.83	E	R	1.45	1.072
Yu,1978	B-0-12-9-H-SS	4.71	2.60	1.35	1.83	E	R	1.70	1.259
Yu,1978	B-0-12-10-H-SS	4.78	2.61	1.37	1.83	E	R	2.25	1.637
Yu,1978	B-0-14-1-0-DS	7.89	3.12	2.13	1.83	B	B&E	2.42	1.321
Yu,1978	B-0-14-2-0-DS	7.89	3.12	2.13	1.83	B	B&E	2.13	1.163
Yu,1978	B-0-14-3-L-DS	7.89	3.12	2.13	1.83	B	B&E	2.55	1.397
Yu,1978	B-0-14-4-L-DS	7.89	3.12	2.13	1.83	B	B&E	2.36	1.290
Yu,1978	B-0-14-5-0-DS	7.89	3.12	2.13	1.83	B	B&E	2.33	1.273
Yu,1978	B-0-14-6-0-DS	7.89	3.12	2.13	1.83	B	B&E	2.14	1.173
Yu,1978	B-0-14-7-L-DS	7.89	3.12	2.13	1.83	B	B&E	3.06	1.674
Yu,1978	B-0-14-8-L-DS	7.89	3.12	2.13	1.83	B	B&E	3.15	1.723
Yu,1978	B-0-14-9-H-DS	7.89	3.12	2.13	1.83	B	B&E	2.46	1.343
Yu,1978	B-0-14-10-H-DS	7.89	3.12	2.13	1.83	B	B&E	2.41	1.319
Yu,1978	B-0-17-1-0-SS	12.5	6.98	3.67	4.89	E	R	5.42	1.474
Yu,1978	B-0-17-2-0-SS	12.5	6.98	3.67	4.89	E	R	4.96	1.351
Yu,1978	B-0-17-3-L-SS	12.7	7.02	3.67	4.89	E	R	5.36	1.459
Yu,1978	B-0-17-4-L-SS	12.5	6.98	3.67	4.89	E	R	5.75	1.565
Yu,1978	B-0-17-5-0-SS	12.5	6.98	3.67	4.89	E	R	5.28	1.438

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
Yu,1978	B-0-17-6-0-SS	12.5	6.98	3.57	4.89	E	R	5.31	1.489
Yu,1978	B-0-17-7-L-SS	12.5	6.98	3.67	4.89	E	R	5.32	1.448
Yu,1978	B-0-17-8-L-SS	12.5	6.98	3.67	4.89	E	R	5.45	1.484
Yu,1978	B-0-17-9-H-SS	12.7	7.02	3.67	4.89	E	R	5.33	1.451
Yu,1978	B-0-17-10-H-SS	12.5	6.98	3.59	4.89	E	R	5.40	1.506
Yu,1978	B-0-18-1-0-SS	19.0	12.6	7.14	9.79	E	R	6.30	0.882
Yu,1978	B-0-18-2-0-SS	19.0	12.6	7.18	9.79	E	R	6.32	0.881
Yu,1978	B-0-18-3-L-SS	19.0	12.6	7.18	9.79	E	R	9.08	1.265
Yu,1978	B-0-18-4-L-SS	19.0	12.6	7.18	9.79	E	R	6.63	0.924
Yu,1978	B-0-18-5-0-SS	19.0	12.6	7.18	9.79	E	R	6.32	0.881
Yu,1978	B-0-18-6-0-SS	19.0	12.6	7.18	9.79	E	R	7.10	0.990
Yu,1978	B-0-18-7-L-SS	19.0	12.6	7.18	9.79	E	R	12.2	1.696
Yu,1978	B-0-18-8-L-SS	19.0	12.6	7.34	9.79	E	R	11.5	1.564
Yu,1978	B-0-18-9-H-SS	19.0	12.6	7.18	9.79	E	R	11.6	1.618
Yu,1978	B-0-18-10-H-SS	19.0	12.6	7.18	9.79	E	R	10.4	1.451
Yu,1978	B-0-21-1-0-DS	20.6	8.36	5.51	4.89	B	B&E	8.37	1.710
Yu,1978	B-0-21-2-0-DS	20.6	8.36	5.71	4.89	B	B&E	8.46	1.728
Yu,1978	B-0-21-3-L-DS	20.6	8.36	5.81	4.89	B	B&E	8.46	1.728
Yu,1978	B-0-21-4-L-DS	20.6	8.36	5.71	4.89	B	B&E	8.52	1.742
Yu,1978	B-0-21-5-0-DS	20.6	8.36	5.71	4.89	B	B&E	8.63	1.764
Yu,1978	B-0-21-6-0-DS	20.6	8.36	5.91	4.89	B	B&E	9.03	1.846
Yu,1978	B-0-21-7-L-DS	20.6	8.36	5.71	4.89	B	B&E	9.68	1.978
Yu,1978	B-0-21-8-L-DS	20.6	8.36	5.71	4.89	B	B&E	9.12	1.864
Yu,1978	B-0-21-9-H-DS	20.6	8.36	5.71	4.89	B	B&E	9.95	2.033
Yu,1978	B-0-21-10-H-DS	20.6	8.36	5.71	4.89	B	B&E	8.90	1.819
Yu,1978	B-0-22-1-0-DS	39.6	16.5	11.4	9.79	B	B&E	11.4	1.164
Yu,1978	B-0-22-2-0-DS	39.6	16.5	11.4	9.79	B	B&E	11.1	1.130
Yu,1978	B-0-22-3-L-DS	39.6	16.5	11.4	9.79	B	B&E	12.8	1.307
Yu,1978	B-0-22-4-L-DS	39.6	16.5	11.4	9.79	B	B&E	10.8	1.103
Yu,1978	B-0-22-5-0-DS	39.6	16.5	11.4	9.79	B	B&R	10.8	1.103
Yu,1978	B-0-22-6-0-DS	39.6	16.5	11.4	9.79	B	B&R	9.8	1.000
Yu,1978	B-0-22-7-L-DS	39.6	16.5	11.4	9.79	B	B&E	12.0	1.228
Yu,1978	B-0-22-8-L-DS	39.6	16.5	11.4	9.79	B	B&E	12.1	1.237
Yu,1978	B-0-22-9-H-DS	39.6	16.5	11.4	9.79	B	B&E	11.8	1.205
Yu,1978	B-0-22-10-H-DS	39.6	16.5	11.6	9.79	B	B&E	12.7	1.301
Yu,1978	B-0-25-1-0-SS	47.5	28.6	16.2	22.1	E	R	18.2	1.122
Yu,1978	B-0-25-2-0-SS	47.5	28.6	16.2	22.1	E	R	19.0	1.172
Yu,1978	B-0-25-3-L-SS	47.5	28.6	16.2	22.1	E	R	20.2	1.246

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
Yu,1978	B-0-25-4-L-SS	47.5	28.6	16.2	22.1	E	R	21.0	1.298
Yu,1978	B-0-25-5-H-SS	47.5	28.6	16.2	22.1	E	R	20.4	1.260
Yu,1978	B-0-25-6-H-SS	47.5	28.6	16.2	22.1	E	R	19.4	1.194
Yu,1978	B-0-26-1-0-SS	66.6	40.8	24.3	33.2	E	R	24.4	1.003
Yu,1978	B-0-26-2-0-SS	66.6	40.8	24.3	33.2	E	R	24.7	1.016
Yu,1978	B-0-26-3-L-SS	66.6	40.8	24.3	33.2	E	R	25.3	1.041
Yu,1978	B-0-26-4-L-SS	66.6	40.8	24.3	33.2	E	R	24.7	1.014
Yu,1978	B-0-26-5-0-SS	66.6	40.8	24.3	33.2	E	R	24.7	1.015
Yu,1978	B-0-26-6-0-SS	66.6	40.8	24.3	33.2	E	R	23.1	0.948
Yu,1978	B-0-26-7-L-SS	66.6	40.8	24.3	33.2	E	R	25.0	1.028
Yu,1978	B-0-26-8-L-SS	66.6	40.8	24.3	33.2	E	R	24.9	1.025
Yu,1978	B-0-26-9-H-SS	66.6	40.8	24.3	33.2	E	R	31.2	1.281
Yu,1978	B-0-26-10-H-SS	66.6	40.8	24.3	33.2	E	R	32.7	1.345
Yu,1978	B-0-29-1-0-DS	103	37.8	26.7	22.1	B	B&E	30.9	1.396
Yu,1978	B-0-29-2-0-DS	103	37.8	26.3	22.1	B	B&E	35.6	1.608
Yu,1978	B-0-29-3-L-DS	103	37.8	25.8	22.1	B	B&E	38.3	1.731
Yu,1978	B-0-29-4-L-DS	103	37.8	26.7	22.1	B	B&E	38.5	1.741
Yu,1978	B-0-29-5-0-DS	103	37.8	27.2	22.1	B	B&E	37.0	1.673
Yu,1978	B-0-29-6-0-DS	103	37.8	27.2	22.1	B	B&E	31.4	1.421
Yu,1978	B-0-29-7-L-DS	103	37.8	26.3	22.1	B	B&E	40.9	1.851
Yu,1978	B-0-29-8-L-DS	103	37.8	27.2	22.1	B	B&E	41.4	1.872
Yu,1978	B-0-29-9-H-DS	103	37.8	27.2	22.1	B	B&E	41.2	1.862
Yu,1978	B-0-29-10-H-DS	103	37.8	27.2	22.1	B	B&E	40.7	1.841
Yu,1978	B-0-30-1-0-DS	158	55.9	36.4	33.2	B	B&E	44.3	1.335
Yu,1978	B-0-30-2-0-DS	158	55.9	37.8	33.2	B	B&E	46.7	1.409
Yu,1978	B-0-30-3-L-DS	158	55.9	37.8	33.2	B	B&E	51.2	1.543
Yu,1978	B-0-30-4-L-DS	158	55.9	37.8	33.2	B	B&E	48.1	1.449
Yu,1978	B-0-30-5-0-DS	158	55.9	37.8	33.2	B	B&E	46.2	1.392
Yu,1978	B-0-30-6-0-DS	158	55.9	37.3	33.2	B	B&E	43.7	1.319
Yu,1978	B-0-30-7-L-DS	158	55.9	37.8	33.2	B	B&E	49.5	1.492
Yu,1978	B-0-30-8-L-DS	158	55.9	37.8	33.2	B	B&E	48.1	1.452
Yu,1978	B-0-30-9-H-DS	158	55.9	36.4	33.2	B	B&E	50.3	1.516
Yu,1978	B-0-30-10-H-DS	158	55.9	36.4	33.2	B	B&E	51.6	1.556
Yu,1978	B-0-32-1-0-SS	9.69	4.97	2.54	3.46	E	B&R	2.45	0.964
Yu,1978	B-0-32-2-0-SS	9.69	4.97	2.45	3.46	E	B&R	2.58	1.054
Yu,1978	B-0-32-3-L-SS	9.69	4.97	2.54	3.46	E	B&R	2.72	1.072
Yu,1978	B-0-32-4-L-SS	9.69	4.97	2.54	3.46	E	B&R	3.14	1.237
Yu,1978	B-0-32-5-0-SS	9.69	4.97	2.54	3.46	E	B&R	2.67	1.051

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
Yu,1978	B-0-32-6-0-SS	9.69	4.97	2.59	3.46	E	B&R	2.41	0.933
Yu,1978	B-0-32-7-L-SS	9.69	4.97	2.54	3.46	E	B&R	2.49	0.981
Yu,1978	B-0-32-8-L-SS	9.69	4.97	2.59	3.46	E	B&R	2.39	0.924
Yu,1978	B-0-32-9-H-SS	9.69	4.97	2.59	3.46	E	B&N.S	3.61	1.397
Yu,1978	B-0-32-10-H-SS	9.69	4.97	2.54	3.46	E	B&N.S	2.89	1.139
Yu,1978	B-0-34-1-0-DS	15.7	5.92	4.04	3.46	B	B&E	3.78	1.092
Yu,1978	B-0-34-2-0-DS	15.7	5.92	4.04	3.46	B	B&E	3.81	1.101
Yu,1978	B-0-34-3-L-DS	15.7	5.92	4.04	3.46	B	B&E	4.25	1.228
Yu,1978	B-0-34-4-L-DS	15.7	5.92	4.04	3.46	B	B&E	4.43	1.280
Yu,1978	B-0-34-5-0-DS	15.7	5.92	4.04	3.46	B	B&E	3.07	0.886
Yu,1978	B-0-34-6-0-DS	15.7	5.92	4.04	3.46	B	B&E	3.63	1.047
Yu,1978	B-0-34-7-L-DS	15.7	5.92	4.04	3.46	B	B&E	3.87	1.118
Yu,1978	B-0-34-8-L-DS	15.7	5.92	4.04	3.46	B	B&E	4.62	1.334
Yu,1978	B-0-34-9-H-DS	15.7	5.92	4.04	3.46	B	B&E	5.03	1.452
Yu,1978	B-0-34-10-H-DS	15.7	5.92	4.04	3.46	B	B&E	4.04	1.165
Yu,1978	B-0-37-1-0-SS	18.4	9.62	4.71	6.43	E	R	5.37	1.140
Yu,1978	B-0-37-2-0-SS	18.4	9.62	4.71	6.43	E	R	5.36	1.137
Yu,1978	B-0-37-3-L-SS	18.4	9.62	4.71	6.43	E	R	5.62	1.192
Yu,1978	B-0-37-4-L-SS	18.4	9.62	4.71	6.43	E	R	5.55	1.178
Yu,1978	B-0-37-5-H-SS	18.4	9.62	4.71	6.43	E	R	5.52	1.172
Yu,1978	B-0-37-6-H-SS	18.4	9.62	4.71	6.43	E	R	8.88	1.884
Yu,1978	B-0-38-1-0-SS	24.5	16.6	9.43	12.9	E	R	7.01	0.744
Yu,1978	B-0-38-2-0-SS	24.5	16.6	9.43	12.9	E	R	7.28	0.772
Yu,1978	B-0-38-3-L-SS	24.5	16.6	9.43	12.9	E	R	10.1	1.067
Yu,1978	B-0-38-4-L-SS	24.5	16.6	9.43	12.9	E	R	8.68	0.921
Yu,1978	B-0-38-5-0-SS	24.5	16.6	9.43	12.9	E	R	7.19	0.762
Yu,1978	B-0-38-6-0-SS	24.5	16.6	9.43	12.9	E	R	7.45	0.791
Yu,1978	B-0-38-7-L-SS	24.5	16.6	9.43	12.9	E	R	10.4	1.107
Yu,1978	B-0-38-8-L-SS	24.5	16.6	9.43	12.9	E	R	8.19	0.869
Yu,1978	B-0-38-9-H-SS	24.5	16.6	9.43	12.9	E	R	9.35	0.991
Yu,1978	B-0-38-10-H-SS	24.5	16.6	9.43	12.9	E	R	10.4	1.100
Yu,1978	B-0-41-1-0-DS	26.6	11.0	7.50	6.43	B	B&E	8.81	1.371
Yu,1978	B-0-41-2-0-DS	26.6	11.0	7.50	6.43	B	B&E	9.63	1.499
Yu,1978	B-0-41-3-L-DS	26.6	11.0	7.50	6.43	B	B&E	10.6	1.655
Yu,1978	B-0-41-4-L-DS	26.6	11.0	7.50	6.43	B	B&E	9.48	1.475
Yu,1978	B-0-41-5-H-DS	26.6	11.0	7.50	6.43	B	B&E	10.3	1.606
Yu,1978	B-0-41-6-H-DS	26.6	11.0	7.50	6.43	B	B&E	10.7	1.662
Yu,1978	B-0-42-1-0-DS	53.1	22.0	15.0	12.9	B	B&E	13.1	1.020

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
Yu,1978	B-0-42-2-0-DS	53.1	22.0	15.0	12.9	B	B&E	12.1	0.938
Yu,1978	B-0-42-3-L-DS	53.1	22.0	15.0	12.9	B	B&E	12.8	0.997
Yu,1978	B-0-42-4-L-DS	53.1	22.0	15.0	12.9	B	B&E	12.1	0.945
Yu,1978	B-0-42-5-0-DS	53.1	22.0	15.0	12.9	B	B&E	13.4	1.042
Yu,1978	B-0-42-6-0-DS	53.1	22.0	15.0	12.9	B	B&E	13.4	1.042
Yu,1978	B-0-42-7-L-DS	53.1	22.0	15.0	12.9	B	B&E	16.8	1.309
Yu,1978	B-0-42-8-L-DS	53.1	22.0	15.0	12.9	B	B&E	12.7	0.987
Yu,1978	B-0-42-9-H-DS	53.1	22.0	15.0	12.9	B	B&E	17.2	1.342
Yu,1978	B-0-42-10-H-DS	53.1	22.0	15.0	12.9	B	B&E	19.3	1.503
Yu,1978	B-0-45-1-0-SS	49.7	35.4	21.7	27.4	E	R	18.0	0.829
Yu,1978	B-0-45-2-0-SS	49.7	35.4	20.1	27.4	E	R	18.2	0.905
Yu,1978	B-0-45-3-L-SS	49.7	35.4	20.1	27.4	E	R	19.3	0.961
Yu,1978	B-0-45-4-L-SS	49.7	35.4	21.0	27.4	E	R	19.2	0.917
Yu,1978	B-0-45-5-H-SS	49.7	35.4	21.0	27.4	E	R	19.8	0.946
Yu,1978	B-0-45-6-H-SS	49.7	35.4	20.1	27.4	E	R	19.8	0.987
Yu,1978	B-0-46-1-0-SS	70.4	50.7	30.1	41.1	E	B&R	25.9	0.861
Yu,1978	B-0-46-2-0-SS	70.4	50.7	30.1	41.1	E	B&R	24.3	0.808
Yu,1978	B-0-46-3-L-SS	70.4	50.7	30.1	41.1	E	B&R	26.7	0.887
Yu,1978	B-0-46-4-L-SS	70.4	50.7	30.1	41.1	E	B&R	26.5	0.881
Yu,1978	B-0-46-5-0-SS	70.4	50.7	30.1	41.1	E	B&R	26.1	0.868
Yu,1978	B-0-46-6-0-SS	70.4	50.7	30.1	41.1	E	B&R	25.9	0.860
Yu,1978	B-0-46-7-L-SS	70.4	50.7	30.1	41.1	E	B&R	29.8	0.989
Yu,1978	B-0-46-8-L-SS	70.4	50.7	30.1	41.1	E	B&R	26.1	0.868
Yu,1978	B-0-46-9-H-SS	70.4	50.7	30.1	41.1	E	B&R	33.4	1.109
Yu,1978	B-0-46-10-H-SS	70.4	50.7	30.1	41.1	E	B&R	29.2	0.970
Yu,1978	B-0-49-1-0-DS	111	47.3	32.5	27.4	B	B&E	42.6	1.557
Yu,1978	B-0-49-2-0-DS	111	47.3	33.1	27.4	B	B&E	37.4	1.366
Yu,1978	B-0-49-3-L-DS	111	47.3	32.5	27.4	B	B&E	39.2	1.434
Yu,1978	B-0-49-4-L-DS	111	47.3	32.5	27.4	B	B&E	39.8	1.455
Yu,1978	B-0-49-5-H-DS	111	47.3	32.5	27.4	B	B&E	40.9	1.496
Yu,1978	B-0-49-6-H-DS	111	47.3	32.5	27.4	B	B&E	42.3	1.545
Yu,1978	B-0-50-1-0-DS	166	69.2	47.9	41.1	B	B&E	54.5	1.328
Yu,1978	B-0-50-2-0-DS	166	69.2	47.9	41.1	B	B&E	53.0	1.290
Yu,1978	B-0-50-3-L-DS	166	69.2	47.9	41.1	B	B&E	55.4	1.349
Yu,1978	B-0-50-4-L-DS	166	69.2	47.9	41.1	B	B&E	51.8	1.263
Yu,1978	B-0-50-5-0-DS	166	69.2	47.9	41.1	B	B&E	50.5	1.230
Yu,1978	B-0-50-6-0-DS	166	69.2	47.9	41.1	B	B&E	48.3	1.176
Yu,1978	B-0-50-7-L-DS	166	69.2	47.9	41.1	B	B&E	53.4	1.301

Table C4 Test-To-Predicted Values (Eurocode 3, 1996)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	P_t (KN)	P_t / P_p
Yu,1978	B-0-50-8-L-DS	166	69.2	47.9	41.1	B	B&E	44.9	1.093
Yu,1978	B-0-50-9-H-DS	166	69.2	47.9	41.1	B	B&E	62.3	1.517
Yu,1978	B-0-50-10-H-DS	166	69.2	47.9	41.1	B	B&E	53.5	1.303
Yu,1978	B-0-51-1-0-SS	189	134	81.4	109	E	R	97.7	1.199
Yu,1978	B-0-51-2-0-SS	189	134	81.4	109	E	R	96.3	1.183
Yu,1978	B-0-51-3-L-SS	189	134	82.9	109	E	R	94.1	1.135
Yu,1978	B-0-51-4-L-SS	189	134	81.4	109	E	R	102	1.251
Yu,1978	B-0-51-5-H-SS	189	134	81.4	109	E	R	95.0	1.166
Yu,1978	B-0-51-6-H-SS	189	134	81.4	109	E	R	97.9	1.202
Yu,1978	B-0-53-1-0-DS	444	183	127	109	B	B&E	158	1.455
Yu,1978	B-0-53-2-0-DS	444	183	130	109	B	B&E	155	1.431
Yu,1978	B-0-53-3-L-DS	444	183	127	109	B	B&E	162	1.492
Yu,1978	B-0-53-4-L-DS	444	183	128	109	B	B&E	161	1.482
Yu,1978	B-0-53-5-H-DS	444	183	124	109	B	B&E	161	1.480

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Carril,1994	AN32-1	62.8	75.3	57.5	31.3	B	B	36.0	1.149
Carril,1994	AN32-2	61.6	73.9	56.5	30.8	B	B	36.5	1.185
Carril,1994	AN33-1	77.2	96.1	57.5	31.3	B	B	40.1	1.278
Carril,1994	AN33-2	78.5	97.7	58.5	31.9	B	B	39.8	1.250
Carril,1994	BN33-1	77.9	97.1	106	63.2	B	B	65.0	1.028
Carril,1994	BN33-2	77.9	97.1	106	63.2	B	B	64.0	1.013
Carril,1994	DN12-2	44.6	57.6	44.0	22.7	B	B	21.1	0.927
Carril,1994	DN12-3	43.6	56.2	43.0	22.0	B	B	21.1	0.959
Carril,1994	DN22-1	65.1	88.2	67.5	36.8	B	B	37.5	1.020
Carril,1994	DN22-2	66.0	89.4	68.2	37.3	B	B	37.8	1.014
Carril,1994	BN32-1	62.7	75.2	105	62.7	B	B&N.S	64.3	1.027
Carril,1994	BN32-2	62.0	74.3	104	62.1	B	B&N.S	65.4	1.052
Carril,1994	DN32-1	127	152	116	63.7	B	B&R	70.1	1.100
Carril,1994	DN32-2	125	150	114	62.7	B	B&R	71.6	1.142
Carril,1994	EN12-1	44.6	57.6	81.0	45.5	B	B&R	38.5	0.846
Carril,1994	EN12-2	44.6	57.6	81.0	45.5	B	B&R	38.7	0.851
Carril,1994	EN22-1	66.0	89.4	125	74.6	B	B&R	70.2	0.940
Carril,1994	EN22-2	66.9	90.5	127	75.7	B	B&R	70.0	0.926
Carril,1994	EN32-1	125	150	210	125	B	B&R	128	1.024
Carril,1994	EN32-2	124	149	208	124	B	B&R	129	1.038
Carril,1994	AN31-2	31.1	29.6	56.4	30.8	N.S	N.S	29.3	0.989
Carril,1994	AN31-3	31.1	29.6	56.9	31.1	N.S	N.S	29.1	0.984
Carril,1994	BN31-1	31.3	29.7	105	62.7	N.S	N.S	29.4	0.988
Carril,1994	BN31-2	31.3	29.6	105	62.7	N.S	N.S	29.4	0.991
Carril,1994	CN11-1	11.0	11.2	58.8	34.1	N.S	N.S	10.2	0.909
Carril,1994	CN11-2	11.0	11.2	58.9	34.1	N.S	N.S	10.4	0.924
Carril,1994	CN12-1	22.2	28.6	58.9	34.1	N.S	N.S	25.5	0.893
Carril,1994	CN12-2	22.2	28.6	58.9	34.1	N.S	N.S	25.5	0.893
Carril,1994	CN21-1	16.7	18.0	91.2	56.0	N.S	N.S	18.2	1.012
Carril,1994	CN21-2	16.9	18.1	92.5	56.8	N.S	N.S	18.1	0.997
Carril,1994	CN21-3	16.9	18.1	92.5	56.8	N.S	N.S	17.9	0.989
Carril,1994	CN22-1	33.1	44.8	91.4	56.0	N.S	N.S	42.7	0.954
Carril,1994	CN22-2	33.6	45.5	92.6	56.8	N.S	N.S	42.9	0.943
Carril,1994	CN22-3	33.1	44.8	91.3	56.0	N.S	N.S	42.9	0.956
Carril,1994	CN31-2	32.0	30.4	155	95.6	N.S	N.S	30.8	1.013
Carril,1994	CN31-3	32.3	30.7	156	96.4	N.S	N.S	30.0	0.980
Carril,1994	CN32-1	64.4	77.2	157	96.4	N.S	N.S	71.2	0.923

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Carril,1994	CN32-2	63.6	76.2	155	95.6	N.S	N.S	70.4	0.924
Carril,1994	DN31-1	63.7	60.4	116	63.7	N.S	N.S	55.2	0.914
Carril,1994	DN31-2	61.7	58.5	112	61.6	N.S	N.S	53.4	0.913
Carril,1994	EN11-1	22.7	23.1	82.8	47.0	N.S	N.S	21.4	0.927
Carril,1994	EN11-2	22.2	22.6	80.9	45.5	N.S	N.S	21.5	0.949
Carril,1994	EN21-1	33.6	36.1	127	75.7	N.S	N.S	37.4	1.037
Carril,1994	EN21-2	33.5	36.0	127	75.7	N.S	N.S	37.4	1.040
Carril,1994	EN31-1	62.2	59.0	209	124	N.S	N.S	58.9	0.999
Carril,1994	EN31-2	62.7	59.5	211	125	N.S	N.S	60.3	1.013
Carril,1994	DN11-1	21.2	21.6	42.1	21.3	B	N&R	18.1	0.852
Carril,1994	DN11-2	21.7	22.1	42.9	22.0	B	N&R	18.7	0.852
Carril,1994	DN21-1	33.6	36.0	69.4	37.8	N.S	N&R	32.0	0.889
Carril,1994	DN21-2	33.1	35.5	68.4	37.3	N.S	N&R	31.5	0.887
Chong,1975	1	35.8	33.9	20.7	9.64	B	B&E	10.9	1.136
Chong,1975	2	35.5	35.8	21.7	6.82	B	B	8.14	1.194
Chong,1975	3	36.3	36.6	22.0	6.82	B	B&E	7.12	1.044
Chong,1975	4	35.8	33.9	20.4	9.64	B	E	9.92	1.030
Chong,1975	5	35.8	33.9	20.8	9.64	B	E	10.8	1.122
Chong,1975	6	35.2	33.3	8.37	9.64	E	B&E	10.6	1.271
Chong,1975	7	35.2	33.3	14.2	9.64	B	E	11.0	1.145
Chong,1975	8	35.2	33.3	17.1	9.64	B	E	10.0	1.039
Chong,1975	9	35.2	33.3	25.8	9.64	B	B	10.1	1.044
Chong,1975	11	35.2	33.3	25.8	9.64	B	B	10.3	1.067
Chong,1975	12	35.2	33.3	14.2	9.64	B	E	10.7	1.113
Chong,1975	13	35.2	33.3	8.37	9.64	E	E&B	10.5	1.255
Chong,1975	14	35.2	33.3	2.55	9.64	E	E	7.48	2.936
Chong,1975	15	35.2	33.3	2.55	9.64	E	E	6.76	2.656
Chong,1975	32	37.1	39.4	24.3	12.8	B	E&B	12.9	1.005
Chong,1975	33	37.1	39.4	23.6	12.8	B	B&E	13.3	1.036
Chong,1975	34	37.1	39.4	23.6	12.8	B	B&E	13.1	1.022
Chong,1975	41	54.9	69.2	5.52	22.6	E	E&B	12.3	2.232
Chong,1975	42	54.9	69.2	5.76	22.6	E	E&B	13.8	2.385
Chong,1975	49	13.9	9.00	41.5	22.6	N.S	N.S	13.5	1.497
Chong,1975	50	13.9	9.00	41.5	22.6	N.S	N.S	12.9	1.438
Chong,1975	51	13.9	9.00	41.5	22.6	N.S	N.S	11.9	1.320
Chong,1975	52	74.3	73.9	72.1	39.1	B	B&E	38.3	0.979
Chong,1975	53	74.3	73.9	72.4	39.1	B	B&E	36.3	0.927
Chong,1975	54	74.3	73.9	72.1	39.1	B	B&E	40.8	1.043

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Chong,1975	55	111	106	102	55.2	B	B&E	55.6	1.008
Chong,1975	16(3b)	26.6	18.4	17.4	19.3	E	N.S	18.1	1.036
Chong,1975	17(3b)	27.0	18.8	16.7	19.3	E	N.S	18.4	1.098
Chong,1975	37(3b)	37.2	33.2	46.1	25.6	B	E&B	24.8	0.969
Chong,1975	40(3b)	54.9	57.8	81.6	45.3	B	B	40.0	0.883
Chong,1975	56(3b)	110	78.9	203	110	N.S	E&N	88.3	1.119
Chong,1975	35(3c)	37.3	34.3	76.9	24.0	B	B	23.3	0.972
Chong,1975	36(3c)	37.3	34.3	77.7	24.0	B	B	24.0	1.000
Chong,1975	18(3d)	8.81	4.24	25.1	19.3	N.S	N.S	7.57	1.782
Chong,1975	19(3d)	8.81	4.24	25.1	19.3	N.S	N.S	6.72	1.583
Chong,1975	22(3d)	17.6	13.9	25.1	19.3	N.S	N.S	14.9	1.066
Chong,1975	23(3d)	17.6	13.9	25.1	19.3	N.S	N.S	15.9	1.139
Chong,1975	28(3d)	35.2	33.3	25.1	19.3	B	E	19.5	1.011
Chong,1975	29(3d)	35.2	33.3	25.1	19.3	B	B&E	19.2	0.998
Chong,1975	45(3d)	27.4	28.9	52.1	45.3	N.S	N.S	30.7	1.063
Chong,1975	46(3d)	27.4	28.9	52.1	45.3	N.S	N.S	31.9	1.103
Chong,1975	20(3e)	8.81	4.24	41.8	28.9	N.S	N.S	7.83	1.845
Chong,1975	21(3e)	8.81	4.24	41.8	28.9	N.S	N.S	4.76	1.122
Chong,1975	24(3e)	17.6	13.9	41.8	28.9	N.S	N.S	15.7	1.126
Chong,1975	25(3e)	17.6	13.9	41.8	28.9	N.S	N.S	15.2	1.088
Chong,1975	26(3e)	34.7	32.8	41.8	28.9	B	E	28.8	0.996
Chong,1975	27(3e)	34.7	32.8	41.8	28.9	B	E	28.8	0.998
Chong,1975	43(3e)	55.3	69.8	86.8	67.9	B	E&B	58.3	0.858
Chong,1975	44(3e)	55.7	70.4	86.8	67.9	B	E&B	60.1	0.885
Chong,1975	47(3e)	13.7	8.80	86.8	67.9	N.S	N.S	13.0	1.476
Chong,1975	48(3e)	13.7	8.80	86.8	67.9	N.S	N.S	13.5	1.532
Gilchrist,1979	1	16.9	17.3	4.79	2.42	B	B&E	3.20	1.325
Gilchrist,1979	2	16.9	17.3	3.40	2.42	B	B&E	2.71	1.122
Gilchrist,1979	3	16.9	17.3	2.56	2.42	B	B&E	2.60	1.076
Gilchrist,1979	4	16.9	16.7	7.24	2.83	B	B&E	3.03	1.070
Gilchrist,1979	5	16.9	16.7	4.45	2.83	B	B	3.00	1.063
Gilchrist,1979	6	16.9	16.7	3.05	2.83	B	B&E	3.16	1.118
Gilchrist,1979	7	24.3	23.9	6.63	3.58	B	B&E	3.78	1.057
Gilchrist,1979	8	24.3	23.9	4.70	3.58	B	B&E	3.89	1.088
Gilchrist,1979	9	24.3	23.9	3.55	3.58	E	B&E	3.69	1.042
Gilchrist,1979	10	24.3	23.1	10.0	4.43	B	B&E	4.01	0.904
Gilchrist,1979	11	24.3	23.1	6.15	4.43	B	B	3.56	0.803
Gilchrist,1979	12	24.3	23.1	4.22	4.43	E	B&E	4.34	1.028

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Gilchrist,1979	13	24.8	24.5	6.81	3.71	B	B&E	4.58	1.235
Gilchrist,1979	14	24.8	24.5	4.83	3.71	B	B&E	4.29	1.157
Gilchrist,1979	15	24.8	24.5	3.64	3.71	E	B&E	4.18	1.150
Gilchrist,1979	16	24.8	23.7	10.3	4.87	B	B&E	4.34	0.890
Gilchrist,1979	17	24.8	23.7	6.31	4.87	B	B&E	4.36	0.895
Gilchrist,1979	18	24.8	23.7	4.33	4.87	E	B&E	4.05	0.935
Gilchrist,1979	19	24.8	22.7	13.6	5.37	B	B&E	7.23	1.348
Gilchrist,1979	20	24.8	22.7	9.65	5.37	B	B	5.21	0.970
Gilchrist,1979	21	24.8	22.7	5.69	5.37	B	B	5.45	1.016
Gilchrist,1979	22	19.8	22.9	6.35	3.47	B	B&E	3.78	1.091
Gilchrist,1979	23	19.8	22.9	4.51	3.47	B	B&E	3.65	1.053
Gilchrist,1979	24	19.8	22.9	3.40	3.47	E	B&E	4.01	1.179
Gilchrist,1979	25	19.8	22.1	9.59	4.55	B	B&E	4.41	0.968
Gilchrist,1979	26	19.8	22.1	5.89	4.55	B	B&E	4.21	0.924
Gilchrist,1979	27	19.8	22.1	4.04	4.55	E	B&E	4.12	1.018
Gilchrist,1979	28	19.8	21.2	12.7	5.01	B	B	7.16	1.430
Gilchrist,1979	29	19.8	21.2	9.01	5.01	B	B	6.50	1.297
Gilchrist,1979	30	19.8	21.2	5.31	5.01	B	B	5.01	0.999
McGill,2002	043-230-3/8-SS-A	8.03	9.88	10.1	1.99	B	B	1.69	0.850
McGill,2002	043-230-3/8-SS-B	8.03	9.88	10.1	1.99	B	B	1.77	0.891
McGill,2002	043-230-3/8-SS-C	8.03	9.88	10.1	1.99	B	B	1.67	0.840
McGill,2002	043-230-3/8-TTSS-A	8.03	9.88	10.1	1.99	B	B	1.87	0.941
McGill,2002	043-230-3/8-TTSS-B	8.03	9.88	10.1	1.99	B	B	1.77	0.891
McGill,2002	043-230-3/8-TTSS-C	8.03	9.88	10.1	1.99	B	B	2.16	1.087
McGill,2002	043-230-3/8-DS-A	8.03	9.88	10.1	3.53	B	B	3.65	1.033
McGill,2002	043-230-3/8-DS-B	8.03	9.88	10.1	3.53	B	B	3.46	0.979
McGill,2002	043-230-3/8-DS-C	8.03	9.88	10.1	3.53	B	B	3.26	0.923
McGill,2002	043-550-3/8-SS-A	19.3	16.4	16.8	3.30	B	B	2.62	0.793
McGill,2002	043-550-3/8-SS-B	19.3	16.4	16.8	3.30	B	B	2.73	0.826
McGill,2002	043-550-3/8-SS-C	19.3	16.4	16.8	3.30	B	B	2.49	0.754
McGill,2002	043-230-1/2-SS-A	8.03	9.38	9.80	2.65	B	B	2.14	0.808
McGill,2002	043-230-1/2-SS-B	8.03	9.38	9.80	2.65	B	B	2.13	0.804
McGill,2002	043-230-1/2-SS-C	8.03	9.38	9.80	2.65	B	B	2.18	0.823
McGill,2002	043-230-1/2-TTSS-A	8.03	9.38	9.80	2.65	B	B	2.29	0.864
McGill,2002	043-230-1/2-TTSS-B	8.03	9.38	9.80	2.65	B	B	2.24	0.845
McGill,2002	043-230-1/2-TTSS-C	8.03	9.38	9.80	2.65	B	B	2.46	0.928
McGill,2002	043-230-1/2-DS-A	8.03	9.38	9.80	4.71	B	B	5.43	1.153
McGill,2002	043-230-1/2-DS-B	8.03	9.38	9.80	4.71	B	B	5.80	1.231

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	043-230-1/2-DS-C	8.03	9.38	9.80	4.71	B	B	5.72	1.214
McGill,2002	043-550-1/2-SS-A	19.3	15.6	16.3	4.40	B	B	3.37	0.765
McGill,2002	043-550-1/2-SS-B	19.3	15.6	16.3	4.40	B	B	3.36	0.763
McGill,2002	043-550-1/2-SS-C	19.3	15.6	16.3	4.40	B	B	3.36	0.763
McGill,2002	043-230-5/8-SS-A	8.03	8.89	9.51	3.31	B	B	2.99	0.903
McGill,2002	043-230-5/8-SS-B	8.03	8.89	9.51	3.31	B	B	2.84	0.857
McGill,2002	043-230-5/8-SS-C	8.03	8.89	9.51	3.31	B	B	2.78	0.839
McGill,2002	043-230-5/8-TTSS-A	8.03	8.89	9.51	3.31	B	B	3.09	0.933
McGill,2002	043-230-5/8-TTSS-B	8.03	8.89	9.51	3.31	B	B	3.22	0.972
McGill,2002	043-230-5/8-TTSS-C	8.03	8.89	9.51	3.31	B	B	3.36	1.014
McGill,2002	043-230-5/8-DS-A	8.03	8.89	9.51	5.89	B	B	7.05	1.197
McGill,2002	043-230-5/8-DS-B	8.03	8.89	9.51	5.89	B	B	7.49	1.272
McGill,2002	043-230-5/8-DS-C	8.03	8.89	9.51	5.89	B	B	7.35	1.248
McGill,2002	043-550-5/8-SS-A	19.3	14.8	15.8	5.51	B	B	3.71	0.674
McGill,2002	043-550-5/8-SS-B	19.3	14.8	15.8	5.51	B	B	3.93	0.714
McGill,2002	043-550-5/8-SS-C	19.3	14.8	15.8	5.51	B	B	3.92	0.712
McGill,2002	064-230-5/8-TTSS-A	14.3	12.6	13.5	4.70	B	B	5.22	1.111
McGill,2002	064-230-5/8-TTSS-B	14.3	12.6	13.5	4.70	B	B	4.88	1.039
McGill,2002	064-230-5/8-TTSS-C	14.3	12.6	13.5	4.70	B	B	5.47	1.164
McGill,2002	064-230-5/8-DS-A	14.3	12.6	13.5	8.35	B	B	11.8	1.417
McGill,2002	064-230-5/8-DS-B	14.3	12.6	13.5	8.35	B	B	11.0	1.319
McGill,2002	064-230-5/8-DS-C	14.3	12.6	13.5	8.35	B	B	11.7	1.401
McGill,2002	064-550-5/8-SS-A	33.3	25.5	27.3	9.51	B	B	8.64	0.909
McGill,2002	064-550-5/8-SS-B	33.3	25.5	27.3	9.51	B	B	8.91	0.937
McGill,2002	064-550-5/8-SS-C	33.3	25.5	27.3	9.51	B	B	8.34	0.877
McGill,2002	064-230-1/2-TTSS-A	14.3	13.3	13.9	4.14	B	B	4.56	1.101
McGill,2002	064-230-1/2-TTSS-B	14.3	13.3	13.9	4.14	B	B	4.44	1.072
McGill,2002	064-230-1/2-TTSS-C	14.3	13.3	13.9	4.14	B	B	4.10	0.990
McGill,2002	064-230-1/2-DS-A	14.3	13.3	13.9	7.35	B	B	8.91	1.213
McGill,2002	064-230-1/2-DS-B	14.3	13.3	13.9	7.35	B	B	9.28	1.263
McGill,2002	064-230-1/2-DS-C	14.3	13.3	13.9	7.35	B	B	9.23	1.256
McGill,2002	064-550-1/2-SS-A	33.3	26.9	28.1	8.38	B	B	6.94	0.828
McGill,2002	064-550-1/2-SS-B	33.3	26.9	28.1	8.38	B	B	7.26	0.866
McGill,2002	064-550-1/2-SS-C	33.3	26.9	28.1	8.38	B	B	7.04	0.840
McGill,2002	064-230-3/8-SS-A	14.3	14.0	14.3	3.90	B	B	3.05	0.783
McGill,2002	064-230-3/8-SS-B	14.3	14.0	14.3	3.90	B	B	2.75	0.706
McGill,2002	064-230-3/8-SS-C	14.3	14.0	14.3	3.90	B	B	2.77	0.711
McGill,2002	064-550-3/8-SS-A	33.3	28.3	29.0	7.88	B	B	5.83	0.740

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	064-550-3/8-SS-B	33.3	28.3	29.0	7.88	B	B	6.43	0.816
McGill,2002	064-550-3/8-SS-C	33.3	28.3	29.0	7.88	B	B	5.82	0.738
McGill,2002	064-230-1/4-DS-A	14.3	14.7	14.7	5.54	B	B	6.76	1.220
McGill,2002	064-230-1/4-DS-B	14.3	14.7	14.7	5.54	B	B	6.67	1.204
McGill,2002	064-230-1/4-DS-C	14.3	14.7	14.7	5.54	B	B	6.38	1.152
McGill,2002	064-550-1/4-SS-A	33.3	29.7	29.8	6.32	B	B	5.68	0.899
McGill,2002	064-550-1/4-SS-B	33.3	29.7	29.8	6.32	B	B	5.55	0.878
McGill,2002	064-550-1/4-SS-C	33.3	29.7	29.8	6.32	B	B	5.90	0.934
McGill,2002	064-230-1/4-SS-A	14.3	14.7	14.7	3.12	B	B	2.92	0.935
McGill,2002	064-230-1/4-SS-B	14.3	14.7	14.7	3.12	B	B	3.07	0.983
McGill,2002	064-230-1/4-SS-C	14.3	14.7	14.7	3.12	B	B	3.00	0.960
McGill,2002	064-230-1/4-TTSS-A	14.3	14.7	14.7	3.12	B	B	2.95	0.944
McGill,2002	064-230-1/4-TTSS-B	14.3	14.7	14.7	3.12	B	B	3.29	1.053
McGill,2002	064-230-1/4-TTSS-C	14.3	14.7	14.7	3.12	B	B	3.80	1.216
McGill,2002	076-230-1/2-SS-A	18.5	17.4	18.2	6.10	B	B	4.77	0.781
McGill,2002	076-230-1/2-SS-B	18.5	17.4	18.2	6.10	B	B	4.53	0.743
McGill,2002	076-230-1/2-SS-C	18.5	17.4	18.2	6.10	B	B	4.90	0.802
McGill,2002	076-230-1/2-TTSS-A	18.5	17.4	18.2	6.10	B	B	5.22	0.855
McGill,2002	076-230-1/2-TTSS-B	18.5	17.4	18.2	6.10	B	B	5.90	0.967
McGill,2002	076-230-1/2-TTSS-C	18.5	17.4	18.2	6.10	B	B	5.41	0.886
McGill,2002	076-230-1/2-DS-A	18.5	17.4	18.2	10.8	B	B	10.8	1.001
McGill,2002	076-230-1/2-DS-B	18.5	17.4	18.2	10.8	B	B	11.8	1.093
McGill,2002	076-230-1/2-DS-C	18.5	17.4	18.2	10.8	B	B	10.5	0.973
McGill,2002	076-550-1/2-SS-A	38.4	31.1	32.5	11.4	B	B	8.50	0.748
McGill,2002	076-550-1/2-SS-B	38.4	31.1	32.5	11.4	B	B	8.06	0.709
McGill,2002	076-550-1/2-SS-C	38.4	31.1	32.5	11.4	B	B	8.50	0.748
McGill,2002	076-230-5/8-SS-A	18.5	16.5	17.6	6.14	B	B	6.17	1.005
McGill,2002	076-230-5/8-SS-B	18.5	16.5	17.6	6.14	B	B	6.04	0.983
McGill,2002	076-230-5/8-SS-C	18.5	16.5	17.6	6.14	B	B	6.04	0.983
McGill,2002	076-550-3/8-SS-A	38.4	32.7	33.5	10.1	B	B	8.19	0.815
McGill,2002	076-550-3/8-SS-B	38.4	32.7	33.5	10.1	B	B	7.80	0.776
McGill,2002	076-550-3/8-SS-C	38.4	32.7	33.5	10.1	B	B	6.61	0.658
McGill,2002	076-550-1/4-SS-A	38.4	34.4	34.4	7.32	B	B	7.01	0.958
McGill,2002	076-550-1/4-SS-B	38.4	34.4	34.4	7.32	B	B	6.80	0.929
McGill,2002	076-550-1/4-SS-C	38.4	34.4	34.4	7.32	B	B	6.55	0.895
McGill,2002	091-230-1/4-SS-A	20.0	21.6	21.7	4.60	B	B	4.65	1.010
McGill,2002	091-230-1/4-SS-B	20.0	21.6	21.7	4.60	B	B	5.14	1.117
McGill,2002	091-230-1/4-SS-C	20.0	21.6	21.7	4.60	B	B	4.83	1.049

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	091-230-1/4-TTSS-A	20.0	21.6	21.7	4.60	B	B	7.94	1.725
McGill,2002	091-230-1/4-TTSS-B	20.0	21.6	21.7	4.60	B	B	7.46	1.621
McGill,2002	091-230-1/4-TTSS-C	20.0	21.6	21.7	4.60	B	B	7.51	1.632
McGill,2002	091-230-1/4-DS-A	20.0	21.6	21.7	8.16	B	B	12.7	1.555
McGill,2002	091-230-1/4-DS-B	20.0	21.6	21.7	8.16	B	B	12.4	1.514
McGill,2002	091-230-1/4-DS-C	20.0	21.6	21.7	8.16	B	B	11.2	1.377
McGill,2002	091-230-1/2-TTSS-A	20.0	19.6	20.4	7.99	B	B	6.91	0.865
McGill,2002	091-230-1/2-TTSS-B	20.0	19.6	20.4	7.99	B	B	6.94	0.868
McGill,2002	091-230-1/2-TTSS-C	20.0	19.6	20.4	7.99	B	B	7.00	0.876
McGill,2002	091-230-1/2-DS-A	20.0	19.6	20.4	14.2	B	B	14.3	1.009
McGill,2002	091-230-1/2-DS-B	20.0	19.6	20.4	14.2	B	B	13.6	0.960
McGill,2002	091-230-1/2-DS-C	20.0	19.6	20.4	14.2	B	B	13.4	0.948
McGill,2002	121-230-1/2-TTSS-A	30.2	30.5	31.9	14.4	B	B	10.3	0.714
McGill,2002	121-230-1/2-TTSS-B	30.2	30.5	31.9	14.4	B	B	10.3	0.720
McGill,2002	121-230-1/2-TTSS-C	30.2	30.5	31.9	14.4	B	B	12.0	0.836
McGill,2002	121-230-1/2-DS-A	30.2	30.5	31.9	25.5	B	B	18.6	0.730
McGill,2002	121-230-1/2-DS-B	30.2	30.5	31.9	25.5	B	B	20.9	0.820
McGill,2002	121-230-1/2-DS-C	30.2	30.5	31.9	25.5	B	B	18.3	0.717
McGill,2002	121-230-3/8-SS-A	30.2	32.1	32.8	10.8	B	B	8.39	0.779
McGill,2002	121-230-3/8-SS-B	30.2	32.1	32.8	10.8	B	B	8.54	0.793
McGill,2002	121-230-3/8-SS-C	30.2	32.1	32.8	10.8	B	B	8.89	0.826
McGill,2002	121-230-3/8-TTSS-A	30.2	32.1	32.8	10.8	B	B	9.28	0.862
McGill,2002	121-230-3/8-TTSS-B	30.2	32.1	32.8	10.8	B	B	9.03	0.839
McGill,2002	121-230-3/8-TTSS-C	30.2	32.1	32.8	10.8	B	B	9.70	0.901
McGill,2002	121-230-3/8-DS-A	30.2	32.1	32.8	19.1	B	B	20.5	1.071
McGill,2002	121-230-3/8-DS-B	30.2	32.1	32.8	19.1	B	B	18.4	0.961
McGill,2002	121-230-3/8-DS-C	30.2	32.1	32.8	19.1	B	B	16.4	0.858
McGill,2002	153-230-1/4-SS-A	33.3	36.5	36.6	7.77	B	B	9.99	1.285
McGill,2002	153-230-1/4-SS-B	33.3	36.5	36.6	7.77	B	B	9.80	1.261
McGill,2002	153-230-1/4-SS-C	33.3	36.5	36.6	7.77	B	B	9.49	1.221
Wallace,2000	1-wo-50	22.4	20.6	27.0	6.99	B	B	6.29	0.900
Wallace,2000	2-wo-50	22.4	20.6	27.0	6.99	B	B	6.95	0.995
Wallace,2000	3-wo-50	22.4	20.6	27.0	6.99	B	B	6.53	0.935
Wallace,2000	1-wo-40	22.4	20.6	21.1	6.99	B	B	6.64	0.950
Wallace,2000	2-wo-40	22.4	20.6	21.1	6.99	B	B	6.12	0.876
Wallace,2000	3-wo-40	22.4	20.6	21.1	6.99	B	B	6.70	0.959
Wallace,2000	1-wo-30	22.4	20.6	15.3	6.99	B	B	6.38	0.913
Wallace,2000	2-wo-30	22.4	20.6	15.3	6.99	B	B	6.41	0.918

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Wallace,2000	3-wo-30	22.4	20.6	15.3	6.99	B	B	6.24	0.893
Wallace,2000	1-wo-20	22.4	20.6	9.41	6.99	B	B	5.89	0.843
Wallace,2000	2-wo-20	22.4	20.6	9.41	6.99	B	B	6.20	0.887
Wallace,2000	3-wo-20	22.4	20.6	9.41	6.99	B	B	6.60	0.945
Wallace,2000	1-wo-20-t5	22.4	20.6	9.41	6.99	B	B	7.24	1.036
Wallace,2000	2-wo-20-t5	22.4	20.6	9.41	6.99	B	B	6.63	0.949
Wallace,2000	3-wo-20-t5	22.4	20.6	9.41	6.99	B	B	6.45	0.923
Wallace,2000	1-wo-20-t15	22.4	20.6	9.41	6.99	B	B	7.11	1.018
Wallace,2000	2-wo-20-t15	22.4	20.6	9.41	6.99	B	B	6.50	0.930
Wallace,2000	3-wo-20-t15	22.4	20.6	9.41	6.99	B	B	7.71	1.104
Wallace,2000	1-wo-30-50	22.4	20.6	40.0	14.0	B	B	14.5	1.035
Wallace,2000	2-wo-30-50	22.4	20.6	40.0	14.0	B	B	15.3	1.094
Wallace,2000	3-wo-30-50	22.4	20.6	40.0	14.0	B	B	14.2	1.013
Wallace,2000	1-wo-30-40	22.4	20.6	34.1	14.0	B	B	14.1	1.012
Wallace,2000	2-wo-30-40	22.4	20.6	34.1	14.0	B	B	14.6	1.042
Wallace,2000	3-wo-30-40	22.4	20.6	34.1	14.0	B	B	14.2	1.015
Wallace,2000	1-wo-30-30	22.4	20.6	28.2	14.0	B	B	15.1	1.081
Wallace,2000	2-wo-30-30	22.4	20.6	28.2	14.0	B	B	15.3	1.098
Wallace,2000	3-wo-30-30	22.4	20.6	28.2	14.0	B	B	14.0	0.998
Wallace,2000	1-wo-40-3/8	22.4	19.0	20.2	8.77	B	B	7.26	0.827
Wallace,2000	2-wo-40-3/8	22.4	19.0	20.2	8.77	B	B	7.52	0.857
Wallace,2000	3-wo-40-3/8	22.4	19.0	20.2	8.77	B	B	7.65	0.872
Wallace,2000	1-wo-30-5/16	22.4	19.8	14.8	8.03	B	B	7.82	0.973
Wallace,2000	2-wo-30-5/16	22.4	19.8	14.8	8.03	B	B	6.58	0.819
Wallace,2000	3-wo-30-5/16	22.4	19.8	14.8	8.03	B	B	6.98	0.869
Wallace,2000	1-wo-50-1/2	22.4	17.5	25.1	9.39	B	B	9.80	1.044
Wallace,2000	2-wo-50-1/2	22.4	17.5	25.1	9.39	B	B	9.62	1.025
Wallace,2000	3-wo-50-1/2	22.4	17.5	25.1	9.39	B	B	9.16	0.976
Wallace,2000	1-wo-50-5/8	22.4	15.9	24.2	10.5	B	B	10.3	0.984
Wallace,2000	2-wo-50-5/8	22.4	15.9	24.2	10.5	B	B	10.3	0.986
Wallace,2000	3-wo-50-5/8	22.4	15.9	24.2	10.5	B	B	10.3	0.979
Wallace,2000	1-wo-ss-5/16	11.2	9.90	7.40	4.02	B	B	3.23	0.804
Wallace,2000	2-wo-ss-5/16	11.2	9.90	7.40	4.02	B	B	3.27	0.814
Wallace,2000	3-wo-ss-5/16	11.2	9.90	7.40	4.02	B	B	3.39	0.844
Wallace,2000	1-wo-sst-5/16	24.6	20.2	15.1	8.90	B	B	9.12	1.025
Wallace,2000	2-wo-sst-5/16	24.6	20.2	15.1	8.90	B	B	8.51	0.956
Wallace,2000	3-wo-sst-5/16	24.6	20.2	15.1	8.90	B	B	8.26	0.928
Wallace,2000	1-wo-sst-1/4	24.6	21.0	15.6	7.12	B	B	9.16	1.287

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Wallace,2000	2-wo-sst-1/4	24.6	21.0	15.6	7.12	B	B	8.92	1.253
Wallace,2000	3-wo-sst-1/4	24.6	21.0	15.6	7.12	B	B	9.03	1.269
Wallace,2000	1-wo-mix-1/4	11.2	10.3	7.64	3.49	B	B	3.52	1.008
Wallace,2000	2-wo-mix-1/4	11.2	10.3	7.64	3.49	B	B	3.47	0.993
Wallace,2000	3-wo-mix-1/4	11.2	10.3	7.64	3.49	B	B	3.73	1.068
Wallace,2000	1-wo-ss-1/4	11.2	10.3	7.64	3.49	B	B	3.27	0.936
Wallace,2000	2-wo-ss-1/4	11.2	10.3	7.64	3.49	B	B	3.30	0.945
Wallace,2000	1-wo-ss-1/2	11.2	8.73	6.71	4.69	B	B	4.25	0.905
Wallace,2000	2-wo-ss-1/2	11.2	8.73	6.71	4.69	B	B	4.43	0.944
Wallace,2000	3-wo-ss-1/2	11.2	8.73	6.71	4.69	B	B	4.00	0.852
Wallace,2000	1-wo-ss-5/8	11.2	7.95	6.24	5.24	B	B	5.45	1.040
Wallace,2000	2-wo-ss-5/8	11.2	7.95	6.24	5.24	B	B	5.43	1.036
Wallace,2000	3-wo-ss-5/8	11.2	7.95	6.24	5.24	B	B	5.41	1.033
Yu,1978	B-0-12-1-0-SS	4.78	4.94	1.43	1.21	B	R	1.73	1.421
Yu,1978	B-0-12-2-0-SS	4.78	4.94	1.43	1.21	B	R	1.40	1.154
Yu,1978	B-0-12-3-L-SS	4.78	4.94	1.48	1.21	B	R	1.40	1.154
Yu,1978	B-0-12-4-L-SS	4.78	4.94	1.48	1.21	B	R	1.50	1.238
Yu,1978	B-0-12-5-0-SS	4.78	4.94	1.43	1.21	B	R	1.36	1.117
Yu,1978	B-0-12-6-0-SS	4.78	4.94	1.48	1.21	B	R	1.44	1.183
Yu,1978	B-0-12-7-L-SS	4.78	4.94	1.43	1.21	B	R	1.58	1.304
Yu,1978	B-0-12-8-L-SS	4.66	4.80	1.45	1.21	B	R	1.45	1.194
Yu,1978	B-0-12-9-H-SS	4.71	4.85	1.45	1.21	B	R	1.70	1.403
Yu,1978	B-0-12-10-H-SS	4.78	4.94	1.48	1.21	B	R	2.25	1.850
Yu,1978	B-0-14-1-0-DS	7.89	8.69	2.58	2.15	B	B&E	2.42	1.122
Yu,1978	B-0-14-2-0-DS	7.89	8.69	2.58	2.15	B	B&E	2.13	0.987
Yu,1978	B-0-14-3-L-DS	7.89	8.69	2.58	2.15	B	B&E	2.55	1.186
Yu,1978	B-0-14-4-L-DS	7.89	8.69	2.58	2.15	B	B&E	2.36	1.095
Yu,1978	B-0-14-5-0-DS	7.89	8.69	2.58	2.15	B	B&E	2.33	1.080
Yu,1978	B-0-14-6-0-DS	7.89	8.69	2.58	2.15	B	B&E	2.14	0.996
Yu,1978	B-0-14-7-L-DS	7.89	8.69	2.58	2.15	B	B&E	3.06	1.421
Yu,1978	B-0-14-8-L-DS	7.89	8.69	2.58	2.15	B	B&E	3.15	1.462
Yu,1978	B-0-14-9-H-DS	7.89	8.69	2.58	2.15	B	B&E	2.46	1.140
Yu,1978	B-0-14-10-H-DS	7.89	8.69	2.58	2.15	B	B&E	2.41	1.120
Yu,1978	B-0-17-1-0-SS	12.5	13.2	3.97	4.40	E	R	5.42	1.365
Yu,1978	B-0-17-2-0-SS	12.5	13.2	3.97	4.40	E	R	4.96	1.250
Yu,1978	B-0-17-3-L-SS	12.7	13.5	3.97	4.40	E	R	5.36	1.350
Yu,1978	B-0-17-4-L-SS	12.5	13.2	3.97	4.40	E	R	5.75	1.449
Yu,1978	B-0-17-5-0-SS	12.5	13.2	3.97	4.40	E	R	5.28	1.331

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-17-6-0-SS	12.5	13.2	3.82	4.40	E	R	5.31	1.392
Yu,1978	B-0-17-7-L-SS	12.5	13.2	3.97	4.40	E	R	5.32	1.340
Yu,1978	B-0-17-8-L-SS	12.5	13.2	3.97	4.40	E	R	5.45	1.374
Yu,1978	B-0-17-9-H-SS	12.7	13.5	3.97	4.40	E	R	5.33	1.344
Yu,1978	B-0-17-10-H-SS	12.5	13.2	3.85	4.40	E	R	5.40	1.405
Yu,1978	B-0-18-1-0-SS	19.0	19.1	7.64	7.67	E	R	6.30	0.825
Yu,1978	B-0-18-2-0-SS	19.0	19.1	7.69	7.67	B	R	6.32	0.824
Yu,1978	B-0-18-3-L-SS	19.0	19.1	7.69	7.67	B	R	9.08	1.184
Yu,1978	B-0-18-4-L-SS	19.0	19.1	7.69	7.67	B	R	6.63	0.865
Yu,1978	B-0-18-5-0-SS	19.0	19.1	7.69	7.67	B	R	6.32	0.824
Yu,1978	B-0-18-6-0-SS	19.0	19.1	7.69	7.67	B	R	7.10	0.927
Yu,1978	B-0-18-7-L-SS	19.0	19.1	7.69	7.67	B	R	12.2	1.588
Yu,1978	B-0-18-8-L-SS	19.0	19.1	7.93	7.67	B	R	11.5	1.498
Yu,1978	B-0-18-9-H-SS	19.0	19.1	7.69	7.67	B	R	11.6	1.515
Yu,1978	B-0-18-10-H-SS	19.0	19.1	7.69	7.67	B	R	10.4	1.358
Yu,1978	B-0-21-1-0-DS	20.6	23.2	6.61	7.81	E	B&E	8.37	1.266
Yu,1978	B-0-21-2-0-DS	20.6	23.2	6.90	7.81	E	B&E	8.46	1.226
Yu,1978	B-0-21-3-L-DS	20.6	23.2	7.05	7.81	E	B&E	8.46	1.199
Yu,1978	B-0-21-4-L-DS	20.6	23.2	6.90	7.81	E	B&E	8.52	1.235
Yu,1978	B-0-21-5-0-DS	20.6	23.2	6.90	7.81	E	B&E	8.63	1.251
Yu,1978	B-0-21-6-0-DS	20.6	23.2	7.19	7.81	E	B&E	9.03	1.256
Yu,1978	B-0-21-7-L-DS	20.6	23.2	6.90	7.81	E	B&E	9.68	1.403
Yu,1978	B-0-21-8-L-DS	20.6	23.2	6.90	7.81	E	B&E	9.12	1.322
Yu,1978	B-0-21-9-H-DS	20.6	23.2	6.90	7.81	E	B&E	9.95	1.442
Yu,1978	B-0-21-10-H-DS	20.6	23.2	6.90	7.81	E	B&E	8.90	1.290
Yu,1978	B-0-22-1-0-DS	39.6	44.5	13.8	13.6	B	B&E	11.4	0.838
Yu,1978	B-0-22-2-0-DS	39.6	44.5	13.8	13.6	B	B&E	11.1	0.813
Yu,1978	B-0-22-3-L-DS	39.6	44.5	13.8	13.6	B	B&E	12.8	0.941
Yu,1978	B-0-22-4-L-DS	39.6	44.5	13.8	13.6	B	B&E	10.8	0.794
Yu,1978	B-0-22-5-0-DS	39.6	44.5	13.8	13.6	B	B&R	10.8	0.794
Yu,1978	B-0-22-6-0-DS	39.6	44.5	13.8	13.6	B	B&R	9.79	0.720
Yu,1978	B-0-22-7-L-DS	39.6	44.5	13.8	13.6	B	B&E	12.0	0.884
Yu,1978	B-0-22-8-L-DS	39.6	44.5	13.8	13.6	B	B&E	12.1	0.890
Yu,1978	B-0-22-9-H-DS	39.6	44.5	13.8	13.6	B	B&E	11.8	0.868
Yu,1978	B-0-22-10-H-DS	39.6	44.5	14.1	13.6	B	B&E	12.7	0.936
Yu,1978	B-0-25-1-0-SS	47.5	43.1	17.4	19.9	E	R	18.2	1.047
Yu,1978	B-0-25-2-0-SS	47.5	43.1	17.4	19.9	E	R	19.0	1.093
Yu,1978	B-0-25-3-L-SS	47.5	43.1	17.4	19.9	E	R	20.2	1.162

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-25-4-L-SS	47.5	43.1	17.4	19.9	E	R	21.0	1.211
Yu,1978	B-0-25-5-H-SS	47.5	43.1	17.4	19.9	E	R	20.4	1.175
Yu,1978	B-0-25-6-H-SS	47.5	43.1	17.4	19.9	E	R	19.4	1.114
Yu,1978	B-0-26-1-0-SS	66.6	59.9	26.4	29.7	E	R	24.4	0.924
Yu,1978	B-0-26-2-0-SS	66.6	59.9	26.4	29.7	E	R	24.7	0.936
Yu,1978	B-0-26-3-L-SS	66.6	59.9	26.4	29.7	E	R	25.3	0.959
Yu,1978	B-0-26-4-L-SS	66.6	59.9	26.4	29.7	E	R	24.7	0.934
Yu,1978	B-0-26-5-0-SS	66.6	59.9	26.4	29.7	E	R	24.7	0.935
Yu,1978	B-0-26-6-0-SS	66.6	59.9	26.4	29.7	E	R	23.1	0.873
Yu,1978	B-0-26-7-L-SS	66.6	59.9	26.4	29.7	E	R	25.0	0.947
Yu,1978	B-0-26-8-L-SS	66.6	59.9	26.4	29.7	E	R	24.9	0.944
Yu,1978	B-0-26-9-H-SS	66.6	59.9	26.4	29.7	E	R	31.2	1.180
Yu,1978	B-0-26-10-H-SS	66.6	59.9	26.4	29.7	E	R	32.7	1.239
Yu,1978	B-0-29-1-0-DS	103	105	32.5	35.3	E	B&E	30.9	0.949
Yu,1978	B-0-29-2-0-DS	103	105	31.8	35.3	E	B&E	35.6	1.117
Yu,1978	B-0-29-3-L-DS	103	105	31.2	35.3	E	B&E	38.3	1.227
Yu,1978	B-0-29-4-L-DS	103	105	32.5	35.3	E	B&E	38.5	1.184
Yu,1978	B-0-29-5-0-DS	103	105	33.2	35.3	E	B&E	37.0	1.115
Yu,1978	B-0-29-6-0-DS	103	105	33.2	35.3	E	B&E	31.4	0.947
Yu,1978	B-0-29-7-L-DS	103	105	31.8	35.3	E	B&E	40.9	1.286
Yu,1978	B-0-29-8-L-DS	103	105	33.2	35.3	E	B&E	41.4	1.248
Yu,1978	B-0-29-9-H-DS	103	105	33.2	35.3	E	B&E	41.2	1.241
Yu,1978	B-0-29-10-H-DS	103	105	33.2	35.3	E	B&E	40.7	1.227
Yu,1978	B-0-30-1-0-DS	158	162	43.8	52.7	E	B&E	44.3	1.011
Yu,1978	B-0-30-2-0-DS	158	162	45.8	52.7	E	B&E	46.7	1.021
Yu,1978	B-0-30-3-L-DS	158	162	45.8	52.7	E	B&E	51.2	1.118
Yu,1978	B-0-30-4-L-DS	158	162	45.8	52.7	E	B&E	48.1	1.050
Yu,1978	B-0-30-5-0-DS	158	162	45.8	52.7	E	B&E	46.2	1.008
Yu,1978	B-0-30-6-0-DS	158	162	45.1	52.7	E	B&E	43.7	0.970
Yu,1978	B-0-30-7-L-DS	158	162	45.8	52.7	E	B&E	49.5	1.081
Yu,1978	B-0-30-8-L-DS	158	162	45.8	52.7	E	B&E	48.1	1.052
Yu,1978	B-0-30-9-H-DS	158	162	43.8	52.7	E	B&E	50.3	1.148
Yu,1978	B-0-30-10-H-DS	158	162	43.8	52.7	E	B&E	51.6	1.178
Yu,1978	B-0-32-1-0-SS	9.69	9.53	2.72	2.47	B	B&R	2.45	0.991
Yu,1978	B-0-32-2-0-SS	9.69	9.53	2.59	2.47	B	B&R	2.58	1.045
Yu,1978	B-0-32-3-L-SS	9.69	9.53	2.72	2.47	B	B&R	2.72	1.103
Yu,1978	B-0-32-4-L-SS	9.69	9.53	2.72	2.47	B	B&R	3.14	1.272
Yu,1978	B-0-32-5-0-SS	9.69	9.53	2.72	2.47	B	B&R	2.67	1.081

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-32-6-0-SS	9.69	9.53	2.79	2.47	B	B&R	2.41	0.977
Yu,1978	B-0-32-7-L-SS	9.69	9.53	2.72	2.47	B	B&R	2.49	1.009
Yu,1978	B-0-32-8-L-SS	9.69	9.53	2.79	2.47	B	B&R	2.39	0.968
Yu,1978	B-0-32-9-H-SS	9.69	9.53	2.79	2.47	B	B&N.S	3.61	1.463
Yu,1978	B-0-32-10-H-SS	9.69	9.53	2.72	2.47	B	B&N.S	2.89	1.171
Yu,1978	B-0-34-1-0-DS	15.7	16.5	4.88	4.38	B	B&E	3.78	0.864
Yu,1978	B-0-34-2-0-DS	15.7	16.5	4.88	4.38	B	B&E	3.81	0.871
Yu,1978	B-0-34-3-L-DS	15.7	16.5	4.88	4.38	B	B&E	4.25	0.971
Yu,1978	B-0-34-4-L-DS	15.7	16.5	4.88	4.38	B	B&E	4.43	1.012
Yu,1978	B-0-34-5-0-DS	15.7	16.5	4.88	4.38	B	B&E	3.07	0.701
Yu,1978	B-0-34-6-0-DS	15.7	16.5	4.88	4.38	B	B&E	3.63	0.828
Yu,1978	B-0-34-7-L-DS	15.7	16.5	4.88	4.38	B	B&E	3.87	0.884
Yu,1978	B-0-34-8-L-DS	15.7	16.5	4.88	4.38	B	B&E	4.62	1.055
Yu,1978	B-0-34-9-H-DS	15.7	16.5	4.88	4.38	B	B&E	5.03	1.148
Yu,1978	B-0-34-10-H-DS	15.7	16.5	4.88	4.38	B	B&E	4.04	0.922
Yu,1978	B-0-37-1-0-SS	18.4	20.2	5.05	5.78	E	R	5.37	1.063
Yu,1978	B-0-37-2-0-SS	18.4	20.2	5.05	5.78	E	R	5.36	1.061
Yu,1978	B-0-37-3-L-SS	18.4	20.2	5.05	5.78	E	R	5.62	1.112
Yu,1978	B-0-37-4-L-SS	18.4	20.2	5.05	5.78	E	R	5.55	1.099
Yu,1978	B-0-37-5-H-SS	18.4	20.2	5.05	5.78	E	R	5.52	1.093
Yu,1978	B-0-37-6-H-SS	18.4	20.2	5.05	5.78	E	R	8.88	1.758
Yu,1978	B-0-38-1-0-SS	24.5	25.1	10.1	9.20	B	R	7.01	0.761
Yu,1978	B-0-38-2-0-SS	24.5	25.1	10.1	9.20	B	R	7.28	0.790
Yu,1978	B-0-38-3-L-SS	24.5	25.1	10.1	9.20	B	R	10.1	1.093
Yu,1978	B-0-38-4-L-SS	24.5	25.1	10.1	9.20	B	R	8.68	0.943
Yu,1978	B-0-38-5-0-SS	24.5	25.1	10.1	9.20	B	R	7.19	0.781
Yu,1978	B-0-38-6-0-SS	24.5	25.1	10.1	9.20	B	R	7.45	0.810
Yu,1978	B-0-38-7-L-SS	24.5	25.1	10.1	9.20	B	R	10.4	1.134
Yu,1978	B-0-38-8-L-SS	24.5	25.1	10.1	9.20	B	R	8.19	0.890
Yu,1978	B-0-38-9-H-SS	24.5	25.1	10.1	9.20	B	R	9.35	1.015
Yu,1978	B-0-38-10-H-SS	24.5	25.1	10.1	9.20	B	R	10.4	1.126
Yu,1978	B-0-41-1-0-DS	26.6	30.5	9.06	10.3	E	B&E	8.81	0.972
Yu,1978	B-0-41-2-0-DS	26.6	30.5	9.06	10.3	E	B&E	9.63	1.063
Yu,1978	B-0-41-3-L-DS	26.6	30.5	9.06	10.3	E	B&E	10.6	1.174
Yu,1978	B-0-41-4-L-DS	26.6	30.5	9.06	10.3	E	B&E	9.48	1.046
Yu,1978	B-0-41-5-H-DS	26.6	30.5	9.06	10.3	E	B&E	10.3	1.139
Yu,1978	B-0-41-6-H-DS	26.6	30.5	9.06	10.3	E	B&E	10.7	1.179
Yu,1978	B-0-42-1-0-DS	53.1	61.1	18.1	16.3	B	B&E	13.1	0.803

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-42-2-0-DS	53.1	61.1	18.1	16.3	B	B&E	12.1	0.739
Yu,1978	B-0-42-3-L-DS	53.1	61.1	18.1	16.3	B	B&E	12.8	0.785
Yu,1978	B-0-42-4-L-DS	53.1	61.1	18.1	16.3	B	B&E	12.1	0.744
Yu,1978	B-0-42-5-0-DS	53.1	61.1	18.1	16.3	B	B&E	13.4	0.821
Yu,1978	B-0-42-6-0-DS	53.1	61.1	18.1	16.3	B	B&E	13.4	0.821
Yu,1978	B-0-42-7-L-DS	53.1	61.1	18.1	16.3	B	B&E	16.8	1.031
Yu,1978	B-0-42-8-L-DS	53.1	61.1	18.1	16.3	B	B&E	12.7	0.777
Yu,1978	B-0-42-9-H-DS	53.1	61.1	18.1	16.3	B	B&E	17.2	1.056
Yu,1978	B-0-42-10-H-DS	53.1	61.1	18.1	16.3	B	B&E	19.3	1.183
Yu,1978	B-0-45-1-0-SS	49.7	53.4	23.8	24.6	E	R	18.0	0.755
Yu,1978	B-0-45-2-0-SS	49.7	53.4	21.5	24.6	E	R	18.2	0.844
Yu,1978	B-0-45-3-L-SS	49.7	53.4	21.5	24.6	E	R	19.3	0.897
Yu,1978	B-0-45-4-L-SS	49.7	53.4	22.8	24.6	E	R	19.2	0.843
Yu,1978	B-0-45-5-H-SS	49.7	53.4	22.8	24.6	E	R	19.8	0.869
Yu,1978	B-0-45-6-H-SS	49.7	53.4	21.5	24.6	E	R	19.8	0.920
Yu,1978	B-0-46-1-0-SS	70.4	75.3	32.7	36.3	E	B&R	25.9	0.793
Yu,1978	B-0-46-2-0-SS	70.4	75.3	32.7	36.3	E	B&R	24.3	0.745
Yu,1978	B-0-46-3-L-SS	70.4	75.3	32.7	36.3	E	B&R	26.7	0.817
Yu,1978	B-0-46-4-L-SS	70.4	75.3	32.7	36.3	E	B&R	26.5	0.812
Yu,1978	B-0-46-5-0-SS	70.4	75.3	32.7	36.3	E	B&R	26.1	0.799
Yu,1978	B-0-46-6-0-SS	70.4	75.3	32.7	36.3	E	B&R	25.9	0.792
Yu,1978	B-0-46-7-L-SS	70.4	75.3	32.7	36.3	E	B&R	29.8	0.911
Yu,1978	B-0-46-8-L-SS	70.4	75.3	32.7	36.3	E	B&R	26.1	0.800
Yu,1978	B-0-46-9-H-SS	70.4	75.3	32.7	36.3	E	B&R	33.4	1.021
Yu,1978	B-0-46-10-H-SS	70.4	75.3	32.7	36.3	E	B&R	29.2	0.893
Yu,1978	B-0-49-1-0-DS	111	134	39.4	43.7	E	B&E	42.6	1.081
Yu,1978	B-0-49-2-0-DS	111	134	40.2	43.7	E	B&E	37.4	0.929
Yu,1978	B-0-49-3-L-DS	111	134	39.4	43.7	E	B&E	39.2	0.996
Yu,1978	B-0-49-4-L-DS	111	134	39.4	43.7	E	B&E	39.8	1.011
Yu,1978	B-0-49-5-H-DS	111	134	39.4	43.7	E	B&E	40.9	1.039
Yu,1978	B-0-49-6-H-DS	111	134	39.4	43.7	E	B&E	42.3	1.073
Yu,1978	B-0-50-1-0-DS	165	201	58.3	64.3	E	B&E	54.5	0.935
Yu,1978	B-0-50-2-0-DS	165	201	58.3	64.3	E	B&E	53.0	0.908
Yu,1978	B-0-50-3-L-DS	165	201	58.3	64.3	E	B&E	55.4	0.950
Yu,1978	B-0-50-4-L-DS	165	201	58.3	64.3	E	B&E	51.8	0.889
Yu,1978	B-0-50-5-0-DS	165	201	58.3	64.3	E	B&E	50.5	0.866
Yu,1978	B-0-50-6-0-DS	165	201	58.3	64.3	E	B&E	48.3	0.828
Yu,1978	B-0-50-7-L-DS	165	201	58.3	64.3	E	B&E	53.4	0.916

Table C5 Test-To-Predicted Values (North American Specification, CSA, 2001)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-50-8-L-DS	165	201	58.3	64.3	E	B&E	44.9	0.769
Yu,1978	B-0-50-9-H-DS	165	201	58.3	64.3	E	B&E	62.3	1.069
Yu,1978	B-0-50-10-H-DS	165	201	58.3	64.3	E	B&E	53.5	0.918
Yu,1978	B-0-51-1-0-SS	188	199	89.1	97.7	E	R	97.7	1.097
Yu,1978	B-0-51-2-0-SS	188	199	89.1	97.7	E	R	96.3	1.082
Yu,1978	B-0-51-3-L-SS	188	199	91.2	97.7	E	R	94.1	1.032
Yu,1978	B-0-51-4-L-SS	188	199	89.1	97.7	E	R	101	1.144
Yu,1978	B-0-51-5-H-SS	188	199	89.1	97.7	E	R	95.0	1.067
Yu,1978	B-0-51-6-H-SS	188	199	89.1	97.7	E	R	97.9	1.099
Yu,1978	B-0-53-1-0-DS	443	531	154	173	E	B&E	157	1.025
Yu,1978	B-0-53-2-0-DS	443	531	158	173	E	B&E	155	0.980
Yu,1978	B-0-53-3-L-DS	443	531	154	173	E	B&E	161	1.051
Yu,1978	B-0-53-4-L-DS	443	531	156	173	E	B&E	160	1.029
Yu,1978	B-0-53-5-H-DS	443	531	149	173	E	B&E	160	1.072

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Carril,1994	AN32-1	62.8	28.8	55.8	31.3	N.S	B	36.0	1.249
Carril,1994	AN32-2	61.6	28.3	54.8	30.8	N.S	B	36.5	1.289
Carril,1994	AN33-1	77.2	29.9	55.7	31.3	N.S	B	40.1	1.338
Carril,1994	AN33-2	78.5	30.4	56.7	31.9	N.S	B	39.8	1.308
Carril,1994	BN33-1	77.9	97.1	104	63.2	B	B	65.0	1.028
Carril,1994	BN33-2	77.9	97.1	104	63.2	B	B	64.0	1.013
Carril,1994	DN12-2	44.6	22.1	42.7	22.7	N.S	B	21.1	0.954
Carril,1994	DN12-3	43.6	21.6	41.7	22.0	N.S	B	21.1	0.977
Carril,1994	DN22-1	65.1	33.8	65.4	36.8	N.S	B	37.5	1.109
Carril,1994	DN22-2	66.0	34.3	66.2	37.3	N.S	B	37.8	1.103
Carril,1994	BN32-1	62.7	75.2	103	62.7	B	B&N.S	64.3	1.027
Carril,1994	BN32-2	62.0	74.3	102	62.1	B	B&N.S	65.4	1.052
Carril,1994	DN32-1	127	58.6	113	63.7	N.S	B&R	70.1	1.196
Carril,1994	DN32-2	125	57.6	111	62.7	N.S	B&R	71.6	1.242
Carril,1994	EN12-1	44.6	57.6	79.6	45.5	B	B&R	38.5	0.846
Carril,1994	EN12-2	44.6	57.6	79.5	45.5	B	B&R	38.7	0.851
Carril,1994	EN22-1	66.0	89.4	123	74.6	B	B&R	70.2	0.940
Carril,1994	EN22-2	66.9	90.5	125	75.7	B	B&R	70.0	0.926
Carril,1994	EN32-1	125	150	206	125	B	B&R	128	1.024
Carril,1994	EN32-2	124	149	204	124	B	B&R	129	1.038
Carril,1994	AN31-2	31.1	22.5	54.7	30.8	N.S	N.S	29.3	1.301
Carril,1994	AN31-3	31.1	22.6	55.2	31.1	N.S	N.S	29.1	1.286
Carril,1994	BN31-1	31.3	29.7	103	62.7	N.S	N.S	29.4	0.988
Carril,1994	BN31-2	31.3	29.6	103	62.7	N.S	N.S	29.4	0.991
Carril,1994	CN11-1	11.0	11.2	58.1	34.1	N.S	N.S	10.2	0.909
Carril,1994	CN11-2	11.0	11.2	58.1	34.1	N.S	N.S	10.4	0.924
Carril,1994	CN12-1	22.2	28.6	58.1	34.1	N.S	N.S	25.5	0.893
Carril,1994	CN12-2	22.2	28.6	58.1	34.1	N.S	N.S	25.5	0.893
Carril,1994	CN21-1	16.7	18.0	90.0	56.0	N.S	N.S	18.2	1.012
Carril,1994	CN21-2	16.9	18.1	91.3	56.8	N.S	N.S	18.1	0.997
Carril,1994	CN21-3	16.9	18.1	91.3	56.8	N.S	N.S	17.9	0.989
Carril,1994	CN22-1	33.1	44.8	90.1	56.0	N.S	N.S	42.7	0.954
Carril,1994	CN22-2	33.6	45.5	91.4	56.8	N.S	N.S	42.9	0.943
Carril,1994	CN22-3	33.1	44.8	90.0	56.0	N.S	N.S	42.9	0.956
Carril,1994	CN31-2	32.0	30.4	153	95.6	N.S	N.S	30.8	1.013
Carril,1994	CN31-3	32.3	30.7	154	96.4	N.S	N.S	30.0	0.980
Carril,1994	CN32-1	64.4	77.2	155	96.4	N.S	N.S	71.2	0.923
Carril,1994	CN32-2	63.6	76.2	153	95.6	N.S	N.S	70.4	0.924

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Carril,1994	DN31-1	63.7	23.2	113	63.7	N.S	N.S	55.2	2.381
Carril,1994	DN31-2	61.7	22.4	109	61.6	N.S	N.S	53.4	2.382
Carril,1994	EN11-1	22.7	23.1	81.3	47.0	N.S	N.S	21.4	0.927
Carril,1994	EN11-2	22.2	22.6	79.5	45.5	N.S	N.S	21.5	0.949
Carril,1994	EN21-1	33.6	36.1	124	75.7	N.S	N.S	37.4	1.037
Carril,1994	EN21-2	33.5	36.0	125	75.7	N.S	N.S	37.4	1.040
Carril,1994	EN31-1	62.2	59.0	205	124	N.S	N.S	58.9	0.999
Carril,1994	EN31-2	62.7	59.5	207	125	N.S	N.S	60.3	1.013
Carril,1994	DN11-1	21.2	8.32	40.8	21.3	N.S	N&R	18.1	2.176
Carril,1994	DN11-2	21.7	8.52	41.7	22.0	N.S	N&R	18.7	2.199
Carril,1994	DN21-1	33.6	13.8	67.3	37.8	N.S	N&R	32.0	2.322
Carril,1994	DN21-2	33.1	13.6	66.3	37.3	N.S	N&R	31.5	2.318
Chong,1975	1	35.8	10.4	20.0	9.64	B	B&E	10.9	1.136
Chong,1975	2	35.5	6.93	19.8	6.82	B	B	8.14	1.194
Chong,1975	3	36.3	6.95	20.0	6.82	B	B&E	7.12	1.044
Chong,1975	4	35.8	10.4	19.7	9.64	B	E	9.92	1.030
Chong,1975	5	35.8	10.4	20.1	9.64	B	E	10.8	1.122
Chong,1975	6	35.2	10.4	9.70	9.64	B	B&E	10.6	1.104
Chong,1975	7	35.2	10.4	14.6	9.64	B	E	11.0	1.145
Chong,1975	8	35.2	10.4	17.0	9.64	B	E	10.0	1.039
Chong,1975	9	35.2	10.4	24.3	9.64	B	B	10.1	1.044
Chong,1975	11	35.2	10.4	24.3	9.64	B	B	10.3	1.067
Chong,1975	12	35.2	10.4	14.6	9.64	B	E	10.7	1.113
Chong,1975	13	35.2	10.4	9.70	9.64	B	E&B	10.5	1.090
Chong,1975	14	35.2	10.4	4.85	9.64	E	E	7.48	1.541
Chong,1975	15	35.2	10.4	4.85	9.64	E	E	6.76	1.394
Chong,1975	32	37.1	12.2	23.4	12.8	N.S	E&B	12.9	1.051
Chong,1975	33	37.1	12.2	22.9	12.8	N.S	B&E	13.3	1.084
Chong,1975	34	37.1	12.2	22.9	12.8	N.S	B&E	13.1	1.069
Chong,1975	41	54.9	21.6	10.3	22.6	E	E&B	12.3	1.201
Chong,1975	42	54.9	21.6	10.5	22.6	E	E&B	13.8	1.314
Chong,1975	49	13.9	11.1	40.2	22.6	N.S	N.S	13.5	1.210
Chong,1975	50	13.9	11.1	40.2	22.6	N.S	N.S	12.9	1.162
Chong,1975	51	13.9	11.1	40.2	22.6	N.S	N.S	11.9	1.066
Chong,1975	52	74.3	34.6	69.5	39.1	N.S	B&E	38.3	1.105
Chong,1975	53	74.3	34.6	69.8	39.1	N.S	B&E	36.3	1.047
Chong,1975	54	74.3	34.6	69.5	39.1	N.S	B&E	40.8	1.178
Chong,1975	55	111	49.0	99.0	55.2	N.S	B&E	55.6	1.135

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Chong,1975	16(3b)	26.6	15.2	20.0	19.3	N.S	N.S	18.1	1.187
Chong,1975	17(3b)	27.0	15.3	19.4	19.3	N.S	N.S	18.4	1.198
Chong,1975	37(3b)	37.2	20.5	44.8	25.6	N.S	E&B	24.8	1.208
Chong,1975	40(3b)	54.9	36.2	79.3	45.3	N.S	B	40.0	1.105
Chong,1975	56(3b)	110	73.3	196	110	N.S	E&N	88.3	1.206
Chong,1975	35(3c)	37.3	19.9	70.0	24.0	N.S	B	23.3	1.174
Chong,1975	36(3c)	37.3	19.9	70.6	24.0	N.S	B	24.0	1.207
Chong,1975	18(3d)	8.81	4.24	26.4	19.3	N.S	N.S	7.57	1.782
Chong,1975	19(3d)	8.81	4.24	26.4	19.3	N.S	N.S	6.72	1.583
Chong,1975	22(3d)	17.6	13.9	26.4	19.3	N.S	N.S	14.9	1.066
Chong,1975	23(3d)	17.6	13.9	26.4	19.3	N.S	N.S	15.9	1.139
Chong,1975	28(3d)	35.2	33.3	26.4	19.3	B	E	19.5	1.011
Chong,1975	29(3d)	35.2	33.3	26.4	19.3	B	B&E	19.2	0.998
Chong,1975	45(3d)	27.4	28.9	54.7	45.3	N.S	N.S	30.7	1.063
Chong,1975	46(3d)	27.4	28.9	54.7	45.3	N.S	N.S	31.9	1.103
Chong,1975	20(3e)	8.81	4.24	43.0	28.9	N.S	N.S	7.83	1.845
Chong,1975	21(3e)	8.81	4.24	43.0	28.9	N.S	N.S	4.76	1.122
Chong,1975	24(3e)	17.6	13.9	43.0	28.9	N.S	N.S	15.7	1.126
Chong,1975	25(3e)	17.6	13.9	43.0	28.9	N.S	N.S	15.2	1.088
Chong,1975	26(3e)	34.7	32.8	43.0	28.9	B	E	28.8	0.996
Chong,1975	27(3e)	34.7	32.8	43.0	28.9	B	E	28.8	0.998
Chong,1975	43(3e)	55.3	69.8	89.3	67.9	B	E&B	58.3	0.858
Chong,1975	44(3e)	55.7	70.4	89.3	67.9	B	E&B	60.1	0.885
Chong,1975	47(3e)	13.7	8.80	89.3	67.9	N.S	N.S	13.0	1.476
Chong,1975	48(3e)	13.7	8.80	89.3	67.9	N.S	N.S	13.5	1.532
Gilchrist,1979	1	16.9	2.70	4.65	2.42	B	B&E	3.20	1.325
Gilchrist,1979	2	16.9	2.70	3.49	2.42	B	B&E	2.71	1.122
Gilchrist,1979	3	16.9	2.70	2.79	2.42	B	B&E	2.60	1.076
Gilchrist,1979	4	16.9	3.92	6.97	2.83	B	B&E	3.03	1.070
Gilchrist,1979	5	16.9	3.92	4.65	2.83	B	B	3.00	1.063
Gilchrist,1979	6	16.9	3.92	3.49	2.83	B	B&E	3.16	1.118
Gilchrist,1979	7	24.3	3.74	6.43	3.58	B	B&E	3.78	1.057
Gilchrist,1979	8	24.3	3.74	4.82	3.58	B	B&E	3.89	1.088
Gilchrist,1979	9	24.3	3.74	3.86	3.58	B	B&E	3.69	1.032
Gilchrist,1979	10	24.3	5.42	9.65	4.43	B	B&E	4.01	0.904
Gilchrist,1979	11	24.3	5.42	6.43	4.43	B	B	3.56	0.803
Gilchrist,1979	12	24.3	5.42	4.82	4.43	B	B&E	4.34	0.979
Gilchrist,1979	13	24.8	3.83	6.60	3.71	B	B&E	4.58	1.235

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Gilchrist,1979	14	24.8	3.83	4.95	3.71	B	B&E	4.29	1.157
Gilchrist,1979	15	24.8	3.83	3.96	3.71	B	B&E	4.18	1.127
Gilchrist,1979	16	24.8	5.56	9.90	4.87	B	B&E	4.34	0.890
Gilchrist,1979	17	24.8	5.56	6.60	4.87	B	B&E	4.36	0.895
Gilchrist,1979	18	24.8	5.56	4.95	4.87	B	B&E	4.05	0.831
Gilchrist,1979	19	24.8	7.09	13.2	5.37	B	B&E	7.23	1.348
Gilchrist,1979	20	24.8	7.09	9.90	5.37	B	B	5.21	0.970
Gilchrist,1979	21	24.8	7.09	6.60	5.37	B	B	5.45	1.016
Gilchrist,1979	22	19.8	3.58	6.16	3.47	B	B&E	3.78	1.091
Gilchrist,1979	23	19.8	3.58	4.62	3.47	B	B&E	3.65	1.053
Gilchrist,1979	24	19.8	3.58	3.70	3.47	B	B&E	4.01	1.156
Gilchrist,1979	25	19.8	5.19	9.24	4.55	B	B&E	4.41	0.968
Gilchrist,1979	26	19.8	5.19	6.16	4.55	B	B&E	4.21	0.924
Gilchrist,1979	27	19.8	5.19	4.62	4.55	B	B&E	4.12	0.904
Gilchrist,1979	28	19.8	6.62	12.3	5.01	B	B	7.16	1.430
Gilchrist,1979	29	19.8	6.62	9.24	5.01	B	B	6.50	1.297
Gilchrist,1979	30	19.8	6.62	6.16	5.01	B	B	5.01	0.999
McGill,2002	043-230-3/8-SS-A	8.03	3.14	9.27	1.99	B	B	1.69	0.850
McGill,2002	043-230-3/8-SS-B	8.03	3.14	9.27	1.99	B	B	1.77	0.891
McGill,2002	043-230-3/8-SS-C	8.03	3.14	9.27	1.99	B	B	1.67	0.840
McGill,2002	043-230-3/8-TTSS-A	8.03	3.14	9.27	1.99	B	B	1.87	0.941
McGill,2002	043-230-3/8-TTSS-B	8.03	3.14	9.27	1.99	B	B	1.77	0.891
McGill,2002	043-230-3/8-TTSS-C	8.03	3.14	9.27	1.99	B	B	2.16	1.087
McGill,2002	043-230-3/8-DS-A	8.03	3.14	9.27	3.53	N.S	B	3.65	1.164
McGill,2002	043-230-3/8-DS-B	8.03	3.14	9.27	3.53	N.S	B	3.46	1.104
McGill,2002	043-230-3/8-DS-C	8.03	3.14	9.27	3.53	N.S	B	3.26	1.040
McGill,2002	043-550-3/8-SS-A	19.3	5.21	15.4	3.30	B	B	2.62	0.793
McGill,2002	043-550-3/8-SS-B	19.3	5.21	15.4	3.30	B	B	2.73	0.826
McGill,2002	043-550-3/8-SS-C	19.3	5.21	15.4	3.30	B	B	2.49	0.754
McGill,2002	043-230-1/2-SS-A	8.03	3.97	9.27	2.65	B	B	2.14	0.808
McGill,2002	043-230-1/2-SS-B	8.03	3.97	9.27	2.65	B	B	2.13	0.804
McGill,2002	043-230-1/2-SS-C	8.03	3.97	9.27	2.65	B	B	2.18	0.823
McGill,2002	043-230-1/2-TTSS-A	8.03	3.97	9.27	2.65	B	B	2.29	0.864
McGill,2002	043-230-1/2-TTSS-B	8.03	3.97	9.27	2.65	B	B	2.24	0.845
McGill,2002	043-230-1/2-TTSS-C	8.03	3.97	9.27	2.65	B	B	2.46	0.928
McGill,2002	043-230-1/2-DS-A	8.03	3.97	9.27	4.71	N.S	B	5.43	1.367
McGill,2002	043-230-1/2-DS-B	8.03	3.97	9.27	4.71	N.S	B	5.80	1.460
McGill,2002	043-230-1/2-DS-C	8.03	3.97	9.27	4.71	N.S	B	5.72	1.440

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	043-550-1/2-SS-A	19.3	6.60	15.4	4.40	B	B	3.37	0.765
McGill,2002	043-550-1/2-SS-B	19.3	6.60	15.4	4.40	B	B	3.36	0.763
McGill,2002	043-550-1/2-SS-C	19.3	6.60	15.4	4.40	B	B	3.36	0.763
McGill,2002	043-230-5/8-SS-A	8.03	4.71	9.27	3.31	B	B	2.99	0.903
McGill,2002	043-230-5/8-SS-B	8.03	4.71	9.27	3.31	B	B	2.84	0.857
McGill,2002	043-230-5/8-SS-C	8.03	4.71	9.27	3.31	B	B	2.78	0.839
McGill,2002	043-230-5/8-TTSS-A	8.03	4.71	9.27	3.31	B	B	3.09	0.933
McGill,2002	043-230-5/8-TTSS-B	8.03	4.71	9.27	3.31	B	B	3.22	0.972
McGill,2002	043-230-5/8-TTSS-C	8.03	4.71	9.27	3.31	B	B	3.36	1.014
McGill,2002	043-230-5/8-DS-A	8.03	4.71	9.27	5.89	N.S	B	7.05	1.498
McGill,2002	043-230-5/8-DS-B	8.03	4.71	9.27	5.89	N.S	B	7.49	1.592
McGill,2002	043-230-5/8-DS-C	8.03	4.71	9.27	5.89	N.S	B	7.35	1.562
McGill,2002	043-550-5/8-SS-A	19.3	7.82	15.4	5.51	B	B	3.71	0.674
McGill,2002	043-550-5/8-SS-B	19.3	7.82	15.4	5.51	B	B	3.93	0.714
McGill,2002	043-550-5/8-SS-C	19.3	7.82	15.4	5.51	B	B	3.92	0.712
McGill,2002	064-230-5/8-TTSS-A	14.3	6.68	13.2	4.70	B	B	5.22	1.111
McGill,2002	064-230-5/8-TTSS-B	14.3	6.68	13.2	4.70	B	B	4.88	1.039
McGill,2002	064-230-5/8-TTSS-C	14.3	6.68	13.2	4.70	B	B	5.47	1.164
McGill,2002	064-230-5/8-DS-A	14.3	6.68	13.2	8.35	N.S	B	11.8	1.774
McGill,2002	064-230-5/8-DS-B	14.3	6.68	13.2	8.35	N.S	B	11.0	1.651
McGill,2002	064-230-5/8-DS-C	14.3	6.68	13.2	8.35	N.S	B	11.7	1.753
McGill,2002	064-550-5/8-SS-A	33.3	13.5	26.6	9.51	B	B	8.64	0.909
McGill,2002	064-550-5/8-SS-B	33.3	13.5	26.6	9.51	B	B	8.91	0.937
McGill,2002	064-550-5/8-SS-C	33.3	13.5	26.6	9.51	B	B	8.34	0.877
McGill,2002	064-230-1/2-TTSS-A	14.3	5.63	13.2	4.14	B	B	4.56	1.101
McGill,2002	064-230-1/2-TTSS-B	14.3	5.63	13.2	4.14	B	B	4.44	1.072
McGill,2002	064-230-1/2-TTSS-C	14.3	5.63	13.2	4.14	B	B	4.10	0.990
McGill,2002	064-230-1/2-DS-A	14.3	5.63	13.2	7.35	N.S	B	8.91	1.581
McGill,2002	064-230-1/2-DS-B	14.3	5.63	13.2	7.35	N.S	B	9.28	1.647
McGill,2002	064-230-1/2-DS-C	14.3	5.63	13.2	7.35	N.S	B	9.23	1.638
McGill,2002	064-550-1/2-SS-A	33.3	11.4	26.6	8.38	B	B	6.94	0.828
McGill,2002	064-550-1/2-SS-B	33.3	11.4	26.6	8.38	B	B	7.26	0.866
McGill,2002	064-550-1/2-SS-C	33.3	11.4	26.6	8.38	B	B	7.04	0.840
McGill,2002	064-230-3/8-SS-A	14.3	4.45	13.2	3.90	B	B	3.05	0.783
McGill,2002	064-230-3/8-SS-B	14.3	4.45	13.2	3.90	B	B	2.75	0.706
McGill,2002	064-230-3/8-SS-C	14.3	4.45	13.2	3.90	B	B	2.77	0.711
McGill,2002	064-550-3/8-SS-A	33.3	9.00	26.6	7.88	B	B	5.83	0.740
McGill,2002	064-550-3/8-SS-B	33.3	9.00	26.6	7.88	B	B	6.43	0.816

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	064-550-3/8-SS-C	33.3	9.00	26.6	7.88	B	B	5.82	0.738
McGill,2002	064-230-1/4-DS-A	14.3	3.11	13.2	5.54	N.S	B	6.76	2.172
McGill,2002	064-230-1/4-DS-B	14.3	3.11	13.2	5.54	N.S	B	6.67	2.143
McGill,2002	064-230-1/4-DS-C	14.3	3.11	13.2	5.54	N.S	B	6.38	2.050
McGill,2002	064-550-1/4-SS-A	33.3	6.30	26.6	6.32	N.S	B	5.68	0.902
McGill,2002	064-550-1/4-SS-B	33.3	6.30	26.6	6.32	N.S	B	5.55	0.882
McGill,2002	064-550-1/4-SS-C	33.3	6.30	26.6	6.32	N.S	B	5.90	0.937
McGill,2002	064-230-1/4-SS-A	14.3	3.11	13.2	3.12	N.S	B	2.92	0.938
McGill,2002	064-230-1/4-SS-B	14.3	3.11	13.2	3.12	N.S	B	3.07	0.986
McGill,2002	064-230-1/4-SS-C	14.3	3.11	13.2	3.12	N.S	B	3.00	0.964
McGill,2002	064-230-1/4-TTSS-A	14.3	3.11	13.2	3.12	N.S	B	2.95	0.948
McGill,2002	064-230-1/4-TTSS-B	14.3	3.11	13.2	3.12	N.S	B	3.29	1.057
McGill,2002	064-230-1/4-TTSS-C	14.3	3.11	13.2	3.12	N.S	B	3.80	1.221
McGill,2002	076-230-1/2-SS-A	18.5	7.37	17.2	6.10	B	B	4.77	0.781
McGill,2002	076-230-1/2-SS-B	18.5	7.37	17.2	6.10	B	B	4.53	0.743
McGill,2002	076-230-1/2-SS-C	18.5	7.37	17.2	6.10	B	B	4.90	0.802
McGill,2002	076-230-1/2-TTSS-A	18.5	7.37	17.2	6.10	B	B	5.22	0.855
McGill,2002	076-230-1/2-TTSS-B	18.5	7.37	17.2	6.10	B	B	5.90	0.967
McGill,2002	076-230-1/2-TTSS-C	18.5	7.37	17.2	6.10	B	B	5.41	0.886
McGill,2002	076-230-1/2-DS-A	18.5	7.37	17.2	10.8	N.S	B	10.8	1.470
McGill,2002	076-230-1/2-DS-B	18.5	7.37	17.2	10.8	N.S	B	11.8	1.606
McGill,2002	076-230-1/2-DS-C	18.5	7.37	17.2	10.8	N.S	B	10.5	1.430
McGill,2002	076-550-1/2-SS-A	38.4	13.2	30.7	11.4	B	B	8.50	0.748
McGill,2002	076-550-1/2-SS-B	38.4	13.2	30.7	11.4	B	B	8.06	0.709
McGill,2002	076-550-1/2-SS-C	38.4	13.2	30.7	11.4	B	B	8.50	0.748
McGill,2002	076-230-5/8-SS-A	18.5	8.72	17.2	6.14	B	B	6.17	1.005
McGill,2002	076-230-5/8-SS-B	18.5	8.72	17.2	6.14	B	B	6.04	0.983
McGill,2002	076-230-5/8-SS-C	18.5	8.72	17.2	6.14	B	B	6.04	0.983
McGill,2002	076-550-3/8-SS-A	38.4	10.4	30.7	10.1	B	B	8.19	0.815
McGill,2002	076-550-3/8-SS-B	38.4	10.4	30.7	10.1	B	B	7.80	0.776
McGill,2002	076-550-3/8-SS-C	38.4	10.4	30.7	10.1	B	B	6.61	0.658
McGill,2002	076-550-1/4-SS-A	38.4	7.27	30.7	7.32	N.S	B	7.01	0.964
McGill,2002	076-550-1/4-SS-B	38.4	7.27	30.7	7.32	N.S	B	6.80	0.935
McGill,2002	076-550-1/4-SS-C	38.4	7.27	30.7	7.32	N.S	B	6.55	0.901
McGill,2002	091-230-1/4-SS-A	20.0	4.57	19.3	4.60	N.S	B	4.65	1.017
McGill,2002	091-230-1/4-SS-B	20.0	4.57	19.3	4.60	N.S	B	5.14	1.124
McGill,2002	091-230-1/4-SS-C	20.0	4.57	19.3	4.60	N.S	B	4.83	1.056
McGill,2002	091-230-1/4-TTSS-A	20.0	4.57	19.3	4.60	N.S	B	7.94	1.736

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	091-230-1/4-TTSS-B	20.0	4.57	19.3	4.60	N.S	B	7.46	1.631
McGill,2002	091-230-1/4-TTSS-C	20.0	4.57	19.3	4.60	N.S	B	7.51	1.642
McGill,2002	091-230-1/4-DS-A	20.0	4.57	19.3	8.16	N.S	B	12.7	2.775
McGill,2002	091-230-1/4-DS-B	20.0	4.57	19.3	8.16	N.S	B	12.4	2.703
McGill,2002	091-230-1/4-DS-C	20.0	4.57	19.3	8.16	N.S	B	11.2	2.458
McGill,2002	091-230-1/2-TTSS-A	20.0	8.28	19.3	7.99	B	B	6.91	0.865
McGill,2002	091-230-1/2-TTSS-B	20.0	8.28	19.3	7.99	B	B	6.94	0.868
McGill,2002	091-230-1/2-TTSS-C	20.0	8.28	19.3	7.99	B	B	7.00	0.876
McGill,2002	091-230-1/2-DS-A	20.0	8.28	19.3	14.2	N.S	B	14.3	1.727
McGill,2002	091-230-1/2-DS-B	20.0	8.28	19.3	14.2	N.S	B	13.6	1.643
McGill,2002	091-230-1/2-DS-C	20.0	8.28	19.3	14.2	N.S	B	13.4	1.623
McGill,2002	121-230-1/2-TTSS-A	30.2	12.9	30.2	14.4	N.S	B	10.3	0.794
McGill,2002	121-230-1/2-TTSS-B	30.2	12.9	30.2	14.4	N.S	B	10.3	0.801
McGill,2002	121-230-1/2-TTSS-C	30.2	12.9	30.2	14.4	N.S	B	12.0	0.929
McGill,2002	121-230-1/2-DS-A	30.2	12.9	30.2	25.5	N.S	B	18.6	1.440
McGill,2002	121-230-1/2-DS-B	30.2	12.9	30.2	25.5	N.S	B	20.9	1.617
McGill,2002	121-230-1/2-DS-C	30.2	12.9	30.2	25.5	N.S	B	18.3	1.414
McGill,2002	121-230-3/8-SS-A	30.2	10.2	30.2	10.8	N.S	B	8.39	0.823
McGill,2002	121-230-3/8-SS-B	30.2	10.2	30.2	10.8	N.S	B	8.54	0.838
McGill,2002	121-230-3/8-SS-C	30.2	10.2	30.2	10.8	N.S	B	8.89	0.872
McGill,2002	121-230-3/8-TTSS-A	30.2	10.2	30.2	10.8	N.S	B	9.28	0.910
McGill,2002	121-230-3/8-TTSS-B	30.2	10.2	30.2	10.8	N.S	B	9.03	0.886
McGill,2002	121-230-3/8-TTSS-C	30.2	10.2	30.2	10.8	N.S	B	9.70	0.952
McGill,2002	121-230-3/8-DS-A	30.2	10.2	30.2	19.1	N.S	B	20.5	2.007
McGill,2002	121-230-3/8-DS-B	30.2	10.2	30.2	19.1	N.S	B	18.4	1.800
McGill,2002	121-230-3/8-DS-C	30.2	10.2	30.2	19.1	N.S	B	16.4	1.607
McGill,2002	153-230-1/4-SS-A	33.3	7.72	32.6	7.77	N.S	B	9.99	1.294
McGill,2002	153-230-1/4-SS-B	33.3	7.72	32.6	7.77	N.S	B	9.80	1.269
McGill,2002	153-230-1/4-SS-C	33.3	7.72	32.6	7.77	N.S	B	9.49	1.229
Wallace,2000	1-wo-50	22.4	6.53	24.4	6.99	N.S	B	6.29	0.963
Wallace,2000	2-wo-50	22.4	6.53	24.4	6.99	N.S	B	6.95	1.064
Wallace,2000	3-wo-50	22.4	6.53	24.4	6.99	N.S	B	6.53	1.000
Wallace,2000	1-wo-40	22.4	6.53	19.6	6.99	N.S	B	6.64	1.017
Wallace,2000	2-wo-40	22.4	6.53	19.6	6.99	N.S	B	6.12	0.937
Wallace,2000	3-wo-40	22.4	6.53	19.6	6.99	N.S	B	6.70	1.026
Wallace,2000	1-wo-30	22.4	6.53	14.7	6.99	N.S	B	6.38	0.977
Wallace,2000	2-wo-30	22.4	6.53	14.7	6.99	N.S	B	6.41	0.982
Wallace,2000	3-wo-30	22.4	6.53	14.7	6.99	N.S	B	6.24	0.956

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Wallace,2000	1-wo-20	22.4	6.53	9.78	6.99	N.S	B	5.89	0.902
Wallace,2000	2-wo-20	22.4	6.53	9.78	6.99	N.S	B	6.20	0.949
Wallace,2000	3-wo-20	22.4	6.53	9.78	6.99	N.S	B	6.60	1.011
Wallace,2000	1-wo-20-t5	22.4	6.53	9.78	6.99	N.S	B	7.24	1.109
Wallace,2000	2-wo-20-t5	22.4	6.53	9.78	6.99	N.S	B	6.63	1.015
Wallace,2000	3-wo-20-t5	22.4	6.53	9.78	6.99	N.S	B	6.45	0.988
Wallace,2000	1-wo-20-t15	22.4	6.53	9.78	6.99	N.S	B	7.11	1.089
Wallace,2000	2-wo-20-t15	22.4	6.53	9.78	6.99	N.S	B	6.50	0.995
Wallace,2000	3-wo-20-t15	22.4	6.53	9.78	6.99	N.S	B	7.71	1.181
Wallace,2000	1-wo-30-50	22.4	20.6	37.2	14.0	B	B	14.5	1.035
Wallace,2000	2-wo-30-50	22.4	20.6	37.2	14.0	B	B	15.3	1.094
Wallace,2000	3-wo-30-50	22.4	20.6	37.2	14.0	B	B	14.2	1.013
Wallace,2000	1-wo-30-40	22.4	20.6	32.3	14.0	B	B	14.1	1.012
Wallace,2000	2-wo-30-40	22.4	20.6	32.3	14.0	B	B	14.6	1.042
Wallace,2000	3-wo-30-40	22.4	20.6	32.3	14.0	B	B	14.2	1.015
Wallace,2000	1-wo-30-30	22.4	20.6	27.4	14.0	B	B	15.1	1.081
Wallace,2000	2-wo-30-30	22.4	20.6	27.4	14.0	B	B	15.3	1.098
Wallace,2000	3-wo-30-30	22.4	20.6	27.4	14.0	B	B	14.0	0.998
Wallace,2000	1-wo-40-3/8	22.4	9.06	19.6	8.77	B	B	7.26	0.827
Wallace,2000	2-wo-40-3/8	22.4	9.06	19.6	8.77	B	B	7.52	0.857
Wallace,2000	3-wo-40-3/8	22.4	9.06	19.6	8.77	B	B	7.65	0.872
Wallace,2000	1-wo-30-5/16	22.4	7.85	14.7	8.03	N.S	B	7.82	0.996
Wallace,2000	2-wo-30-5/16	22.4	7.85	14.7	8.03	N.S	B	6.58	0.838
Wallace,2000	3-wo-30-5/16	22.4	7.85	14.7	8.03	N.S	B	6.98	0.889
Wallace,2000	1-wo-50-1/2	22.4	11.1	24.4	9.39	B	B	9.80	1.044
Wallace,2000	2-wo-50-1/2	22.4	11.1	24.4	9.39	B	B	9.62	1.025
Wallace,2000	3-wo-50-1/2	22.4	11.1	24.4	9.39	B	B	9.16	0.976
Wallace,2000	1-wo-50-5/8	22.4	12.6	24.4	10.5	B	B	10.3	0.984
Wallace,2000	2-wo-50-5/8	22.4	12.6	24.4	10.5	B	B	10.3	0.986
Wallace,2000	3-wo-50-5/8	22.4	12.6	24.4	10.5	B	B	10.3	0.979
Wallace,2000	1-wo-ss-5/16	11.2	3.93	7.33	4.02	N.S	B	3.23	0.822
Wallace,2000	2-wo-ss-5/16	11.2	3.93	7.33	4.02	N.S	B	3.27	0.833
Wallace,2000	3-wo-ss-5/16	11.2	3.93	7.33	4.02	N.S	B	3.39	0.863
Wallace,2000	1-wo-sst-5/16	24.6	8.00	14.9	8.90	N.S	B	9.12	1.140
Wallace,2000	2-wo-sst-5/16	24.6	8.00	14.9	8.90	N.S	B	8.51	1.063
Wallace,2000	3-wo-sst-5/16	24.6	8.00	14.9	8.90	N.S	B	8.26	1.032
Wallace,2000	1-wo-sst-1/4	24.6	6.65	14.9	7.12	N.S	B	9.16	1.377
Wallace,2000	2-wo-sst-1/4	24.6	6.65	14.9	7.12	N.S	B	8.92	1.341

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Wallace,2000	3-wo-sst-1/4	24.6	6.65	14.9	7.12	N.S	B	9.03	1.357
Wallace,2000	1-wo-mix-1/4	11.2	3.26	7.33	3.49	N.S	B	3.52	1.078
Wallace,2000	2-wo-mix-1/4	11.2	3.26	7.33	3.49	N.S	B	3.47	1.063
Wallace,2000	3-wo-mix-1/4	11.2	3.26	7.33	3.49	N.S	B	3.73	1.142
Wallace,2000	1-wo-ss-1/4	11.2	3.26	7.33	3.49	N.S	B	3.27	1.002
Wallace,2000	2-wo-ss-1/4	11.2	3.26	7.33	3.49	N.S	B	3.30	1.011
Wallace,2000	1-wo-ss-1/2	11.2	5.54	7.33	4.69	B	B	4.25	0.905
Wallace,2000	2-wo-ss-1/2	11.2	5.54	7.33	4.69	B	B	4.43	0.944
Wallace,2000	3-wo-ss-1/2	11.2	5.54	7.33	4.69	B	B	4.00	0.852
Wallace,2000	1-wo-ss-5/8	11.2	6.31	7.33	5.24	B	B	5.45	1.040
Wallace,2000	2-wo-ss-5/8	11.2	6.31	7.33	5.24	B	B	5.43	1.036
Wallace,2000	3-wo-ss-5/8	11.2	6.31	7.33	5.24	B	B	5.41	1.033
Yu,1978	B-0-12-1-0-SS	4.78	1.57	1.60	1.21	B	R	1.73	1.421
Yu,1978	B-0-12-2-0-SS	4.78	1.57	1.60	1.21	B	R	1.40	1.154
Yu,1978	B-0-12-3-L-SS	4.78	1.57	1.65	1.21	B	R	1.40	1.154
Yu,1978	B-0-12-4-L-SS	4.78	1.57	1.65	1.21	B	R	1.50	1.238
Yu,1978	B-0-12-5-0-SS	4.78	1.57	1.60	1.21	B	R	1.36	1.117
Yu,1978	B-0-12-6-0-SS	4.78	1.57	1.65	1.21	B	R	1.44	1.183
Yu,1978	B-0-12-7-L-SS	4.78	1.57	1.60	1.21	B	R	1.58	1.304
Yu,1978	B-0-12-8-L-SS	4.66	1.56	1.62	1.21	B	R	1.45	1.194
Yu,1978	B-0-12-9-H-SS	4.71	1.56	1.62	1.21	B	R	1.70	1.403
Yu,1978	B-0-12-10-H-SS	4.78	1.57	1.65	1.21	B	R	2.25	1.850
Yu,1978	B-0-14-1-0-DS	7.89	1.67	2.56	2.15	N.S	B&E	2.42	1.446
Yu,1978	B-0-14-2-0-DS	7.89	1.67	2.56	2.15	N.S	B&E	2.13	1.273
Yu,1978	B-0-14-3-L-DS	7.89	1.67	2.56	2.15	N.S	B&E	2.55	1.529
Yu,1978	B-0-14-4-L-DS	7.89	1.67	2.56	2.15	N.S	B&E	2.36	1.412
Yu,1978	B-0-14-5-0-DS	7.89	1.67	2.56	2.15	N.S	B&E	2.33	1.393
Yu,1978	B-0-14-6-0-DS	7.89	1.67	2.56	2.15	N.S	B&E	2.14	1.284
Yu,1978	B-0-14-7-L-DS	7.89	1.67	2.56	2.15	N.S	B&E	3.06	1.833
Yu,1978	B-0-14-8-L-DS	7.89	1.67	2.56	2.15	N.S	B&E	3.15	1.886
Yu,1978	B-0-14-9-H-DS	7.89	1.67	2.56	2.15	N.S	B&E	2.46	1.470
Yu,1978	B-0-14-10-H-DS	7.89	1.67	2.56	2.15	N.S	B&E	2.41	1.444
Yu,1978	B-0-17-1-0-SS	12.5	4.19	4.41	4.40	N.S	R	5.42	1.291
Yu,1978	B-0-17-2-0-SS	12.5	4.19	4.41	4.40	N.S	R	4.96	1.183
Yu,1978	B-0-17-3-L-SS	12.7	4.20	4.41	4.40	N.S	R	5.36	1.274
Yu,1978	B-0-17-4-L-SS	12.5	4.19	4.41	4.40	N.S	R	5.75	1.371
Yu,1978	B-0-17-5-0-SS	12.5	4.19	4.41	4.40	N.S	R	5.28	1.259
Yu,1978	B-0-17-6-0-SS	12.5	4.19	4.28	4.40	N.S	R	5.31	1.267

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-17-7-L-SS	12.5	4.19	4.41	4.40	N.S	R	5.32	1.268
Yu,1978	B-0-17-8-L-SS	12.5	4.19	4.41	4.40	N.S	R	5.45	1.300
Yu,1978	B-0-17-9-H-SS	12.7	4.20	4.41	4.40	N.S	R	5.33	1.268
Yu,1978	B-0-17-10-H-SS	12.5	4.19	4.31	4.40	N.S	R	5.40	1.288
Yu,1978	B-0-18-1-0-SS	19.0	7.95	8.56	7.67	B	R	6.30	0.821
Yu,1978	B-0-18-2-0-SS	19.0	7.95	8.61	7.67	B	R	6.32	0.824
Yu,1978	B-0-18-3-L-SS	19.0	7.95	8.61	7.67	B	R	9.08	1.184
Yu,1978	B-0-18-4-L-SS	19.0	7.95	8.61	7.67	B	R	6.63	0.865
Yu,1978	B-0-18-5-0-SS	19.0	7.95	8.61	7.67	B	R	6.32	0.824
Yu,1978	B-0-18-6-0-SS	19.0	7.95	8.61	7.67	B	R	7.10	0.927
Yu,1978	B-0-18-7-L-SS	19.0	7.95	8.61	7.67	B	R	12.2	1.588
Yu,1978	B-0-18-8-L-SS	19.0	7.95	8.81	7.67	B	R	11.5	1.498
Yu,1978	B-0-18-9-H-SS	19.0	7.95	8.61	7.67	B	R	11.6	1.515
Yu,1978	B-0-18-10-H-SS	19.0	7.95	8.61	7.67	B	R	10.4	1.358
Yu,1978	B-0-21-1-0-DS	20.6	4.47	6.61	7.81	N.S	B&E	8.37	1.872
Yu,1978	B-0-21-2-0-DS	20.6	4.47	6.85	7.81	N.S	B&E	8.46	1.892
Yu,1978	B-0-21-3-L-DS	20.6	4.47	6.98	7.81	N.S	B&E	8.46	1.892
Yu,1978	B-0-21-4-L-DS	20.6	4.47	6.85	7.81	N.S	B&E	8.52	1.907
Yu,1978	B-0-21-5-0-DS	20.6	4.47	6.85	7.81	N.S	B&E	8.63	1.932
Yu,1978	B-0-21-6-0-DS	20.6	4.47	7.09	7.81	N.S	B&E	9.03	2.021
Yu,1978	B-0-21-7-L-DS	20.6	4.47	6.85	7.81	N.S	B&E	9.68	2.166
Yu,1978	B-0-21-8-L-DS	20.6	4.47	6.85	7.81	N.S	B&E	9.12	2.041
Yu,1978	B-0-21-9-H-DS	20.6	4.47	6.85	7.81	N.S	B&E	9.95	2.225
Yu,1978	B-0-21-10-H-DS	20.6	4.47	6.85	7.81	N.S	B&E	8.90	1.991
Yu,1978	B-0-22-1-0-DS	39.6	8.91	13.7	13.6	N.S	B&E	11.4	1.279
Yu,1978	B-0-22-2-0-DS	39.6	8.91	13.7	13.6	N.S	B&E	11.1	1.242
Yu,1978	B-0-22-3-L-DS	39.6	8.91	13.7	13.6	N.S	B&E	12.8	1.437
Yu,1978	B-0-22-4-L-DS	39.6	8.91	13.7	13.6	N.S	B&E	10.8	1.212
Yu,1978	B-0-22-5-0-DS	39.6	8.91	13.7	13.6	N.S	B&R	10.8	1.212
Yu,1978	B-0-22-6-0-DS	39.6	8.91	13.7	13.6	N.S	B&R	9.79	1.099
Yu,1978	B-0-22-7-L-DS	39.6	8.91	13.7	13.6	N.S	B&E	12.0	1.349
Yu,1978	B-0-22-8-L-DS	39.6	8.91	13.7	13.6	N.S	B&E	12.1	1.359
Yu,1978	B-0-22-9-H-DS	39.6	8.91	13.7	13.6	N.S	B&E	11.8	1.324
Yu,1978	B-0-22-10-H-DS	39.6	8.91	13.9	13.6	N.S	B&E	12.7	1.429
Yu,1978	B-0-25-1-0-SS	47.5	18.0	19.5	19.9	N.S	R	18.2	1.013
Yu,1978	B-0-25-2-0-SS	47.5	18.0	19.5	19.9	N.S	R	19.0	1.058
Yu,1978	B-0-25-3-L-SS	47.5	18.0	19.5	19.9	N.S	R	20.2	1.125
Yu,1978	B-0-25-4-L-SS	47.5	18.0	19.5	19.9	N.S	R	21.0	1.172

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-25-5-H-SS	47.5	18.0	19.5	19.9	N.S	R	20.4	1.137
Yu,1978	B-0-25-6-H-SS	47.5	18.0	19.5	19.9	N.S	R	19.4	1.077
Yu,1978	B-0-26-1-0-SS	66.6	26.8	29.2	29.7	N.S	R	24.4	0.912
Yu,1978	B-0-26-2-0-SS	66.6	26.8	29.2	29.7	N.S	R	24.7	0.924
Yu,1978	B-0-26-3-L-SS	66.6	26.8	29.2	29.7	N.S	R	25.3	0.946
Yu,1978	B-0-26-4-L-SS	66.6	26.8	29.2	29.7	N.S	R	24.7	0.922
Yu,1978	B-0-26-5-0-SS	66.6	26.8	29.2	29.7	N.S	R	24.7	0.923
Yu,1978	B-0-26-6-0-SS	66.6	26.8	29.2	29.7	N.S	R	23.1	0.862
Yu,1978	B-0-26-7-L-SS	66.6	26.8	29.2	29.7	N.S	R	25.0	0.935
Yu,1978	B-0-26-8-L-SS	66.6	26.8	29.2	29.7	N.S	R	24.9	0.932
Yu,1978	B-0-26-9-H-SS	66.6	26.8	29.2	29.7	N.S	R	31.2	1.164
Yu,1978	B-0-26-10-H-SS	66.6	26.8	29.2	29.7	N.S	R	32.7	1.223
Yu,1978	B-0-29-1-0-DS	103	20.2	32.1	35.3	N.S	B&E	30.9	1.528
Yu,1978	B-0-29-2-0-DS	103	20.2	31.5	35.3	N.S	B&E	35.6	1.760
Yu,1978	B-0-29-3-L-DS	103	20.2	31.0	35.3	N.S	B&E	38.3	1.895
Yu,1978	B-0-29-4-L-DS	103	20.2	32.1	35.3	N.S	B&E	38.5	1.906
Yu,1978	B-0-29-5-0-DS	103	20.2	32.6	35.3	N.S	B&E	37.0	1.832
Yu,1978	B-0-29-6-0-DS	103	20.2	32.6	35.3	N.S	B&E	31.4	1.555
Yu,1978	B-0-29-7-L-DS	103	20.2	31.5	35.3	N.S	B&E	40.9	2.027
Yu,1978	B-0-29-8-L-DS	103	20.2	32.6	35.3	N.S	B&E	41.4	2.049
Yu,1978	B-0-29-9-H-DS	103	20.2	32.6	35.3	N.S	B&E	41.2	2.038
Yu,1978	B-0-29-10-H-DS	103	20.2	32.6	35.3	N.S	B&E	40.7	2.016
Yu,1978	B-0-30-1-0-DS	158	30.5	43.7	52.7	N.S	B&E	44.3	1.453
Yu,1978	B-0-30-2-0-DS	158	30.5	45.3	52.7	N.S	B&E	46.7	1.533
Yu,1978	B-0-30-3-L-DS	158	30.5	45.3	52.7	N.S	B&E	51.2	1.679
Yu,1978	B-0-30-4-L-DS	158	30.5	45.3	52.7	N.S	B&E	48.1	1.577
Yu,1978	B-0-30-5-0-DS	158	30.5	45.3	52.7	N.S	B&E	46.2	1.515
Yu,1978	B-0-30-6-0-DS	158	30.5	44.8	52.7	N.S	B&E	43.7	1.435
Yu,1978	B-0-30-7-L-DS	158	30.5	45.3	52.7	N.S	B&E	49.5	1.624
Yu,1978	B-0-30-8-L-DS	158	30.5	45.3	52.7	N.S	B&E	48.1	1.580
Yu,1978	B-0-30-9-H-DS	158	30.5	43.7	52.7	N.S	B&E	50.3	1.650
Yu,1978	B-0-30-10-H-DS	158	30.5	43.7	52.7	N.S	B&E	51.6	1.694
Yu,1978	B-0-32-1-0-SS	9.69	2.98	3.05	2.47	B	B&R	2.45	0.991
Yu,1978	B-0-32-2-0-SS	9.69	2.98	2.94	2.47	B	B&R	2.58	1.045
Yu,1978	B-0-32-3-L-SS	9.69	2.98	3.05	2.47	B	B&R	2.72	1.103
Yu,1978	B-0-32-4-L-SS	9.69	2.98	3.05	2.47	B	B&R	3.14	1.272
Yu,1978	B-0-32-5-0-SS	9.69	2.98	3.05	2.47	B	B&R	2.67	1.081
Yu,1978	B-0-32-6-0-SS	9.69	2.98	3.10	2.47	B	B&R	2.41	0.977

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-32-7-L-SS	9.69	2.98	3.05	2.47	B	B&R	2.49	1.009
Yu,1978	B-0-32-8-L-SS	9.69	2.98	3.10	2.47	B	B&R	2.39	0.968
Yu,1978	B-0-32-9-H-SS	9.69	2.98	3.10	2.47	B	B&N.S	3.61	1.463
Yu,1978	B-0-32-10-H-SS	9.69	2.98	3.05	2.47	B	B&N.S	2.89	1.171
Yu,1978	B-0-34-1-0-DS	15.7	3.16	4.85	4.38	N.S	B&E	3.78	1.195
Yu,1978	B-0-34-2-0-DS	15.7	3.16	4.85	4.38	N.S	B&E	3.81	1.205
Yu,1978	B-0-34-3-L-DS	15.7	3.16	4.85	4.38	N.S	B&E	4.25	1.345
Yu,1978	B-0-34-4-L-DS	15.7	3.16	4.85	4.38	N.S	B&E	4.43	1.401
Yu,1978	B-0-34-5-0-DS	15.7	3.16	4.85	4.38	N.S	B&E	3.07	0.970
Yu,1978	B-0-34-6-0-DS	15.7	3.16	4.85	4.38	N.S	B&E	3.63	1.146
Yu,1978	B-0-34-7-L-DS	15.7	3.16	4.85	4.38	N.S	B&E	3.87	1.224
Yu,1978	B-0-34-8-L-DS	15.7	3.16	4.85	4.38	N.S	B&E	4.62	1.460
Yu,1978	B-0-34-9-H-DS	15.7	3.16	4.85	4.38	N.S	B&E	5.03	1.589
Yu,1978	B-0-34-10-H-DS	15.7	3.16	4.85	4.38	N.S	B&E	4.04	1.276
Yu,1978	B-0-37-1-0-SS	18.4	5.62	5.66	5.78	N.S	R	5.37	0.955
Yu,1978	B-0-37-2-0-SS	18.4	5.62	5.66	5.78	N.S	R	5.36	0.953
Yu,1978	B-0-37-3-L-SS	18.4	5.62	5.66	5.78	N.S	R	5.62	0.999
Yu,1978	B-0-37-4-L-SS	18.4	5.62	5.66	5.78	N.S	R	5.55	0.988
Yu,1978	B-0-37-5-H-SS	18.4	5.62	5.66	5.78	N.S	R	5.52	0.982
Yu,1978	B-0-37-6-H-SS	18.4	5.62	5.66	5.78	N.S	R	8.88	1.579
Yu,1978	B-0-38-1-0-SS	24.5	10.4	11.3	9.2	B	R	7.01	0.761
Yu,1978	B-0-38-2-0-SS	24.5	10.4	11.3	9.2	B	R	7.28	0.790
Yu,1978	B-0-38-3-L-SS	24.5	10.4	11.3	9.2	B	R	10.1	1.093
Yu,1978	B-0-38-4-L-SS	24.5	10.4	11.3	9.2	B	R	8.68	0.943
Yu,1978	B-0-38-5-0-SS	24.5	10.4	11.3	9.2	B	R	7.19	0.781
Yu,1978	B-0-38-6-0-SS	24.5	10.4	11.3	9.2	B	R	7.45	0.810
Yu,1978	B-0-38-7-L-SS	24.5	10.4	11.3	9.2	B	R	10.4	1.134
Yu,1978	B-0-38-8-L-SS	24.5	10.4	11.3	9.2	B	R	8.19	0.890
Yu,1978	B-0-38-9-H-SS	24.5	10.4	11.3	9.2	B	R	9.35	1.015
Yu,1978	B-0-38-10-H-SS	24.5	10.4	11.3	9.2	B	R	10.4	1.126
Yu,1978	B-0-41-1-0-DS	26.6	5.87	9.00	10.3	N.S	B&E	8.81	1.501
Yu,1978	B-0-41-2-0-DS	26.6	5.87	9.00	10.3	N.S	B&E	9.63	1.641
Yu,1978	B-0-41-3-L-DS	26.6	5.87	9.00	10.3	N.S	B&E	10.6	1.812
Yu,1978	B-0-41-4-L-DS	26.6	5.87	9.00	10.3	N.S	B&E	9.48	1.615
Yu,1978	B-0-41-5-H-DS	26.6	5.87	9.00	10.3	N.S	B&E	10.3	1.759
Yu,1978	B-0-41-6-H-DS	26.6	5.87	9.00	10.3	N.S	B&E	10.7	1.819
Yu,1978	B-0-42-1-0-DS	53.1	11.7	18.0	16.3	N.S	B&E	13.1	1.116
Yu,1978	B-0-42-2-0-DS	53.1	11.7	18.0	16.3	N.S	B&E	12.1	1.027

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-42-3-L-DS	53.1	11.7	18.0	16.3	N.S	B&E	12.8	1.092
Yu,1978	B-0-42-4-L-DS	53.1	11.7	18.0	16.3	N.S	B&E	12.1	1.035
Yu,1978	B-0-42-5-0-DS	53.1	11.7	18.0	16.3	N.S	B&E	13.4	1.141
Yu,1978	B-0-42-6-0-DS	53.1	11.7	18.0	16.3	N.S	B&E	13.4	1.141
Yu,1978	B-0-42-7-L-DS	53.1	11.7	18.0	16.3	N.S	B&E	16.8	1.433
Yu,1978	B-0-42-8-L-DS	53.1	11.7	18.0	16.3	N.S	B&E	12.7	1.080
Yu,1978	B-0-42-9-H-DS	53.1	11.7	18.0	16.3	N.S	B&E	17.2	1.469
Yu,1978	B-0-42-10-H-DS	53.1	11.7	18.0	16.3	N.S	B&E	19.3	1.645
Yu,1978	B-0-45-1-0-SS	49.7	22.2	26.0	24.6	N.S	R	18.0	0.808
Yu,1978	B-0-45-2-0-SS	49.7	22.2	24.1	24.6	N.S	R	18.2	0.816
Yu,1978	B-0-45-3-L-SS	49.7	22.2	24.1	24.6	N.S	R	19.3	0.867
Yu,1978	B-0-45-4-L-SS	49.7	22.2	25.2	24.6	N.S	R	19.2	0.865
Yu,1978	B-0-45-5-H-SS	49.7	22.2	25.2	24.6	N.S	R	19.8	0.892
Yu,1978	B-0-45-6-H-SS	49.7	22.2	24.1	24.6	N.S	R	19.8	0.890
Yu,1978	B-0-46-1-0-SS	70.4	33.2	36.1	36.3	N.S	B&R	25.9	0.781
Yu,1978	B-0-46-2-0-SS	70.4	33.2	36.1	36.3	N.S	B&R	24.3	0.733
Yu,1978	B-0-46-3-L-SS	70.4	33.2	36.1	36.3	N.S	B&R	26.7	0.804
Yu,1978	B-0-46-4-L-SS	70.4	33.2	36.1	36.3	N.S	B&R	26.5	0.799
Yu,1978	B-0-46-5-0-SS	70.4	33.2	36.1	36.3	N.S	B&R	26.1	0.787
Yu,1978	B-0-46-6-0-SS	70.4	33.2	36.1	36.3	N.S	B&R	25.9	0.780
Yu,1978	B-0-46-7-L-SS	70.4	33.2	36.1	36.3	N.S	B&R	29.8	0.896
Yu,1978	B-0-46-8-L-SS	70.4	33.2	36.1	36.3	N.S	B&R	26.1	0.787
Yu,1978	B-0-46-9-H-SS	70.4	33.2	36.1	36.3	N.S	B&R	33.4	1.005
Yu,1978	B-0-46-10-H-SS	70.4	33.2	36.1	36.3	N.S	B&R	29.2	0.879
Yu,1978	B-0-49-1-0-DS	111	25.1	39.0	43.7	N.S	B&E	42.6	1.699
Yu,1978	B-0-49-2-0-DS	111	25.1	39.7	43.7	N.S	B&E	37.4	1.491
Yu,1978	B-0-49-3-L-DS	111	25.1	39.0	43.7	N.S	B&E	39.2	1.565
Yu,1978	B-0-49-4-L-DS	111	25.1	39.0	43.7	N.S	B&E	39.8	1.588
Yu,1978	B-0-49-5-H-DS	111	25.1	39.0	43.7	N.S	B&E	40.9	1.633
Yu,1978	B-0-49-6-H-DS	111	25.1	39.0	43.7	N.S	B&E	42.3	1.686
Yu,1978	B-0-50-1-0-DS	165	37.7	57.5	64.3	N.S	B&E	54.5	1.445
Yu,1978	B-0-50-2-0-DS	165	37.7	57.5	64.3	N.S	B&E	53.0	1.404
Yu,1978	B-0-50-3-L-DS	165	37.7	57.5	64.3	N.S	B&E	55.4	1.469
Yu,1978	B-0-50-4-L-DS	165	37.7	57.5	64.3	N.S	B&E	51.8	1.374
Yu,1978	B-0-50-5-0-DS	165	37.7	57.5	64.3	N.S	B&E	50.5	1.339
Yu,1978	B-0-50-6-0-DS	165	37.7	57.5	64.3	N.S	B&E	48.3	1.280
Yu,1978	B-0-50-7-L-DS	165	37.7	57.5	64.3	N.S	B&E	53.4	1.416
Yu,1978	B-0-50-8-L-DS	165	37.7	57.5	64.3	N.S	B&E	44.9	1.189

Table C6 Test-To-Predicted Values (North American Specification, AISI, 2001a)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-50-9-H-DS	165	37.7	57.5	64.3	N.S	B&E	62.3	1.652
Yu,1978	B-0-50-10-H-DS	165	37.7	57.5	64.3	N.S	B&E	53.5	1.419
Yu,1978	B-0-51-1-0-SS	188	87.8	97.7	97.7	N.S	R	97.7	1.112
Yu,1978	B-0-51-2-0-SS	188	87.8	97.7	97.7	N.S	R	96.3	1.097
Yu,1978	B-0-51-3-L-SS	188	87.8	99.5	97.7	N.S	R	94.1	1.072
Yu,1978	B-0-51-4-L-SS	188	87.8	97.7	97.7	N.S	R	101	1.161
Yu,1978	B-0-51-5-H-SS	188	87.8	97.7	97.7	N.S	R	95.0	1.082
Yu,1978	B-0-51-6-H-SS	188	87.8	97.7	97.7	N.S	R	97.9	1.115
Yu,1978	B-0-53-1-0-DS	443	99.7	151	173	N.S	B&E	157	1.584
Yu,1978	B-0-53-2-0-DS	443	99.7	155	173	N.S	B&E	155	1.557
Yu,1978	B-0-53-3-L-DS	443	99.7	151	173	N.S	B&E	161	1.624
Yu,1978	B-0-53-4-L-DS	443	99.7	153	173	N.S	B&E	160	1.613
Yu,1978	B-0-53-5-H-DS	443	99.7	148	173	N.S	B&E	160	1.611

Table C7 Test-To-Predicted Values (Proposed method 1)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Carril,1994	AN32-1	62.8	75.3	55.8	29.2	B	B	36.0	1.231
Carril,1994	AN32-2	61.6	73.9	54.8	28.7	B	B	36.5	1.269
Carril,1994	AN33-1	77.2	96.1	55.7	29.2	B	B	40.1	1.370
Carril,1994	AN33-2	78.5	97.7	56.7	29.7	B	B	39.8	1.339
Carril,1994	BN33-1	77.9	97.1	104	59.0	B	B	65.0	1.102
Carril,1994	BN33-2	77.9	97.1	104	59.0	B	B	64.0	1.085
Carril,1994	DN12-2	44.6	57.6	42.7	21.2	B	B	21.1	0.994
Carril,1994	DN12-3	43.6	56.2	41.7	20.5	B	B	21.1	1.027
Carril,1994	DN22-1	65.1	88.2	65.4	34.3	B	B	37.5	1.093
Carril,1994	DN22-2	66.0	89.4	66.2	34.8	B	B	37.8	1.086
Carril,1994	BN32-1	62.7	75.2	103	58.5	B	B&N.S	64.3	1.100
Carril,1994	BN32-2	62.0	74.3	102	58.0	B	B&N.S	65.4	1.127
Carril,1994	DN32-1	127	152	113	59.5	B	B&R	70.1	1.178
Carril,1994	DN32-2	125	150	111	58.5	B	B&R	71.6	1.223
Carril,1994	EN12-1	44.6	57.6	79.6	42.5	B	B&R	38.5	0.907
Carril,1994	EN12-2	44.6	57.6	79.5	42.5	B	B&R	38.7	0.912
Carril,1994	EN22-1	66.0	89.4	123	69.7	B	B&R	70.2	1.008
Carril,1994	EN22-2	66.9	90.5	125	70.6	B	B&R	70.0	0.992
Carril,1994	EN32-1	125	150	206	116	B	B&R	128	1.097
Carril,1994	EN32-2	124	149	204	115	B	B&R	129	1.113
Carril,1994	AN31-2	31.1	29.6	54.7	28.7	B	N.S	29.3	1.019
Carril,1994	AN31-3	31.1	29.6	55.2	29.0	B	N.S	29.1	1.004
Carril,1994	BN31-1	31.3	29.7	103	58.5	N.S	N.S	29.4	0.988
Carril,1994	BN31-2	31.3	29.6	103	58.5	N.S	N.S	29.4	0.991
Carril,1994	CN11-1	11.0	11.2	58.1	31.8	N.S	N.S	10.2	0.909
Carril,1994	CN11-2	11.0	11.2	58.1	31.8	N.S	N.S	10.4	0.924
Carril,1994	CN12-1	22.2	28.6	58.1	31.8	N.S	N.S	25.5	0.893
Carril,1994	CN12-2	22.2	28.6	58.1	31.8	N.S	N.S	25.5	0.893
Carril,1994	CN21-1	16.7	18.0	90.0	52.2	N.S	N.S	18.2	1.012
Carril,1994	CN21-2	16.9	18.1	91.3	53.0	N.S	N.S	18.1	0.997
Carril,1994	CN21-3	16.9	18.1	91.3	53.0	N.S	N.S	17.9	0.989
Carril,1994	CN22-1	33.1	44.8	90.1	52.2	N.S	N.S	42.7	0.954
Carril,1994	CN22-2	33.6	45.5	91.4	53.0	N.S	N.S	42.9	0.943
Carril,1994	CN22-3	33.1	44.8	90.0	52.2	N.S	N.S	42.9	0.956
Carril,1994	CN31-2	32.0	30.4	153	89.2	N.S	N.S	30.8	1.013
Carril,1994	CN31-3	32.3	30.7	154	90.0	N.S	N.S	30.0	0.980
Carril,1994	CN32-1	64.4	77.2	155	90.0	N.S	N.S	71.2	0.923

Table C7 Test-To-Predicted Values (Proposed method 1)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Carril,1994	CN32-2	63.6	76.2	153	89.2	N.S	N.S	70.4	0.924
Carril,1994	DN31-1	63.7	60.4	113	59.5	B	N.S	55.2	0.928
Carril,1994	DN31-2	61.7	58.5	109	57.5	B	N.S	53.4	0.929
Carril,1994	EN11-1	22.7	23.1	81.3	43.8	N.S	N.S	21.4	0.927
Carril,1994	EN11-2	22.2	22.6	79.5	42.5	N.S	N.S	21.5	0.949
Carril,1994	EN21-1	33.6	36.1	124	70.6	N.S	N.S	37.4	1.037
Carril,1994	EN21-2	33.5	36.0	125	70.6	N.S	N.S	37.4	1.040
Carril,1994	EN31-1	62.2	59.0	205	115	N.S	N.S	58.9	0.999
Carril,1994	EN31-2	62.7	59.5	207	116	N.S	N.S	60.3	1.013
Carril,1994	DN11-1	21.2	21.6	40.8	19.8	B	N&R	18.1	0.913
Carril,1994	DN11-2	21.7	22.1	41.7	20.5	B	N&R	18.7	0.912
Carril,1994	DN21-1	33.6	36.0	67.3	35.3	B	N&R	32.0	0.906
Carril,1994	DN21-2	33.1	35.5	66.3	34.8	B	N&R	31.5	0.905
Chong,1975	1	35.8	33.9	20.0	8.99	B	B&E	10.9	1.217
Chong,1975	2	35.5	35.8	19.8	6.37	B	B	8.14	1.279
Chong,1975	3	36.3	36.6	20.0	6.37	B	B&E	7.12	1.118
Chong,1975	4	35.8	33.9	19.7	8.99	B	E	9.92	1.103
Chong,1975	5	35.8	33.9	20.1	8.99	B	E	10.8	1.202
Chong,1975	6	35.2	33.3	9.70	8.99	B	B&E	10.6	1.183
Chong,1975	7	35.2	33.3	14.6	8.99	B	E	11.0	1.227
Chong,1975	8	35.2	33.3	17.0	8.99	B	E	10.0	1.113
Chong,1975	9	35.2	33.3	24.3	8.99	B	B	10.1	1.118
Chong,1975	11	35.2	33.3	24.3	8.99	B	B	10.3	1.143
Chong,1975	12	35.2	33.3	14.6	8.99	B	E	10.7	1.192
Chong,1975	13	35.2	33.3	9.70	8.99	B	E&B	10.5	1.168
Chong,1975	14	35.2	33.3	4.85	8.99	E	E	7.48	1.541
Chong,1975	15	35.2	33.3	4.85	8.99	E	E	6.76	1.394
Chong,1975	32	37.1	39.4	23.4	11.9	B	E&B	12.9	1.077
Chong,1975	33	37.1	39.4	22.9	11.9	B	B&E	13.3	1.110
Chong,1975	34	37.1	39.4	22.9	11.9	B	B&E	13.1	1.095
Chong,1975	41	54.9	69.2	10.3	21.1	E	E&B	12.3	1.201
Chong,1975	42	54.9	69.2	10.5	21.1	E	E&B	13.8	1.314
Chong,1975	49	13.9	9.00	40.2	21.1	N.S	N.S	13.5	1.497
Chong,1975	50	13.9	9.00	40.2	21.1	N.S	N.S	12.9	1.438
Chong,1975	51	13.9	9.00	40.2	21.1	N.S	N.S	11.9	1.320
Chong,1975	52	74.3	73.9	69.5	36.5	B	B&E	38.3	1.048
Chong,1975	53	74.3	73.9	69.8	36.5	B	B&E	36.3	0.994
Chong,1975	54	74.3	73.9	69.5	36.5	B	B&E	40.8	1.118

Table C7 Test-To-Predicted Values (Proposed method 1)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Chong,1975	55	111	106	99.0	51.5	B	B&E	55.6	1.081
Chong,1975	16(3b)	26.6	18.4	20.0	18.0	B	N.S	18.1	1.004
Chong,1975	17(3b)	27.0	18.8	19.4	18.0	B	N.S	18.4	1.022
Chong,1975	37(3b)	37.2	33.2	44.8	23.9	B	E&B	24.8	1.038
Chong,1975	40(3b)	54.9	57.8	79.3	42.3	B	B	40.0	0.946
Chong,1975	56(3b)	110	78.9	196	102	N.S	E&N	88.3	1.119
Chong,1975	35(3c)	37.3	34.3	70.0	22.4	B	B	23.3	1.041
Chong,1975	36(3c)	37.3	34.3	70.6	22.4	B	B	24.0	1.071
Chong,1975	18(3d)	8.81	4.24	26.4	18.0	N.S	N.S	7.57	1.782
Chong,1975	19(3d)	8.81	4.24	26.4	18.0	N.S	N.S	6.72	1.583
Chong,1975	22(3d)	17.6	13.9	26.4	18.0	N.S	N.S	14.9	1.066
Chong,1975	23(3d)	17.6	13.9	26.4	18.0	N.S	N.S	15.9	1.139
Chong,1975	28(3d)	35.2	33.3	26.4	18.0	B	E	19.5	1.084
Chong,1975	29(3d)	35.2	33.3	26.4	18.0	B	B&E	19.2	1.069
Chong,1975	45(3d)	27.4	28.9	54.7	42.3	N.S	N.S	30.7	1.063
Chong,1975	46(3d)	27.4	28.9	54.7	42.3	N.S	N.S	31.9	1.103
Chong,1975	20(3e)	8.81	4.24	43.0	27.0	N.S	N.S	7.83	1.845
Chong,1975	21(3e)	8.81	4.24	43.0	27.0	N.S	N.S	4.76	1.122
Chong,1975	24(3e)	17.6	13.9	43.0	27.0	N.S	N.S	15.7	1.126
Chong,1975	25(3e)	17.6	13.9	43.0	27.0	N.S	N.S	15.2	1.088
Chong,1975	26(3e)	34.7	32.8	43.0	27.0	B	E	28.8	1.067
Chong,1975	27(3e)	34.7	32.8	43.0	27.0	B	E	28.8	1.069
Chong,1975	43(3e)	55.3	69.8	89.3	63.4	B	E&B	58.3	0.920
Chong,1975	44(3e)	55.7	70.4	89.3	63.4	B	E&B	60.1	0.948
Chong,1975	47(3e)	13.7	8.80	89.3	63.4	N.S	N.S	13.0	1.476
Chong,1975	48(3e)	13.7	8.80	89.3	63.4	N.S	N.S	13.5	1.532
Gilchrist,1979	1	16.9	17.3	4.65	2.26	B	B&E	3.20	1.419
Gilchrist,1979	2	16.9	17.3	3.49	2.26	B	B&E	2.71	1.202
Gilchrist,1979	3	16.9	17.3	2.79	2.26	B	B&E	2.60	1.153
Gilchrist,1979	4	16.9	16.7	6.97	2.64	B	B&E	3.03	1.147
Gilchrist,1979	5	16.9	16.7	4.65	2.64	B	B	3.00	1.138
Gilchrist,1979	6	16.9	16.7	3.49	2.64	B	B&E	3.16	1.197
Gilchrist,1979	7	24.3	23.9	6.43	3.34	B	B&E	3.78	1.133
Gilchrist,1979	8	24.3	23.9	4.82	3.34	B	B&E	3.89	1.166
Gilchrist,1979	9	24.3	23.9	3.86	3.34	B	B&E	3.69	1.106
Gilchrist,1979	10	24.3	23.1	9.65	4.14	B	B&E	4.01	0.968
Gilchrist,1979	11	24.3	23.1	6.43	4.14	B	B	3.56	0.861
Gilchrist,1979	12	24.3	23.1	4.82	4.14	B	B&E	4.34	1.049

Table C7 Test-To-Predicted Values (Proposed method 1)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Gilchrist,1979	13	24.8	24.5	6.60	3.46	B	B&E	4.58	1.323
Gilchrist,1979	14	24.8	24.5	4.95	3.46	B	B&E	4.29	1.240
Gilchrist,1979	15	24.8	24.5	3.96	3.46	B	B&E	4.18	1.207
Gilchrist,1979	16	24.8	23.7	9.90	4.55	B	B&E	4.34	0.954
Gilchrist,1979	17	24.8	23.7	6.60	4.55	B	B&E	4.36	0.959
Gilchrist,1979	18	24.8	23.7	4.95	4.55	B	B&E	4.05	0.890
Gilchrist,1979	19	24.8	22.7	13.2	5.01	B	B&E	7.23	1.444
Gilchrist,1979	20	24.8	22.7	9.90	5.01	B	B	5.21	1.040
Gilchrist,1979	21	24.8	22.7	6.60	5.01	B	B	5.45	1.088
Gilchrist,1979	22	19.8	22.9	6.16	3.23	B	B&E	3.78	1.169
Gilchrist,1979	23	19.8	22.9	4.62	3.23	B	B&E	3.65	1.128
Gilchrist,1979	24	19.8	22.9	3.70	3.23	B	B&E	4.01	1.238
Gilchrist,1979	25	19.8	22.1	9.24	4.25	B	B&E	4.41	1.037
Gilchrist,1979	26	19.8	22.1	6.16	4.25	B	B&E	4.21	0.990
Gilchrist,1979	27	19.8	22.1	4.62	4.25	B	B&E	4.12	0.969
Gilchrist,1979	28	19.8	21.2	12.3	4.68	B	B	7.16	1.532
Gilchrist,1979	29	19.8	21.2	9.24	4.68	B	B	6.50	1.389
Gilchrist,1979	30	19.8	21.2	6.16	4.68	B	B	5.01	1.071
McGill,2002	043-230-3/8-SS-A	8.03	9.88	9.27	1.86	B	B	1.69	0.911
McGill,2002	043-230-3/8-SS-B	8.03	9.88	9.27	1.86	B	B	1.77	0.954
McGill,2002	043-230-3/8-SS-C	8.03	9.88	9.27	1.86	B	B	1.67	0.900
McGill,2002	043-230-3/8-TTSS-A	8.03	9.88	9.27	1.86	B	B	1.87	1.008
McGill,2002	043-230-3/8-TTSS-B	8.03	9.88	9.27	1.86	B	B	1.77	0.954
McGill,2002	043-230-3/8-TTSS-C	8.03	9.88	9.27	1.86	B	B	2.16	1.164
McGill,2002	043-230-3/8-DS-A	8.03	9.88	9.27	3.18	B	B	3.65	1.148
McGill,2002	043-230-3/8-DS-B	8.03	9.88	9.27	3.18	B	B	3.46	1.088
McGill,2002	043-230-3/8-DS-C	8.03	9.88	9.27	3.18	B	B	3.26	1.025
McGill,2002	043-550-3/8-SS-A	19.3	16.4	15.4	3.08	B	B	2.62	0.850
McGill,2002	043-550-3/8-SS-B	19.3	16.4	15.4	3.08	B	B	2.73	0.885
McGill,2002	043-550-3/8-SS-C	19.3	16.4	15.4	3.08	B	B	2.49	0.808
McGill,2002	043-230-1/2-SS-A	8.03	9.38	9.27	2.47	B	B	2.14	0.865
McGill,2002	043-230-1/2-SS-B	8.03	9.38	9.27	2.47	B	B	2.13	0.861
McGill,2002	043-230-1/2-SS-C	8.03	9.38	9.27	2.47	B	B	2.18	0.881
McGill,2002	043-230-1/2-TTSS-A	8.03	9.38	9.27	2.47	B	B	2.29	0.926
McGill,2002	043-230-1/2-TTSS-B	8.03	9.38	9.27	2.47	B	B	2.24	0.906
McGill,2002	043-230-1/2-TTSS-C	8.03	9.38	9.27	2.47	B	B	2.46	0.995
McGill,2002	043-230-1/2-DS-A	8.03	9.38	9.27	4.24	B	B	5.43	1.281
McGill,2002	043-230-1/2-DS-B	8.03	9.38	9.27	4.24	B	B	5.80	1.368

Table C7 Test-To-Predicted Values (Proposed method 1)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	043-230-1/2-DS-C	8.03	9.38	9.27	4.24	B	B	5.72	1.349
McGill,2002	043-550-1/2-SS-A	19.3	15.6	15.4	4.11	B	B	3.37	0.820
McGill,2002	043-550-1/2-SS-B	19.3	15.6	15.4	4.11	B	B	3.36	0.817
McGill,2002	043-550-1/2-SS-C	19.3	15.6	15.4	4.11	B	B	3.36	0.817
McGill,2002	043-230-5/8-SS-A	8.03	8.89	9.27	3.09	B	B	2.99	0.967
McGill,2002	043-230-5/8-SS-B	8.03	8.89	9.27	3.09	B	B	2.84	0.919
McGill,2002	043-230-5/8-SS-C	8.03	8.89	9.27	3.09	B	B	2.78	0.899
McGill,2002	043-230-5/8-TTSS-A	8.03	8.89	9.27	3.09	B	B	3.09	0.999
McGill,2002	043-230-5/8-TTSS-B	8.03	8.89	9.27	3.09	B	B	3.22	1.041
McGill,2002	043-230-5/8-TTSS-C	8.03	8.89	9.27	3.09	B	B	3.36	1.087
McGill,2002	043-230-5/8-DS-A	8.03	8.89	9.27	5.30	B	B	7.05	1.330
McGill,2002	043-230-5/8-DS-B	8.03	8.89	9.27	5.30	B	B	7.49	1.413
McGill,2002	043-230-5/8-DS-C	8.03	8.89	9.27	5.30	B	B	7.35	1.387
McGill,2002	043-550-5/8-SS-A	19.3	14.8	15.4	5.14	B	B	3.71	0.722
McGill,2002	043-550-5/8-SS-B	19.3	14.8	15.4	5.14	B	B	3.93	0.765
McGill,2002	043-550-5/8-SS-C	19.3	14.8	15.4	5.14	B	B	3.92	0.763
McGill,2002	064-230-5/8-TTSS-A	14.3	12.6	13.2	4.39	B	B	5.22	1.190
McGill,2002	064-230-5/8-TTSS-B	14.3	12.6	13.2	4.39	B	B	4.88	1.113
McGill,2002	064-230-5/8-TTSS-C	14.3	12.6	13.2	4.39	B	B	5.47	1.247
McGill,2002	064-230-5/8-DS-A	14.3	12.6	13.2	7.52	B	B	11.8	1.575
McGill,2002	064-230-5/8-DS-B	14.3	12.6	13.2	7.52	B	B	11.0	1.466
McGill,2002	064-230-5/8-DS-C	14.3	12.6	13.2	7.52	B	B	11.7	1.556
McGill,2002	064-550-5/8-SS-A	33.3	25.5	26.6	8.87	B	B	8.64	0.974
McGill,2002	064-550-5/8-SS-B	33.3	25.5	26.6	8.87	B	B	8.91	1.004
McGill,2002	064-550-5/8-SS-C	33.3	25.5	26.6	8.87	B	B	8.34	0.940
McGill,2002	064-230-1/2-TTSS-A	14.3	13.3	13.2	3.87	B	B	4.56	1.179
McGill,2002	064-230-1/2-TTSS-B	14.3	13.3	13.2	3.87	B	B	4.44	1.148
McGill,2002	064-230-1/2-TTSS-C	14.3	13.3	13.2	3.87	B	B	4.10	1.060
McGill,2002	064-230-1/2-DS-A	14.3	13.3	13.2	6.63	B	B	8.91	1.344
McGill,2002	064-230-1/2-DS-B	14.3	13.3	13.2	6.63	B	B	9.28	1.400
McGill,2002	064-230-1/2-DS-C	14.3	13.3	13.2	6.63	B	B	9.23	1.392
McGill,2002	064-550-1/2-SS-A	33.3	26.9	26.6	7.82	B	B	6.94	0.887
McGill,2002	064-550-1/2-SS-B	33.3	26.9	26.6	7.82	B	B	7.26	0.928
McGill,2002	064-550-1/2-SS-C	33.3	26.9	26.6	7.82	B	B	7.04	0.900
McGill,2002	064-230-3/8-SS-A	14.3	14.0	13.2	3.64	B	B	3.05	0.839
McGill,2002	064-230-3/8-SS-B	14.3	14.0	13.2	3.64	B	B	2.75	0.756
McGill,2002	064-230-3/8-SS-C	14.3	14.0	13.2	3.64	B	B	2.77	0.762
McGill,2002	064-550-3/8-SS-A	33.3	28.3	26.6	7.36	B	B	5.83	0.792

Table C7 Test-To-Predicted Values (Proposed method 1)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	064-550-3/8-SS-B	33.3	28.3	26.6	7.36	B	B	6.43	0.874
McGill,2002	064-550-3/8-SS-C	33.3	28.3	26.6	7.36	B	B	5.82	0.791
McGill,2002	064-230-1/4-DS-A	14.3	14.7	13.2	5.00	B	B	6.76	1.352
McGill,2002	064-230-1/4-DS-B	14.3	14.7	13.2	5.00	B	B	6.67	1.334
McGill,2002	064-230-1/4-DS-C	14.3	14.7	13.2	5.00	B	B	6.38	1.276
McGill,2002	064-550-1/4-SS-A	33.3	29.7	26.6	5.90	B	B	5.68	0.963
McGill,2002	064-550-1/4-SS-B	33.3	29.7	26.6	5.90	B	B	5.55	0.941
McGill,2002	064-550-1/4-SS-C	33.3	29.7	26.6	5.90	B	B	5.90	1.000
McGill,2002	064-230-1/4-SS-A	14.3	14.7	13.2	2.92	B	B	2.92	1.001
McGill,2002	064-230-1/4-SS-B	14.3	14.7	13.2	2.92	B	B	3.07	1.053
McGill,2002	064-230-1/4-SS-C	14.3	14.7	13.2	2.92	B	B	3.00	1.029
McGill,2002	064-230-1/4-TTSS-A	14.3	14.7	13.2	2.92	B	B	2.95	1.012
McGill,2002	064-230-1/4-TTSS-B	14.3	14.7	13.2	2.92	B	B	3.29	1.128
McGill,2002	064-230-1/4-TTSS-C	14.3	14.7	13.2	2.92	B	B	3.80	1.303
McGill,2002	076-230-1/2-SS-A	18.5	17.4	17.2	5.70	B	B	4.77	0.837
McGill,2002	076-230-1/2-SS-B	18.5	17.4	17.2	5.70	B	B	4.53	0.796
McGill,2002	076-230-1/2-SS-C	18.5	17.4	17.2	5.70	B	B	4.90	0.859
McGill,2002	076-230-1/2-TTSS-A	18.5	17.4	17.2	5.70	B	B	5.22	0.916
McGill,2002	076-230-1/2-TTSS-B	18.5	17.4	17.2	5.70	B	B	5.90	1.036
McGill,2002	076-230-1/2-TTSS-C	18.5	17.4	17.2	5.70	B	B	5.41	0.950
McGill,2002	076-230-1/2-DS-A	18.5	17.4	17.2	9.77	B	B	10.8	1.109
McGill,2002	076-230-1/2-DS-B	18.5	17.4	17.2	9.77	B	B	11.8	1.211
McGill,2002	076-230-1/2-DS-C	18.5	17.4	17.2	9.77	B	B	10.5	1.078
McGill,2002	076-550-1/2-SS-A	38.4	31.1	30.7	10.6	B	B	8.50	0.801
McGill,2002	076-550-1/2-SS-B	38.4	31.1	30.7	10.6	B	B	8.06	0.760
McGill,2002	076-550-1/2-SS-C	38.4	31.1	30.7	10.6	B	B	8.50	0.801
McGill,2002	076-230-5/8-SS-A	18.5	16.5	17.2	5.73	B	B	6.17	1.076
McGill,2002	076-230-5/8-SS-B	18.5	16.5	17.2	5.73	B	B	6.04	1.054
McGill,2002	076-230-5/8-SS-C	18.5	16.5	17.2	5.73	B	B	6.04	1.054
McGill,2002	076-550-3/8-SS-A	38.4	32.7	30.7	9.38	B	B	8.19	0.873
McGill,2002	076-550-3/8-SS-B	38.4	32.7	30.7	9.38	B	B	7.80	0.831
McGill,2002	076-550-3/8-SS-C	38.4	32.7	30.7	9.38	B	B	6.61	0.705
McGill,2002	076-550-1/4-SS-A	38.4	34.4	30.7	6.83	B	B	7.01	1.026
McGill,2002	076-550-1/4-SS-B	38.4	34.4	30.7	6.83	B	B	6.80	0.995
McGill,2002	076-550-1/4-SS-C	38.4	34.4	30.7	6.83	B	B	6.55	0.959
McGill,2002	091-230-1/4-SS-A	20.0	21.6	19.3	4.30	B	B	4.65	1.082
McGill,2002	091-230-1/4-SS-B	20.0	21.6	19.3	4.30	B	B	5.14	1.197
McGill,2002	091-230-1/4-SS-C	20.0	21.6	19.3	4.30	B	B	4.83	1.124

Table C7 Test-To-Predicted Values (Proposed method 1)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	091-230-1/4-TTSS-A	20.0	21.6	19.3	4.30	B	B	7.94	1.848
McGill,2002	091-230-1/4-TTSS-B	20.0	21.6	19.3	4.30	B	B	7.46	1.737
McGill,2002	091-230-1/4-TTSS-C	20.0	21.6	19.3	4.30	B	B	7.51	1.748
McGill,2002	091-230-1/4-DS-A	20.0	21.6	19.3	7.36	B	B	12.7	1.723
McGill,2002	091-230-1/4-DS-B	20.0	21.6	19.3	7.36	B	B	12.4	1.678
McGill,2002	091-230-1/4-DS-C	20.0	21.6	19.3	7.36	B	B	11.2	1.526
McGill,2002	091-230-1/2-TTSS-A	20.0	19.6	19.3	7.46	B	B	6.91	0.926
McGill,2002	091-230-1/2-TTSS-B	20.0	19.6	19.3	7.46	B	B	6.94	0.930
McGill,2002	091-230-1/2-TTSS-C	20.0	19.6	19.3	7.46	B	B	7.00	0.939
McGill,2002	091-230-1/2-DS-A	20.0	19.6	19.3	12.8	B	B	14.3	1.118
McGill,2002	091-230-1/2-DS-B	20.0	19.6	19.3	12.8	B	B	13.6	1.064
McGill,2002	091-230-1/2-DS-C	20.0	19.6	19.3	12.8	B	B	13.4	1.051
McGill,2002	121-230-1/2-TTSS-A	30.2	30.5	30.2	13.4	B	B	10.3	0.765
McGill,2002	121-230-1/2-TTSS-B	30.2	30.5	30.2	13.4	B	B	10.3	0.772
McGill,2002	121-230-1/2-TTSS-C	30.2	30.5	30.2	13.4	B	B	12.0	0.895
McGill,2002	121-230-1/2-DS-A	30.2	30.5	30.2	23.0	B	B	18.6	0.810
McGill,2002	121-230-1/2-DS-B	30.2	30.5	30.2	23.0	B	B	20.9	0.909
McGill,2002	121-230-1/2-DS-C	30.2	30.5	30.2	23.0	B	B	18.3	0.795
McGill,2002	121-230-3/8-SS-A	30.2	32.1	30.2	10.1	B	B	8.39	0.835
McGill,2002	121-230-3/8-SS-B	30.2	32.1	30.2	10.1	B	B	8.54	0.850
McGill,2002	121-230-3/8-SS-C	30.2	32.1	30.2	10.1	B	B	8.89	0.884
McGill,2002	121-230-3/8-TTSS-A	30.2	32.1	30.2	10.1	B	B	9.28	0.923
McGill,2002	121-230-3/8-TTSS-B	30.2	32.1	30.2	10.1	B	B	9.03	0.898
McGill,2002	121-230-3/8-TTSS-C	30.2	32.1	30.2	10.1	B	B	9.70	0.965
McGill,2002	121-230-3/8-DS-A	30.2	32.1	30.2	17.2	B	B	20.5	1.187
McGill,2002	121-230-3/8-DS-B	30.2	32.1	30.2	17.2	B	B	18.4	1.065
McGill,2002	121-230-3/8-DS-C	30.2	32.1	30.2	17.2	B	B	16.4	0.951
McGill,2002	153-230-1/4-SS-A	33.3	36.5	32.6	7.25	B	B	9.99	1.377
McGill,2002	153-230-1/4-SS-B	33.3	36.5	32.6	7.25	B	B	9.80	1.351
McGill,2002	153-230-1/4-SS-C	33.3	36.5	32.6	7.25	B	B	9.49	1.308
Wallace,2000	1-wo-50	22.4	20.6	24.4	6.52	B	B	6.29	0.965
Wallace,2000	2-wo-50	22.4	20.6	24.4	6.52	B	B	6.95	1.066
Wallace,2000	3-wo-50	22.4	20.6	24.4	6.52	B	B	6.53	1.001
Wallace,2000	1-wo-40	22.4	20.6	19.6	6.52	B	B	6.64	1.018
Wallace,2000	2-wo-40	22.4	20.6	19.6	6.52	B	B	6.12	0.939
Wallace,2000	3-wo-40	22.4	20.6	19.6	6.52	B	B	6.70	1.028
Wallace,2000	1-wo-30	22.4	20.6	14.7	6.52	B	B	6.38	0.978
Wallace,2000	2-wo-30	22.4	20.6	14.7	6.52	B	B	6.41	0.983

Table C7 Test-To-Predicted Values (Proposed method 1)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Wallace,2000	3-wo-30	22.4	20.6	14.7	6.52	B	B	6.24	0.957
Wallace,2000	1-wo-20	22.4	20.6	9.78	6.52	B	B	5.89	0.903
Wallace,2000	2-wo-20	22.4	20.6	9.78	6.52	B	B	6.20	0.951
Wallace,2000	3-wo-20	22.4	20.6	9.78	6.52	B	B	6.60	1.012
Wallace,2000	1-wo-20-t5	22.4	20.6	9.78	6.52	B	B	7.24	1.110
Wallace,2000	2-wo-20-t5	22.4	20.6	9.78	6.52	B	B	6.63	1.017
Wallace,2000	3-wo-20-t5	22.4	20.6	9.78	6.52	B	B	6.45	0.989
Wallace,2000	1-wo-20-t15	22.4	20.6	9.78	6.52	B	B	7.11	1.090
Wallace,2000	2-wo-20-t15	22.4	20.6	9.78	6.52	B	B	6.50	0.997
Wallace,2000	3-wo-20-t15	22.4	20.6	9.78	6.52	B	B	7.71	1.182
Wallace,2000	1-wo-30-50	22.4	20.6	37.2	13.0	B	B	14.5	1.109
Wallace,2000	2-wo-30-50	22.4	20.6	37.2	13.0	B	B	15.3	1.172
Wallace,2000	3-wo-30-50	22.4	20.6	37.2	13.0	B	B	14.2	1.086
Wallace,2000	1-wo-30-40	22.4	20.6	32.3	13.0	B	B	14.1	1.084
Wallace,2000	2-wo-30-40	22.4	20.6	32.3	13.0	B	B	14.6	1.117
Wallace,2000	3-wo-30-40	22.4	20.6	32.3	13.0	B	B	14.2	1.087
Wallace,2000	1-wo-30-30	22.4	20.6	27.4	13.0	B	B	15.1	1.159
Wallace,2000	2-wo-30-30	22.4	20.6	27.4	13.0	B	B	15.3	1.176
Wallace,2000	3-wo-30-30	22.4	20.6	27.4	13.0	B	B	14.0	1.070
Wallace,2000	1-wo-40-3/8	22.4	19.0	19.6	8.19	B	B	7.26	0.887
Wallace,2000	2-wo-40-3/8	22.4	19.0	19.6	8.19	B	B	7.52	0.918
Wallace,2000	3-wo-40-3/8	22.4	19.0	19.6	8.19	B	B	7.65	0.934
Wallace,2000	1-wo-30-5/16	22.4	19.8	14.7	7.50	B	B	7.82	1.043
Wallace,2000	2-wo-30-5/16	22.4	19.8	14.7	7.50	B	B	6.58	0.878
Wallace,2000	3-wo-30-5/16	22.4	19.8	14.7	7.50	B	B	6.98	0.931
Wallace,2000	1-wo-50-1/2	22.4	17.5	24.4	8.76	B	B	9.80	1.119
Wallace,2000	2-wo-50-1/2	22.4	17.5	24.4	8.76	B	B	9.62	1.098
Wallace,2000	3-wo-50-1/2	22.4	17.5	24.4	8.76	B	B	9.16	1.045
Wallace,2000	1-wo-50-5/8	22.4	15.9	24.4	9.78	B	B	10.3	1.054
Wallace,2000	2-wo-50-5/8	22.4	15.9	24.4	9.78	B	B	10.3	1.056
Wallace,2000	3-wo-50-5/8	22.4	15.9	24.4	9.78	B	B	10.3	1.049
Wallace,2000	1-wo-ss-5/16	11.2	9.90	7.33	3.75	B	B	3.23	0.862
Wallace,2000	2-wo-ss-5/16	11.2	9.90	7.33	3.75	B	B	3.27	0.872
Wallace,2000	3-wo-ss-5/16	11.2	9.90	7.33	3.75	B	B	3.39	0.904
Wallace,2000	1-wo-sst-5/16	24.6	20.2	14.9	8.30	B	B	9.12	1.098
Wallace,2000	2-wo-sst-5/16	24.6	20.2	14.9	8.30	B	B	8.51	1.025
Wallace,2000	3-wo-sst-5/16	24.6	20.2	14.9	8.30	B	B	8.26	0.995
Wallace,2000	1-wo-sst-1/4	24.6	21.0	14.9	6.64	B	B	9.16	1.379

Table C7 Test-To-Predicted Values (Proposed method 1)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Wallace,2000	2-wo-sst-1/4	24.6	21.0	14.9	6.64	B	B	8.92	1.343
Wallace,2000	3-wo-sst-1/4	24.6	21.0	14.9	6.64	B	B	9.03	1.359
Wallace,2000	1-wo-mix-1/4	11.2	10.3	7.33	3.26	B	B	3.52	1.080
Wallace,2000	2-wo-mix-1/4	11.2	10.3	7.33	3.26	B	B	3.47	1.064
Wallace,2000	3-wo-mix-1/4	11.2	10.3	7.33	3.26	B	B	3.73	1.144
Wallace,2000	1-wo-ss-1/4	11.2	10.3	7.33	3.26	B	B	3.27	1.003
Wallace,2000	2-wo-ss-1/4	11.2	10.3	7.33	3.26	B	B	3.30	1.012
Wallace,2000	1-wo-ss-1/2	11.2	8.73	7.33	4.38	B	B	4.25	0.970
Wallace,2000	2-wo-ss-1/2	11.2	8.73	7.33	4.38	B	B	4.43	1.011
Wallace,2000	3-wo-ss-1/2	11.2	8.73	7.33	4.38	B	B	4.00	0.913
Wallace,2000	1-wo-ss-5/8	11.2	7.95	7.33	4.89	B	B	5.45	1.114
Wallace,2000	2-wo-ss-5/8	11.2	7.95	7.33	4.89	B	B	5.43	1.110
Wallace,2000	3-wo-ss-5/8	11.2	7.95	7.33	4.89	B	B	5.41	1.106
Yu,1978	B-0-12-1-0-SS	4.78	4.94	1.60	1.13	B	R	1.73	1.523
Yu,1978	B-0-12-2-0-SS	4.78	4.94	1.60	1.13	B	R	1.40	1.236
Yu,1978	B-0-12-3-L-SS	4.78	4.94	1.65	1.13	B	R	1.40	1.236
Yu,1978	B-0-12-4-L-SS	4.78	4.94	1.65	1.13	B	R	1.50	1.327
Yu,1978	B-0-12-5-0-SS	4.78	4.94	1.60	1.13	B	R	1.36	1.197
Yu,1978	B-0-12-6-0-SS	4.78	4.94	1.65	1.13	B	R	1.44	1.268
Yu,1978	B-0-12-7-L-SS	4.78	4.94	1.60	1.13	B	R	1.58	1.397
Yu,1978	B-0-12-8-L-SS	4.66	4.80	1.62	1.13	B	R	1.45	1.279
Yu,1978	B-0-12-9-H-SS	4.71	4.85	1.62	1.13	B	R	1.70	1.503
Yu,1978	B-0-12-10-H-SS	4.78	4.94	1.65	1.13	B	R	2.25	1.982
Yu,1978	B-0-14-1-0-DS	7.89	8.69	2.56	1.94	B	B&E	2.42	1.243
Yu,1978	B-0-14-2-0-DS	7.89	8.69	2.56	1.94	B	B&E	2.13	1.094
Yu,1978	B-0-14-3-L-DS	7.89	8.69	2.56	1.94	B	B&E	2.55	1.314
Yu,1978	B-0-14-4-L-DS	7.89	8.69	2.56	1.94	B	B&E	2.36	1.213
Yu,1978	B-0-14-5-0-DS	7.89	8.69	2.56	1.94	B	B&E	2.33	1.197
Yu,1978	B-0-14-6-0-DS	7.89	8.69	2.56	1.94	B	B&E	2.14	1.103
Yu,1978	B-0-14-7-L-DS	7.89	8.69	2.56	1.94	B	B&E	3.06	1.575
Yu,1978	B-0-14-8-L-DS	7.89	8.69	2.56	1.94	B	B&E	3.15	1.621
Yu,1978	B-0-14-9-H-DS	7.89	8.69	2.56	1.94	B	B&E	2.46	1.264
Yu,1978	B-0-14-10-H-DS	7.89	8.69	2.56	1.94	B	B&E	2.41	1.241
Yu,1978	B-0-17-1-0-SS	12.5	13.2	4.41	4.11	B	R	5.42	1.318
Yu,1978	B-0-17-2-0-SS	12.5	13.2	4.41	4.11	B	R	4.96	1.207
Yu,1978	B-0-17-3-L-SS	12.7	13.5	4.41	4.11	B	R	5.36	1.304
Yu,1978	B-0-17-4-L-SS	12.5	13.2	4.41	4.11	B	R	5.75	1.399
Yu,1978	B-0-17-5-0-SS	12.5	13.2	4.41	4.11	B	R	5.28	1.285

Table C7 Test-To-Predicted Values (Proposed method 1)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-17-6-0-SS	12.5	13.2	4.28	4.11	B	R	5.31	1.293
Yu,1978	B-0-17-7-L-SS	12.5	13.2	4.41	4.11	B	R	5.32	1.294
Yu,1978	B-0-17-8-L-SS	12.5	13.2	4.41	4.11	B	R	5.45	1.326
Yu,1978	B-0-17-9-H-SS	12.7	13.5	4.41	4.11	B	R	5.33	1.297
Yu,1978	B-0-17-10-H-SS	12.5	13.2	4.31	4.11	B	R	5.40	1.314
Yu,1978	B-0-18-1-0-SS	19.0	19.1	8.56	7.15	B	R	6.30	0.880
Yu,1978	B-0-18-2-0-SS	19.0	19.1	8.61	7.15	B	R	6.32	0.883
Yu,1978	B-0-18-3-L-SS	19.0	19.1	8.61	7.15	B	R	9.08	1.269
Yu,1978	B-0-18-4-L-SS	19.0	19.1	8.61	7.15	B	R	6.63	0.927
Yu,1978	B-0-18-5-0-SS	19.0	19.1	8.61	7.15	B	R	6.32	0.883
Yu,1978	B-0-18-6-0-SS	19.0	19.1	8.61	7.15	B	R	7.10	0.993
Yu,1978	B-0-18-7-L-SS	19.0	19.1	8.61	7.15	B	R	12.2	1.701
Yu,1978	B-0-18-8-L-SS	19.0	19.1	8.81	7.15	B	R	11.5	1.605
Yu,1978	B-0-18-9-H-SS	19.0	19.1	8.61	7.15	B	R	11.6	1.623
Yu,1978	B-0-18-10-H-SS	19.0	19.1	8.61	7.15	B	R	10.4	1.455
Yu,1978	B-0-21-1-0-DS	20.6	23.2	6.61	7.05	E	B&E	8.37	1.266
Yu,1978	B-0-21-2-0-DS	20.6	23.2	6.85	7.05	E	B&E	8.46	1.234
Yu,1978	B-0-21-3-L-DS	20.6	23.2	6.98	7.05	E	B&E	8.46	1.212
Yu,1978	B-0-21-4-L-DS	20.6	23.2	6.85	7.05	E	B&E	8.52	1.244
Yu,1978	B-0-21-5-0-DS	20.6	23.2	6.85	7.05	E	B&E	8.63	1.260
Yu,1978	B-0-21-6-0-DS	20.6	23.2	7.09	7.05	B	B&E	9.03	1.282
Yu,1978	B-0-21-7-L-DS	20.6	23.2	6.85	7.05	E	B&E	9.68	1.413
Yu,1978	B-0-21-8-L-DS	20.6	23.2	6.85	7.05	E	B&E	9.12	1.332
Yu,1978	B-0-21-9-H-DS	20.6	23.2	6.85	7.05	E	B&E	9.95	1.452
Yu,1978	B-0-21-10-H-DS	20.6	23.2	6.85	7.05	E	B&E	8.90	1.299
Yu,1978	B-0-22-1-0-DS	39.6	44.5	13.7	12.3	B	B&E	11.4	0.929
Yu,1978	B-0-22-2-0-DS	39.6	44.5	13.7	12.3	B	B&E	11.1	0.902
Yu,1978	B-0-22-3-L-DS	39.6	44.5	13.7	12.3	B	B&E	12.8	1.043
Yu,1978	B-0-22-4-L-DS	39.6	44.5	13.7	12.3	B	B&E	10.8	0.880
Yu,1978	B-0-22-5-0-DS	39.6	44.5	13.7	12.3	B	B&R	10.8	0.880
Yu,1978	B-0-22-6-0-DS	39.6	44.5	13.7	12.3	B	B&R	9.79	0.798
Yu,1978	B-0-22-7-L-DS	39.6	44.5	13.7	12.3	B	B&E	12.0	0.980
Yu,1978	B-0-22-8-L-DS	39.6	44.5	13.7	12.3	B	B&E	12.1	0.987
Yu,1978	B-0-22-9-H-DS	39.6	44.5	13.7	12.3	B	B&E	11.8	0.961
Yu,1978	B-0-22-10-H-DS	39.6	44.5	13.9	12.3	B	B&E	12.7	1.038
Yu,1978	B-0-25-1-0-SS	47.5	43.1	19.5	18.6	B	R	18.2	0.980
Yu,1978	B-0-25-2-0-SS	47.5	43.1	19.5	18.6	B	R	19.0	1.023
Yu,1978	B-0-25-3-L-SS	47.5	43.1	19.5	18.6	B	R	20.2	1.088

Table C7 Test-To-Predicted Values (Proposed method 1)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-25-4-L-SS	47.5	43.1	19.5	18.6	B	R	21.0	1.133
Yu,1978	B-0-25-5-H-SS	47.5	43.1	19.5	18.6	B	R	20.4	1.100
Yu,1978	B-0-25-6-H-SS	47.5	43.1	19.5	18.6	B	R	19.4	1.042
Yu,1978	B-0-26-1-0-SS	66.6	59.9	29.2	27.7	B	R	24.4	0.879
Yu,1978	B-0-26-2-0-SS	66.6	59.9	29.2	27.7	B	R	24.7	0.891
Yu,1978	B-0-26-3-L-SS	66.6	59.9	29.2	27.7	B	R	25.3	0.913
Yu,1978	B-0-26-4-L-SS	66.6	59.9	29.2	27.7	B	R	24.7	0.889
Yu,1978	B-0-26-5-0-SS	66.6	59.9	29.2	27.7	B	R	24.7	0.890
Yu,1978	B-0-26-6-0-SS	66.6	59.9	29.2	27.7	B	R	23.1	0.831
Yu,1978	B-0-26-7-L-SS	66.6	59.9	29.2	27.7	B	R	25.0	0.902
Yu,1978	B-0-26-8-L-SS	66.6	59.9	29.2	27.7	B	R	24.9	0.898
Yu,1978	B-0-26-9-H-SS	66.6	59.9	29.2	27.7	B	R	31.2	1.123
Yu,1978	B-0-26-10-H-SS	66.6	59.9	29.2	27.7	B	R	32.7	1.179
Yu,1978	B-0-29-1-0-DS	103	105	32.1	31.8	B	B&E	30.9	0.969
Yu,1978	B-0-29-2-0-DS	103	105	31.5	31.8	E	B&E	35.6	1.129
Yu,1978	B-0-29-3-L-DS	103	105	31.0	31.8	E	B&E	38.3	1.236
Yu,1978	B-0-29-4-L-DS	103	105	32.1	31.8	B	B&E	38.5	1.209
Yu,1978	B-0-29-5-0-DS	103	105	32.6	31.8	B	B&E	37.0	1.162
Yu,1978	B-0-29-6-0-DS	103	105	32.6	31.8	B	B&E	31.4	0.987
Yu,1978	B-0-29-7-L-DS	103	105	31.5	31.8	E	B&E	40.9	1.299
Yu,1978	B-0-29-8-L-DS	103	105	32.6	31.8	B	B&E	41.4	1.300
Yu,1978	B-0-29-9-H-DS	103	105	32.6	31.8	B	B&E	41.2	1.293
Yu,1978	B-0-29-10-H-DS	103	105	32.6	31.8	B	B&E	40.7	1.279
Yu,1978	B-0-30-1-0-DS	158	162	43.7	47.5	E	B&E	44.3	1.013
Yu,1978	B-0-30-2-0-DS	158	162	45.3	47.5	E	B&E	46.7	1.031
Yu,1978	B-0-30-3-L-DS	158	162	45.3	47.5	E	B&E	51.2	1.129
Yu,1978	B-0-30-4-L-DS	158	162	45.3	47.5	E	B&E	48.1	1.060
Yu,1978	B-0-30-5-0-DS	158	162	45.3	47.5	E	B&E	46.2	1.018
Yu,1978	B-0-30-6-0-DS	158	162	44.8	47.5	E	B&E	43.7	0.977
Yu,1978	B-0-30-7-L-DS	158	162	45.3	47.5	E	B&E	49.5	1.091
Yu,1978	B-0-30-8-L-DS	158	162	45.3	47.5	E	B&E	48.1	1.062
Yu,1978	B-0-30-9-H-DS	158	162	43.7	47.5	E	B&E	50.3	1.151
Yu,1978	B-0-30-10-H-DS	158	162	43.7	47.5	E	B&E	51.6	1.181
Yu,1978	B-0-32-1-0-SS	9.69	9.53	3.05	2.30	B	B&R	2.45	1.062
Yu,1978	B-0-32-2-0-SS	9.69	9.53	2.94	2.30	B	B&R	2.58	1.120
Yu,1978	B-0-32-3-L-SS	9.69	9.53	3.05	2.30	B	B&R	2.72	1.182
Yu,1978	B-0-32-4-L-SS	9.69	9.53	3.05	2.30	B	B&R	3.14	1.363
Yu,1978	B-0-32-5-0-SS	9.69	9.53	3.05	2.30	B	B&R	2.67	1.158

Table C7 Test-To-Predicted Values (Proposed method 1)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-32-6-0-SS	9.69	9.53	3.10	2.30	B	B&R	2.41	1.046
Yu,1978	B-0-32-7-L-SS	9.69	9.53	3.05	2.30	B	B&R	2.49	1.081
Yu,1978	B-0-32-8-L-SS	9.69	9.53	3.10	2.30	B	B&R	2.39	1.037
Yu,1978	B-0-32-9-H-SS	9.69	9.53	3.10	2.30	B	B&N.S	3.61	1.568
Yu,1978	B-0-32-10-H-SS	9.69	9.53	3.05	2.30	B	B&N.S	2.89	1.255
Yu,1978	B-0-34-1-0-DS	15.7	16.5	4.85	3.95	B	B&E	3.78	0.957
Yu,1978	B-0-34-2-0-DS	15.7	16.5	4.85	3.95	B	B&E	3.81	0.965
Yu,1978	B-0-34-3-L-DS	15.7	16.5	4.85	3.95	B	B&E	4.25	1.077
Yu,1978	B-0-34-4-L-DS	15.7	16.5	4.85	3.95	B	B&E	4.43	1.122
Yu,1978	B-0-34-5-0-DS	15.7	16.5	4.85	3.95	B	B&E	3.07	0.777
Yu,1978	B-0-34-6-0-DS	15.7	16.5	4.85	3.95	B	B&E	3.63	0.918
Yu,1978	B-0-34-7-L-DS	15.7	16.5	4.85	3.95	B	B&E	3.87	0.980
Yu,1978	B-0-34-8-L-DS	15.7	16.5	4.85	3.95	B	B&E	4.62	1.169
Yu,1978	B-0-34-9-H-DS	15.7	16.5	4.85	3.95	B	B&E	5.03	1.273
Yu,1978	B-0-34-10-H-DS	15.7	16.5	4.85	3.95	B	B&E	4.04	1.021
Yu,1978	B-0-37-1-0-SS	18.4	20.2	5.66	5.40	B	R	5.37	0.995
Yu,1978	B-0-37-2-0-SS	18.4	20.2	5.66	5.40	B	R	5.36	0.993
Yu,1978	B-0-37-3-L-SS	18.4	20.2	5.66	5.40	B	R	5.62	1.040
Yu,1978	B-0-37-4-L-SS	18.4	20.2	5.66	5.40	B	R	5.55	1.029
Yu,1978	B-0-37-5-H-SS	18.4	20.2	5.66	5.40	B	R	5.52	1.023
Yu,1978	B-0-37-6-H-SS	18.4	20.2	5.66	5.40	B	R	8.88	1.645
Yu,1978	B-0-38-1-0-SS	24.5	25.1	11.3	8.59	B	R	7.01	0.816
Yu,1978	B-0-38-2-0-SS	24.5	25.1	11.3	8.59	B	R	7.28	0.847
Yu,1978	B-0-38-3-L-SS	24.5	25.1	11.3	8.59	B	R	10.1	1.171
Yu,1978	B-0-38-4-L-SS	24.5	25.1	11.3	8.59	B	R	8.68	1.010
Yu,1978	B-0-38-5-0-SS	24.5	25.1	11.3	8.59	B	R	7.19	0.837
Yu,1978	B-0-38-6-0-SS	24.5	25.1	11.3	8.59	B	R	7.45	0.868
Yu,1978	B-0-38-7-L-SS	24.5	25.1	11.3	8.59	B	R	10.4	1.215
Yu,1978	B-0-38-8-L-SS	24.5	25.1	11.3	8.59	B	R	8.19	0.953
Yu,1978	B-0-38-9-H-SS	24.5	25.1	11.3	8.59	B	R	9.35	1.088
Yu,1978	B-0-38-10-H-SS	24.5	25.1	11.3	8.59	B	R	10.4	1.207
Yu,1978	B-0-41-1-0-DS	26.6	30.5	9.00	9.25	E	B&E	8.81	0.979
Yu,1978	B-0-41-2-0-DS	26.6	30.5	9.00	9.25	E	B&E	9.63	1.071
Yu,1978	B-0-41-3-L-DS	26.6	30.5	9.00	9.25	E	B&E	10.6	1.182
Yu,1978	B-0-41-4-L-DS	26.6	30.5	9.00	9.25	E	B&E	9.48	1.054
Yu,1978	B-0-41-5-H-DS	26.6	30.5	9.00	9.25	E	B&E	10.3	1.147
Yu,1978	B-0-41-6-H-DS	26.6	30.5	9.00	9.25	E	B&E	10.7	1.187
Yu,1978	B-0-42-1-0-DS	53.1	61.1	18.0	14.7	B	B&E	13.1	0.890

Table C7 Test-To-Predicted Values (Proposed method 1)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-42-2-0-DS	53.1	61.1	18.0	14.7	B	B&E	12.1	0.819
Yu,1978	B-0-42-3-L-DS	53.1	61.1	18.0	14.7	B	B&E	12.8	0.870
Yu,1978	B-0-42-4-L-DS	53.1	61.1	18.0	14.7	B	B&E	12.1	0.825
Yu,1978	B-0-42-5-0-DS	53.1	61.1	18.0	14.7	B	B&E	13.4	0.910
Yu,1978	B-0-42-6-0-DS	53.1	61.1	18.0	14.7	B	B&E	13.4	0.910
Yu,1978	B-0-42-7-L-DS	53.1	61.1	18.0	14.7	B	B&E	16.8	1.142
Yu,1978	B-0-42-8-L-DS	53.1	61.1	18.0	14.7	B	B&E	12.7	0.861
Yu,1978	B-0-42-9-H-DS	53.1	61.1	18.0	14.7	B	B&E	17.2	1.171
Yu,1978	B-0-42-10-H-DS	53.1	61.1	18.0	14.7	B	B&E	19.3	1.311
Yu,1978	B-0-45-1-0-SS	49.7	53.4	26.0	23.0	B	R	18.0	0.782
Yu,1978	B-0-45-2-0-SS	49.7	53.4	24.1	23.0	B	R	18.2	0.790
Yu,1978	B-0-45-3-L-SS	49.7	53.4	24.1	23.0	B	R	19.3	0.839
Yu,1978	B-0-45-4-L-SS	49.7	53.4	25.2	23.0	B	R	19.2	0.837
Yu,1978	B-0-45-5-H-SS	49.7	53.4	25.2	23.0	B	R	19.8	0.863
Yu,1978	B-0-45-6-H-SS	49.7	53.4	24.1	23.0	B	R	19.8	0.861
Yu,1978	B-0-46-1-0-SS	70.4	75.3	36.1	33.8	B	B&R	25.9	0.766
Yu,1978	B-0-46-2-0-SS	70.4	75.3	36.1	33.8	B	B&R	24.3	0.719
Yu,1978	B-0-46-3-L-SS	70.4	75.3	36.1	33.8	B	B&R	26.7	0.789
Yu,1978	B-0-46-4-L-SS	70.4	75.3	36.1	33.8	B	B&R	26.5	0.784
Yu,1978	B-0-46-5-0-SS	70.4	75.3	36.1	33.8	B	B&R	26.1	0.772
Yu,1978	B-0-46-6-0-SS	70.4	75.3	36.1	33.8	B	B&R	25.9	0.765
Yu,1978	B-0-46-7-L-SS	70.4	75.3	36.1	33.8	B	B&R	29.8	0.880
Yu,1978	B-0-46-8-L-SS	70.4	75.3	36.1	33.8	B	B&R	26.1	0.773
Yu,1978	B-0-46-9-H-SS	70.4	75.3	36.1	33.8	B	B&R	33.4	0.986
Yu,1978	B-0-46-10-H-SS	70.4	75.3	36.1	33.8	B	B&R	29.2	0.863
Yu,1978	B-0-49-1-0-DS	111	134	39.0	39.4	E	B&E	42.6	1.093
Yu,1978	B-0-49-2-0-DS	111	134	39.7	39.4	B	B&E	37.4	0.948
Yu,1978	B-0-49-3-L-DS	111	134	39.0	39.4	E	B&E	39.2	1.006
Yu,1978	B-0-49-4-L-DS	111	134	39.0	39.4	E	B&E	39.8	1.021
Yu,1978	B-0-49-5-H-DS	111	134	39.0	39.4	E	B&E	40.9	1.050
Yu,1978	B-0-49-6-H-DS	111	134	39.0	39.4	E	B&E	42.3	1.084
Yu,1978	B-0-50-1-0-DS	165	201	57.5	58.0	E	B&E	54.5	0.948
Yu,1978	B-0-50-2-0-DS	165	201	57.5	58.0	E	B&E	53.0	0.921
Yu,1978	B-0-50-3-L-DS	165	201	57.5	58.0	E	B&E	55.4	0.964
Yu,1978	B-0-50-4-L-DS	165	201	57.5	58.0	E	B&E	51.8	0.902
Yu,1978	B-0-50-5-0-DS	165	201	57.5	58.0	E	B&E	50.5	0.879
Yu,1978	B-0-50-6-0-DS	165	201	57.5	58.0	E	B&E	48.3	0.840
Yu,1978	B-0-50-7-L-DS	165	201	57.5	58.0	E	B&E	53.4	0.929

Table C7 Test-To-Predicted Values (Proposed method 1)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-50-8-L-DS	165	201	57.5	58.0	E	B&E	44.9	0.780
Yu,1978	B-0-50-9-H-DS	165	201	57.5	58.0	E	B&E	62.3	1.084
Yu,1978	B-0-50-10-H-DS	165	201	57.5	58.0	E	B&E	53.5	0.931
Yu,1978	B-0-51-1-0-SS	188	199	97.7	91.2	B	R	97.7	1.071
Yu,1978	B-0-51-2-0-SS	188	199	97.7	91.2	B	R	96.3	1.056
Yu,1978	B-0-51-3-L-SS	188	199	99.5	91.2	B	R	94.1	1.032
Yu,1978	B-0-51-4-L-SS	188	199	97.7	91.2	B	R	101	1.117
Yu,1978	B-0-51-5-H-SS	188	199	97.7	91.2	B	R	95.0	1.042
Yu,1978	B-0-51-6-H-SS	188	199	97.7	91.2	B	R	97.9	1.074
Yu,1978	B-0-53-1-0-DS	443	531	151	156	E	B&E	157	1.039
Yu,1978	B-0-53-2-0-DS	443	531	155	156	E	B&E	155	0.998
Yu,1978	B-0-53-3-L-DS	443	531	151	156	E	B&E	161	1.066
Yu,1978	B-0-53-4-L-DS	443	531	153	156	E	B&E	160	1.046
Yu,1978	B-0-53-5-H-DS	443	531	148	156	E	B&E	160	1.082

Table C8 Test-To-Predicted Values (Proposed method 2)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Carril,1994	AN32-1	62.8	75.3	55.8	31.3	B	B	36.0	1.149
Carril,1994	AN32-2	61.6	73.9	54.8	30.8	B	B	36.5	1.185
Carril,1994	AN33-1	77.2	96.1	55.7	31.3	B	B	40.1	1.278
Carril,1994	AN33-2	78.5	97.7	56.7	31.9	B	B	39.8	1.250
Carril,1994	BN33-1	77.9	97.1	104	63.2	B	B	65.0	1.028
Carril,1994	BN33-2	77.9	97.1	104	63.2	B	B	64.0	1.013
Carril,1994	DN12-2	44.6	57.6	42.7	22.7	B	B	21.1	0.927
Carril,1994	DN12-3	43.6	56.2	41.7	22.0	B	B	21.1	0.959
Carril,1994	DN22-1	65.1	88.2	65.4	36.8	B	B	37.5	1.020
Carril,1994	DN22-2	66.0	89.4	66.2	37.3	B	B	37.8	1.014
Carril,1994	BN32-1	62.7	75.2	103	62.7	B	B&N.S	64.3	1.027
Carril,1994	BN32-2	62.0	74.3	102	62.1	B	B&N.S	65.4	1.052
Carril,1994	DN32-1	127	152	113	63.7	B	B&R	70.1	1.100
Carril,1994	DN32-2	125	150	111	62.7	B	B&R	71.6	1.142
Carril,1994	EN12-1	44.6	57.6	79.6	45.5	B	B&R	38.5	0.846
Carril,1994	EN12-2	44.6	57.6	79.5	45.5	B	B&R	38.7	0.851
Carril,1994	EN22-1	66.0	89.4	123	74.6	B	B&R	70.2	0.940
Carril,1994	EN22-2	66.9	90.5	125	75.7	B	B&R	70.0	0.926
Carril,1994	EN32-1	125	150	206	125	B	B&R	128	1.024
Carril,1994	EN32-2	124	149	204	124	B	B&R	129	1.038
Carril,1994	AN31-2	31.1	29.6	54.7	30.8	N.S	N.S	29.3	0.989
Carril,1994	AN31-3	31.1	29.6	55.2	31.1	N.S	N.S	29.1	0.984
Carril,1994	BN31-1	31.3	29.7	103	62.7	N.S	N.S	29.4	0.988
Carril,1994	BN31-2	31.3	29.6	103	62.7	N.S	N.S	29.4	0.991
Carril,1994	CN11-1	11.0	11.2	58.1	34.1	N.S	N.S	10.2	0.909
Carril,1994	CN11-2	11.0	11.2	58.1	34.1	N.S	N.S	10.4	0.924
Carril,1994	CN12-1	22.2	28.6	58.1	34.1	N.S	N.S	25.5	0.893
Carril,1994	CN12-2	22.2	28.6	58.1	34.1	N.S	N.S	25.5	0.893
Carril,1994	CN21-1	16.7	18.0	90.0	56.0	N.S	N.S	18.2	1.012
Carril,1994	CN21-2	16.9	18.1	91.3	56.8	N.S	N.S	18.1	0.997
Carril,1994	CN21-3	16.9	18.1	91.3	56.8	N.S	N.S	17.9	0.989
Carril,1994	CN22-1	33.1	44.8	90.1	56.0	N.S	N.S	42.7	0.954
Carril,1994	CN22-2	33.6	45.5	91.4	56.8	N.S	N.S	42.9	0.943
Carril,1994	CN22-3	33.1	44.8	90.0	56.0	N.S	N.S	42.9	0.956
Carril,1994	CN31-2	32.0	30.4	153	95.6	N.S	N.S	30.8	1.013
Carril,1994	CN31-3	32.3	30.7	154	96.4	N.S	N.S	30.0	0.980
Carril,1994	CN32-1	64.4	77.2	155	96.4	N.S	N.S	71.2	0.923

Table C8 Test-To-Predicted Values (Proposed method 2)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Carril,1994	CN32-2	63.6	76.2	153	95.6	N.S	N.S	70.4	0.924
Carril,1994	DN31-1	63.7	60.4	113	63.7	N.S	N.S	55.2	0.914
Carril,1994	DN31-2	61.7	58.5	109	61.6	N.S	N.S	53.4	0.913
Carril,1994	EN11-1	22.7	23.1	81.3	47.0	N.S	N.S	21.4	0.927
Carril,1994	EN11-2	22.2	22.6	79.5	45.5	N.S	N.S	21.5	0.949
Carril,1994	EN21-1	33.6	36.1	124	75.7	N.S	N.S	37.4	1.037
Carril,1994	EN21-2	33.5	36.0	125	75.7	N.S	N.S	37.4	1.040
Carril,1994	EN31-1	62.2	59.0	205	124	N.S	N.S	58.9	0.999
Carril,1994	EN31-2	62.7	59.5	207	125	N.S	N.S	60.3	1.013
Carril,1994	DN11-1	21.2	21.6	40.8	21.3	B	N&R	18.1	0.852
Carril,1994	DN11-2	21.7	22.1	41.7	22.0	B	N&R	18.7	0.852
Carril,1994	DN21-1	33.6	36.0	67.3	37.8	N.S	N&R	32.0	0.889
Carril,1994	DN21-2	33.1	35.5	66.3	37.3	N.S	N&R	31.5	0.887
Chong,1975	1	35.8	33.9	20.0	9.64	B	B&E	10.9	1.136
Chong,1975	2	35.5	35.8	19.8	6.82	B	B	8.14	1.194
Chong,1975	3	36.3	36.6	20.0	6.82	B	B&E	7.12	1.044
Chong,1975	4	35.8	33.9	19.7	9.64	B	E	9.92	1.030
Chong,1975	5	35.8	33.9	20.1	9.64	B	E	10.8	1.122
Chong,1975	6	35.2	33.3	9.70	9.64	B	B&E	10.6	1.104
Chong,1975	7	35.2	33.3	14.6	9.64	B	E	11.0	1.145
Chong,1975	8	35.2	33.3	17.0	9.64	B	E	10.0	1.039
Chong,1975	9	35.2	33.3	24.3	9.64	B	B	10.1	1.044
Chong,1975	11	35.2	33.3	24.3	9.64	B	B	10.3	1.067
Chong,1975	12	35.2	33.3	14.6	9.64	B	E	10.7	1.113
Chong,1975	13	35.2	33.3	9.70	9.64	B	E&B	10.5	1.090
Chong,1975	14	35.2	33.3	4.85	9.64	E	E	7.48	1.541
Chong,1975	15	35.2	33.3	4.85	9.64	E	E	6.76	1.394
Chong,1975	32	37.1	39.4	23.4	12.8	B	E&B	12.9	1.005
Chong,1975	33	37.1	39.4	22.9	12.8	B	B&E	13.3	1.036
Chong,1975	34	37.1	39.4	22.9	12.8	B	B&E	13.1	1.022
Chong,1975	41	54.9	69.2	10.3	22.6	E	E&B	12.3	1.201
Chong,1975	42	54.9	69.2	10.5	22.6	E	E&B	13.8	1.314
Chong,1975	49	13.9	9.00	40.2	22.6	N.S	N.S	13.5	1.497
Chong,1975	50	13.9	9.00	40.2	22.6	N.S	N.S	12.9	1.438
Chong,1975	51	13.9	9.00	40.2	22.6	N.S	N.S	11.9	1.320
Chong,1975	52	74.3	73.9	69.5	39.1	B	B&E	38.3	0.979
Chong,1975	53	74.3	73.9	69.8	39.1	B	B&E	36.3	0.927
Chong,1975	54	74.3	73.9	69.5	39.1	B	B&E	40.8	1.043

Table C8 Test-To-Predicted Values (Proposed method 2)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Chong,1975	55	111	106	99.0	55.2	B	B&E	55.6	1.008
Chong,1975	16(3b)	26.6	18.4	20.0	19.3	N.S	N.S	18.1	0.983
Chong,1975	17(3b)	27.0	18.8	19.4	19.3	N.S	N.S	18.4	0.979
Chong,1975	37(3b)	37.2	33.2	44.8	25.6	B	E&B	24.8	0.969
Chong,1975	40(3b)	54.9	57.8	79.3	45.3	B	B	40.0	0.883
Chong,1975	56(3b)	110	78.9	196	110	N.S	E&N	88.3	1.119
Chong,1975	35(3c)	37.3	34.3	70.0	24.0	B	B	23.3	0.972
Chong,1975	36(3c)	37.3	34.3	70.6	24.0	B	B	24.0	1.000
Chong,1975	18(3d)	8.81	4.24	26.4	19.3	N.S	N.S	7.57	1.782
Chong,1975	19(3d)	8.81	4.24	26.4	19.3	N.S	N.S	6.72	1.583
Chong,1975	22(3d)	17.6	13.9	26.4	19.3	N.S	N.S	14.9	1.066
Chong,1975	23(3d)	17.6	13.9	26.4	19.3	N.S	N.S	15.9	1.139
Chong,1975	28(3d)	35.2	33.3	26.4	19.3	B	E	19.5	1.011
Chong,1975	29(3d)	35.2	33.3	26.4	19.3	B	B&E	19.2	0.998
Chong,1975	45(3d)	27.4	28.9	54.7	45.3	N.S	N.S	30.7	1.063
Chong,1975	46(3d)	27.4	28.9	54.7	45.3	N.S	N.S	31.9	1.103
Chong,1975	20(3e)	8.81	4.24	43.0	28.9	N.S	N.S	7.83	1.845
Chong,1975	21(3e)	8.81	4.24	43.0	28.9	N.S	N.S	4.76	1.122
Chong,1975	24(3e)	17.6	13.9	43.0	28.9	N.S	N.S	15.7	1.126
Chong,1975	25(3e)	17.6	13.9	43.0	28.9	N.S	N.S	15.2	1.088
Chong,1975	26(3e)	34.7	32.8	43.0	28.9	B	E	28.8	0.996
Chong,1975	27(3e)	34.7	32.8	43.0	28.9	B	E	28.8	0.998
Chong,1975	43(3e)	55.3	69.8	89.3	67.9	B	E&B	58.3	0.858
Chong,1975	44(3e)	55.7	70.4	89.3	67.9	B	E&B	60.1	0.885
Chong,1975	47(3e)	13.7	8.80	89.3	67.9	N.S	N.S	13.0	1.476
Chong,1975	48(3e)	13.7	8.80	89.3	67.9	N.S	N.S	13.5	1.532
Gilchrist,1979	1	16.9	17.3	4.65	2.42	B	B&E	3.20	1.325
Gilchrist,1979	2	16.9	17.3	3.49	2.42	B	B&E	2.71	1.122
Gilchrist,1979	3	16.9	17.3	2.79	2.42	B	B&E	2.60	1.076
Gilchrist,1979	4	16.9	16.7	6.97	2.83	B	B&E	3.03	1.070
Gilchrist,1979	5	16.9	16.7	4.65	2.83	B	B	3.00	1.063
Gilchrist,1979	6	16.9	16.7	3.49	2.83	B	B&E	3.16	1.118
Gilchrist,1979	7	24.3	23.9	6.43	3.58	B	B&E	3.78	1.057
Gilchrist,1979	8	24.3	23.9	4.82	3.58	B	B&E	3.89	1.088
Gilchrist,1979	9	24.3	23.9	3.86	3.58	B	B&E	3.69	1.032
Gilchrist,1979	10	24.3	23.1	9.65	4.43	B	B&E	4.01	0.904
Gilchrist,1979	11	24.3	23.1	6.43	4.43	B	B	3.56	0.803
Gilchrist,1979	12	24.3	23.1	4.82	4.43	B	B&E	4.34	0.979

Table C8 Test-To-Predicted Values (Proposed method 2)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Gilchrist,1979	13	24.8	24.5	6.60	3.71	B	B&E	4.58	1.235
Gilchrist,1979	14	24.8	24.5	4.95	3.71	B	B&E	4.29	1.157
Gilchrist,1979	15	24.8	24.5	3.96	3.71	B	B&E	4.18	1.127
Gilchrist,1979	16	24.8	23.7	9.90	4.87	B	B&E	4.34	0.890
Gilchrist,1979	17	24.8	23.7	6.60	4.87	B	B&E	4.36	0.895
Gilchrist,1979	18	24.8	23.7	4.95	4.87	B	B&E	4.05	0.831
Gilchrist,1979	19	24.8	22.7	13.2	5.37	B	B&E	7.23	1.348
Gilchrist,1979	20	24.8	22.7	9.90	5.37	B	B	5.21	0.970
Gilchrist,1979	21	24.8	22.7	6.60	5.37	B	B	5.45	1.016
Gilchrist,1979	22	19.8	22.9	6.16	3.47	B	B&E	3.78	1.091
Gilchrist,1979	23	19.8	22.9	4.62	3.47	B	B&E	3.65	1.053
Gilchrist,1979	24	19.8	22.9	3.70	3.47	B	B&E	4.01	1.156
Gilchrist,1979	25	19.8	22.1	9.24	4.55	B	B&E	4.41	0.968
Gilchrist,1979	26	19.8	22.1	6.16	4.55	B	B&E	4.21	0.924
Gilchrist,1979	27	19.8	22.1	4.62	4.55	B	B&E	4.12	0.904
Gilchrist,1979	28	19.8	21.2	12.3	5.01	B	B	7.16	1.430
Gilchrist,1979	29	19.8	21.2	9.24	5.01	B	B	6.50	1.297
Gilchrist,1979	30	19.8	21.2	6.16	5.01	B	B	5.01	0.999
McGill,2002	043-230-3/8-SS-A	8.03	9.88	9.27	1.99	B	B	1.69	0.850
McGill,2002	043-230-3/8-SS-B	8.03	9.88	9.27	1.99	B	B	1.77	0.891
McGill,2002	043-230-3/8-SS-C	8.03	9.88	9.27	1.99	B	B	1.67	0.840
McGill,2002	043-230-3/8-TTSS-A	8.03	9.88	9.27	1.99	B	B	1.87	0.941
McGill,2002	043-230-3/8-TTSS-B	8.03	9.88	9.27	1.99	B	B	1.77	0.891
McGill,2002	043-230-3/8-TTSS-C	8.03	9.88	9.27	1.99	B	B	2.16	1.087
McGill,2002	043-230-3/8-DS-A	8.03	9.88	9.27	3.18	B	B	3.65	1.148
McGill,2002	043-230-3/8-DS-B	8.03	9.88	9.27	3.18	B	B	3.46	1.088
McGill,2002	043-230-3/8-DS-C	8.03	9.88	9.27	3.18	B	B	3.26	1.025
McGill,2002	043-550-3/8-SS-A	19.3	16.4	15.4	3.30	B	B	2.62	0.793
McGill,2002	043-550-3/8-SS-B	19.3	16.4	15.4	3.30	B	B	2.73	0.826
McGill,2002	043-550-3/8-SS-C	19.3	16.4	15.4	3.30	B	B	2.49	0.754
McGill,2002	043-230-1/2-SS-A	8.03	9.38	9.27	2.65	B	B	2.14	0.808
McGill,2002	043-230-1/2-SS-B	8.03	9.38	9.27	2.65	B	B	2.13	0.804
McGill,2002	043-230-1/2-SS-C	8.03	9.38	9.27	2.65	B	B	2.18	0.823
McGill,2002	043-230-1/2-TTSS-A	8.03	9.38	9.27	2.65	B	B	2.29	0.864
McGill,2002	043-230-1/2-TTSS-B	8.03	9.38	9.27	2.65	B	B	2.24	0.845
McGill,2002	043-230-1/2-TTSS-C	8.03	9.38	9.27	2.65	B	B	2.46	0.928
McGill,2002	043-230-1/2-DS-A	8.03	9.38	9.27	4.24	B	B	5.43	1.281
McGill,2002	043-230-1/2-DS-B	8.03	9.38	9.27	4.24	B	B	5.80	1.368

Table C8 Test-To-Predicted Values (Proposed method 2)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	043-230-1/2-DS-C	8.03	9.38	9.27	4.24	B	B	5.72	1.349
McGill,2002	043-550-1/2-SS-A	19.3	15.6	15.4	4.40	B	B	3.37	0.765
McGill,2002	043-550-1/2-SS-B	19.3	15.6	15.4	4.40	B	B	3.36	0.763
McGill,2002	043-550-1/2-SS-C	19.3	15.6	15.4	4.40	B	B	3.36	0.763
McGill,2002	043-230-5/8-SS-A	8.03	8.89	9.27	3.31	B	B	2.99	0.903
McGill,2002	043-230-5/8-SS-B	8.03	8.89	9.27	3.31	B	B	2.84	0.857
McGill,2002	043-230-5/8-SS-C	8.03	8.89	9.27	3.31	B	B	2.78	0.839
McGill,2002	043-230-5/8-TTSS-A	8.03	8.89	9.27	3.31	B	B	3.09	0.933
McGill,2002	043-230-5/8-TTSS-B	8.03	8.89	9.27	3.31	B	B	3.22	0.972
McGill,2002	043-230-5/8-TTSS-C	8.03	8.89	9.27	3.31	B	B	3.36	1.014
McGill,2002	043-230-5/8-DS-A	8.03	8.89	9.27	5.30	B	B	7.05	1.330
McGill,2002	043-230-5/8-DS-B	8.03	8.89	9.27	5.30	B	B	7.49	1.413
McGill,2002	043-230-5/8-DS-C	8.03	8.89	9.27	5.30	B	B	7.35	1.387
McGill,2002	043-550-5/8-SS-A	19.3	14.8	15.4	5.51	B	B	3.71	0.674
McGill,2002	043-550-5/8-SS-B	19.3	14.8	15.4	5.51	B	B	3.93	0.714
McGill,2002	043-550-5/8-SS-C	19.3	14.8	15.4	5.51	B	B	3.92	0.712
McGill,2002	064-230-5/8-TTSS-A	14.3	12.6	13.2	4.70	B	B	5.22	1.111
McGill,2002	064-230-5/8-TTSS-B	14.3	12.6	13.2	4.70	B	B	4.88	1.039
McGill,2002	064-230-5/8-TTSS-C	14.3	12.6	13.2	4.70	B	B	5.47	1.164
McGill,2002	064-230-5/8-DS-A	14.3	12.6	13.2	7.52	B	B	11.8	1.575
McGill,2002	064-230-5/8-DS-B	14.3	12.6	13.2	7.52	B	B	11.0	1.466
McGill,2002	064-230-5/8-DS-C	14.3	12.6	13.2	7.52	B	B	11.7	1.556
McGill,2002	064-550-5/8-SS-A	33.3	25.5	26.6	9.51	B	B	8.64	0.909
McGill,2002	064-550-5/8-SS-B	33.3	25.5	26.6	9.51	B	B	8.91	0.937
McGill,2002	064-550-5/8-SS-C	33.3	25.5	26.6	9.51	B	B	8.34	0.877
McGill,2002	064-230-1/2-TTSS-A	14.3	13.3	13.2	4.14	B	B	4.56	1.101
McGill,2002	064-230-1/2-TTSS-B	14.3	13.3	13.2	4.14	B	B	4.44	1.072
McGill,2002	064-230-1/2-TTSS-C	14.3	13.3	13.2	4.14	B	B	4.10	0.990
McGill,2002	064-230-1/2-DS-A	14.3	13.3	13.2	6.63	B	B	8.91	1.344
McGill,2002	064-230-1/2-DS-B	14.3	13.3	13.2	6.63	B	B	9.28	1.400
McGill,2002	064-230-1/2-DS-C	14.3	13.3	13.2	6.63	B	B	9.23	1.392
McGill,2002	064-550-1/2-SS-A	33.3	26.9	26.6	8.38	B	B	6.94	0.828
McGill,2002	064-550-1/2-SS-B	33.3	26.9	26.6	8.38	B	B	7.26	0.866
McGill,2002	064-250-1/2-SS-C	33.3	26.9	26.6	8.38	B	B	7.04	0.840
McGill,2002	064-230-3/8-SS-A	14.3	14.00	13.2	3.90	B	B	3.05	0.783
McGill,2002	064-230-3/8-SS-B	14.3	14.00	13.2	3.90	B	B	2.75	0.706
McGill,2002	064-230-3/8-SS-C	14.3	14.00	13.2	3.90	B	B	2.77	0.711
McGill,2002	064-550-3/8-SS-A	33.3	28.3	26.6	7.88	B	B	5.83	0.740

Table C8 Test-To-Predicted Values (Proposed method 2)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	064-550-3/8-SS-B	33.3	28.3	26.6	7.88	B	B	6.43	0.816
McGill,2002	064-550-3/8-SS-C	33.3	28.3	26.6	7.88	B	B	5.82	0.738
McGill,2002	064-230-1/4-DS-A	14.3	14.7	13.2	5.00	B	B	6.76	1.352
McGill,2002	064-230-1/4-DS-B	14.3	14.7	13.2	5.00	B	B	6.67	1.334
McGill,2002	064-230-1/4-DS-C	14.3	14.7	13.2	5.00	B	B	6.38	1.276
McGill,2002	064-550-1/4-SS-A	33.3	29.7	26.6	6.32	B	B	5.68	0.899
McGill,2002	064-550-1/4-SS-B	33.3	29.7	26.6	6.32	B	B	5.55	0.878
McGill,2002	064-550-1/4-SS-C	33.3	29.7	26.6	6.32	B	B	5.90	0.934
McGill,2002	064-230-1/4-SS-A	14.3	14.7	13.2	3.12	B	B	2.92	0.935
McGill,2002	064-230-1/4-SS-B	14.3	14.7	13.2	3.12	B	B	3.07	0.983
McGill,2002	064-230-1/4-SS-C	14.3	14.7	13.2	3.12	B	B	3.00	0.960
McGill,2002	064-230-1/4-TTSS-A	14.3	14.7	13.2	3.12	B	B	2.95	0.944
McGill,2002	064-230-1/4-TTSS-B	14.3	14.7	13.2	3.12	B	B	3.29	1.053
McGill,2002	064-230-1/4-TTSS-C	14.3	14.7	13.2	3.12	B	B	3.80	1.216
McGill,2002	076-230-1/2-SS-A	18.5	17.4	17.2	6.10	B	B	4.77	0.781
McGill,2002	076-230-1/2-SS-B	18.5	17.4	17.2	6.10	B	B	4.53	0.743
McGill,2002	076-230-1/2-SS-C	18.5	17.4	17.2	6.10	B	B	4.90	0.802
McGill,2002	076-230-1/2-TTSS-A	18.5	17.4	17.2	6.10	B	B	5.22	0.855
McGill,2002	076-230-1/2-TTSS-B	18.5	17.4	17.2	6.10	B	B	5.90	0.967
McGill,2002	076-230-1/2-TTSS-C	18.5	17.4	17.2	6.10	B	B	5.41	0.886
McGill,2002	076-230-1/2-DS-A	18.5	17.4	17.2	9.77	B	B	10.8	1.109
McGill,2002	076-230-1/2-DS-B	18.5	17.4	17.2	9.77	B	B	11.8	1.211
McGill,2002	076-230-1/2-DS-C	18.5	17.4	17.2	9.77	B	B	10.5	1.078
McGill,2002	076-550-1/2-SS-A	38.4	31.1	30.7	11.4	B	B	8.50	0.748
McGill,2002	076-550-1/2-SS-B	38.4	31.1	30.7	11.4	B	B	8.06	0.709
McGill,2002	076-550-1/2-SS-C	38.4	31.1	30.7	11.4	B	B	8.50	0.748
McGill,2002	076-230-5/8-SS-A	18.5	16.5	17.2	6.14	B	B	6.17	1.005
McGill,2002	076-230-5/8-SS-B	18.5	16.5	17.2	6.14	B	B	6.04	0.983
McGill,2002	076-230-5/8-SS-C	18.5	16.5	17.2	6.14	B	B	6.04	0.983
McGill,2002	076-550-3/8-SS-A	38.4	32.7	30.7	10.1	B	B	8.19	0.815
McGill,2002	076-550-3/8-SS-B	38.4	32.7	30.7	10.1	B	B	7.80	0.776
McGill,2002	076-550-3/8-SS-C	38.4	32.7	30.7	10.1	B	B	6.61	0.658
McGill,2002	076-550-1/4-SS-A	38.4	34.4	30.7	7.32	B	B	7.01	0.958
McGill,2002	076-550-1/4-SS-B	38.4	34.4	30.7	7.32	B	B	6.80	0.929
McGill,2002	076-550-1/4-SS-C	38.4	34.4	30.7	7.32	B	B	6.55	0.895
McGill,2002	091-230-1/4-SS-A	20.0	21.6	19.3	4.60	B	B	4.65	1.010
McGill,2002	091-230-1/4-SS-B	20.0	21.6	19.3	4.60	B	B	5.14	1.117
McGill,2002	091-230-1/4-SS-C	20.0	21.6	19.3	4.60	B	B	4.83	1.049

Table C8 Test-To-Predicted Values (Proposed method 2)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
McGill,2002	091-230-1/4-TTSS-A	20.0	21.6	19.3	4.60	B	B	7.94	1.725
McGill,2002	091-230-1/4-TTSS-B	20.0	21.6	19.3	4.60	B	B	7.46	1.621
McGill,2002	091-230-1/4-TTSS-C	20.0	21.6	19.3	4.60	B	B	7.51	1.632
McGill,2002	091-230-1/4-DS-A	20.0	21.6	19.3	7.36	B	B	12.7	1.723
McGill,2002	091-230-1/4-DS-B	20.0	21.6	19.3	7.36	B	B	12.4	1.678
McGill,2002	091-230-1/4-DS-C	20.0	21.6	19.3	7.36	B	B	11.2	1.526
McGill,2002	091-230-1/2-TTSS-A	20.0	19.6	19.3	7.99	B	B	6.91	0.865
McGill,2002	091-230-1/2-TTSS-B	20.0	19.6	19.3	7.99	B	B	6.94	0.868
McGill,2002	091-230-1/2-TTSS-C	20.0	19.6	19.3	7.99	B	B	7.00	0.876
McGill,2002	091-230-1/2-DS-A	20.0	19.6	19.3	12.8	B	B	14.3	1.118
McGill,2002	091-230-1/2-DS-B	20.0	19.6	19.3	12.8	B	B	13.6	1.064
McGill,2002	091-230-1/2-DS-C	20.0	19.6	19.3	12.8	B	B	13.4	1.051
McGill,2002	121-230-1/2-TTSS-A	30.2	30.5	30.2	14.4	B	B	10.3	0.714
McGill,2002	121-230-1/2-TTSS-B	30.2	30.5	30.2	14.4	B	B	10.3	0.720
McGill,2002	121-230-1/2-TTSS-C	30.2	30.5	30.2	14.4	B	B	12.0	0.836
McGill,2002	121-230-1/2-DS-A	30.2	30.5	30.2	23.0	B	B	18.6	0.810
McGill,2002	121-230-1/2-DS-B	30.2	30.5	30.2	23.0	B	B	20.9	0.909
McGill,2002	121-230-1/2-DS-C	30.2	30.5	30.2	23.0	B	B	18.3	0.795
McGill,2002	121-230-3/8-SS-A	30.2	32.1	30.2	10.8	B	B	8.39	0.779
McGill,2002	121-230-3/8-SS-B	30.2	32.1	30.2	10.8	B	B	8.54	0.793
McGill,2002	121-230-3/8-SS-C	30.2	32.1	30.2	10.8	B	B	8.89	0.826
McGill,2002	121-230-3/8-TTSS-A	30.2	32.1	30.2	10.8	B	B	9.28	0.862
McGill,2002	121-230-3/8-TTSS-B	30.2	32.1	30.2	10.8	B	B	9.03	0.839
McGill,2002	121-230-3/8-TTSS-C	30.2	32.1	30.2	10.8	B	B	9.70	0.901
McGill,2002	121-230-3/8-DS-A	30.2	32.1	30.2	17.2	B	B	20.5	1.187
McGill,2002	121-230-3/8-DS-B	30.2	32.1	30.2	17.2	B	B	18.4	1.065
McGill,2002	121-230-3/8-DS-C	30.2	32.1	30.2	17.2	B	B	16.4	0.951
McGill,2002	153-230-1/4-SS-A	33.3	36.5	32.6	7.77	B	B	9.99	1.285
McGill,2002	153-230-1/4-SS-B	33.3	36.5	32.6	7.77	B	B	9.80	1.261
McGill,2002	153-230-1/4-SS-C	33.3	36.5	32.6	7.77	B	B	9.49	1.221
Wallace,2000	1-wo-50	22.4	20.6	24.4	11.2	B	B	6.29	0.563
Wallace,2000	2-wo-50	22.4	20.6	24.4	11.2	B	B	6.95	0.622
Wallace,2000	3-wo-50	22.4	20.6	24.4	11.2	B	B	6.53	0.584
Wallace,2000	1-wo-40	22.4	20.6	19.6	11.2	B	B	6.64	0.594
Wallace,2000	2-wo-40	22.4	20.6	19.6	11.2	B	B	6.12	0.548
Wallace,2000	3-wo-40	22.4	20.6	19.6	11.2	B	B	6.70	0.599
Wallace,2000	1-wo-30	22.4	20.6	14.7	11.2	B	B	6.38	0.571
Wallace,2000	2-wo-30	22.4	20.6	14.7	11.2	B	B	6.41	0.573

Table C8 Test-To-Predicted Values (Proposed method 2)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Wallace,2000	3-wo-30	22.4	20.6	14.7	11.2	B	B	6.24	0.558
Wallace,2000	1-wo-20	22.4	20.6	9.78	11.2	E	B	5.89	0.602
Wallace,2000	2-wo-20	22.4	20.6	9.78	11.2	E	B	6.20	0.634
Wallace,2000	3-wo-20	22.4	20.6	9.78	11.2	E	B	6.60	0.675
Wallace,2000	1-wo-20-t5	22.4	20.6	9.78	11.2	E	B	7.24	0.740
Wallace,2000	2-wo-20-t5	22.4	20.6	9.78	11.2	E	B	6.63	0.678
Wallace,2000	3-wo-20-t5	22.4	20.6	9.78	11.2	E	B	6.45	0.660
Wallace,2000	1-wo-20-t15	22.4	20.6	9.78	11.2	E	B	7.11	0.727
Wallace,2000	2-wo-20-t15	22.4	20.6	9.78	11.2	E	B	6.50	0.665
Wallace,2000	3-wo-20-t15	22.4	20.6	9.78	11.2	E	B	7.71	0.788
Wallace,2000	1-wo-30-50	22.4	20.6	37.2	22.4	N.S	B	14.5	0.703
Wallace,2000	2-wo-30-50	22.4	20.6	37.2	22.4	N.S	B	15.3	0.743
Wallace,2000	3-wo-30-50	22.4	20.6	37.2	22.4	N.S	B	14.2	0.688
Wallace,2000	1-wo-30-40	22.4	20.6	32.3	22.4	N.S	B	14.1	0.688
Wallace,2000	2-wo-30-40	22.4	20.6	32.3	22.4	N.S	B	14.6	0.708
Wallace,2000	3-wo-30-40	22.4	20.6	32.3	22.4	N.S	B	14.2	0.689
Wallace,2000	1-wo-30-30	22.4	20.6	27.4	22.4	N.S	B	15.1	0.735
Wallace,2000	2-wo-30-30	22.4	20.6	27.4	22.4	N.S	B	15.3	0.746
Wallace,2000	3-wo-30-30	22.4	20.6	27.4	22.4	N.S	B	14.0	0.678
Wallace,2000	1-wo-40-3/8	22.4	19.0	19.6	14.0	B	B	7.26	0.517
Wallace,2000	2-wo-40-3/8	22.4	19.0	19.6	14.0	B	B	7.52	0.536
Wallace,2000	3-wo-40-3/8	22.4	19.0	19.6	14.0	B	B	7.65	0.545
Wallace,2000	1-wo-30-5/16	22.4	19.8	14.7	12.9	B	B	7.82	0.608
Wallace,2000	2-wo-30-5/16	22.4	19.8	14.7	12.9	B	B	6.58	0.512
Wallace,2000	3-wo-30-5/16	22.4	19.8	14.7	12.9	B	B	6.98	0.543
Wallace,2000	1-wo-50-1/2	22.4	17.5	24.4	15.0	B	B	9.80	0.652
Wallace,2000	2-wo-50-1/2	22.4	17.5	24.4	15.0	B	B	9.62	0.640
Wallace,2000	3-wo-50-1/2	22.4	17.5	24.4	15.0	B	B	9.16	0.610
Wallace,2000	1-wo-50-5/8	22.4	15.9	24.4	16.8	N.S	B	10.3	0.648
Wallace,2000	2-wo-50-5/8	22.4	15.9	24.4	16.8	N.S	B	10.3	0.649
Wallace,2000	3-wo-50-5/8	22.4	15.9	24.4	16.8	N.S	B	10.3	0.645
Wallace,2000	1-wo-ss-5/16	11.2	9.90	7.33	4.02	B	B	3.23	0.804
Wallace,2000	2-wo-ss-5/16	11.2	9.90	7.33	4.02	B	B	3.27	0.814
Wallace,2000	3-wo-ss-5/16	11.2	9.90	7.33	4.02	B	B	3.39	0.844
Wallace,2000	1-wo-sst-5/16	24.6	20.2	14.9	8.90	B	B	9.12	1.025
Wallace,2000	2-wo-sst-5/16	24.6	20.2	14.9	8.90	B	B	8.51	0.956
Wallace,2000	3-wo-sst-5/16	24.6	20.2	14.9	8.90	B	B	8.26	0.928
Wallace,2000	1-wo-sst-1/4	24.6	21.0	14.9	7.12	B	B	9.16	1.287

Table C8 Test-To-Predicted Values (Proposed method 2)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Wallace,2000	2-wo-sst-1/4	24.6	21.0	14.9	7.12	B	B	8.92	1.253
Wallace,2000	3-wo-sst-1/4	24.6	21.0	14.9	7.12	B	B	9.03	1.269
Wallace,2000	1-wo-mix-1/4	11.2	10.3	7.33	3.49	B	B	3.52	1.008
Wallace,2000	2-wo-mix-1/4	11.2	10.3	7.33	3.49	B	B	3.47	0.993
Wallace,2000	3-wo-mix-1/4	11.2	10.3	7.33	3.49	B	B	3.73	1.068
Wallace,2000	1-wo-ss-1/4	11.2	10.3	7.33	3.49	B	B	3.27	0.936
Wallace,2000	2-wo-ss-1/4	11.2	10.3	7.33	3.49	B	B	3.30	0.945
Wallace,2000	1-wo-ss-1/2	11.2	8.73	7.33	4.69	B	B	4.25	0.905
Wallace,2000	2-wo-ss-1/2	11.2	8.73	7.33	4.69	B	B	4.43	0.944
Wallace,2000	3-wo-ss-1/2	11.2	8.73	7.33	4.69	B	B	4.00	0.852
Wallace,2000	1-wo-ss-5/8	11.2	7.95	7.33	5.24	B	B	5.45	1.040
Wallace,2000	2-wo-ss-5/8	11.2	7.95	7.33	5.24	B	B	5.43	1.036
Wallace,2000	3-wo-ss-5/8	11.2	7.95	7.33	5.24	B	B	5.41	1.033
Yu,1978	B-0-12-1-0-SS	4.78	4.94	1.60	1.21	B	R	1.73	1.421
Yu,1978	B-0-12-2-0-SS	4.78	4.94	1.60	1.21	B	R	1.40	1.154
Yu,1978	B-0-12-3-L-SS	4.78	4.94	1.65	1.21	B	R	1.40	1.154
Yu,1978	B-0-12-4-L-SS	4.78	4.94	1.65	1.21	B	R	1.50	1.238
Yu,1978	B-0-12-5-0-SS	4.78	4.94	1.60	1.21	B	R	1.36	1.117
Yu,1978	B-0-12-6-0-SS	4.78	4.94	1.65	1.21	B	R	1.44	1.183
Yu,1978	B-0-12-7-L-SS	4.78	4.94	1.60	1.21	B	R	1.58	1.304
Yu,1978	B-0-12-8-L-SS	4.66	4.80	1.62	1.21	B	R	1.45	1.194
Yu,1978	B-0-12-9-H-SS	4.71	4.85	1.62	1.21	B	R	1.70	1.403
Yu,1978	B-0-12-10-H-SS	4.78	4.94	1.65	1.21	B	R	2.25	1.850
Yu,1978	B-0-14-1-0-DS	7.89	8.69	2.56	1.94	B	B&E	2.42	1.243
Yu,1978	B-0-14-2-0-DS	7.89	8.69	2.56	1.94	B	B&E	2.13	1.094
Yu,1978	B-0-14-3-L-DS	7.89	8.69	2.56	1.94	B	B&E	2.55	1.314
Yu,1978	B-0-14-4-L-DS	7.89	8.69	2.56	1.94	B	B&E	2.36	1.213
Yu,1978	B-0-14-5-0-DS	7.89	8.69	2.56	1.94	B	B&E	2.33	1.197
Yu,1978	B-0-14-6-0-DS	7.89	8.69	2.56	1.94	B	B&E	2.14	1.103
Yu,1978	B-0-14-7-L-DS	7.89	8.69	2.56	1.94	B	B&E	3.06	1.575
Yu,1978	B-0-14-8-L-DS	7.89	8.69	2.56	1.94	B	B&E	3.15	1.621
Yu,1978	B-0-14-9-H-DS	7.89	8.69	2.56	1.94	B	B&E	2.46	1.264
Yu,1978	B-0-14-10-H-DS	7.89	8.69	2.56	1.94	B	B&E	2.41	1.241
Yu,1978	B-0-17-1-0-SS	12.5	13.2	4.41	4.40	B	R	5.42	1.230
Yu,1978	B-0-17-2-0-SS	12.5	13.2	4.41	4.40	B	R	4.96	1.127
Yu,1978	B-0-17-3-L-SS	12.7	13.5	4.41	4.40	B	R	5.36	1.217
Yu,1978	B-0-17-4-L-SS	12.5	13.2	4.41	4.40	B	R	5.75	1.306
Yu,1978	B-0-17-5-0-SS	12.5	13.2	4.41	4.40	B	R	5.28	1.200

Table C8 Test-To-Predicted Values (Proposed method 2)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-17-6-0-SS	12.5	13.2	4.28	4.40	E	R	5.31	1.241
Yu,1978	B-0-17-7-L-SS	12.5	13.2	4.41	4.40	B	R	5.32	1.208
Yu,1978	B-0-17-8-L-SS	12.5	13.2	4.41	4.40	B	R	5.45	1.238
Yu,1978	B-0-17-9-H-SS	12.7	13.5	4.41	4.40	B	R	5.33	1.211
Yu,1978	B-0-17-10-H-SS	12.5	13.2	4.31	4.40	E	R	5.40	1.255
Yu,1978	B-0-18-1-0-SS	19.0	19.1	8.56	7.67	B	R	6.30	0.821
Yu,1978	B-0-18-2-0-SS	19.0	19.1	8.61	7.67	B	R	6.32	0.824
Yu,1978	B-0-18-3-L-SS	19.0	19.1	8.61	7.67	B	R	9.08	1.184
Yu,1978	B-0-18-4-L-SS	19.0	19.1	8.61	7.67	B	R	6.63	0.865
Yu,1978	B-0-18-5-0-SS	19.0	19.1	8.61	7.67	B	R	6.32	0.824
Yu,1978	B-0-18-6-0-SS	19.0	19.1	8.61	7.67	B	R	7.10	0.927
Yu,1978	B-0-18-7-L-SS	19.0	19.1	8.61	7.67	B	R	12.2	1.588
Yu,1978	B-0-18-8-L-SS	19.0	19.1	8.81	7.67	B	R	11.5	1.498
Yu,1978	B-0-18-9-H-SS	19.0	19.1	8.61	7.67	B	R	11.6	1.515
Yu,1978	B-0-18-10-H-SS	19.0	19.1	8.61	7.67	B	R	10.4	1.358
Yu,1978	B-0-21-1-0-DS	20.6	23.2	6.61	7.05	E	B&E	8.37	1.266
Yu,1978	B-0-21-2-0-DS	20.6	23.2	6.85	7.05	E	B&E	8.46	1.234
Yu,1978	B-0-21-3-L-DS	20.6	23.2	6.98	7.05	E	B&E	8.46	1.212
Yu,1978	B-0-21-4-L-DS	20.6	23.2	6.85	7.05	E	B&E	8.52	1.244
Yu,1978	B-0-21-5-0-DS	20.6	23.2	6.85	7.05	E	B&E	8.63	1.260
Yu,1978	B-0-21-6-0-DS	20.6	23.2	7.09	7.05	B	B&E	9.03	1.282
Yu,1978	B-0-21-7-L-DS	20.6	23.2	6.85	7.05	E	B&E	9.68	1.413
Yu,1978	B-0-21-8-L-DS	20.6	23.2	6.85	7.05	E	B&E	9.12	1.332
Yu,1978	B-0-21-9-H-DS	20.6	23.2	6.85	7.05	E	B&E	9.95	1.452
Yu,1978	B-0-21-10-H-DS	20.6	23.2	6.85	7.05	E	B&E	8.90	1.299
Yu,1978	B-0-22-1-0-DS	39.6	44.5	13.7	12.3	B	B&E	11.4	0.929
Yu,1978	B-0-22-2-0-DS	39.6	44.5	13.7	12.3	B	B&E	11.1	0.902
Yu,1978	B-0-22-3-L-DS	39.6	44.5	13.7	12.3	B	B&E	12.8	1.043
Yu,1978	B-0-22-4-L-DS	39.6	44.5	13.7	12.3	B	B&E	10.8	0.880
Yu,1978	B-0-22-5-0-DS	39.6	44.5	13.7	12.3	B	B&R	10.8	0.880
Yu,1978	B-0-22-6-0-DS	39.6	44.5	13.7	12.3	B	B&R	9.79	0.798
Yu,1978	B-0-22-7-L-DS	39.6	44.5	13.7	12.3	B	B&E	12.0	0.980
Yu,1978	B-0-22-8-L-DS	39.6	44.5	13.7	12.3	B	B&E	12.1	0.987
Yu,1978	B-0-22-9-H-DS	39.6	44.5	13.7	12.3	B	B&E	11.8	0.961
Yu,1978	B-0-22-10-H-DS	39.6	44.5	13.9	12.3	B	B&E	12.7	1.038
Yu,1978	B-0-25-1-0-SS	47.5	43.1	19.5	19.9	E	R	18.2	0.935
Yu,1978	B-0-25-2-0-SS	47.5	43.1	19.5	19.9	E	R	19.0	0.977
Yu,1978	B-0-25-3-L-SS	47.5	43.1	19.5	19.9	E	R	20.2	1.038

Table C8 Test-To-Predicted Values (Proposed method 2)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-25-4-L-SS	47.5	43.1	19.5	19.9	E	R	21.0	1.082
Yu,1978	B-0-25-5-H-SS	47.5	43.1	19.5	19.9	E	R	20.4	1.050
Yu,1978	B-0-25-6-H-SS	47.5	43.1	19.5	19.9	E	R	19.4	0.995
Yu,1978	B-0-26-1-0-SS	66.6	59.9	29.2	29.7	E	R	24.4	0.835
Yu,1978	B-0-26-2-0-SS	66.6	59.9	29.2	29.7	E	R	24.7	0.847
Yu,1978	B-0-26-3-L-SS	66.6	59.9	29.2	29.7	E	R	25.3	0.867
Yu,1978	B-0-26-4-L-SS	66.6	59.9	29.2	29.7	E	R	24.7	0.845
Yu,1978	B-0-26-5-0-SS	66.6	59.9	29.2	29.7	E	R	24.7	0.846
Yu,1978	B-0-26-6-0-SS	66.6	59.9	29.2	29.7	E	R	23.1	0.790
Yu,1978	B-0-26-7-L-SS	66.6	59.9	29.2	29.7	E	R	25.0	0.857
Yu,1978	B-0-26-8-L-SS	66.6	59.9	29.2	29.7	E	R	24.9	0.854
Yu,1978	B-0-26-9-H-SS	66.6	59.9	29.2	29.7	E	R	31.2	1.067
Yu,1978	B-0-26-10-H-SS	66.6	59.9	29.2	29.7	E	R	32.7	1.121
Yu,1978	B-0-29-1-0-DS	103	105	32.1	31.8	B	B&E	30.9	0.969
Yu,1978	B-0-29-2-0-DS	103	105	31.5	31.8	E	B&E	35.6	1.129
Yu,1978	B-0-29-3-L-DS	103	105	31.0	31.8	E	B&E	38.3	1.236
Yu,1978	B-0-29-4-L-DS	103	105	32.1	31.8	B	B&E	38.5	1.209
Yu,1978	B-0-29-5-0-DS	103	105	32.6	31.8	B	B&E	37.0	1.162
Yu,1978	B-0-29-6-0-DS	103	105	32.6	31.8	B	B&E	31.4	0.987
Yu,1978	B-0-29-7-L-DS	103	105	31.5	31.8	E	B&E	40.9	1.299
Yu,1978	B-0-29-8-L-DS	103	105	32.6	31.8	B	B&E	41.4	1.300
Yu,1978	B-0-29-9-H-DS	103	105	32.6	31.8	B	B&E	41.2	1.293
Yu,1978	B-0-29-10-H-DS	103	105	32.6	31.8	B	B&E	40.7	1.279
Yu,1978	B-0-30-1-0-DS	158	162	43.7	47.5	E	B&E	44.3	1.013
Yu,1978	B-0-30-2-0-DS	158	162	45.3	47.5	E	B&E	46.7	1.031
Yu,1978	B-0-30-3-L-DS	158	162	45.3	47.5	E	B&E	51.2	1.129
Yu,1978	B-0-30-4-L-DS	158	162	45.3	47.5	E	B&E	48.1	1.060
Yu,1978	B-0-30-5-0-DS	158	162	45.3	47.5	E	B&E	46.2	1.018
Yu,1978	B-0-30-6-0-DS	158	162	44.8	47.5	E	B&E	43.7	0.977
Yu,1978	B-0-30-7-L-DS	158	162	45.3	47.5	E	B&E	49.5	1.091
Yu,1978	B-0-30-8-L-DS	158	162	45.3	47.5	E	B&E	48.1	1.062
Yu,1978	B-0-30-9-H-DS	158	162	43.7	47.5	E	B&E	50.3	1.151
Yu,1978	B-0-30-10-H-DS	158	162	43.7	47.5	E	B&E	51.6	1.181
Yu,1978	B-0-32-1-0-SS	9.69	9.53	3.05	2.47	B	B&R	2.45	0.991
Yu,1978	B-0-32-2-0-SS	9.69	9.53	2.94	2.47	B	B&R	2.58	1.045
Yu,1978	B-0-32-3-L-SS	9.69	9.53	3.05	2.47	B	B&R	2.72	1.103
Yu,1978	B-0-32-4-L-SS	9.69	9.53	3.05	2.47	B	B&R	3.14	1.272
Yu,1978	B-0-32-5-0-SS	9.69	9.53	3.05	2.47	B	B&R	2.67	1.081

Table C8 Test-To-Predicted Values (Proposed method 2)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-32-6-0-SS	9.69	9.53	3.10	2.47	B	B&R	2.41	0.977
Yu,1978	B-0-32-7-L-SS	9.69	9.53	3.05	2.47	B	B&R	2.49	1.009
Yu,1978	B-0-32-8-L-SS	9.69	9.53	3.10	2.47	B	B&R	2.39	0.968
Yu,1978	B-0-32-9-H-SS	9.69	9.53	3.10	2.47	B	B&N.S	3.61	1.463
Yu,1978	B-0-32-10-H-SS	9.69	9.53	3.05	2.47	B	B&N.S	2.89	1.171
Yu,1978	B-0-34-1-0-DS	15.7	16.5	4.85	3.95	B	B&E	3.78	0.957
Yu,1978	B-0-34-2-0-DS	15.7	16.5	4.85	3.95	B	B&E	3.81	0.965
Yu,1978	B-0-34-3-L-DS	15.7	16.5	4.85	3.95	B	B&E	4.25	1.077
Yu,1978	B-0-34-4-L-DS	15.7	16.5	4.85	3.95	B	B&E	4.43	1.122
Yu,1978	B-0-34-5-0-DS	15.7	16.5	4.85	3.95	B	B&E	3.07	0.777
Yu,1978	B-0-34-6-0-DS	15.7	16.5	4.85	3.95	B	B&E	3.63	0.918
Yu,1978	B-0-34-7-L-DS	15.7	16.5	4.85	3.95	B	B&E	3.87	0.980
Yu,1978	B-0-34-8-L-DS	15.7	16.5	4.85	3.95	B	B&E	4.62	1.169
Yu,1978	B-0-34-9-H-DS	15.7	16.5	4.85	3.95	B	B&E	5.03	1.273
Yu,1978	B-0-34-10-H-DS	15.7	16.5	4.85	3.95	B	B&E	4.04	1.021
Yu,1978	B-0-37-1-0-SS	18.4	20.2	5.66	5.78	E	R	5.37	0.950
Yu,1978	B-0-37-2-0-SS	18.4	20.2	5.66	5.78	E	R	5.36	0.947
Yu,1978	B-0-37-3-L-SS	18.4	20.2	5.66	5.78	E	R	5.62	0.993
Yu,1978	B-0-37-4-L-SS	18.4	20.2	5.66	5.78	E	R	5.55	0.982
Yu,1978	B-0-37-5-H-SS	18.4	20.2	5.66	5.78	E	R	5.52	0.977
Yu,1978	B-0-37-6-H-SS	18.4	20.2	5.66	5.78	E	R	8.88	1.570
Yu,1978	B-0-38-1-0-SS	24.5	25.1	11.3	9.20	B	R	7.01	0.761
Yu,1978	B-0-38-2-0-SS	24.5	25.1	11.3	9.20	B	R	7.28	0.790
Yu,1978	B-0-38-3-L-SS	24.5	25.1	11.3	9.20	B	R	10.1	1.093
Yu,1978	B-0-38-4-L-SS	24.5	25.1	11.3	9.20	B	R	8.68	0.943
Yu,1978	B-0-38-5-0-SS	24.5	25.1	11.3	9.20	B	R	7.19	0.781
Yu,1978	B-0-38-6-0-SS	24.5	25.1	11.3	9.20	B	R	7.45	0.810
Yu,1978	B-0-38-7-L-SS	24.5	25.1	11.3	9.20	B	R	10.4	1.134
Yu,1978	B-0-38-8-L-SS	24.5	25.1	11.3	9.20	B	R	8.19	0.890
Yu,1978	B-0-38-9-H-SS	24.5	25.1	11.3	9.20	B	R	9.35	1.015
Yu,1978	B-0-38-10-H-SS	24.5	25.1	11.3	9.20	B	R	10.4	1.126
Yu,1978	B-0-41-1-0-DS	26.6	30.5	9.00	9.25	E	B&E	8.81	0.979
Yu,1978	B-0-41-2-0-DS	26.6	30.5	9.00	9.25	E	B&E	9.63	1.071
Yu,1978	B-0-41-3-L-DS	26.6	30.5	9.00	9.25	E	B&E	10.6	1.182
Yu,1978	B-0-41-4-L-DS	26.6	30.5	9.00	9.25	E	B&E	9.48	1.054
Yu,1978	B-0-41-5-H-DS	26.6	30.5	9.00	9.25	E	B&E	10.3	1.147
Yu,1978	B-0-41-6-H-DS	26.6	30.5	9.00	9.25	E	B&E	10.7	1.187
Yu,1978	B-0-42-1-0-DS	53.1	61.1	18.0	14.7	B	B&E	13.1	0.890

Table C8 Test-To-Predicted Values (Proposed method 2)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-42-2-0-DS	53.1	61.1	18.0	14.7	B	B&E	12.1	0.819
Yu,1978	B-0-42-3-L-DS	53.1	61.1	18.0	14.7	B	B&E	12.8	0.870
Yu,1978	B-0-42-4-L-DS	53.1	61.1	18.0	14.7	B	B&E	12.1	0.825
Yu,1978	B-0-42-5-0-DS	53.1	61.1	18.0	14.7	B	B&E	13.4	0.910
Yu,1978	B-0-42-6-0-DS	53.1	61.1	18.0	14.7	B	B&E	13.4	0.910
Yu,1978	B-0-42-7-L-DS	53.1	61.1	18.0	14.7	B	B&E	16.8	1.142
Yu,1978	B-0-42-8-L-DS	53.1	61.1	18.0	14.7	B	B&E	12.7	0.861
Yu,1978	B-0-42-9-H-DS	53.1	61.1	18.0	14.7	B	B&E	17.2	1.171
Yu,1978	B-0-42-10-H-DS	53.1	61.1	18.0	14.7	B	B&E	19.3	1.311
Yu,1978	B-0-45-1-0-SS	49.7	53.4	26.0	24.6	B	R	18.0	0.730
Yu,1978	B-0-45-2-0-SS	49.7	53.4	24.1	24.6	E	R	18.2	0.754
Yu,1978	B-0-45-3-L-SS	49.7	53.4	24.1	24.6	E	R	19.3	0.801
Yu,1978	B-0-45-4-L-SS	49.7	53.4	25.2	24.6	B	R	19.2	0.781
Yu,1978	B-0-45-5-H-SS	49.7	53.4	25.2	24.6	B	R	19.8	0.806
Yu,1978	B-0-45-6-H-SS	49.7	53.4	24.1	24.6	E	R	19.8	0.822
Yu,1978	B-0-46-1-0-SS	70.4	75.3	36.1	36.3	E	B&R	25.9	0.717
Yu,1978	B-0-46-2-0-SS	70.4	75.3	36.1	36.3	E	B&R	24.3	0.674
Yu,1978	B-0-46-3-L-SS	70.4	75.3	36.1	36.3	E	B&R	26.7	0.739
Yu,1978	B-0-46-4-L-SS	70.4	75.3	36.1	36.3	E	B&R	26.5	0.734
Yu,1978	B-0-46-5-0-SS	70.4	75.3	36.1	36.3	E	B&R	26.1	0.723
Yu,1978	B-0-46-6-0-SS	70.4	75.3	36.1	36.3	E	B&R	25.9	0.717
Yu,1978	B-0-46-7-L-SS	70.4	75.3	36.1	36.3	E	B&R	29.8	0.824
Yu,1978	B-0-46-8-L-SS	70.4	75.3	36.1	36.3	E	B&R	26.1	0.724
Yu,1978	B-0-46-9-H-SS	70.4	75.3	36.1	36.3	E	B&R	33.4	0.924
Yu,1978	B-0-46-10-H-SS	70.4	75.3	36.1	36.3	E	B&R	29.2	0.808
Yu,1978	B-0-49-1-0-DS	111	134	39.0	39.4	E	B&E	42.6	1.093
Yu,1978	B-0-49-2-0-DS	111	134	39.7	39.4	B	B&E	37.4	0.948
Yu,1978	B-0-49-3-L-DS	111	134	39.0	39.4	E	B&E	39.2	1.006
Yu,1978	B-0-49-4-L-DS	111	134	39.0	39.4	E	B&E	39.8	1.021
Yu,1978	B-0-49-5-H-DS	111	134	39.0	39.4	E	B&E	40.9	1.050
Yu,1978	B-0-49-6-H-DS	111	134	39.0	39.4	E	B&E	42.3	1.084
Yu,1978	B-0-50-1-0-DS	165	201	57.5	58.0	E	B&E	54.5	0.948
Yu,1978	B-0-50-2-0-DS	165	201	57.5	58.0	E	B&E	53.0	0.921
Yu,1978	B-0-50-3-L-DS	165	201	57.5	58.0	E	B&E	55.4	0.964
Yu,1978	B-0-50-4-L-DS	165	201	57.5	58.0	E	B&E	51.8	0.902
Yu,1978	B-0-50-5-0-DS	165	201	57.5	58.0	E	B&E	50.5	0.879
Yu,1978	B-0-50-6-0-DS	165	201	57.5	58.0	E	B&E	48.3	0.840
Yu,1978	B-0-50-7-L-DS	165	201	57.5	58.0	E	B&E	53.4	0.929

Table C8 Test-To-Predicted Values (Proposed method 2)(continued)

SOURCE	SPECIMEN	Gross Section (KN)	Net Section (KN)	End Pull-Out (KN)	Bearing (S136) (KN)	Predicted Failure Mode	Actual Failure Mode	Pt (KN)	P_t / P_p
Yu,1978	B-0-50-8-L-DS	165	201	57.5	58.0	E	B&E	44.9	0.780
Yu,1978	B-0-50-9-H-DS	165	201	57.5	58.0	E	B&E	62.3	1.084
Yu,1978	B-0-50-10-H-DS	165	201	57.5	58.0	E	B&E	53.5	0.931
Yu,1978	B-0-51-1-0-SS	188	199	97.7	97.7	B	R	97.7	1.000
Yu,1978	B-0-51-2-0-SS	188	199	97.7	97.7	B	R	96.3	0.986
Yu,1978	B-0-51-3-L-SS	188	199	99.5	97.7	B	R	94.1	0.963
Yu,1978	B-0-51-4-L-SS	188	199	97.7	97.7	B	R	101	1.043
Yu,1978	B-0-51-5-H-SS	188	199	97.7	97.7	B	R	95.0	0.972
Yu,1978	B-0-51-6-H-SS	188	199	97.7	97.7	B	R	97.9	1.002
Yu,1978	B-0-53-1-0-DS	443	531	151	156	E	B&E	157	1.039
Yu,1978	B-0-53-2-0-DS	443	531	155	156	E	B&E	155	0.998
Yu,1978	B-0-53-3-L-DS	443	531	151	156	E	B&E	161	1.066
Yu,1978	B-0-53-4-L-DS	443	531	153	156	E	B&E	160	1.046
Yu,1978	B-0-53-5-H-DS	443	531	148	156	E	B&E	160	1.082

Table C9 Prediction of Displacement Capacity, $P_{6.35}$ (North American Specification, AISI, 2001a, CSA, 2001)

SPECIMEN	$P_{P6.35}$ (kN)	SPECIMEN	$P_{P6.35}$ (kN)
043-230-3/8-SS-A	2.36	043-230-5/8-TTSS-A	3.94
043-230-3/8-SS-B	2.36	043-230-5/8-TTSS-B	3.94
043-230-3/8-SS-C	2.36	043-230-5/8-TTSS-C	3.94
043-230-3/8-SS-D	2.36	043-230-5/8-TTSS-D	3.94
043-230-3/8-TTSS-A	2.36	043-230-5/8-DS-A	3.94
043-230-3/8-TTSS-B	2.36	043-230-5/8-DS-B	3.94
043-230-3/8-TTSS-C	2.36	043-230-5/8-DS-C	3.94
043-230-3/8-TTSS-D	2.36	043-230-5/8-DS-D	3.94
043-230-3/8-DS-A	2.36	043-550-5/8-SS-A	6.50
043-230-3/8-DS-B	2.36	043-550-5/8-SS-B	6.50
043-230-3/8-DS-C	2.36	043-550-5/8-SS-C	6.50
043-230-3/8-DS-D	2.36	043-550-5/8-SS-D	6.50
043-550-3/8-SS-A	3.90	064-230-5/8-TTSS-A	5.73
043-550-3/8-SS-B	3.90	064-230-5/8-TTSS-B	5.73
043-550-3/8-SS-C	3.90	064-230-5/8-TTSS-C	5.73
043-550-3/8-SS-D	3.90	064-230-5/8-TTSS-D	5.73
043-230-1/2-SS-A	3.15	064-230-5/8-DS-A	5.73
043-230-1/2-SS-B	3.15	064-230-5/8-DS-B	5.73
043-230-1/2-SS-C	3.15	064-230-5/8-DS-C	5.73
043-230-1/2-SS-D	3.15	064-230-5/8-DS-D	5.73
043-230-1/2-TTSS-A	3.15	064-550-5/8-SS-A	11.58
043-230-1/2-TTSS-B	3.15	064-550-5/8-SS-B	11.58
043-230-1/2-TTSS-C	3.15	064-550-5/8-SS-C	11.58
043-230-1/2-TTSS-D	3.15	064-550-5/8-SS-D	11.58
043-230-1/2-DS-A	3.15	064-230-1/2-TTSS-A	4.58
043-230-1/2-DS-B	3.15	064-230-1/2-TTSS-B	4.58
043-230-1/2-DS-C	3.15	064-230-1/2-TTSS-C	4.58
043-230-1/2-DS-D	3.15	064-230-1/2-TTSS-D	4.58
043-550-1/2-SS-A	5.20	064-230-1/2-DS-A	4.58
043-550-1/2-SS-B	5.20	064-230-1/2-DS-B	4.58
043-550-1/2-SS-C	5.20	064-230-1/2-DS-C	4.58
043-550-1/2-SS-D	5.20	064-230-1/2-DS-D	4.58
043-230-5/8-SS-A	3.94	064-550-1/2-SS-A	9.27
043-230-5/8-SS-B	3.94	064-550-1/2-SS-B	9.27
043-230-5/8-SS-C	3.94	064-550-1/2-SS-C	9.27
043-230-5/8-SS-D	3.94	064-550-1/2-SS-D	9.27
064-230-3/8-SS-A	3.44	076-550-1/2-SS-A	10.86

Table C9 Prediction of Displacement Capacity, $P_{6.35}$ (North American Specification, AISI, 2001a, CSA, 2001)(continued)

SPECIMEN	$P_{P6.35}$ (kN)	SPECIMEN	$P_{P6.35}$ (kN)
064-230-3/8-SS-B	3.44	076-550-1/2-SS-B	10.86
064-230-3/8-SS-C	3.44	076-550-1/2-SS-C	10.86
064-230-3/8-SS-D	3.44	076-550-1/2-SS-D	10.86
064-550-3/8-SS-A	6.95	076-230-5/8-SS-A	7.56
064-550-3/8-SS-B	6.95	076-230-5/8-SS-B	7.56
064-550-3/8-SS-C	6.95	076-230-5/8-SS-C	7.56
064-550-3/8-SS-D	6.95	076-230-5/8-SS-D	7.56
064-230-1/4-DS-A	2.29	076-550-3/8-SS-A	8.14
064-230-1/4-DS-B	2.29	076-550-3/8-SS-B	8.14
064-230-1/4-DS-C	2.29	076-550-3/8-SS-C	8.14
064-230-1/4-DS-D	2.29	076-550-3/8-SS-D	8.14
064-550-1/4-SS-A	4.63	076-550-1/4-SS-A	5.43
064-550-1/4-SS-B	4.63	076-550-1/4-SS-B	5.43
064-550-1/4-SS-C	4.63	076-550-1/4-SS-C	5.43
064-550-1/4-SS-D	4.63	076-550-1/4-SS-D	5.43
064-230-1/4-SS-A	2.29	091-230-1/4-SS-A	3.47
064-230-1/4-SS-B	2.29	091-230-1/4-SS-B	3.47
064-230-1/4-SS-C	2.29	091-230-1/4-SS-C	3.47
064-230-1/4-SS-D	2.29	091-230-1/4-SS-D	3.47
064-230-1/4-TTSS-A	2.29	091-230-1/4-TTSS-A	3.47
064-230-1/4-TTSS-B	2.29	091-230-1/4-TTSS-B	3.47
064-230-1/4-TTSS-C	2.29	091-230-1/4-TTSS-C	3.47
064-230-1/4-TTSS-D	2.29	091-230-1/4-TTSS-D	3.47
076-230-1/2-SS-A	6.05	091-230-1/4-DS-A	3.47
076-230-1/2-SS-B	6.05	091-230-1/4-DS-B	3.47
076-230-1/2-SS-C	6.05	091-230-1/4-DS-C	3.47
076-230-1/2-SS-D	6.05	091-230-1/4-DS-D	3.47
076-230-1/2-TTSS-A	6.05	091-230-1/2-TTSS-A	6.94
076-230-1/2-TTSS-B	6.05	091-230-1/2-TTSS-B	6.94
076-230-1/2-TTSS-C	6.05	091-230-1/2-TTSS-C	6.94
076-230-1/2-TTSS-D	6.05	091-230-1/2-TTSS-D	6.94
076-230-1/2-DS-A	6.05	091-230-1/2-DS-A	6.94
076-230-1/2-DS-B	6.05	091-230-1/2-DS-B	6.94
076-230-1/2-DS-C	6.05	091-230-1/2-DS-C	6.94
076-230-1/2-DS-D	6.05	091-230-1/2-DS-D	6.94

Table C9 Prediction of Displacement Capacity, $P_{6.35}$ (North American Specification, AISI, 2001a, CSA, 2001)(continued)

SPECIMEN	$P_{P6.35}$ (kN)	SPECIMEN	$P_{P6.35}$ (kN)
121-230-1/2-TTSS-A	11.33	121-230-3/8-TTSS-A	8.50
121-230-1/2-TTSS-B	11.33	121-230-3/8-TTSS-B	8.50
121-230-1/2-TTSS-C	11.33	121-230-3/8-TTSS-C	8.50
121-230-1/2-TTSS-D	11.33	121-230-3/8-TTSS-D	8.50
121-230-1/2-DS-A	11.33	121-230-3/8-DS-A	8.50
121-230-1/2-DS-B	11.33	121-230-3/8-DS-B	8.50
121-230-1/2-DS-C	11.33	121-230-3/8-DS-C	8.50
121-230-1/2-DS-D	11.33	121-230-3/8-DS-D	8.50
121-230-3/8-SS-A	8.50	153-230-1/4-SS-A	6.24
121-230-3/8-SS-B	8.50	153-230-1/4-SS-B	6.24
121-230-3/8-SS-C	8.50	153-230-1/4-SS-C	6.24
121-230-3/8-SS-D	8.50	153-230-1/4-SS-D	6.24

APPENDIX D

Example Calculation for Bolted Connections

D.1 Single Shear Single Bolted Connections Without Washers

D.1.1.General Information

Test Specimen: 091-230-1/4-SS-A

	Top	Bottom
t_b	0.91mm	0.91mm
w	75mm	75mm
e	60mm	60mm
d_{hole}	7.938mm	7.938mm
d	6.35mm	6.35mm
f_y	293MPa	293MPa
f_u	354MPa	354MPa
f_{uBolt}	827MPa	827MPa
d_{uBolt}	6.35mm	6.35mm
p_{uBolt}	1.3mm	1.3mm
P_t	4.65KN	

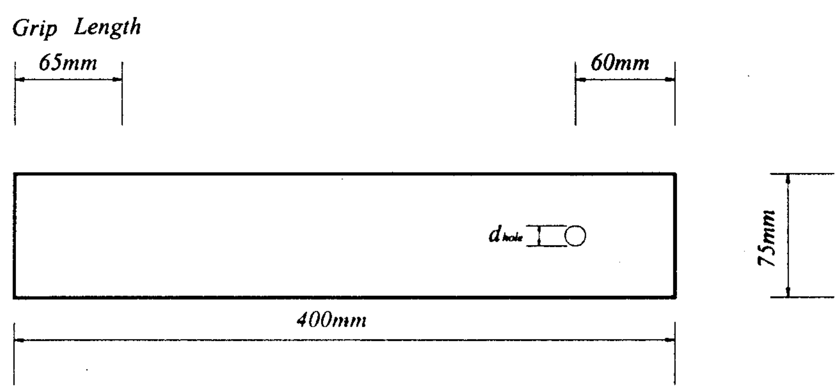


Figure D.1 Dimensions Of Test 091-230-1/4-SS-A

D.1.2. Canada (CSA, 1994)

$\phi = \phi_u = \phi_c = 1.0$ (Nominal calculations being carried out)

Gross Section Yielding

$T_r = \phi\ A_g\ F_y$ C1.6.3.1

$Ag = 75 * 0.91 = 68.25\ mm^2$

$T_r = 1.0 * 68.25 * 293 = 20.0\ KN$

Net Section Fracture

$T_r = \phi_u A_n F_u$ Cl.6.3.1
$A_n = 68.25 - 0.91 * 7.938 = 61.0\text{mm}^2$
$T_r = 1.0 * 61.0 * 354 = 21.6$ KN

End Pull-Out

$T_r = \phi_u A_n F_u$ Cl.6.3.1
$A_n = 2 * 0.6 (60 - 0.5 * 7.938) * 0.91 = 61.2 \text{ mm}^2$
$T_r = 1.0 * 61.2 * 354 = 21.7$ KN

Bearing

$B_r = \phi_u C d t F_u$ Cl.7.3.5.1
$d/t = 6.35 / 0.91 = 6.98$
$C = 3$
$B_r = 1.0 * 3 * 6.35 * 0.91 * 354 = 6.1$ KN

Bolt Shear

$V_r = \phi c\ 0.6\ A_b F_u^*$ Cl.7.3.2
Assume bolt threads in the shear plane
$V_r = 0.7\ V_r$
$A_b = \pi\ 6.35^2 / 4 = 31.7 \text{ mm}^2$
$V_r = 0.7 * 31.7 * 827 = 18.3$ KN

Predicted Mode of Failure: Bearing (6.1 KN)

D.1.3. USA(AISI,1999)

Gross Section Yielding

$T_n = A_g F_y$ Eq. C2-1
$A_g = 75 * 0.91 = 68.25 \text{ mm}^2$
$Tn = 68.25 * 293 = 20.0$ KN

Net Section Fracture

$P_n = (1.0 - r + 2.5\ r\ d / s)\ A_n F_u \quad A_n F_u$ Eq. E3.2-1
$A_n = 68.25 - 0.91 * 7.938 = 61.0 \text{ mm}^2$
$r = 1.0$
$P_n = (1.0 - 1.0 + 2.5 * 1.0 * 6.35 / 75) * 61.0 * 354 = 4.6$ KN

End Pull-Out

$P_n = t\, e\, F_u$ Eq.E3.1-1

$P_n = 0.91 * (60 - 7.938 / 2\,) * 354 = 18.0$ KN

Bearing

$P_n = 2.22\, F_u\, d\, t$ Table E3.3-1

$P_n = 2.22 * 354 * 6.35 * 0.91 = 4.5$ KN

Bolt Shear

Assume bolt threads in the shear plane

$P_n = F\, A_b$ Eq. E3.4-1

$F = F_{nv} = 465$ MPa Table E3.4-1

$F = F_{nv} = 465$ Mpa

$A_b = \pi\, 6.35^2 / 4 = 31.7\ mm^2$

$P_n = 31.7 * 465 = 14.7$ KN

Predicted Mode of Failure: Bearing (4.5 KN)

D.1.4. Australia/New Zealand(AS/NZS, 1996)

Gross Section Yielding

$N^* \quad \phi_t N_t$ Sec. 3.2.1

$N_t = A_g\, f_y$ Eq. 3.2.1(1)

$A_g = 75 * 0.91 = 68.25\ mm^2$

$N_t = 68.25 * 293 = 20.0$ KN

Net Section Fracture

$N^*_f \quad \phi_t N_f$ Sec. 5.3.3

$N_f = (1.0 - r + 2.5\, r_f d_f / s_f)\, A_n f_u \quad A_n f_u$ Eq. 5.3.3(1)

$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$

$r = 1.0$

$N_f = (1.0 - 1.0 + 2.5 * 1.0 * 6.35 / 75) * 59.6 * 354 = 4.6$ KN

$N_f \quad 61 * 354 = 21.6$ KN

End Pull-Out

$V^*_f \quad \phi\, V_f$ Sec. 5.3.2

$V_f = t\, e\, f_u$ Eq.5.3.2

$V_f = 0.91 * (60 - 7.938 / 2) * 354 = 18.0$ KN

Bearing

$V^*_b \quad \phi V_b$ Sec. 5.3.4
$V_b = 2.22\ f_u\, d_f\, t$ Table 5.3.4.1
$V_b = 2.22 * 354 * 6.35 * 0.91 = 4.5$ KN

Bolt Shear

Assume bolt threads in the shear plane
$V^*_{fv} \quad \phi V_{fv}$ Sec. 5.3.5.1
$V^*_{fv} = 0.62\ f_{uf}(n_n A_c + n_x A_o)$ Eq. 5.3.5.1
$A_c = \pi\ (d_{bolt} - 1.0825\ p_{uBolt})^2 / 4$
$A_c = \pi\ (6.35 - 1.0825 * 1.3)^2 / 4 = 19.2\ mm^2$
$V^*_{fv} = 0.62 * 827 * (1 * 19.2) = 9.8$ KN

Predicted Mode of Failure: Bearing(4.5 KN)

D.1.5. Europe (Eurocode, 1996)

$\gamma_{MO} = \gamma_{M2} = 1.0$

Gross Section Yielding Sec. 5.2

$N_{t,\,Rd} = f_{ya}\, A_g / \gamma_{MO}$ Eq. 5.1
$A_g = 75 * 0.91 = 68.25\ mm^2$
$N_{t,\,Rd} = 68.25 * 293 / 1.0 = 20.0$ KN

Net Section Fracture Sec. 8.4

$F_{n,\,Rd} = (1.0 + 3r\ (d_0 / u - 0.3))\ A_{net}\, f_u / \gamma_{M2} \quad A_{net}\, f_u / \gamma_{M2}$ Table 8.4
$A_{net} = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$
$r = 1.0$
$F_{n,\,Rd} = (1.0 + 3 * 1.0\ (7.938 / 75 - 0.3)) * 61.0 * 354 = 9.0$ KN
$F_{n,\,Rd} \quad 61 * 354 / 1.0 = 21.6$ KN

End Pull-Out Sec. 8.4

$F_{b,\,Rd} = f_u\, e_1\, t / 1.2 / \gamma_{M2}$ Table 8.4
$F_{b,\,Rd} = 354 * (60 - 7.938 / 2) * 0.91 / 1.2 / 1.0 = 15.0$ KN

Bearing Sec.8.4

$F_{b,\,Rd} = 2.5 f_u\ d\ t / \gamma_{M2}$ Table 8.4

$F_{b,Rd} = 2.5 * 354 * 6.35 * 0.91 / 1.0 = 5.1$ KN

Bolt Shear Sec.8.4

Assume bolt threads in the shear plane

$F_{v,Rd} = 0.6\ f_{ub}\ A_s / \gamma_{M2}$ Table 8.4

$A_s = \pi\ (d_{bolt} - 0.9382\ p_{uBolt})^2 / 4$

$A_s = \pi\ (6.35 - 0.9382 * 1.3)^2 / 4 = 20.7\ mm^2$

$F_{v,Rd} = 0.6 * 827 * 20.7 / 1.0 = 10.3$ KN

Predicted Mode of Failure: Bearing (5.1 KN)

D.1.6. Proposed North American Specification

D.1.6a United States (AISI, 2001a)

Gross Section Yielding

$T_n = A_g\ F_y$ Eq. C2-1

$A_g = 75 * 0.91 = 68.25\ mm^2$

$T_n = 68.25 * 293 = 20.0$ KN

Net Section Fracture

$P_n = (2.5\ d / s)\ A_n\ F_u \quad A_n\ F_u$ Eq. E3.2-4

$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$

$P_n = (2.5 * 6.35 / 75) * 61.0 * 354 = 4.57$ KN

End Pull-Out

$P_n = t\ e\ F_u$ Eq.E3.1-1

$P_n = 0.91 * (60 - 7.938 / 2) * 354 = 18.0$ KN

Bearing

$P_n = \alpha\ C\ d\ t\ F_u$ Eq. E3.3.1-1

$d / t = 7.938 / 0.91 = 8.72 < 10$

$C = 3.0$ Table E3.3.1-1

$\alpha = 0.75$ Table E3.3.1-2

$P_n = 0.75 * 3.0 * 6.35 * 0.91 * 354 = 4.60$ KN

Bolt Shear

Assume bolt threads in the shear plane

$P_n = F\ A_b$ Eq. E3.4-1

$F = F_{nv} = 465$ Mpa Table E3.4-1

$F = F_{nv} = 465$ Mpa

$A_b = \pi\ 6.35^2 / 4 = 31.7\ mm^2$

$P_n = 31.7 * 465 = 14.7$ KN

Predicted Mode of Failure: Net Section Fracture (4.57 KN)

D.1.6b Canada (CSA,2001)

$\phi = \phi_u = \phi_c = 1.0$

Gross Section Yielding

$T_r = \phi\ A_g\ F_y$ Eq. C2.1-1

$A_g = 75 * 0.91 = 68.25\ mm^2$

$T_r = 1.0 * 68.25 * 293 = 20.0$ KN

Net Section Fracture

$T_r = \phi_u\ A_n\ F_u$ Eq. C2.2-1

$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$

$T_r = 1.0 * 61.0 * 354 = 21.6$ KN

End Pull-Out

$T_r = \phi_u\ A_n\ F_u$ Eq. C2.2-1

$A_n = 2 * 0.6\ (60 - 0.5 * 7.938) * 0.91 = 61.2\ mm^2$

$T_r = 1.0 * 61.2 * 354 = 21.7$ KN

Bearing

$P_n = \alpha\ C\ d\ t\ F_u$ Eq. E3.3.1-1

$d / t = 7.938 / 0.91 = 8.72 < 10$

$C = 3.0$ Table E3.3.1-1

$\alpha = 0.75$ Table E3.3.1-2

$P_n = 0.75 * 3.0 * 6.35 * 0.91 * 354 = 4.6$ KN

Bolt Shear

$V_r = \phi_c\ 0.6\ A_b\ F_u^*$ Cl.7.3.2

Assume bolt threads in the shear plane

$V_r = 0.7\ V_r$

$A_b = \pi\ 6.35^2 / 4 = 31.7\ mm^2$

$V_r = 0.7 * 31.7 * 827 = 18.3$ KN

Predicted Mode of Failure: Bearing(4.6 KN)

D.2 Single Shear Single Bolted Connections With Washers

D.2.1.General Information

Test Specimen: 091-230-1/4-SS-D

	Top	Bottom
t_b	0.91mm	0.91mm
w	75mm	75mm
e	60mm	60mm
d	6.35mm	6.35mm
d_{hole}	7.938mm	7.938mm
f_y	293MPa	293MPa
f_u	354MPa	354MPa
f_{uBolt}	827MPa	827MPa
d_{uBolt}	6.35mm	6.35mm
p_{uBolt}	1.3mm	1.3mm
P_t	6.41KN	

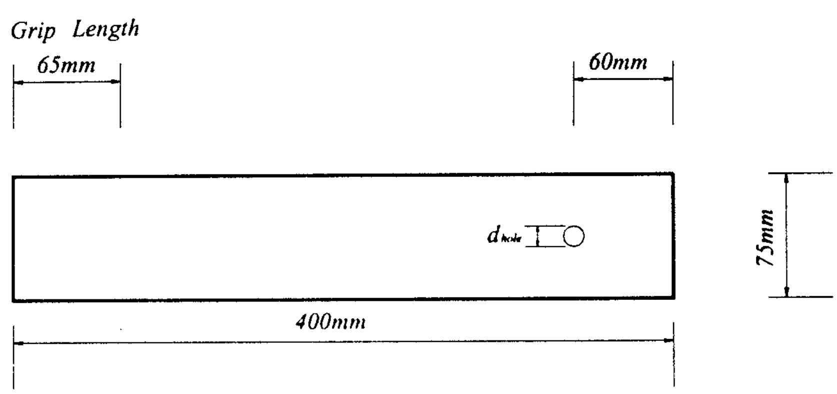


Figure D.2 Dimensions Of Test 091-230-1/4-SS-D

D.2.2. Canada (CSA, 1994)

$\phi = \phi_u = \phi_c = 1.0$

Gross Section Yielding

$T_r = \phi\, A_g\, F_y$ Cl.6.3.1

$Ag = 75 * 0.91 = 68.25\ mm^2$

$T_r = 1.0 * 68.25 * 293 = 20.0$ KN

Net Section Fracture

$T_r = \phi_u A_n F_u$ Cl.6.3.1
$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$
$T_r = 1.0 * 61.0 * 354 = 21.6$ KN

End Pull-Out

$T_r = \phi_u A_n F_u$ Cl.6.3.1
$A_n = 2 * 0.6 (60 - 0.5 * 7.938) * 0.91 = 61.2\ mm^2$
$T_r = 1.0 * 61.2 * 354 = 21.7$ KN

Bearing

$B_r = \phi_u C d t F_u$ Cl.7.3.5.1
$d/t = 6.35 / 0.91 = 6.98$
$C = 3$
$B_r = 1.0 * 3 * 6.35 * 0.91 * 354 = 6.1$ KN

Bolt Shear

$V_r = \phi c\ 0.6\ A_b F_u^*$ Cl.7.3.2
Assume bolt threads in the shear plane
$V_r = 0.7\ V_r$
$A_b = \pi\ 6.35^2 / 4 = 31.7\ mm^2$
$V_r = 0.7 * 31.7 * 827 = 18.3$ KN

Predicted Mode of Failure: Bearing (6.1 KN)

D.2.3. USA(AISI,1999)

Gross Section Yielding

$T_n = A_g F_y$ Eq. C2-1
$A_g = 75 * 0.91 = 68.25\ mm^2$
$Tn = 68.25 * 293 = 20.0$ KN

Net Section Fracture

$P_n = (1.0 - 0.9\ r + 3.0\ r\ d / s)\ A_n F_u \quad A_n F_u$ Eq. E3.2-1

$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$
$r = 1.0$
$P_n = (1.0 - 0.9*1.0 + 3.0 * 1.0 * 6.35 / 75) * 61.0 * 354 = 7.6\ KN$

End Pull-Out

$P_n = t\ e\ F_u$ Eq.E3.1-1
$P_n = 0.91 * (60 - 7.938 / 2) * 354 = 18.0\ KN$

Bearing

$P_n = 3.0\ F_u\ d\ t$ Table E3.3-1
$P_n = 3.0 * 354 * 6.35 * 0.91 = 6.1\ KN$

Bolt Shear

Assume bolt threads in the shear plane
$P_n = F\ A_b$ Eq. E3.4-1
$F = F_{nv} = 465$ MPa Table E3.4-1
$F = F_{nv} = 465$ Mpa
$A_b = \pi\ 6.35^2 / 4 = 31.7\ mm^2$
$P_n = 31.7 * 465 = 14.7\ KN$

Predicted Mode of Failure: Bearing (6.1 KN)

D.2.4. Australia/New Zealand (SA/SNZ, 1996)

Gross Section Yielding

$N^* \quad \phi_t N_t$ Sec. 3.2.1
$N_t = A_g f_y$ Eq. 3.2.1(1)
$A_g = 75 * 0.91 = 68.25\ mm^2$
$N_t = 68.25 * 293 = 20.0\ KN$

Net Section Fracture

$N^*_f \quad \phi_t N_f$ Sec. 5.3.3
$N_f = (1.0 - 0.9\ r + 3.0\ r_f d_f / s_f)\ A_n f_u \quad A_n f_u$ Eq. 5.3.3(1)
$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$
$r = 1.0$
$N_f = (1.0 - 0.9*1.0 + 3.0 * 1.0 * 6.35 / 75) * 61.0 * 354 = 7.6\ KN$
$N_f \quad 61 * 354 = 21.6\ KN$

End Pull-Out

$V^*_f \quad \phi V_f$ Sec. 5.3.2

$V_f = t\, e\, f_u$ Eq.5.3.2

$V_f = 0.91 * (60 - 7.938 / 2) * 354 = 18.0$ KN

Bearing

$V^*_b \quad \phi V_b$ Sec. 5.3.4

$V_b = 3.0\, f_u\, d_f\, t$ Table 5.3.4.1

$V_b = 3.0 * 354 * 6.35 * 0.91 = 6.1$ KN

Bolt Shear

Assume bolt threads in the shear plane

$V^*_{fv} \quad \phi V_{fv}$ Sec. 5.3.5.1

$V^*_{fv} = 0.62\, f_{uf} (n_n A_c + n_x A_o)$ Eq. 5.3.5.1

$A_c = \pi\, (d_{bolt} - 1.0825\, p_{uBolt})^2 / 4$

$A_c = \pi\, (6.35 - 1.0825 * 1.3)^2 / 4 = 19.2 \text{ mm}^2$

$V^*_{fv} = 0.62 * 827 * (1 * 19.2) = 9.8$ KN

Predicted Mode of Failure: Bearing (6.1 KN)

D.2.5. Europe (Eurocode, 1996)

$\gamma_{MO} = \gamma_{M2} = 1.0$

Gross Section Yielding Sec. 5.2

$N_{t,\,Rd} = f_{ya}\, A_g / \gamma_{MO}$ Eq. 5.1

$A_g = 75 * 0.91 = 68.25 \text{ mm}^2$

$N_{t,\,Rd} = 68.25 * 293 / 1.0 = 20.0$ KN

Net Section Fracture Sec. 8.4

$F_{n,\,Rd} = (1.0 + 3r\, (d_0 / u - 0.3))\, A_{net}\, f_u / \gamma_{M2} \quad A_{net}\, f_u / \gamma_{M2}$ Table 8.4

$A_{net} = 68.25 - 0.91 * 7.938 = 61.0 \text{ mm}^2$

$r = 1.0$

$F_{n,\,Rd} = (1.0 + 3 * 1.0\, (7.938 / 75 - 0.3)) * 61.0 * 354 = 9.0$ KN

$F_{n,\,Rd} \quad 61 * 354 / 1.0 = 21.6$ KN

End Pull-Out Sec. 8.4

$F_{b,\,Rd} = f_u\, e_1\, t / 1.2 / \gamma_{M2}$ Table 8.4

$F_{b,\,Rd} = 354 * (60 - 7.938 / 2) * 0.91 / 1.2 / 1.0 = 15.0$ KN

Bearing Sec.8.4

$F_{b,Rd} = 2.5\ f_u\ d\ t / \gamma_{M2}$ Table 8.4

$F_{b,Rd} = 2.5 * 354 * 6.35 * 0.91 / 1.0 = 5.1$ KN

Bolt Shear Sec.8.4

Assume bolt threads in the shear plane

$F_{v,Rd} = 0.6\ f_{ub}\ A_s / \gamma_{M2}$ Table 8.4

$A_s = \pi\ (d_{bolt} - 0.9382\ p_{uBolt})^2 / 4$

$A_s = \pi\ (6.35 - 0.9382 * 1.3)^2 / 4 = 20.7\ mm^2$

$F_{v,Rd} = 0.6 * 827 * 20.7 / 1.0 = 10.3$ KN

Predicted Mode of Failure: Bearing (5.1 KN)

D.2.6. Method proposed by University of Sydney (1998)

Gross Section Yielding

$T_r = A_g\ F_y$

$A_g = 75 * 0.91 = 68.25\ mm^2$

$T_r = 1.0 * 68.25 * 293 = 20.0$ KN

Net Section Fracture

$T_r = A_n\ F_u$

$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$

$T_r = 1.0 * 61.0 * 354 = 21.6$ KN

End Pull-Out

$V_f = f_u\ e\ t / 1.2$

$V_f = 354 * (60 - 7.938 / 2) * 0.91 / 1.2 = 15.0$ KN

Bearing

$B_r = C\ d\ t\ F_u$

$d/t = 6.35 / 0.91 = 6.98$

$C = 3$

$B_r = 1.0 * 3 * 6.35 * 0.91 * 354 = 6.1$ KN

Predicted Mode of Failure: Bearing (6.1 KN)

D.2.7. Proposed North America Specification

D.2.7a United States & Mexico

Gross Section Yielding

$T_n = A_g F_y$ Eq. C2-1
$A_g = 75 * 0.91 = 68.25$ mm^2
$T_n = 68.25 * 293 = 20.0$ KN

Net Section Fracture

$P_n = (0.1+3\ d\ /\ s)\ A_n F_u \quad A_n F_u$ Eq. E3.2-4
$A_n = 68.25 - 0.91 * 7.938 = 61.0$ mm^2
$P_n = (0.1 + 3.0 * 6.35 / 75) * 61.0 * 354 = 7.6$ KN

End Pull-Out

$P_n = t\ e\ F_u$ Eq.E3.1-1
$P_n = 0.91 * (60 - 7.938 / 2) * 354 = 18.0$ KN

Bearing

$P_n = \alpha\ C\ d\ t\ F_u$ Eq. E3.3.1-1
$d / t = 7.938 / 0.91 = 8.72 < 10$
$C = 3.0$ Table E3.3.1-1
$\alpha = 1.0$ Table E3.3.1-2
$P_n = 1.0 * 3.0 * 6.35 * 0.91 * 354 = 6.1$ KN

Bolt Shear

Assume bolt threads in the shear plane
$P_n = F\ A_b$ Eq. E3.4-1
$F = F_{nv} = 465$ Mpa Table E3.4-1
$F = F_{nv} = 465$ Mpa
$A_b = \pi\ 6.35^2 / 4 = 31.7$ mm^2
$P_n = 31.7 * 465 = 14.7$ KN

Predicted Mode of Failure: Bearing (6.1 KN)

D.2.7b Canada

$\phi = \phi_u = \phi_c = 1.0$

Gross Section Yielding

$T_r = \phi\ A_g\ F_y$ Eq. C2.1-1

$A_g = 75 * 0.91 = 68.25\ mm^2$

$T_r = 1.0 * 68.25 * 293 = 20.0$ KN

Net Section Fracture

$T_r = \phi_u\ A_n\ F_u$ Eq. C2.2-1

$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$

$T_r = 1.0 * 61.0 * 354 = 21.6$ KN

End Pull-Out

$T_r = \phi_u\ A_n\ F_u$ Eq. C2.2-1

$A_n = 2 * 0.6\ (60 - 0.5 * 7.938) * 0.91 = 61.2\ mm^2$

$T_r = 1.0 * 61.2 * 354 = 21.7$ KN

Bearing

$P_n = \alpha\ C\ d\ t\ F_u$ Eq. E3.3.1-1

$d / t = 7.938 / 0.91 = 8.72 < 10$

$C = 3.0$ Table E3.3.1-1

$\alpha = 1.0$ Table E3.3.1-2

$P_n = 1.0 * 3.0 * 6.35 * 0.91 * 354 = 6.1$ KN

Bolt Shear

$V_r = \phi_c\ 0.6\ A_b\ F_u^*$ Cl.7.3.2

Assume bolt threads in the shear plane

$V_r = 0.7\ V_r$

$A_b = \pi\ 6.35^2 / 4 = 31.7\ mm^2$

$V_r = 0.7 * 31.7 * 827 = 18.3$ KN

Predicted Mode of Failure: Bearing (6.1 KN)

D.3 Double Shear Single Bolted Connections Without Washers

D.3.1.General Information

Test Specimen: 091-230-1/4-DS-A

	Top	Bottom
t_b	0.91mm	1.51mm
w	75mm	75mm
e	60mm	60mm
d	6.35mm	6.35mm
d_{hole}	7.938mm	7.938mm
f_y	293MPa	295MPa
f_u	354MPa	361MPa
f_{uBolt}	827MPa	827MPa
d_{uBolt}	6.35mm	6.35mm
p_{uBolt}	1.3mm	1.3mm
P_t	12.69 KN	

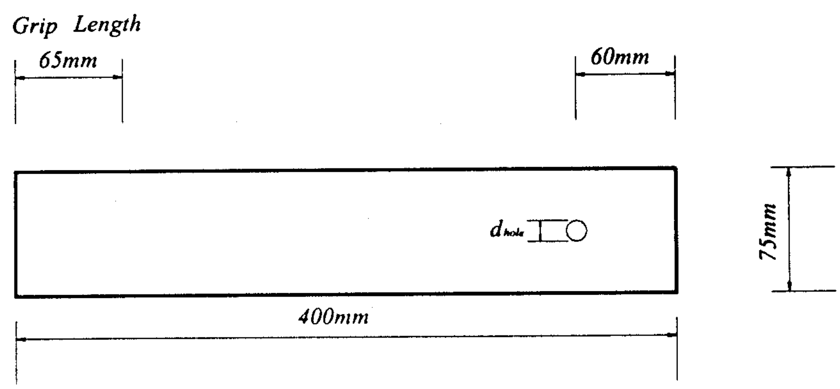


Figure D.3 Dimensions Of Test 091-230-1/4-DS-A

D.3.2. Canada (CSA, 1994)

$\phi = \phi_u = \phi_c = 1.0$

Gross Section Yielding

$T_r = \phi\, A_g\, F_y$ Cl.6.3.1
$Ag = 75 * 0.91 = 68.25\ mm^2$
$T_r = 1.0 * 68.25 * 293 = 20.0\ KN$

Net Section Fracture

$T_r = \phi_u\, A_n\, F_u$ — Cl.6.3.1

$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$

$T_r = 1.0 * 61.0 * 354 = 21.6\ KN$

End Pull-Out

$T_r = \phi_u\, A_n\, F_u$ — Cl.6.3.1

$A_n = 2 * 0.6\ (60 - 0.5 * 7.938) * 0.91 = 61.2\ mm^2$

$T_r = 1.0 * 61.2 * 354 = 21.7\ KN$

Bearing

$B_r = \phi_u\, C\, d\, t\, F_u$ — Cl.7.3.5.1

$d/t = 6.35 / 0.91 = 6.98$

$C = 3$

$B_r = 1.0 * 3 * 6.35 * 0.91 * 354 = 6.1\ KN$

Bolt Shear

$V_r = \phi_c\, 0.6\, A_b\, F_u^*$ — Cl.7.3.2

Assume bolt threads in the shear plane

$V_r = 0.7\ V_r$

$A_b = 2\ \pi\ 6.35^2 / 4 = 63.4\ mm^2$

$V_r = 0.7 * 63.4 * 827 = 36.6\ KN$

Predicted Mode of Failure: Bearing (6.1 KN)

D.3.3. USA (AISI,1999)

Gross Section Yielding

$T_n = A_g\, F_y$ — Eq. C2-1

$A_g = 75 * 0.91 = 68.25\ mm^2$

$Tn = 68.25 * 293 = 20.0\ KN$

Net Section Fracture

$P_n = (1.0 - r + 2.5\ r\ d / s)\ A_n\, F_u \quad A_n\, F_u$ — Eq. E3.2-1

$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$

$r = 1.0$

$P_n = (1.0 - 1.0 + 2.5 * 1.0 * 6.35 / 75) * 61.0 * 354 = 4.6\ KN$

End Pull-Out

$P_n = t\ e\ F_u$ Eq.E3.1-1
$P_n = 0.91 * (60 - 7.938 / 2) * 354 = 18.0$ KN

Bearing

$P_n = 3.0\ F_u\ d\ t$ Table E3.3-1
$P_n = 3.0 * 354 * 6.35 * 0.91 = 6.1$ KN

Bolt Shear

Assume bolt threads in the shear plane
$P_n = F\ A_b$ Eq. E3.4-1
$F = F_{nv} = 465$ MPa Table E3.4-1
$F = F_{nv} = 465$ MPa
$A_b = 2\ \pi\ 6.35^2 / 4 = 63.4$ mm^2
$P_n = 63.4 * 465 = 29.4$ KN

Predicted Mode of Failure: Bearing (6.1 KN)

D.3.4. Australia/New Zealand (SA/SNZ, 1996)

Gross Section Yielding

$N^* \quad \phi_t N_t$ Sec. 3.2.1
$N_t = A_g\ f_y$ Eq. 3.2.1(1)
$A_g = 75 * 0.91 = 68.25$ mm^2
$N_t = 68.25 * 293 = 20.0$ KN

Net Section Fracture

$N^*_f \quad \phi_t N_f$ Sec. 5.3.3
$N_f = (1.0 - r + 2.5\ r_f d_f / s_f)\ A_n\ f_u \quad A_n\ f_u$ Eq. 5.3.3(1)
$A_n = 68.25 - 0.91 * 7.938 = 61.0$ mm^2
$r = 1.0$
$N_f = (1.0 - 1.0 + 2.5 * 1.0 * 6.35 / 75) * 61.0 * 354 = 4.6$ KN
$N_f \quad 61 * 354 = 21.6$ KN

End Pull-Out

$V^*_f \quad \phi\ V_f$ Sec. 5.3.2
$V_f = t\ e\ f_u$ Eq.5.3.2
$V_f = 0.91 * (60 - 7.938 / 2) * 354 = 18.0$ KN

Bearing

$V^*_b \quad \phi V_b$ — Sec. 5.3.4

$V_b = 3.0 f_u d_f t$ — Table 5.3.4.1

$V_b = 3.0 * 354 * 6.35 * 0.91 = 4.5$ KN

Bolt Shear

Assume bolt threads in the shear plane

$V^*_{fv} \quad \phi V_{fv}$ — Sec. 5.3.5.1

$V^*_{fv} = 0.62 f_{uf} (n_n A_c + n_x A_o)$ — Eq. 5.3.5.1

$A_c = 2 \pi (d_{bolt} - 1.0825 p_{uBolt})^2 / 4$

$A_c = 2 \pi (6.35 - 1.0825 * 1.3)^2 / 4 = 38.4$ mm^2

$V^*_{fv} = 0.62 * 827 * (1 * 38.4) = 19.6$ KN

Predicted Mode of Failure: Bearing (4.5 KN)

D.3.5. Europe (Eurocode, 1996)

$\gamma_{MO} = \gamma_{M2} = 1.0$

Gross Section Yielding — Sec. 5.2

$N_{t, Rd} = f_{ya} A_g / \gamma_{MO}$ — Eq. 5.1

$A_g = 75 * 0.91 = 68.25$ mm^2

$N_{t, Rd} = 68.25 * 293 / 1.0 = 20.0$ KN

Net Section Fracture — Sec. 8.4

$F_{n, Rd} = (1.0 + 3r (d_0 / u - 0.3)) A_{net} f_u / \gamma_{M2} \quad A_{net} f_u / \gamma_{M2}$ — Table 8.4

$A_{net} = 68.25 - 0.91 * 7.938 = 61.0$ mm^2

$r = 1.0$

$F_{n, Rd} = (1.0 + 3 * 1.0 (7.938 / 75 - 0.3)) * 61.0 * 354 = 9.0$ KN

$F_{n, Rd} \quad 61 * 354 / 1.0 = 21.6$ KN

End Pull-Out — Sec. 8.4

$F_{b, Rd} = f_u e_1 t / 1.2 / \gamma_{M2}$ — Table 8.4

$F_{b, Rd} = 354 * (60 - 7.938 / 2) * 0.91 / 1.2 / 1.0 = 15.0$ KN

Bearing — Sec.8.4

$F_{b, Rd} = 2.5 f_u d t / \gamma_{M2}$ — Table 8.4

$F_{b, Rd} = 2.5 * 354 * 6.35 * 0.91 / 1.0 = 5.1$ KN

Bolt Shear Sec.8.4

Assume bolt threads in the shear plane
$F_{v,Rd} = 0.6\ f_{ub}\ A_s / \gamma_{M2}$ Table 8.4
$A_s = 2\ \pi\ (d_{bolt} - 0.9382\ p_{uBolt})^2 / 4$
$A_s = 2\ \pi\ (6.35 - 0.9382 * 1.3)^2 / 4 = 41.4\ mm^2$
$F_{v,Rd} = 0.6 * 827 * 41.4 / 1.0 = 20.6$ KN

Predicted Mode of Failure: Bearing (5.1 KN)

D.3.6. Proposed North American Specification

D.3.6a United States & Mexico

Gross Section Yielding

$T_n = A_g\ F_y$ Eq. C2-1
$A_g = 75 * 0.91 = 68.25\ mm^2$
$T_n = 68.25 * 293 = 20.0$ KN

Net Section Fracture

$P_n = (2.5\ d / s)\ A_n\ F_u \quad A_n\ F_u$ Eq. E3.2-4
$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$
$P_n = (2.5 * 6.35 / 75) * 61.0 * 354 = 4.6$ KN

End Pull-Out

$P_n = t\ e\ F_u$ Eq.E3.1-1
$P_n = 0.91 * (60 - 7.938 / 2) * 354 = 18.0$ KN

Bearing

$P_n = \alpha\ C\ d\ t\ F_u$ Eq. E3.3.1-1
$d / t = 7.938 / 0.91 = 8.72 < 10$
$C = 3.0$ Table E3.3.1-1
$\alpha = 1.33$ Table E3.3.1-2
$P_n = 1.33 * 3.0 * 6.35 * 0.91 * 354 = 8.2$ KN

Bolt Shear

Assume bolt threads in the shear plane
$P_n = F\ A_b$ Eq. E3.4-1
$F = F_{nv} = 465$ Mpa Table E3.4-1
$F = F_{nv} = 465$ Mpa

$A_b = 2\ \pi\ 6.35^2 / 4 = 63.4\ mm^2$
$P_{..} = 63.4 * 465 = 29.4$ KN

Predicted Mode of Failure: Net Section Fracture (4.6 KN)

D.3.6b Canada

$\phi = \phi_u = \phi_c = 1.0$

Gross Section Yielding

$T_r = \phi\ A_g\ F_y$ Eq. C2.1-1
$A_g = 75 * 0.91 = 68.25\ mm^2$
$T_r = 1.0 * 68.25 * 293 = 20.0$ KN

Net Section Fracture

$T_r = \phi_u\ A_n\ F_u$ Eq. C2.2-1
$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$
$T_r = 1.0 * 61.0 * 354 = 21.6$ KN

End Pull-Out

$T_r = \phi_u\ A_n\ F_u$ Eq. C2.2-1
$A_n = 2 * 0.6\ (60 - 0.5 * 7.938) * 0.91 = 61.2\ mm^2$
$T_r = 1.0 * 61.2 * 354 = 21.7$ KN

Bearing

$P_n = \alpha\ C\ d\ t\ F_u$ Eq. E3.3.1-1
$d / t = 7.938 / 0.91 = 8.72 < 10$
$C = 3.0$ Table E3.3.1-1
$\alpha = 1.33$ Table E3.3.1-2
$P_n = 1.33 * 3.0 * 6.35 * 0.91 * 354 = 8.2$ KN

Bolt Shear

$V_r = \phi_c\ 0.6\ A_b\ F_u^*$ Cl.7.3.2
Assume bolt threads in the shear plane
$V_r = 0.7\ V_r$
$A_b = 2\ \pi\ 6.35^2 / 4 = 63.4\ mm^2$
$V_r = 0.7 * 63.4 * 827 = 36.6$ KN

Predicted Mode of Failure: Bearing (8.2 KN)

D.4 Double Shear Single Bolted Connections With Washers

D.4.1.General Information

Test Specimen: 091-230-1/4-DS-D

	Top	Bottom
t_b	0.91mm	1.51mm
w	75mm	75mm
e	60mm	60mm
d	6.35mm	6.35mm
d_{hole}	7.938mm	7.938mm
f_y	293Mpa	295Mpa
f_u	354Mpa	361Mpa
f_{uBolt}	827Mpa	827Mpa
d_{uBolt}	6.35mm	6.35mm
p_{uBolt}	1.3mm	1.3mm
P_t	14.62 KN	

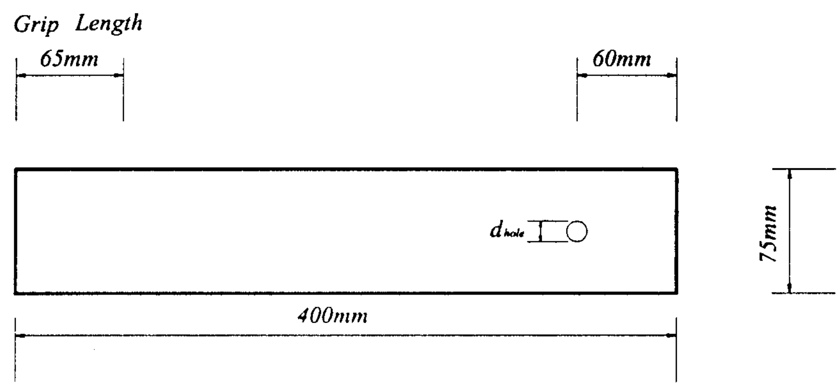


Figure D.4 Dimensions of Test 091-230-1/4-DS-D

D.4.2. Canada (CSA, 1994)

$\phi = \phi_u = \phi_c = 1.0$

Gross Section Yielding

$T_r = \phi\, A_g\, F_y$ Cl.6.3.1

$Ag = 75 * 0.91 = 68.25\ mm^2$

$T_r = 1.0 * 68.25 * 293 = 20.0$ KN

Net Section Fracture

$T_r = \phi_u\, A_n\, F_u$ Cl.6.3.1

$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$

$T_r = 1.0 * 61.0 * 354 = 21.6$ KN

End Pull-Out

$T_r = \phi_u\, A_n\, F_u$ Cl.6.3.1

$A_n = 2 * 0.6\,(60 - 0.5 * 7.938) * 0.91 = 61.2\ mm^2$

$T_r = 1.0 * 61.2 * 354 = 21.7$ KN

Bearing

$B_r = \phi_u\, C\, d\, t\, F_u$ Cl.7.3.5.1

$d/t = 6.35 / 0.91 = 6.98$

$C = 3$

$B_r = 1.0 * 3 * 6.35 * 0.91 * 354 = 6.1$ KN

Bolt Shear

$V_r = \phi c\ 0.6\, A_b\, F_u^{*}$ Cl.7.3.2

Assume bolt threads in the shear plane

$V_r = 0.7\, V_r$

$A_b = 2\,\pi\, 6.35^2 / 4 = 63.4\ mm^2$

$V_r = 0.7 * 63.4 * 827 = 36.6$ KN

Predicted Mode of Failure: Bearing (6.1 KN)

D.4.3. USA(AISI,1999)

Gross Section Yielding

$T_n = A_g\, F_y$ Eq. C2-1

$A_g = 75 * 0.91 = 68.25\ mm^2$

$Tn = 68.25 * 293 = 20.0$ KN

Net Section Fracture

$P_n = (1.0 - 0.9\, r + 3.0\, r\, d / s)\, A_n\, F_u \quad A_n\, F_u$ Eq. E3.2-1

$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$
$r = 1.0$
$P_n = (1.0 - 0.9*1.0 + 3.0 * 1.0 * 6.35 / 75) * 61.0 * 354 = 7.6\ KN$

End Pull-Out

$P_n = t\ e\ F_u$ Eq.E3.1-1
$P_n = 0.91 * (60 - 7.938 / 2) * 354 = 18.0\ KN$

Bearing

$P_n = 3.33\ F_u\ d\ t$ Table E3.3-1
$P_n = 3.33 * 354 * 6.35 * 0.91 = 6.8\ KN$

Bolt Shear

Assume bolt threads in the shear plane
$P_n = F\ A_b$ Eq. E3.4-1
$F = F_{nv} = 465$ Mpa Table E3.4-1
$F = F_{nv} = 465$ Mpa
$A_b = 2\ \pi\ 6.35^2 / 4 = 63.4\ mm^2$
$P_n = 63.4 * 465 = 29.4\ KN$

Predicted Mode of Failure: Bearing (6.8 KN)

D.4.4. Australia/New Zealand(AS/NZS, 1996)

Gross Section Yielding

$N^* \quad \phi_t N_t$ Sec. 3.2.1
$N_t = A_g\ f_y$ Eq. 3.2.1(1)
$A_g = 75 * 0.91 = 68.25\ mm^2$
$N_t = 68.25 * 293 = 20.0\ KN$

Net Section Fracture

$N^*_f \quad \phi_t N_f$ Sec. 5.3.3
$N_f = (1.0 - 0.9\ r + 3.0\ r_f d_f / s_f)\ A_n f_u \quad A_n f_u$ Eq. 5.3.3(1)
$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$
$r = 1.0$
$N_f = (1.0 - 0.9*1.0 + 3.0 * 1.0 * 6.35 / 75) * 61.0 * 354 = 7.6\ KN$
$N_f \quad 61 * 354 = 21.6\ KN$

End Pull-Out

$V^*_f \quad \phi V_f$ Sec. 5.3.2

$V_f = t\, e\, f_u$ Eq.5.3.2

$V_f = 0.91 * (60 - 7.938 / 2) * 354 = 18.0$ KN

Bearing

$V^*_b \quad \phi V_b$ Sec. 5.3.4

$V_b = 3.33\, f_u\, d_f\, t$ Table 5.3.4.1

$V_b = 3.33 * 354 * 6.35 * 0.91 = 6.8$ KN

Bolt Shear

Assume bolt threads in the shear plane

$V^*_{fv} \quad \phi V_{fv}$ Sec. 5.3.5.1

$V^*_{fv} = 0.62\, f_{uf}\, (n_n A_c + n_x A_o)$ Eq. 5.3.5.1

$A_c = 2\, \pi\, (d_{bolt} - 1.0825\, p_{uBolt})^2 / 4$

$A_c = 2\, \pi\, (6.35 - 1.0825 * 1.3)^2 / 4 = 38.4\ mm^2$

$V^*_{fv} = 0.62 * 827 * (1 * 38.4) = 19.6$ KN

Predicted Mode of Failure: Bearing (6.8 KN)

D.4.5. Europe (Eurocode, 1996)

$\gamma_{MO} = \gamma_{M2} = 1.0$

Gross Section Yielding Sec. 5.2

$N_{t,Rd} = f_{ya}\, A_g / \gamma_{MO}$ Eq. 5.1

$A_g = 75 * 0.91 = 68.25\ mm^2$

$N_{t,Rd} = 68.25 * 293 / 1.0 = 20.0$ KN

Net Section Fracture Sec. 8.4

$F_{n,Rd} = (1.0 + 3r\, (d_0 / u - 0.3))\, A_{net}\, f_u / \gamma_{M2} \quad A_{net}\, f_u / \gamma_{M2}$ Table 8.4

$A_{net} = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$

$r = 1.0$

$F_{n,Rd} = (1.0 + 3 * 1.0\, (7.938 / 75 - 0.3)) * 61.0 * 354 = 9.0$ KN

$F_{n,Rd} \quad 61 * 354 / 1.0 = 21.6$ KN

End Pull-Out Sec. 8.4

$F_{b,Rd} = f_u\, e_1\, t / 1.2 / \gamma_{M2}$ Table 8.4

$F_{b,Rd} = 354 * (60 - 7.938 / 2) * 0.91 / 1.2 / 1.0 = 15.0$ KN

Bearing Sec.8.4

$F_{b,Rd} = 2.5\ f_u\ d\ t\ /\ \gamma_{M2}$ Table 8.4

$F_{b,Rd} = 2.5 * 354 * 6.35 * 0.91 / 1.0 = 5.1$ KN

Bolt Shear Sec.8.4

Assume bolt threads in the shear plane

$F_{v,Rd} = 0.6\ f_{ub}\ A_s / \gamma_{M2}$ Table 8.4

$A_s = 2\ \pi\ (d_{bolt} - 0.9382\ p_{uBolt})^2 / 4$

$A_s = 2\ \pi\ (6.35 - 0.9382 * 1.3)^2 / 4 = 41.4\ mm^2$

$F_{v,Rd} = 0.6 * 827 * 41.4 / 1.0 = 20.6$ KN

Predicted Mode of Failure: Bearing(5.1 KN)

D.4.6. Method proposed by University of Sydney (1998)

Gross Section Yielding

$T_r = A_g\ F_y$

$A_g = 75 * 0.91 = 68.25\ mm^2$

$T_r = 1.0 * 68.25 * 293 = 20.0$ KN

Net Section Fracture

$T_r = A_n\ F_u$

$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$

$T_r = 1.0 * 61.0 * 354 = 21.6$ KN

End Pull-Out

$V_f = f_u\ e\ t / 1.2$

$V_f = 354 * (60 - 7.938 / 2) * 0.91 / 1.2 = 15.0$ KN

Bearing

$B_r = C\ d\ t\ F_u$

$d/t = 6.35 / 0.91 = 6.98$

$C = 3$

$B_r = 1.0 * 3 * 6.35 * 0.91 * 354 = 6.1$ KN

Predicted Mode of Failure: Bearing (6.1 KN)

D.4.7. Proposed North American Specification

D.4.7a United States (AISI, 2001a)

Gross Section Yielding

$T_n = A_g F_y$ Eq. C2-1
$A_g = 75 * 0.91 = 68.25\ mm^2$
$T_n = 68.25 * 293 = 20.0$ KN

Net Section Fracture

$P_n = (0.1+3\ d / s)\ A_n F_u \quad A_n F_u$ Eq. E3.2-4
$A_n = 68.25 - 0.91 * 7.938 = 61.0\ mm^2$
$P_n = (0.1 + 3.0 * 6.35 / 75) * 61.0 * 354 = 7.6$ KN

End Pull-Out

$P_n = t\ e\ F_u$ Eq.E3.1-1
$P_n = 0.91 * (60 - 7.938 / 2) * 354 = 18.0$ KN

Bearing

$P_n = \alpha\ C\ d\ t\ F_u$ Eq. E3.3.1-1
$d / t = 7.938 / 0.91 = 8.72 < 10$
$C = 3.0$ Table E3.3.1-1
$\alpha = 1.33$ Table E3.3.1-2
$P_n = 1.33 * 3.0 * 6.35 * 0.91 * 354 = 8.2$ KN

Bolt Shear

Assume bolt threads in the shear plane
$P_n = F\ A_b$ Eq. E3.4-1
$F = F_{nv} = 465$ Mpa Table E3.4-1
$F = F_{nv} = 465$ Mpa
$A_b = 2\ \pi\ 6.35^2 / 4 = 63.4\ mm^2$
$P_n = 63.4 * 465 = 14.7$ KN

Predicted Mode of Failure: Net Section Fracture (7.6 KN)

D.4.7b Canada (CSA, 2001)

$\phi = \phi_u = \phi_c = 1.0$

Gross Section Yielding

$T_r = \phi \, A_g \, F_y$ Eq. C2.1-1
$A_g = 75 * 0.91 = 68.25 \text{ mm}^2$
$T_r = 1.0 * 68.25 * 293 = 20.0$ KN

Net Section Fracture

$T_r = \phi_u \, A_n \, F_u$ Eq. C2.2-1
$A_n = 68.25 - 0.91 * 7.938 = 61.0 \text{ mm}^2$
$T_r = 1.0 * 61.0 * 354 = 21.6$ KN

End Pull-Out

$T_r = \phi_u \, A_n \, F_u$ Eq. C2.2-1
$A_n = 2 * 0.6\,(60 - 0.5 * 7.938) * 0.91 = 61.2 \text{ mm}^2$
$T_r = 1.0 * 61.2 * 354 = 21.7$ KN

Bearing

$P_n = \alpha \, C \, d \, t \, F_u$ Eq. E3.3.1-1
$d / t = 7.938 / 0.91 = 8.72 < 10$
$C = 3.0$ Table E3.3.1-1
$\alpha = 1.33$ Table E3.3.1-2
$P_n = 1.33 * 3.0 * 6.35 * 0.91 * 354 = 8.2$ KN

Bolt Shear

$V_r = \phi_c \, 0.6 \, A_b \, F_u^*$ Cl.7.3.2
Assume bolt threads in the shear plane
$V_r = 0.7 \, V_r$
$A_b = \pi \, 6.35^2 / 4 = 31.7 \text{ mm}^2$
$V_r = 0.7 * 31.7 * 827 = 18.3$ KN

Predicted Mode of Failure: Bearing(8.2 KN)