5.3.3 Spacing and edge distance

In addition to the requirements of Clause 5.3.4, the minimum distance between centres of bolt holes shall provide sufficient clearance for bolt heads, nuts, washers and the wrench, but shall not be less than $3d_f$. Also, the distance from the centre of any standard hole to the end or other boundary of the connecting member shall not be less than $1.5d_f$.

For oversized and slotted holes, the distance between the edges of two adjacent holes and the distance from the edge of the hole to the end or other boundary of the connecting member in the line of force shall not be less than $[e-(d_h/2)]$, where e is the distance measured in the line of the applied force from the centre of a standard hole to the nearest edge of an adjacent hole or to the end of the connected part.

The clear distance between the edges of two adjacent holes shall not be less than $2d_f$ and the distance between the edge of the hole and the end of the member shall not be less than d_f.

5.3.4 Tear out capacity of the connected part

For lapped joints between structural members in which bolts are loaded in shear, both the spacing between bolts and the edge distance from a bolt in the line of the applied force shall be such that in a connected part—

$$V_f^* \leq \phi V_f \qquad \text{. . . 5.3.4(1)}$$

where

V_f^* = design shear force per bolt

ϕ = 0.70

V_f = nominal shear capacity per bolt

= $te f_{ut}$ . . . 5.3.4(2)

t = thickness of the thinnest connected part

f_{ut} = tensile strength of the connected part transverse to the direction of the applied force.

5.3.5 Net section tensile capacity of the connected part

For lap joints between structural members in which bolts are loaded in shear, both the spacing between bolts and the edge distance from a bolt transverse to the line of the applied force shall be such that in a connected part—

$$N_f^* \leq \phi N_f \qquad \text{. . . 5.3.5(1)}$$

where

N_f^* = design tensile force in the connected part

ϕ = 0.70

N_f = nominal tensile capacity of the connected part

= $A_n f_t$ . . . 5.3.5(2)

A_n = net area of the connected part at the line of bolts transverse to the line of the applied force

f_t = tensile strength for connections with washers under both bolt head and nut, determined as follows:

(a) For single shear connections:

$$f_t = \left(1.0 - r_f + (2.5 r_f d_f / s_f)\right) f_u \leq f_u \qquad \text{. . . 5.3.5(3)}$$

(b) For double shear connection:

$$f_t = \left(1.0 - 0.9 r_f + (3 r_f d_f / s_f)\right) f_u \leq f_u \qquad \text{. . . 5.3.5(4)}$$

r_f = ratio of the force transmitted by the bolt or bolts at the section considered, divided by the tensile force in the member at that section. If r_f is less than 0.2, it may be taken as zero

s_f = spacing of bolts transverse to the line of the force, or in the case of a single bolt, the width of the connected part

f_u = tensile strength of the connected part in the direction of the applied force.

In addition, N_f^* shall not be greater than $0.85 A_n f_y$, where f_y is the specified yield stress in tension of the connected part.

5.3.6 Bearing capacity of the connected part

For lapped joints between structural members in which bolts are loaded in shear, the design bearing force (V_b^*) at a bolt shall be such that in a connected part—

$$V_b^* \leq \phi V_b \qquad \text{. . . 5.3.6(1)}$$

where

ϕ = 0.65

V_b = nominal bearing capacity per bolt of the connected part, where bolts have washers under both bolt head and nut, determined as follows:

(a) For single shear connections:

$$V_b = 2.0 d_f t f_u \qquad \text{. . . 5.3.6(2)}$$

(b) For double shear connection:

$$V_b = 2.75 d_f t f_u \qquad \text{. . . 5.3.6(3)}$$

f_u = compressive strength of the connected part in the direction of the applied force.

5.3.7 Stainless steel bolts to ASTM Standards

5.3.7.1 *General*

The design capacity of bolts determined in accordance with Clause 5.3.7 applies to bolts complying with ASTM A 193/A 193 M, ASTM A 276 and ASTM F 593.

The design capacity described in this Clause is based on the provisions of ANSI/ASCE-8-90.

The nominal shear strength (f_{nv}) and the nominal tensile strength (f_{nt}) for stainless steel bolts complying with ASTM Standards shall be obtained from Table 5.3.7, as appropriate.

5.3.7.2 *Bolts in shear*

The design shear force (V_{fv}^*) for bolts loaded in shear shall satisfy—

$$V_{fv}^* \leq \phi V_{fv} \qquad \text{. . . 5.3.7.2(1)}$$

where

ϕ = 0.65

V_{fv} = nominal shear capacity of the stainless steel bolt

$= A_f f_{nv}$ . . . 5.3.7.2(2)

A_f = gross cross-sectional area of the stainless steel bolt

f_{nv} = nominal shear strength of the stainless steel bolt given in Table 5.3.7.

5.3.7.3 *Bolts in tension*

The design tensile force $\left(N^*_{ft}\right)$ shall satisfy—

$$N^*_{ft} \leq \phi N_{ft} \quad \text{. . . 5.3.7.3(1)}$$

where

ϕ = 75

$N_{ft} = A_f f_{nt}$ . . . 5.3.7.3(2)

f_{nt} = nominal tensile strength of the stainless steel bolt given in Table 5.3.7

The pull-over (pull-through) capacity of the connected part at the bolt head, nut or washer shall be considered where bolt tension is concerned.

The increase in pull-out force resulting from bending moments or prying forces transmitted into the bolt from various adjacent structural components shall be taken into account.

5.3.7.4 *Bolts in combined shear and tension*

For a bolt subjected simultaneously to a design shear force (V^*_{fv}) and a design tensile force $\left(N^*_{ft}\right)$, the design tensile force $\left(N^*_{ft}\right)$ shall satisfy—

$$N^*_{ft} \leq \phi N'_{ft} \quad \text{. . . 5.3.7.4(1)}$$

where

ϕ = 0.75

$N^*_{ft} = A_f f'_{nt}$ . . . 5.3.7.4(2)

f'_{nt} shall be determined as follows:

(a) Threads in the shear plane—

$$f'_{nt} = 1.25 f_{nt} - 2.4 f_v \leq f_{nt} \quad \text{. . . 5.3.7.4(3)}$$

(b) No threads in the shear plane—

$$f'_{nt} = 1.25 f_{nt} - 1.9 f_v \leq f_{nt} \quad \text{. . . 5.3.7.4(4)}$$

where

f'_{nt} = nominal tensile strength for bolts subject to combined shear and tension

f_{nt} = nominal tensile strength given in Table 5.3.7

f_v = shear stress resulting from the design shear force $\left(V^*_{fv}\right)$

$$= \frac{V^*_{fv}}{A_f} \leq f_{nv} \quad \text{. . . 5.3.7.4(5)}$$

f_{nv} = nominal shear strength given in Table 5.3.7

TABLE 5.3.7

NOMINAL SHEAR AND TENSILE STRENGTHS FOR STAINLESS STEEL BOLTS COMPLYING WITH ASTM STANDARDS

Type of stainless steel	Diameter (d_f) mm	Nominal shear strength (f_{nv}) (see Note 1) MPa		Nominal tensile strength (f_{nt}) (see Note 1) MPa
		No threads in shear plane	Threads in shear plane	
201 (see Note 2)	All	311	232	386
304, 316 (see Note 3)	All	311	232	386
304, 316 (see Notes 5)	≤ 12.7	372	279	465
304, 316 (see Note 7)	≤ 19.1	517	388	646
304, 316 (see Note 4)	$6.4 \leq d_f \leq 38.1$	290	217	362
304, 316 (see Note 6)	$6.4 \leq d_f \leq 15.9$	393	295	491
304, 316 (see Note 6)	$19.1 \leq d_f \leq 38.1$	331	248	414
430 (see Note 2)	All	248	186	310
430 (see Note 4)	$6.4 \leq d_f \leq 38.1$	290	217	362

NOTES:

1 Reduction of the nominal strength given in this Table is required for $d_f < 12.7$ mm. For $d_f < 12.7$ mm, the value shall be reduced to $0.9f_{nv}$ for nominal shear strength and to $0.9f_{nt}$ for nominal tensile strength.

2 Condition A in ASTM A 276, hot-finished or cold-finished.

3 Condition A in ASTM A 276, hot-finished and Class 1(solution-treated) in ASTM A 193/A 193M, hot-finished.

4 Condition A in ASTM F 593, machined from annealed or solution-annealed stock or hot-formed and solution-annealed. The minimum tensile strength is based on tests on the machined specimen.

5 Condition A in ASTM A 276, cold-finished.

6 Condition CW in ASTM F 593, headed and rolled from annealed stock thus acquiring a degree of cold work. Sizes 19.05 mm diameter and larger may be hot-worked. The minimum tensile strength is based on tests on the machined specimen.

7 Condition B (cold-worked) in ASTM A 276 cold-finished and Class 2 (solution-treated and strain-hardened) in ASTM A 193/A 193M.

5.3.8 Stainless steel bolts to ISO 3506

5.3.8.1 *General*

The design capacity of bolts determined in accordance with Clause 5.3.8 applies only to bolts and nuts complying with ISO 3506, with washers of austenitic stainless steel complying with ISO 7089 or ISO 7090, as appropriate.

The design capacity described in this Clause is based on the provisions of ENV 1993-1-1 and ENV 1993-1-4.

For items resisting shear or tension through the threaded portion with cut threads, such as anchor bolts or tie rods fabricated from round stainless steel bars where the threads are cut by the steelwork fabricator and not by a specialist bolt manufacturer, the relevant values given in Table 5.3.8 shall be reduced by multiplying them by a factor of 0.85.

The nominal yield stress (f_{ny}) and the nominal tensile strength (f_{nt}) for stainless steel bolts complying with ISO 3506 shall be obtained from Table 5.3.8, as appropriate.

The specified properties shall be verified by a recognized quality control system, with samples from each batch of fasteners.

TABLE 5.3.8

BOLTS COMPLYING WITH ISO 3506

Material groups	Property class to ISO 3506 (see Note 1)	Range of sizes	Nominal yield stress (f_{ny}) MPa	Nominal tensile strength (f_{nt}) MPa
Austenitic and austenitic ferritic	50	≤ M39	210	500
	70	≤ M20 (see Note 2)	450	700
	80	≤ M20 (see Note 2)	600	800

NOTES:

1 In addition to the various steel types specified in ISO 3506 under property classes 50, 70 and 80, other steel types to EN 10088-3 may also be used.

2 For bolts of property classes 70 and 80 with lengths greater than 8 diameters or with sizes larger than M20, the values of the mechanical properties shall be obtained from the bolt manufacturer.

5.3.8.2 *Bolts in shear*

The design shear force (V^*_{fv}) shall satisfy—

$$V^*_{fv} \leq \phi V_{fv}$$

Where

ϕ = 0.44

V_{fv} = $A_b f_{nt}$ if the shear plane passes through the unthreaded portion of the bolt; or

= $A_{bs} f_{nt}$ if the shear plane passes through the threaded portion of the bolt

A_b = gross cross-sectional area of the bolt

A_{bs} = tensile stress area of the bolt

f_{nt} = nominal tensile strength of the stainless steel bolt given in Table 5.3.8

The shear strength of a bolt in a lapped joint shall be the lesser of the shear capacity of the bolt (ϕV_{fv}) or the bearing capacity per bolt (ϕV_b), specified in Clause 5.3.6.

5.3.8.3 *Bolts in tension*

The design tensile force (N^*_{ft}), inclusive of any force due to prying action, shall satisfy—

$$N^*_{ft} \le \phi N_{ft}$$

where

ϕ = 0.67

N_{ft} = $A_{bs} f_{nt}$

f_{nt} = nominal tensile strength of the stainless steel bolt given in Table 5.3.8

The tensile capacity of a bolt in a joint shall be the lesser of the tensile capacity of the bolt (ϕN_{ft}) or the pull through (punching shear) resistance of the bolt head and nut (N^*_{pt}) calculated as follows:

$$N^*_{pt} = 0.44\phi d_m t_p f_u$$

where

d_m = mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

t_p = thickness of the plate under the bolt head or the nut

5.3.8.4 *Bolts in combined shear and tension*

A bolt subjected simultaneously to a design shear force (V^*_{fv}) and a design tensile force (N^*_{ft}) shall satisfy—

$$\frac{V^*_{fv}}{0.44V_{fv}} + \frac{N^*_{ft}}{0.94N_{ft}} \le 1.0$$

SECTION 6 TESTING

6.1 TESTING FOR DETERMINING MATERIAL PROPERTIES

6.1.1 Design based on measured values of yield stress

Where the design is based on measured values of yield stress as determined from mill certificates or in accordance with Clauses 6.1.2, 6.1.3, 6.1.4 and 6.1.5.2, the capacity [strength reduction] factors (ϕ) shall be reduced by 6%. Alternatively, the reduction in capacity [strength reduction] factor may be determined in accordance with Appendix K when statistical values of the mean and coefficient of variation of the ratio of measured to nominal yield stress is available, as it may apply to production runs of specific products.

6.1.2 Testing of unformed steel

Where the stainless steels specified in Clause 1.5.2.2 are used or the yield stress of stainless steel is required for the purpose of Clause 6.1.4, unformed stainless steel tensile properties shall be determined by tests in accordance with AS 1391.

Test specimens shall be taken from positions located one quarter of the coil width from either edge near the outer end of the coil or other location to determine the lowest strength of the material in the coil. At the option of the manufacturer, the test specimens may be cut longitudinally or transversely and may be tested in tension or compression, provided the manufacturer demonstrates that such tests reliably indicate the yield stress of the section when subjected to the kind of stress under which the member is to be used.

6.1.3 Compression testing

Compressive mechanical properties may be obtained from coupon or stub column tests. Compressive coupon tests shall be in accordance with ASTM E9. For coupon tests of unformed steel, test specimens shall be taken as specified in Clause 6.1.2.

Stub column tests shall be made on flat-end specimens whose length shall not be less than three times the largest dimension of the section but no more than 20 times the least radius of gyration. If tests of ultimate compressive strength are used to determine yield stress for quality control purposes, the length of the section shall be not less than 15 times the least radius of gyration. In making the compression tests, the specimen in the testing machine shall be centred so that the load is applied concentrically with respect to the centroidal axis of the section.

NOTE: For further information regarding compression testing using coupons or stub columns, reference may be made to ASTM E9, and to Technical Memoranda Nos 2 and 3 of the Column Research Council, 'Notes on Compression Testing of Materials', and 'Stub-Column Test Procedure', reprinted in the Column Research Council Guide to Stability Design Criteria for Metal Structures, Fifth Edition, 1998. Where tangent or secant moduli are to be derived from compression tests, reference is made to ASTM E111.

6.1.4 Testing of full sections

This Clause applies only to the determination of the mechanical properties of a fully formed section for the purposes specified in Clause 1.5.2.4. It shall not be interpreted as forbidding the use of test procedures instead of the usual design calculations.

The procedure shall be as follows:

(a) Determine the tensile yield stress (f_{yt}) in accordance with AS 1391 or the compressive yield stress (f_{yc}) by coupon testing in accordance with ASTM E9.

(b) Determine the compressive yield stress (f_{yc}) by means of compression tests as specified in Clause 6.1.3.

(c) Where the principal effect of the loading to which the member will be subjected in service is to produce bending stresses, determine the yield stress for the flanges. In determining the yield stress, carry out tests on specimens cut from the section. Each such specimen shall consist of one complete flange plus a portion of the web of such flat width ratio so that the section is fully effective.

(d) For acceptance and control purposes, make two full section tests from formed material lots. Material lots shall be considered as parcels, as defined in the relevant Standard's material specification in the Clauses on selection and preparation of test samples for mechanical testing.

(e) Use either tension or compression tests for routine acceptance and control purposes, provided it is demonstrated that such tests reliably indicate the yield stress of the section when subjected to the kind of stress under which the member is to be used.

6.1.5 Testing of flat coupons of formed members

6.1.5.1 *Assessment of strength increase*

Tests for determining material properties of flat coupons of formed members and material properties of unformed steel for the purpose of assessing strength increase resulting from cold-forming as specified in Clause 1.5.2.4 shall be made as follows:

(a) The yield stress of flats (f_{yf}) shall be established by means of a weighed average of the yield stresses of standard tensile coupons taken longitudinally from the major flat portions of a cold-formed member. The weighted average shall be the sum of the products of the average yield stress for each major flat portion times its cross-sectional area, divided by the total area of the major flats in the cross-section.

(b) Where the actual yield stress of the unformed steel exceeds the specified minimum yield stress, the yield stress of the flats (f_{yf}) shall be adjusted by multiplying the test values by the ratio of the specified minimum yield stress to the actual yield stress of the unformed steel.

6.1.5.2 *Design properties*

Tests for determining material properties of flat coupons of formed members for the purpose of establishing design properties of the formed members as specified in Clause 1.5.2.2 shall be made as follows:

(a) The test specimens shall be taken longitudinally from a major flat portion of the section midway between corners (excluding the corners) or midway between a corner and a free edge (excluding the corner).

(b) The test specimen shall be taken from the flat portion with the least strength increase from cold-forming.

(c) The minimum yield stress (f_y) and the minimum tensile strength (f_u) used in design shall be determined in accordance with AS 1391.

6.2 TESTING FOR ASSESSMENT OR VERIFICATION

6.2.1 General

The methods of test specified in this Clause apply to prototype units of complete structures, parts of structures, individual members or connections for design verification as an alternative to calculation. The methods do not apply to the testing of structural models nor to the establishment of general design criteria.

6.2.2 Static tests for strength or serviceability

6.2.2.1 *Test specimens*

The prototype test specimens shall be identical nominally to the class of units for which structural verification is required. The materials and fabrication of the prototype specimens shall comply with the relevant specifications used in production. Any additional requirements of a manufacturing specification shall be complied with. The method of assembly used shall simulate that which is used in production.

6.2.2.2 *Test loads*

The target test loads (R_t) for the number of units to be tested shall be equal to the design action effects [design actions] (S^*) for the relevant strength or serviceability requirements, multiplied by the appropriate factor (k_t) to allow for variability of structural units, given in Table 6.2.2, i.e. R_t is equal to $k_t S^*$.

The design action effects [design actions] shall be determined in accordance with AS 1170.1, AS 1170.2, AS 1170.3, AS 1170.4 or NZS 4203, as appropriate.

TABLE 6.2.2

FACTORS (k_t) TO ALLOW FOR VARIABILITY OF STRUCTURAL UNITS

No. of units to be tested	Coefficient of variation of structural characteristics (k_{sc})					
	5%	10%	15%	20%	25%	30%
1	1.20	1.46	1.79	2.21	2.75	3.45
2	1.17	1.38	1.64	1.96	2.36	2.86
3	1.15	1.33	1.56	1.83	2.16	2.56
4	1.15	1.30	1.50	1.74	2.03	2.37
5	1.13	1.28	1.46	1.67	1.93	2.23
10	1.10	1.21	1.34	1.49	1.66	1.85
100	1.00	1.00	1.00	1.00	1.00	1.00

6.2.2.3 *Coefficient of variation of structural characteristics*

The coefficient of variation of structural characteristics (k_{sc}) refers to the variability of the total population of the production units. This includes the total population variation due to fabrication (k_f) and material (k_m). It can be approximated as follows:

$$k_{sc} = \sqrt{k_f^2 + k_m^2} \quad \ldots 6.2.2.3$$

6.2.2.4 *Test requirements*

Loading devices shall be calibrated and care shall be taken to ensure that no unintentional restraints on the specimen are applied by the loading systems. The distribution and duration of the forces applied in the test shall represent those forces to which the structure is deemed to be subjected. For short-term static test, the test load shall be applied at a uniform rate such that the test duration shall be not less than 5 min.

Deformations shall, as a minimum, be recorded at the following times:

(a) Prior to the application of the test load.

(b) After the test load has been applied.

(c) After the removal of the test load.

6.2.2.5 *Criteria for acceptance*

Criteria for acceptance shall be as follows:

(a) Acceptance for static strength.

(b) All test units shall be capable of resisting the target test load.

(c) Acceptance for serviceability.

(d) All test units shall be capable of sustaining the target test load while remaining within the limiting serviceability value appropriate for the required performance level and the elastic recovery (after the removal of the test load) is 95% complete.

6.2.2.6 *Test report*

The report of the test of each unit shall contain, in addition to the test results, a clear statement of the conditions of testing, including the method of loading and of measuring deflection, together with any relevant data. The report shall also contain a statement as to whether the units tested satisfy the acceptance criteria.

6.2.2.7 *Design capacity of specific products and assemblies*

The design capacity (R_d) of a specific product or a specific assembly may be established by prototype testing of that specific product or assembly. The design capacity (R_d) shall satisfy—

$$R_d \leq \left(\frac{R_{min.}}{k_t}\right) \quad \ldots 6.2.2.7$$

where $R_{min.}$ is the minimum value of the test results and k_t is as given in Table 6.2.2.