PD 6695-1-10:2009

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Recommendations for the design of structures to BS EN 1993-1-10

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Foreword

Publishing information

This Published Document is published by BSI and came into effect on 31 January 2009. It was prepared by Subcommittee B/525/10, *Bridges*, in consultation with B/525/31, *Structural use of steel*, under the authority of Technical Committee B/525, *Building and civil engineering structures*. A list of organizations represented on these committees can be obtained on request to their secretary.

Relationship with other publications

This Published Document gives non-contradictory complementary information for use in the UK with Part 1-10 of the Eurocode for the design of steel structures, BS EN 1993, and its National Annex.

Presentational conventions

The provisions in this Published Document are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

The word "should" is used to express recommendations of this Published Document. The word "may" is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the clause. The word "can" is used to express possibility, e.g. a consequence of an action or an event.

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1 Scope

This Published Document gives non-contradictory complementary information for use in the UK with BS EN 1993-1-10 and its UK National Annex.

2 Selection of Charpy impact sub-grade

2.1 Maximum permissible values of thickness for reference temperatures above 10 °C and below –50 °C (BS EN 1993-1-10:2005, 2.3)

Recommended maximum permissible values of element thickness *t* are given in Table 1 for reference temperatures above and below those given in BS EN 1993-1-10.

Table 1 **Maximum permissible values of element thickness, *t*, for $\sigma_{Ed} = 0.75f_y(t)$**

Steel grade	Sub-grade	Charpy energy CVN		Maximum values of element thickness *t* (mm) according to the reference temperature T_{Ed} (°C)						
		at *T* (°C)	J_{min}	50 A)	40 A)	30 A)	20 A)	–60 A)	–70 A)	–80 A)
S235	JR	20	27	125	105	90	75	15	10	10
	J0	0	27	170	145	125	105	25	20	15
	J2	–20	27	200	195	170	145	35	30	25
S275	JR	20	27	110	95	75	65	10	10	5
	J0	0	27	160	135	110	95	20	15	10
	J2	–20	27	200	185	160	135	30	25	20
	M, N	–20	40	200	200	200	185	35	30	25
	ML, NL	–50	27	200	200	200	200	55	45	35
S355	JR	20	27	90	75	60	50	10	5	5
	J0	0	27	130	110	90	75	15	10	10
	J2	–20	27	180	155	130	110	20	15	15
	K2, M, N	–20	40	200	180	155	130	25	20	15
	ML, NL	–50	27	200	200	200	180	40	35	25
S420	M, N	–20	40	185	160	135	115	25	20	15
	ML, NL	–50	27	200	200	185	160	35	25	20
S460	Q	–20	30	150	125	105	90	15	10	10
	M, N	–20	40	180	150	125	105	20	15	10
	QL	–40	30	200	180	150	125	25	20	15
	ML, NL	–50	27	200	200	180	150	30	25	20
	QL1	–60	30	200	200	200	180	40	30	25
S690	Q	0	40	90	75	60	50	5	5	5
	Q	–20	30	110	90	75	60	10	5	5
	QL	–20	40	130	110	90	75	10	10	5
	QL	–40	30	155	130	110	90	15	10	10
	QL1	–40	40	180	155	130	110	20	15	10
	QL1	–60	30	200	180	155	130	25	20	15

A) Reference temperature, T_{Ed}.

2.2 Maximum permissible values of thickness for buildings in the UK

The maximum thickness values for steelwork inside and outside the building envelope, based on minimum shade air temperatures of –5 °C and –15 °C respectively, are given in Table 2 and Table 3 for the most common conditions of use (see Table 2, footnote A for limitations). The maximum thicknesses are derived from requirements given in BS EN 1993-1-10, including its National Annex, and the extension of the range of reference temperatures in Table 1 of this Published Document.

NOTE The minimum temperatures in Tables 2 and 3 are expected to cover the majority of future steel building locations in the UK. For more specific data on minimum shade air temperature distributions in the UK, see NA to BS EN 1991-1-5. In cases where lower temperatures apply, the use of JR sub-grade in external applications may be restricted (see NA to BS EN 1993-1-10:2005, Table NA.3).

The procedure for use of Tables 2 and 3 is as follows:

a) Identify potential notch inducing details on member/component being checked and classify in terms of ΔT_{RD} value (see NA to BS EN 1993-1-10:2005, **NA.2.1.1.2**).

b) Calculate the maximum tensile stresses at the details concerned in terms of $\sigma_{Ed}/f_y(t)$ according to selected steel grades and element thickness.

c) Select relevant column in Table 2 for each detail according to ΔT_{RD} and $\sigma_{Ed}/f_y(t)$ values (each column corresponds to a particular value of adjustment to the reference temperature).

d) Check the conditions assumed in Table 2, footnote A. In the event that any of the four parameters are not equal to zero for any detail, move from the relevant column to a new column to the right. The number of column moves should be one for each 10 °C adjustment of ΔT that is required.

e) Using the detail which relates to the column which is furthest to the right for the member/component being checked, select the lowest Charpy subgrade, appropriate to the intended steel grade, that has a permissible thickness equal to or exceeding that of the member/component element thickness at the controlling detail.

f) In borderline cases it is valid to interpolate between values of $\sigma_{Ed}/f_y(t)$ and thickness in adjacent columns to determine the limiting thickness.

EXAMPLE
Transverse welded stiffener detail in internal beam 762 × 267 × 197UB to BS EN 10025-2:2004, Grade 275 with σ_{Ed} = 190 N/mm^2. Conditions in Table 2, Note 1 apply.

Flange thickness = 25.4 mm
$f_y(t)$ = 265 N/mm^2
$\sigma_{Ed}/f_y(t)$ = 0.72

Therefore ΔT_{RD} = 0 °C and $\sigma_{Ed}/f_y(t) > 0.5$ (see Table 2).

Use seventh column in Table 2. Maximum permissible thickness for S275 JR = 40 mm. Therefore JR subgrade is acceptable.

Table 2 **Maximum thicknesses for internal steelwork in buildings for T_{md} = –5 °C** [A)]

Detail type		**Tensile stress level, $\sigma_{Ed}/f_y(t)$ appropriate to stress level and detail type** [B), C)]									
Description [D)]	**ΔT_{RD}** [D)]	**Comb.1**	**Comb.2**	**Comb.3**	**Comb.4**	**Comb.5**	**Comb.6**	**Comb.7**	**Comb.8**	**Comb.9**	**Comb.10**
Plain material	+30 °C	⩽0	0.15	0.3	⩾0.5						
Bolted	+20 °C		⩽0	0.15	0.3	⩾0.5					
Welded – moderate	0 °C				⩽0	0.15	0.3	⩾0.5			
Welded – severe	–20 °C						⩽0	0.15	0.3	⩾0.5	
Welded – very severe	–30 °C							⩽0	0.15	0.3	⩾0.5
Steel grade	**Subgrade**	**Maximum thickness (mm) according to combination of stress level and detail type** [C)]									
		Comb.1	**Comb.2**	**Comb.3**	**Comb.4**	**Comb.5**	**Comb.6**	**Comb.7**	**Comb.8**	**Comb.9**	**Comb.10**
S235	JR	135	115	97.5	82.5	67.5	55	45	37.5	32.5	27.5
	J0	199.5	182.5	157.5	135	115	97.5	82.5	67.5	55	45
	J2	200	200	197.5	182.5	157.5	135	115	97.5	82.5	67.5
S275	JR	122.5	102.5	85	70	60	50	40	32.5	27.5	22.5
	J0	192.5	172.5	147.5	122.5	102.5	85	70	60	50	40
	J2	200	200	192.5	172.5	147.5	122.5	102.5	85	70	60
	M, N	200	200	200	192.5	172.5	147.5	122.5	102.5	85	70
	ML, NL	200	200	200	200	200	192.5	172.5	147.5	122.5	102.5
S355	JR	82.5	67.5	55	45	37.5	30	22.5	17.5	15	12.5
	J0	142.5	120	100	82.5	67.5	55	45	37.5	30	22.5
	J2	190	167.5	142.5	120	100	82.5	67.5	55	45	37.5
	22.5	200	190	167.5	142.5	120	100	82.5	67.5	55	45
	ML, NL	200	200	200	190	167.5	142.5	120	100	82.5	67.5
S420	M, N	172.5	147.5	125	105	87.5	72.5	60	50	40	32.5
	ML, MN	200	192.5	172.5	148.5	125	105	87.5	72.5	60	50
S460	Q	137.5	115	97.5	80	65	55	45	35	27.5	22.5
	M, N	162.5	137.5	115	97.5	80	65	55	45	35	27.5
	Q, L	187.5	162.5	137.5	115	97.5	80	65	55	45	35
	ML, NL	200	187.5	162.5	137.5	115	97.5	80	65	55	45
	QL1	200	200	181.5	162.5	137.5	115	97.5	80	65	55
S690	Q (0)	82.5	67.5	55	45	35	27.5	22.5	17.5	12.5	10
	Q (–20)	100	82.5	67.5	55	45	35	27.5	22.5	17.5	12.5
	QL (–20)	120	100	82.5	67.5	55	45	35	27.5	22.5	17.5
	QL (–40)	140	120	100	82.5	67.5	55	45	35	27.5	22.5
	QL1 (–40)	162.5	140	120	100	82.5	67.5	55	45	35	27.5
	QL1 (–60)	187.5	162.5	140	120	100	82.5	67.5	55	45	35

[A)] This table is based on the following conditions:

a) ΔT_{Rg} = 0. See NA to BS EN 1993-1-10:2005, **NA.2.1.1.2**, Table NA.2.
For further guidance on types of geometry where there is likely to be a gross stress concentration factor (SCF) greater than unity see PD 6695-1-9:2008, Figure 2b and 2c.

b) ΔT_R = 0. See BS EN 1993-1-10:2005, **2.2**(5) (radiation loss).

c) ΔT_{ε} = 0. See BS EN 1993-1-10:2005, **2.2**(5) and **2.3.1**(2) (impact loading).

d) $\Delta T_{\varepsilon cf}$ = 0. See BS EN 1993-1-10:2005, **2.2**(5) and **2.3.1**(2) (cold forming).

If any of conditions a) to d) are not complied with, an appropriate adjustment towards the right side of the Table should be made in accordance with the relevant clauses above.

[B)] See NA to BS EN 1993-1-10:2005, **NA.2.1.1.5**, and BS EN 1993-1-10:2005, **2.2.3**.

[C)] The "Comb.X" column headings indicate combinations of levels of stress and detail type.

[D)] Simplified descriptions indicating notch severity. For a full description of detail types and definition of ΔT_{RD}, see NA to BS EN 1993-1-10:2005, **NA.2.1.1.2** and **NA.2.1.1.1** respectively.

Table 3 **Maximum thicknesses for external steelwork in buildings for T_{md} = –15 °C** [A)]

Detail type		**Tensile stress level, $\sigma_{Ed}/f_y(t)$ appropriate to stress level and detail type** [B), C)]									
Description [D)]	**ΔT_{RD}** [D)]	**Comb.1**	**Comb.2**	**Comb.3**	**Comb.4**	**Comb.5**	**Comb.6**	**Comb.7**	**Comb.8**	**Comb.9**	**Comb.10**
Plain material	+30 °C	⩽0	0.15	0.3	⩾0.5						
Bolted	+20 °C		⩽0	0.15	0.3	⩾0.5					
Welded – moderate	0 °C				⩽0	0.15	0.3	⩾0.5			
Welded – severe	–20 °C						⩽0	0.15	0.3	⩾0.5	
Welded – very severe	–30 °C							⩽0	0.15	0.3	⩾0.5
Steel grade	**Subgrade**	**Maximum thickness (mm) according to combination of stress level and detail type** [C)]									
		Comb.1	**Comb.2**	**Comb.3**	**Comb.4**	**Comb.5**	**Comb.6**	**Comb.7**	**Comb.8**	**Comb.9**	**Comb.10**
S235	JR	82.5	67.5	55	45	37.5	32.5	27.5	22.5	17.5	12.5
	J0	182.5	157.5	135	115	97.5	82.5	67.5	55	45	37.5
	J2	200	197.5	182.5	157.5	135	115	97.5	82.5	67.5	55
S275	JR	70	60	50	40	32.5	27.5	22.5	17.5	12.5	10
	J0	172.5	147.5	122.5	102.5	85	70	60	50	40	32.5
	J2	200	192.5	172.5	147.5	122.5	102.5	85	70	60	50
	M, N	200	200	192.5	172.5	147.5	122.5	102.5	85	70	60
	ML, NL	200	200	200	200	192.5	172.5	147.5	122.5	102.5	85
S355	JR	45	37.5	30	22.5	17.5	15	12.5	10	7.5	5
	J0	120	100	82.5	67.5	55	45	37.5	30	22.5	17.5
	J2	167.5	142.5	120	100	82.5	67.5	55	45	37.5	30
	K_2, M, N	190	167.5	142.5	120	100	82.5	67.5	55	45	37.5
	ML, NL	200	200	190	167.5	142.5	120	100	82.5	67.5	55
S420	M, N	147.5	125	105	87.5	72.5	60	50	40	32.5	27.5
	ML, MN	192.5	172.5	147.5	125	105	87.5	72.5	60	50	40
S460	Q	115	97.5	80	65	55	45	35	27.5	22.5	17.5
	M, N	137.5	115	97.5	80	65	55	45	35	27.5	22.5
	Q, L	162.5	137.5	115	97.5	80	65	55	45	35	27.5
	ML, NL	187.5	162.5	137.5	115	975	80	65	55	45	35
	QL1	200	187.5	162.5	137.5	115	97.5	80	65	55	45
S690	Q (0)	67.5	55	45	35	27.5	22.5	17.5	12.5	10	7.5
	Q (–20)	82.5	67.5	55	45	35	27.5	22.5	17.5	12.5	10
	QL (–20)	100	82.5	67.5	55	45	35	27.5	22.5	17.5	12.5
	QL (–40)	120	100	82.5	67.5	55	45	35	27.5	22.5	17.5
	QL1 (–40)	140	120	100	82.5	67.5	55	45	35	27.5	22.5
	QL1 (–60)	162.5	140	120	100	82.5	67.5	55	45	35	27.5

[A)] This table is based on the following conditions:

a) ΔT_{Rg} = 0. See NA to BS EN 1993-1-10:2005, **NA.2.1.1.2**, Table NA.2.
For further guidance on types of geometry where there is likely to be a gross stress concentration factor (SCF) greater than unity see PD 6695-1-9:2008, Figure 2b and 2c.

b) ΔT_R = 0. See BS EN 1993-1-10:2005, **2.2**(5) (radiation loss).

c) ΔT_ε = 0. See BS EN 1993-1-10:2005, **2.2**(5) and **2.3.1**(2) (impact loading).

d) $\Delta T_{\varepsilon cf}$ = 0. See BS EN 1993-1-10:2005, **2.2**(5) and **2.3.1**(2) (cold forming).

If any of conditions a) to d) are not complied with, an appropriate adjustment towards the right side of the Table should be made in accordance with the relevant clauses above.

[B)] See NA to BS EN 1993-1-10:2005, **NA.2.1.1.5**, and BS EN 1993-1-10:2005, **2.2.3**.

[C)] The “Comb.X” column headings indicate combinations of levels of stress and detail type.

[D)] Simplified descriptions indicating notch severity. For a full description of detail types and definition of ΔT_{RD}, see NA to BS EN 1993-1-10:2005, **NA.2.1.1.2** and **NA.2.1.1.1** respectively.

2.3 Maximum permissible values of thickness for bridges in the UK

For steelwork in bridges, Table 4 may be used for deriving thickness limits where the minimum design temperature is not below –20 °C. The maximum thicknesses have been derived from the same sources as in Tables 2 and 3.

However, attention should be paid to the conditions in Table 4, footnote A, which may apply in certain types of bridge. For example, members with access holes, with sudden changes in cross section or with intersections with other members without sufficient stiffening, will require a ΔT_{Rg} adjustment [see Table 4, footnote A, item a)]. Members designed for accidental impact forces will require a ΔT_{ε} adjustment which is not allowed for in Table 4 [see Table 4, footnote A, item c)].

NOTE The minimum temperature in Table 4 is expected to cover the majority of future bridge locations in UK. For more specific data on minimum shade air temperature distributions in the UK, see the NA to BS EN 1991-1-5.

2.4 Maximum permitted thicknesses for other structures

For statically loaded structures it is recommended that the requirements for buildings should apply.

For structures susceptible to fatigue it is recommended that the requirements for bridges should apply.

NOTE The rules for bridges are the same as for buildings, with the exception of the values of ΔT_{RT} (see NA to BS EN 1993-1-10:2005, Table NA.3, which prohibits the use of JR subgrade in bridges where the minimum temperature is below 0 °C).

Table 4 **Maximum thicknesses for external steelwork in bridges for T_{md} = –20 °C** [A)]

Detail type		**Tensile stress level, $\sigma_{Ed}/f_y(t)$ appropriate to stress level and detail type** [B), C)]									
Description [D)]	**ΔT_{RD}** [D)]	**Comb.1**	**Comb.2**	**Comb.3**	**Comb.4**	**Comb.5**	**Comb.6**	**Comb.7**	**Comb.8**	**Comb.9**	**Comb.10**
Plain material	+30 °C	⩽0	0.15	0.3	⩾0.5						
Bolted	+20 °C		⩽0	0.15	0.3	⩾0.5					
Welded – moderate	0 °C				⩽0	0.15	0.3	⩾0.5			
Welded – severe	–20 °C						⩽0	0.15	0.3	⩾0.5	
Welded – very severe	–30 °C							⩽0	0.15	0.3	⩾0.5
Steel grade	**Subgrade**	**Maximum thickness (mm) according to combination of stress level and detail type C)**									
		Comb.1	**Comb.2**	**Comb.3**	**Comb.4**	**Comb.5**	**Comb.6**	**Comb.7**	**Comb.8**	**Comb.9**	**Comb.10**
S235	JR	0	0	0	0	0	0	0	0	0	0
	J0	170	145	125	105	90	75	60	50	40	35
	J2	200	195	170	145	125	105	90	75	60	50
S275	JR	0	0	0	0	0	0	0	0	0	0
	J0	160	135	110	95	75	65	55	45	35	30
	J2	200	185	160	135	110	95	75	65	55	45
	M, N	200	200	185	160	135	110	95	75	65	55
	ML, NL	200	200	200	200	180	160	135	110	95	75
S355	JR	0	0	0	0	0	0	0	0	0	0
	J0	110	90	75	60	50	40	35	25	20	15
	J2	155	130	110	90	75	60	50	40	35	25
	K_2, M, N	180	155	130	110	90	75	60	50	40	35
	ML, NL	200	200	185	155	130	110	90	75	60	50
S420	M, N	135	115	95	80	65	55	45	35	30	25
	ML, MN	185	160	135	115	95	80	65	55	45	35
S460	Q	105	90	70	60	50	40	30	25	20	15
	M, N	125	105	90	70	60	50	40	30	25	20
	Q, L	150	125	105	90	70	60	50	40	30	25
	ML, NL	175	150	125	105	90	70	60	50	40	30
	QL1	200	175	150	125	105	90	70	60	50	40
S690	Q (0)	60	50	40	30	25	20	15	10	10	5
	Q (–20)	75	60	50	40	30	25	20	15	10	10
	QL (–20)	90	75	60	50	40	30	25	20	15	10
	QL (–40)	110	90	75	60	50	40	30	25	20	15
	QL1 (–40)	130	110	90	75	60	50	40	30	25	20
	QL1 (–60)	150	130	110	90	75	60	50	40	30	25

A) This table is based on the following conditions:

a) ΔT_{Rg} = 0. See NA to BS EN 1993-1-10:2005, **NA.2.1.1.2**, Table NA.2.
For further guidance on types of geometry where there is likely to be a gross stress concentration factor (SCF) greater than unity see PD 6695-1-9:2008, Figure 2b and 2c.

b) ΔT_R = 0. See BS EN 1993-1-10:2005, **2.2**(5) (radiation loss).

c) ΔT_ε = 0. See BS EN 1993-1-10:2005, **2.2**(5) and **2.3.1**(2) (impact loading).

d) $\Delta T_{\varepsilon cf}$ = 0. See BS EN 1993-1-10:2005, **2.2**(5) and **2.3.1**(2) (cold forming).

If any of conditions a) to d) are not complied with, an appropriate adjustment towards the right side of the Table should be made in accordance with the relevant clauses above.

B) See NA to BS EN 1993-1-10:2005, **NA.2.1.1.5**, and BS EN 1993-1-10:2005, **2.2.3**.

C) The "Comb.X" column headings indicate combinations of levels of stress and detail type.

D) Simplified descriptions indicating notch severity. For a full description of detail types and definition of ΔT_{RD}, see NA to BS EN 1993-1-10:2005, **NA.2.1.1.2** and **NA.2.1.1.1** respectively.

3 Prevention of lamellar tearing in welded structural steelwork (BS EN 1993-1-10:2005, Clause 3)

3.1 General

Lamellar tearing is only a risk when building up large deposits of weld metal in the tee, cruciform and corner joints in steels which contain inclusions, particularly sulfur. The measures which the steelwork fabricator can take to minimize this risk are given in **3.2**.

3.2 Options for the fabricator

The risk of lamellar tearing can be mitigated by the following fabrication control measures:

a) procurement of steel from a mill known to produce clean steel, particularly with low sulfur levels. Such material is likely to exhibit a reasonable level of through-thickness properties (Z15, Z25 or even Z35) as a matter of course;

b) checking of the mill certificates on delivery to identify material with higher sulfur levels, particularly where steel is from an unknown source. Ultrasonic inspection may help to identify some areas of higher material susceptibility, but this is not foolproof;

c) ordering steel with a maximum specified sulfur level;.

d) use of favourable weld preparation geometries;

e) use of assembly sequences and jigging to minimize long range restraint;

f) use of welding run sizes and balanced sequence to minimize local shrinkage stresses;

g) use of reduced strength buttering runs on the surfaces of the transversely stressed (or "through") material, and if necessary increasing the buttering depths by prior excavation;

h) control of heat input to avoid high differential thermal strains.

3.3 Options for the designer

In low- and medium-risk situations, the measures recommended in **3.2** should be followed to avoid lamellar tearing.

Through-thickness (Z) testing (which usually requires ultrasonic plate testing as well) is expensive and is often unnecessary. The designer needs to specify Z35 quality to BS EN 10164 only in high-risk situations. This option should apply only to the material with welds on its surface, i.e. the through material not the incoming material (see Figure 1 and Figure 2).

The following situations are considered to be high risk:

- tee joints, t_z >35 mm;
- cruciform joints, t_z >25 mm.

Where t_z for all butt welds and deep penetration fillet welds should be taken as the thickness of the incoming material (see Figure 1). For fillet welded joints, t_z should be the throat size of the largest fillet weld.

In the case of corner joints the risk of lamellar tearing can normally be overcome by preparing the corner of the through material (see Figure 2). Where this cannot be achieved, a value of t_z greater than 20 mm for the incoming material should be taken as high risk, and through-thickness testing or the use of Z steel for the through material might be more appropriate.

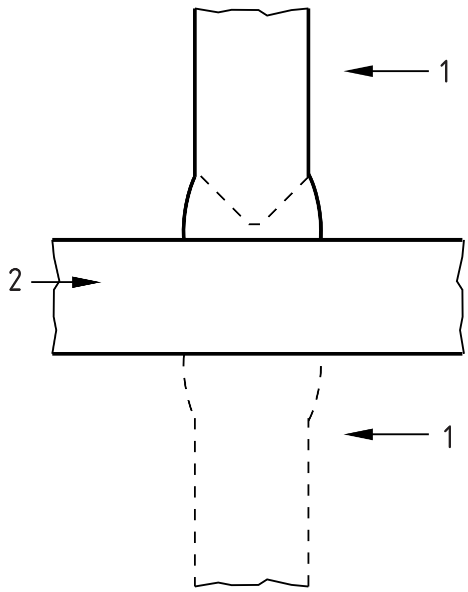
Z35 quality should not be difficult to obtain for plates. However in the case of open sections, (not welded hollow sections made from plates), it may be difficult to find a supplier. In which case specification of a maximum sulfur level of 0.005% for the through material should be used.

In high-risk situations the following measures are also recommended.

a) Do not over-specify the weld throat size.

b) Reduce the weld volume to a minimum. In heavy tee/cruciform joints, double partial penetration butt welds with reinforcing fillet welds may be preferable to full penetration butt welds or large fillet welds (provided that fatigue through the throat is not the governing mode of failure).

Figure 1 **Tee and cruciform joints**

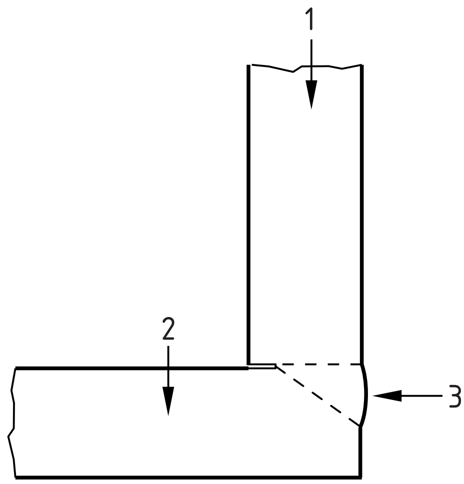


Key

1 "Incoming" material

2 "Through" material

Figure 2 **Corner joint**



Key

1 "Incoming" material

2 "Through" material

3 Preparation on "through" material

Bibliography

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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