Indian Standard

CODE OF PRACTICE FOR USE OF METAL ARC WELDING FOR GENERAL CONSTRUCTION IN MILD STEEL

(First Revision)

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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Indian Standard

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(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 19 December 1969, after the draft finalized by the Structural Welding Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 This standard was published in 1956. As a result of experience gained during these years it has been decided to revise this standard with the following modifications:

a) The scope of the code has been extended to semi-automatic and automatic welding processes.

b) The size of the deep penetration welds for processes other than manual metal arc, has been left to the discretion of the designer.

c) The allowable stresses in welds have been increased to bring them in line with those for parent metal given in IS : 800-1962*.

d) Formulæ for combination of stresses for fillet welds have been included.

0.3 In the formulation of this code assistance has been derived from the following publications:

DIN 4100-1968 Above-ground steel structures. Calculation and design. Deutscher Normenausschuss, Berlin.

B.S. 1856 : 1964 General requirements for the metal-arc welding of mild steel. British Standards Institution, London.

1. SCOPE

1.1 This code is supplement to IS : 800-1962* and covers the use of metal arc welding in the design and fabrication of steel structures in

*Code of practice for use of structural steel in general building construction (*revised*).

general building construction. It is intended primarily for manual arc welding but may also be applied to automatic and semi-automatic arc processes.

1.2 This code, subject to the provisions of IS : 1024-1968* shall also apply to bridges and structures subject to dynamic loading.

1.3 The provisions of this code generally apply to the repair of existing building construction in mild steel but do not necessarily cover all the provisions applicable to the strengthening of existing structures which should be the subject of special consideration. Special provisions covering the design and fabrication of pipelines, boiler storage tanks and tubular steel structures, are intended to be dealt with in separate codes.

2. TERMINOLOGY

2.1 All terms relating to arc welded construction shall have, unless specially defined in this code, the meaning assigned to them in IS : 812-1957†.

3. MATERIAL

3.1 Mild Steel — All steel used for structural members and connections shall be mild steel of weldable quality conforming to IS : 226-1969‡ or IS : 2062-1969§ or equivalent.

3.2 Electrodes — Electrodes shall conform to IS : 814 (Part I)-1974|| and IS : 814 (Part II)-1974

3.3 Filler Wire and Flux — The filler wire and flux combination for submerged arc welding shall conform to the requirements for the desired application as laid down in IS : 3613-1966**

4. DRAWINGS AND PROCEDURE SHEETS

4.1 Drawings and procedure sheets shall be prepared in accordance with IS : 696-1972†† and IS : 962-1967‡‡.

4.2 Symbols for welding used on shop drawings and procedure sheets shall be according to IS : 813-1961§§.

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*Code of practice for use of welding in bridges and structures subject to dynamic loading.

†Glossary of terms relating to welding and cutting of metals.

‡Specification for structural steel (standard quality) (*fourth revision*).

§Specification for structural steel (fusion welding quality) (*first revision*).

||Covered electrodes for metal arc welding of structural steels: Part I For welding products other than sheets (*fourth revision*).

¶Covered electrodes for metal arc welding of structural steels: Part II For welding sheets (*fourth revision*).

**Acceptance tests for wire flux combinations for submerged-arc welding.

††Code of practice for general engineering drawings (*revised*).

‡‡Code of practice for architectural and building drawings (*first revision*).

§§Scheme of symbols for welding (*amended*).

4.3 The working drawings and/or welding procedure sheets prepared by the fabricator or the designer for direction of the welding organization shall include the following information:

a) Specification of the parent metal,

b) Welding procedure with reference to provisions of IS : 823-1964* and IS : 4353-1967† as appropriate, and

c) Testing requirements for special or highly stressed welds.

5. TYPES OF CONSTRUCTION

5.1 Two basic types of construction and design assumptions are permissible under the respective conditions stated in this code and each shall govern in specific manner, the sizes of members and the types and strength of their connections.

5.1.1 Type 1, commonly designated as 'simple' (unrestrained, free-ended), assumes that the ends of beams and girders are connected for shear only, and are free to rotate under load.

5.1.2 Type 2, commonly designated as 'rigid frame' (continuous, restrained) assumes that the end connections of beams, girders and all other members in the frame have sufficient rigidity to hold virtually unchanged the original angles between such members and the members to which they connect.

6. DESIGN

6.1 Butt Weld

6.1.1 For all butt welds, the details shall in general conform to the provisions of IS : 823-1964* in the case of manual metal arc welding and IS : 4353-1967† in the case of submerged arc welding.

6.1.2 Unsealed butt welds of *V*, *U*, *J* and bevel types and incomplete penetration butt welds should not be used for highly stressed joints and joints subjected to dynamic, repeating or alternating forces. They shall also not be subjected to a bending moment about the longitudinal axis of the weld other than that normally resulting from the eccentricity of the weld metal relative to the parts joined.

6.1.3 Size — The size of a butt weld shall be specified by the effective throat thickness.

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*Code of procedure for manual metal arc welding of mild steel.

†Recommendations for submerged arc welding of mild steel and low alloy steels.

6.1.4 *Effective Throat Thickness*

6.1.4.1 *Complete penetration butt welds* — The effective throat thickness of a complete penetration butt weld shall be taken as the thickness of the thinner part joined. The effective throat thickness of 'T' or 'L' butt joints shall be the thickness of the abutting part. Reinforcement may be provided to ensure full cross-sectional area, but shall not be considered as part of the effective throat thickness.

6.1.4.2 *Incomplete penetration or unsealed single butt welds**

a) The effective throat thickness of an incomplete penetration butt weld shall be taken as the minimum thickness of the weld metal common to the parts joined, excluding reinforcement.

b) Unsealed single butt welds of *V*, *U*, *J* and bevel types, and incomplete penetration butt welds welded from one side only, should have a throat thickness of at least $\frac{7}{8}$ of the thickness of the thinner of the parts joined. If required, evidence (*see* Note) should be produced by the fabricator to show that this effective throat thickness has been obtained. For the purpose of stress calculation, a reduced effective throat thickness not exceeding $\frac{5}{8}$ of the thickness of the thinner part joined should be used.

NOTE — The nature of such evidence should be decided by agreement between the designer/purchaser and the fabricator, and may, for example, comprise:

i) Tests carried out before welding to show that the welding procedure is capable of providing the required penetration, and inspection during welding to establish that the correct procedure has been followed;

ii) Test pieces made as continuations of the seams during welding; and

iii) Examination, after welding, by radiographic or other suitable non-destructive methods.

c) The unwelded portion in incomplete penetration butt welds, welded from both sides, shall not be greater than $\frac{1}{4}$ of the thickness of the thinner part joined, and should be central in the depth of the weld. If required, evidence [*see* Note under **6.1.4.2** (b)] should be produced by the fabricator to show that this required penetration has been achieved. For the purpose of stress calculation, a reduced effective throat thickness not exceeding $\frac{5}{8}$ of the thickness of the thinner part joined should be used.

*An incomplete penetration butt weld is a butt weld in which the weld metal is intentionally not deposited through the full thickness of the joint.

6.1.5 *Effective Length* — The effective length of a butt weld shall be taken as the length of the continuous full size weld except in the following two cases, when the full width of the joint or piece shall be taken as effective length:

a) The ends of the butt welds are extended past the edges of the parts joined by the use of run-on and run-off plates with a similar joint preparation and of a reasonable thickness not less than the thickness of the parts joined and of length not less than 40 mm (*see* Fig. 1). If run-on and run-off plates are removed after completion of the weld, the ends of the weld shall be smooth and flush with the edges of the abutting parts.

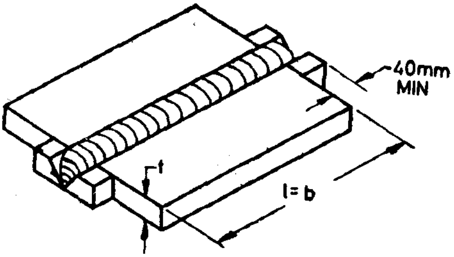


FIG. 1 BUTT WELDED JOINTS WITH RUN-ON AND RUN-OFF PLATES

b) The parent metal is not more than 20 mm thick, the end shall be chipped or cut back to solid metal and welds applied having a width not less than 1½ times the '*V*' opening between the parts joined to fill out the ends of the same re-inforcement as the faces of the weld (*see* Fig. 2).

6.1.5.1 In most cases of butt welds, full width of the plate should be welded adopting the procedure mentioned under **6.1.5** (a) or **6.1.5** (b). If, in any case, the butt weld need not be for the full width of the member, detailed instructions regarding the type of joint should be given on the drawings.

6.1.5.2 A transverse skewed butt weld shall not be assumed in computations to be longer than the width of the joint or piece perpendicular to the direction of stress.

6.1.6 The effective area of a butt weld shall be considered as the effective length multiplied by the effective throat thickness.

6.1.7 *Load Carrying Butt Welds* — Butt welds shall be considered as the parent metal for purpose of design calculations.

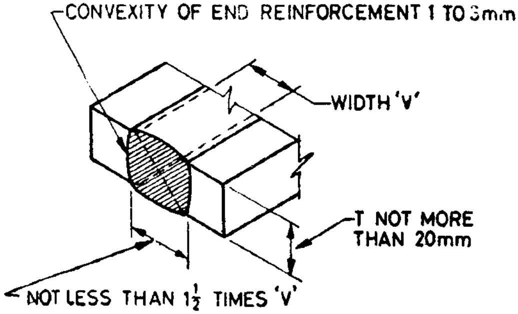


FIG. 2 BUTT WELDS END REINFORCEMENT

6.1.8 *Non-Load Carrying Butt Welds* — Butt welds where the penetration is less than that specified in **6.1.4** due to non-accessibility are to be considered as non-load carrying for purposes of design calculations.

6.1.9 *Intermittent Butt Welds*

6.1.9.1 Intermittent butt welds should be used to resist shear only, and the effective length of such weld should not be less than four times the longitudinal space between the effective length of welds nor more than 16 times thinner part joined except as specified under **9.1**, **10.4** and **11.6**.

6.1.9.2 Intermittent butt welds shall not be used in positions subject to dynamic, repetitive and alternate stress.

6.1.10 *Sealing or Backing*

6.1.10.1 Single *V*, *U*, *J* or bevelled butt welds intended to carry the permissible stresses based on the full-plate thickness should be completed by depositing a sealing run of weld metal on the back of the joints. The back of the first run shall be cut out with a round-nosed chisel prior to the application of subsequent runs on the reverse side. The depth to which the first run is cut out shall be sufficient to expose the clean face of the first run. The grooves thus formed and the roots of the single *V*, *U*, *J* or bevelled weld shall be filled in and sealed.

6.1.10.2 Where another steel part of the structure or a special steel backing strip is provided in contact with the back of the joint, single *V*, *U*, *J* or bevelled butt welds welded from one side only be permitted, provided the steel parts of the joint are bevelled to an edge with a root gap sufficient to ensure fusion into the bottom of the '*V*' and the steel part at the back of the joint.

6.1.11 *Butt Welding Parts of Unequal Cross Section*

6.1.11.1 In butt welding steel parts in line with each other and which are intended to withstand dynamic, repeating or alternating forces, and which are of unequal width, or where the difference in thickness of the parts exceeds 25 percent of the thinner part or 3·0 mm, whichever is greater the dimensions of the wider or thicker part should be reduced at the butt joint to those of the smaller part, the slope being not steeper than one in five (*see* Fig. 3A and 3B).

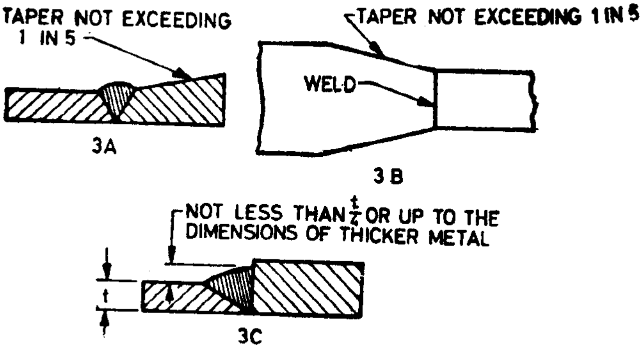


FIG. 3 BUTT WELDING OF PARTS OF UNEQUAL THICKNESS AND UNEQUAL WIDTHS

6.1.11.2 Where the reduction of the dimensions of the thicker part is impracticable, and/or where structures are not designed to withstand dynamic, repeating or alternating forces, the weld metal should be built up at the junction with the thicker part to dimensions at least 25 percent greater than those of the thinner part, or, alternatively, to the dimensions of the thicker member (*see* Fig. 3C). Where the reduction of the width of wider part is impracticable, the ends of the weld shall be returned to ensure full throat thickness.

6.1.12 *Reinforcement* — Only sufficient surface convexity shall be provided by reinforcement to ensure full cross-sectional area at the joint. The reinforcement shall not be considered as part of the throat thickness and may be removed to give a flush surface, if desired.

6.2 Fillet Welds

6.2.1 *Size* — The size of a normal fillet shall be taken as the minimum leg length (*see* Fig. 4). For deep penetration welds, where the depth of penetration beyond the root run is 2·4 mm (*Min*), the size of the fillet should be taken as the minimum leg length + 2·4 mm.

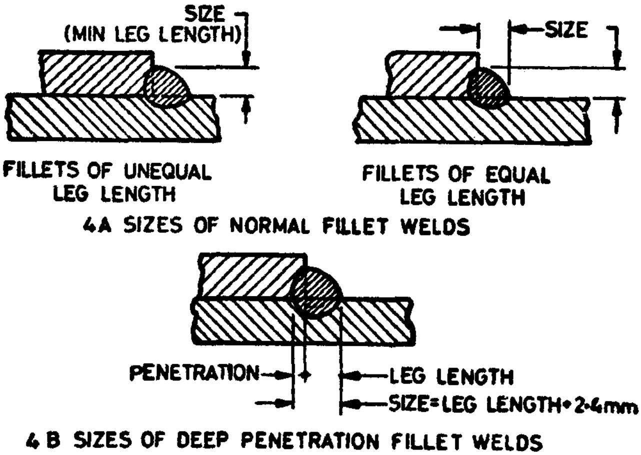


FIG. 4 SIZES OF FILLET WELDS

6.2.1.1 For fillet welds made by semi-automatic or automatic processes where the depth of penetration is considerably in excess of 2·4 mm the size shall be subject to agreement between the purchaser and the contractor.

6.2.2 The size of fillet weld shall not be less than 3 mm nor more than the thickness of the thinner part joined. The minimum size of the first run or of a single run fillet weld shall be as given in Table 1, to avoid the risk of cracking in the absence of preheating.

6.2.3 *Effective Throat Thickness* — The effective thickness of a fillet weld shall not be less than 3 mm and shall generally not exceed 0·7t and 1·0 t under special circumstances, where t is the thickness of the thinner part.

6.2.3.1 For the purpose of stress calculations the effective throat thickness shall be taken as $K \times$ fillet size where K is a constant. The value of K for different angles between fusion faces (*see* **6.2.3.3**) shall be as given in Table 2.

6.2.3.2 For concave fillets the designer shall specify the minimum throat thickness and the minimum leg length.

6.2.3.3 *Angle between fusion faces* — Fillet welds should not be used for connecting parts whose fusion faces form an angle of more than 120°

TABLE 1 MINIMUM SIZE OF FIRST RUN OR OF A SINGLE RUN FILLET WELD

(*Clause* 6.2.2)

Thickness of Thicker Part		Minimum Size
Over mm	Up to and Including mm	mm
—	10	3
10	20	5
20	32	6
32	50 (*see* Notes below)	8 First run 10 Minimum size of fillet

Note 1 — When the minimum size of the fillet weld given in the table is greater than the thickness of the thinner part, the minimum size of the weld should be equal to the thickness of the thinner part. The thicker part shall be adequately preheated to prevent cracking of the weld.

Note 2 — Where the thicker part is more than 50 mm thick, special precautions like pre-heating will have to be taken.

or less than 60°, unless such welds are demonstrated by practical tests to develop the required strength.

6.2.4 *Effective Length* — The effective length of a fillet weld shall be taken as that length only which is of the specified size and required throat thickness. In practice the actual length of weld is made of the effective length shown on the drawing + twice the weld size.

6.2.4.1 *Minimum length* — The effective length of a fillet weld designed to transmit loading shall not be less than four times the size of the weld.

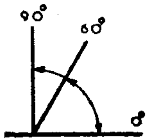
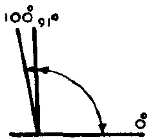
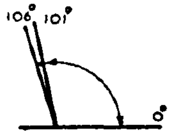
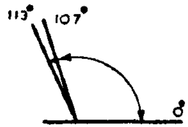
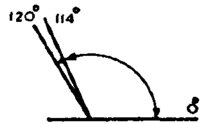
6.2.5 *Fillet Weld Applied to the Edge of a Plate or Section*

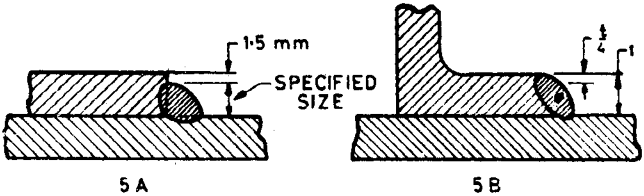
6.2.5.1 Where a fillet weld is applied to the square edge of a part, the specified size of the weld should generally be at least 1·5 mm less than the edge thickness in order to avoid washing down the exposed arris (*see* Fig. 5A).

6.2.5.2 Where the fillet weld is applied to the rounded toe of a rolled section, the specified size of the weld should generally not exceed 3/4 of the thickness of the section at the toe (*see* Fig. 5B).

TABLE 2 VALUE OF *K* FOR DIFFERENT ANGLES BETWEEN FUSION FACES

(*Clause* 6.2.3.1)

Angle Between Fusion Faces:	60° — 90°	91° — 100°	101° — 106°	107° — 113°	114° — 120°
					
Constant *K*:	0·70	0·65	0·60	0·55	0·50



IG. 5 FILLET WELDS ON SQUARE EDGE OF PLATE OR ROUND TOE OF ROLLED SECTION

6.2.5.3 Where the size specified for a fillet weld is such that the parent metal will not project beyond the weld, no melting of the outer cover or covers shall be allowed to occur to such an extent as to reduce the throat thickness (*see* Fig. 6).

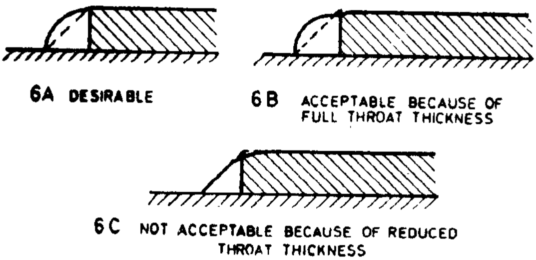


FIG. 6 FULL SIZE FILLET WELD APPLIED TO THE EDGE OF A PLATE OR SECTION

6.2.5.4 When fillet welds are applied to the edges of a plate or section in members subject to dynamic loading, the fillet weld shall be of full size, that is, with its leg length equal to the thickness of the plate or section, with the limitations enumerated in **6.2.5.3**.

6.2.5.5 End fillet weld normal to the direction of force shall be of unequal size with a throat thickness not less than 0·5t where t is the thickness of the part as shown in Fig. 7. The difference in thickness of outward side welds shall be negotiated in a uniform slope (*see* Fig. 7).

6.2.6 *Intermittent Fillet Welds*

6.2.6.1 Intermittent fillet welds may be used to transfer calculated stress across a joint when the strength required is less than that developed by a continuous fillet weld of the smallest allowable size for the thickness of the parts joined. Any section of intermittent fillet welding

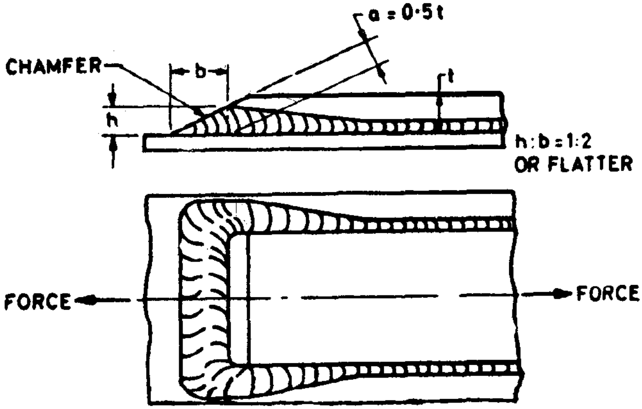


FIG. 7 END FILLET WELD NORMAL TO DIRECTION OF FORCE

shall have an effective length of not less than four times the weld size with a minimum of 40 mm except as otherwise specified under **11.6** for plate girder stiffeners.

6.2.6.2 The clear spacing between the effective lengths of intermittent fillet welds carrying calculated stress shall not exceed the following number of times the thickness of the thinner plate joined and shall in no case be more than 20·0 cm:

12 times for compression, and

16 times for tension.

Longitudinal fillet welds at the ends of built-up members shall have an effective length of not less than the width of the component part joined unless end transverse welds are used, in which case, the sum of the end longitudinal and end transverse welds shall be not less than twice the width of the component part.

Chain intermittent welding is to be preferred to staggered intermittent welding. Where staggered intermittent welding is used, the ends of the component parts shall be welded on both sides.

6.2.6.3 In a line of intermittent fillet welds, the welding should extend to the ends of the parts connected; for welds staggered about two edges, this applies generally to both edges, but need not apply to subsidiary fittings or components, such as intermediate web stiffeners.

6.2.6.4 Intermittent welds are not recommended to be used in the case of main members of structures directly exposed to weather. However, if such intermittent welds are preferred for reasons of economy or otherwise, the welds shall be returned around the corners.

6.2.7 *Lap Joints*

6.2.7.1 The overlap of parts in stress carrying lap joints shall be not less than five times the thickness of the thinner part, except as provided under **10.2** and **10.3** for lacing and battening. Unless lateral deflection of the parts is prevented, they shall be connected by at least two transverse lines of fillet, plug or slot welds or by two or more longitudinal fillet or slot joints.

6.2.7.2 If longitudinal fillet welds are used alone in end connections, the length of each fillet weld shall be not less than the perpendicular distance between them. The transverse spacing of longitudinal fillet welds used in end connections shall not exceed 16 times the thickness of the thinner part connected unless end transverse welds or intermediate plug or slot welds are used to prevent buckling or separation of the parts.

6.2.8 *Fillet Welds in Slots or Holes*

6.2.8.1 Where fillet welds are used in slots or holes through one or more of the parts being joined, the dimensions of the slot or hole should comply with the following limits in terms of the thickness of the part in which the slot or hole is formed:

a) The width or diameter should be not less than three times the thickness or 25 mm whichever is greater;

b) Corners at the enclosed ends or slots should be rounded with a radius not less than 1·5 times the thickness or 12 mm whichever is greater; and

c) The distance between the edge of the part and the edge of the slot or hole, or between adjacent slots or holes, should be not less than twice the thickness and not less than 25 mm for holes.

6.2.8.2 When welding inside a slot or a hole, in a plate or other part, in order to join the same to an underlying part, fillet welding may be used along the wall or walls of the slot or the hole, but the latter shall not be filled with weld metal or partially filled in such a manner as to form a direct weld metal connection between opposite walls, except that fillet welds along opposite walls may overlap each other for a distance of 1/4th of their size.

6.2.9 *End Returns* — Fillet welds terminating at the ends or sides of parts or members should, wherever practicable, be returned continuously around the corners in the same plane for a distance not less than twice the size of the weld. This provision should, in particular, apply to side and top fillet welds in tension which connect brackets, beam seatings and similar parts.

6.2.10 *Bending About a Single Fillet* — A single fillet weld should not be subjected to a bending moment about the longitudinal axis of the fillet.

6.3 Plug Welds

6.3.1 *Effective Area* — The effective area of a plug weld shall be considered as the nominal area of the hole in the plane of the faying surface.

6.3.2 Plug welds shall not be designed to carry stresses.

6.4 Combinations of Welds — If two or more of the general types of weld (butt, fillet, plug, slot) are combined in a single joint, the effective capacity of each shall be separately computed with reference to the axis of the group in order to determine the allowable capacity of the combination.

6.5 If two or more plates or rolled shapes are used to build up a member, sufficient welds (of the fillet, plug or slot type) to make the parts act in unison shall be provided (*see* **6.5.1** to **6.5.3**), except where transfer of calculated stress between the parts joined, requires closer spacing.

6.5.1 For plates, the longitudinal clear spacing between the welds shall not exceed the provisions of **6.2.6** and the transverse spacing shall not exceed 32 times the thickness of the thinner plate joined.

6.5.2 For members composed of two or more rolled shapes in contact with one another, the longitudinal spacing of the welds shall not exceed 60 cm or limits prescribed under **6.5.3**.

6.5.3 For members composed of rolled shapes, separated one from the other by a gusset plate, the component parts shall be welded together at intervals such that critical ratio l/r for each component between welds shall not exceed 50, or 0·7 of the critical ratio for the whole member, whichever is the lesser.

7. PERMISSIBLE STRESSES IN WELDS

7.1 Shop Welds

7.1.1 *Butt Welds* — Butt welds shall be treated as parent metal with a thickness equal to the throat thickness, and the stresses shall not exceed those permitted in the parent metal (*see* **10** of IS : 800-1962*).

*Code of practice for use of structural steel in general building construction (*revised*).

7.1.2 *Fillet Welds* — The permissible stress in fillet welds based on its throat area shall be 1 100 kgf/cm².

7.1.3 *Plug Welds* — The permissible shear stress on plug welds shall be 1 100 kgf/cm².

7.2 Permissible Stresses in Site Welds — The permissible stresses for shear and tension for site welds made during erection of structural members shall be reduced to 80 percent of those given in **7.1**.

7.3 Increased Permissible Stresses — Where design calculations take into consideration the effects of wind or earthquake or both, the permissible stresses given in **7.1** may be increased by 25 percent. In no case shall the welds thus provided be less than those needed if the wind or earthquake or both effects are neglected.

7.4 Stresses Due to Individual Forces

7.4.1 *Symbols* — Unless otherwise specified the symbols used in the following clauses shall have the following meaning:

P_a = permissible stress due to axial force in kgf/cm²

P_b = permissible bending stress in kgf/cm²

f_a = calculated stress due to axial force in kgf/cm²

f_b = calculated stress due to bending in kgf/cm²

t,c = suffixes to indicate tension or compression

q = shear stress in kgf/cm²

M = bending moment in kg.cm

Q = shear force in kgf

S = static moment of area of parts to be joined about the centre of gravity of the whole section in cm³

J = moment of inertia of the section in about its centre of gravity in cm⁴

y = distance of the weld from the centre of gravity of the section in cm

a = effective throat thickness

l = effective length

7.4.2 *Stresses Due to Compression, Tension and Shear* — When subjected to compressive or tensile or shear force one at a time, the stress in the weld is given by:

$$f_a \text{ or } q = \frac{P}{a \cdot l}$$

where

P is the type of force transmitted (axial load N or the shear force Q).

7.5 Combination of Stresses

7.5.1 *Fillet Welds*

7.5.1.1 The stresses shall be combined using the following formula:

$$f_e = \sqrt{f^2 + 1{\cdot}8\, q^2}$$

where

f = normal stresses, compression or tension due to axial or bending forces.

f_e = equivalent stress.

7.5.1.2 The equivalent f_e shall not exceed 1 100 kgf/cm².

7.5.1.3 Check for the combination of stresses need not be done :

a) for side fillet welds joining cover plates and flange plates, and

b) for fillet welds where sum of normal and shear stresses does not exceed 1 100 kgf/cm² (axial or bending).

7.5.2 *Butt Welds*

7.5.2.1 Check for the combination of stresses in butt welds need not be done if:

a) butt welds are axially loaded, and

b) in single and doulbe bevel welds the sum of normal and shear stresses does not exceed the permissible normal stress, and the shear stress does not exceed 0·5 permissible shear stress.

7.5.2.2 *Combined bending and shear* — The equivalent stress f_e due to co-existent bending stress (tension or compression) and shear stress is obtained from the following formula:

$$f_e = \sqrt{f_{bc}^2 + 3q^2} \quad \text{or} \quad \sqrt{f_{bt}^2 + 3q^2}$$

7.5.2.3 *Combined bearing, bending and shear stresses* — Where a bearing stress f_{br} is combined with bending (tensile or compressive) and shear stresses under the most unfavourable conditions of loading, the equivalent stress f_e is obtained from the following formulæ:

$$f_e = \sqrt{f_{bt}^2 + f_{br}^2 + f_{bt} f_{br} + 3q^2}$$

or

$$f_e = \sqrt{f_{bc}^2 + f_{br}^2 - f_{bc} f_{br} + 3q^2}$$

7.5.2.4 The equivalent stress f_e as calculated from the formulae mentioned in **7.5.2.2** and **7.5.2.3** shall not exceed the values allowed for the parent metal.

7.5.3 *Stresses Due to Bending Moment* — When subjected to bending moment only, the normal stress $f_b = \frac{M}{J}y$.

7.5.4 The horizontal shear (V) resulting from the bending forces is calculated from the following formula:

$$V = \frac{Q.S}{J} \text{ kg/cm length of joint.}$$

8. WELDING IN COMPRESSION MEMBERS

8.1 For general design considerations, reference shall be made to IS : 800-1962*.

8.2 The welds between the plates of a column built up of three or more plates in I or box form should be proportioned to resist a transverse shear at any section in the length of the column equal to 2·5 percent of the axial load in the compression member.

8.3 Joints in Compression Members

8.3.1 Where the ends of compression members to be spliced are faced for bearing over the whole area, there shall be sufficient weld to hold the connected parts accurately in place and to resist any tension caused by bending.

8.3.2 Where the ends of compression members to be spliced are not faced for complete bearing, there should be sufficient weld to transmit all the forces to which the joint is subjected.

9. WELDING IN TENSION MEMBERS

9.1 Where welds are used to connect together the parts of tension members built up from two or more sections, the spacing and dimensions of such welds should be determined by the relative stiffnesses of the sections, but the spacing of such welds should not exceed 105 cm.

10. LACING AND BATTENING

10.1 For general design considerations relating to lacing and battening, reference shall be made to IS : 800-1962*.

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*Code of practice for use of structural steel in general building construction (*revised*)

10.2 Lacing — Where lacing bars overlap the main members, the amount of lap measured along either edge of the lacing bar should be not less than four times the thickness of the bar or members, whichever is less. Welding should be sufficient to transmit the load in the bar and should in any case be provided along each side of the bar for the full length of lap.

10.2.1 Where lacing bars are fitted between the main members, they shall be connected to each member by fillet welds on each side of the bar or by full penetration butt welds. The lacing bars shall be so placed as to be generally opposite the flange or stiffening element of the main member.

10.3 Battening — Where tie or batten plates overlap the main members, the amount of lap should not be less than four times the thickness of the plate. The length of weld connecting each edge of the batten plate to the member shall in aggregate be not less than half the depth of the batten plate. At least one-third of this welding shall be placed at each end of this edge. The length of weld and depth of batten plate shall be measured along the longitudinal axis of the main member.

In addition, the welding shall be returned along the other two edges of the plates transversely to the axis of the main member for a length not less than the minimum lap specified above.

10.3.1 Where tie or batten plates are fitted between the main members, they shall be connected to each member by a fillet weld on each side of the plate equal in length to at least that specified under **10.3** or full penetration butt welds. The tie or batten plate shall be so placed as to be generally opposite the flange or stiffening element of the main member.

10.3.2 The size of fillet welds connecting tie or batten plates to the main members should be not less than half of the thickness of the plate, and in no case less than 5·0 mm.

10.4 Use of Butt Welds in Place of Batten Plates — Where the component sections of a built-up compression member are closer together so that it is practicable, by butt welding the sections together, to dispense with batten plates, the minimum length of such welds shall be not less than four times the thickness of the thinner part joined. The spacing of the butt welds should be such that the critical ratio l/r for each component between welds shall not exceed 40 or 0·6 of the critical ratio for the whole member, whichever is the lesser. The throat thickness of the welds should, wherever possible, be not less than 6·0 mm and in no case less than 5·0 mm.

10.5 In no case shall the welding be less than that necessary to carry the resultant shears and moments as specified for lacing or battens in IS : 800-1962*.

11. WELDING IN PLATE GIRDERS

11.1 For general design considerations relating to plate girders, reference shall be made to IS : 800-1962*.

11.2 In welded plate girders each flange should preferably consist of a single section rather than of two or more sections superimposed, but the single section may comprise a series of sections laid end to end and effectively welded at their junctions.

11.2.1 The flange plate welded directly to the web plate shall not be more than 20 mm thick when steel conforms to IS : 226-1969† and not more than 50 mm thick when steel conforms to IS : 2062-1969‡.

11.3 Flange plates shall be joined by butt welds wherever possible. These butt welds shall develop the full strength of the plates.

11.3.1 The weld joining the ends of flange plates should be at right angles to the direction of the load.

11.3.2 The ends of the flange plates shall be welded before assembly. When more than one flange plate is used the butt joints should be staggered as far as possible (*see* Fig. 8). When unavoidable and the joints lie in the same plane the welding shall be done as shown in Fig. 9 and 10. The ends of the plates are joined first with a *V*-weld. The size of this shall be such that it does not melt away when the butt weld is completed.

11.3.3 Where splice plates are used, their area shall be not less than 5 percent in excess of the area of the flange element spliced and their centre of gravity shall coincide as far as possible with that of the element spliced. There shall be enough welds on each side of the splice to develop the load in the element spliced plus 5 percent, but in no case should the strength developed be less than 50 percent of the effective strength of member spliced.

11.4 Web plates shall preferably be joined by complete penetration butt welds. Where splice plates are used, they shall be designed to resist the shear and moment at the spliced section.

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*Code of practice for use of structural steel in general building construction (*revised*).

†Secification for structural steel (standard quality) (*fourth revision*).

‡Specification for structural steel (fusion welding quality) (*first revision*).

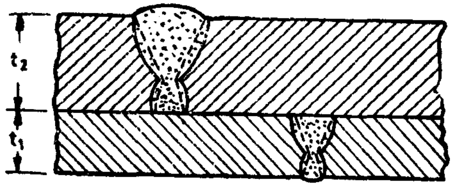

Fig. 8 Welds Connecting Flange Plates Staggered

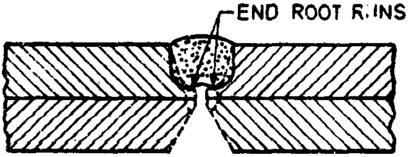

Fig. 9 Welding of Flange Plates at a Junction, Double-Vee Butt Welds

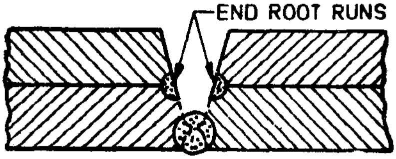

Fig. 10 Welding of Flange Plates at a Junction, Single-Vee Butt Welds

11.5 Welds connecting the flange to web of plate girders shall be proportioned to resist the maximum horizontal shear forces resulting from the bending forces on the girder.

11.5.1 Additionally, welds connecting flange to web shall be proportioned to transmit any vertical loads applied directly to the flange. Where the web is machined and is in close contact with the flange before welding, such vertical loads may be deemed to be resisted entirely by bearing between the flange and the web provided that the bearing stresses so produced are within the permissible limits, assuming the dispersion of load through parts at 30° to horizontal.

11.5.1.1 In case the bearing stresses exceed permissible values, bearing stiffeners shall be designed to carry the concentrated loads applied directly to the flange.

11.5.2 The junction of longitudinal and transverse, that is, flange splice or web splice weld with the weld connecting flange and web plates should be avoided by providing copings in the web (*see* Fig. 11).

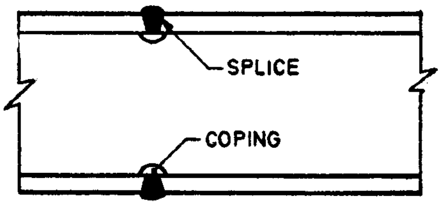

FIG. 11 COPING IN THE WEB

11.5.2.1 If flange and web splicing are done separately coping may not be necessary.

11.6 The welding between stiffeners and web should be in accordance with the following requirements:

a) The size of the fillet welds should be obtained from Table 1 in relation to the thickness of the web or stiffener, whichever is the greater;

b) Where intermittent welds are used, the distance between the effective lengths of any two welds, even if staggered on opposite sides of the stiffeners should not exceed 16 times the thickness of the stiffener nor 30 cm;

c) Where intermittnet welds are placed on one side only of the stiffener, or on both sides but staggered or where single plate stiffeners are butt welded to the web, the effective length of each weld should be not less than 10 times the thickness of the stiffener;

d) Where intermittent welds are placed in pairs, one weld on each side of the stiffener, the effective length of each weld should be not less than four times the thickness of the stiffener; and

e) For bearing stiffeners, the welding should, in addition, be sufficient to transmit to the web the full reaction or load.

11.7 Where stiffeners are required to be connected to the flanges, they should not be welded to the flanges subjected to tensile forces in structures subject to dynamic loading wherever possible.

11.8 The corners of the stiffeners should be notched to prevent the concentration of longitudinal and transverse welds (*see* Fig. 12).

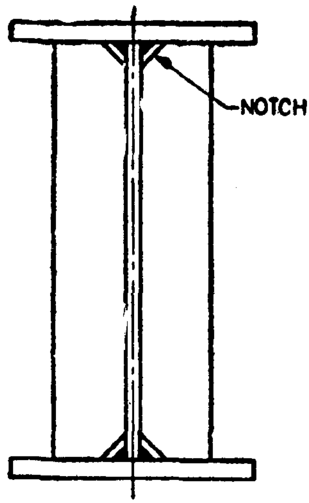

FIG. 12 STIFFENERS ARE NOTCHED TO PREVENT WELD CONCENTRATION

12. DESIGN OF CONNECTIONS

12.1 Eccentricity of Members — Members meeting at a joint should, where practicable, have their gravity axes meeting at a point so as to avoid eccentricity. Where this cannot be done, allowance shall be made for the bending moments due to eccentricity.

12.2 Eccentricity of Connections — Wherever practicable, the line of action of the force should pass through the centre of resistance of a connection so as to avoid an eccentricity moment on the section; otherwise allowance shall be made for eccentricity.

12.3 Connections of Tension and Compression Members in Trusses — Welded connections at ends of tension or compression members in trusses shall either develop the full effective strength of the material or they shall develop the strength required by total stresses, but in no case should such strength developed be less than 50 percent of the effective strength of the material connected.

12.4 Packing — Where a packing is used between two parts, the packing and the welds connecting it to each part, should be capable of transmitting the load between the parts, except where a properly fitted packing is used in compression. Where a packing is too thin to carry the load or permit the provision of adequate welds, it should be trimmed flush with the edges of the narrower part and the load should be transmitted through the welds alone, the welds being increased in size by the thickness of the packing.

12.5 Welding Combined with Riveting or Bolting (*see also* 14) — In new work welds and rivets or bolts combined in one connection should not be considered as sharing the load, and welds should be provided to carry the entire load for which the connection is designed.

12.6 Joints should be so developed that individual components may have flexibility at least in one direction. Alternatively the joint may be designed for the indirect secondary bending and torsion and stress due to rigid connections of components at the joints.

13. WELDING OF ROLLED STEEL SECTIONS

13.1 Fillet welding of segregated zones of rolled steel sections should be avoided for fear of unfavourable internal stresses being developed.

14. WELDING FOR STRENGTHENING OF EXISTING RIVETED OR BOLTED CONNECTIONS AND STRUCTURES

14.1 When welding is used for strengthening an existing riveted or bolted connection, the rivets or bolts shall be assumed to carry the dead load, provided they are capable of carrying it without over-stress, and welding shall be added to carry all live and impact loads. If rivets or bolts are over-stressed by dead load only, then welding shall be added to carry all loads (dead, live and impact).

14.2 Where a compression member is strengthened by welding while under load, the work shall be carried out in such a way that:

a) the least radius of gyration is substantially increased, and

b) large compression shrinkage stresses are not induced in the extreme fibres.

14.3 Compression members, while they are subject to a calculated stress exceeding 470 kgf/cm^2, shall not be strengthened by welding.

15. FABRICATION

15.1 General — For general requirements relating to the fabrication of structural steel, reference should be made to IS : 800-1962*.

*Code of practice for use of structural steel in general building construction (*revised*).

15.2 Welding Equipment and Electrodes

15.2.1 *Plant* — Welding plant, instruments and accessories should conform to the appropriate Indian Standard, if any, and should be of adequate capacity to carry out the welding procedure laid down. All welding plant shall be maintained in good working order.

15.2.2 *Welding Current Measurement* — Adequate means of measuring the current drawn on the welding side should be available, either as part of the welding plant or by the provision of a portable ammeter.

15.2.3 *Electrodes* — The types of electrodes used should be only those recommended by the manufacturer for use in the position in which the welds are to be made. Electrodes should be stored in their original bundles or cartons in a dry place and adequately protected for weather effects. Electrodes which have areas of the flux covering broken away or damaged should be discarded. If electrodes become affected by dampness, but are not otherwise damaged, they may be used only after being dried in a manner approved by the manufacturer, and after undergoing appropriate performance tests, indicating that the electrodes are still satisfactory for use.

15.3 Welding Procedure

15.3.1 *General* — For procedure of welding and pre- and post- heat treatment, reference should be made to IS : 823-1964*.

15.3.2 Cutting may be effected by shearing, cropping or sawing. Gas cutting by mechanically controlled torch may be permitted for mild steel only. Gas cutting of high tensile steel may also be permitted provided special care is taken to leave sufficient metal to be removed by machining so that all metal that has been hardened by flame is removed. Hand flame cutting may be permitted subject to the approval of the inspector.

15.3.3 Shearing, cropping and gas cutting, shall be clean, reasonably square, and free from any distortion, and should the inspector find it necessary, the edges shall be ground afterwards.

15.3.4 During the entire welding or cooling cycle, the joints and parts shall not be subjected to any external forces, shocks or vibrations.

15.4 Where welding has to be done in low temperatures, provisions as given in IS : 4944-1968† shall apply.

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*Code of procedure for manual metal arc welding of mild steel.

†Code of procedure for welding at low ambient temperature.

15.5 Workmanship — For details of workmanship, quality of welds, correction of weld faults, peening, painting, etc, reference should be made to IS : 823-1964*.

16. INSPECTION AND TESTING

16.1 For purpose of inspection and testing, reference should be made to IS : 822†.

17. CONTROL OF SHRINKAGE AND DISTORTION

17.1 Effects of distortion and shrinkage shall be taken care of while detailing and fabricating the structures.

18. OPERATOR QUALIFICATION

18.1 The welders shall be trained in accordance with IS : 817-1966‡. They shall also be subjected to appropriate qualifying tests specified in IS : 1181-1967§.

19. SAFETY REQUIREMENTS AND HEALTH PROVISIONS

19.1 For purpose of safety requirements and health provisions, reference may be made to IS : 818-1968||.

*Code of procedure for manual metal arc welding of mild steel.

†Code of practice for inspection of welds (*under preparation*).

‡Code of practice for training and testing of metal arc welders (*revised*).

§Qualifying tests of metal arc welders (engaged in welding structures other than pipes)(*first revision*).

||Code of practice for safety and health requirements in electric and gas welding and cutting operations (*first revision*).

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