IS 12303 (1987): Criteria for design of RCC hinges [CED 2: Cement and Concrete]

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Indian Standard

CRITERIA FOR DESIGN OF RCC HINGES

UDC 691·88 : 621·888·2

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Indian Standard

CRITERIA FOR DESIGN OF RCC HINGES

0. FOREWORD

0.1 This Indian Standard was adopted by the Bureau of Indian Standards on 30 December 1987, after the draft finalized by the Criteria for Design of Special Structures Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 In the formulation of this standard, assistance has been derived from the following:

a) Ministry of Transport, UK : Rules for the design and use of Freyssinet concrete hinges in highway structures, London, HMSO, 1966 Memorandum No. 577/1;

b) NAASRA Bridge Design Specification : (fifth edition — 1976); and

c) Lectures Notes on 'Concrete structures' by Dr F. Leonhardt Vorlesungen uber Massirbau — Zweiter Teil, Sonder falle der Bemmesung in Stahlbetonban (Zweite Auflange).

0.3 It has been assumed in this standard that the detailed design will be prepared by a structural civil engineer experienced in the structural use of the concrete and that the execution of the work will be carried out under the direction of a competent supervisor familiar with the making of high quality concrete.

0.4 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 The criteria given in this standard are intended to be applied to only the Freyssinet hinge in which reinforcement through the throat, when provided, should not exceed 2 percent of the cross-sectional area of the throat. It is assumed that the rotation takes place in the plane only.

1.2 Limitation of Use — This type of hinge should not be used where:

a) there is risk of collision with a structure causing damage or displacement of the hinge, and

b) under any loading there is a resultant uplift on all or a part of the hinge.

2. SYMBOLS

2.1 For the purpose of this standard, the following letter symbols shall have the meaning indicated against each; where other symbols are used, they are explained at appropriate places:

A_t = effective area of throat — (*a.b or* $2.4r^2$) in mm^2;

A_{sl} = secondary reinforcement placed longitudinal or parallel to throat in mm^2;

A_{sr} = ring or spiral reinforcement in the hinge in mm^2;

A_{ss} = spalling reinforcement in the hinge in mm^2;

A_{st} = transverse or main reinforcement in the hinge in mm^2;

a = minimum width of the throat measured in the plane of rotation in mm;

b = minimum length of the throat measured normal to the plane of rotation in mm;

b_r = width of shoulder in mm;

c = length of the hinge measured normal to the plane of rotation in mm;

d = width of the hinge measured in the plane of rotation in mm;

d_w = clear inside diameter of spiral in reinforcement in mm;

E_c = modulus of elasticity of the concrete for short term loading in MPa;

f_{ck} = characteristic compressive strength of concrete in MPa;

f_{ct} = compressive strength of concrete at any time, t in MPa;

f_y = characteristic strength of steel in MPa;

f_{yp} = permissible strength of steel in MPa;

h = height between the throats in case of double hinged bearing in mm;

$\phi = \phi_S + \frac{\phi_L}{2}$ = total rotation of hinge (radians);

ϕ_S = total rotation due to short term transient effects such as live load and temperature (radian);

ϕ_L = total rotation due to long term effects such as dead load, shrinkage, creep and annual temperature cycle (radians);

$he = \frac{Ec.I.\phi}{M}$ = effective height of the throat (mm) taken as 125 mm in the absence of experimentally measured values;

I = moment of inertia of the cross-section at the throat in mm^4;

K = notch factor of the hinge, that is, the ratio of compressive stress at the edge of the throat due to axial load to average compressive stress in the throat due to axial loading = 1·5;

M = moment required to produce rotation in N/mm;

P = load per unit length of the throat in N/mm;

P_{max} = total maximum resolved component of force acting on hinge = $b\sqrt{P^2+S^2}$, in N;

R = effective radius of curvature of hinge in mm;

r = radius at the throat in case of circular shape in mm;

S = shear force per unit length of the throat in N/mm;

s = spacing of stirrups or pitch of spiral reinforcement in mm; and

t = throat thickness in mm.

3. MATERIALS

3.1 Unless otherwise specified, the materials and other requirements shall be generally conforming to the stipulations of IS : 456-1978* and IS : 1343-1980†.

3.2 Cement — The cement used shall be any of the following with the prior approval of the engineer-in-charge:

a) Ordinary or low heat Portland cement conforming to IS : 269-1976‡,

*Code of practice for plain and reinforced concrete (*third revision*).

†Code of practice for prestressed concrete (*first revision*).

‡Specification for ordinary and low heat Portland cement (*third revision*).

b) Rapid hardening Portland cement conforming to IS : 8041-1978*, or

c) High strength ordinary Portland cement conforming to IS : 8112-1976†.

NOTE — In hot humid climates, rapid hardening cement shall not be used.

3.3 Aggregates — Aggregates shall comply with the requirements of IS : 383-1970‡.

3.3.1 Aggregates for concrete shall be from natural sources which may have been naturally reduced to size or crushed. Flaky and enlongated material shall not be used.

3.3.2 *Size of Aggregates* — The nominal maximum size of aggregate shall be 10 mm in the zone covered by transverse mat reinforcement.

3.4 Reinforcement — The reinforcement shall be any of the following:

a) Mild steel and medium tensile steel bars conforming to IS : 432 (Part 1)-1982§,

b) Hot rolled deformed bars conforming to IS : 1786-1985‖,

c) Cold twisted bars conforming to IS : 1786-1985‖, or

d) Hard drawn steel wire fabric conforming to IS : 1566-1982¶.

3.4.1 All reinforcement shall be free from loose mill scales, loose rust and coats of paints, oil, mud or other coatings which may destroy or reduce bond.

3.4.2 The modulus of elasticity of steel shall be taken as 200 kN/mm^2.

3.5 Concrete

3.5.1 *Grade of Concrete* — The grade of concrete for the hinge shall not be inferior to M40 conforming to IS : 456-1978**.

3.5.2 In the absence of test data, the short term modulus of elasticity of concrete, E_c in MPa shall be taken as:

$$E_c = 5\,700\sqrt{f_{ck}} \text{ in N/mm}^2$$

where f_{ck} = characteristic compressive strength of concrete in MPa.

*Specification for rapid hardening Portland cement (*first revision*).

†Specification for high strength ordinary Portland cement.

‡Specification for coarse and fine aggregates from natural sources for concrete (*second revision*).

§Specification for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement : Part 1 Mild steel and medium tensile steel bars (*third revision*).

‖Specification for high strength deformed steel bars and wires for concrete reinforcement (*third revision*).

¶Specification for hard-drawn steel wire fabric for concrete reinforcement (*second revision*).

**Code of practice for plain and reinforcement concrete (*third revision*).

3.5.3 Creep and shrinkage effects shall be taken in accordance with IS : 1343-1980* unless experimental data is available.

4. GENERAL DESIGN REQUIREMENTS

4.1 Loads and Forces

4.1.1 In structural design, account shall be taken of the dead, live and wind loads and forces such as those caused by earthquake, effects due to shrinkage, creep, temperature, etc, where applicable.

4.1.2 The general method of working out the loads and load combinations shall be as given in IS : 875-1964†, IS : 1893-1984‡ and other stipulations covered in IS : 456-1978§.

4.2 Basis for Designs

4.2.1 *Basic Assumptions* — The following are the assumptions for designing throat:

a) Any reinforcement through the throat of the hinge shall be only nominal or such as to account for handling stresses in case of a precast hinge. The effects of the reinforcement, when provided, shall be neglected.

b) Shrinkage cracks may occur in reinforced throats, in particular, while the axial forces are still very small. These need not be considered detrimental to the functioning of the hinge or to its final load carrying capacity provided precautions are taken to prevent penetration of water and subsequent corrosion.

c) Construction practice shall generally be such as to ensure earliest possible application of self weight and dead load in all types of concrete hinges to avoid shrinkage cracks.

d) For short term loading the behaviour of the concrete is elastic.

e) For long term loading, the creep is proportional to the initial stress.

f) In considering the transverse tensile forces on either side of the throat, the tensile strength of the concrete is neglected.

4.2.2 The shear across the throat shall not exceed one-third of the co-existing axial load.

4.3 Permissible Stresses

4.3.1 *Concrete* — The average compressive stress $\frac{(P)}{(a)}$ in the concrete at the throat shall not exceed $2 f_{ck}$ or 100 MPa, whichever is less, when subjected to any loading combination as specified for appropriate structure under consideration.

*Code of practice for prestressed concrete (*first revision*).

†Code of practice for structural safety of buildings : Loading standards (*revised*).

‡Criteria for earthquake resistant design of structures (*fourth revision*).

§Code of practice for plain and reinforced concrete (*third revision*).

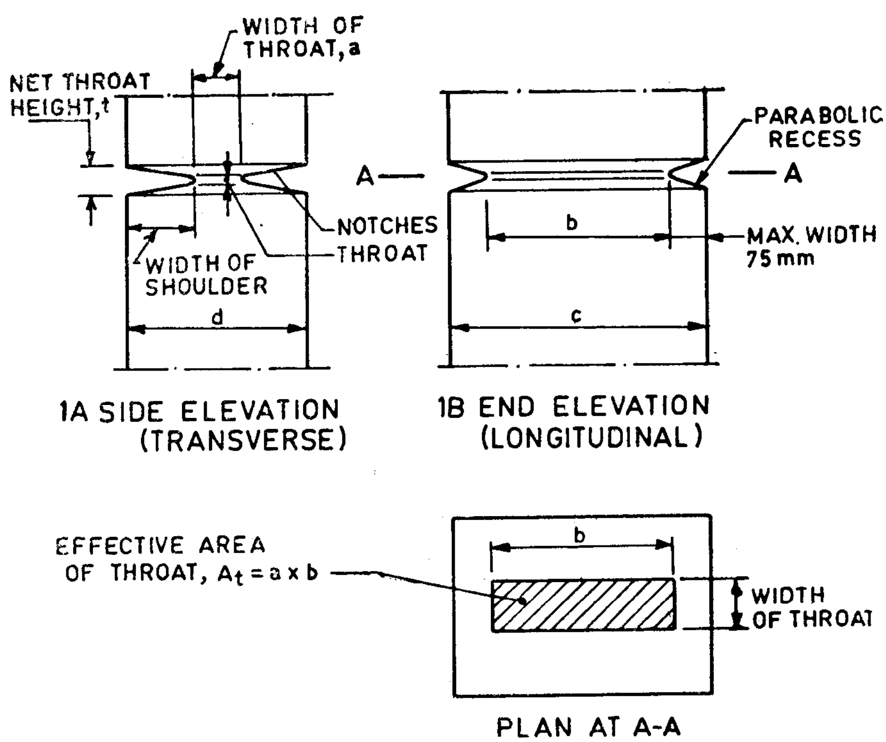
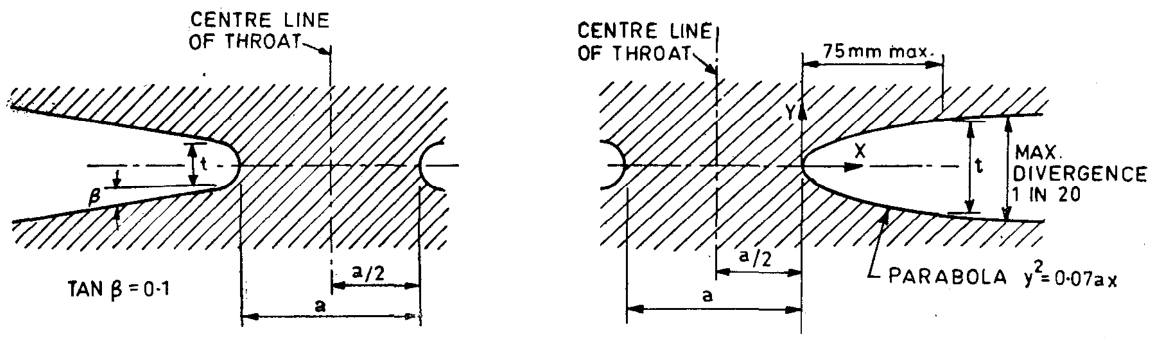


FIG. 1 TYPICAL RECTANGULAR HINGE — LAYOUT AND SHAPE — *Contd*



1C DETAILS OF THROAT (ALT-I) 1D DETAILS OF THROAT (ALT. II)

FIG. 1 TYPICAL RECTANGULAR HINGE — LAYOUT AND SHAPE

Tensile stresses in the throat shall not be permitted except for shrinkage stresses which may arise during construction.

4.3.2 *Reinforcement* — The stresses in the transverse mat reinforcement shall not exceed $0{\cdot}85 f_y$ subject to a maximum of 180 MPa.

4.4 Design of Throat

4.4.1 The width of the throat shall be such that:

a) the required short-term and long-term rotations are accommodated without causing tensile stresses in the throat, and

b) the bending moment transmitted by the hinge is acceptable.

4.4.2 A recess of not less than 50 mm shall be provided at each end of the throat from the face of the column or member containing the hinge. The shape of the notch in the immediate vicinity of the throat shall approximate to a parabola and merge into slightly diverging straight lines to the edges of the member or alternatively, shall have a slope of not less than 1 in 10 as shown in Fig. 1.

The above rules are equally applicable to hinges with circular throat (*see* Fig. 2).

4.4.3 To prevent tensile stress in throat when rotation is applied, it is necessary that the maximum direct compressive stress at the sides

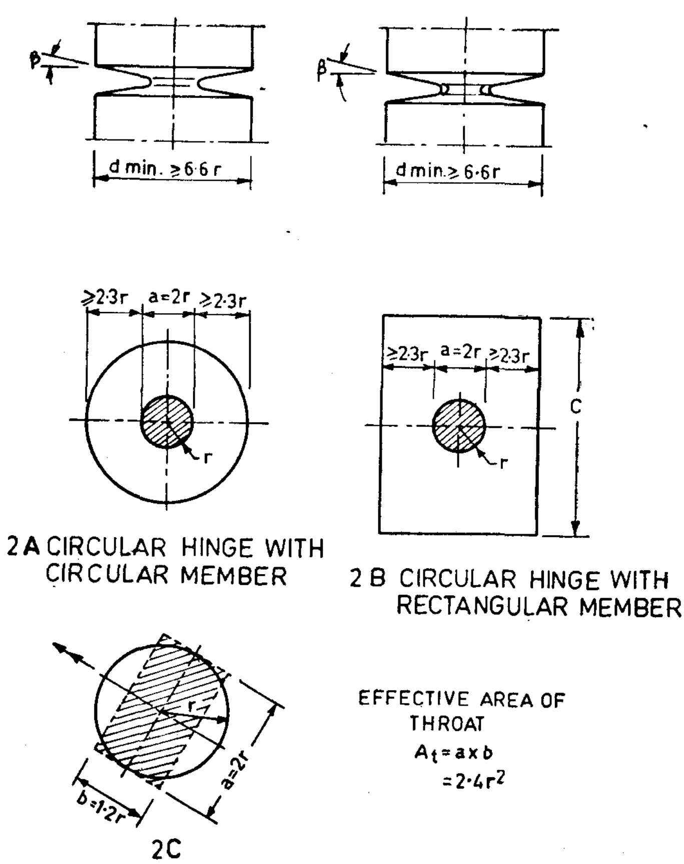


FIG. 2 TYPICAL CIRCULAR HINGE — LAYOUT AND SHAPE

of the throat shall be greater than or equal to the maximum bending stress (*see* Fig. 3) when subjected to any loading combination co-existing. This may be expressed as:

$$\Sigma\ E_c\ \phi \leqslant 2K\ h_e \frac{P}{a^2}$$

where

$\Sigma\ E_c\ \phi$ = sum of the products of rotations and effective modulus of elasticity (MPa).

In the absence of experimentally measured value for the hinge being designed, the following may be assumed:

$$\Sigma\ E_c\phi = E_c \frac{(\phi_s + \phi_L)}{2}$$

h_e = 125 mm

K = 1·5

4.4.4 The design requirements of the throat shall be governed by the following:

i) Throat width, a:

$$a \geqslant 50 \text{ mm} \qquad (1)$$

$$\geqslant \frac{P}{100} \text{ mm} \qquad (2)$$

$$\geqslant \frac{P}{2f_{ck}} \text{ mm} \qquad (3)$$

$$\leqslant \sqrt{\frac{3h_e\ P}{E_c\ \phi}} \text{ mm} \qquad (4)$$

If condition (4) is not compatible with conditions (1), (2) and (3), the situation may be resolved by prestressing.

It is preferable to keep $a \leqslant 0{\cdot}3d$ mm.

ii) Throat thickness t: $\frac{a}{2} > t > \frac{a}{3}$

It is preferable to keep $t \leqslant 20$ mm.

iii) The recommended shape of notch:

a) Width of shoulder $b_r > 0{\cdot}7\ a > 50$ mm.

b) The recommended slope of notch (*see* Fig. 1)

$\tan\beta = 0{\cdot}1$

iv) The rotational stiffness of the hinge

$$M \text{ applied to structures} = \frac{(\Sigma\ E_c\phi)\ a^3}{12h_e}$$

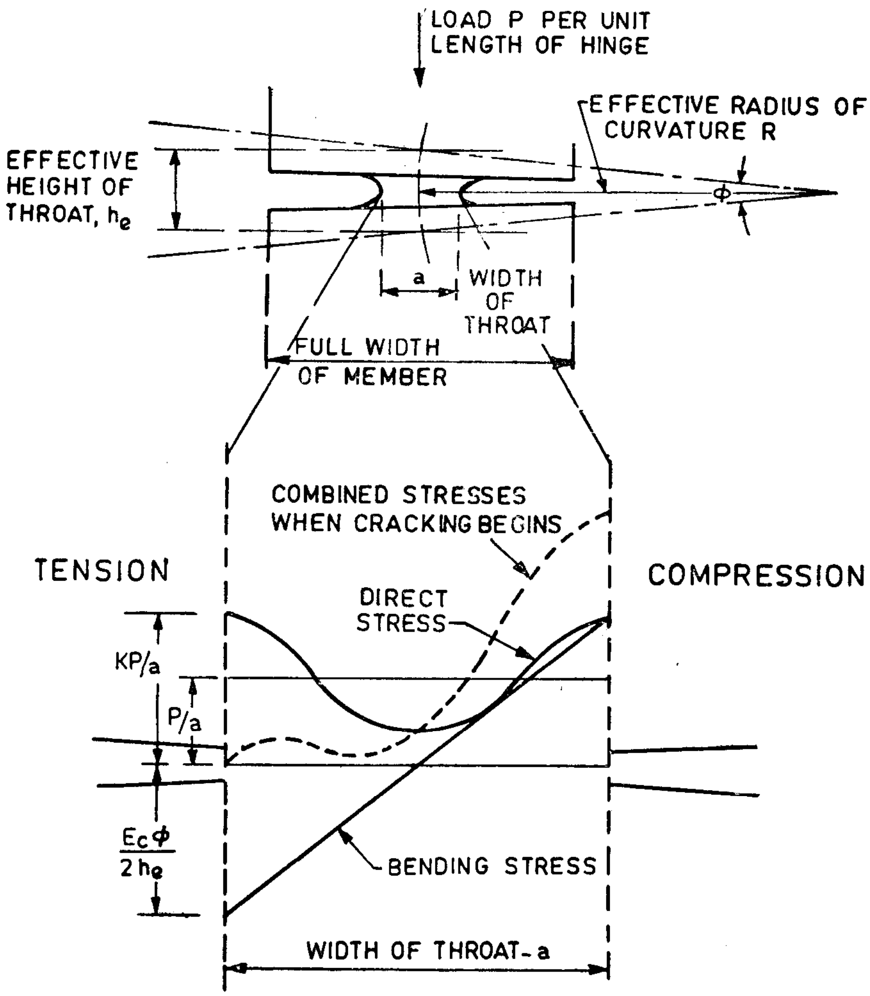


FIG 3. HINGE ROTATION AND STRESS DISTRIBUTIONS

4.5 Bending Moment Transmitted by the Hinge — For the purposes of this section only, it shall be assumed that when the maximum direct compressive stress occurs at the side of the throat, the eccentricity of the load is $a/3$ and the bending moment transmitted by the hinge is $\frac{P.a}{3}$.

4.6 Design for Bursting Reinforcement

4.6.1 The reinforcement may consist of any, or a combination, of the following:

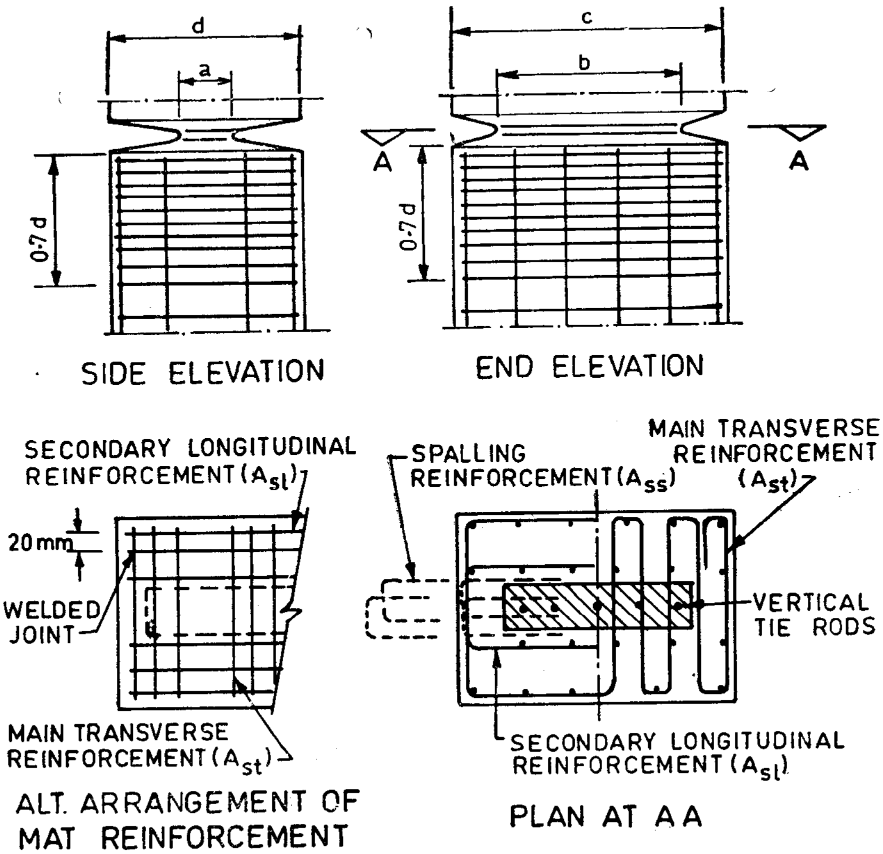
a) Parallel mats, each of which consists of a set of primary bars transverse to the plane of potential cracking and a set of secondary bars perpendicular to the primary bars and spalling reinforcement,

b) Reinforcing fabric,

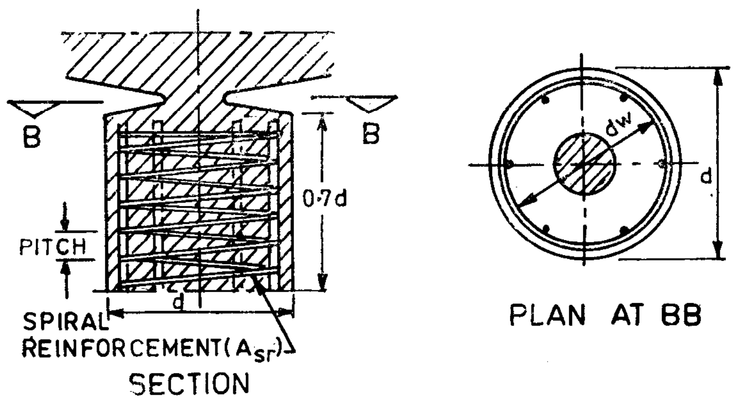
c) Sets of closed ties, and

d) Spiral reinforcement in case of circular hinge.

4.6.2 Whichever type of reinforcement is used, the aim should be to cross the planes of potential cracking by bars as close as possible subject to minimum clear spacing limited to 20 mm. Typical details are shown in Fig. 4 and 5.



4A For Rectangular Section



4B Circular Section

FIG. 4 TYPICAL ARRANGEMENT OF HINGE REINFORCEMENT

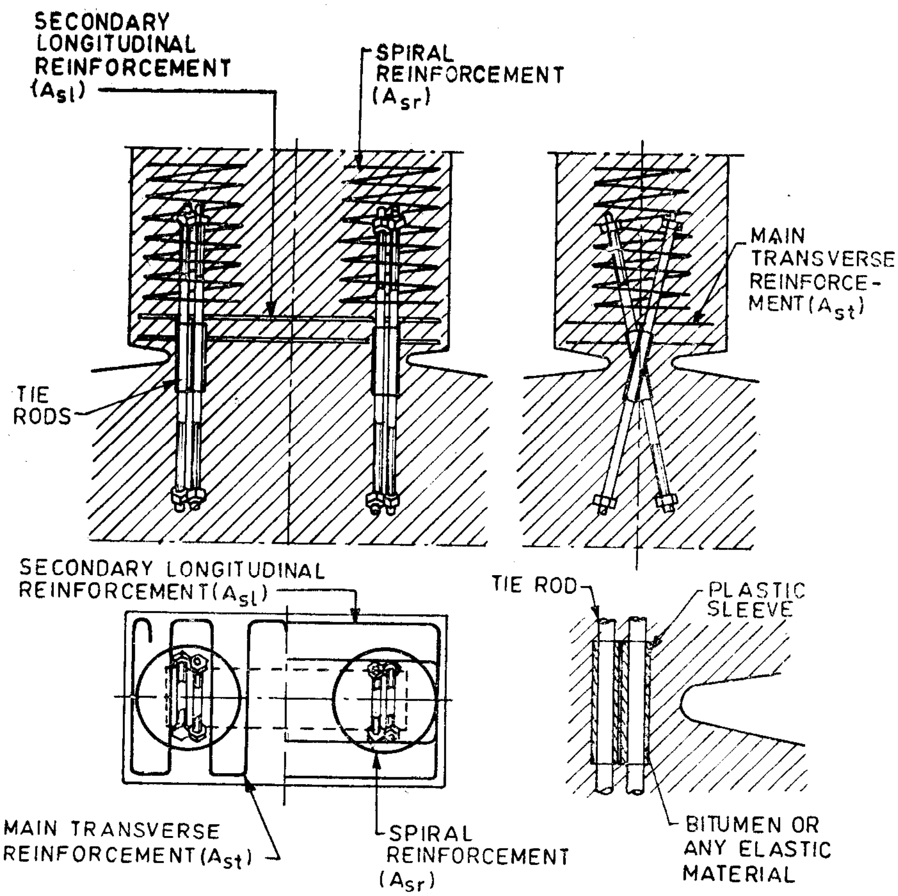


FIG. 5 ALTERNATIVE ARRANGEMENT OF HINGE REINFORCEMENT

All bars should extend to the faces of the column subject to normal edge cover and be anchored adequately so that the yield stress of the bars is developed under ultimate load conditions.

4.6.3 In concrete hinges, the tensile 'bursting zones' start very close to the hinge and the reinforcement should, therefore, start as close to the hinge throat as practicable. This mat reinforcement shall be placed starting from 0·1 d to 0·7 d. The minimum clear cover for reinforcement shall be 25 mm in this zone [*see* Fig. 4(a) and (b)].

4.6.4 The zones immediately adjacent to the hinge shall be reinforced to carry the 'bursting force' generated by the concentrated load from the throat in accordance with the principles adopted for the design of anchorages in IS : 1343-1980*.

Alternatively, the magnitude of the bursting force may be taken as follows:

4.6.4.1 *Hinge with rectangular throat*

i) $A_{st} = \dfrac{0.3\, P_{max}}{0.85 f_y}$ in mm²

ii) $A_{sl} = 0.3 \left(1 - \dfrac{b}{c}\right) \times \dfrac{P_{max}}{0.85 f_y}$ in mm²

iii) Spalling reinforcement

$$A_{ss} = \frac{0.03\, a^2}{A_t} \times \frac{P_{max}}{0.85 f_y} \text{ in mm}^2$$

4.6.4.2 *Hinge with circular throat* — The bursting reinforcement shall be provided in the form of spiral of area :

$$A_{sr} = \frac{P_{max}}{8\, d_w \times 0.85 f_y} \times s \text{ mm}^2$$

where

d_w = clear inside diameter of spiral reinforcement (mm) and shall be at least 2·5 a or 5 r.

4.6.5 In addition to the reinforcement in the bursting zones, there shall be sufficient longitudinal and transverse reinforcement throughout the column to prevent propagation of bursting crack along the centre plane of the column.

5. WORKMANSHIP

5.1 General Requirements — Workmanship shall comply with the requirements of IS : 456-1978*.

5.2 Formwork — The formwork shall be designed and constructed to the shape, lines and dimensions shown on the drawings within the tolerance

*Code of practice for prestressed concrete (*first revision*).

*Code of practice for plain and reinforcement concrete (*third revision*).

given below:

a) Deviation from specified dimensions of cross-section of throat : $\pm$ 3 mm

b) Deviation of alignment at throat with respect to theoretical position of least throat thickness : 3 mm, (*Max*)

5.3 Curing — Throat of concrete shall be kept continuously in damp or wet condition by ponding or by covering with a layer of sacking, canvas, hessian or similar materials and kept constantly wet for at least 14 days from the date of placing concrete.

5.4 Position of Construction Joints — Construction joints shall not be formed through the throat. Where a joint is necessary, it is recommended that it should be formed as a recess below the throat level with the top reinforcement mat. The width of the recess should be slightly greater than the width of the throat.

5.5 Protection of Joint During Construction — Wherever possible, hinges shall be adequately supported to prevent rotation at the throat from the time of casting to the completion of the structure incorporating it. The permissible loads, rotation and shears during this period shall be related to each other and to the strength of the concrete f_{ct} in accordance with **4.4.4** (i) (2), 3 and (4); f_{ck} being replaced in (3) by f_{ct}, when f_{ct} has a lesser value. Care shall be taken to see that the conditions in **1.2** do not arise.

5.6 Inspection — So far as practicable, provision should be made to enable hinges to be inspected in service.

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002
Telephones: 3310131, 3311375

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