Reinforced Concrete Structural Elements

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1 Compression Members

1.1 Definitions

1.1.1

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Column or strut is a compression member, the effective length of which exceeds three times the least lateral dimension.

1.1.2 Short and Slender Compresion Members

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A compression member may be considered as short when both the slenderness ratios l_{ex}/D and l_{ey}/D are less than 12, where:

b	width of the member
D	depth in respect of the major axis
l_{ex}	effective length in respect of the major axis
l_{ey}	effective length in respect of the minor axis

It shall otherwise be considered as a slender compression member.

1.1.3 Unsupported Length

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The unsupported length , l, of a compression member shall be taken as the clear distance between end restraints except that:

(a) in flat slab construction, it shall be clear distance between the floor and the lower extremity of the capital, the drop panel or slab whichever is the least.

(b) in beam and slab construction, it shall be the clear distance between the floor and the underside of shallower beam framing into the columns in each direction at the next higher floor level.

(c) in columns restrained laterally by struts, it shall be the clear distance between consecutive struts in each vertical plane, provided that to be an adequate support, two such struts shall be meet the columns at approximately the same level and the angle between vertical planes through the struts shall not vary more than 30^o from a right angle. Such struts shall be of adequate dimensions and shall have sufficient anchorage to restrain the member against lateral deflection.

(d) in colmns restrained laterally by struts or beams, with backets used at the juctions, it shall be the clear distance between the floor and the lower edge of the bracket, provided that the backet width equals that of the beam strut and is at least half that of the column.

1.2 Effective Length of Compression Members

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In the absence of more exact analysis, the effective length l_{ef} of colmns may be obtained as described in Annex E **??**.

1.3 Slenderness Limits for Columns

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The unsupported length between end resraints shall not exceed 60 times the least lateral dimension of a column.

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If, in any given plane, one end of a column is unrestrained, its unsupported, l shall not exceed $100 \times b^2/D$, where

b	width of that cross-section, and
D	depth of the cross-section measured in he plane under consideration

1.4 Minimun Eccentricity

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All columns shall be designed for minimum eccentricity, equal to the unsupported length of column / 500 plus lateral dimension / 30, subject to a minimum of 20 mm. Where bi-axial bending is considered, it is sufficient to ensure that eccentricity exceeds the minimum about one axis at a time.

2 Limit State of Collapse: Flexure

2.1 Assumptions

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Design for the limit state of collapse in flexure shall be based on the assumptions given below:

(a) Plane secions normal to the axis remain plane after bending.

(b) The maximum strain in concrete at the outermost compression fibre is taken as 0.0035 (0.35%) in bending.

(c) The relationship between the compressive stress distribution in concrete and the stain in concrete may be assumed to be rectangular, trapezoid, parabola or any other shape which results in prediction of strength in substantial agreement with the results of test. An accepable stress-strain curve is given in Fig. **??**. For design purpose , the compressive strength of concrete in the structure shall be assumed to be 0.67 times the characteristic strength. The partial safety factor $\gamma_m = 1.5$ shall be applied in addition to this.

NOTE:— For the stress-strain curve in Fig. **??** the design stress block parameters are as follows (see Fig. **??**):

Area of stress block	$0.36 f_{ck}.x_u$
Depth of centre of compressive strength from the extreme fibre in compression	$0.42 x_u$

where

f_{ck} characteristic compressive strength of concrete, and
x_u depth of neutral axis.

(d) The tensile strength is ignored.

(e) The stresses in the reinforcement are derived from representative stress-strain curve for the type of steel used. Typical curves are shown in Fig. **??**. For design purposes the partial safety factor γ_m, equal to 1.15 shall be applied.

(f) The maximum strain in the tension reinforcement in the section at failure shall not be less than:

$$\frac{f_y}{1.15E_s} + 0.002$$

where

f_y characteristic strength of steel, and
E_s modulus of elasticity of steel.

NOTE:— The limiting values of the depth of netural axis for different grades of steel based on the assumptions in **??** are as follows:

f_y	$x_{u,max}/d$
250	0.53
415	0.48
500	0.46

The expression for obtaining the moments of resistance for rectangular and T-sections, based on the assumptions of **??**, are given in Annex **??**

3 LIMIT STATE OF COLLAPSE: COMPRESSION

3.1 Assumptions

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In addition to the assumptions given in 38.1 (a) to 38.1 (e) for flexure, the following shall be assumed:

(a) The maximum compressive stain in concrete in axial compression is taken as 0.002.

(b) The maximum compressive strain at the highly compressed extreme fibre in concrete subjected to axial compression and bending and when there is no tension on the section shall be 0.0035 minus 0.75 times the strain at the least compressed extreme fibre.

3.2 Minimun Eccentricity

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All members in compression shall be designed for the minimum eccentricity in accordance with 1.4. Where calculated eccentricity is larger, the minimum eccentricity shold be ignored.

3.3 Short Axially Loaded Members in Compression

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The member shall be designed by considering the assumptions given in 3.1 and the minimum eccentricity. When the minimum eccentricity as per 1.4 does not exceed 0.05 times the lateral dimension, te members may be designed by the following equation:

$$P_u = 0.4 \times f_{ck} \times A_c + 0.67 * f_y \times A_{sc}$$

P_u	axial load on the member
f_{ck}	characteristic compressive strength of the concrete
A_c	Area of concrete
f_y	characteristic strength of the compression reinforcement
A_{sc}	area of longitudinal reinforcement for columns

3.4 Compression Members with Helical Reinforcement

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The strength of compression members with helical reinforcement satisfying the requirement of 3.4.1 shall be taken as 1.05 times the strength of similar member with lateral ties.

3.4.1

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The ratio of the volume og the helical reinforcement to the volme of the core shall not be less than $0.36(A_g/A_c - 1)f_{ck}/f_y$; where

A_g	gross area of the section
A_c	area of the core of the helcally reinforced column measured to the outside diameter of the helix
f_{ck}	characteristic compressive strength of the concrete
f_y	characteristic strength of the helical reinforcement but not exceeding $415 N/mm^2$