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Simplified RCC Column Design: An International Version

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ABSTRACT
1st time in the history of engineering a revolutionary idea for RCC column design is unearthed made so easy even on Android, Designing a column conventionally is a challenge to many structural engineers because it is cumbersome, complicated and time consuming in nature. The design method has also changed from time to time. The working stress method used in early 1970s. was improved with the introduction of ultimate design, which remained in vogue from early 1970's until 1980's. Now the limit state approach is being used. In these methods, curves and charts are given in different RCC Hand Books apart from these methods there are so many software are also available. Now, based on fundamental principles, A simple Program which simplify the arduous column design procedure, have been developed. The procedure adopted is applicable to all countries' codes.

Keywords: *column design, structure, RCC, International Version*

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INTRODUCTION

Every structural engineer knows the importance of columns' role in the structure.

Column as a main structural member which transfers all possible loads including earth quake loads and wind loads resulting the generation of axial loads and moments from beams above supporting Floors and Roofs. The safety and stability of structure mainly depends on columns. This paper presents new research and development for RCC column design based on basic concept and fundamentals in a very simplified method. This method is not only applicable for Indian code but also to all country codes. The design engineers will definitely get rid of the tardy, tedious, error in reading and time-consuming method by using various charts prepared based on trials and experiments with so many approximations from time immemorial.

THEORY AND METHOD

The initial work is based on first principal i.e., "moment is nothing but multiple of, force and eccentricity, due to these eccentricities, the increase in area of concrete section with no eccentricity, is again calculated then this area of concrete is converted in proportion to the area of steel. The summation of both these areas of steel, i.e., one due to pure axial compression and other due to converted area of steel due to the eccentricities. The theory for this research is explained for Indian, British and ACI Code similarly may be derived for other Country Codes. This simple Excel computer program may be made developed With minimum calculations requiring less than 10 KB storage even on Android .Columns are the most common vertical load-bearing elements in reinforced concrete structures. The primary role of a column in a typical building is to support floor structures such as slabs , beams and girders and transmit the load to the lower levels and then to the foundation. Columns are mainly subjected to axial compression loads and are often called compression member. In reality however, few reinforced concrete columns are subjected to purely axial compression loads. More often, bending moments are also present due to eccentricity of applied loads, applied end moments, and lateral loading on the column. The moment in column may be due to gravity loads, wind loads or earthquake loads. Even the internal columns of a symmetrically framed building carry some amount of moments due to gravity loads when different types of live loads arrangement are applied. For wind and earthquake loads, all columns may carry some moments. So in effect, columns are subjected to combined axial load and flexure.

Here RCC columns are divided in 2 parts where Part A deals with column without Slenderness, i.e., Short column having axial load, uni-axial and bi-axial bending ,Part B deals with slender column having axial load, uni-axial and bi-axial moments are considered ,if the column is slender use Part B first then Part A otherwise wise versa

PARTA (When the RCC column is Short with Axial load, Uni-axial and Bi-Axial Moments.)

Basic concept of proposed simplified method for a sample design of short RCC columns is explained as under:

As the moment are Mx and My, hence eccentricity ex and ey will be governing.

Due to this eccentricity of load in x-direction and y-direction, the load P or Puz will be at the junction of EF and IJ.

Where AB or CD is the width of section and AC or BD is the depth of section.

Consider CG of the section is at the origin of x-axis and y-axis

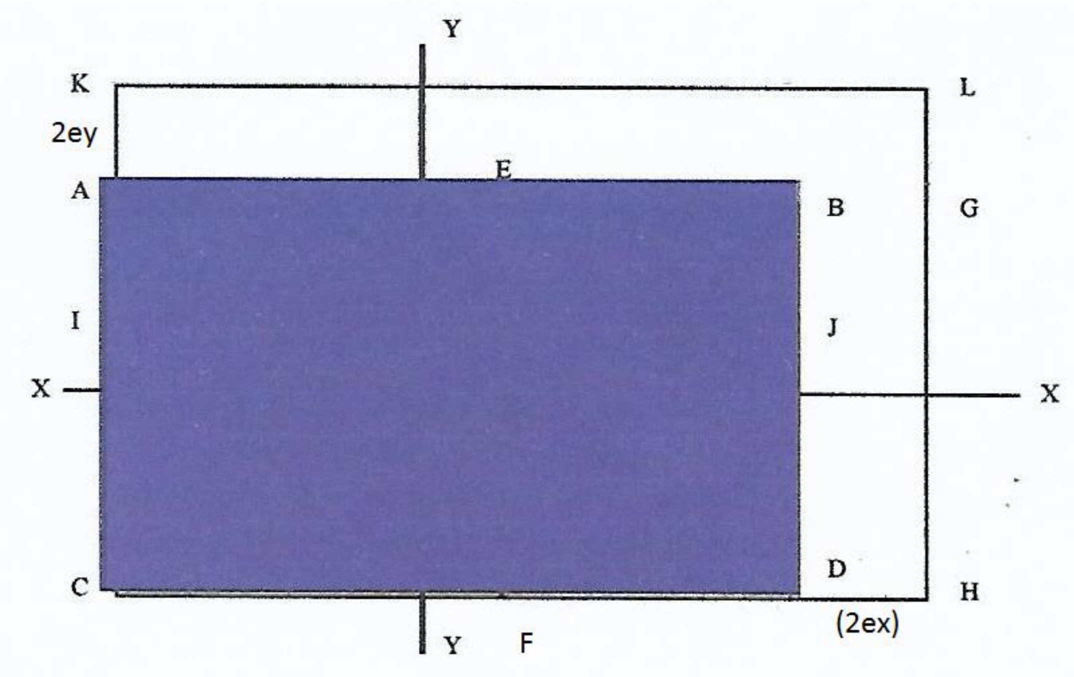

Fig. 1. *Concrete section.*

Eccentricity ex= Mx/P, i.e., Position of load due to moment Mx from CG, Hence distance of CG from line AC = Bx/2

Eccentricity ey= My/P, i.e., Position of load due to moment My from CG, Hence distance of CG from line CD=Dy/2

To neutralize the effect of eccentricity load has to be placed at CG(new), i.e.,

by a distance ex away from y-axis and ey away from x-axis at junction of line EF and IJ.

The revised width of the concrete core block shall be double of CF, i.e., CH

Hence revised half width CF=Bx/2+ex

Therefore revised full width CH or Bx1= 2x(Bx/2+ex), i.e., (Bx+2ex)

The revised depth of the concrete core block shall be double of CI, i.e., CK

Hence revised half depth CI=Dy/2+ey

Therefore revised full depth CK or Dy1 = 2x(Dy/2+ey), i.e., (Dy+2ey)

Hence equivalent core section without the effect of eccentricity shall be area

AREA enclosed by KLCH or A2=AK × CH or Bx1×Dy1, i.e., (Dy+2ey)×(Bx+2ex)

This equivalent area of concrete is divided in to two parts, i.e.,

First part, i.e., AREA enclosed by ABCD or A1=(Dy)×(Bx)

Second part i.e. Difference of AREAS between A2 and A1, i.e.,(A2-A1)as enclosed Blank Area in Figure1.

As maximum stresses in concrete and steel at axial strain of 0.002 i/c factor of safety

As per Indian Code IS 456-1978 vide clause 38.6,Equation for ultimate Axial Load without any eccentricity

Puz = (0.45) × (fck) × (Ac) + (0.75)× (fy) × (Asc)

Factor for concrete a = (0.45) × (fck) and Factor for steel b = (0.75)× (fy) respectively.

Puz = (0.450) × (fck) × (A1-Asc) + (0.75)× (fy) × (Asc)

As1 or Asc = (Puz-(0.450) × (fck)) × (A1)/(0.75 × (fy)-0.450 × (fck))

As2 = equivalent area of steel in proportion to concrete area in excess of original core area

Excessive area of concrete = (A2-A1)

Conversion factor for equivalent concrete to steel a/b = (0.45)× (fck)/(0.75)× (fy)

As2 = 0.450× fck/0.75× (fy)) × [A2-A1]

As =As1+As2
If the value of As1 or Asc comes out to be less than zero than put it, i.e., As1 or Asc as zero.

Replace the value of Fck proportionally as Fck '= (Puz) × 1000/(0.45 × A1)

Revise the calculations of accordingly.

PARTB (when the RCC column is Slender with axial load, uni-axial and Bi-axial moments)

When Slender Ratio Lex/Bx or Ley/Dy> 12,the RCC column is supposed to be Slender

Where Lex is effective length of the column parallel to Bx direction

Where Ley is effective length of the column parallel to Bx direction

And L is unsupported length of RCC column

SRx = Lex/Bx and SRy = Ley/Dy

Factor for revised Bx = SRx/12> 1 or 1 And Factor for revised Dy = SRy/12 > 1 or 1

Revised Bx' = (SRx/12)×(Bx) And Revised Dy' = (SRy/12)×Dy

Increase eccentricity due to Bx', i.e., ex1=(Bx'-Bx)/2 and increase eccentricity due to By', i.e., ey1=(Dy'-Dy)/2

Total Eccentricity parallel to Bx,i.e., ex"=ex + ex' And Total Eccentricity parallel to Dy, i.e., ey"= ey + ey'

Replace Bx' with Bx and Dy' with Dy And Replace ex" with ex and ey" with ex

Now replace these revised values of PART B to PART A and repeat the calculate to get the final results.

ILLUSTRATIVE CALCULATION

Example of RCC rectangular column (Dr S.R.CARVE and Dr V.L.SHAH Ex.9.8-2 on P-899) [1]:

Design a short R.C. column of rectangular section for the following data:
Size of column 230 mm × 530 mm
Factored load Pu, i.e., P1200 kN
Mux, i.e., Mx 50 kNm
Muy, i.e., My 10 kNm
Concrete Mix, i.e., Fck M20
Characteristic strength of reinforcement Fe i.e., Fy 250 N/mm^2
Bx =530.00 mm
Dy =230.00 mm
Ex, i.e., Mx/P=50× 1000/1200 =41.67 mm
Ey, i.e., My/P= 10×1000/1200 = 8.33 mm but < 20 mm hence 20 mm taken

Area A1 =230× 530=121900 mm^2

Area
A2 =(530+2× 41.67)× (230+2× 20) =165600 mm^2
As1 =(1000× 1200-0.45× 20× 121900)/(0.75× 250-0.45× 20)=576.47 mm^2
As2=0.45× 20/(0.75x250)× (165600-12100)=2097.60 mm^2
As1+ As2 = (576.47+2097.60)

As =2674.07 mm^2 as against 2560.00 mm^2

RCC CIRCULAR COLUMN

PARTA (When the RCC column is Short with Axial load, Uni-axial and Bi-Axial Moments.)

Basic Concept of Proposed simplified method for a sample design of Short RCC columns Is explained as under:

As the moment are Mx and My , hence eccentricity ex and ey will be governing.

As the RCC Column section is square hence resultant of Mx and My will be M = $\sqrt{(Mx^2+My^2)}$

Due to eccentricity of load in x-direction and y-direction, the load P or Puz will be at the junction of O', i.e., AB'/2

Where AB is the diameter of circular section, i.e., DIA And Area of original section of column, i.e., A1= (π/4)× (DIA)^2

Where, AB' is the diameter of circular section after considering moment, i.e., DIA1

Consider CG of the original section is at the junction of x-axis and y-axis, i.e., at O

Hence, distance of CG from A, i.e., AO= DIA/2,and Hence, distance of CG from A, i.e., AO'= DIA1/2

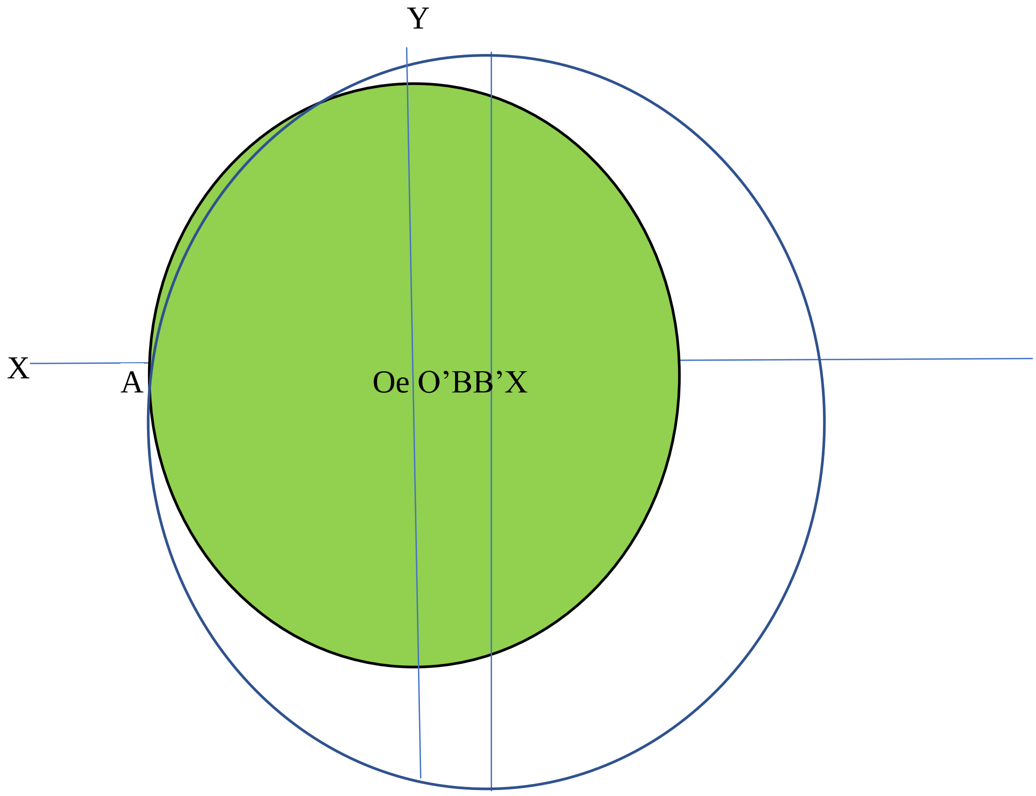

Fig. 2. *Concrete Section.*

Eccentricity e= M/P, i.e., Position of load due to moment M from CG, i.e., O

Hence, eccentricity e= AO'-AO =(DIA1/2-DIA/2)

To neutralize the effect of eccentricity load has to be placed at CG(new), i.e., O' by a distance e away from x-axis at junction of line AO and AO'.

Hence equivalent core section without the effect of eccentricity shall be area $A2=(\pi/4) \times (DIA1)^2$

This equivalent area of concrete is divided in to two parts, i.e.,

Second part, i.e., Difference of AREAS between A2 and A1, i.e., (A2-A1) as enclosed Blank Area in Figure 2.

As maximum stresses in concrete and steel at strain of 0.002 including factor of safety

As per Indian Code IS 456 -1978 vide clause 38.6 ,Equation for ultimate Axial Load without eccentricity Puz=(0.45) × (fck) × (Ac)+(0.75) × (fy) × (Asc)

Factor for concrete a = (0.45) × (fck) And
Factor for steel b = (0.75) × (fy)
respectively.

Puz =(0.450) × (fck) × (A1-Asc)+(0.75) × (fy) × (Asc)

As1 or Asc =(Puz-(0.450) × (fck)) × (A1)/(0.75× (fy)-0.450× (fck))

As2 = equivalent area of steel in proportion to concrete area in excess of original core Area.

Excessive area of concrete =(A2-A1)
Conversion factor for equivalent concrete to steel a/b = (0.45) × (fck)/(0.75) × (fy)

As2 = 0.450 × fck/0.75× (fy)) × [A2-A1]

As =As1+As2
If the value of As1 or Asc comes out to be less than zero than put it, i.e., As1 or Asc as zero.

Replace the value of Fck proportionally as Fck '= (Puz) × 1000/(0.45 × A1) And Revise the calculations

PARTB (when the RCC column is Slender with axial load, uni-axial and Bi-axial moments)

When Slender Ratio Le/DIA> 12 ,the RCC column is supposed to be Slender

Where Leis effective length of the column And L is unsupported length of RCC column

SR= Le/DIA
Factor for revised DIA= SR/12 > 1 or 1

Revised DIA' = SR/12 × DIA

Hence increase in eccentricity due to slenderness, i.e., e'=(DIA'-DIA)/2

Total eccentricity to slenderness, i.e., e"= e+ e'

Replace DIA' with DIA and Replace e'' with e

Now replace these revised values of PART B to PART A and calculate to get the final results.

ILLUSTRATIVE CALCULATION
Example of RCC Circular Column (RCC by ASHOK K JAIN vide Example 16.9 on P-494) [2]:

Design a Slender Braced Circular Column under uni-axial bending with the following data:
Size of column, i.e., DIA 40cm
Concrete grade, i.e., Fck M20
Steel grade, i.e., Fy 415 N/mm^2
Effective length, i.e.,Le6.0 m
Unsupported length, i.e., L7.0 m
Factored load, i.e., P 1200 kN
Factored moment750 kNm at top50kNm at bottom

Design Moment M=0.6× 75 +0.4× 50 = 65 kNm

As the RCC column is slender use PART B

e, i.e., M/P=65× 1000/1200 =54.17 mm
SF = 6000/400 = 15
DIA' =15/12× 400 = 500 mm
e' =(500-400)/2 =50 mmande" =54.17 + 50 = 104.17 mm

Now use Part A
DIA= 500 mm
e = 104.17 mm
Area A1 =(π/4)× 500^2= 196349.54 mm^2
Area A2 =(π/4)× (500+2× 104.17)
× (500+2× 104.17) =394062.62
As1 = (1200× 1000-0.45× 20× 196349.54)/(0.75× 415-0.45× 20)= -1878.77 mm^2< 0

Hence As1 =0.Therefore,Revise the value fck

Fck'= 1200× 1000/(0.45× 196349.54) = 13.58 N/mm^2

As2 =0.45× 13.58/(0.75× 415)× (394062.62 - 196349.54) = 3882.20

As1+ As2 = (0.0 +3882.2),i.e., As = 3882.2 mm^2 as against3800.00 mm^2

RCC L-SHAPE COLUMN
PART A (When the RCC column is Short with Axial load, Uni-axial and Bi-Axial Moments.)

Basic Concept of Proposed simplified method for a sample design of Short RCC columns is

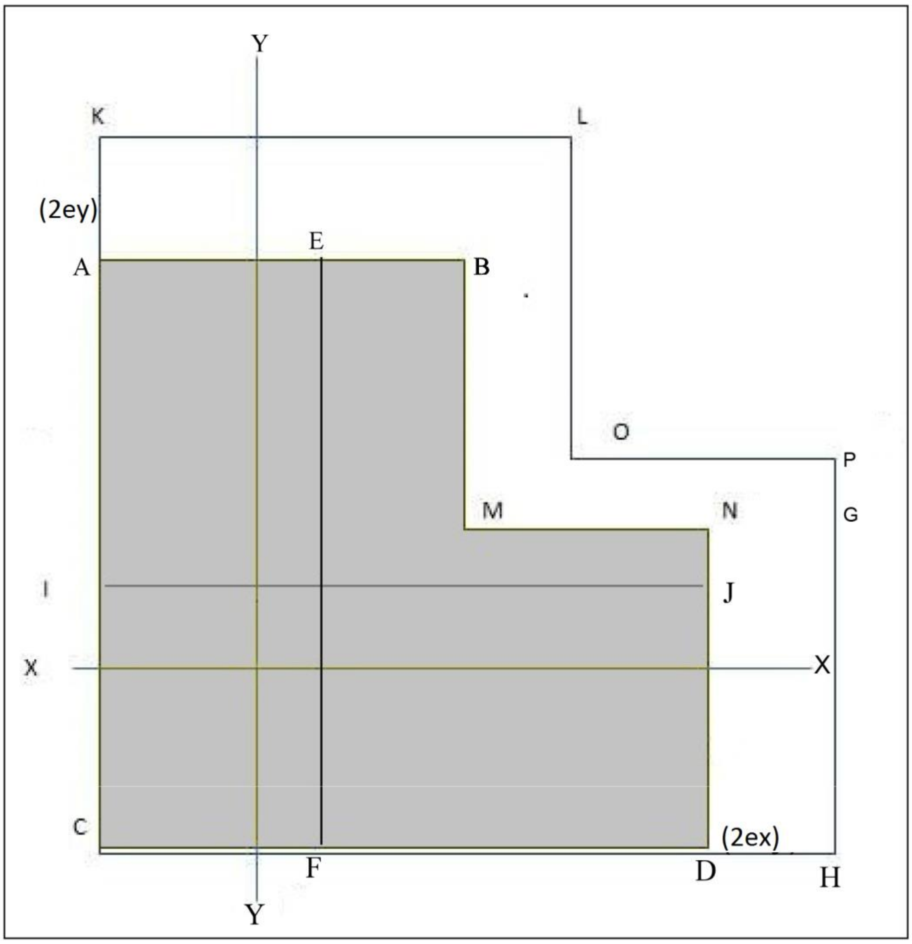

Fig.3. *Concrete Section.*

As the moment are Mx and My, hence eccentricity ex and ey will be governing.

Due to this eccentricity of load in x-direction and y-direction, the load P or Puz will be at the junction of EF and IJ.

Where CD is the width of section, i.e., Bx and AC is the depth of section i.e. Dy

Thickness of leg in X-direction, i.e., AB = Tx and Thickness of leg in Y-direction i.e. ND = Ty

Consider CG of the section is at the origin of x-axis and y-axis

Eccentricity ex= Mx/P, i.e., Position of load due to moment Mx from CG

Eccentricity ey = My/P, i.e., Position of load due to moment My from CG

To neutralize the effect of eccentricity load has to be placed at CG(new), i.e.,. by a distance ex away from y-axis and ey away from x-axis at junction of line EF and IJ.

The revised width shown for the concrete core block shall be extended by a value of 2times ex in X-direction

The revised depth shown for the concrete core block shall be extended by a value of 2 times ey in Y-direction

Hence original area of concrete, i.e.,A1 = (Bx)× (Ty) +(Dy-Ty)× (Tx)

Hence, equivalent core section without the effect of eccentricity shall be area, i.e.,

A2 = (Bx+2ex)× (Ty+2ey)+ (Dy - Ty)× (Tx+2ex)

This equivalent area of concrete is divided in to two parts, i.e.,

First part, i.e., AREA of original L-section = A1

Second part, i.e., Difference of AREAS between A2 and A1, i.e., (A2-A1)as enclosed Area in Figure 3.

As per Indian Code IS 456 -1978 vide clause 38.6,AndEquation for ultimate Axial Load without eccentricity

Puz = (0.45)× (fck)× (Ac)+(0.75) × (fy) × (Asc)

Factor for concrete a = (0.45)× (fck) And Factor for steel b = (0.75)× (fy) respectively.

Puz = (0.450)× (fck)× (A1-Asc)+(0.75)× (fy)× (Asc)

As1 or Asc = (Puz-(0.450)× (fck))× (A1)/(0.75× (fy)-0.450× (fck))

As2 = equivalent area of steel in proportion to concrete area in excess of original core area.

Excessive area of concrete = (A2-A1) as enclosed Blank in Figure 3.

Conversion factor for equivalent concrete to steel a/b = (0.45)×(fck)/(0.75)×(fy)

As2 = 0.450×fck/0.75x(fy))×[A2-A1] And As =As1+As2

If the value of As1 or Asc comes out to be less than zero than put it, i.e., As1 or Asc as zero.

Replace the value of Fck proportionally as Fck '= (Puz) × 1000/(0.45× A1), i.e., Revise the calculations accordingly.

PARTB (when the RCC column is Slender with axial load, uni-axial and Bi-axial moments)

When Slender Ratio Lex/Bx or Ley/Dy> 12,the RCC column is supposed to be Slender

Where Lex is effective length of the column parallel to Bx direction

Where Ley is effective length of the column parallel to Bx direction

And L is unsupported length of RCC column

SRx = Lex/Bxand SRy = Ley/Dy
Factor for revised Bx = SRx/12 > 1 or 1 And Factor for revised Dy = SRy/12 > 1 or 1

Revised Bx' = (SRx/12)× Bx And Revised Dy' =(SRy/12)× Dy

increase in eccentricity due to Bx', i.e., ex1=(Bx'-Bx)/2 and increase in eccentricity due to By', i.e., ey1=(Dy'-Dy)/2

Total Eccentricity parallel to Bx, i.e., ex"= ex + ex' And Total Eccentricity parallel to Dy, i.e., ey"= ey + ey'

Replace Bx' with Bx and Dy' with Dy And Replace ex" with ex and ey" with ex

Now replace these revised values of PART B to PART A and repeat the calculate to get the final results.

ILLUSTRATIVE CALCULATION

Example of RCC L-Shape Column (Ramamurthy and Shah using method 1 and method 2 [3].

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Design a Short Column under bi-axial bending with dimension 400 mm × 300 mm × 200 mm nominal cover of 50 mm and subjected to an axial load of 890.8 kN and a factored moments of 90.4 and 56.5 kNm about x- and y-axis, respectively. compressive strength of concrete Fck is 25 N/mm^2 and yield strength of steel Fy is 415 N/mm^2:

Size of column 400mm × 300mm × 200mm
Factored load P 890.8 kN
Mux, i.e., Mx 90.4kNm
Muy, i.e., My 56.5kNm
Concrete Mix, i.e., Fck M20
Characteristic strength of reinforcement Fy = 415 N/mm^2
Bx = 400.00 mm
Dy = 300.00 mm
Tx = 200 mm and Ty = 200 mm
Ex, i.e., Mx/P=90.4× 1000/890.8=101.48 mm
ey, i.e., My/P = 56.5× 1000/890.8=63.43 mm
Area A1 =400× 200 + (300-200)× 200
= 100000 mm^2
Area A2 = (400+2× 101.48) × (200+2× 63.43) + (300-200)× (200+2× 101.48)
=237376.39 mm^2

As (890.8× 1000-0.45× 25× 100000) < 0.0So As1= 0.0
So Fck' = 890.8× 1000/(0.45× 100000)=19.80 mm^2

As2= 0.45× 19.80/(0.75× 415)× (237376.39-100000)= 3931.72 mm^2

As1+ As2 = (0.0+3931.72)and As = 3931.72 mm^2as against 3920 mm^2

BRITISH CODE

The ultimate axial load of column is derived partially from concrete section and partially from quantity of steel as per British Code-8111 as per Ultimate Axial load, i.e.,

Puz = 0.45 Fck. Ac + 0.95 Fy. Asc" (worked out by Author, but it may vary)

Factor for concrete a = (0.45)× (fck) And Factor for steel b = (0.95)× (fy) respectively.

ACI CODE

The ultimate axial load of column is derived partially from concrete section and partially from quantity of steel as per ACI-CODE 318 as per Ultimate Axial load, i.e.,

Puz = 0.442Fck.Ac + 0.52Fy.Asc" (worked out by Author, but it may vary)
Factor for concrete a = (0.45)× (fck) And Factor for steel b = (0.95)× (fy) respectively.

Similarly theory and Procedure for the Design of RCC Column as per BRITISH CODE And as per ACI are same as in the case of INDIAN CODE except the Values of 'a' and 'b' in the above equation for ultimate axial load.

RESULTS AND CONCLUSION

The examples' results will be so surprising to all Engineer's community that so complicated and time consuming process to design All RCC Columns with axial Load and bi-Axial moments having slenderness of any shape and size particularly L-Shape and Irregular Shape RCC Columns with different dimensions and thicknesses in Both the directions as well ,are made so easy even on Android Phone. It is most simplified method ever attempted before as it requires minimum calculations. The results obtained are very authentic as being based on first principles of Force and Moment and Relationship with Eccentricity and The Results reasonably comparable to all the existing methods of design and software available for the design of RCC Columns.

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AUTHORS’ BIOGRAPHY

R.G. Gupta, a structural engineer and structural consultant graduated from Government Engineering College Jabalpur (India) completed BE (Hons) in Civil Engineering in year 1967 and joined Delhi Development Authority (India) worked as Structural Engineer in Central Design Organization of DDA retired as Superintending Engineer in year April 2005.Since a Firm was launched Namely ‘Pitambara Structural Consultant’ got empaneled as Structural Consultant From DDA has provided Consultancy to number of major civil projects in India.

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