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Comparative Study on Structural Analysis and Design of a RCC Building Frame

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Abstract—*The paper covers all the aspects of analysis and design of the RCC building frame. In brief, it gives full coverage of analysis and design of a residential building frame using three methods i.e. moment distribution method, IS code coefficient method and using STAAD Pro and then the comparison of the results obtained from the three methods. The design philosophy followed in the present work is Limit state Design. All the design carried out in the project is based on the specification recommended by Indian standard code of practices. I.S Codes which have been thoroughly used are IS 456:2000 (Code of Practice for plain and reinforced concrete), IS 875:1987, design aid to IS 456, i.e SP-16. For Earthquake forces the recommendation made by IS 1894:1984 and IS 1894:2002 have been followed.*

1. INTRODUCTION

A Multi-story is a building that has multiple floors above ground in the building. Multi-story buildings aim to increase the floor area of the building without increasing the area of the land the building is built on, hence saving land and, in most cases, money.

The RCC frame is of (G+1) storey commercial building with 5 offices, corridor and stair case (Fig. 1 & 2). The total covered area is 228 sq.m with total no. of storey (G+1). Total height of building is 7.2m. Type of structure is RCC framed & type of foundation is isolated footing.

STAAD.Pro V8i is a comprehensive and integrated finite element analysis and design offering, including a state-of the-art user interface, visualization tools, and international design codes. It is capable of analyzing any structure exposed to static loading, a dynamic response, wind, earthquake, and moving loads. STAAD PRO is very powerful software which can be used for 3-D analysis & is useful for analysis and design of multi-storied buildings.

2. MOMENT AND SHEAR COEFFICIENT OF IS 456:2000

SALIENT FEATURES OF PROJECT

Building type: Public Building

Height of the building: 7.2 m

Plan area of building: 20 x 11.4 m^2

Column size: 450 x 450 mm

Beam size: 300 x 500 mm

Thickness of slab: 150 mm

Grade of concrete used: M 25

Grade of steel used: Fe 415

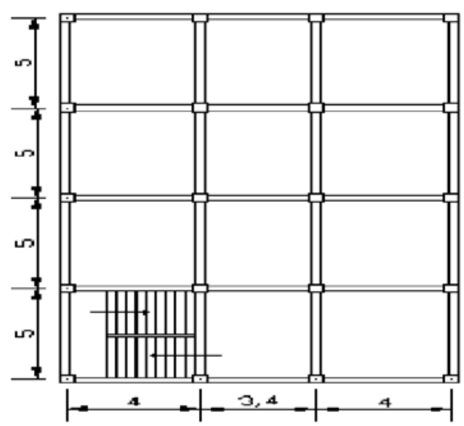

Fig. 1: Plan view of the RCC building frame.

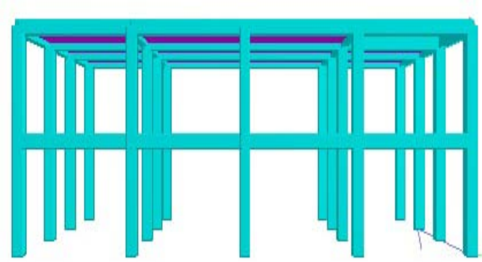

Fig. 2: Side elevation of the RCC building frame.

Load calculation on beam:

The frame as shown below (Fig. 3) is outer frame which is being analysed by the method considered.

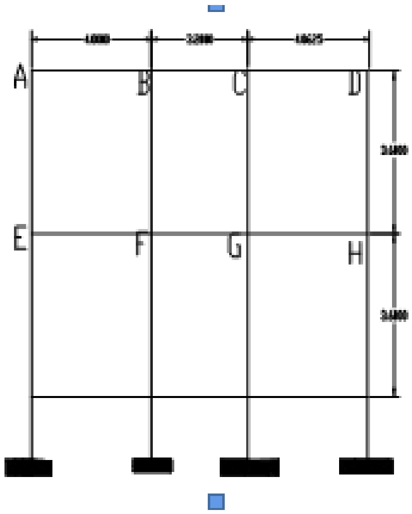

Fig. 3: Outer frame

Load coming on beam of second storey

Self-wt. of Parapet wall=20×1×0.2=4 kN/m

Load from Slab=distributed load from slab on beam AB

$=\frac{(self\ wt.of\ slab+finishing\ load)\times area of\ \ distribution}{span\ \ length\ of\ AB}$

$=\frac{(0.15\times25+2)\times4}{4}=5.75$kN/m

Self-wt. of beam AB=25×0.45×0.3=3.75kN/m

4. Load on Beam due to live load on slab distributed as per clause 24.5 in IS 456:2000 i.e.2×4/4=2kN/m

Bending moments:

Mid span moments (KN-m)

Let's calculate for Beam AB which is end span & according to Table 12 Is 456:2000 the bending moment coefficients for AB are 1/12 for dead load (Wd) & 1/10 for live load (WL)

Mmidspan of AB=$\frac{W_d\times l^2}{12}+\frac{W_L\times l^2}{10}$

$=\frac{\mathbf{20.25}\times4.3^2}{12}+\frac{3\times4.3^2}{10}$

=36.74 kN-m

Similarly for other Beams considering their cases & as above other moments are calculated and shown in the table 1.

Table 1: Mid span Moments (KN-m)

Span	Effective span(m)	dead load(Wd)	live load(WL)	Moment(kNm)
AB	4.3	20.25	3	36.74
BC	3.7	18.94	2.55	18.5
CD	4.3	20.25	3	35.3
EF	4.3	46.32	3	75.5
FG	3.7	45.07 5	5.1	42.7
GH	4.3	46.32	3	76

Support Moments (i.e. hogging moment):

The moment from Beam AB to Support A will be calculated as per 22.5.2 i.e. moment Coefficients will be 1/12for dead as well as live load

MAB=$\frac{W_d\times l^2}{12}+\frac{W_L\times l^2}{12}$

$=\frac{20.25\times4.3^2}{12}+\frac{3\times4.3^2}{12}$

= 35.82kN-m

Now for Support B from Beam AB i.e. MBA

MBA =$\frac{W_D\times l^2}{10}+\frac{W_L\times l^2}{9}$

$=\frac{20.25\times4.3^2}{10}+\frac{3\times4.3^2}{9}$

= 43.6KN-m

Similarly for other Beams considering their cases & as above other moments are calculated and shown in the table 2.

Table 2: Support Moments (KN-m)

support	Effective span(m)	Dead load	Live load	Moment
M_{AB}	4.3	20.25	3	35.82
M_{BA}	4.3	20.25	3	43.6
M_{BC}	3.7	18.94	2.55	28.83
M_{CB}	3.7	18.94	2.55	28.83
M_{CD}	4.3	20.25	3	41.87
M_{DC}	4.3	20.25	3	35.82

3. DESIGN OF BEAM AND COLUMN

Design of a beam of first storey:

Taking beam IJ

Effective span length= 4.3m

Effective depth = 400 – 30 – 10 = 360 mm

Width = 300 mm

Mid span moment= 94.24 KN-m

MU ,lim= 0.36fckbxulim (d -0.42xulim)

$M_{U\ lim}$ = 0.36 x25x0.48x360x(360 – 0.42x0.48x360)

= 135 kN-m

$R_{ulim} = \frac{MU\ lim}{bd^2}$

$d = \sqrt{\frac{MU\ lim}{bd\text{^}2}} = \sqrt{\frac{94.24*10\text{^}6}{3.46*360}}$ = 301.31 < 360 (ok)

Calculation of reinforcement:

MU =0.87fYAst (d - 0.42xu)

94.24x106 = 0.87x415xAstx (360 - $\frac{0.42x0.87x415xAst}{0.36X25X360}$)

Ast = 832 mm2

Providing 3- 16Φ + 1 -20Φ

Ast provided = 917.345 mm2

Deflection check:

$\frac{l}{d}$ =26

$d = \frac{l}{26} = \frac{4300}{26}$ = 166 <360 mm (ok)

Minimum reinforcement

$\frac{Ast}{bd} = \frac{0.87}{fy}$

Amin $= \frac{0.87X300X360}{415}$ = 221.20 mm

Maximum reinforcement:

Astmax =.04bD = .04x300x400

=4800 mm2

Reinforcement for negative moment

At support S, Mu = 91.93 KN-m

Mu = 0.87 x fy xAstx (d – 0.42xu)

91.93x106 = 0.87x415xAstx (360 – 0.42$\frac{0.87x415xAst}{.36X25X300}$)

Ast = 808.75 mm2

Providing 2 - 16Φ +1- 20Φ

At support F'

Moment =118.85 mm2

118.85x106 = 0.87x415xAst (360 - $\frac{0.87x415xAst}{.36X25X360}$)

Ast = 1103.21 mm2

Providing 6 -16Φ

Design for shear :

Dead load = 54.05 KN/m

Live load = 7.5 KN/m

As per IS code 456 -2000

Shear force for fixed load =0.6x54.05x4.3

=139.5 kN

Shear force for live load = 0.6x7.5x4.3

= 19.35kN

Ultimate shear force = 139.5+19.35

VU =156.85 kN

Nominal shear stress

$\tau v = \frac{Vu}{bd}$

$= \frac{158.86*1000}{300*360}$ = 1.47 MPa p = $\frac{100X917.345}{300X360}$ =0.85 %

shear strength of concrete

τc = 0.16 MPa

Shear carried by shear reinforcement = VU – τ cxbd

=158.85x1000-0.6x300x360

=92.970 kN

Providing vertical stirrup

Vu = $\frac{0.87x415xAsvx\,d}{Sv}$

SV =$\frac{0.87x415x2x\pi x8x8}{92970X4}$x360

=140.55mm

Check for spacing

Minimum of 3d 300mm

0.75x360 = 270 mm

Providing spacing 140 mm c/c (Fig. 4).

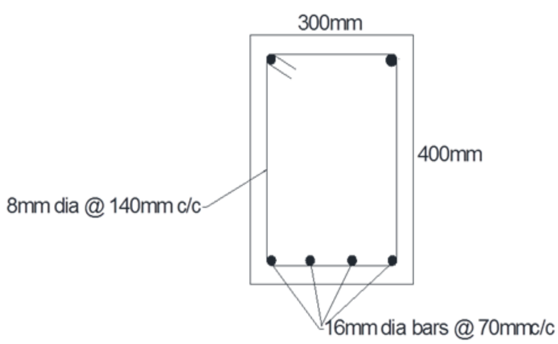

Fig. 4: Detailing of reinforcement of beam

Design of column:

For load calculated on column by moment and shear cofficients method of IS456:2000

Pu = 930kN

Column Size = 450 x 450 mm

Height of column = 3.6 m

Assume 0.8 % steel

Ag = 202500 mm2

Asc = 0.8 x Ag

Load Carrying Capacity of Column

Pu = 0.4xfck x Ac + 0.67xfy x Asc

= 0.4 x 30 x (Ag – Asc) + 0.67 x 415 x 0.008 x Ag

= 0.4 x 30 x (202500 -1620) + 0.67 x 415 x 0.008 x 202500

= 2861 kN>930 kN

So Provide minimum reinforcement of 0.8%

Provide 8-16mm dia bars

Asc,prov = 1608.5 mm2

LATERAL TIES:

DIAMETER OF LATERAL TIES

1) Greater than one fourth of largest longitudinal bar=12/4=3mm

2) Greater than 6mm

So provide 8mm diameter.

PITCH

1) Less than least lateral dimension=450mm

2)16 times smallest dia of longitudinal reinforcement=16×12=192mm

3)300mm

So provide pitch of 190mm (Fig. 5).

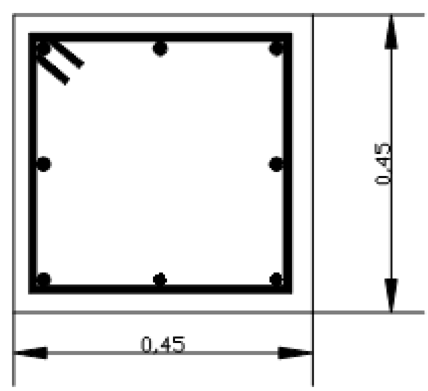

Fig. 5: Detailing of reinforcement of beam

4. MOMENT DISTRIBUTION METHOD

Load Considered:

(a).Dead Load

(b).Live Load

As per IS code,we took the load factor equals to 1.5 and accordingly the structure is designed for a load combination i.e. 1.5(D.L + L.L)

Procedure to be followed:

1. Determine the load on the structure i.e on beams caused by the dead and live load.

2. Find out the moments at every node using Moment distribution moment.
3. The indeterminate structure now convert into determinate structure and now determine the structural parameters(Shear force & Bending moment) in each member.
4. Design the beams and columns using Shear force and bending moments.

Steps:

Step 1.

Determine the load on members.

IS code says that if the uniformly distributed load from the two way slab coming over the beams the distributed to the orthogonal beams as shown in Fig. 7 above.

Care must be taken to distribute the load on the members.

Step 2.

Find out the moment at every node using moment distribution method.

Step 3.

Design of members.

The frame is analysed using moment distribution method as discussed above and some results as sample have been given below (table 3).

Table 3: Moment distribution table in partial form (For the Outermost Bay in X-Direction)

Joints	A	B		
members	AB	BA	BL	BC
D.F	0	0.385	0.23	0.385
FEM	0.00	0.00	-43.73	0.00
BAL		16.84	10.06	16.84
C.O	8.42	0.00	-1.20	13.67
BAL		-4.80	-2.87	-4.80
C.O	-2.40	0.00	-0.32	-2.09
BAL		0.93	0.56	0.93
C.O	0.46	0.00	0.27	1.11
BAL		-0.53	-0.32	-0.53
C.O	-0.26	0.00	-0.02	-0.18
BAL		0.08	0.05	0.08
FINAL MOMENTS	9.33	18.77	-56.29	37.52

5. ANALYSIS AND DESIGN BY STAAD PRO

Staad Pro provides an easiest and efficient means of analysis and design of a multi-storey structure. The basic steps to be followed (Fig. 6 - 8).

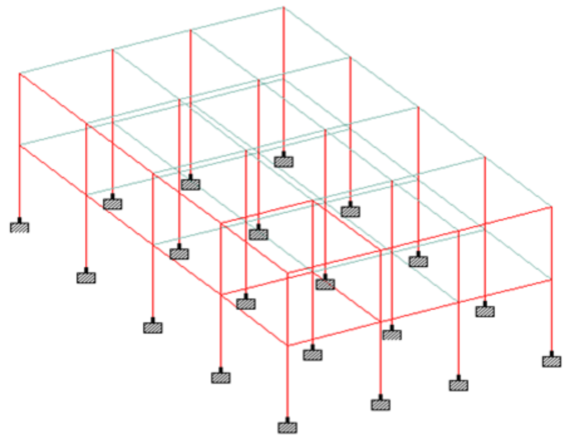

Fig. 6: Model of the structure in STAAD Pro

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BEAM NO.   71 DESIGN RESULTS

M30          Fe415 (Main)          Fe415 (Sec.)

LENGTH: 5000.0 mm    SIZE: 300.0 mm X 450.0 mm   COVER: 25.0 mm

SUMMARY OF REINF. AREA (Sq.mm)
SECTION    0.0 mm    1250.0 mm    2500.0 mm    3750.0 mm    5000.0 mm
TOP        846.22      0.00         0.00         0.00       844.75
REINF.    (Sq. mm)   (Sq. mm)     (Sq. mm)     (Sq. mm)     (Sq. mm)

BOTTOM      0.00      257.46       410.47       257.46       0.00
REINF.    (Sq. mm)   (Sq. mm)     (Sq. mm)     (Sq. mm)     (Sq. mm)

SUMMARY OF PROVIDED REINF. AREA
SECTION    0.0 mm    1250.0 mm    2500.0 mm    3750.0 mm    5000.0 mm
TOP      11-10i      2-10i       2-10i       2-10i       11-10i
REINF.  2 layer(s)  1 layer(s)  1 layer(s)  1 layer(s)  2 layer(s)

BOTTOM   2-12i       3-12i       4-12i       3-12i       2-12i
REINF.  1 layer(s)  1 layer(s)  1 layer(s)  1 layer(s)  1 layer(s)

SHEAR  2 legged 8i 2 legged 8i 2 legged 8i 2 legged 8i 2 legged 8i
REINF. @ 150 mm c/c @ 150 mm c/c @ 150 mm c/c @ 150 mm c/c @ 150 mm c/c

SHEAR DESIGN RESULTS AT DISTANCE d (EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT

SHEAR DESIGN RESULTS AT  640.0 mm AWAY FROM START SUPPORT
VY =  101.34 MX =   0.01 LD=   3
Provide 2 Legged 8i @ 150 mm c/c

SHEAR DESIGN RESULTS AT  640.0 mm AWAY FROM END SUPPORT
VY = -102.73 MX =   0.01 LD=   3
Provide 2 Legged 8i @ 150 mm c/c
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Fig. 7: Design Output in STAAD Pro

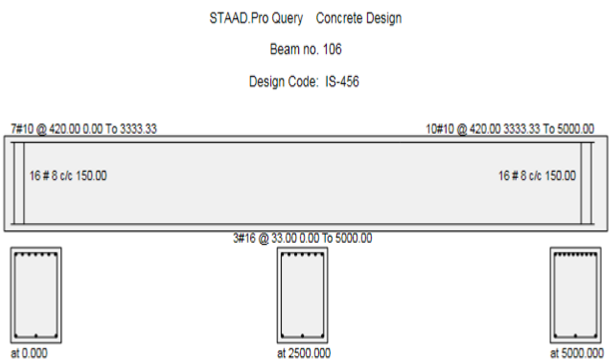

Fig. 8: Reinforcement detailing from STAAD Pro

Comparison of mid span moments and steel and shear force by different methods are given in tabular form (table 4):

Table 4: Comparison of results from three methods

	Beam /column	Moment distribution method	IS Code method	Staad pro analysis
BEAM No.	105			
Shear force(kN)		70.87	60	88.9
Bending moment(kN-m)		-47.18	-43.6	-47.78
Reinforcement(mm^2)		-474.88	-340	-452.39
BEAM No.	75			
Shear force(kN)		64.6	60.51	80.2
Bending moment(kN-m)		-57.8	-75.3	-50.60
Reinforcement(mm^2)		-392.8	-595	-392.7
BEAM No.	113			
Shear force(kN)		94	66.3	116
Bending moment(kN-m)		-78.66	-62.125	-75.4
Reinforcement(mm^2)		-706.86	-488	-785.35

6. CONCLUSIONS

The building has been designed predominantly by using the software STAAD. The building has been conceived as a framed structure without shear walls. The beams and columns are designed using STAAD PrO software.

Apart from this we have designed building frame manually for the purpose to check & compare the results obtained from different methods. Manually frame analysis and design has been done by moment & shear cofficients method of IS456:2000 and by moment distribution method. We can compare the results of different methods given in above table.

REFERENCES

[1] IS 456:2000 Indian standard plain and reinforced concrete code of practice (fourth revision), Bureau of Indian Standards, New Delhi.

[2] IS 875:1987 Code of Practice for design loads (other than Earthquake) for building structures, Bureau of Indian Standards, New Delhi.

[3] IS 1893:2002 Criteria for Earthquake design of structures (fourth revision), Bureau of Indian Standards, New Delhi.

[4] SP-16:2000 Design Aids for Reinforced Concrete to IS 456:2000, Bureau of Indian Standards, New Delhi.