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Analysis And Design Of Multistoried RCC Building (G+2) Compared With STAAD Pro

S. Gayathri
G. Raghu
V. Rajeswari
UG Student, DMSSVH College, Machilipatnam,
Andhra Pradesh, India

K. Nehemiya
Assistant Professor in Civil Engineering Department,
DMSSVH College, Machilipatnam,
Andhra Pradesh, India

***Abstract:** As per present scenario utilization of a piece land is the major task in front of a civil engineer in rapid developing towns. As the cost of land is high, it is essential to construct multi-storey building. Structural design is an art of designing, with economy and elegance, a safe serviceable and durable structure. The process of designing commences with the planning of the structure, primary to meet the functional requirements of the user. The functional requirements and economy of the structure for its intended use over the life span of the structure are intended to by the structural design. The main aim of this paper is analysis and design of a Multi storied RCC building (G+2) manually and the calculated values are verified with the help of STAAD pro.*

***Keywords:** Loads, Slabs, Beams, Columns, Footings, Structural Designing, Relevant Is Codes, STAAD Pro*

I. INTRODUCTION

Structural design is an art of designing, with economy and elegance, a safe serviceable and durable structure. Slabs are the main structural components, which directly exposed to the live loads in a structure, whether it is multi storied structure or a load bearing structure. In case of multistoried structure the loads from the slabs is transferred to the beams and in turn to the columns, which are resisting on a footing. The footing transfers the load to the soil there by the load is safely transferred to the earth. Where as in case of load bearing structures the loads from the slabs is directly transferred to the load bearing walls, which in turn transferred to the earth through isolated footings. This present project is the design of such multistoried structure which is practically viable

Here in this paper, work based on software named "STAAD. Pro" has been used. Few standard problems also have been solved to show how "STAAD. Pro" can be used in different cases. These typical problems have been solved using basic concept of loading, analysis, condition as per IS code. These basic techniques may be found useful for further analysis of problems.

A. ADVANTAGES OF STAAD PRO

- ✓ Extremely Flexible Modeling Environment.
- ✓ Broad Spectra of Design Codes.
- ✓ International Best Seller.
- ✓ Interoperability and Open Architecture.
- ✓ Covering All Aspects of Structural Engineering.
- ✓ Quality Assurance.
- ✓ Easy Reports and Documentation.

B. SOIL INVESTIGATION

Soil investigation are done to know the safe bearing capacity of soil. Direct shear test is used to know the SBC soil

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Figure 1: Collection and Testing of Soil Sample

CALCULATION OF SAFE BEARING CAPACITY OF SOIL

$q_u = CN_c + qN_q + 0.5B\gamma N_\gamma$
after testing in direct shear apparatus and
From graph, $C = 3kN/m^2$, $\gamma = 15.58\ kN/m^3$
$S.B.C = 120.7\ kN/m^2 = 12\ t/m^2$

C. REVISION OF IS CODES

- ✓ Dead Load can be calculated by IS875 part-1
- ✓ Live Load can be calculated by IS875 part-2
- ✓ Wind Load can be calculated by IS875 part-3
- ✓ Earthquake Load can be calculated by IS1893-2002

Analysis and design can be calculated by using IS456-2000, SP16

D. PLAN

The selected dimensions of the building are shown below according to indian Vaastu

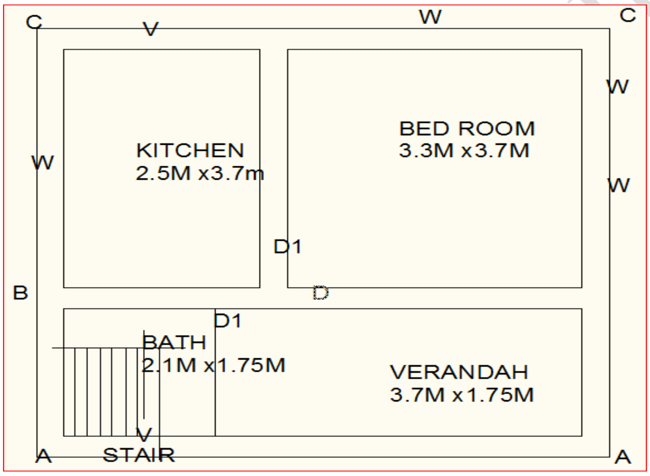

Figure 2: Plan of a building

E. OBJECTIVES

- ✓ Test for safe bearing capacity of soil.
- ✓ Analysis and design of the structure by using IS codes
- ✓ Analysis and design of structure by using STAAD Pro and Comparison of results

II. LITERATURE REVIEW

- ✓ *V.Varalakshmi:* The design and analysis of multistoried G+5 building at Kukatpally, Hyderabad, India. The Study includes design and analysis of columns, beams, footings and slabs by using well known civil engineering software named as STAAD.PRO. Test on safe bearing capacity of soil was obtained.
- ✓ *P.Jayachandran:* The design and analysis of multistoried G+4 building at Salem, tamilnadu, India. The study includes design and analysis of footings, columns, beams and slabs by using two software's named as STAAD. PRO and RCC Design Suit.

III. COLLECTION OF PRELIMINARY DATA FOR A SELECTED SITE

- ✓ Type of structure = multistory RC building
- ✓ Zone = III(IS875 part-II)
- ✓ Importance of building = residential building
- ✓ Number of stories = three (G+2)
- ✓ Floor-to-floor height = 3.5m
- ✓ Size of exterior column = 300×300mm
- ✓ Size of interior column = 250×250mm
- ✓ Size of beams in longitudinal and transverse direction =300×450mm
- ✓ Depth of slab = 120mm
- ✓ Thickness of external = 250mm
- ✓ Thickness of internal walls =150mm
- ✓ Live load = $3.5kN/m^2$
- ✓ Materials = M 20 and Fe 415
- ✓ Design procedure = limit state method according to IS456:2000

IV. LOADS

A. DEAD LOAD

AT ROOF LEVEL

Weight of slab = $3\ KN/m^2$
Weight of terrace + Floor Finish = 1.5 + 0.5
= $2\ KN/m^2$
Total weight = $5\ KN/m^2$

AT FLOOR LEVEL

Dead load on floor = $3\ KN/m^2$
Floor Finish = $0.5\ KN/m^2$
Total weight = $3.5\ KN/m^2$

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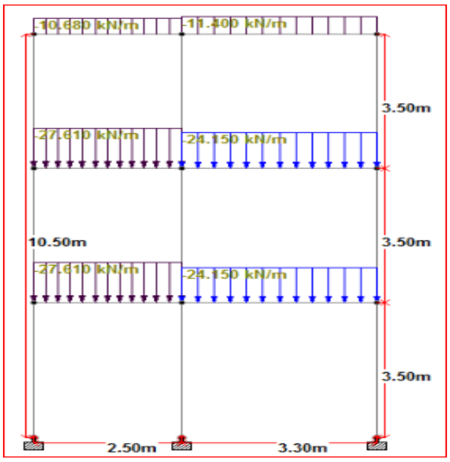

Figure 3: Dead loads on frame

B. LIVE LOAD

At Roof Level = 1.5 KN/m^2
At Floor Level = 3.5 KN/m^2

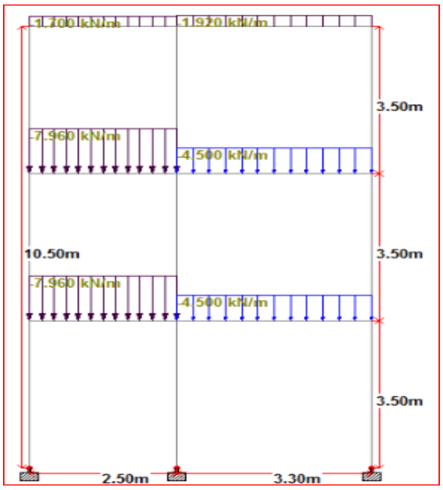

Figure 4: Live loads on frame

C. EARTHQUAKE LOAD

Design horizontal Seismic coefficient:
$A_h = ZIS_a / 2Rg$
Total Base Shear (V_B) = A_h x W

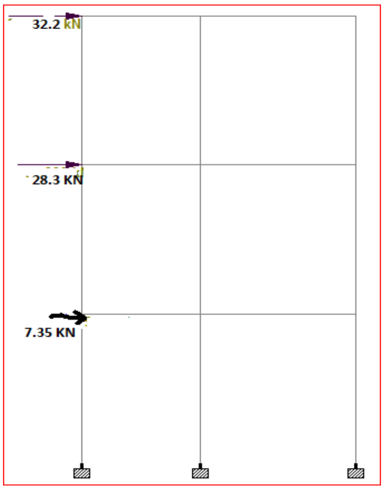

Figure 5: Earthquake loads at each floors

D. LOAD COMBINATION

Load combination for Static analysis:

- ✓ 1.5(DL + LL)
- ✓ 1.2(DL + LL ± EL)
- ✓ 1.5(DL ± EL)
- ✓ 0.9 DL ± 1.5 EL

In the above load combinations, the maximum load combination is 1.5(DL + LL) from STAAD pro analysis.

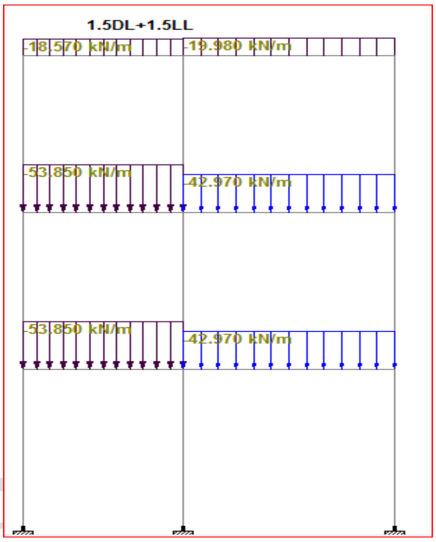

Figure 6: Load Combinations

V. ANALYSIS BY KANIS METHOD

Calculations of MI and rotation factors
$I_{ext} = bd^3/12 = (300x300^3)/12 = 675x10^6$ mm^4 = I
$I_{int} = bd^3/12 = (250x250^3)/12 = 325.52x10^6$ mm^4 = 0.482I
$I_{beam} = bd^3/12 = (300x450^3)/12 = 2278.1x10^6$ mm^4 = 3.37I
K = (4EI)/L → K = I/L (R.F) = -0.5(K/∑K)

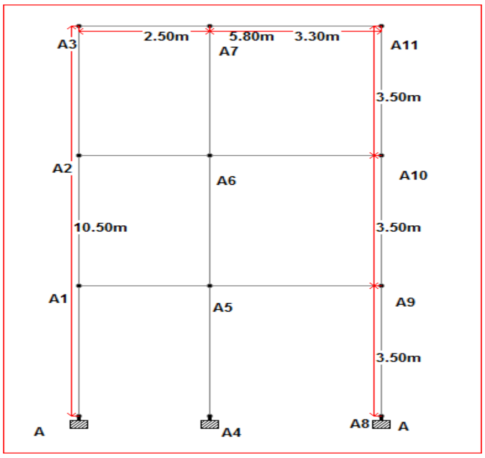

Figure 7: beam and column designations

FINAL MOMENTS

M_{AA1} = 0 + 2x0 + 1.78 = 1.78 KN-m;
M_{A1A} = 0 + 2x1.78 + 0 = 3.56KN-m

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M_{A1A2} = 0 + 2x1.78 + 1.78 = 5.34KN-m;
M_{A2A1} = 0 + 2x1.78 + 1.78 = 5.34KN-m
M_{A2A3} = 0 + 2x1.78 + 0.371 = 3.931KN-m
M_{A3A2} = 0 + 2x0.371 + 1.78 = 2.522KN-m
M_{A4A5} = 0 + 2x0 + 0.441 = 0.441 KN-m
M_{A5A4} = 0 + 2x0.441 + 0 = 0.882 KN-m
M_{A5A6} = 0 + 2x0.441 + 0.4 = 1.282 KN-m
M_{A6A5} = 0 + 2x0.4 + 0.441 = 1.241 KN-m
M_{A6A7} = 0 + 2x0.4 + 0.51 = 1.31 KN-m
M_{A7A6} = 0 + 2x0.51 + 0.4 = 1.42 KN-m
M_{A8A9} = 0 + 2x0 + (-3.82) = -3.82 KN-m
M_{A9A8} = 0 + 2x(-3.82) + 0 = -7.641 KN-m
M_{A9A10} = 0 + 2x(-3.82) + (-3.58) = -11.22 KN-m
M_{A10A9} = 0 + 2x(-3.58) + (-3.82) = -10.98 KN-m
M_{A10A11} = 0 + 2x(-3.58) + (-1.874) = -9.031 KN-m
M_{A11A10} = 0 + 2x(-1.874) + (-3.58) = -7.66 KN-m
M_{A1A5} = -27.78 + 2x7.58 + 3.675 = -8.945 KN-m
M_{A5A1} = 27.78 + 2x(3.675) + 7.58 = 42.71 KN-m
M_{A2A6} = -27.78 + 2x7.57 + 3.37 = -9.27 KN-m
M_{A6A2} = 27.78 + 2x3.37 + 7.57 = 42.09 KN-m
M_{A3A7} = -9.67 + 2x(1.95) + 3.38 = -2.47 KN-m
M_{A7A3} = 9.67 + 2x(3.38) + 1.95 = 18.22 KN-m
M_{A5A9} = -39 + 2x(2.79) + (-11.46) = -47.88 KN-m
M_{A9A5} = 39 + 2x(-11.46) + 2.79 = 18.87 KN-m
M_{A6A10} = -39 + 2x2.56 + (-10.76) = -44.64 KN-m
M_{A10A6} = 39 + 2x(-10.76) + 2.56 = 20.04 KN-m
M_{A7A11} = -18.13 + 2x2.5 + (-6.64) = -19.77 KN-m
M_{A11A7} = 18.13 + 2x(-6.64) + 2.5 = 7.35 KN-m

VI. DESIGN OF RCC ELEMENTS

The RCC elements are slab, beam, column, footing and stair case etc…

A. DESIGN OF SLAB

Slabs are most widely used structural elements forming floor and roof of building. Slab support mainly transverse load and transfer them to supports by bending actions more or one directions. On the basis of spanning direction: It is two type one way slabs and two way slab.

ONE WAY SLAB: When the slab is supported on two opposite side parallel edges, it spans only in the directions perpendicular to the supporting edges. It bends in one directions and main steel is provided in the directions of the span. Such a slab is known as one- way slab.

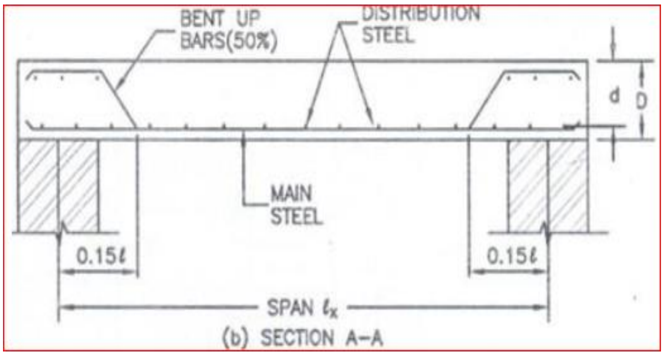

Figure 8: Reinforcement detailing in one-way sab

TWO WAY SLAB: When the is supported on four edges and the load distribution is also on four edges of the panel. The reinforcement is provided on both the sides. Such slab is known as two way slab.

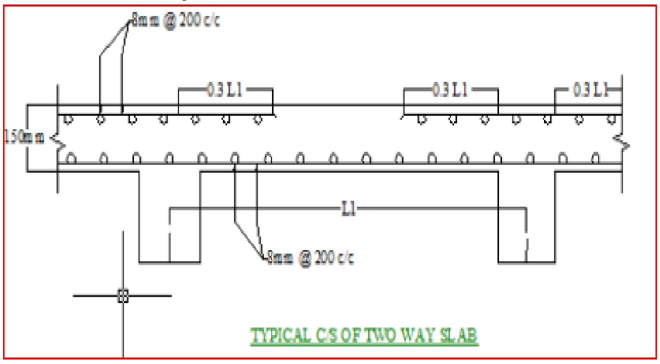

Figure 9: Reinforcement detailing in two-way sab

B. INTENSITY OF LOADS ON SLABS

AT ROOF LEVEL

D.L = 5 KN/m^2
L.L = 1.5 KN/m^2
T.L = 1.5 x (D.L+L.L) = 1.5 x (5+1.5)
= 9.75 KN/m^2

AT FLOOR LEVEL

D.L = 3.5 KN/m^2
L.L = 3.5 KN/m^2
W = 1.5 x (D.L+L.L) = 1.5 x (3.5+3.5)
= 10.5 KN/m^2
Formula for calculation of loads and moments
$W_x = W \times l_x$, $W_y = W \times l_y$
$M_x = \alpha_x W_x l_x^2$ $M_y = \alpha_y W_y l_x^2$
Area of steel:
$M_u = 0.87 f_y A_{st} d(1- (A_{st} f_y / bdf_{ck}))$

VII. DESIGN OF BEAM

There are two types of reinforced concrete beams
- ✓ Single reinforced beams
- ✓ Double reinforced beams

SINGLE REINFORCED BEAMS

In singly reinforced simply supported beams steel bars are placed near the bottom of the beam where they are effective in resisting in the tensile bending stress

DOUBLE REINFORCED BEAMS

It is reinforced under compression tension regions. The necessities of steel of compression region arise due to two reasons. When depth of beam is restricted. The strength availability singly reinforced beam is in adequate.
Minimum area of steel: $Ast_{min}/bd = 0.85/f_y$
Maximum area of steel: Ast_{max} = 4% of gross area

Area of steel:
$M_u = 0.87 f_y A_{st} d(1 - (A_{st} f_y / b d f_{ck}))$

CHECK FOR SHEAR

$\tau_v = Vu/bd$
$\tau_v < \tau_c$ (O.K)

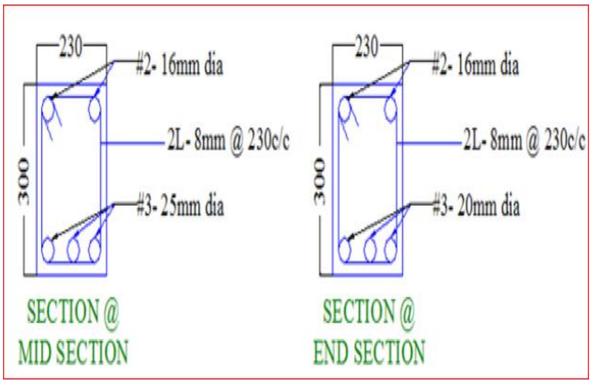

Figure 10: Reinforcement detailing at cross sections AA_1

VIII. COLUMN

A column may be defined as an element used primary to support axial compressive loads and with a height of a least three times its lateral dimension. The strength of column depends upon the strength of materials, shape and size of cross section, length and degree of proportional and dedicational restrains at its ends.

COLUMN P_{A8A9}
$P_u = 150$ KN, $M_u = 17.5$ KN-m
b = 300 mm; D = 300 mm; $f_{ck} = 20$ MPa; d′ = 30 mm
d′/D = 30/300 = 0.1
$M_u/f_{ck}bd^2 = (17.5 \times 10^6)/(20 \times 300 \times 300^2) = 0.035$
$P_u/f_{ck}bd = (150 \times 10^3)/(20 \times 300 \times 300) = 0.08$
From chart 32 of sp-16 ;
$P/f_{ck} = 0.03 \rightarrow P = 0.03 \times 20 = 0.6$
$Asc_1 = PbD/100 = (0.6 \times 300 \times 300)/100 = 540\ mm^2$
But $Asc_{min} = 720\ mm^2$
provide $\phi = 16$mm; $A_\phi = \pi/4 \times 16^2 = 201\ mm^2$
n = 720/201 = 3.58 = 4

LATERAL TIES

Dia. not less than (i) ¼ x 16 = 4 mm (ii) 6mm
Provide 6mm dia.

PITCH

Not more than (i) B = 300mm (ii) 16 x dia. = 256 mm (iii) 300 mm
Provide 260mm spacing
provide 4 no. of 16mmϕ bars longitudinal and 6mm lateral ties @ 260mm c/c

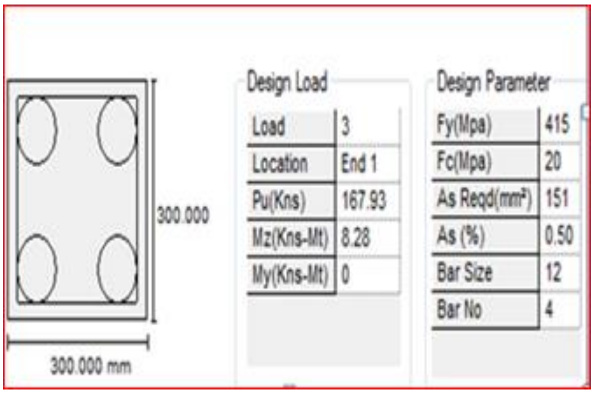

Figure 11: Reinforcement detailing at cross sections A8A9

IX. FOOTING

Foundations are structural elements that transfer loads from the building or individual column to the earth .If these loads are to be properly transmitted, foundations must be designed to prevent excessive settlement or rotation, to minimize differential settlement and to provide adequate safety against sliding and overturning.

CHECK FOR ONE WAY SHEAR (BEAM SHEAR)

The critical section for one way shear is at a distance‘d’ from the face of the column

CHECK FOR TWO WAY SHEAR (PUNCHING SHEAR)

The critical section for two way shear is at a distance ‘d/2’ from the face of the column

X. DESIGN OF STAIR CASE

The purpose of a stair case to provide access to pedestrian in a building. The geometrical forms of staircase may be quite different depending on the individual circumstances involved.

Assume straight stair, supported on wall at one side and by stringer beam on the other side.
Horizontal span = 1.2m
Rise = 150mm
Thread = 300mm
M20, Fe415
Live load = 3 KN/m^2 (residential building)

XI. ANALYSIS AND DESIGN OF A BUILDING USING STAAD PRO

PROCEDURE

- ✓ Draw plan and elevation based on dimensions of the site.
- ✓ Assigning of material properties and the elements.
- ✓ Assigning of supports.
- ✓ Assigning of loads.

- ✓ Assigning of load combinations.
- ✓ Analyze the results and view output file.
- ✓ Design of structure using IS code recommendations.
- ✓ Detailing of members.

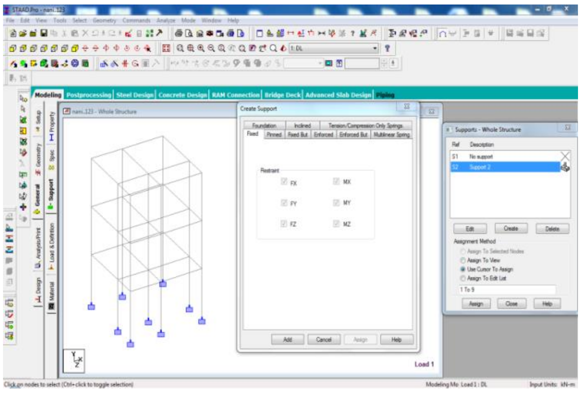

Figure 12: Assigning of supports

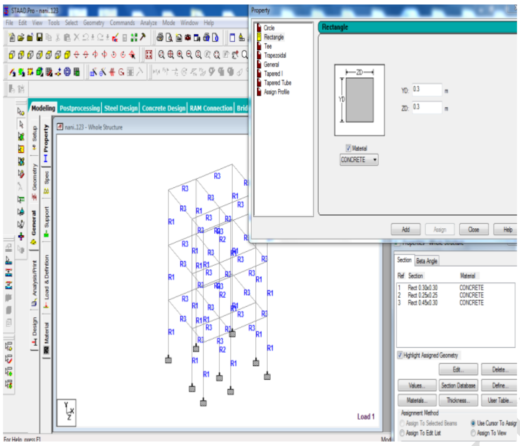

Figure 13: Assigning of material properties

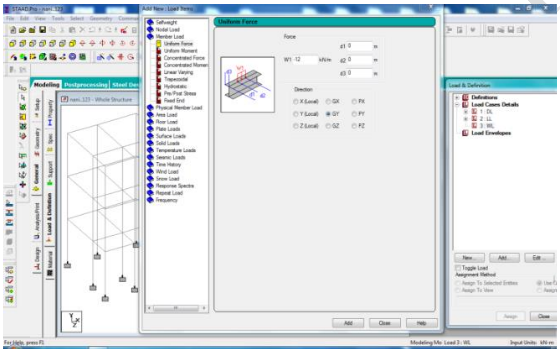

Figure 14: Assigning of loads

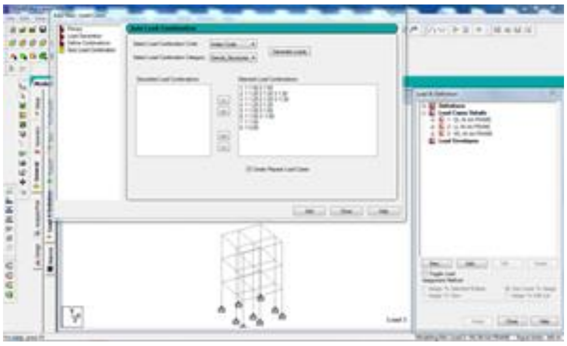

Figure 15: Assigning of load combinations

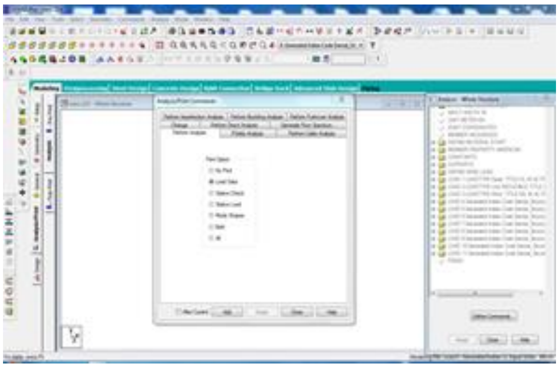

Figure 16: Results and view output file

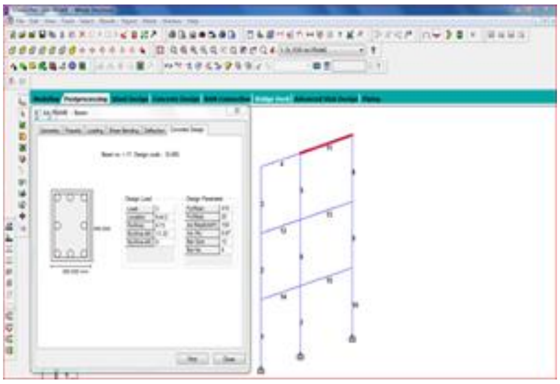

Figure 17: Detailing of members

```
            Bean no.12              Design result

     LENGTH:   2500.0  m   SIZE:   300.0  mm  X   450.0  mm

          SUMMARY  OF  REINF.  AREA  (Sq.mm)
------------------------------------------------------------
SECTION          0.0  mm          625.0  mm          1250.0  mm
                 1875.0  mm       2500.0  mm
------------------------------------------------------------
 TOP             255.00              0.00              0.00
REINF.          (Sq.  mm)         (Sq.  mm)         (Sq.  mm)
                (Sq.  mm)         (Sq.  mm)

BOTTOM            0.00             255.00            255.00
REINF.          (Sq.  mm)         (Sq.  mm)         (Sq.  mm)
                (Sq.  mm)         (Sq.  mm)

          SUMMARY  OF  PROVIDED  REINF.  AREA
------------------------------------------------------------
SECTION          0.0  mm          625.0  mm          1250.0  mm
                 1875.0  mm       2500.0  mm
------------------------------------------------------------
 TOP            4-10í             2-10í             2-10í
                2-10í             4-10í
REINF.       1  layer(s)       1  layer(s)       1  layer(s)
             1  layer(s)       1  layer(s)

BOTTOM          2-10í             4-10í             4-10í
                4-10í             2-10í
REINF.       1  layer(s)       1  layer(s)       1  layer(s)
             1  layer(s)       1  layer(s)

SHEAR      2  legged    8í    2  legged    8í    2  legged    8í
           2  legged    8í    2  legged    8í
REINF.     @  300  mm  c/c    @  300  mm  c/c    @  300  mm  c/c
           @  300  mm  c/c    @  300  mm  c/c
------------------------------------------------------------

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

SHEAR  DESIGN  RESULTS  AT.560.0  mm  AWAY  FROM  START  SUPPORT
      VY  =      33.39  MX  =          0.00  LD=        3
      Provide  2  Legged          8í     @  300  mm  c/c

SHEAR  DESIGN  RESULTS  AT.560.0  mm  AWAY  FROM  END  SUPPORT
      VY  =     -40.24  MX  =          0.00  LD=        3
```

Column 1 Design results

M20
Fe415 (Main)

LENGTH: 3500.0 mm
CROSS SECTION: 300.0 mm X 300.0 mm
COVER: 40.0 mm

** GUIDING LOAD CASE: 3 END JOINT:1

SHORT COLUMN

REQD. STEEL AREA : 132.24 Sq.mm.
REQD. CONCRETE AREA: 16529.69 Sq.mm.
MAIN REINFORCEMENT : Provide 4 - 12 dia.(0.50%, 452.39 Sq.mm)
(Equally distributed)

TIE REINFORCEMENT:
Provide8 mm dia. rectangular ties @ 190 mm c/c

SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)

Puz : 849.97 Muz1 : 22.57 Muy1 : 22.57

INTERACTION RATIO: 0.26 (as per Cl. 39.6, IS456:2000)

SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (KNS-MET)

WORST LOAD CASE: 3
END JOINT: 2 Puz : 946.73
Muz : 34.51
Muy : 34.51

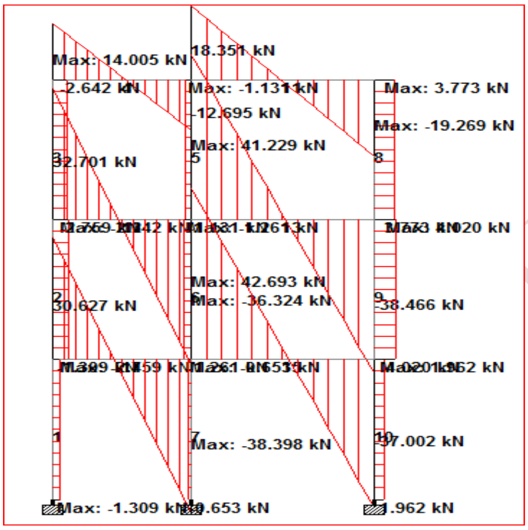

Figure 18: Shear force diagram

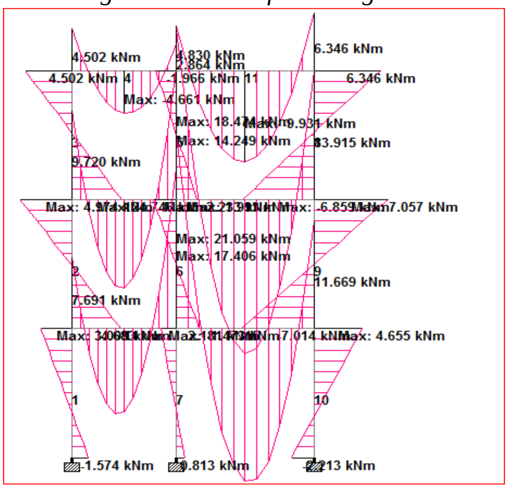

Figure 19: Bending moment diagram

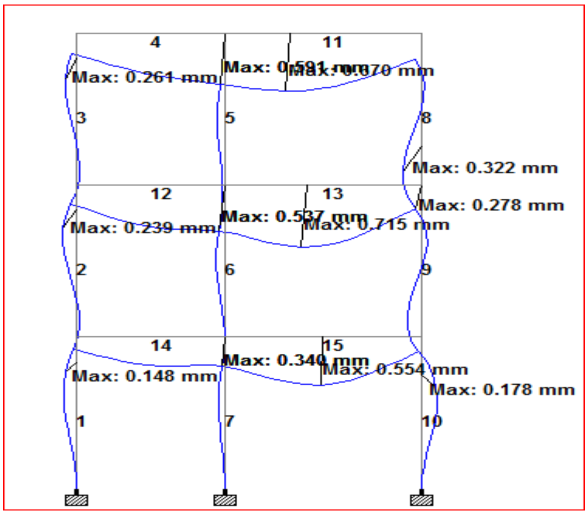

Figure 20: Defection diagram

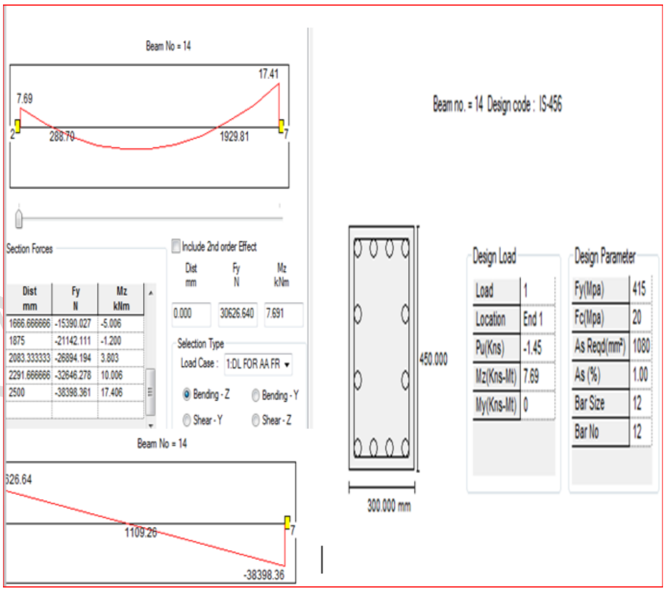

Figure 21: Reinforcement detailing at Beam No 14

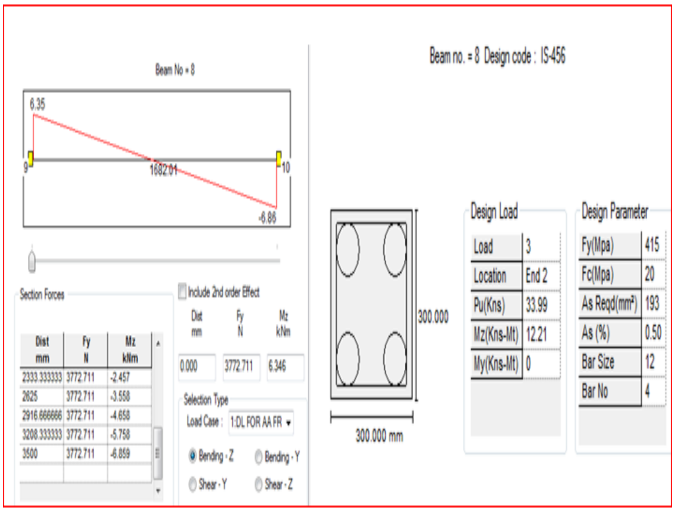

Figure 22: Reinforcement detailing at Column No 1

XII. CONCLUSIONS

- ✓ Short term deflection of all horizontal members is within 20mm.
- ✓ The structural components of the building are safe in shear and flexure.
- ✓ Amount of steel provided for the structure is economic.
- ✓ There is no such large difference in analysis results of STAAD Pro and Kani’s method.
- ✓ Designing using Software’s like STAAD Pro reduces lot of time in design work.
- ✓ Details of each and every member can be obtained using STAAD Pro.
- ✓ All the List of failed beams can be obtained and also Better Section is given by the software.
- ✓ Accuracy is Improved by using software

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