Indian J.Sci.Res. 17(2): 440 - 448, 2018

ISSN: 0976-2876 (Print)
ISSN: 2250-0138(Online)

SEISMIC ANALYSIS AND DESIGN OF RESIDENTIAL BUILDING (G+4) USING STAAD-PRO

[1] S.Ramanarayan, [2]A.Manjunath, [3]K V R Satya Sai, [4]S Lokeswari
[1]Civil Engineering, Aurora's Scientific Technological Research Academy, Hyderabad
[2]Civil Engineering, MVSR Engineering College, Nadergul, Hyderabad,
[3] Civil Engineering, Jawaharlal Nehru Technological University, Anantapur
[4]Civil Engineering, Matrusri Engineering College, Hyderabad

Abstract - To design a structure, it is divided into two categories -by using manual method and software based method. Due to advancement in technology, humans are creating software for designing of structures to make the process easier and save time. It is true that design using software is easy and time saving and mostly the results are accurate. As STAAD Pro is the current leading design software in the market, many structural designing companies use this software for their project design purposes. So, this article mainly deals with the analysis of the results obtained from the design of a building structure when it is designed using STAAD Pro Software. The software method of analysis is used for a G+4 Residential building located in Zone-II. The scope behind presenting this work is to learn how relevant Indian standard codes are used for design of various building elements such as beams, columns, slabs, and foundation and stair case by using STAAD Pro package when seismic loads and wind loads are acting on the structure. Earthquakes that occurred in past lead to the complete collapse of the buildings as structures are not well designed and constructed without adequate strength. To ensure safety against seismic forces of building, there is need to study the seismic analysis to design earthquake resistant structures. The present work deals with the analysis of a residential building of G+4 in which the dead load and live loads are applied and the structural design dimensions for beams, columns, footing is obtained. Beams and columns shall be designed as per IS 456:2000 and IS 875 (part1).

Key words: Analysis and Design of Structure, STAAD Pro,seismic loads,seismic zone,Indian standard codes.

I. Introduction

The procedure for analysis and design of a given building will depend on the type of building, its complexity, the number of stories etc. First the architectural drawings of the building are studied, structural system is finalized and sizes of structural members are decided and brought to the knowledge of the concerned architect. The procedure for structural design will involve some steps which will depend on the type of building and also its complexity and the time available for structural design. Often, the work is required to start soon, so the steps in design are to be arranged in such a way the foundation drawings can be taken up in hand within a reasonable period of time.

A. Basic codes for design

The design should be carried so as to conform to the following:

1) IS 456: 2000 – Plain and reinforced concrete – code of practice (fourth revision)
2) National Building Code 2005
3) Loading Standards IS 875 (Part 1-5): 1987 – Code of practice for design loads (other than earthquake) for buildings and structures (second revision)
    - Part 1: Dead loads
    - Part 2: Imposed (live) loads
    - Part 3: Wind loads
    - Part 4: Snow loads
    - Part 5: Special loads and load combinations
4) Design Handbooks
    - SP 16: 1980 – Design Aids (for Reinforced Concrete) to IS 456: 1978
    - SP 24: 1983 – Explanatory handbook on IS 456: 1978
    - SP 34: 1987 – Handbooks on Concrete Reinforced and Detailing.

B. Features of the STAAD Pro

1) The STAAD-Pro Graphical User Interface:

    It is used to generate them model, which can then be analyzed using the STAAD engineer. After analysis and design is completed, the GUI can also be used to view the results graphically.

2) The STAAD-Pro analysis and design engine:

It is a general-purpose calculation engineer for structural analysis and integrated Steel, Concrete, Timber and Aluminum design.

[1]Corresponding Author

STAAD (structural analysis and design) is powerful design software licensed by Bentley. Any object which is stable under a given loading can be considered as structure. So first find the outline of the structure, where as analysis is the estimation of what are the type of loads that acts on the beam and calculation of shear force and bending moment comes under analysis stage. Design phase is designing the type of materials and its dimensions to resist the load. This we do after the analysis. To calculate shear force diagram (s.f.d) and Bending moment diagram (b.m.d) of a complex loading beam it takes about an hour. So when it comes into the building with several members it will take a week. STAAD pro is a very powerful tool which does this job in just an hour's STAAD is a best alternative for high rise buildings. Now a days most of the high rise buildings are designed by STAAD which makes a compulsion for a civil engineer to know about this software. These software can be used to carry RCC steel, bridge, truss etc according to various country codes.

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.

L.G.Kalurkar: The design and analysis of multistoried G+5 building using composite structure at earthquake zone-3. A three dimensional modeling and analysis of the structure are carried out with the help of SAP 2000 software. Equivalent Static Method of Analysis and Response spectrum analysis method are used for the analysis of both Composite and RCC structures. The results are compared and found that composite structure more economical.

Dharne Sidramappa Shivashaankar, Patel Raobahdur Yashwanth presents the various limitations in design and construction practices along with the feedback to over come the limitations and make the structures safer to take the earthquake forces. The paper focuses on software used in the civil engineering for analysis and design, construction methods/practices, use of materials, types of structures, experiments for earthquake studies, quality control parameters etc.

Prashanth.P, Anshuman.S, Pandey.R.K, Arpan Herbert present day leading design software's in the market .Many design companies use these software's for their project design purpose. So, this project mainly deals with the comparative analysis of the results obtained from the design of a regular and a plain irregular (as per IS 1893) multi storey building when design using STAAD-Pro and ETABS software's separately. These results will also be compared with manual calculations of a sample beam and column of the same structure designed as per IS 456.

Chaitanya Kumari J.D, Lute analyzed G+4 storey residential building. The structural system consists of load bearing walls and one way slabs for gravity and lateral loads have been taken for analysis. Various wall forces, displacements and moments have been worked out for different load combinations. This work is limited to the analysis of structural elements only not the connection details.

Ismail Sab, Prof .S.M. Hashmi, generated a 3D analytical model of different building models and analyzed using structural analysis tools ETABS. To study the effects of infill, ground soft, bare frame and models with ground soft having concrete core wall and shear walls and concrete bracings at different positions during earthquakes; seismic analysis using both linear static and dynamic has been performed.

III. Consideration of Loads

A. Dead Loads

The dead load comprises of the weights of walls, partitions, floor finish false, ceilings, false floors and the other permanent constructions in the buildings. The dead loads may be calculated from the dimensions of various members and their unit weights. The unit weights of plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate maybe taken as 24 kN/m^2 and 25 kN/m^2 respectively.

B. Imposed Loads

Imposed load is produced by the intended use or occupancy of a building including the weight of movable partitions, distributed and concentrated loads, load due to impact and vibration and dust loads. Imposed loads do not include loads due to wind, seismic activity, snow, and loads imposed due to temperature changes to which the structure will be subjected to, creep and shrinkage of the structure, the differential settlements to which the structure may undergo.

C. Seismic Loads

1) Equivalent Static Analysis:

It is one of the methods for calculating the seismic loads. The high rise structures are not considered for the design simple static method. In practical as it does not take into account all the factors that are the importance of the foundation condition. The equivalent static analysis is used to design only for the small structures. In this method only one mode is considered for each direction. The earthquake resistant designing for the low rise structures the equivalent static method is enough. Tall structures are needed more than two modes and mass weight of each story to design earthquake resistant loads. This is not suitable to design those structures and dynamic analysis method to be used for high rise structures.

2) Response Spectrum Analysis:

The seismic forces strikes the foundation of a structure will move with the ground motion. It shows that structure movement is generally more than the ground motion. The movement of the structure as compared to the ground is refused as the dynamic amplification. It depends on the natural frequency of vibration, damping, type of foundation, method of detailing of the structure.

The response "design acceleration spectrum" which refers to the max acceleration called spectral acceleration coefficient Sa/g, as a function of the structure for a specified damping ratio for earthquake excitation at the base for a single degree freedom system. The revised IS 1893-2002 uses the dynamic analysis by response spectrum. In this method takes into account all the five important engineering properties of the structures.

- The fundamental natural period of vibration of the building (T in seconds).
- The damping properties of the structure.
- Type of foundation provided for the building.
- Importance factor of the building
- The ductility of the structure represented by response reduction factor.

These loads are horizontal loads caused by the earthquake and shall be computed in accordance with IS 1893. For monolithic reinforced concrete structures located in the seismic zone 2, and 3 without more than 5 storey high and importance factor less than 1, the seismic forces are not critical.

D. Zone factors for different zones in India

TABLE I.Seismic zone factors

Zone	Seismic coefficient of 1984	Seismic zone factor (z of 2002)
V	0.08	0.36
IV	0.05	0.24
III	0.04	0.16
II	0.02	0.1

IV. Analysis of G + 4 residential building using STAAD-pro

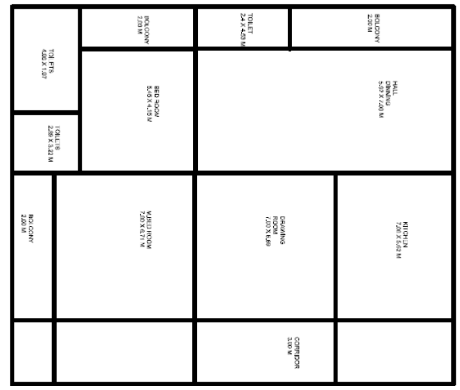

Fig.1.Plan of the reisdential building

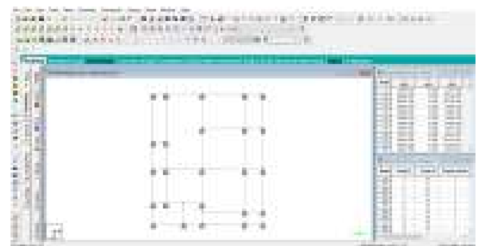

Fig.2.Column positions

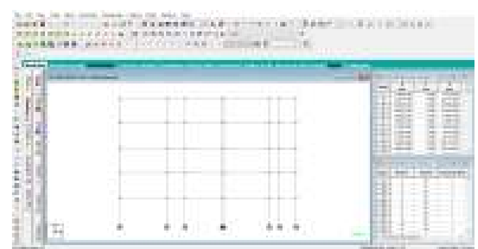

Fig.3.Elevation

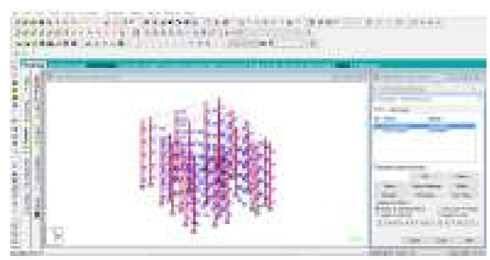

Fig.4.Generation of member property of columns

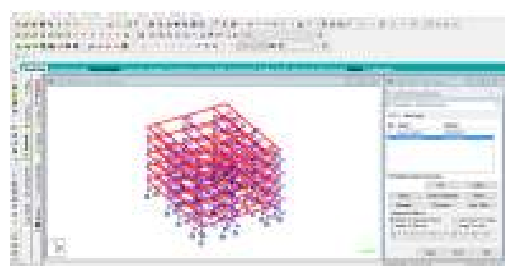

Fig.5.Generation of member property of beams

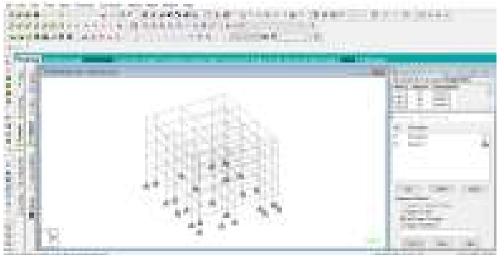

Fig.6. Fixing Supports

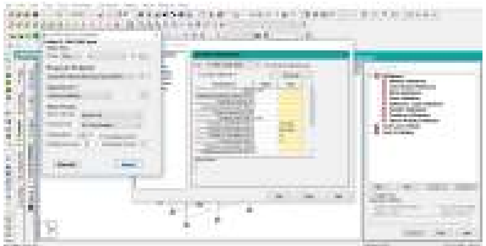

Fig.7.Seismic Definition

A. Salient features

- Physical parameters of a building are All columns = 0.4 × 0.3 m ,All beams = 0.35 × 0.3 m
- Slabs = 0.15 m thick
- Length = 21m
- Width = 18m
- Height = 3m + 4 storey's @ 3m= 15m (1.0 m parapet being non- structural for seismic purposes, is not considered of building frame height)
- Grade of concrete and steel used M30 concrete and Fe415 steel

Generation of member property can be done in STAAD-Pro by using the window as shown above. The member section is selected and the dimensions have been specified. The beams are having a dimension of 0.35×0.35m and the columns are having a dimension of 0.4×0.3m. The base supports of the structure were assigned as fixed. The supports were generated using the STAAD-Pro support generator. The materials for the structure were specified as concrete with their various constants as per standard IS code of practice.

The loadings were calculated partially manually and rest was generated using STAAD-Pro load generator. The loading cases were categorized as:

- Self-weight:The self weight of the structure can be generated by STAAD-Pro itself with the self weight command in the load case column.
- Dead load from slab:Dead load from slab can also be generated by STAAD-Pro by specifying the floor thickness and the load on the floor per sqm. Calculation of the load per sq.m was done considering the weight of beam, weight of column, weight of RCC slab, weight of terracing, external walls, internal walls and parapet over roof.
- Live load:The live load considered in each floor and for the terrace level it was considered to be 0.75 KN/sq m. The live loads were generated in a similar manner as done in the earlier case for dead load in each floor. This may be done from the member load button from the load case column.
- Load combination:The structure has been analyzed for load combinations considering all the previous loads in proper ratio. In the first case a combination of self-weight, dead load, live load and wind load was taken into consideration. In the second combination case instead of wind load, seismic load was taken into consideration.

IV. Design of G+4 residential building using STAAD-Pro

A. Design Parameters

The structure was designed for concrete in accordance with IS code. The parameters such as clear cover, F_y, F_c, etc were specified. The window shown below is the input window for the design purpose. Then it has to be specified which members are to be designed as beams and which member are to be designed as columns.

Fig.8.Input window for design purpose

Fig.9.Design parameters for column cover

Fig.10. Design parameters for beam cover

Fig.11.Design parameters for yield strength of main steel

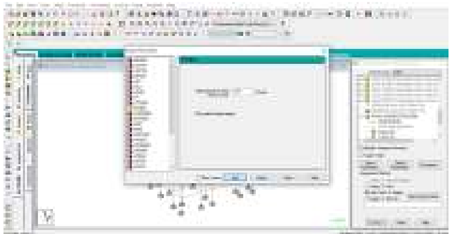

Fig.12. Design parameters for yield strength of shear reinforcement

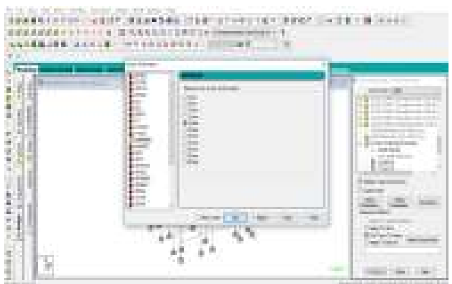

Fig.13.Maximum size of Main reinforcement

Fig.14. Maximum size of Secondary reinforcement

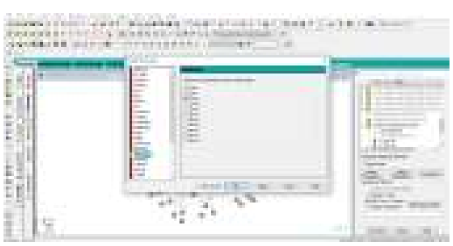

Fig.15. Minimum size of Main reinforcement

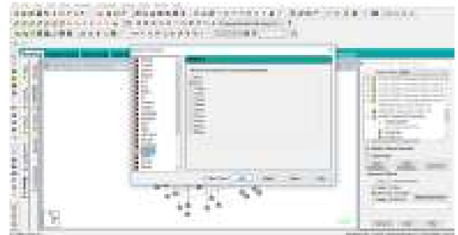

Fig.16. Minimum size of secondary reinforcement

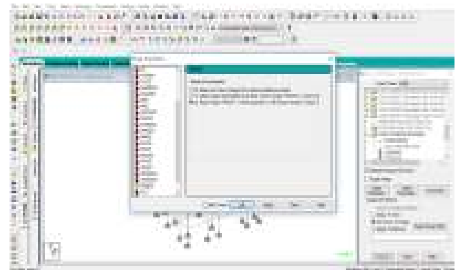

Fig.17.Design parameters of Track

B. Slab design

Slab design is shown as follows:

TABLE II. Slab design

SLAB DESIGN :-						
				in ft.		
	Short Span (Clear)			60	= 18.29	m
	Long Span (Clear)			70	21.34	m
	Live Load on the Slab (LL)				3.5	KN / sqm
	Comp.stess of concrete M - 15 (fck)				15	N / sqm
	Tensile stress of steel (fy)				415	N / sqm
	Unit wt of concrete				25	KN / cum
	Unit wt of floor finish 50 mm				24	KN / sqm
	Clear concrete cover				15	mm
	Bearing of slab				230	mm
	Overall depth				609.6	mm
	Provide Overall depth		D		**125**	mm
	Dia of bars for short direction				10	mm
	Dia of bars for long direction				10	mm
	Effective Depth		d		105	mm
	Loading on the slab					
	Dead Load of the slab (DL)				3.13	KN / sqm
	Floor Finish				1.2	KN / sqm
	Other Load				0.5	KN / sqm
	Live Load on the slab				3.5	KN / sqm
	Total Load on the slab (TL)				8.33	KN / sqm
	Design Load = (Total Load x Load Factor i.e. 1.5)				12.49	KN / sqm
	Effective Span	l_x			18.39	m
		l_y			21.44	m
	Ratio	l_y/l_x			**1.166**	
	From Table (26 or 27 of IS 456) BM Coefficients are as follows;					
		1.5	αx	1.75	αy	
For negative moments (at top)		0.075	0.062966	0.084	0.047	
For positive moments (at bottom)		0.056	0.04664	0.063	0.035	
	Calculated BM per unit width of slab are as					

	Calculated BM per unit width of slab are as						
				$Mx = \alpha x\ w\ l_x^2$		$My = \alpha y\ w\ l_x^2$	
For negative moments (at top)				266		198.55	KN-m/m
For positive moments (at bottom)				197.03		147.86	KN-m/m
Effective depth of slab will now be fixed up on consideration							
of flexural strength as well as control of deflection.							
Flexural strength consideration							
			Maximum B.M =	266	KN-m/m		
BM =	0.36 x fck x 0.48 (1-0.42 x 0.48) x 1000 d^2 =					B.M x 10^6	N-mm/m
Or	0.36 x 15 x 0.48 (1-0.42 x 0.48) x 1000 d^2 =					266002065	
	or		d =	359	mm		
Tension R/F for the positive BM along the short span is							
					BM =	197.03	
		Ast =	BM / 0.87 x fy (1-0.42 x 0.48)				
		=	1970332 08	/ 0.87 x 415 (1-0.42 x 0.48) x359			
		=	1906.5	mm^2/m			
Control of deflection							
	Actual Span / effective depth			=	18393	/	359
				=	**51.3**		
		Ast/bd =	100 x 1906.5 / 1000 x 359 =			**0.53**	
	From Modification curve, Modification factor =					1.2	
	Basic value of span / effective depth ratio =					26	
	Therefore permitted value of span / effective depth					26 x 1.2	
				=	**31.2**		
				Actual S/d is	>	Permitted S/d	
	Hence effective depth "d" should				**increase**		
		Try an effective depth "d" =			**150**	mm	
	Tension R/F for short span +BM is given by						
0.87 x fy x Ast (d - fy x Ast / (fck x 1000))					=	197.03 x 1000000	
0.87 x 415 x Ast (150 - 415 x Ast / (15 x 1000))					=	197033208	
			13333203			***1.97E+08***	
					Ast =	258.52	
	Actual Span / effective depth			=	18393	/	150
				=		**122.62**	
		pt = 100 Ast/bd =	100 x 258.52 / 1000 x 150 =			0.172	
	From Modification curve, Modification					1.45	
	Basic value of span / effective depth ratio =					26	
	Therefore permitted value of span / effective depth					26 x 1.45	
				=	**37.7**		
			Actual S/d is		>	Permitted S/d	
	Hence effective depth "d" should						
		Adopt Overall thickness (D) =			**170**	mm	
	Minimum R/F in slab =			0.12% of area of			
			=	0.12 x D x 1000 /			
			=	**204**	mm2/m	8 mm dia 246 mm c/c	
	0.87 x 415 x Ast (d - 415 x Ast / (15 x				=	BM x 1000000	
Effective depth for R/F in long direction will, therefore, be =					150 - dia. Of long R/F		
		=	150 - 10	=	140	mm	
Tension R/F per unit width of slab calculated by above eq. For different BM are as follow;							
			Bendind Moments				
			Short Span			Long Span	
For negative moments (at top)			Increase Steel	KN-m/m		Increase Steel	KN-m/m
For positive moments (at bottom)			Increase Steel	KN-m/m		Increase Steel	KN-m/m
			Short Span			Long Span	
Top R/F (At support)			357			233	mm2/m
Bottom R/F (At Mid Span)			258.52			160	mm2/m
These R/F will be provided within the middle strips in the two directions.							
Adopting 8 or 10 mm dia bars for the R/F, the calculated spacing of bars will be as follows;							
			Reinforcements				
		Dia of bars	Short Span		Dia of bars	Long Span	
Top R/F (At support)		10	210		10	330	mm c/c
Bottom R/F (At Mid Span)		10	300		10	490	mm c/c
Maximum Spacing			300			300	mm c/c
			No. of bars in slab				
		Short Span			**Long Span**		
Top R/F		103	Nos. of Length 21441		56	Nos. of Length 18393	
Bottom R/F		72	Nos. of Length 21441		38	Nos. of Length 18393	

V. Analysis and Design Results

A. Ground floor beam and column Design

Beam No.87 Design Results

M30 Fe415 (Main) Fe415 (Sec.)

LENGTH: 5031.4 mm SIZE: 300.0 mm X 350.0 mm COVER: 25.0 mm

Design Load Summary (Kn Met)

Section | Flexure (Maxm.Sagging/Hogging moments)| Shear

(in mm) | P MZ MX Load Case | VY MX Load Case

0.0 | 0.00 3.06 0.06 7 | 1.15 -0.06 9

| 0.00 -3.06 -0.06 9 |

419.3 | 0.00 2.58 0.06 7 | 1.15 -0.06 9

| 0.00 -2.58 -0.06 9 |

838.6 | 0.00 2.10 0.06 7 | 1.15 -0.06 9

| 0.00 -2.10 -0.06 9 |

1257.8 | 0.00 1.61 0.06 7 | 1.15 -0.06 9

| 0.00 -1.61 -0.06 9 |

1677.1 | 0.00 1.13 0.06 7 | 1.15 -0.06 9

| 0.00 -1.13 -0.06 9 |

2096.4 | 0.00 0.65 0.06 7 | 1.15 -0.06 9

| 0.00 -0.65 -0.06 9 |

2515.7 | 0.00 0.16 0.06 7 | 1.15 -0.06 9

| 0.00 -0.16 -0.06 9 |

2935.0 | 0.00 0.32 -0.06 9 | 1.15 -0.06 9

| 0.00 -0.32 0.06 7 |

3354.3 | 0.00 0.80 -0.06 9 | 1.15 -0.06 9

| 0.00 -0.80 0.06 7 |

3773.5 | 0.00 1.29 -0.06 9 | 1.15 -0.06 9

| 0.00 -1.29 0.06 7 |

4192.8 | 0.00 1.77 -0.06 9 | 1.15 -0.06 9

| 0.00 -1.77 0.06 7 |

4612.1 | 0.00 2.26 -0.06 9 | 1.15 -0.06 9

| 0.00 -2.26 0.06 7 |

5031.4 | 0.00 2.74 -0.06 9 | 1.15 -0.06 9

| 0.00 -2.74 0.06 7 |

SUMMARY OF REINF. AREA (Sq.mm)

SECTION | TOP | BOTTOM | STIRRUPS

(in mm) | Reqd./Provided reinf. | Reqd./Provided reinf. | (2 legged)

0.0 | 196.01/ 339.29(3-12í)| 196.01/ 339.29(3-12í)| 8í @ 140 mm

419.3 | 196.01/ 339.29(3-12í)| 196.01/ 339.29(3-12í)| 8í @ 140 mm

838.6 | 196.01/ 339.29(3-12í)| 196.01/ 339.29(3-12í)| 8í @ 140 mm

1257.8 | 196.01/ 339.29(3-12í)| 196.01/ 339.29(3-12í)| 8í @ 140 mm

1677.1 | 196.01/ 339.29(3-12í)| 196.01/ 339.29(3-12í)| 8í @ 140 mm

2096.4 | 196.01/ 339.29(3-12í)| 196.01/ 339.29(3-12í)| 8í @ 140 mm

2515.7 | 196.01/ 339.29(3-12í)| 196.01/ 339.29(3-12í)| 8í @ 140 mm

2935.0 | 196.01/ 339.29(3-12í)| 196.01/ 339.29(3-12í)| 8í @ 140 mm

3354.3 | 196.01/ 339.29(3-12í)| 196.01/ 339.29(3-12í)| 8í @ 140 mm

3773.5 | 196.01/ 339.29(3-12í)| 196.01/ 339.29(3-12í)| 8í @ 140 mm

4192.8 | 196.01/ 339.29(3-12í)| 196.01/ 339.29(3-12í)| 8í @ 140 mm

4612.1 | 196.01/ 339.29(3-12í)| 196.01/ 339.29(3-12í)| 8í @ 140 mm

5031.4 | 196.01/ 339.29(3-12í)| 196.01/ 339.29(3-12í)| 8í @ 140 mm

Shear Design Results At Distance D (Effective Depth) From Face Of The Support

----

Shear Design Results At 519.0 Mm Away From Start Support

VY = 1.15 MX = -0.06 LD= 9

Provide 2 Legged 8í @ 140 mm c/c

Shear Design Results At 519.0 Mm Away From End Support

VY = 1.15 MX = -0.06 LD= 9

Provide 2 Legged 8í @ 140 mm c/c

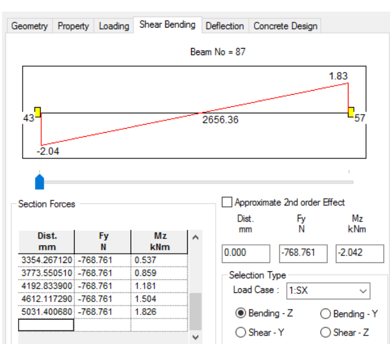

Fig.18.shear bending of beam no.87

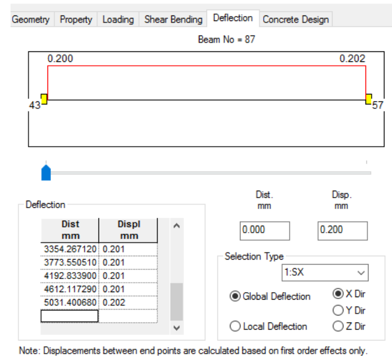

Fig.19.Deflection of beam no.87

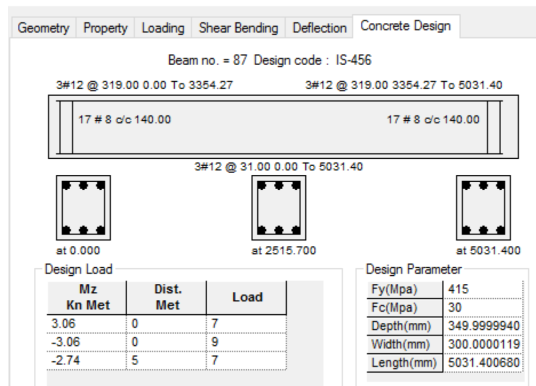

Fig.20. Concrete beam design for beam no.87

Column no.32 Design Results

M30 Fe415 (Main) Fe415 (Sec.)

Length: 3000.0 mm cross section: 300.0 mm x 400.0 mm cover: 40.0 mm

** guiding load case: 1 end joint: 1 tension column

Design forces (kns-met)

Design axial force (pu) : -4.38

About z about y

Initial moments : 2.97 0.07

Moments due to minimum ecc. : 0.09 0.09

Slenderness ratios : - -

Moments due to slenderness effect : - -

Moment reduction factors : - -

Addition moments (maz and may) : - -

Total design moments : 2.97 0.09

Reqd. Steel area : 960.00 sq.mm.

Reqd. Concrete area: 119040.00 sq.mm.

Main reinforcement : provide 4 - 20 dia. (1.05%, 1256.64 sq.mm.)

(equally distributed)

Tie reinforcement : provide 8 mm dia. rectangular ties @ 300 mm c/c

Section capacity based on reinforcement required (kns-met)

Puz : 1905.84 muz1 : 57.03 muy1 : 41.23

Interaction ratio: 0.05 (as per cl. 39.6, is456:2000)

Section capacity based on reinforcement provided (kns-met)

Worst load case: 10

End joint: 1 puz : 1994.16 muz : 62.23 muy : 44.44 ir: 0.36

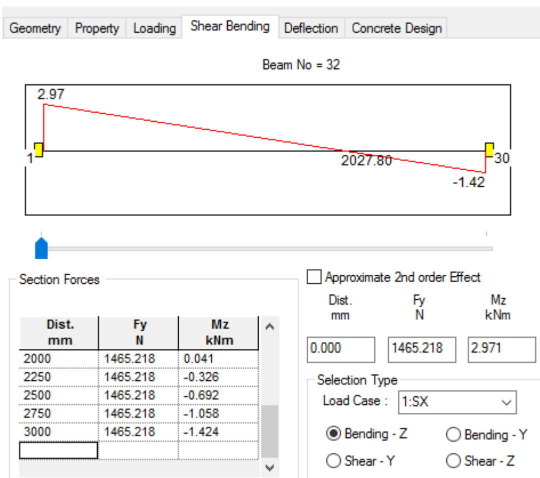

Fig.21. Shear bending of column no.32

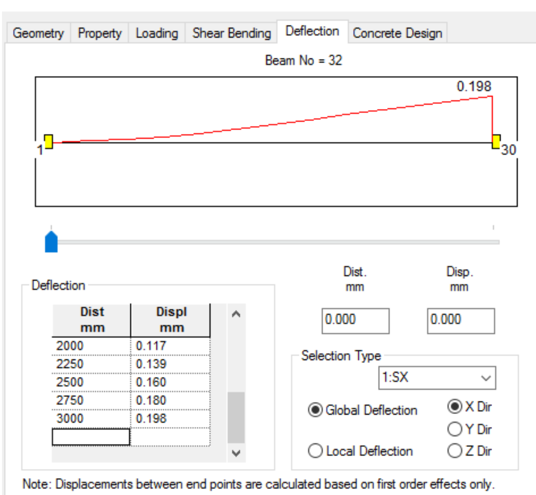

Fig.22. Deflection of column no.32

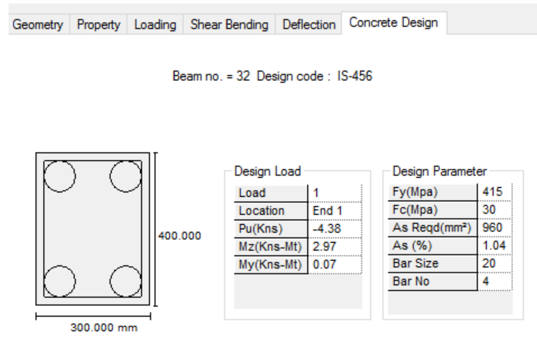

Fig.23. Concrete column design for column no.32

VI.Conclusions

STAAD-PRO has the capability to calculate the re inforcement needed for any concrete section. The program contains a number of parameters which are designed as per IS:456(2000). Beams are designed for flexure, shear and torsion.

A. Design for Flexure:

Maximum sagging (creating tensile stress at the bottom face of the beam)and hogging (creating tensile stress at the top face) moments are calculated for all active load cases at each of the above mentioned sections. Each of these sections are designed to resist both of these critical sagging and hogging moments. Where ever the rectangular section is in adequate as singly reinforced section, doubly reinforced section is tried.

B. Design for Shear:

Shear reinforcement is calculated to resist both shear forces and torsion moments. Shear capacity calculation at different sections without the shear reinforcement is based on the actual tensile reinforcement provided by STAAD program. Two-legged stirrups are provided to take care of the balance shear forces acting on these sections.

C. Beam Design Output:

The default design output of the beam contains flexural and shear reinforcement provided along the length of the beam.

D. Column Design:

Columns are designed for axial forces and biaxial moments at the ends. All active load cases are tested to calculate reinforcement. The loading which yield maximum reinforcement is called the critical load. Column design is done for square section. Square columns are designed with reinforcement distributed on each side equally for the sections under biaxial moments and with reinforcement distributed equally in two faces for sections under uni-axial moment. All major criteria for selecting longitudinal and transverse reinforcement as stipulated by IS: 456 have been taken care of in the column design of STAAD-pro.

References

[1] Mohit Sharma, Dr. Savita Maru. IOSR Journal of Mechanical and Civil Engineering, Volume 11, Issue 1. Ver. II (Jan-2014), PP 37-42.

[2] IS: 1893-2002 (part-1) "criteria for earthquake resistant design of structures" fifth revision, Bureau of Indian Standards,New Delhi.

[3] IS: 456-2000 (Indian Standard Plain Reinforced Concrete Code of Practice) –Fourth Revision.

[4] IS: 875-1987 (part-1) for Dead Loads, code of practice of Design loads (other than earthquake) for buildings and structures.

[5] IS: 875-1987 (part-2) for Live Loads or Imposed Loads, code of practice of Design loads (other than earthquake) for buildings and structures.

[6] IS: 875-1987 (part-3) for Wind Loads, code of practice of Design loads (other than earthquake) for buildings and structures.

[7] Dr. S.K Duggal, Earthquake Resistance Design of Structure.

[8] P. C. Varghese, Advanced Reinforced Concrete Design, Second Edition.

[9] S.R.Karve & Dr.V.L.Shah, Illustrated design of Reinforced concrete Buildings.

[10] N. Krishna Raju,Advanced Reinforced Concrete design.

[11] STAADPro2004 v8i–Getting started & tutorials-Published by: R .E.I.

[12] STAADPro2004v8i–Technical reference manual"-Published by: R.E.I.