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SEISMIC PERFORMANCE OF SINGLE PIER BUILDING

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ABSTRACT

India concentrated to move new technologies to resist earthquake and implement various ideas to build the infra structures. These new techniques should reduce the cost and give durability for the structure. The structural engineers implement various new techniques. Floating column or single pier building is very useful in commercial structure many projects adopted floating columns, especially above the ground floor, where transfer girder are employed, so that large open space is available in the ground floor. These open spaces can be used for assembly hall or parking purpose. During the earthquake failure starts at a point of weak zone. The weakness arises due to discontinuity in mass, stiffness and geometry of structure. The structures having the discontinuity are termed as irregular structures. Vertical irregularities are one of the major reasons of failure of structure. The single pier is used it prevented vertical irregularities and prevents the failure of structure. My research project aims at evaluating the single pier G+3 building for seismic conditions. For designing equivalent lateral force procedure is acquired and the Demand Capacity Ratio (DCR) is carried out for beams and columns in order to assess the member for seismic load, live load & dead load. Analysis are carried out by using Staad pro software and manual design also done with respect to consideration. In this project three types of irregularity are used namely mass, stiffness and vertical geometry is considered. Finite element analysis was conducted for each type of irregularity and the storey shear forces obtained were compared with that of a regular structure. In this frequency content was varied in three types of ground motion i.e., low, intermediate, high. By use finite element analysis each types of irregularities ground motion and nodal displacement were compared. Finally, design of above mentioned single pier irregularities building frames is carried out use IS13920correspondened to finite element analysis.

KEYWORDS: Single Pier, Vertical irregularities, STAAD Pro, DCR.

INTRODUCTION

Seismic Analysis is a subset of structural analysis and is the calculation of the response of a building structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent. The most important earthquakes are located close to the borders of the main tectonic plates which cover the surface of the globe. These plates tend to move relative to one another but are prevented by doing so by friction until the stresses between plates under the epicenter point become so high that a move suddenly takes place. This is an earthquake. The local shock generates waves in the ground which propagate over the earth's surface, creating movement at the bases of structures. The importance of waves reduces with the distance from the epicenter. Therefore, there exists region of the world with more or less high seismic risk, depending on their proximity to the boundaries of the main tectonic plates.

Besides the major earthquakes which take place at tectonic plate boundaries, others have their origin at the interior of the plates at fault lines. Called "intra plates earthquakes, these less energy, but can still be destructive in the vicinity of the epicenter

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A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground. The term floating column is also a vertical element which (due to architectural design/ site situation) at its lower level (termination Level) rests on a beam which is a horizontal member. The beams in turn transfer the load to other columns below it.

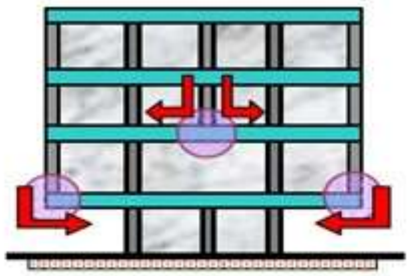

Figure 1. Floating Column

There are many projects in which floating columns are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available in the ground floor. These open spaces may be required for assembly hall or parking purpose. The transfer girders have to be designed and detailed properly, especially in earth quake zones. The column is a concentrated load on the beam which supports it. As far as analysis is concerned, the column is often assumed pinned at the base and is therefore taken as a point load on the transfer beam. STAAD Pro, ETABS and SAP2000 can be used to do the analysis of this type of structure. Floating columns are competent enough to carry gravity loading but transfer girder must be of adequate dimensions (Stiffness) with very minimal deflection.

According to the Seismic Zoning Map of IS: 1893-2002, India is divided into four zones on the basis of seismic activities. They are Zone II, Zone III, Zone IV and Zone V. Chennai lies in Zone II.
The methodologies available so far for the evaluation of existing buildings can be divided into two categories
- (i) Qualitative method
- (ii) Analytical method.

The qualitative methods are based on the background information available of the building and its construction site, which require some or few documents like drawings, past performance of the similar buildings under seismic activities, visual inspection report and some non-destructive test results. The analytical methods are based on the consideration of the capacity and ductility of buildings on the basis of available drawings.

OBJECTIVES

- To calculate the design lateral forces on single pier buildings using finite element analysis and to compare the results of different structures.
- To study three irregularities in structures namely mass, stiffness and vertical geometry irregularities.
- To calculate the response of buildings subjected to various types of ground motions namely low, intermediate and high frequency ground motion using Finite element analysis and to compare the results.
- To carry out ductility-based earthquake-resistant design as per IS 13920 corresponding to equivalent static analysis and finite element analysis and to compare the difference in design.

To carry out a seismic evaluation case study of a RC framed building considering nonlinearity in shear as well as flexure using the developed modelling parameters. The objective of the present work is to study the behavior of single pier multistory buildings with floating columns under earthquake excitations.

METHODOLOGY

- Carry-out detailed literature review on behaviour of shear in RC rectangular sections to determine nonlinear modelling parameters (yield and ultimate shear strength and associated displacement).
- The objective is to evaluate the Torsional Effect under earthquake forces.
- Firstly preliminary evaluation is done and then detailed evaluation is carried out.
- STAAD-Pro V8*i* is used for loading and designing the building.

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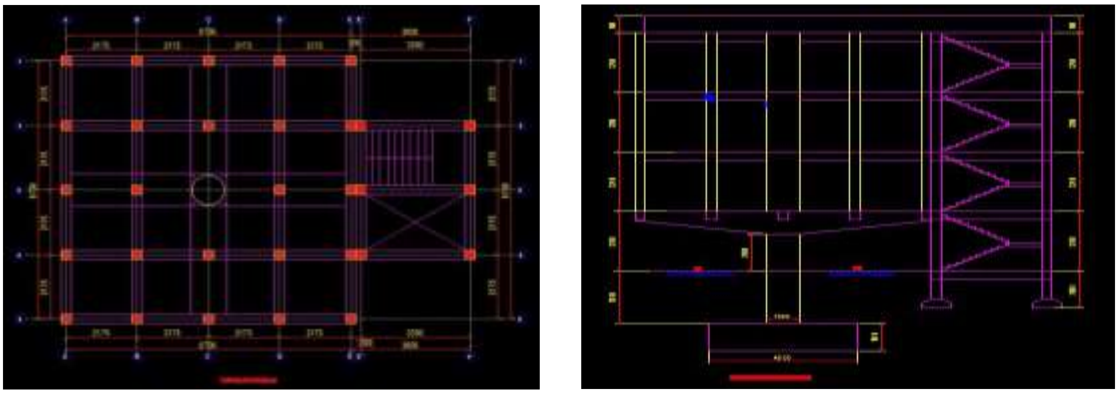

(a) *(b)*

Figure 2. (a) Top View Of Single Pier (b) Front View Of Single Pier Irregular Structure

REVIEW OF CODE PROVISIONS

This chapter reviews major international design codes with regard to the shear provision in RC section. This includes Indian Standard IS 456: 2000, British standard BS 8110: 1997 (Part 1), American Standard ACI 318: 2008 and FEMA 356: 2000. The shear capacity of a section is the maximum amount of shear the beam can withstand before failure. In a RC member without shear reinforcement, shear force generally resisted by:

i) Shear resistance *Vcz* of the uncracked portion of concrete.
ii) Vertical component *Vay* of the 'interface shear' (*aggregate interlock*) force *Va*.
iii) Dowel force *Vd* in the tension reinforcement (due to dowel action).

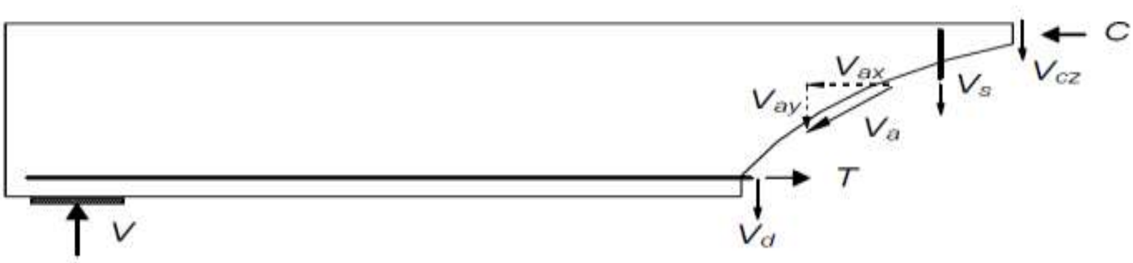

Figure 3. Shear Transfer Mechanism

Member with shear reinforcement, shear force is mainly carried by uncracked portion of concrete (*Vcz*) and transverse reinforcement (*Vs*). Shear carried by aggregate interlock (*Va*) and dowel force in the tension reinforcement (*Vd*) are very small hence their effects are considered negligible.

International design codes except British Standard recommend procedures to calculate shear strength of rectangular and circular RC sections with transverse reinforcement. However, all the design codes are silent about the maximum shear displacement capacity of RC sections

LITERATURE REVIEW

Bahrain M. Shahrooz and Jack P. Moehle - Undertook an experimental and analytical study to understand the earthquake response of setback structures. The experimental study involved design, construction, and earthquake simulation testing of a quarter- scale model of a multistory, reinforced concrete, setback frame. The analytical studies involved design and inelastic analysis of several multistory frames having varying degrees of setbacks.

Among the issues addressed were:
(1) The influence of setbacks on dynamic response;
(2) The adequacy of current static and dynamic design requirements for setback buildings; (3) Design methods to improve the response of setback buildings.

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Valmundsson, E and Nau, J - It evaluated the earthquake response of 5-, 10-, and 20story framed structures with non-uniform mass, stiffness, and strength distributions. The response calculated from TH analysis was compared with that predicted by the ELF procedure embodied in UBC. Based on this comparison, the aim was to evaluate the current requirements under which a structure can be considered regular and the ELF provisions applicable.

Chandrasekaran and Rao - It investigated the design of multi- storied RCC buildings for seismicity. Reinforced concrete multi-storied buildings are very complex to model as structural systems for analysis. Usually, they are modeled as two-dimensional or three-dimensional frame systems using finite beam elements.

Karayannis et al., - It performed experimental investigations on shear capacity of RC rectangular beam with continuous spiral transverse reinforcement under monotonic loading. Three specimens consist of beam with common stirrups, spiral transversal reinforcement and spiral transversal reinforcement with favourably inclined leg with shear span ratio 2.67 constructed. Based on experimental results and the behavioural curve of tested beams they found that the specimens with continuous spiral reinforcements demonstrated 15% and 17% respectively higher shear strength than the beam with closed stirrups. Beam with spiral reinforcements with favourably inclined legs exhibited enhanced performance and rather ductile response whereas other beam shows brittle shear failure.

Devesh et al., - It agreed on the increase in drift demand in the tower portion of set-back structures and on the increase in seismic demand for buildings with discontinuous distributions in mass, strength and stiffness. The largest seismic demand was found for the combined stiffness and strength irregularity. It was found out that seismic behavior is influenced by the type of model.

Karavasilis et al., - It studied the inelastic seismic response of plane steel moment-resisting frames with vertical mass irregularity. The analysis of the created response databank showed that the number of storeys, ratio of strength of beam and column and the location of the heavier mass influence the height-wise distribution and amplitude of inelastic deformation demands, while the response does not seem to be affected by the mass ratio.

Sadjadi et al., - It presented an analytical approach for seismic assessment of RC frames using nonlinear finite element analysis and push-over analysis. The analytical models were validated against available experimental results and used in a study to evaluate the seismic behavior of these 5-story frames. It was concluded that both the ductile and the less ductile frames behaved very well under the earthquake considered, while the seismic performance of the GLD structure was not satisfactory. The retrofitted GLD frame had improved seismic performance.

Kim and Elnashai - It observed that buildings that are seismically designed to contemporary codes would have survived the earthquake. But, the vertical motion would have significantly reduced the shear capacity in vertical members.

Duan et al., - According to the numerical results, the structures designed by GB50011-2010 provides the inelastic behavior and response intended by the code and satisfies the inter-storey drift and maximum plastic rotation limits recommended by ASCE/SEI 41-06. The push-over analysis indicated the potential for a soft first story mechanism under significant lateral demands.

Poonam et al., - Results of the numerical analysis showed that any storey, especially the first storey, must not be softer/weaker than the storeys above or below. Irregularity in mass distribution also contributes to the increased response of the buildings. The irregularities, if required to be provided, need to be provided by appropriate and extensive analysis and design processes. Moehle found that standard limit analysis and static inelastic analysis provide good measures of strength and deformation characteristics under strong earthquake motions

SINGLE PIER BUILDING

Details of Building Models

1. Seismic Zone – III
2. Number of stories – G+3
3. Floor Height – 3.5m
4. Infill wall - -----
5. Type of soil – Hard soil

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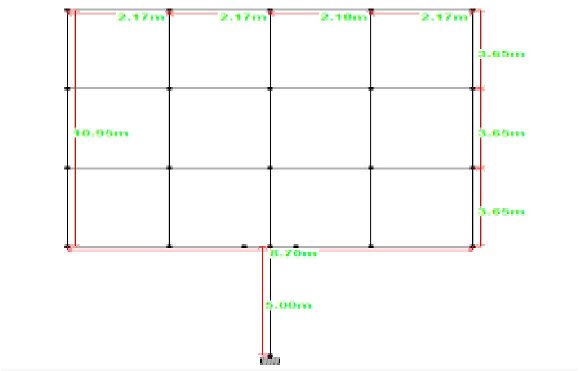
6. Material – Concrete, Steel
7. Grade of concrete – M25
8. Grade of Steel – Fe 415
9. Support condition – fixed
10. Total height of building – 13.5m

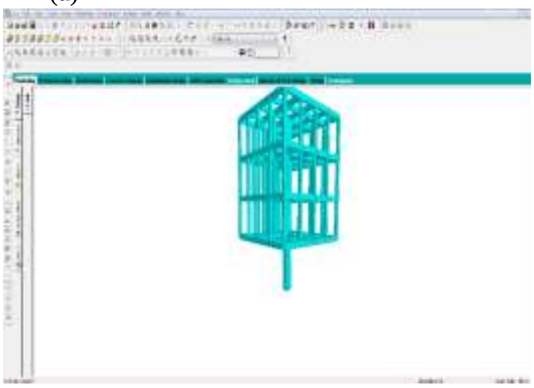
The present study is to compare, how the behaviour of a single pier building having only floating column and having a floating column with complexities. The floating column locations are also varied to find the optimum position. For zone II and V, live load and dead loads were varied for heavy load condition. Analysis is carried out for various complex systems and the results are presented in the form of tables and figures and are discussed in the present chapter. The results are obtained in terms of Displacements, Storey shear, Storey drifts, for different parameters varied.

Seismic Analysis
It is a major tool in earthquake engineering which is used to understand the response of buildings due to seismic excitations in a simpler manner. In the past the buildings were designed just for gravity loads and seismic analysis is a recent development. It is a part of structural analysis and a part of structural design where earthquake is prevalent.

There are different types of earthquake analysis methods. Some of them used in the project are
I. Equivalent Static Analysis
II. Time History Analysis
III. Finite element Analysis

(a)





(b)
Figure 4. (a) Staad View Of Single Pier (b) 3d Rendering View Of Single Pier Structure

Ductility Based Design
Ductility in the structures results from inelastic material behavior and reinforcement detailing such that brittle fracture is prevented and ductility is introduced by allowing steel to yield in a controlled manner. Thus the chief task is to ensure that building has adequate ductility to withstand the effects of earth quakes, which is likely to be experienced by the structure during its lifetime. Ductility of the structure acts as a shock absorber and reduces the transmitted forces to the structure. The ductility of a structure can assess by

- Displacement ductility
- Rotational and Curvature ductility
- Structural ductility

Ductility is the capability of a material to undergo deformation after its initial yield without any significant reduction in yield strength.
The factors which affect the ductility of a structure are as follows,

- Ductility increases with increase in shear strength of concrete for small axial compressive stress between 0-1MPa.The variation is linear in nature.
- Ductility varies linearly up to the point when axial compressive stress becomes equal to the compressive stress at balanced failure.

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- The ductility factor increases with increase in ultimate strain of concrete. Thus confinement of concrete increases ductility.
- The ductility increases with increase in concrete strength and decreases with the increase in yield strength of steel.
- The effect of lateral reinforcement is to enhance the ductility by preventing the shear failure .It also restrains the compression reinforcement from buckling.

Requirements of ductility

- It allows the structure to develop its maximum potential strength through distribution of internal forces.
- Structural ductility allows the structure as a mechanism under its maximum potential strength resulting in the dissipation of large amount of energy.
- IS 13920 was followed for ductility based design.

Response Structure Analysis

Response Structure analysis was performed on regular and various irregular buildings using Staad-Pro. The storey shear forces were calculated for each floor and graph was plotted for each structure.

Structural Modelling

Seismic loads are calculated as per IS 1893 - 2002 Part 1 with respect to my consideration of building. After the load calculation we get spectral acceleration co-efficient value (Ah).

Wind loads are calculated as per IS 875 -Part 3 and design as member load and the load values are tabulated below

Design as Member Load			
Direction (+X)			
At End of Panel	=	1.89 x 0.54375	
	=	1.03	Kn/m
At Mid of Panel	=	1.89 x 2.175	
	=	4.11	Kn/m
Direction (-X)			
At End of Panel	=	-1.74 x 0.54375	
	=	-0.95	Kn/m
At Mid of Panel	=	-1.74 x 2.175	
	=	-3.78	Kn/m
Direction (+Z)			
At End of Panel	=	0.32 x 0.54375	
	=	0.17	Kn/m
At Mid of Panel	=	0.32 x 2.175	
	=	0.7	Kn/m
Direction (-Z)			
At End of Panel	=	-1.18 x 0.54375	
	=	-0.64	Kn/m
At Mid of Panel	=	-1.18 x 2.175	
	=	-2.57	Kn/m

Dynamic Analysis

If dynamic loads changes gradually the structure's response may be approximately by a static analysis in which inertia forces can be neglected. But if the dynamic load changes quickly, the response must be determined with the help of dynamic analysis in which we cannot neglect inertial force which is equal to mass time of acceleration (Newton's 2nd law).

Mathematically F = M x a

Where F is inertial force, M is inertial mass and 'a' is acceleration

Normally loads are calculated the particular as per Indian standard recommendation. Then slabs are previously dived into one-way and two-way slabs which is depends upon the dimension of the slab. Loads are based upon the usage, length and width of slab.

In case of one-way slab means loads should be dived into trapezoidal loads and two-way slab load dived into trapezoidal and triangle loads. Mass single pier Irregular Structure: The structure is modeled as same as that of regular structure

Height of building- 4.5 m
Live load – 3KN/m2
Floor finish – 1Kn/m2
Unit weight – 25Kn/m3
Dead load – 4.175 KN/m2

The shear force is maximum in central single pier and it decreases as we move up in the structure. Mass irregular storey shear force is more in lower storeys as compared to regular structure. The graph closes in as we move up the structure and the mass irregular Shear force becomes less than that in regular structure above the storey.

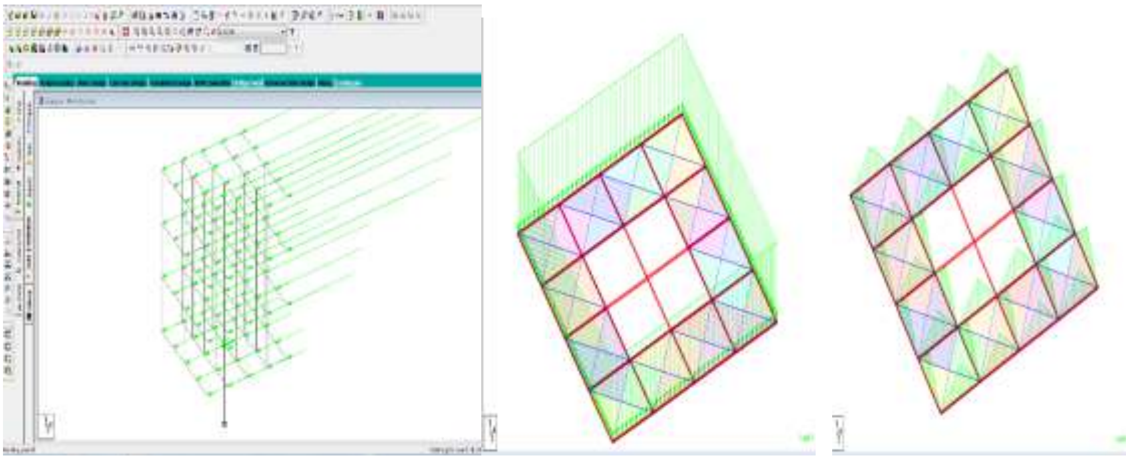

Figure 5. Staad 3-D View Of Load Distribution Of Single Pier Irregular Structure

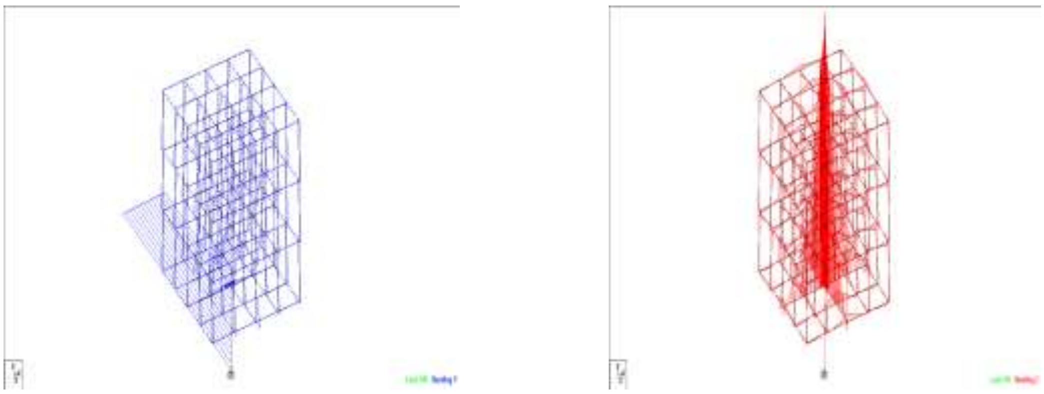

Figure 6. Analysis Of Irregular Structure Minor Axis And Major Axis Moment

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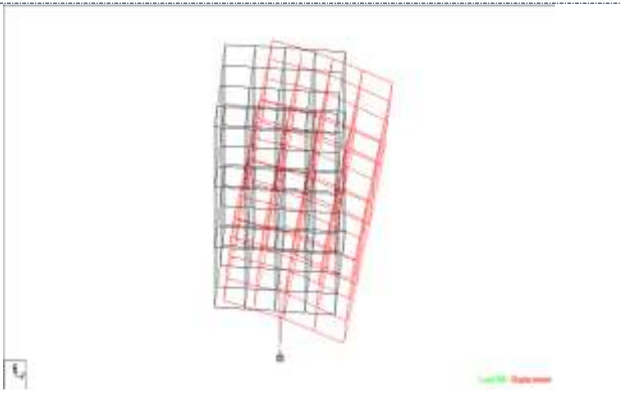

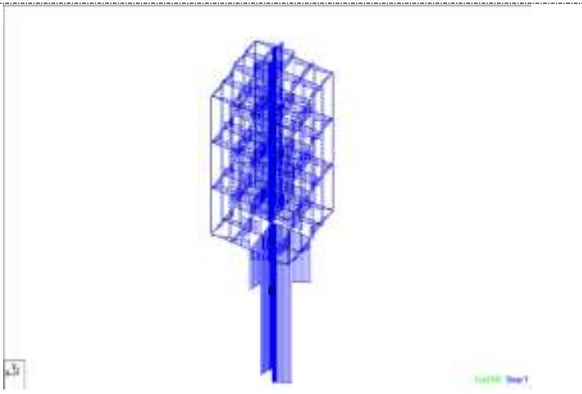

Figure 7. Analysis Of Irregular Structure Deflection And Shear Force

The above figures show bending moments, torsion, shear force, displacements of the single pier column of geometry irregular structure respectively. Similarly finite element displacements were obtained for other floors in the structure and the maximum displacement was plotted in the graph.

Due to less stiff ground storey the inter-storey drift is found to be more in stiffness irregular structure. Hence, the floor displacement is more in stiffness irregular structure than regular structure.

RESULT AND DISCUSSION

The behavior of building frame with and without floating column is studied under static load, free vibration and forced vibration condition.

Static Analysis

A three storey two bay 2d frame with and without floating column are analyzed for static loading using the present FEM code and the commercial software *STAAD Pro*.

Example

The following are the input data of the test specimen:

Size of beam – 0.3 X 0.45 m

Size of column – 0.3 X 0.3 m

- 1000mm (diameter of single center column)

Span of each bay – 3.0 m

Storey height – 4.5m, 3.0 m

Modulus of Elasticity, E = 206.84 X 106 kN/m2

Support condition – Fixed

Loading type – As per IS code (IS 875)

Circular Analysis Report

From the staad pro we got the excel data now we understand central single pier column have maximum shear force, bending moment and torsion effect compare to other member of structures. More than 500 nodes are available in the structures. Example purpose we are considered as any example value of node result for bending moment, shear force, torsion effects etc.

The values are common and we understand moment are not as a constant because which is various from the x, y, z directions. Similarly shear force are also varied.

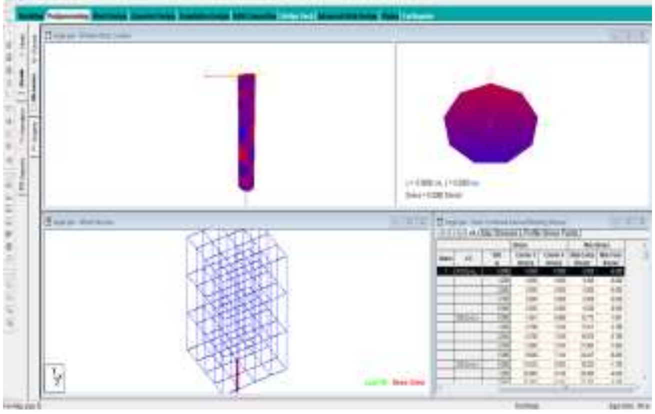

Figure 8. 3-D View Of Storey Mass Irregular Structure With Highlighted Beam

Beam Analysis Report

Plinth Beam analysis , 1st floor beam analysis, 2nd floor beam analysis, 3rd floor beam analysis and roof beam analysis reports are taken from the staad pro post processing from the report we get Beam No, Node, Axial force, Shear force at –Y & -Z, Torsion, Moment at –Y & -Z for exam 1st floor beam analysis report has been tabulated below

Table 1. 1st Floor Beam Analysis Report

Beam	L/C	Node	Axial Force kN	Shear -Y kN	Shear -Z kN	Torsion kNm	Moment -Y kNm	Moment -Z kNm
67	101	27	0	0	0	0	0	0
		28	0	0	0	0	0	0
	102	27	2.84	-10.00	0.66	5.86	-0.77	-35.31
		28	-2.84	54.67	-0.66	-5.86	-0.66	-35.01
	103	27	-0.69	-7.51	-0.84	6.68	0.96	-34.00
		28	0.69	61.11	0.84	-6.68	0.87	-40.62
	104	27	-1.17	-9.48	0.08	6.88	-0.21	-37.79
		28	1.17	63.08	-0.08	-6.88	0.04	-41.13
	105	27	-0.49	-10.81	-0.32	6.79	0.66	-39.66
		28	0.49	64.42	0.32	-6.79	0.04	-42.15
	106	27	-0.54	-11.95	1.46	7.09	-1.76	-42.54
		28	0.54	65.55	-1.46	-7.09	-1.42	-41.74
	107	27	-1.56	-7.55	-1.41	6.63	1.64	-33.80
		28	1.56	61.16	1.41	-6.63	1.42	-40.93
	108	27	-2.43	-7.73	1.28	7.06	-1.85	-35.36
		28	2.43	61.34	-1.28	-7.06	-0.94	-39.75
	109	27	0.33	-11.77	-1.23	6.66	1.73	-40.98
		28	-0.33	65.38	1.23	-6.66	0.94	-42.92

From the above discussion, it can be concluded that a large number of research studies and building codes have addressed the issue of effects of vertical irregularities. Building codes provide criteria to classify the vertically irregular structures and suggest elastic finite element analysis or elastic finite element analysis to obtain the design lateral force distribution. A majority of studies have evaluated the elastic response only. Most of the studies have focused on investigating two types of irregularities

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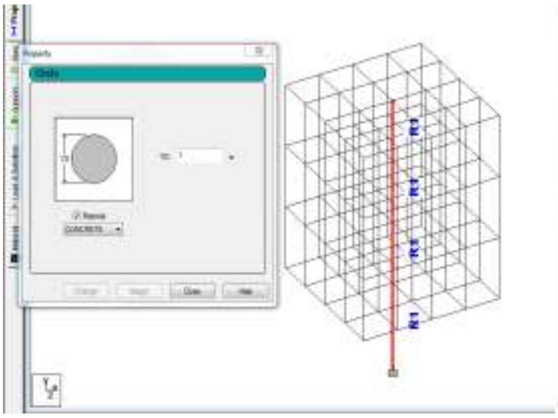

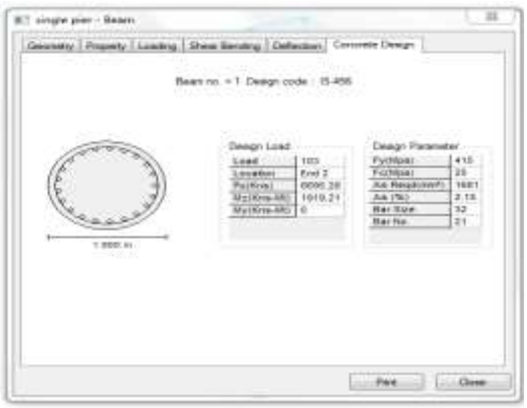

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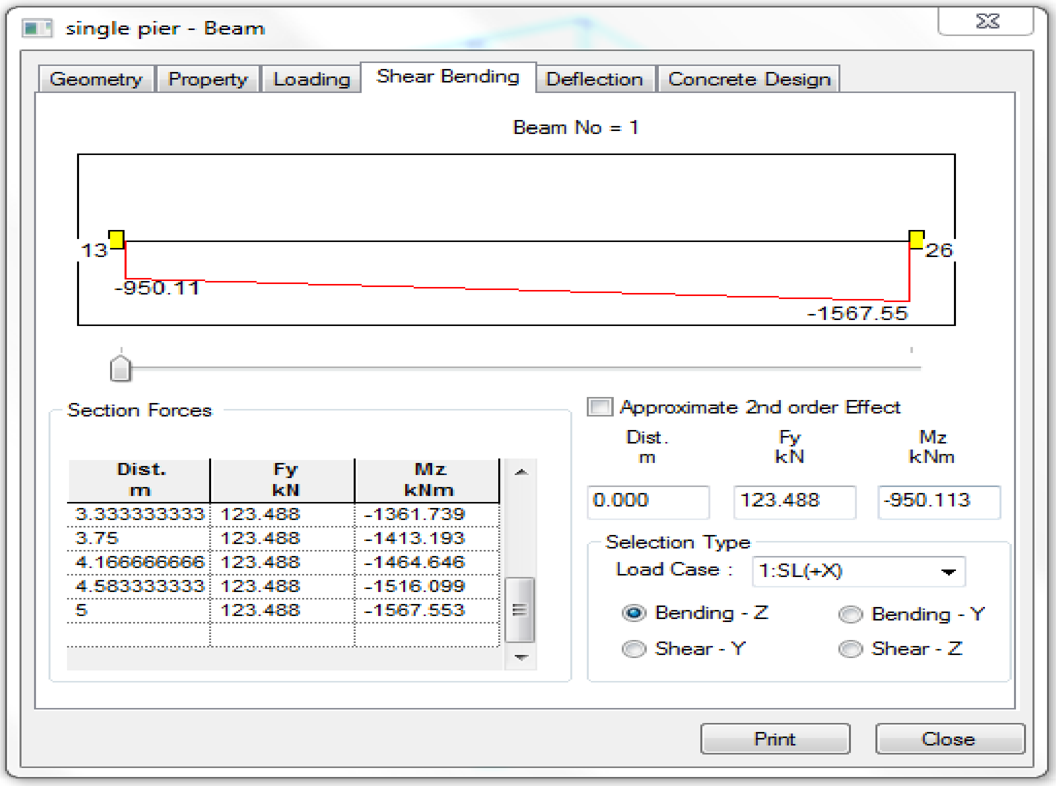

Figure 9. Results Of Design Of Beam As Per Is Code

CONCLUSION

Three types of irregularities namely mass irregularity, stiffness irregularity and vertical geometry irregularity were considered .All three kinds of single pier irregular RC building frames had plan symmetry. Finite element analysis was conducted for each type of irregularity and the storey shear forces obtained were compared with that of a regular structure. Three types of ground motion with varying frequency content, i.e., low (imperial), intermediate (IS code),high (San Francisco) frequency were considered. Finite element analysis was conducted for each type of irregularity corresponding to the above mentioned ground motions and nodal displacements were compared. Finally, design of above mentioned single pier irregular building frames was carried out using IS 13920 corresponding to Finite element analysis

- According to results, the single pier shear force and torsion was found to be maximum for the single pier and it decreased to a minimum in the top storey in all cases.
- According to results, it was found that mass irregular building frames experience larger base shear than similar regular building frames.
- According to results the stiffness irregular building experienced lesser base shear and has larger inter storey drifts.
- The absolute displacements obtained from finite element analysis of geometry irregular building at respective nodes were found to be greater than that in case of regular building for upper stories but gradually as we move to lower stories displacements in both structures tended to converge. This is because in a geometry irregular structure upper stories have lower stiffness (due to L-shape) than the lower stories. Lower stiffness results in higher displacements of upper stories.
- When finite element analysis was done for regular as well as stiffness irregular building (soft storey),it was found that displacements of upper stories did not vary much from each other but as we moved down to lower stories the absolute displacement in case of soft storey were higher compared to respective stories in regular building.
- Those in set-back and soft and/or weak first story structures. Conflicting conclusions have been found for the set-back structures; most of the studies, however, agree on the increase in drift demand for the tower portion of the set-back structures.

- For the soft and weak first story structures, increase in seismic demand has been observed as compared to the regular structures.
- Finally, buildings with a wide range of vertical irregularities that were designed specifically for code based limits on drift, strength and ductility, have exhibited reasonable performances, even though the design forces were obtained from the (seismic coefficient) procedures.
- The behavior of multistory building with and without floating column is studied under different earthquake excitation. The static and free vibration results obtained using present finite element code is validated. The dynamic analysis of frame is studied by varying the column dimension. It is concluded that with increase in ground floor column the maximum displacement, torsion, inter storey drift values are reducing. The base shear and overturning moment vary with the change in column dimension.

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