A Simplified Procedure for Seismic Analysis using ETBAS 19 Software

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Abstract- Seismic engineering has received a great deal of attention in recent years to ensure the construction of safe structures that can safely withstand earthquakes of reasonable magnitude. Seismic force requires ductility. Ductility is an essential feature of the structure that must respond to strong ground movements. It is the ability of a structure to deform or deform without damage or failure, causing energy dissipation. In present work reinforced concrete frame having irregular plan have been designed as strong column weak beam design criteria. The models consist of having four different heights of G+3, G+5, G+7 and G+10. For analysis of plan irregularity, "L, T and H" shaped plan has been taken. The frame has fulfilled the design provisions of different codes such as IS 456: 2000, IS 1893: 2016 (Part 1) and IS 13920: 2016. For seismic demand prediction and performance evaluation of structure has been carried out. Analysis is done with the help of ETABS 19 software.

KEYWORDS: Beam Design, Seismic Analysis, Ductility, plan irregularity, ETABS 19

I. INTRODUCTION

Seismic activity or earthquakes can be described as the shaking, displacement or cracking of the earth's surface due to movements within its crust. These "earthquakes" are caused by any transmission of a seismic wave through the Earth, and it is this energy that causes the Earth to move, warp, or ripple. Earthquakes are one of the major natural hazards to life on earth and have affected countless towns and villages on most continents. Earthquake damage is mainly man-made frenzied structures. Hundreds of small earthquakes occur around the world every day and every year earthquakes kill thousands of people. Therefore, it is necessary to design earthquake-resistant buildings. Seismic actions, it also reveals the uncertain nature of future seismic actions for which such structures must be designed. Thus, probabilistic concepts related to seismic actions and designs against seismic actions also emerged. Seismologists focus on global seismic problems and are more interested in geological aspects, including prediction of seismic action. On the other hand, seismic engineers are mainly concerned with the local effects of seismic actions that can cause significant damage to the structure. Convert seismic data to a format more suitable for structural failure prediction or safe structure design1.

The higher the ability of the structure to plastically deform without collapse, the greater the resulting ductility and energy dissipation. This leads to a decrease in effective seismic force. The strong column weak beam is based on the deterministic allocation of structural element strength and ductility for successful response and collapse prevention in the event of a catastrophic earthquake by rationally selecting a continuous region of energy dissipation so that pre-decided energy dissipation mechanism would hold throughout the seismic action2. Many researchers have worked in this area, some of them showing noteworthy outcomes are as mentioned in next section

II. LITERATURE REVIEW

Some of researchers have shown noticeable work in this field. Firdose H. M. A. et al.3 did study on dynamic behavior of irregular RC framed structures with different location of shear walls. Ma H., Liu et al.4 studied about the influence of seismic input in the oblique direction on the strong-column weak-beam mechanism for RC frame. Patil R. D. et al.5did study of torsional effects on unsymmetrical RC framed building. The main purpose of this study is to minimize the torsion ratio to the limit according to IS 1893: 2016 (Part 1) by changing the stiffness of the vertical elements of the planar composition. Teddy L.6 attempts to calculate new method in calculating columns and beams dimensions that meets requirements of the strong column weak beam and non-soft story. Irfani M. M. A. and Vimala A7 tries to find the collapse mechanism of three buildings of 5, 12 and 15 floors for the concept of weak beams into strong columns. Liu Y., et al.8 did an analysis on strong column and weak beam behavior of steel-concrete mixed frames. Bento R. and Lopes M.9 worked on evaluation of the need for weak beam-strong column design in dual frame-wall structures. Daniel D. M. and John S. T. 10 have done a pushover analysis on RC framed building. Xinxia L. et al.11 investigates new factors that characterize the strong column weak beam mechanism of the RC frame structure. The comprehensive study and analysis of available literature leads to the conclusion that relying only on the code-prescribed requirement for the strong column-weak beam design concept may not be sufficient for avoiding the formation of the plastic hinge in the columns of RC frames and other seismic detailing like an adequate lap splice length should be provided. Thus, the formation of column hinges is not a single structural component behavior but is determined by the overall frame characteristic. More delicate explanation could be put forward only if more attention is concentrated on the overall frame system performance. In this paper 12 models of different heights are considered. Models have plan irregularity of "L" shaped, "T" shaped and "H" shaped are proposed. Linear static and linear dynamic analysis (Pseudo static method and Response spectrum method) and static nonlinear (push over) analysis is done using ETBAS 19 software.

III. SEISMIC RESISTANT DESIGN OF STRUCTURES

In seismic design, problems are somewhat complicated by the greater uncertainty surrounding appropriate design load estimates as well as the capabilities of structural members and connections. However, the information accumulated over the past three decades from analytical and experimental studies, as well as the assessment of structural behavior in recent earthquakes, has provided a solid basis for solving the problem, this particular in a more sensible way. As with other growing areas of knowledge, improvements in design approaches can be expected as more information is accumulated about earthquakes and the response of specific structures to seismic-like loads. The design problem of reinforced concrete buildings subjected to earthquakes, such as the design of structures (concrete, steel or other material) for other loading conditions, is essentially the determination of forces and/or deformations expected in a preliminary design and provided for these conditions by properly proportional and detailed allocation of members and their connections.

IV. MODELLING AND ANALYSIS

the 3D building model which is based on capacity-based design (strong column weak beam) criteria analyzed using the Pseudo Static method (Linear static analysis), Response Spectrum method (Linear dynamic analysis) and Push Over analysis (Nonlinear static analysis). The building models of varying plan irregularities having “L” shaped, “T” shaped and “H” shaped plan of different storey height as G+3, G+5, G+7, G+10 is analysed using ETABS v19 software. The seismic codes are unique to a particular region of the country. In India, Indian standard for design of seismic structures IS 1893:2016 is used which is the main standard that provides the outline for the calculation of seismic design forces and for achieving strong column weak beam design concept.

TABLE 1
Nomenclature of different models consider for analysis

SN	Model Name	Height	Irregularity
1.	L 1	G+3	L shaped
2.	L 2	G+5	L shaped
3.	L 3	G+7	L shaped
4.	L 4	G+10	L shaped
5.	T 1	G+3	T shaped
6.	T 2	G+5	T shaped
7.	T 3	G+7	T shaped
8.	T 4	G+10	T shaped
9.	H 1	G+3	H shaped
10.	H 2	G+5	H shaped
11.	H 3	G+7	H shaped
12.	H 4	G+10	H shaped

TABLE 2
Data for Analysis of R.C. Frame

SN	Particulars	Type	Dimension/ Value
1	Plan Area	L shape	720 m^2
		T shape	720 m^2
		H shape	720 m^2
2	Height of the building	G+3	12 m
		G+5	18 m
		G+7	24 m
		G+10	33 m
3	Height of base storey	-	3 m
4	Height of each storey	-	3 m
5	Height of parapet		1.2 m
6	Thickness	Slab	150 mm
		Walls	230 mm
	Length of Beam	-	4 m
7	Seismic zone	-	IV
	Importance factor	-	1.5
	Zone factor	-	0.24
	Damping ratio	-	5%
8	Floor finish	-	1.0kN/m2
	Live load at all floors	-	3.0 kN/m
	Wall load	-	21 KN/m
	Parapet wall	-	9 KN/m
	Density of concrete	-	25 kN/m3
	Density of brick	-	20 kN/m3
	Grade of concrete	column	M30
		Beam	M30
		Slab	M30
9	Grade of	reinforcing steel	HYSD 500
		tie steel	Fe 450
10	Soil condition	-	Medium soil (TYPE II)

TABLE 3
Section Property of Beams and Columns

SN	*Model*	Beam	Column
1.	L 1	200 X 250	450 X 450
2.	L 2	200 X 250	500 X 500
3.	L 3	200 X 300	500 X 500
4.	L 4	200 X 300	700 X 700
5.	T 1	200 X 250	450 X 450
6.	T 2	200 X 250	500 X 500
7.	T 3	200 X 300	525 X 525
8.	T 4	200 X 300	700 X 700
9.	H 1	200 X 300	475 X 475
10.	H 2	200 X 300	500 X 500
11.	H 3	200 X 300	550 X 550
12.	H 4	200 X 300	750 X 750

V. BRIEF DISCUSSION ABOUT MODELLING PROCEDURE FOR ACHIEVING STRONG COLUMN WEAK BEAM IN RC FRAME AS PER IS 13920: 2016

First the general steps are followed in ETABS to made the model for analysis such as defining grids and height of the frame. Then define the materials and section property (beam, column and slab section). Then draw the model and apply the loads as per IS 875: 1987 (Part 1 and 2) for fixed support condition. In the design preferences of concrete frame design, enable the option of P- delta effect and B/C ratio, disable the option of consider additional moments. Then define the mass source of frame system. Then model is analyzed and designed as per IS 456: 2000, IS 1893: 2016 (Part 1) and IS 13920: 2016 for linear static and linear dynamic seismic analysis. Then this model is checked for column beam capacity ratio which should be greater than 1.4 for all joint. After satisfying the column beam capacity ratio for all the joints and members are passed for seismic analysis, push over analysis of displacement control methodology will carry out. In this type of push over analysis procedure first define the dead load as nonlinear static load in load case type. Then define the push in x direction and in y direction of displacement control of 300 mm to 500 mm depends upon the performance point found. Define plastic hinges in beam and column at 10% distance form either side as per ASCE 41-13. After meeting performance point (as per FEMA 440) hinge results are checked for different minimum performance objective (e.g., I.O., L.S., C.P.) as per ASCE 41 and FEMA356. After hinge results, ductility ratio, moment rotation and back bone curves are analyzed. Different analysis results of linear static and linear dynamic are also analyzed for storey drift and mode vs frequency. Since the frame is irregular in plan torsional analysis is also considered.

- **Model L 1**

In this model, "L" shaped plan irregularity with one entrant corner and height of 4 stories (G+3) is being considered for analysis.

- **Model T 2**

For this model, plan irregularity is "T" shaped which has two entrant corners back-to-back. Height of 6 stories (G+5) is being taken.

- **Model H 3**

For this model, 8 story height (G+7) is being adopted for analysis. "H" shaped plan irregularity has four entrant corners.

- **Model L 4**

This model also has L shaped plan irregularity but height is 11 stories (G+10).

Figure 3.7 Showing column beam capacity ratio for model L 4.

Defining mass source as 100 % of dead load and 50% of live load under specified load pattern and named it as "MaSrc1". Select this mass source for all calculations of push over and seismic analysis.

Ductility Ratio

Ductility ratio is the total deflection to the deflection at elastic limit. The deflection at elastic limit is the deflection at which strength behavior can be assume to change from elastic to plastic. Nonlinear static analysis is being carried out to find the ductility ratio in all twelve models. Results are shown below in the graphical format. The New Zealand code is proposing the relation of the maximum values of the design ductility factor. According to this code if thestructure is ductile then the ductility factor or ductility ratio should be between 3 to 6. All models which are being in consideration showing ductility ratio in between 3 to 5. Hence it canbe inferred that the all models are ductile. It can also be inferred that as storey height increasesductility ratio also increases because the size of column also increases. Since all the columns are designed as per IS 13920: 2016, it possesses the higher ductility. This ductility of columnsis being transferred to structure which provide the structure a better overall ductility. From the above results it can be infer that the irregularity type "L" to irregularity type "T" andirregularity type "T" to irregularity type "H" ductility ratio increases irrespective of height. This is due to increase in sectional property of structure to achieve strong column weak beam criteria.

VI. PERFORMANCE POINT

Pushover curve represents the lateral resisting capacity and response spectrum curve representsthe seismic demand. The performance point, which represents the state of maximum inelastic capacity of the structure, is found through the cross point of the capacity spectrum and demandspectrum for a given damping ratio. Hence it can be inferred that performance point is obtained by superimposing demand spectrum on capacity curve into spectral coordinate. Performance point decides the flexibility or stiffness of the structure. Thus, as the performance point increases the capacity of structure to withstand in given earthquake also increases. Performance point for all twelve models is being represented by graphical format.

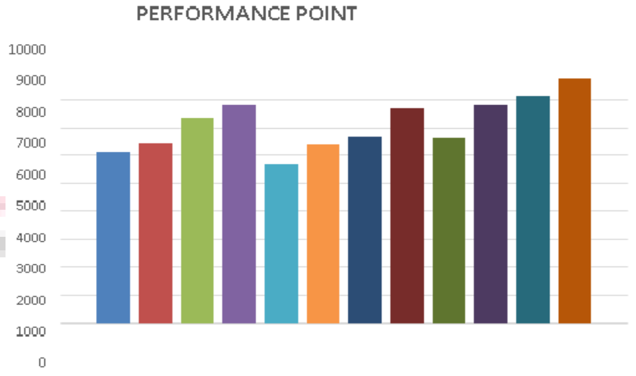

Fig. 1. Showing performance point for all twelve models for push X

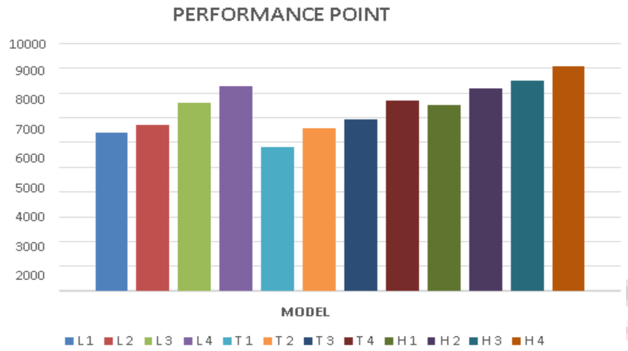

Fig. 2. Showing performance point for all twelve models for push Y

In the above analysis it can be inferred that performance point increases as the height increases.This is because stiffness and ductility of the structural member increases because size of the structural member increases to achieve strong column weak beam design criteria. Also by changing irregularity the performance point increases significantly. From irregularity type "L" to type "T" the performance point increases. Irregularity type "H" shows better performance innonlinear strength among other two irregularity. This is because of in "H" type irregularity, stability and stiffness comes out to be significant.

- **Model L 1**

In this model, number of storey is G+3 and irregularity is of "L" type. Hinge formation and hinge results are shown below. In this model, push of 450 mm is being given. Table 4.2 and table 4.3 shows the hinge state details obtained during push in X and Y direction respectively. It can be seen that for the performance point for push X, taken as step 12 (which actually lies between steps 11 and 13), 63.95% of hinges are within A-IO, 34.81% within IO-LS performance level and 1.2% are greater than CP limit. Figure 4.11 shows the hinge states during9/27 (9th step out of total 27th step) stage in course of the analysis at push X (PaX). For push Y direction performance point taken as step 12 (which actually lies between steps 11 and 13), 65.98% of hinges are within A-IO, 33.64% within IO-LS performance level and 0.3% are greater than CP limit. Figure 4.12 shows the hinge states during 9/24 (9th step out of total 24th step) stage in course of the analysis at push Y (PaY). As it can be inferred from the figure shownbelow that the hinges are forming in the beams prior to columns for both push X and push Y. Hence this model satisfying the strong column weak beam design criteria as per hinge state results. In this study three different irregular plan of "L" shape, "T" shape and "H" shape with differentheight has been taken. By comparing different height for strong column weak beam criteria, it can infer that irregularity of type "H" height of G+3, G+5 and G+7 is performing better. Although irregularity type "L" and type "T" performing well enough for the height of G+3 and G+3 to G+5 respectively to achieve strong column weakbeam design criteria. While considering all three irregularities, from dynamic analysis it can beinfer that entrant corner playing a vital role in predefined hinge formation but stability and stiffness of the structure which is defined by their plan irregularity somehow restrains the effect of additional torsion generated due to entrant corner. Thus, by providing lateral load resisting element in the "L" type planned irregular structure for the height above G+3, stabilizes the structure and additional torsion can be minimized generated due to entrant corner and irregular distribution of mass. After analysis of model and results discussed in previous chapter. Some concluded points are listed below.

VII. CONCLUSION

Frequency of models increases from irregularity type "L" to type "T" and decreases form type "L" to type "H". Average increment of frequency on irregularity type "L" to type "T" for average three fundamental modes is 6.8% and drastic decrease over type "T" to type "H" by 75%. Explanation to this decrement because of stiffness and stability achieving fromthe type of irregularity "H" possesses.

- In a similar manner, average decrement in frequency of irregularity type "L" is 18.2%, for irregularity type "T" decrement is 17.03% and for type "H" it is 4.5% as the height increases. This result leads to a conclusion that type "H" irregularity behaves as a stable and stiff structurefor all three fundamental modes.

REFERENCES

[1] K.S. Sivakumaran, T. Balendra, Seismic analysis of asymmetric multistorey buildings including foundation interaction and P-Δ effects, Engineering Structures, vol 16, no. 8, 1994, pp. 609-624, 1994

[2] Ladjinovic DZ, Folic RJ, "Seismic analysis of asymmetric in plan buildings". In The 14th World Conference on Earthquake Engineering, Beijing, China 2008, Oct 12.

[3] Firdose, H.A., Kumar, A.S., Narayana, G. and Narendra, B.K., "Study on Dynamic Behaviour of Irregular RC Framed Structures with Different Location of Shear Walls". In *IOP Conference Series: Earth and Environmental Science* , vol. 982, no. 1, p. 012076, IOP Publishing, March2022.

[4] Ma, Hua, Chun Yang Liu, Zhen Bao Li, Jian Qiang Han, and Shi Cai Chen. "The Influence of Seismic Input in the Oblique Direction on the Strong-Column Weak-Beam Mechanism for RC Frame." Advanced Materials Research. Trans Tech Publications, Ltd., Vos. 243–249, pp. 5144–5151, May 2011.

[5] Patil R. D., Mulay B. N., Patil S. K. and Pujari A. B. (2020), "Assessment on Torsional Effect of Unsymmetrical Buildings" International Research Journal of Engineering and Technology (IRJET), vol 07, no. 07, pp 4276-4280,July 2020.

[6] Teddy L., Hardiman G., Nuroji N., Tudjono S. (2019), "The New Method in Calculating Columns and Beams Dimensions That Meets Requirements of The Strong Column - Weak Beam and Non - Soft

Story" Journal of Architectural Design and Urbanism, vol 1, no 2, pp 1-8, March 2019.

[7] Mohd Moazzam Ali Irfani, A Vimala, "Collapse Mechanism of Strong Column Weak Beam Buildings of Varying Heights" International Journal of Engineering and Advanced Technology (IJEAT), vol-9, no.-1. pp-4144-4148, October, 2019.

[8] Yangbing Liu, Yuanxin Liao & Nina Zheng, "Analysis of Strong Column and Weak Beam Behaviour of Steel-concrete Mixed Frames" 15th world conference on earthquake engineering, 2018.

[9] Bento R. and Lopes M., "Evaluation of The Need for Weak Beam-Strong Column Design in Dual Frame-Wall Structures" 12th world conference on earthquake engineering, 2018.

[10] Dona Mary Daniel, Shemin T. John, "Pushover analysis of RC building" nternational Journal of Scientific & Engineering Research, vol 7, no.10, pp-88-92, October-2016.

[11] Xinxia L., Maosheng G., Qinghua H., Lili X. (2015), "New Factor to Characterize Mechanism of "Strong Column-Weak Beam" of RC Frame Structures", 21: 484-491, Tianjin University and Springer-Verlag Berlin Heidelberg.

[12] JOUR Li, Xinxia Gong, Maosheng Han, Qinghua Xie, Lili. New factor to characterize mechanism of "strong column-weak beam" of RC frame structures. Transactions of Tianjin University. vol. 21, pp. 484–491, December 2015.