Effect of joint rigidity on structural behavior of RC buildings

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Abstract: Non-linear static analysis or pushover analysis is now-a –days generally preferred by many researchers to analyse the non-linear behaviour of the structure. Present study includes the effect of joint rigidity on the behaviour of the structure. A building is modeled with 5 and 10 story and designed for gravity and earthquake resistant loads by considering joint rigidity factor as 0 and 1. The analysis is done in both X and Y directions by using pushover analysis in SAP2000 software. Comparison is made between then capacity curves obtained from designed models of rigidity and non-rigidity models. From the results it is concluded that structure designed using joint rigidity has more strength when compared non-rigid joints.

1 Introduction

Pushover analysis is one of the major analysis adopted many scholars to study the non-linear behavior of the structure during seismic analysis. This is also known as non-linear static analysis, which is used to study the behavior of the structure during collapse stage and how much does the building resist the forces and how much does it displace. This can be known, by getting the capacity curve from non-linear analysis or pushover analysis. From this, we can get the capacity of the building for which its going to resist before the collapse occurs.

To do a building analysis, modelling and designing of a building plays a major role for getting the absolute results. Modelling of the building is the initial step to be considered and to be worked at the beginning itself. So care must be taken while modelling a building. A small change in the geometric and material change also effects the building analysis results. These type of changes may increase or decrease the capacity of building to resist the forces. It's based on the characteristic of geometric and material parameters they prefer to adopt during modelling. In the same way, modelling assumptions also have a great effect on the capacity of the building. some of the modelling assumptions generally we consider are effects due to support conditions, effects due to monolithic rigid joints and effect of lintel beams. These changes in the modelling detailing has a very drastic change in the behavior of the building.

Researches are going on from many years to improve the seismic performance of a structure by using many techniques and also by changing the modeling parameters, which may help in improving the performance. Dhanaraj M.patil et.al[1]and Dia Eddin Nassanil et.al[2] conducted a non-linear static pushover analysis on a high rise 2D steel building with different systems. They are moment resisting frames (MRF's), chevron brace frames (CBF's), V-braced frames (VBF's), X-braced frames (XBF's) and zipper braced frames (ZBF's). After the analysis is done by using non-linear static analysis and non-linear dynamic analysis, the concluded that there is a improvement in the seismic resistance of frames when bracings are used. R.senthilkumar and S.R.Satish Kumar [3] designed a semi-rigid connection by following some guidelines, to resist the earthquake in low and medium seismic zones. Based on the guidelines the semi rigid composite frames are designed using force based design and direct displacement based design. After the pushover analysis done on the structure, the results shown that force based design has performed less when compared to the direct displacement based design. Hamdy Abou- Elfath et.al[4] conducted a study on seismic performance of a 6 story MRSF(Moment Resisting Steel Frames), designed with 3 different story drift limts and the analysis is done with both pushover analysis and time history analysis on the structure with 100 ground motions and with different PGA levels. Results shows that the strength and stiffness decreases as the story drift ratio increases in MRSF. Many technics are used to improve the seismic performance of the structure to resist the seismic forces. Some of the studies which used techniques are, Farzad Saeedi et.al[5] used Triangular Plate Added Damping and Stiffness(TADAS) devices in moment resist frames and observed that target displacement, elastic and effective fundamental period decreases and lateral stiffness, response modification factor and capacity increases when TADAS device is used. M.Maahmoudi et.al [6] introduced 12 different shape memory alloy (SMA) bars in the X-Knee braced frames. They are introduced in between the beam column joint, knee members, analyzed using time history analysis, and pushover analysis. Results shows that the alloys does not have effect on strength and stiffness but they effectively improved the state of plastic hinges within knees and there is increase in the re-centering capacity of structure. Ghasem Pachindeh et.al [7] conducted pushover analysis on 18 frames with steel plate shear wall (SPSW) and 9 special moment resisting frames with different story heights. They modelled with steel special moment resisting frames, single span and double span moment resisting frames. Results shown that single span SPSW got better results so no need of double span and it performance is better in tall structures compared to short and intermediate structures. Onkar G. Kumbhar et.al [8] highlighted the effect of modelling assumptions on seismic behavior of structure. He analyzed the building with non-linear static analysis called pushover analysis for different modelling assumptions like lintel beam, support conditions and rigidity in beam column joints. By the results, he concluded that designers should give proper importance to modelling assumptions because it can lead to unsafe design of buildings. Vishal R.Deoda et.al [9] made a non-linear static analysis to know how tha joints in the precast structure effect the behavior of the structure and to know the effect of soil foundation system on monolithic and precast structure. The results says that precast structure performance increases with decrease in R-value considered and the failure pattern in the precast structure with soil foundation follows more realistic compared to the monolithic structure with soil foundation system. Neena Panandikar(Hede) et.al [10] conducted a pushover analysis and compared it with the experimental investigation to give the clarity on how sensitive are the geometric and material modelling parameters during the analysis. He attempted to show the sensitivity of modelling assumptions and parameters like variation in material properties, modeling techniques, inaccuracies in placement of reinforcement and effect of confinement of concrete.

In the present study, author shows the effect of modelling assumptions or changes on the behavior of the structure. By considering one of the modelling assumption as mentioned above, such as effect of monolithic rigid joints on building behavior. An analysis called pushover analysis is done on both five and ten story buildings. Analysis is done for buildings designed with gravity loads and earthquake resistant loads. Analysis is done in both X and Y directions. And the results show the effect of modeling assumption on the behavior of the structure.

2 Detailing of the structure

An RC building with a regular plan model as shown in the figure (1), with both 5 and 10 stories are designed using a software called SAP2000 software. The building is designed according to the Indian standard codes such as IS 456:2000 [19] and IS 1893:2002 [20] for both gravity and earthquake resistant loads in both X and Y directions. The detailing of the building elements are as below in table1 and table 2.

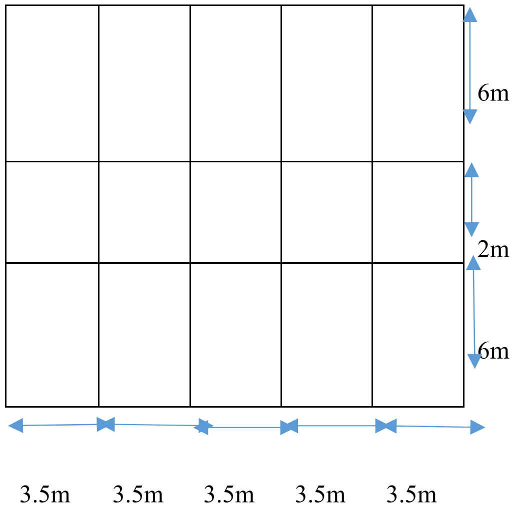

Fig.1. building plan view of 5 story and 10 story building.

Table. 1. beam dimensions of the building.

Beams	**5 story**	**10 story**
B1	238.50x300mm	300x500mm
B2	230x350mm	300x600mm

Table 2. column dimensions of the building

5 story		**10 story**	
Outer columns (C1)(mm)	Inner columns (C2)(mm)	1st and 2nd story (C1)(mm)	3 to 10 story (C2)(mm)
230x400	400x400	750x750	600x600

3 Modelling assumptions

An RC building with a regular plan model is designed using SAP2000 software. To know the effects of modelling assumptions on the building capacity, building

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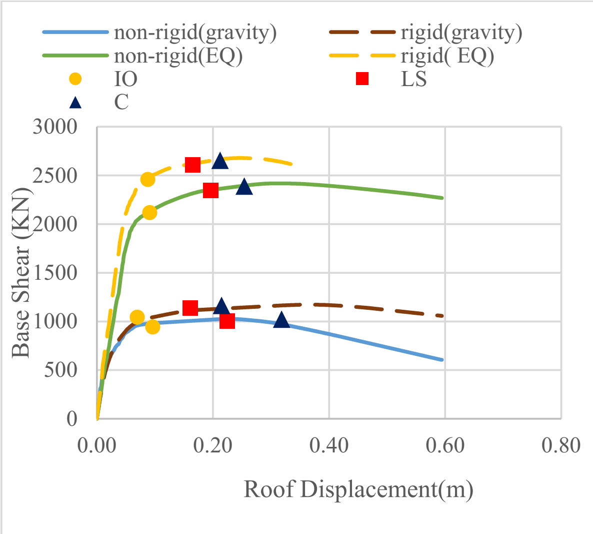
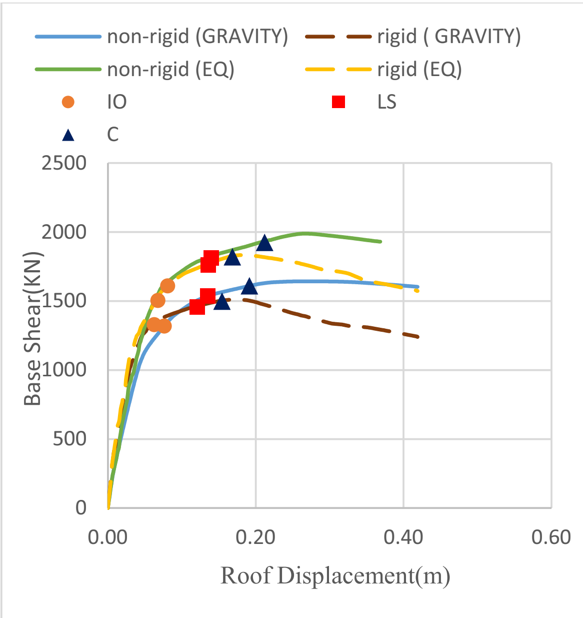
is designed for both rigid joints and non-rigid joints. To model the flexibility of the beam column joints, generally there are 3 types of approaches in SAP2000 software, they are centerline to centerline method, rigid end offset method and panel zone springs. In this paper, we used rigid end offset approach to model the flexibility of beam column joint. In the approach we fix the rigidity factor as 0 and 1 respectively i.e., the beam column joints is non-rigid for rigidity factor 0 and completely rigid for rigidity factor 1. The design is done for both 5 and 10 story models with rigidity factors (β) as 0 and 1. And the analysis is done for above models for gravity and earthquake resistant loads in X and Y directions. As a result, the capacity curves are obtained from the pushover analysis, which has to be compared for both rigid and non-rigid modeled buildings.



(a) 5-story (PUSH X)



(b) 5-story(PUSH Y)

Fig. 2. Comparison of capacity curves for 10 story structure designed and analyzed for rigid joints and non-rigid joints in X and Y directions

4 Results

Pushover analysis is done for both the 5 story and 10 story buildings. The buildings are designed and analyzed for rigidity factor 0 and 1. Rigidity factor (β) 0 defines that the beam column joint is completely flexible and rigidity factor (β) 1 defines that the beam column join is completely flexible. The analysis is done for different story buildings, which are designed for gravity loads and earthquake resistant loads. Completely 4 models are designed for 5 story in X and Y directions, by designing non rigid joint with gravity loads, rigid joints with gravity loads, non-rigid joints with earthquake resistant loads and rigid joint with earthquake resistant loads. Similarly for 10 story building in X and Y direction respectively. As a result, capacity curves will be obtained which shows a graph between the target displacement on the X axis and base shear on the Y axis. The target displacements defines the how much does the structure deforms after experiencing all types of loads and base shear defines how much maximum load does the building is able to resist. Following the capacity curves obtained from the pushover analysis, which are shown in the figure1, 2, 3 and 4 respectively. The capacity curve compares the graphs between the rigidity and non-rigidity of both gravity based designed structures and earthquake based designed structures, in both X and Y directions for 5 story and 10 story buildings. By studying the curve, we can say that the strength of building is increased when the structure is designed and analyzed for beam column joint as rigid when compared with non-rigid joint. From the graph it says that the capacity of the building is increased approximately 20% when the building is designed for rigid joints, when compare with the flexible joints. From the capacity curves we can observe that strength of the earthquake resistant designed building is more when compared to the gravity load designed building. we can even observe the formation of hinge points such as IO, LS and C points on capacity curves.

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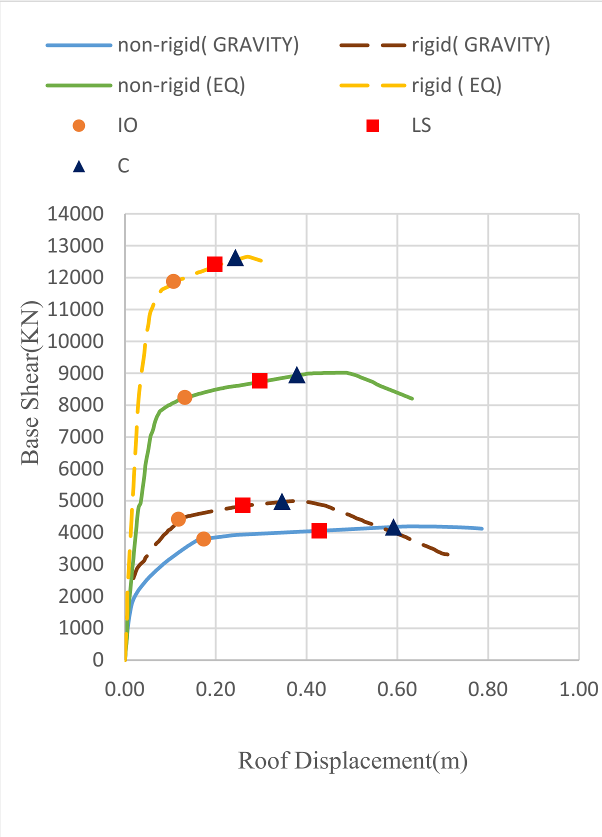
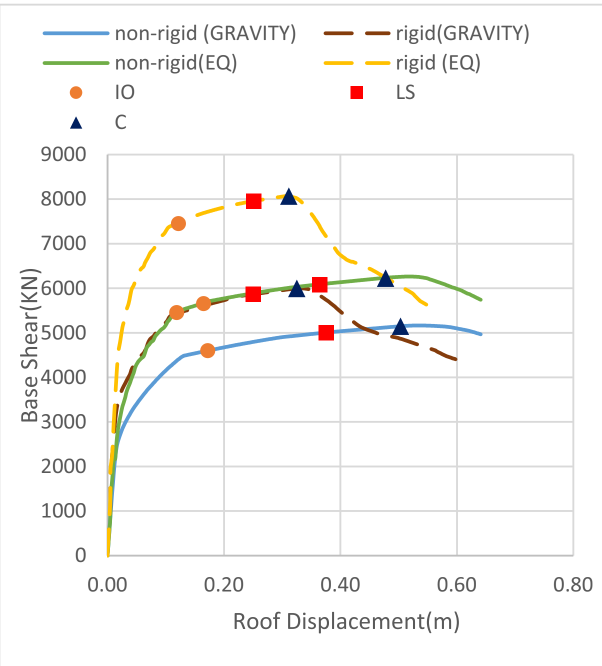


(a) 10 story(PUSH X)



(b) 10 story(PUSH Y)

Fig. 3. Comparison of capacity curves for 10 story structures designed and analyzed for rigid joints and non-rigid joints in X and Y directions.

5 Conclusions

By comparing the capacity curves or pushover curves of both rigid and non-rigid designed models with both gravity and earthquake resistant loads in both X and Y directions, we can conclude that

1. The rigidity in between the beam column joint increases the strength of the structure when compared to the flexible joint.
2. Modelling assumptions plays a key role in estimating and analyzing a structure, which can resist the seismic loads.
3. Therefore, designers should take utmost proper care while modeling a structure by doing a keen research on the required structural details and adopt the requirements accordingly, which benefits the structural behavior.
4. While designing a structure, designers should consider the joint designing from the code IS 13920: 2016. Because of considering joint rigidity designing, it helps in increasing the strength of the building.

6 References

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