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Evaluation of Seismic Performance on Setback Buildings

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***Abstract* - Irregularity in a building seems inevitable with greater demand for advancement and innovation in the field of construction and architecture. Irregularity can be present in both plan and elevation and are more vulnerable to earthquakes than regular buildings. In this paper, three different storied setback building models i.e. 3, 6, and 12 stories were considered and seismic analysis was performed as per IS 1893 (Part 1): 2016. Responses such as base shear, story drift, and lateral sway were obtained and compared with the regular building model. It was observed that base shear decreases in setback models due to lesser seismic weight. Story drift and lateral sway were not much affected due to setbacks in 3 story model. Whereas the greater influence of setbacks was seen in the 6 and 12 stories as drift and displacement rise corresponding to the positions of setbacks due to the reduction in story stiffness. Also, setbacks should be discouraged in upper floors to check the story drift as the maximum drift was observed in the 10th story in the 12-story model.**

***Index Terms* - Irregularity, setback, story drift, seismic analysis.**

I.INTRODUCTION

Irregularities are categorized in plan irregularity and vertical irregularities as per IS1893 (Part 1): 2016 which makes the structure susceptible to damage if not considered during design. A setback is a type of vertical geometric irregularity in which the horizontal dimension of earthquake resisting elements of a building decreases in elevation.

Stepped building frames constitute a category of vertical irregularity, whose seismic evaluation has not received adequate attention in existing research and code formulation [1]. The vertical irregularity resulting from setback buildings has a great impact in attenuating the seismic structural response under various earthquake ground motions [2]. For the residual drift, it is observed that with the increase in the story irregularity, the rate of increase in the residual drift also increases as compared to the stories with regular story stiffness [3]. Displacement obtained in the geometric irregular building is greater than the regular for upper stories and the lesser the stiffness greater the displacement [4]. An increase in irregularity increases story displacement and maximum displacement occurs where lateral stiffness is lesser [5]. Stiffness decreases with the height of the building and is lesser in irregular buildings than in regular-shaped buildings [6]. A case study of the proposed correction to the empirical formula of the code demonstrates an accurate estimation of the fundamental period of three-dimensional building [7]. Appropriate distribution of stiffness provides proper stability in setback and stiffness irregular building [8]. Setback results in the sudden increase in displacement of building causing a decrease of the slope [9].

II.BUILDING CONFIGURATION

Modeling of the structures was done using ETABS 2017. Three building models of three, six, and twelve stories were considered. For each regular building model without a setback, two different alternatives with setbacks were created whose responses were compared with the regular model. Fig.1 represents regular Models of all 12, 6, and 3 stories respectively without setbacks referred to as Model 1 later in this paper, moreover, Fig.2, 3, and 4 display setback models for 12, 6, and 3 stories respectively named as Model 2 and Model 3. Model 2 consists of a setback in two steps while model 3 consists of a single step setback as shown in elevation in Fig.1.

Properties
Grade of concrete: M25
Height of ground floor: 3.5 m
Typical story height: 3m
Span in X & Y direction: 6@4m
Slab thickness: 125mm
Masonry load: 11.5 & 9.5 kN/m
Seismic Zone: V
Importance factor: 1.2

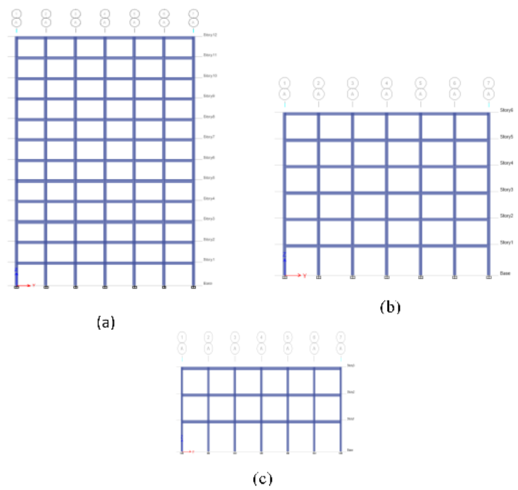

Fig.1.Model 1 for (a) 12 story building, (b) 6 story building and (c) 3 story building

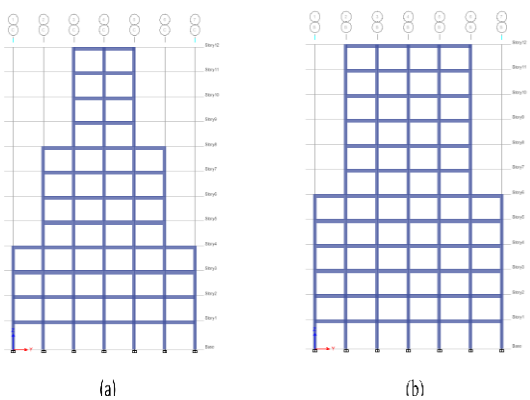

Fig. 2. 12 story frame with setback (a) Model 2 & (b) Model 3

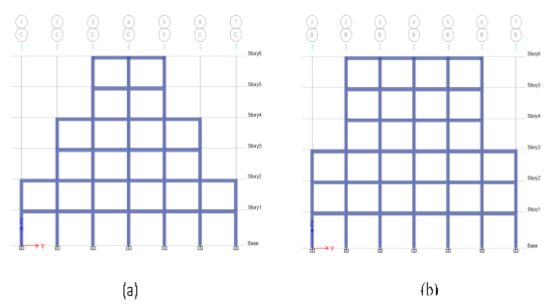

Fig.3. 6 story frame with setback (a) Model 2 & (b) Model 3

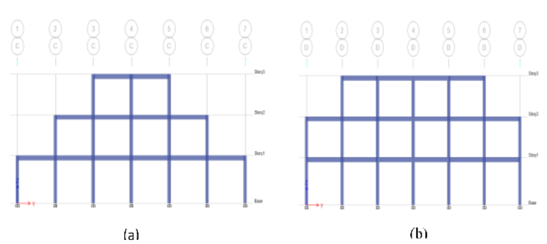

Fig. 4. 3 story frame with setback (a) Model 2 & (b) Model 3

III.RESULTS AND DISCUSSION

The building was analyzed and the result is presented in terms of base shear, story drift, lateral sway, and story stiffness and is compared between the models.

Base shear

Base shear for all three different storied models is presented in Fig. 5. Base shear is seen to be decreased in models 2 and 3 when setbacks are introduced due to the decrease in seismic weight of the structure. Moreover, base shear decreases if the setback is greater as shown by Fig.2 3, and 4 that has lesser base shear and a greater setback.

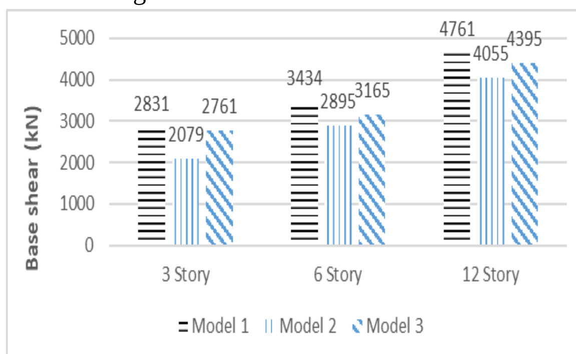

Fig.5. base shear in all models

Story drift

It can be perceived from Fig. 6 that story drift in all models for 3 stories has a similar pattern. Drift in irregular or setback models was lesser than that of Model 1 which is a regular model. So, setbacks in 3 stories didn’t surge the drift. Whereas, from Fig. 7 we can perceive that story drift in models 2 and 3 with setbacks were greater than that in the regular Model 1. Value of drift was escalated up to 2nd story and gradually decreased in Model 1 but the maximum drift was attained in 4th and 3rd story corresponding to Model 2 and 3.

Also, from Fig. 8. It was observed that story drift gradually increased up to the 4th story and decreased in the same order in Model 1 of 12 story building. However, in Model 2, drift rose till the 6th story and reduced up to the 8th story, and afterward, maximum drift was attained in the 9th story. And in the Model, the smooth curve was obtained until the 6th story after which an abrupt increase was seen with maximum drift at the 8th story. From these patterns, we can witness a rise in story drift with greater setbacks or irregularities in elevation.

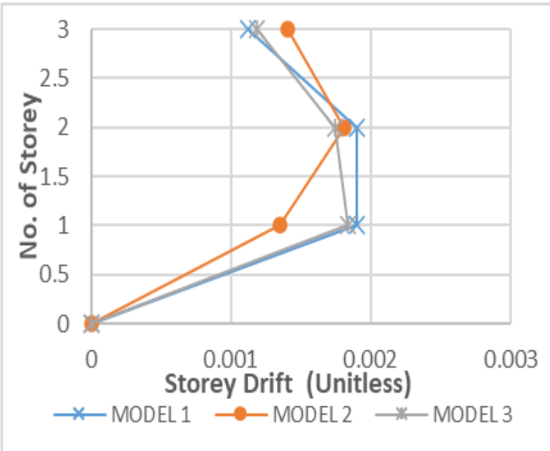

Fig.6. Story drift for 3 story buildings in X-direction

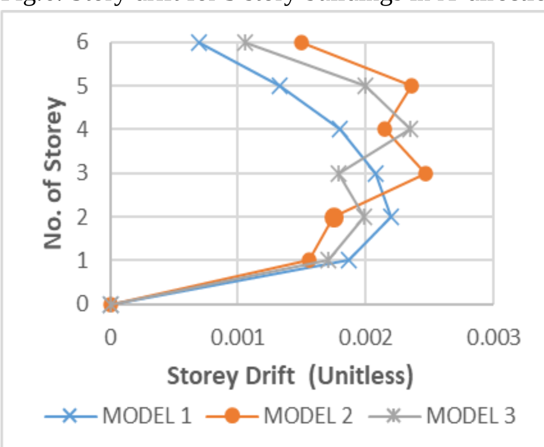

Fig.7. Story drift for 6 story buildings in X-direction

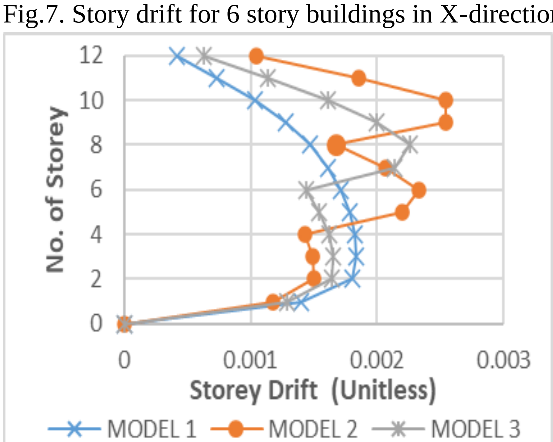

Fig. 8. Story drift for 12 story buildings in X-direction

Lateral sway

Lateral sway is the displacement of the building frame. From Fig.9, it is illustrated that in 3 story models regular model had the largest value of roof displacement than other irregular models. Model 2 had the least displacement than other models as the setback was greater in this model.

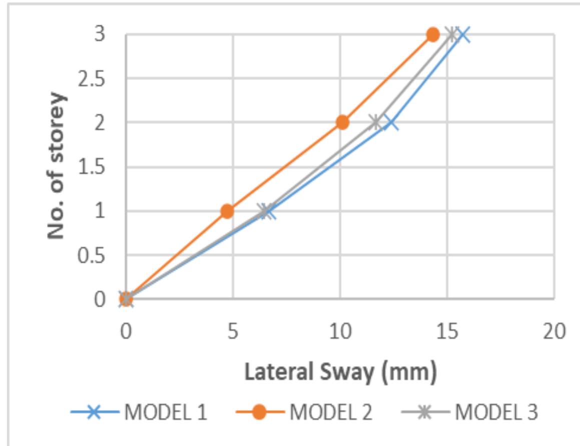

Fig. 9 Lateral sway for 3 story models

On the contrary, the lateral sway of setback models was greater than the regular model in 6 story and 12 story buildings. The rise in roof displacement of single setback model 3 was 10% which increased to 20% in Model 2 which contains double step setbacks and is shown in Fig 10. In this type of vertical irregular structure, stiffness to oppose the lateral load decreases with an increase in setbacks which results in greater lateral sway of the building.

Similarly, Fig. 10 depicts an increment in lateral sway of around 30% in Model 2 in 12 story model which has multiple setbacks whereas, only a 12% rise was noticed in Model 3 with the single setback. The maximum displacement was developed corresponding to the number of steps of setbacks in the building structure.

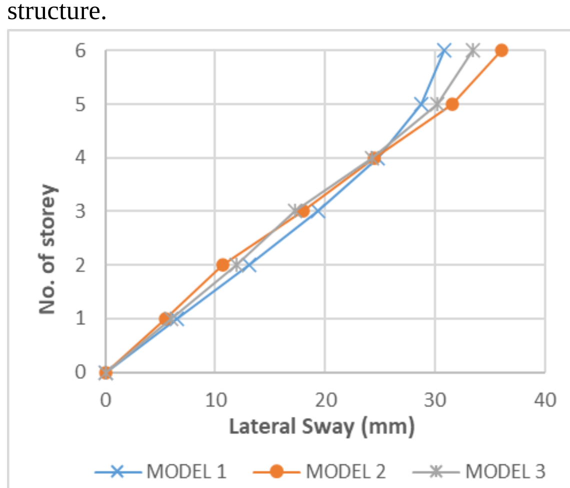

Fig. 10 Lateral sway for 6 story models

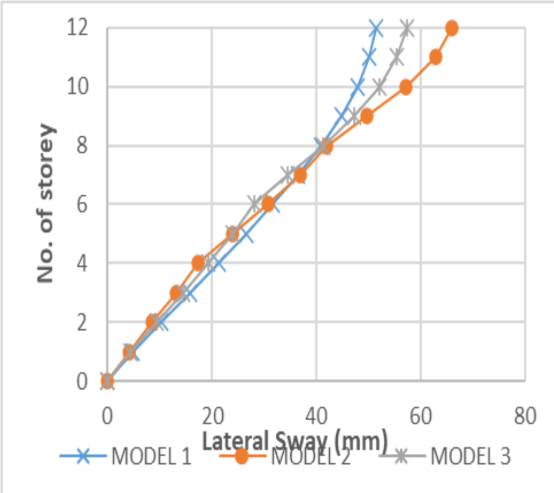

Fig. 11 Lateral sway for 12 story models

IV CONCLUSION

1. Story shear was decreased with an increase in the setback as Seismic weight decreases.
2. In 3 story building, model drift was decreased in setback models than the normal regular model.
3. In 6 story building, model story drift was 6-12% greater in irregular models 2 and 3 than in the regular model 1.
4. In 12 story model, the rise in story drift was 38% in Model 2 with multiple-step setbacks and 23% in Model 3 with single setbacks than regular Model 1.
5. The position of occurrence of maximum drift varied with the location of a setback in elevation. Also, setbacks in lesser floors exhibited lesser drift than the higher floors.
6. Lateral sway in Model 1 was highest than the other two models in 3 story building.
7. An increment of 20 % and 10 % in roof displacement was observed in Model 2 and 3 than Model 1 of the 6-story building model.
8. Lateral sway was escalated to 30 % in Model 2 than the regular model in 12 story building model.
9. Lateral sway was increased in irregular frame building than the regular frame building.

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