International Association of Scientific Innovation and Research (IASIR)
(An Association Unifying the Sciences, Engineering, and Applied Research)

ISSN (Print): 2279-0020
ISSN (Online): 2279-0039

International Journal of Engineering, Business and Enterprise Applications (IJEBEA)

www.iasir.net

Parametric Study of Rigid Frame Multistory R/C Buildings with Vertical Geometric Irregularity

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Abstract: *Irregularity is inevitable in design of a building. This paper presents the study of vertical irregular buildings which have setback in their different elevation points. All the possible shapes of vertical geometric irregular buildings are considered for the study. Parameters that are used for the assessment are internal forces that induce in the critical members of the building. With the help of this study, decisions can be make about providing setback in a building at different elevation points. For the study purpose only twenty one story buildings are considered in which rigid frame structural system is used. All the buildings are modeled and analyzed in program STAAD.pro. Analysis used for the present study is response spectrum analysis. Earthquake load is set as described in IS 1893: 2002 and other loads like dead loads, live loads and wind loads are set as described in code IS 875 part 1, 2 and 3 respectively. All load combinations are set as per the relevant Indian standard codes.*

Key words: *Multi-store R/C Buildings, Vertical Irregularity, Earthquake loads, Wind Loads.*

I. Introduction

High rise buildings are becoming the modern trend of construction in the urban areas of developing countries. Because of the scarcity of land available or the high cost of land in urban areas, construction of high rise building is the only option. Multistory buildings serve many purposes like office, residential and commercial purpose etc. Aesthetic view of the area where the multistory buildings exists also increases.

In the present paper twenty one story high buildings are considered in which rigid frame structural system is used. According to M.M Ali and K.S Moon, for twenty storey building, rigid frame structural system is appropriate for resisting vertical loads as well as lateral loads.

Figure.1 shows the perspective view of all building models that are considered for this study. Those buildings are given the name as L shape, V shape and T shape according to the geometric shape they have. Also the buildings with name P, Q and R are the Models in which relative study can be made about vertical geometric irregularity in a building. In these models more than one setback is being provided. At one side setback is kept constant at some particular elevation and the other side setback is varying with each building.

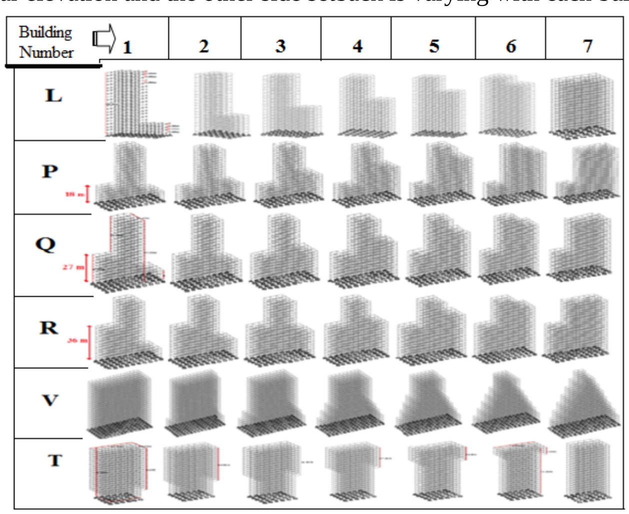

Figure.1: Perspective view of models considered: model L, model P, model Q, model R, model V and model T.

II. Literature review

Beyza Taskin et. al. presents their study on the architectural aspects of designing a building. At the very planning stage of a building an Architect can decide the orientation of columns such that the building can behave equally well in both directions as per the requirement of loading. A good example of vertical irregularity in structure is the projections that are made by the planners that comes out from the actual orientation of the column series. This is dangerous to give such kind of irregular shape because vertical component of the earthquake gives thrust to these projections giving damage to them.

S.K. Jain et. al. have given emphasis on avoiding the formation of soft first story in a building. Because of commercial purpose or providing parking facilities, the first ground story is kept open or height of this story is kept a bit high than the rest of the stories. Either way this reduces the stiffness and strength of this first ground story making it weak with comparison to others. They suggested the use of Central Concrete Core method or extra strengthening the ground story columns for elimination the effect of formation of first soft story.

Eggert V. Valmundsson et. al. compared the two analysis methods Equivalent Static Load Method and Time History Analysis for the vertically irregular buildings. Irregularities that were considered for the study were mass, stiffness and strength irregularity as described in Uniform Building Code. The motive of the study was to evaluate the performance of vertically irregular structure by both methods and making comparison in the results of both. After detailed analysis they set some requirement in UBC for the structures to be considered for analysis by Equivalent Static Load Method.

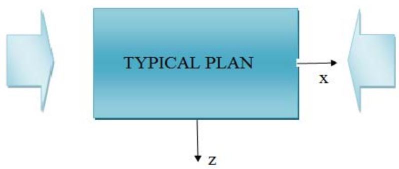

Figure.2: shows the pattern of providing setback in a building.

III. Problem Statement

Figure.1 shows different models considered in this study. Model L, Model V and model T are being given the name as per the geometric configuration of the buildings. Models P, Q and R are specific models that are considered for study to understand the relative performance of the building if more than one setback has to be provided. For convenience, in all models, geometric irregularity is provided along global X direction only (Figure 2). It means that there will be no change in geometric shape of a building in Z direction but changes will be in X direction only. Once the performance of a building is known by providing setback in one horizontal direction then it can be understood for the other direction also.

In this project each building is twenty one stories high. Each bay, horizontal in plan is of 4 m x 4m length and floor to floor distance considered is 3 meters high. Material considered is of reinforce concrete. Column cross section is set constant as 500 mm x 500 mm for all columns in all modals and beam cross section is taken as 600 mm x300 mm throughout.

IV. Results and Discussions

Figure 3 shows the variation of X directional bending moment for the columns shown in insert near the setback level of L shape buildings. In comparison, values of B.M. are high at setback level relative to the story above and below it. Also the values keep on decreasing as the height of the building increases. For X-directional bending moment, in all buildings, same kind of variation is noticed. This is because of geometric shape of all buildings is changing in X direction only.

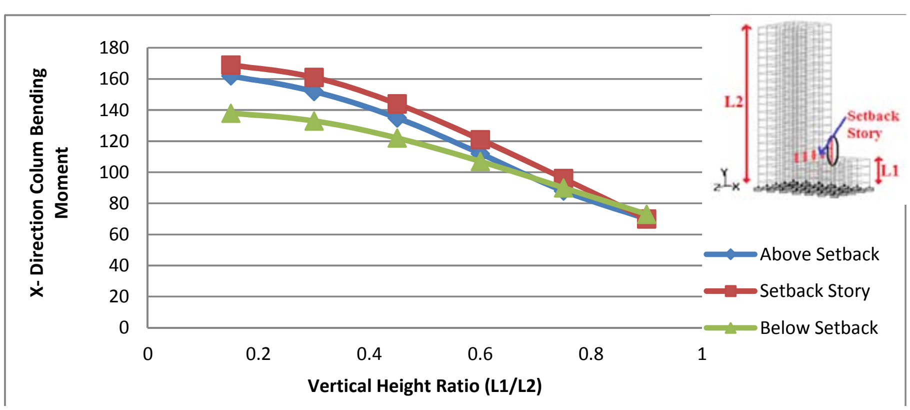

Figure.3: Variation of B.M. in X direction at the setback story, above and below of it, for the columns highlighted.

Results for Model L

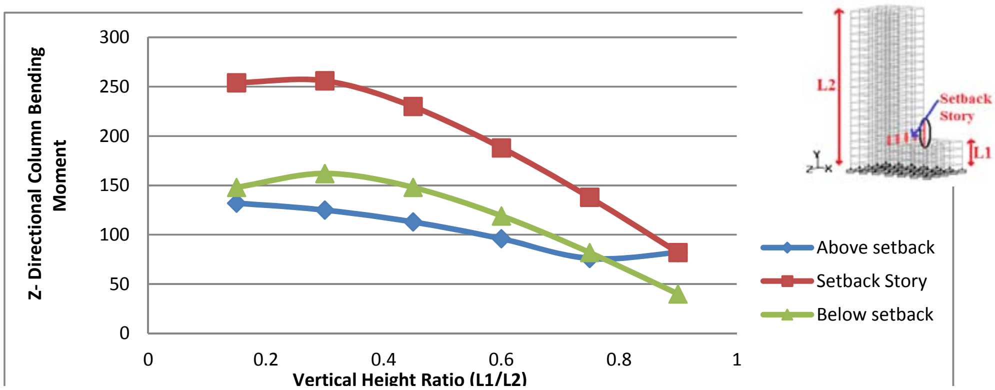

Figure.4: Variation of Z directional B.M. at the setback story, above and below of it for the columns highlighted.

Figure 4 shows the graph of variation of Z- directional bending moment of the three stories near setback. It can be observed that at the setback level there is considerable change in magnitude of B.M. relative to the other two stories.

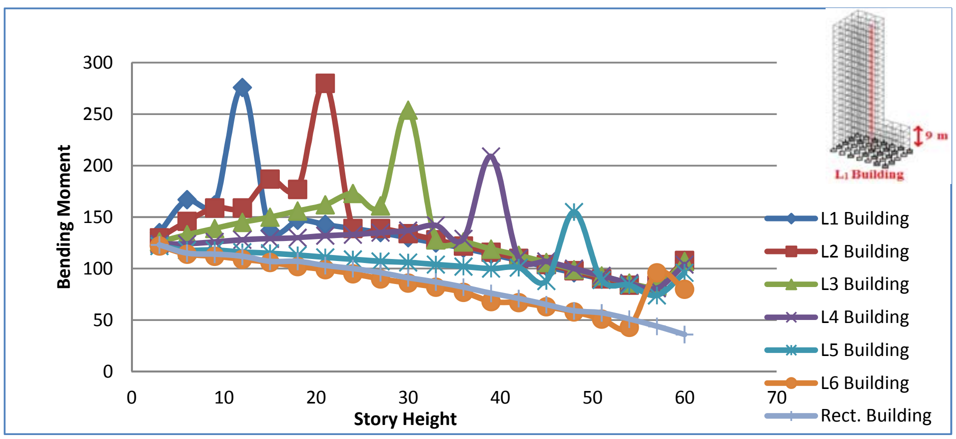

Figure.5: Variation of B.M from ground to top story for all buildings of L model together. In the insert highlighted columns of L_1 building of which B.M is taken, are shown.

Figure 5 shows the variation of bending moment from ground to top story for each building considered in this model. In this picture inserted figure of L_1 building is shown. Highlighted columns of this building are taken to know the variation of bending moment from ground to top story. This variation can be seen in the graph. In the same way plot of variation of these bending moments from ground to top storey for all buildings are drawn together for comparison purpose. It can be seen from each graph that at setback level there is a sudden increase in the value of bending moment. While comparing the result of all building together, it can be observed that the highest value of bending moment in each building at setback level decreases as vertical height ratio increases. In another words, it can be stated that the effect of providing setback in a building of this kind decreases as the elevation of point of setback in a building increases. In this figure, it can also be observed that the values of bending moment for building L_6, for which setback is at highest level, are even less than the rectangular building of this model but increases suddenly at the setback level.

Results for Model P

Model P, Model Q and Model R are the critical models that are considered for study to know the performance of the building if more than one setback is to be provided. As described earlier also that geometric shape of the building will change one global X- direction only (figure.2). The three models are almost of same geometric

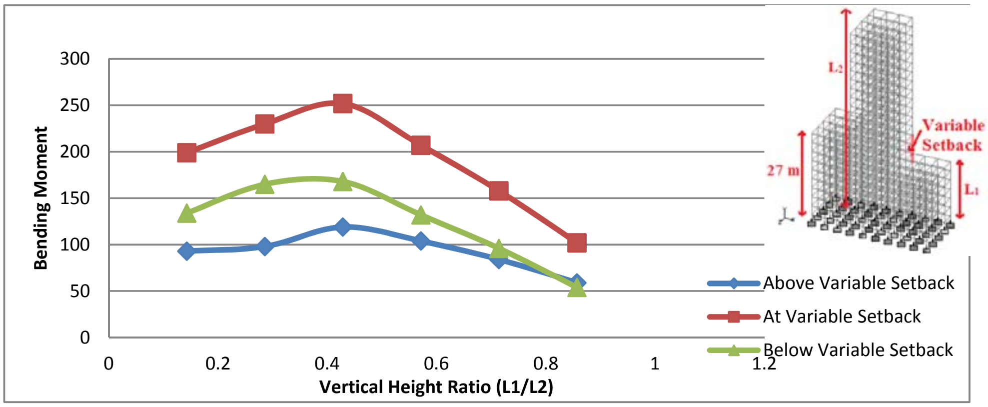

Figure.6: Variation of bending moment versus vertical height ratio for the highlighted columns of variable setback.

type except the elevation of the stationary setback that is at 18 m for model Q, at 27 m for model R and is at 36 m for R model.

Graphs of Figure 6 shows the variation of bending moment for the columns of setback story which is changing as the vertical height ratio is changing. It can be observed from the graphs that for lateral length ratio 6/21 (P_2 building), values of bending moments are highest in comparison to other buildings of this model.

Figure 7 shows the variation of bending moments of columns from ground story to top story with all buildings of this model together. It can be observed that among all these graphs building P_2 is giving the highest value at the point of variable setback. In this building, variable setback and stationary setback are at the same elevation.

Results for Model Q

In all buildings of model Q, invariable setback is kept constant at the elevation of 27 m from ground whereas another setback is changing as vertical height ratio changes (Figure.1). Height of invariable setback is approximately at the middle of the building in this model.

Figure 8 shows the variation of bending moment of the columns of setback story that is changing as the vertical height ratio changing. It can be noticed, for building Q_3 values are high in all three stories below setback, above setback and at the point of setback.

Figure 9 also shows the variation of bending moment of columns for all buildings from ground to top story. It can be observed that for building Q_3 values of bending moments are high at setback point.

Response of building Q_7 with comparison to the rectangular building can also be observed in figure 9.

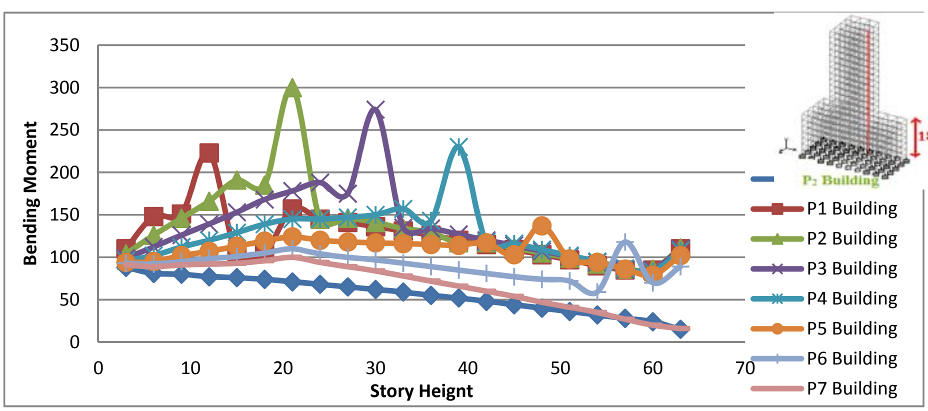

Figure.7: Variation of B.M from ground to top story for all buildings of P model together. In the insert highlighted columns of P_2 building of which B.M is taken, are shown.

Results for Model R

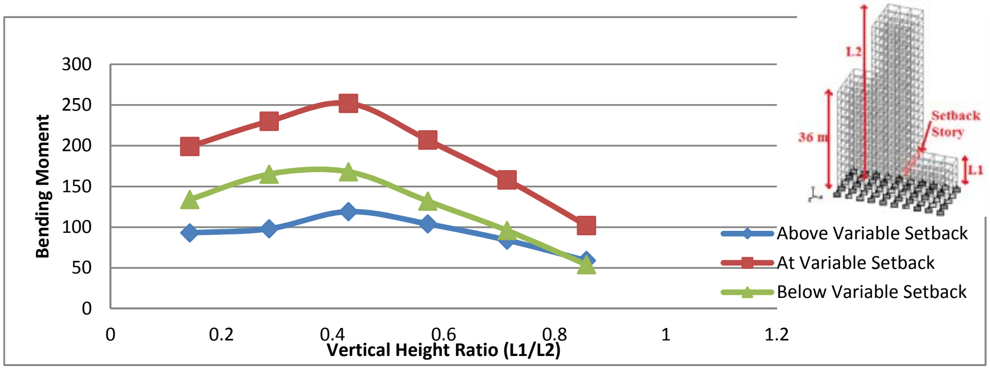

Figure.8: Variation of bending moment versus vertical height ratio for highlighted columns near variable setback.

In this model, in all buildings invariable setback is set at the height of 36 meters. Figure 10 and 11 shows the graphs for the buildings of this model. From the graphs of figure 11, it can be observed that buildings of vertical height ratio 9/21 (R_3 building) has relatively high in comparison to nearby buildings but difference is not much. Figure 11 shows the graphs of all buildings together, values of bending moment of columns from ground to top story is drawn versus the vertical height ratio. It can be seen that for model R_3 values are high at the setback level.

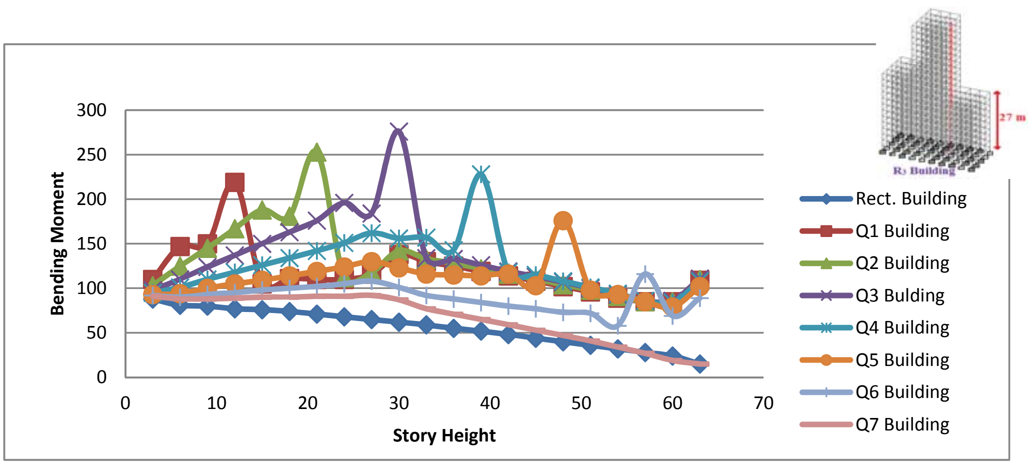

Figure.9: Variation of B.M from ground to top story for all buildings of Q model together. In the insert highlighted columns of Q_3 building of which B.M is taken, are shown.

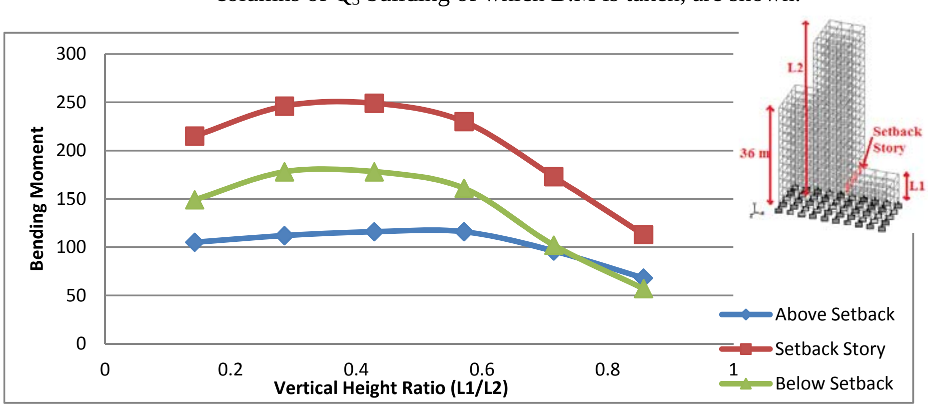

Figure.10: Typical variation of bending moment versus vertical height ratio for highlighted columns of variable setback.

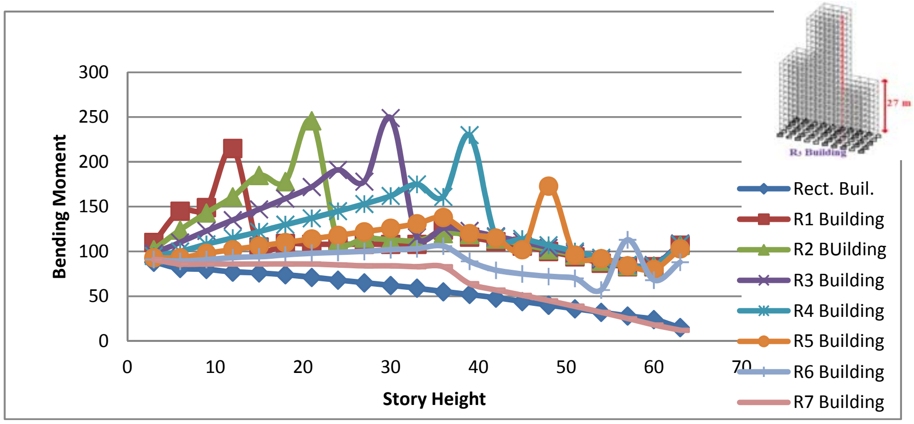

Figure.11: Variation of B.M from ground to top story for all buildings of R model together. In the insert highlighted columns of R_3 building of which B.M is taken, are shown.

Results for Model V

Buildings of model V are alike a pyramid in shape. In this model, in all buildings one setback is provided with each increase in vertical height ratio. It can be observed from figure 12 that at the setback level, building with vertical height ratio 9/21 (V_3 building) has the maximum value of bending moment in comparison to all other buildings in this model. In this building setback is almost at the mid height of the building.

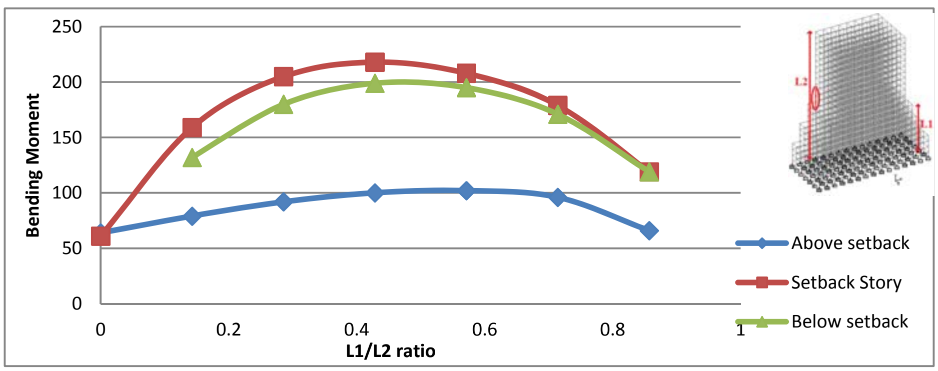

Figure.12: Variation of bending moment versus vertical height ratio for highlighted columns.

In plot of graphs of figure 13, where performance of rectangular building is also shown, it can be observed that for V_3 building (L_1/L_2 = 9/21), values of bending moments are high. Also it can observed that values of bending moments for either rectangular or V_6 (L_1/L_2 = 18/21) are the least among all making both the most stable building among all of this model.

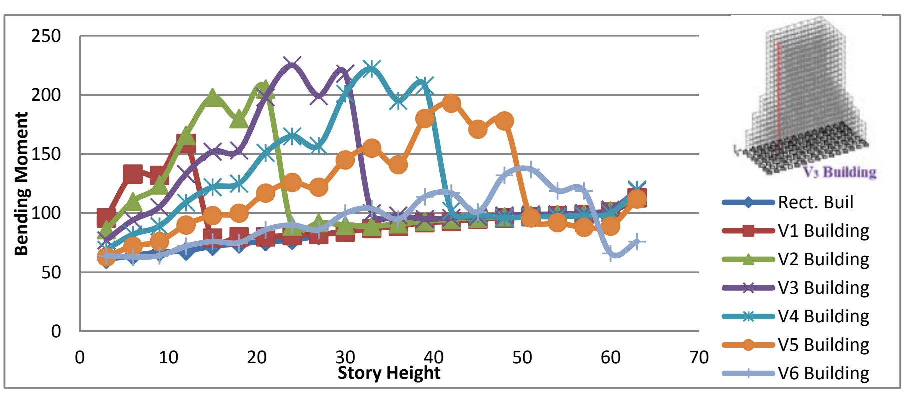

Figure.13: Variation of bending moment for all buildings of model V from ground to top story. In the insert highlighted columns of V_3 building are shown.

Results for Model T

Figure 14 and 15 shows the response of buildings of model T. In these graphs, it can be observed that at the point of setback, values of bending moments change tremendously with high magnitude. Although as the vertical height ratio increases effect of providing setback of this kind decreases.

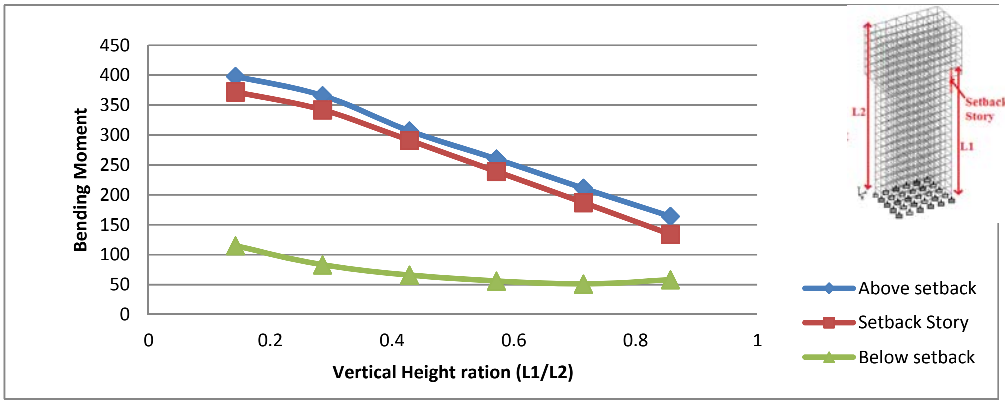

Figure.14: Variation of bending moment versus vertical height ratio for the highlighted columns.

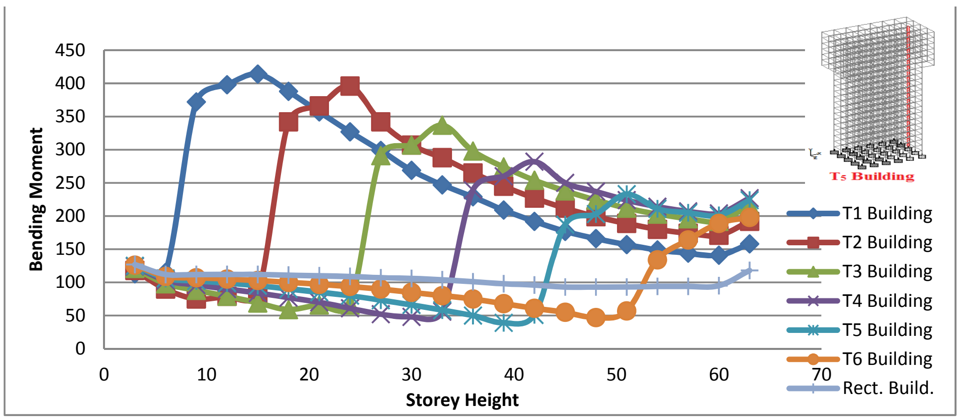

Figure.15: Variation of bending moment for all buildings of model T from ground to top story. In the insert highlighted columns of T_5 building are shown.

V. Conclusion

- From the response of model L and T, it can be stated that effect of providing setback in a building of this type decreases as the elevation point of providing setback increases.
- From the response of model P, Q and R, it can be stated that providing setback from both side at any particular elevation is not good although effect of vertical geometric irregularity reduces as vertical height ratio increases.
- For model V, V_3 building (L_1/L_2 = 9/21) is giving the highest values of bending moment so either rectangular or pyramid shape of a building are the most stable buildings.
- From the response of the models P, Q, R and V, it can be concluded that providing step by step setback but not together at any particular elevation, in a building makes the building behaving good.

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