# Influence of Geometric Parameters of Connections' Members on Behavior of RC Buildings: A Computational Study

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**Abstract:** One of the most important structures to resist against lateral loading, are moment frames. It is obvious that the beam-column connections play an important role in frame behavior especially on the lateral displacement of structure. In this study, 3 buildings with 5, 10 and 15 stories respectively was modeled by ETABS software and various dimension was applied on beams and columns of these buildings in order to accurately assess the effect of dimension variation of beam and column in connections. It was revealed that the amount of drift ratio significantly decreased by increasing the ratio of beam height to beam width. Moreover, the enhancement of ratio of column width to column height caused to decrease the drift in connections. The increase of ratio of width of beam to width of column will lead to decrease drift, as well.

**Keywords:** Reinforced Concrete, Medium Ductility Moment Frame, Beam-Column Connection

## 1. Introduction

Many experimental investigations were carried out in order to improve behavior of joints against seismic loads by strengthening them. It is because of that the joints are the most critical areas against seismic loads in moment frames structures. Esmaeel Esmaeeli et al. [1] evaluated the effect of strengthening of interior reinforced concrete beam-column connections by prefabricated hybrid composite plates which is composed of a thin plate made of strain hardening cementitious composite (SHCC) reinforced with CFRP sheets/laminates. They conclude that behavior of connections dramatically improved. Muhammad, N. S et al. [2] assessed two RC t joints by using concrete covers and carbon fiber reinforced polymer (CFRP) jacketing for circular columns. They observed that the specimens' behavior considerably improved. Thomas Vincent et al. [3] carried out an experimental test to investigate the effect of concrete compressive strength and confinement on high and ultra-high strength concrete (HSC and UHSC) specimens and they concluded that confinement lead to high ductile behavior of specimens. Moreover, some scientist studied on effect of dimension of beams in joints, specially increasing width of beam in connections. Russell Gentry and Wight [4]

experimentally assessed the behavior of the wide beam-column joint in high seismic areas. Their study revealed that to design such a connection, the possibility of transferring the plastic hinge bending moments to the column should be carefully computed. Otherwise, transverse beam can be damaged by cracking caused by torsional moments. LaFave and Wight [5] studied the wide beam-column joints in which exterior RC had transverse lateral beam. The experimental investigation conducted by Elsouri et al. [6] revealed that detailed design of the reinforcements of exterior wide beam-column connection can effectively increase the earthquake-resistant. Furthermore, another study was carried out (Elsouri and Harajli [7]) on four full-scale interior joints with wide beams, demonstrated that improvement of reinforcements details, can lead to increase the seismic performance by postponing of connection shear failure. Dominguez et al. [8] evaluated performance of buildings which were one slab with wide beams under Lorca earth quick (an earthquake (11-05-2011) in Spain). They concluded the buildings that were designed without any seismic provisions did not survive Lorca record, even in low seismicity areas. While, other buildings that had met seismic requirements, survived under higher seismic loadings. An investigation conducted by Fernando et al. [9] compared wide beam– column joints with

conventional beam– column joints to approve provisions of potential high ductility performance of joints with wide beam. Results showed that both wide and conventional beam joints had, generally, similar seismic capacities. An experimental test was conducted to compare the behavior of the two conventional and wide beam-column roof joint (Mirzabagheri et al. [10]). They found out wide beam-column joint had sufficient joint shear strength unlike conventional one. Therefore, joint shear requirements could be relaxed for roof wide beam-column joint. Georgia E Thermou [11] investigated analytical modeling of old structures retrofitted by jacketing the old joint with new concrete and found that with one additional degree of freedom the strength of joints increased. Two experimental and numerical studies were developed by Li and Kulkarni [12], [13] to evaluate behavior of the interior and exterior wide beam-column connection respectively in several conditions. To this aim they used a parametric study. It was understood from their results that column axial load, transverse beam, and beam bar anchorage ratio play important roles in behavior of this connection (Li and Kulkarni [12], [13]). It can be seen there are several investigations about behavior of the building connections. This study aims to clarify the influence of dimension of beams and columns in RC connections on the behavior of different buildings subjected to seismic loading.

## 2. Modelling of the Structures

ETABS software can be used for parametric studies of different engineering structures particularly for analyzing in the realm of civil engineering [14]. By ETABS software (version 9.7.0), Three 5, 10 and 15 stories buildings, as short, average and tall buildings were modeled. The height of the each story is 3 meter. Compressive strength of the concrete used in structures was 21.5 MPa and yield stress of the reinforcements was 392 MPa. The plan and 3 dimensional view of the building are shown in the figures 1-4. The earthquake coefficients of the 5, 10 and 15 stories building are 0.118, 0.085 and 0.069, respectively. These coefficient shows that for this amount the weight of building can be applied for design of earthquake. Additionally, the 200 and 600 kg/m$^2$ live and dead load was applied to all buildings. The type of ceiling systems is T joist, as it is shown at figure 1. Moment frames with medium ductility is used for modelling. The sections of columns for lowest stories is bigger than higher stories. For each kind of building, all geometric parameters were constant and just the ratio of the beam height to beam width (β) were changed. 3 values of β (β=0.5, β=1 and β=1.5) were modeled and analyzed. After achieving results, the ratio of the column width to column height (γ) were changed for the value of γ=0.5, γ=1, γ=2 and γ=3. Lastly, the ratio of the beam width to column width (α) were changed. For each type of building 6 values (α = 0.5, α =0.75, α =1, α =1.5, α =2 and α =3) of α were modeled and analyzed. Finally, the influence of these changes on drift ratio and lateral displacement is investigated. Story drift is usually

interpreted as inter-story drift - the lateral displacement of one level relative to the other level above or below. Story displacement is the lateral displacement of the story relative to the base.
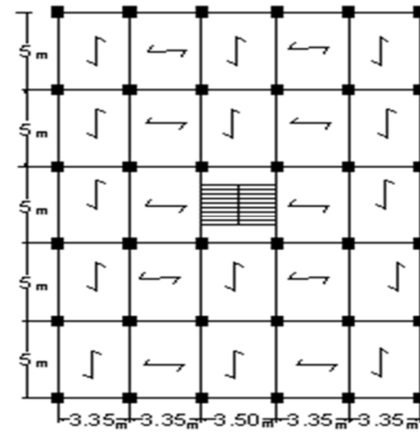


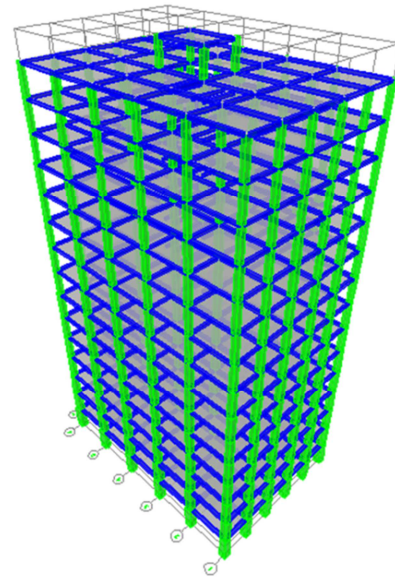**Figure 1.** *Plan of the buildings.*



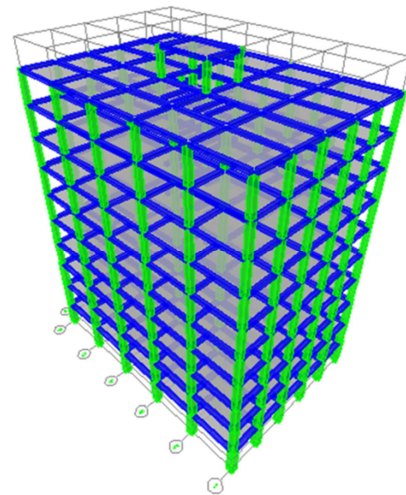**Figure 2.** *Three dimensional view of the 15 stories building.*



**Figure 3.** *Three dimensional view of the 10 stories building.*
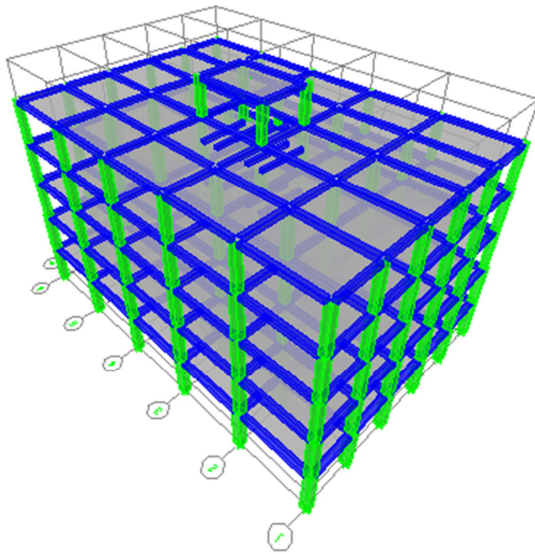
*Figure 4. Three dimensional view of the 5 stories building.*

# 3. Results and Discussion

## 3.1. The Influence of the Ratio of the Beam Height to Beam Width (β) on Maximum Drift

### 3.1.1. Five Stories Building

Figure 5, 6 and 7 shows the drift ratio of stories for different values of β.

Figure 5 shows with increasing the value of β to 1.5, the value of the drift in stories has considerably decreased. Additionally, for each β, it is apparent that there is a maximum drift at the third story for the five story building. The reason of this can be that in the middle of building the height from ground until middle story is on average and the drift is average as well. Whereas at top stories the height is huge and the high value of denominator will lead to make small the fraction answer.
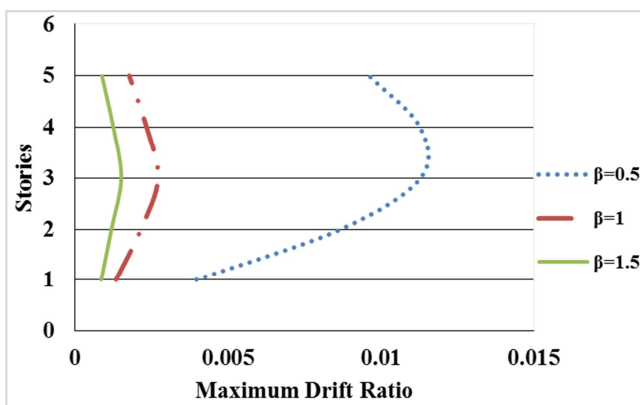


*Figure 5. Maximum drift of the 5 stories building.*

### 3.1.2. Ten Stories Building

Figure 6 shows that by rising β from 0.5 to 1.5, maximum drift significantly declined. Moreover, it is clear that the maximum value of drift was at sixth story for each β. For the reason which is cited before.
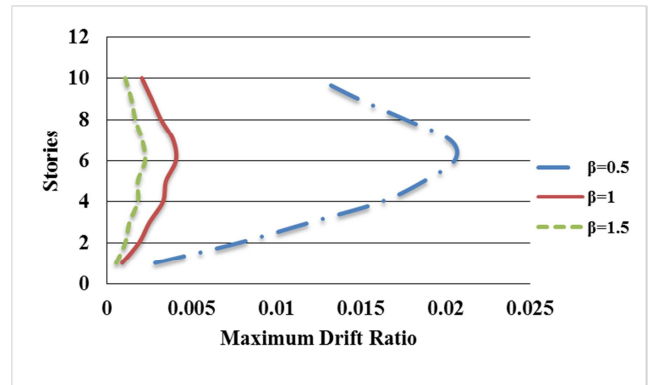


*Figure 6. Maximum drift of the 10 stories building.*

### 3.1.3. Fifteen Stories Building

It can be observed from figure 7 that by increasing the value of β to 1.5, the value of the drift in stories has considerably declined. Especially the distance between β = 1 to β = 1.5 is dramatically huge. The graphs are fluctuated although maximum drift between eighth and tenth story of 15 story building is at highest level.
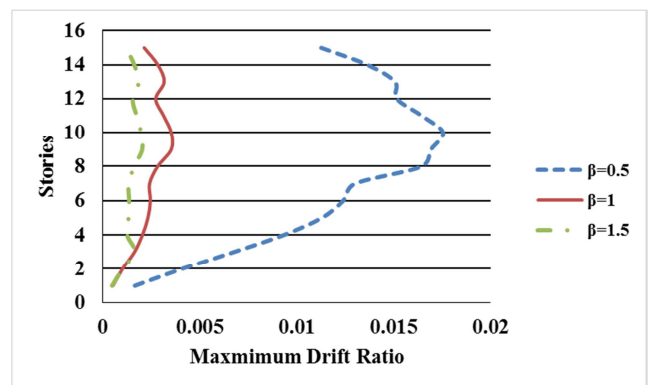


*Figure 7. Maximum drift of the 15 stories building.*

### 3.1.4. The Effect of Height

Figures 8 and 9 show the influence of the height of buildings on the value of the drift and displacement for the roof of the 5, 10 and 15 stories buildings in different values of β.
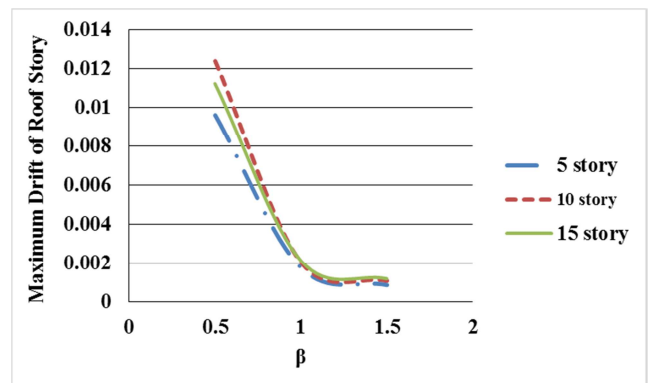


*Figure 8. Maximum drift of the highest story versus β.*

It is apparent from figure 8 that the changes at the highest

story for 5, 10 and 15 stories buildings between β = 1 to β = 1.5 is the same. It can be also concluded from this figure that by increasing the value of the β from 0.5 to 1.5 for 10 stories building, the maximum drift of the highest story has decreased by 92% and accordingly the stiffness and the energy absorption has increased.
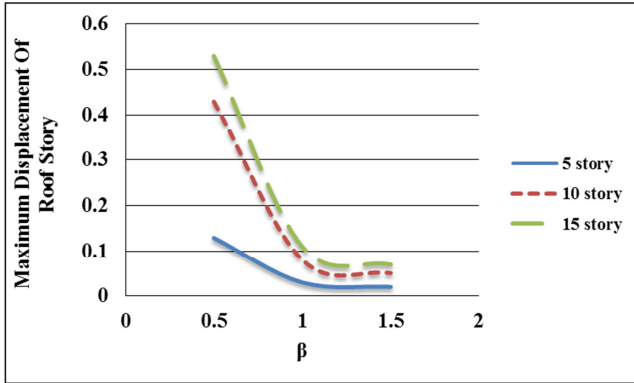


*Figure 9. Maximum lateral displacement of the highest story versus β.*

The lateral displacement of building is It is clear from the figure 9 that the displacements related to the 5 stories building is smaller than the other type of buildings. So that when β increases from 0.5 to 1.5 the decreasing of displacement at the highest story for 5, 10 and 15 stories buildings are 33%, 37% and 37%, respectively.

### 3.2. The Influence of the Ratio of the Column Width to Column Height (γ) on Maximum Drift

#### 3.2.1. Five Stories Building

Figure 10 reveals that maximum drift by increasing γ from 0.5 to 3 dramatically decreased. For each amount of γ the value of maximum drift in the third story is the highest level. Additionally, the distance between γ from 0.5 to 1 is much bigger than the distance between γ=1 to γ=3.
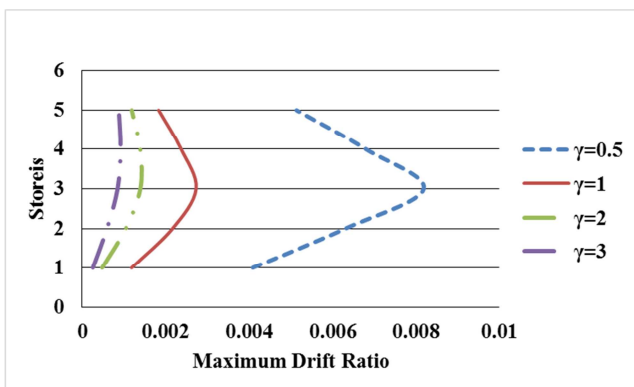


*Figure 10. Maximum drift of the 5 stories building.*

#### 3.2.2. Ten Stories Building

Figure 11 shows that maximum drift by increasing γ from 0.5 to 3 dramatically declined. The graphs are fluctuated but it can be seen that for each amount of γ the value of drift in the sixth story is maximum. Moreover, the distance between γ from 0.5 to 1 is much bigger than the distance between γ=1
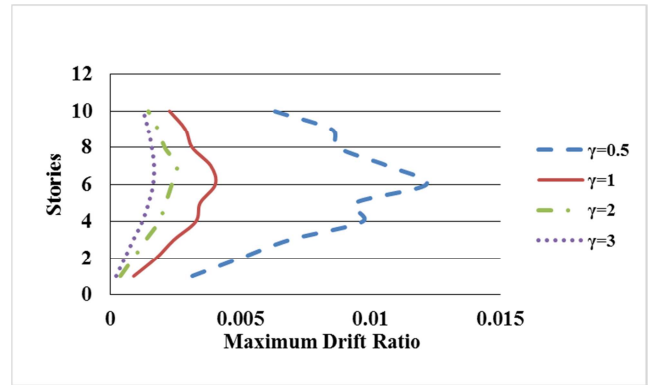
to γ=3.



*Figure 11. Maximum drift of the 10 stories building.*

### 3.2.3. Fifteen Stories Building

According to Figure 12, the maximum drift by increasing γ from 0.5 to 3 significantly decreased. The graphs are fluctuated. Moreover, the distance between γ from 0.5 to 1 is much bigger than the distance between γ=1 to γ=3.
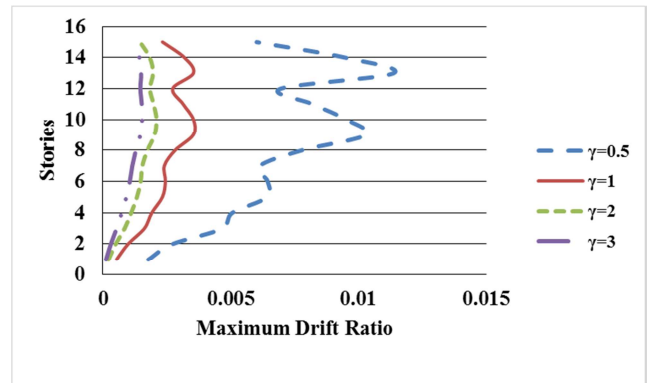


*Figure 12. Maximum drift of the 15 stories building.*

### 3.2.4. The Effect of Height

Figures 13 and 14 show the effect of the height of buildings on the value of the drift and displacement for the roof of the 5, 10 and 15 stories buildings in different values of γ.
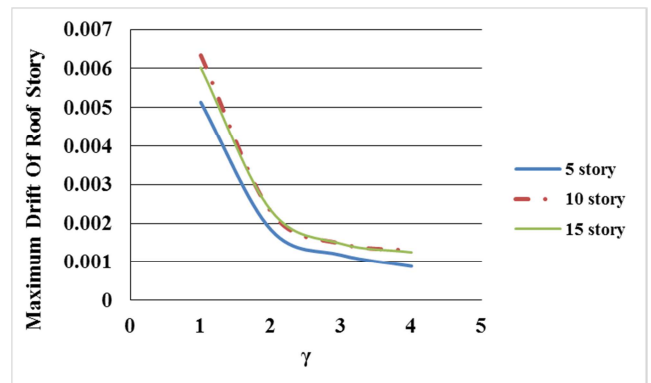


*Figure 13. Maximum drift of the highest story versus γ.*

It is apparent from figure 13 that the reduction of the

maximum drift at the higher story for 10 and 15 stories buildings is the same. It can be also concluded from this figure that by increasing the value of the $\gamma$ from 0.5 to 3, the maximum drift of the highest story has decreased by 79% and accordingly the stiffness and the energy absorption has increased.
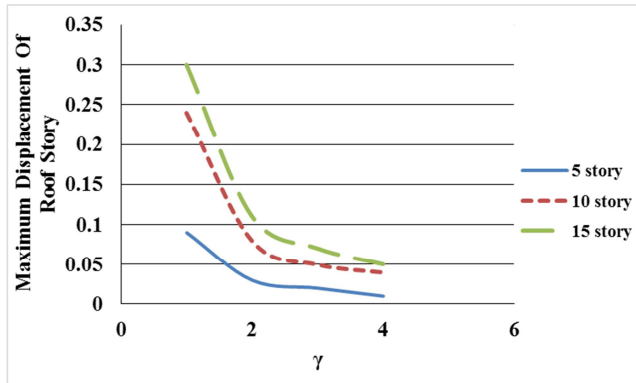


*Figure 14. Maximum lateral displacement of the highest story versus.*

It is apparent from the figure 14 that the displacements related to the 5 stories building is smaller than the other type of buildings. So that when $\gamma$ increases from 0.5 to 3 the reductions of the displacement at the highest story for 5, 10 and 15 stories buildings are 89%, 83% and 83%, respectively.

### 3.3. The Influence of the Ratio of the Column Width to Column Height ($\alpha$) on Maximum Drift

#### 3.3.1. Five Stories Building

Figure 15 shows the maximum displacement of stories for different values of $\alpha$. It can be seen that with increasing the value of $\alpha$ from 0.5 to 3, the value of the drift in stories has considerably decreased. But from $\alpha=2$ to $\alpha=3$ there is no change. Therefore it can be conclude that for value which are more than $\alpha=1.5$ there is no effect on maximum drift ratio.
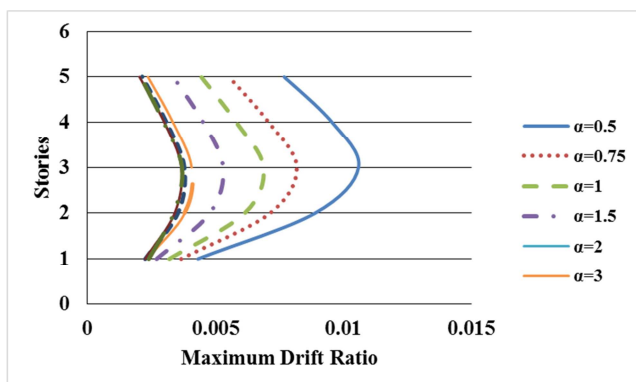


*Figure 15. Maximum drift of the 5 stories building.*

Table 1 shows the reduction of the displacements in the first, middle and last stories of the 5 stories building in different values of $\alpha$.

*Table 1. Reduction of the displacements in different values of $\alpha$.*

| A \ stories | 1 | 3 | 5 |
|---|---|---|---|
| ($\alpha= 0.5$) / ($\alpha=1$) | 2% | 29% | 33% |
| ($\alpha= 1$) / ($\alpha=3$) | 3% | 40% | 38% |

According to table 1, third story, as the middle story, has the most reduction of displacement equal to 40%, when $\alpha$ increased from 1 to 3.

#### 3.3.2. Ten Stories Building

Figure 16 shows the drift of stories for different values of $\alpha$.
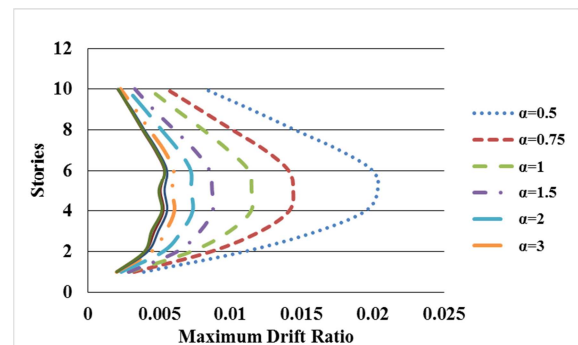


*Figure 16. Maximum drift of the 10 stories building.*

According to the figure 16 it is clear that by rising $\alpha$ from 0.5 to 3 maximum drift declined. Moreover, from $\alpha=2$ there is no effect in rising of $\alpha$.

Table 2 shows the reduction of the displacements in the first, middle and last stories of the 10 stories building in different values of $\alpha$.

*Table 2. Reduction of the displacements in different values of $\alpha$.*

| $\alpha$ \ stories | 1 | 3 | 5 |
|---|---|---|---|
| ($\alpha= 0.5$) / ($\alpha=1$) | 2% | 38% | 43% |
| ($\alpha= 1$) / ($\alpha=3$) | 3% | 46% | 46% |

According to table 2, third story as the middle story, has the most reduction of displacement equal to 46%, when $\alpha$ increased from 1 to 3.

#### 3.3.3. Fifteen Stories Building

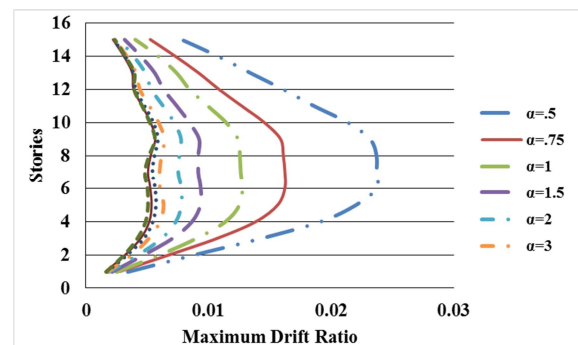Figure 17 shows the drift of stories for different values of $\alpha$.



*Figure 17. Maximum drift of the 15 stories building.*

Figure 17 shows reduction of drift against rise of α and it is clear that the gap between is huge (0.015) while for α=1 to α=1.5 the gap is about 0.003 which is too small respect to α=0.5 to α=1.

### 3.3.4. The Effect of Height

Figures 18 and 19 show the influence of the height on the value of the displacement and drift for the last story of the 5, 10 and 15 stories buildings in different values of α.
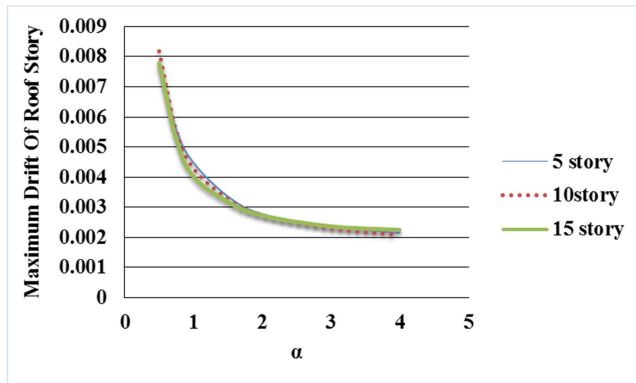


**Figure 18.** *Maximum drift of the highest story versus α.*

It is apparent from figure 18 that the changes of maximum drift at the higher story for 5, 10 and 15 stories buildings is the same. It can be also concluded from this figure that by increasing the value of α from 0.5 to 3, the maximum drift of the highest story has decreased by 70% and accordingly the stiffness and the energy absorption has increased.
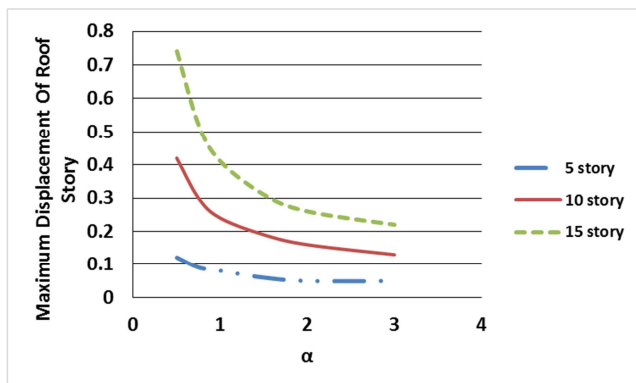


**Figure 19.** *Maximum displacement of the highest story versus α.*

It is apparent from the figure 19 that the displacements related to the 5 stories building is smaller than the other type of buildings. So that when α increases from 1 to 3 the reductions of the displacement at the highest story for 5, 10 and 15 stories buildings are 58%, 69% and 70%, respectively.

# 4. Conclusions

1. In all small, medium and tall buildings with increasing the ratio of height of beam to width of beam, drift ratio dramatically decreased. Furthermore, it can be concluded that by increasing of the ratio of height of beam to width of beam from 1 to 1.5 maximum drift ratio of the roof 92 percent decreased which it lead to rise of stiffness and energy absorption.

2. Declining of displacement of 5 stories building was the lowest compared with other buildings. For instance, the decreasing of displacement in the roof story was 33, 37 and 37 percent for the 5, 10 and 15 stories building respectively.

3. By rising the ratio of width of column to the height of column, the drift ratio in all small, medium and tall buildings significantly decreased.

4. Height of buildings has not significant effect in decreasing of drift ratio so that the graphs are related to 10 and 15 stories building are completely the same. Furthermore, it can be concluded that by increasing of the ratio of width of column to the height of column (γ) from 0.5 to 3, maximum drift ratio of the roof 79 percent decreased which it lead to rise of stiffness and energy absorption.

5. In all of small, medium and tall buildings with increasing the ratio of width of beam to width of column (α), maximum drift ratio dramatically declined.

6. In all three buildings it was revealed that the variation of decreasing of displacement in higher stories was more significant than lower stories.

7. The height of buildings has no effect in decreasing of drift ratio so that the all graph are completely the same. Furthermore, it can be concluded that by increasing the ratio of width of beam to width of column (α) from 1 to 3 maximum drift ratio of the roof 70 percent decreased which it lead to rise of stiffness and energy absorption.

8. For variation of the ratio of width of beam to width of column, the declining of displacement of 5 stories building was the lowest compared with other buildings. For instance, the decreasing of displacement in the roof story was 66, 71 and 74 percent for the 5, 10 and 15 stories building respectively.

9. Generally, other factors can also effect on decreasing of drift ratio of buildings such as the number and arrangement of reinforcements which is needed more investigation. Furthermore as the conclusions cited above in all kind of RC buildings by changing the geometric parameters of connections' elements can declined the lateral drift ratio.

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