

PASSIVE CONTROL OF STRUCTURES USING SLIDING ISOLATORS AT INTERMEDIATE FLOOR LEVELS

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Abstract

Base isolation or seismic isolation enables the reduction in earthquake forces by lengthening the natural time period of structure; hence it is significantly effective in low and mid-rise buildings with less than 10 stories. Taller building with height more than 10 storey already have larger time period and the effectiveness of base isolation is reduced. In this paper an attempt has made to study the feasibility of sliding isolation at intermediate floor levels. Two R.C.C. building 12 storey and 18 storey are analyzed by dividing each building into different segment and each segment is isolated with Friction Pendulum isolators. The response of structure with isolators at multiple floor levels are studied with 1940 El Centro, 1994 Northridge and 1995 Kobe time-history and responses are compared to the conventional fixed base structure and with structures isolated at base. Considerable reduction is observed in the building isolated at intermediate floor level.

Keywords: Base isolation, friction pendulum system, time history, segmental buildings.

1. INTRODUCTION

Base isolation has been recognized as one of the effective passive control technique to reduce the earthquake forces. Base isolation is the technique which decouples the building or structure from the horizontal components of the ground motion by interposing the structural element with low horizontal stiffness between structure and foundation [1]. Base isolation enables the reduction in earthquake forces by lengthening the time-period of structure. Base isolation is quite effective in buildings which have lower natural time-period i.e. generally buildings with height less than 10 stories. Buildings with more than 10 stories or 15 stories already have contained the larger time period and not needed to be isolated. Taller buildings are already flexible in nature and after application of base isolation flexibility increase much more. Hence it attracts less earthquake forces than stiff buildings. But in taller building there is enough deformation available which may lead to damage of structure and non-structure components of building, and therefore some technique must be used to control the structure. One technique may be concept of segmental building in which the building or structure is divided in different segment and each segment is isolated. In this paper attempt is made to investigate the feasibility of sliding isolation with friction pendulum at intermediate floor level. The 12 storey and 18 storey R.C.C. buildings are divided into different segment and isolated. Non-linear time history analysis is carried out for 1940 El Centro, 1994 Northridge and 1995 Kobe earthquake time history by using SAP 2000.

2. ANALYTICAL MODEL

RCC structures taken for the current study are 12 storey and 18 storey high. Following cases are studied to investigate the dynamic behavior of sliding isolators at intermediate floor levels.

(1) Fixed base structure (Case-A) (2) structure with all isolated at base (Case-B) (3) structure with isolators at two different levels, at base and at mid height of structure (Case-C) (4) structure with isolators at three different levels, at base and two other levels of 1/3 height (Case-D). location of isolators are shown in fig1 and fig2.

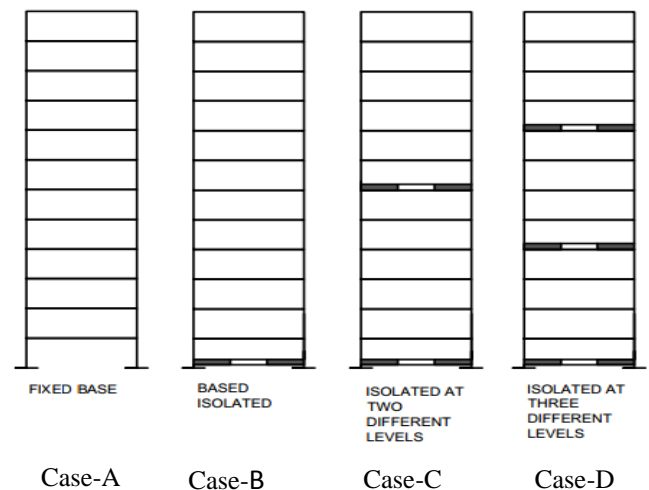


Fig1. Location of isolators for 12 storey building

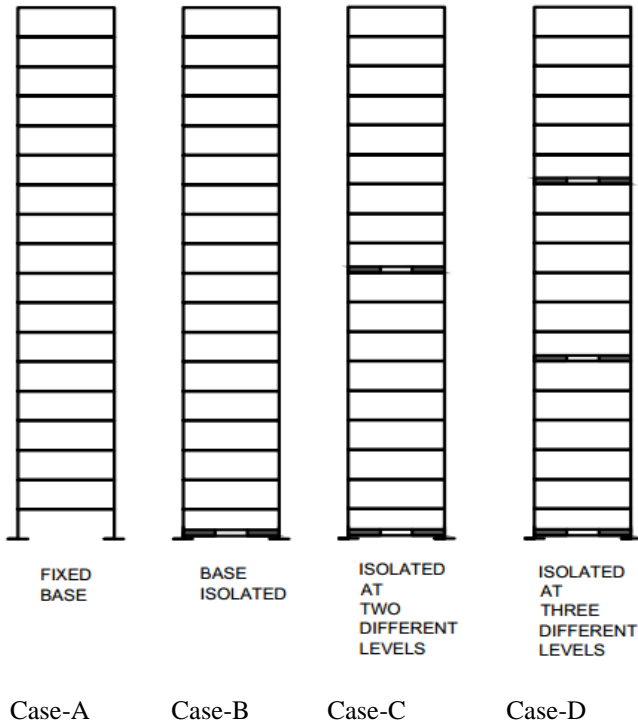


Fig2. Location of isolators for 18 storey building

2.1 Dimensions and Properties of Material

2.1.1 12-Storey Building

This building is reinforced concrete building consisting of 3 bays in both direction as shown in Figure, the plan of the building is 18m x18 m with storey height of 3m. Total height of the building is 36 m. The thickness of slab of each floor is 150 mm. The grade of concrete is M-30. The size of beams and columns are 0.45x 0.60 and 0.6x0.6 respectively.

2.1.2 12-storey Building

This building is reinforced concrete building consisting of 3 bays in both direction as shown in Figure, the plan of the building is 18m x18 m with storey height of 3m. Total height of the building is 54 m. The thickness of slab of each floor is 200 mm. The grade of concrete is M-30. The size of beams and columns are 0.8x 0.45 and 0.7x0.7 respectively.

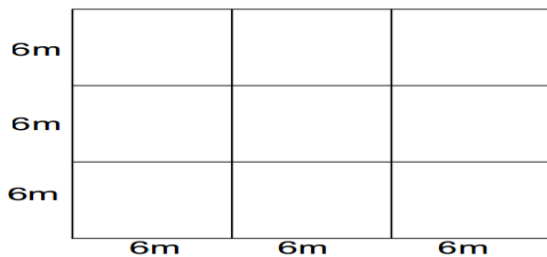


Fig3. Plan of 12 storey and 18 storey building

2.2 Time History

Table1. Time history

| Time history | Earthquake Magnitude | Distance (km) | PGA (cm/sec ²) | PGA (g's) |
|----------------------------------|----------------------|---------------|----------------------------|-----------|
| Imperial Valley, 1940, El Centro | 6.9 | 10.0 | 452.03 | 0.46 |
| 1994 Northridge | 6.7 | 7.5 | 851.62 | 0.87 |
| 1995 Kobe | 6.9 | 3.4 | 902.75 | 0.92 |

Source: SAC Steel Project | 1301 S. 46th Street | Richmond, CA 94804-4698 | <http://www.sacsteel.org/>

3. ANALYTICAL RESULTS

After non-linear time history analysis, following results are obtained.

3.1 Natural Time Period

Natural time period of 12-storey and 18-storey structure for first three modes with four different cases are shown in fig.it is observed that the time period of Case-D is highest for all modes as compared to the other Cases. It is due to the increase in number of isolators at multiple levels.

Table2. Natural Time period of 12-storey Structure (sec)

| | Case-A | Case-B | Case-C | Case-D |
|--------|--------|--------|--------|--------|
| Mode-1 | 1.36 | 3.45 | 4.52 | 5.45 |
| Mode-2 | 1.36 | 3.45 | 4.52 | 5.45 |
| Mode-3 | 1.15 | 2.98 | 3.93 | 4.75 |

Table3. Natural Time period of 18-storey Structure (sec)

| | Case-A | Case-B | Case-C | Case-D |
|--------|--------|--------|--------|--------|
| Mode-1 | 1.74 | 4.65 | 6.02 | 7.18 |
| Mode-2 | 1.74 | 4.65 | 6.02 | 7.18 |
| Mode-3 | 1.41 | 3.90 | 5.12 | 6.14 |

3.2 Storey Drifts

Considerable reduction in storey drift can be seen in structures isolated at multiple levels when compared to the structure isolated at base level. The maximum storey drift reduction with respect to fixed base structure in 12 storey is shown as 81.48% for Case-D in Kobe time history, and in 18-storey the maximum reduction is shown as 83.29% for Case-D in Northridge time history. It is observed that when isolators are

provided at multiple levels, there are considerable reductions in storey drift as compared to the fixed base structure as well as base isolated structures. The plots of storey drift for different cases and for different time history are shown in fig. to fig. Table 1 and Table 2 Shown the reduction in storey drift for different cases.

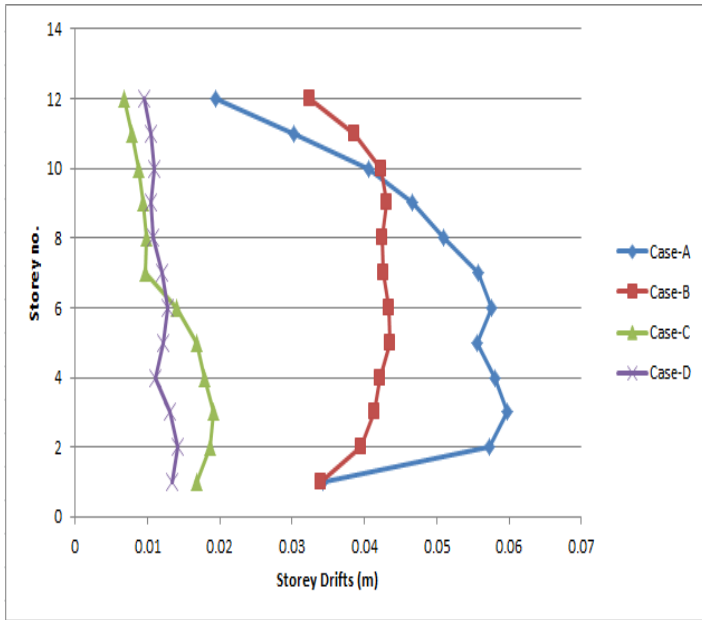


Fig4. Plot of storey drift for El Centro in 12 storey building

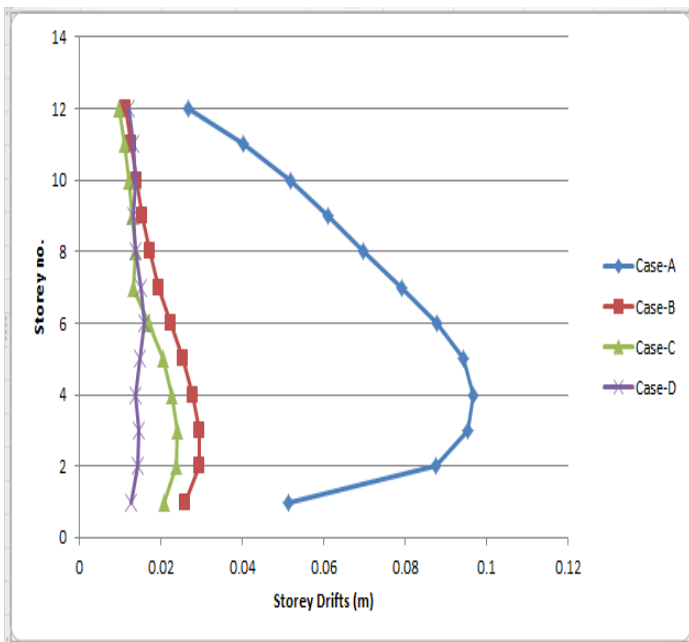


Fig5. Plot of storey drift for Northbridge in 12 storey

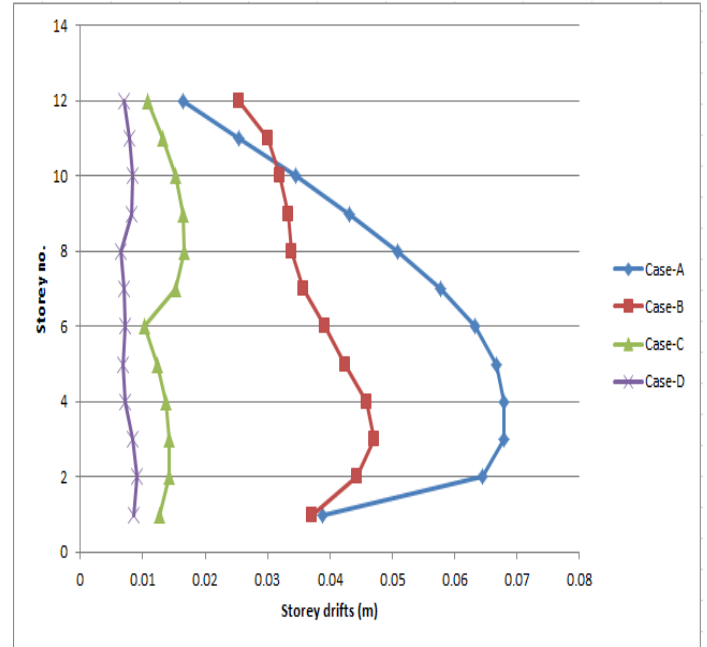


Fig6. Plot of storey drift for Kobe in 12 storey building

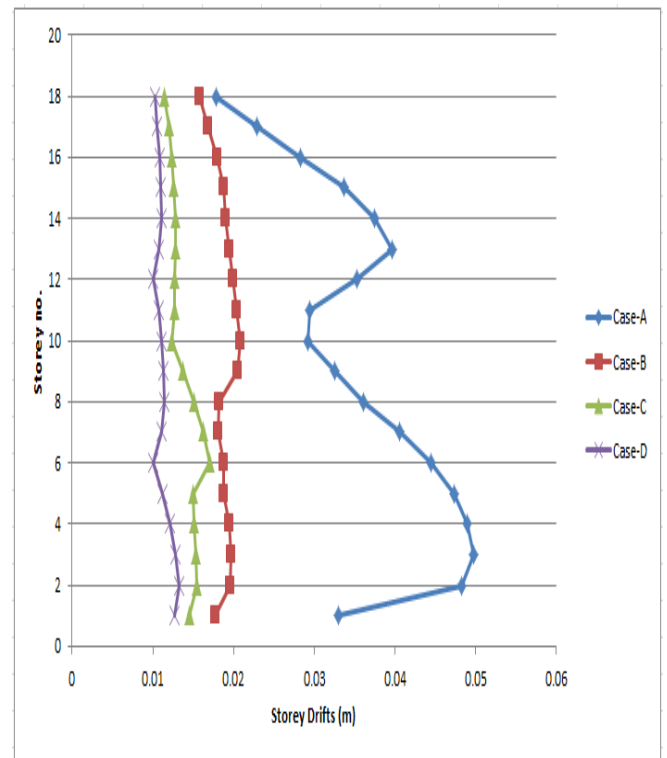


Fig7. Plot of storey drift for El Centro in 18 storey building

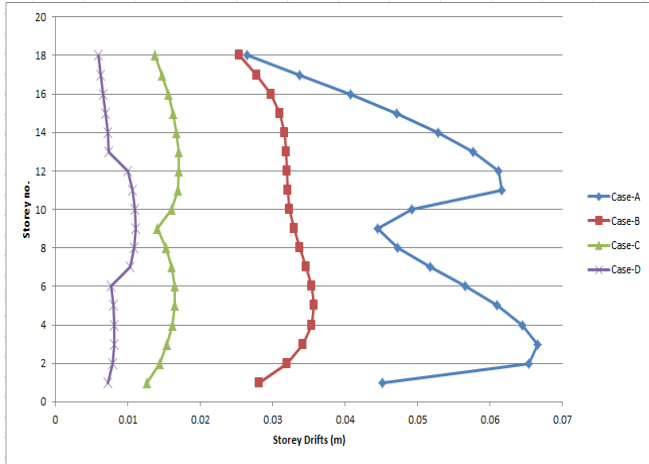


Fig8. Plot of storey drift for Northbridge in 18 storey building

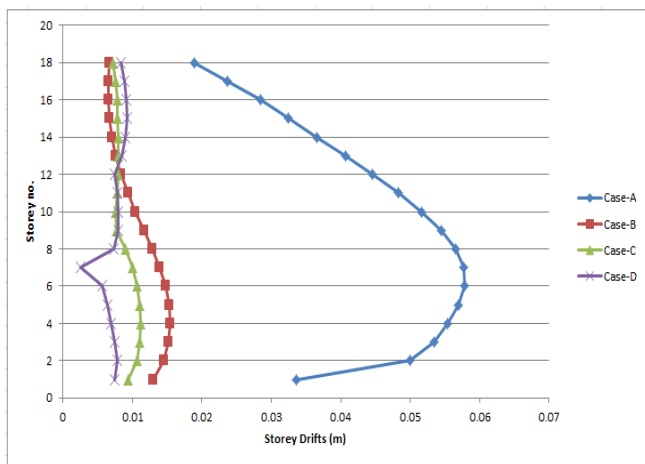


Fig9. Plot of storey drift for Kobe in 18 storey building

Table4. Reduction in Storey Drifts (%) w.r.t Case -A (Fixed Base)

| | Case-B | Case-C | Case-D |
|-------------|--------|--------|--------|
| El Centro | 7.19 | 71.84 | 73.02 |
| Northbridge | 69.10 | 74.94 | 77.69 |
| Kobe | 16.86 | 67.48 | 81.47 |

Table5. Reduction in Storey Drifts (%) w.r.t Case -A (Fixed Base)

| | Case-B | Case-C | Case-D |
|-------------|--------|--------|--------|
| El Centro | 44.93 | 60.16 | 67.15 |
| Northbridge | 35.98 | 68.58 | 83.28 |
| Kobe | 75.19 | 78.52 | 80.40 |

3.3 Acceleration

Acceleration of different cases are shown in fig. to fig. it is observed from the results that there are considerable reductions in acceleration as compared to the fixed base structure and structure isolated at base. The maximum reduction in acceleration in 12 storey structure as compared to fixed base is shown as 73.5% for Case-D in Northbridge time history and in 18 storey structure the maximum reduction is shown as 81.50% for Case-D in Kobe time history. The tabular comparisons of reductions in acceleration for different cases are shown in table and table.

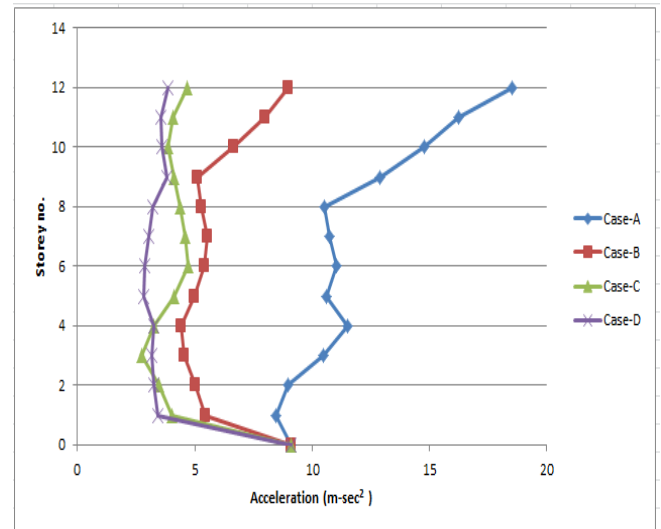


Fig10. Plot of Acceleration for El Centro in 12 storey building

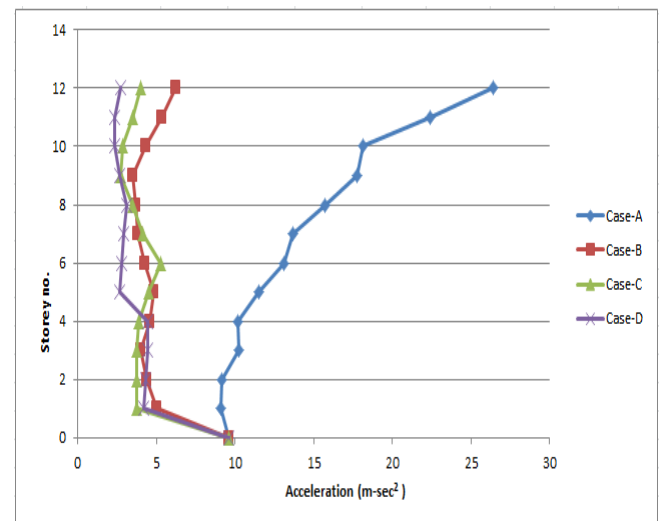


Fig11. Plot of Acceleration for Northbridge in 12 storey building

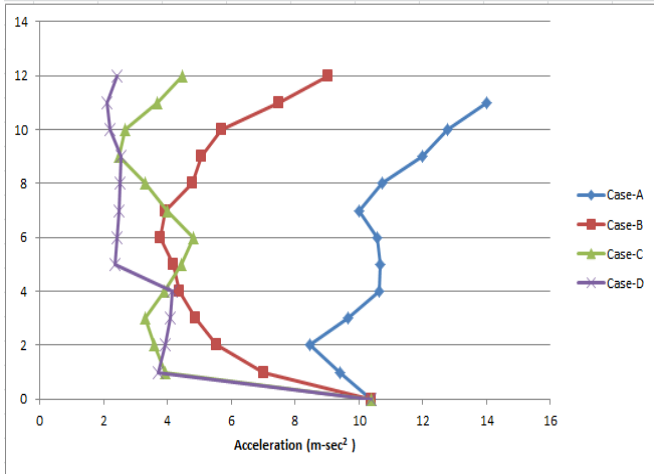


Fig12. Plot of Acceleration for Kobe in 12 storey building

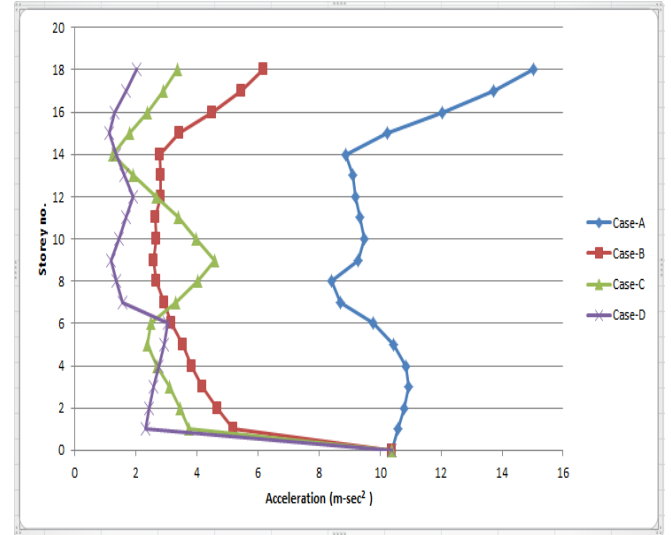


Fig15. Plot of Acceleration for Kobe in 18 storey building

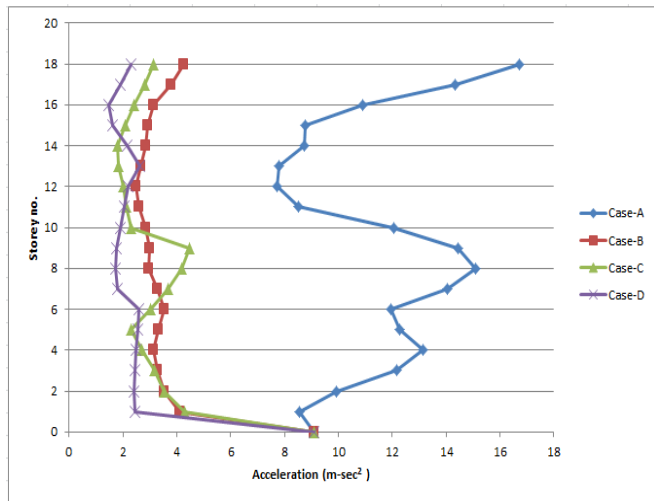


Fig13. Plot of Acceleration for El Centro in 18 storey building

Table6. Reduction in Acceleration (%) for 12-storey w.r.t. Case-A (Fixed base)

| | Case-B | Case-C | Case-D |
|-------------|--------|--------|--------|
| El Centro | 51.49 | 65.39 | 71.39 |
| Northbridge | 66.37 | 70.87 | 73.84 |
| Kobe | 50.97 | 65.87 | 72.52 |

Table7. Reduction in Acceleration (%) for 18-storey w.r.t. Case-A (Fixed base)

| | Case-B | Case-C | Case-D |
|-------------|--------|--------|--------|
| El Centro | 71.03 | 74.46 | 80.18 |
| Northbridge | 66.98 | 73.43 | 78.63 |
| Kobe | 65.29 | 70.77 | 81.50 |

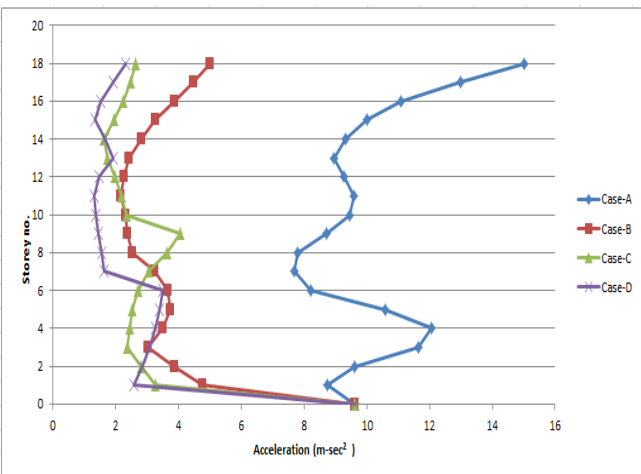


Fig14. Plot of Acceleration for Northbridge in 18 storey building

3.4 Base Shear

The base shear charts for different cases are shown in fig. to fig. the maximum reduction in base shear for 12 storey structure as compared to the fixed base is observed as 76.6% for Case-D in El Centro time history and for 18 storey structure the maximum reduction in base shear as compared to the fixed base is observed as 80.8% for Case-D in El Centro ground motion. Tabular comparison of reduction in maximum base shear as compared to the fixed base is shown in table and table.

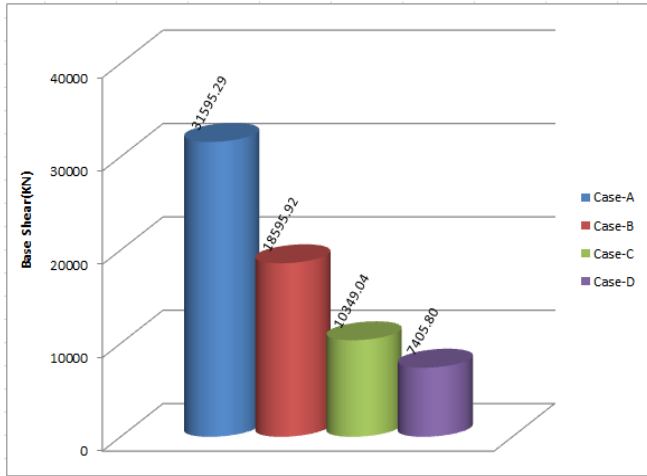


Fig16. Plot of Base shear for El Centro in 12 storey building

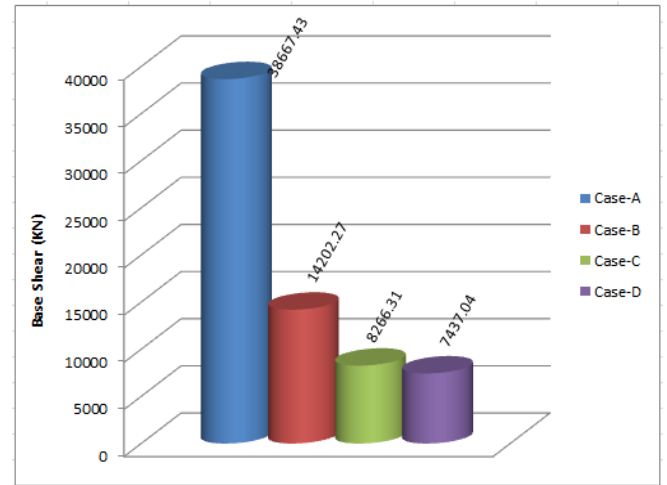


Fig19. Plot of Base shear for El Centro in 18 storey building

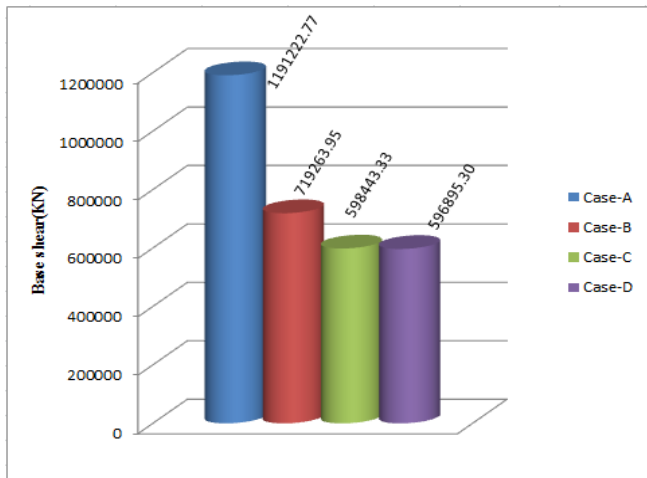


Fig17. Plot of Base shear for Northridge in 12 storey building

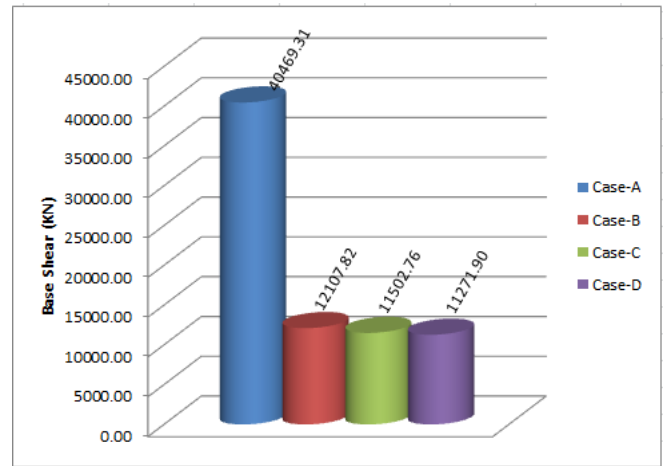


Fig20. Plot of Base shear for Northridge in 18 storey building

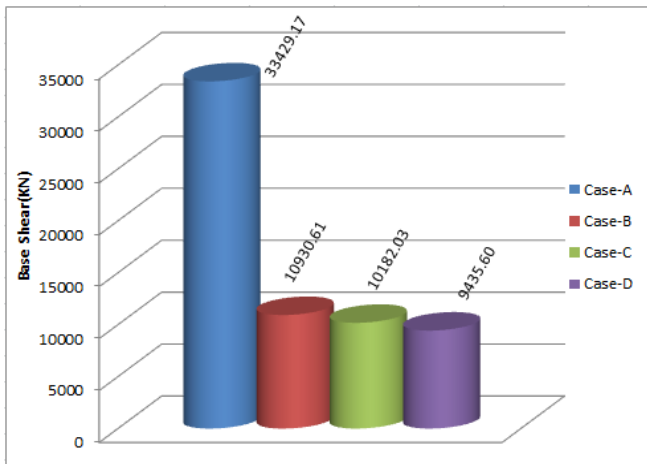


Fig18. Plot of Base shear for Kobe in 12 storey building

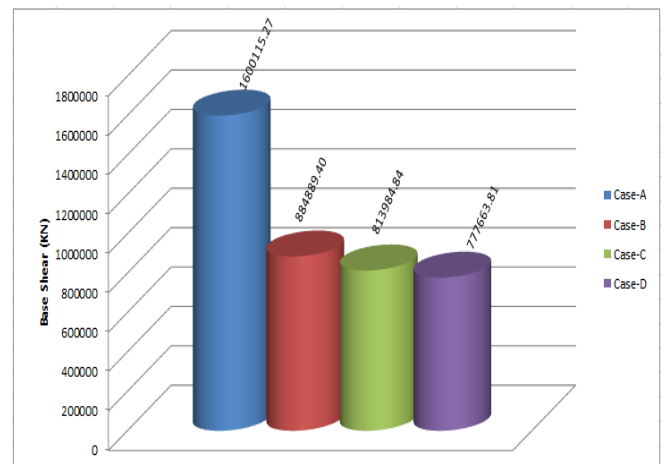


Fig21. Plot of Base shear for Kobe in 18 storey building

Table8. Reduction in Base Shear (%) for 12-storey w.r.t. Case-A (Fixed base)

| | Case-B | Case-C | Case-D |
|-------------|--------|--------|--------|
| El Centro | 41.14 | 67.24 | 76.56 |
| Northbridge | 67.78 | 71.20 | 72.23 |
| Kobe | 67.30 | 69.54 | 71.77 |

Table9. Reduction in Base Shear (%) for 18-storey w.r.t. Case-A (Fixed base)

| | Case-B | Case-C | Case-D |
|-------------|--------|--------|--------|
| El Centro | 63.27 | 78.62 | 80.77 |
| Northbridge | 70.08 | 71.58 | 72.15 |
| Kobe | 74.46 | 78.07 | 78.63 |

3.5 Overturning Moment

The considerable reduction in Overturning Moment can be seen for structures isolated at multiple levels as compared to the fixed base as well as isolated at base. The maximum reduction in Overturning Moment for 12 storey structure as compared to fixed base structure is shown as 49.9% in Case-D for Northbridge time history and for 18 storey structure the maximum reduction as compared to fixed base is shown as 55.5% in Case-D for Northbridge time history ground motion. The fig. to fig. are shown the charts for Overturning Moment for different Cases. Tabular comparisons for different cases in reduction in Overturning Moment are shown in Table and Table.

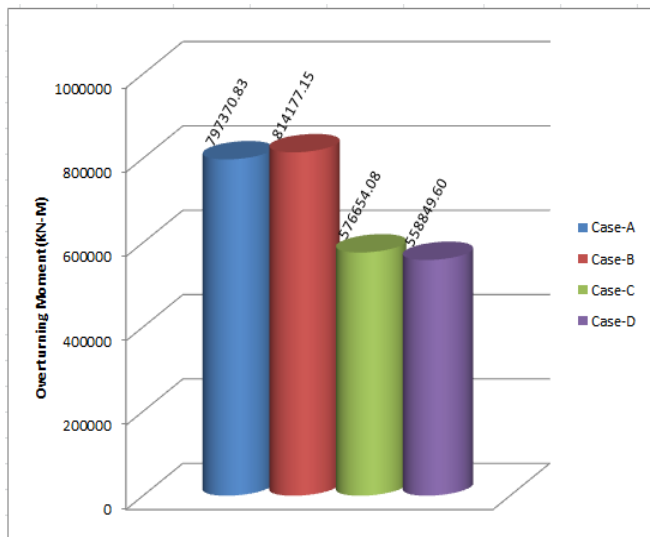


Fig22. Plot of Overturning Moment for El Centro in 12 storey building

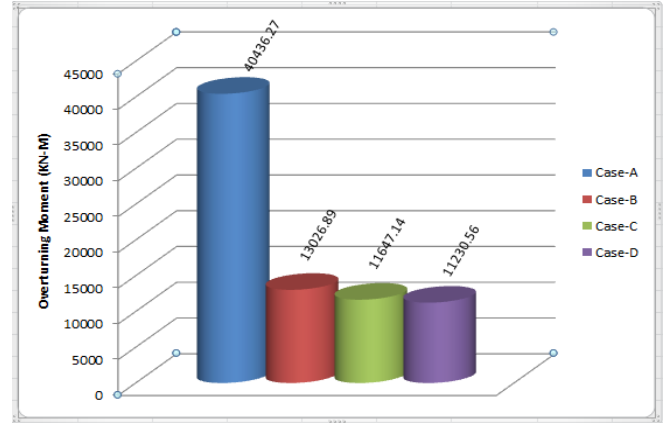


Fig23. Plot of Overturning Moment for Northbridge in 12 storey building

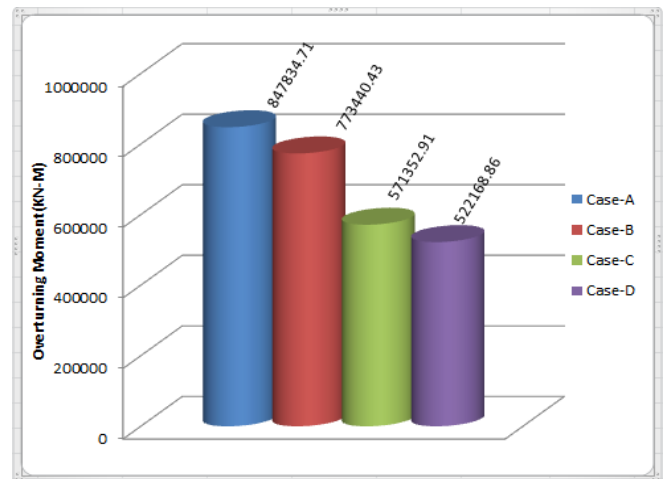


Fig24. Plot of Overturning Moment for Kobe in 12 storey building

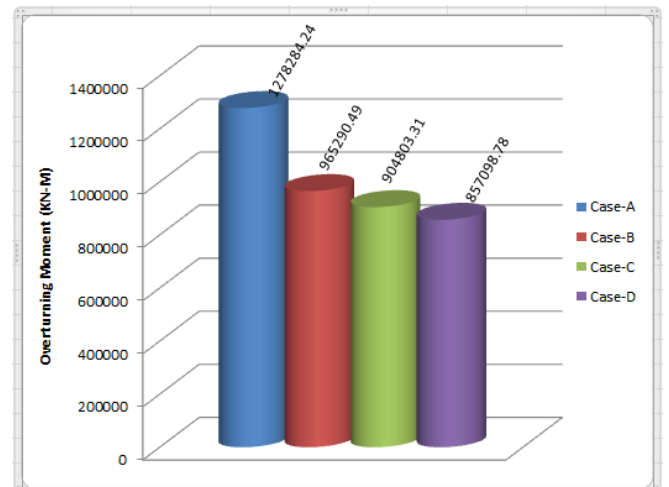


Fig25. Plot of Overturning Moment for El Centro in 18 storey building

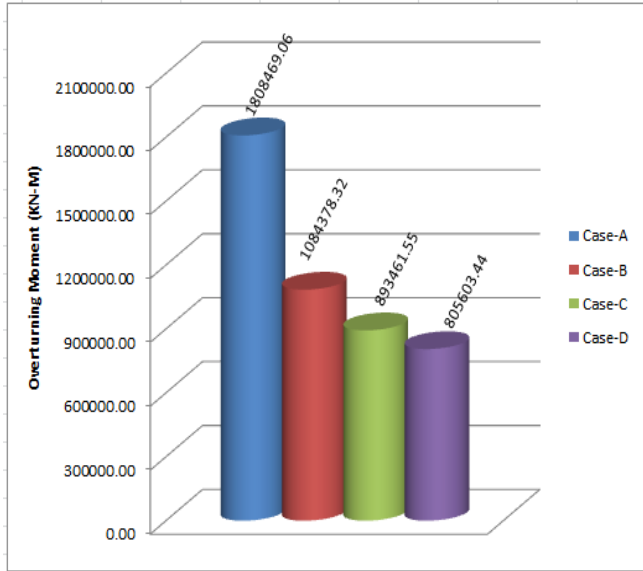


Fig26. Plot of Overturning Moment for Northbridge in 18 storey building

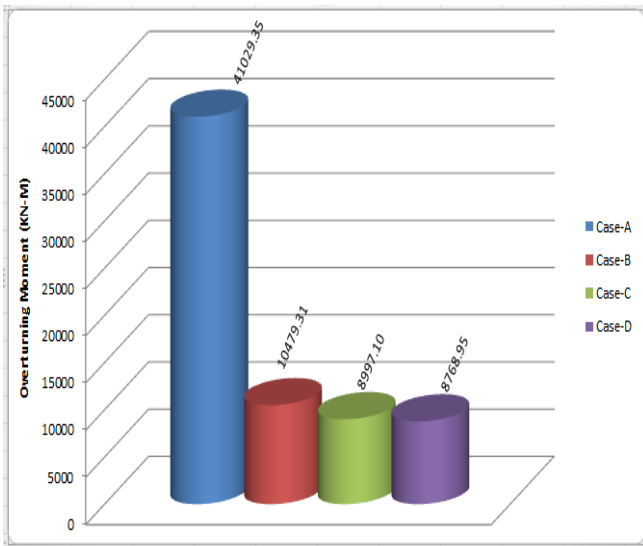


Fig27. Plot of Overturning Moment for Northbridge in 18 storey building

Table10. Overturning Moment (%) for 12-storey w.r.t. Case-A (Fixed base)

| | Case-B | Case-C | Case-D |
|-------------|--------|--------|--------|
| El Centro | -2.11 | 27.68 | 29.91 |
| Northbridge | 39.62 | 49.76 | 49.89 |
| Kobe | 8.77 | 32.61 | 38.41 |

Table11. Overturning Moment (%) for 18-storey w.r.t. Case-A (Fixed base)

| | Case-B | Case-C | Case-D |
|-------------|--------|--------|--------|
| El Centro | 24.49 | 29.22 | 32.95 |
| Northbridge | 40.04 | 50.60 | 55.45 |
| Kobe | 44.70 | 49.13 | 51.40 |

4. CONCLUSIONS

From the above analytical study following observations are noted

- (1). Increase in fundamental time periods from 1.36 sec to 4.5 sec is observed in 12 storey and 1.78 to 7.18 in Case-D.
- (2). For the 12-Storey building, maximum reduction in storey drift was observed in Case-D. The average reduction was observed to be 81.47% as compared to Case-A (fixed base) and 20.73% reduction as compared to Case-B. In 18-Storey building, the drift is reduced by 83.28% reduction in Case-D as compared to Case-A and 21.43% as compared to base isolated Case-B.
- (3). Maximum Reduction in base Shear was observed to be 76.56% and 80.77% in 12 and 18 storey respectively in Case-D as compared to fixed base system Case-A. Also the maximum reduction was observed to be 2.8 % and 13.86% as compared to base isolated Case-B for 12 and 18 storey structure respectively.
- (4). Maximum Reduction in Acceleration is 81.50% and 73.78% in 12 and 18 storey respectively in Case-D as compared to fixed base system Case-A. Maximum reduction was observed to be of 15.16% and 4.2% as compared to base isolated Case-B for 18 storey structure.
- (5). Maximum Reduction in over-turning moment is about 49.89% and 55.45% for 12 and 18 storey structure respectively in Case-D as compared to fixed base structure.

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BIOGRAPHIES



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