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# A Study on Changes in Certain Parameters that Influence Dynamic Behaviors, & their Impact on the Base Shear of a Building

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## ABSTRACT

*Structures on the earth are generally subjected to two types of load: Static load and Dynamic load. Static loads are unvarying with time while dynamic loads are time – varying. The majority of Civil Engineering structures are designed with the assumption that all applied loads are static in nature In the present work, the various aspects of dynamic analysis are considered. The main aim of this research is to study on changes in certain parameters that influence dynamic behaviors, and their impact on the base shear of a building.*
***Keywords: Earthquake, base shear, multistory building, dynamic behavior, mass and height etc.***

## NTRODUCTION

The behaviour of structure or building during an earthquake is basically a problem of vibration. The structure vibrates due to the seismic movement of the ground and causes structural deformity in the building. Several parameters regarding this deformity, like time period, frequency of vibration, and amplitude, are of considerable importance and define the overall response of the structure. These responses also depend on the distribution of seismic forces within the structure which further depends on the methodology which is used to calculate this distribution. Various methods of 3-dimensional dynamic analysis of structures have become more efficient in use along with the advancement of technology. The response spectrum analysis method for seismic analysis is one of them. which also can give more precise results than an equivalent static approach. The major advantage of using the lateral forces obtained from a dynamic analysis as the basis for a structural design is that The vertical distribution of lateral forces may be considerably different from the lateral forces obtained from an equivalent static load analysis. As a result, the use of dynamic analysis will produce structural designs that are more earthquake resistant than structures designed using static load analysis. [1]

## FACTORS GOVERNING DYNAMIC BEHAVIOUR

The factors that govern the dynamic behavior of a building are stated below [2]

### Effect of Mass and Height

The earthquake load acting on the buildings is called as lateral loads since their effect is observed mainly in the horizontal direction. This is in contrast to the weights of the building (and occupants) which act vertically downward due to gravity. The earthquake force is also called seismic force. These forces are induced in a building because of the heavy masses present at various floor levels. Such forces are called inertial forces. Inertial forces are calculated by the products of the accelerations and their respective masses. The accelerations, which are generated by the seismic waves in the ground, are transmitted through the vibrating structure to the masses at various floor levels, thereby producing the horizontal seismic forces. The building behaves like a vertical cantilever and horizontally swings like an inverted pendulum such that masses at higher levels swing more because of the cantilever action of the building; the forces accumulate from top to bottom. Total horizontal force acting on the ground-story columns is the sum of the seismic forces acting at all the levels above. This is defined as the base shear.

**Effect of Stiffness**

Under service loads, buildings are expected to behave elastically. Elasticity is that property by virtue of which a structure displaced by a load regains its original shape when unloading. Because of this property, those buildings that are pushed horizontally by mild earthquake loads regain their original vertical configuration after the vibration has passed. The deflection of the building under the given load is measured by a property called stiffness, which may be defined as the force required to produce unit deflection. The stiffer the building,the less it will deflect. The lateral stiffness and mass of the building contribute to another important structural property, termed as the natural period of vibration. The value of which governs the magnitude of seismic force that the building will attract.

**Effect of Ductility**

The capability of a structure to deform with damages & without sudden break down is termed as ductility. Due to ductility a building can continue to resist seismic forces without sudden collapse.

If the structural components in a building can "hold on" through ductile behaviour, without breaking during the short period of the major earthquake the building will not collapse. It may get damaged; such ductile buildings attract lesser load with increasing deformation. Dueto the earthquake, a considerable amount of the input energy in the building gets dissipated through the yielding of the ductile materials or else the entire input energy will to be stored as elastic strain energy. If the required ductility can be provided in the building, the design seismic force can be much lower (up to 21%) than that of in an elastic building.

**Effect of Layout and Configuration**

The building should have a simple plan and geometrical shape, like rectangular or circular. If the building is too long in one direction or too large in plan, it is possible to be damaged during earthquake. Buildings which have, 'U', 'H' 'V', 'L' or 'Y' shapes in plan are also undesirable attracting severe stresses at the interior corners called as re entrant corners. Buildings which are not symmetrical in plan are bound to twist under an earthquake,attracting further damages. If the complex geometries are utterly required, then it is desirable to break up the building plan into simple rectangular segments with proper separation joints such that they behave as individual units under an earthquake load.

**Effect of Soil**

The accelerations that occur in the rock layer of the crust during an earthquake get transmitted to the building through the soil strata over the rock layer. If the soil is relatively soft, the accelerations tend to get exaggerated, which results in the structure attracting higher seismic loads. In the presence of subsoil water, buildings located in loose granular soils have another severe and potential danger, which can occur during an earthquake. The granular soil will behave like quicksand through a phenomenon called liquefaction. Buildings that are located in those soils may sink or float and tilt extensively and collapse.

**Effect of Strength and Integrity**

The strength of every structural component is the magnitude of the maximum internal force such as bending moment or axial force or shear force, which can resist under a certain type of loading. When this strength is exceeded by the applied load, the material tends to fail (or collapse). The strength depends upon not only on the size of the cross section, but also on other factors, such as type of material. During an earthquake the load attracted by a structural component depends upon the lateral stiffness and mass of the building. If the building is designed not to "yield", and to behave in a ductile manner, it will be required to resist higher loads during an earthquake to avoid a sudden failure of a building. A structural component should be designed to have a strength which is not less than the maximum internal force, associated with ductility and with the overall seismic load on the building.

**METHODS OF DYNAMICANALYSIS**

Following are the methods of dynamic analysis.

**Time History Analysis**

It is an analysis of the dynamic response of the structure at each increment of time, when its base is subjected to a specific ground motion time history. Accelerograms at the ground surface are needed for input into the analyses. All accelerograms selected for the analyses must be compatible with the design earthquake scenario, the seismic-tectonic environment of the region, the geology of the area and geotechnical details in relation to the overlying soil particles of the sites. [13]

**Response Spectrum Analysis**

The representation of the maximum response of idealized single degree freedom system having certain period and damping, during different earthquake ground motions. Such a representation is called as a site response spectrum. A site response spectrum is a graph in which the maximum response values of displacements, acceleration, or relative velocity are plotted against un-damped natural period (and frequency) arid for various damping values. Site response spectra are very important tools in earthquake engineering. [9]

**OBJECTIVES**

Study of variation of certain parameters which affect dynamic behaviours (like Spectral acceleration coefficient, Zone factor, response reduction factor) and their effects on building response parameter (like base shear, peak storey shear, storey drift etc.) of the building being considered.

**INPUTPARAMETERS**

Following Parameters Are Considered In Analysis [16]

**Materials for the structure**

The materials for the building are specified as concrete with their various constants as per standard IS code of practice.

**Loading Details**

The loadings are calculated partially manually and rest was produced by STAAD Proload generator. The loading cases are considered as:

**Self-weight-** The self-weight of the structure is generated by STAAD.Pro itself with the self-weight command in the load case column.

**Dead load from slab-** Dead load from slab is also produced using STAAD Pro by specifying the thickness of the floor and the load on the floor per sq m. The Calculation of the load per sq m is done considering the weight of beam, weight of column, weight of walls, and weight of RCC slab.

**Live load-** The load applied to the framed building is of different intensities.

- Live load on roof is -1.50kN/$m^2$
- Live load as a floor load is of intensities-1kN/$m^2$,-2 kN/$m^2$,and-3kN/$m^2$
- Live load as a member load is ofmagnitude-10 kN/m, -13.20kN/m

The live loads are produced in a similar manner as done in the earlier case for dead load for each floor. This may be done from the member load button from the load case column.

**Seismic load-** The seismic load values are calculated as per IS 1893-2002. STAAD Pro has a seismic load generator in compliance with the IS code mentioned above. [16] The seismic load generator is used to produce lateral loads in the X and Z directions only. Y is the direction of gravity loads. This feature has not been developed for cases where the Z axis is set to be the vertical direction using the “SET Z UP” command.

## VARIATIONS OF INPUT PARAMETERS

For the building model, changes have been made in the values of response reduction factor, zone factor, and type of soil. Different values of response reduction factor may cover different types of structure, while different values of zone factor may cover different areas/seismic zones of the country. Different types of soil may be covered by considering hard/medium/soft soils. For a particular soil type (like hard soil or medium soil or soft soil), the changes have been made in response to the reduction factor for each zone. Then corresponding changes in output parameters are obtained.

For a particular zone (like Zone II or Zone III or Zone IV or Zone V), the changes have been made in soil type for each response reduction factor. Then corresponding changes in output parameters are obtained.

For a particular soil type (like hard soil or medium soil or soft soil), the changes have been made in the zone factor for each response reduction factor. Then the corresponding changes in output parameters are obtained.

## OUTPUT PARAMETERS

The following are the output parameters considered in the analysis:

### Modal Participation Factor ($P_k$)

Modal participation factor of mode k of vibration is the amount by which mode k contributes to the overall vibration of the structure under horizontal and vertical earthquake ground motions. Since the amplitudes of 95 percent mode shapes can be scaled arbitrarily, the value of this factor depends on the scaling used for mode shapes.

### Storey Drift

Drift is the lateral movement of a building under the influence of earthquake induced vibrations. It is the displacement of one level relative to the other level above or below. Drift as a limiting factor is important in order to ensure that exterior facades do not break off or crack excessively. When the two buildings or portions of buildings are isolated by a seismic joint, they must be separated by at least the sum of the drifts to avoid pounding during an earthquake.

### Design Seismic Base Shear

The total design lateral force or design seismic base shear ($V_B$) along any principal direction shall be determined by the following expression:

$$V_B = W*A_h$$

Where

$A_h$=Design horizontal acceleration spectrum value W = Seismic weight of the building

**Peak Storey Shear**

It is the Storey Shear Forces due to all modes considered is obtained by combining those due to each Mode.

**Frequency**

Natural Period $T_n$ of a building is the time taken by it to complete one cycle of oscillation. This property of a building is controlled by its mass m and stiffness k. These three quantities are related by

$$T_n = 2\pi\sqrt{\frac{m}{k}}$$

The reciprocal ($1/T_n$)of natural period of a building is called the Natural Frequency $f_n$; its unit is Hertz (Hz)

**VARIATIONS IN BUILDING RESPONSES**

The analysis consists of variation of displacements, base shear and peak storey shear with respect to response reduction factor at each zone for different types of soil. The displacements due to seismic forces at each floor is calculated in mm, peak storey shear at each floor is calculated in kN and base shear for each mode is calculated in kN.

Here R = 3 represents response reduction factor corresponds to ordinary moment resisting frame and R = 5 represents response reduction factor corresponds to special moment resisting frame.

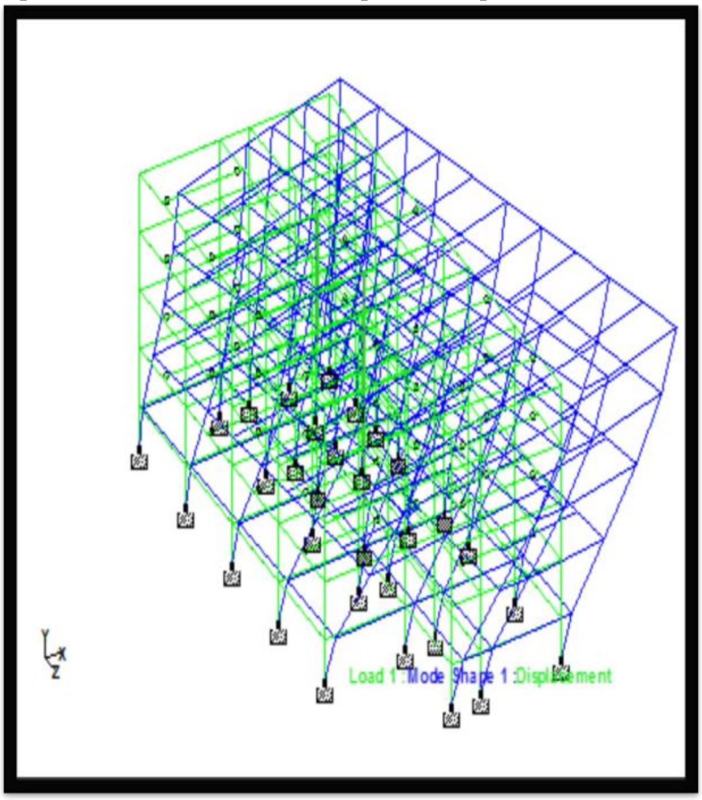


**Figure 1: Deflected shape of the building generated by STAAD Pro**

## ANALYSIS & DISCUSSIONS OF RESULTS

The base shear (x direction) in each mode for different response reduction factors are shown below. These base shears correspond to hard soil strata for various zone factors.

**Table 1: Base Shear corresponding to hard soil for R=3**

| Mode | Base Shear in kN (Zone II) | Base Shear in kN (Zone III) | Base Shear in kN (Zone IV) | Base Shear in kN (Zone V) |
|---|---|---|---|---|
| 1 | 580.59 | 928.83 | 1393.22 | 2089.84 |
| 2 | 180.91 | 289.53 | 434.37 | 651.49 |
| 3 | 53.51 | 85.73 | 128.67 | 192.87 |
| 4 | 159.71 | 255.60 | 383.46 | 575.17 |
| 5 | 29.91 | 47.96 | 71.97 | 107.97 |

**Table 2: Base Shear corresponding to hard soil for R=5**

| Mode | Base Shear in kN (Zone II) | Base Shear in kN (Zone III) | Base Shear in kN (Zone IV) | Base Shear in kN (Zone V) |
|---|---|---|---|---|
| 1 | 348.37 | 557.29 | 835.91 | 1253.99 |
| 2 | 108.51 | 173.72 | 260.55 | 390.89 |
| 3 | 32.11 | 51.48 | 77.19 | 115.77 |
| 4 | 95.88 | 153.36 | 230.09 | 345.09 |
| 5 | 17.91 | 28.77 | 43.19 | 64.79 |

**Table 3: Percentage variations in Base Shear for hard soil**

| Mode | % Variation in Base Shear | % Variation in Base Shear | % Variation in Base Shear | % Variation in Base Shear |
|---|---|---|---|---|
| | ZoneII | ZoneIII | ZoneIV | ZoneV |
| 1 | 39.991 | 40.000 | 40.001 | 40.007 |
| 2 | 40.009 | 39.999 | 39.997 | 40.006 |
| 3 | 39.991 | 39.998 | 40.007 | 39.996 |
| 4 | 40.005 | 40.000 | 40.008 | 40.008 |
| 5 | 40.002 | 40.013 | 40.001 | 40.009 |

The percentage change is calculated as change in base shear corresponds to R=3 and R=5with base shear corresponds to R=3 response reduction factor. The percentage variation of base shear in x direction with variation of R for different zones (Zone II, Zone III, Zone IV and Zone V) for hard soil has been plotted graphically as shown below

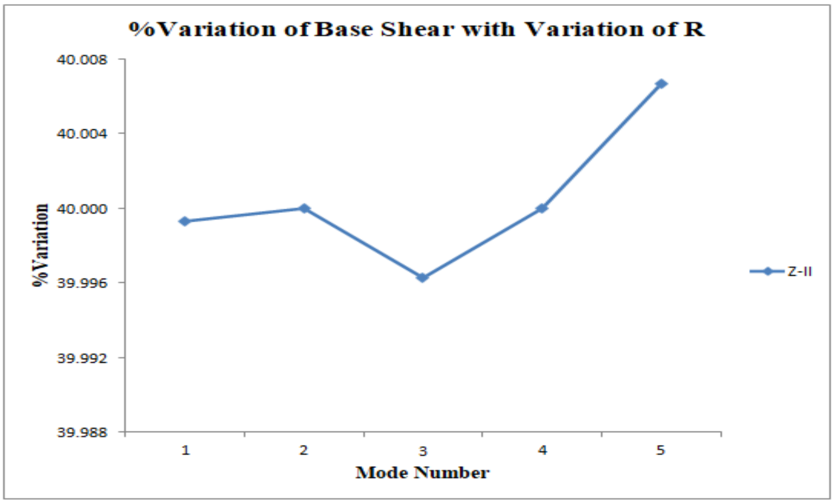


**Figure 2: Percentage variation of Base Shear for Zone II for hard soil**

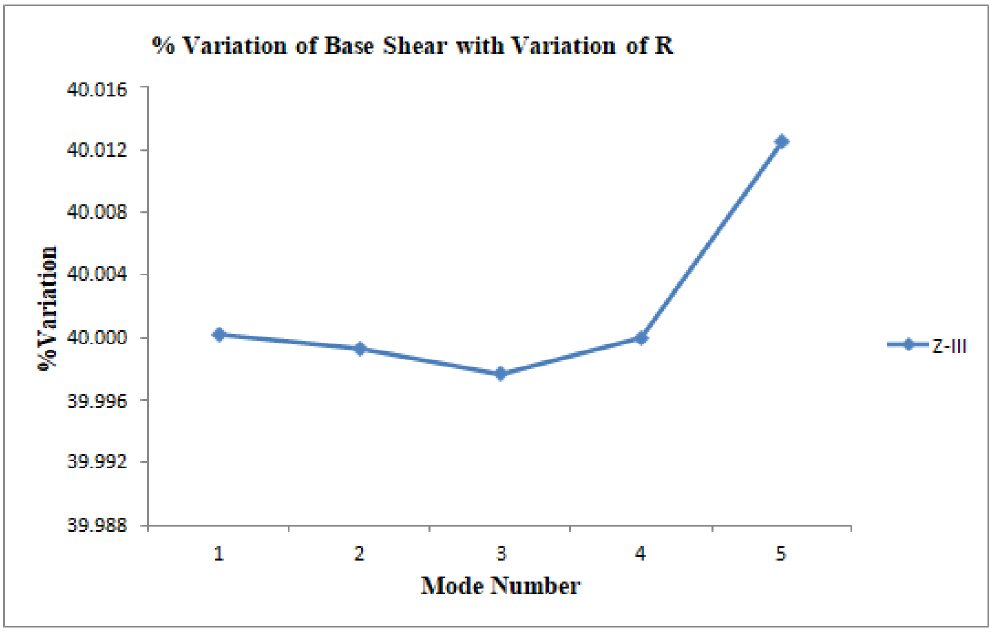


**Figure 3: Percentage variation of Base Shear for Zone III for hard soil**

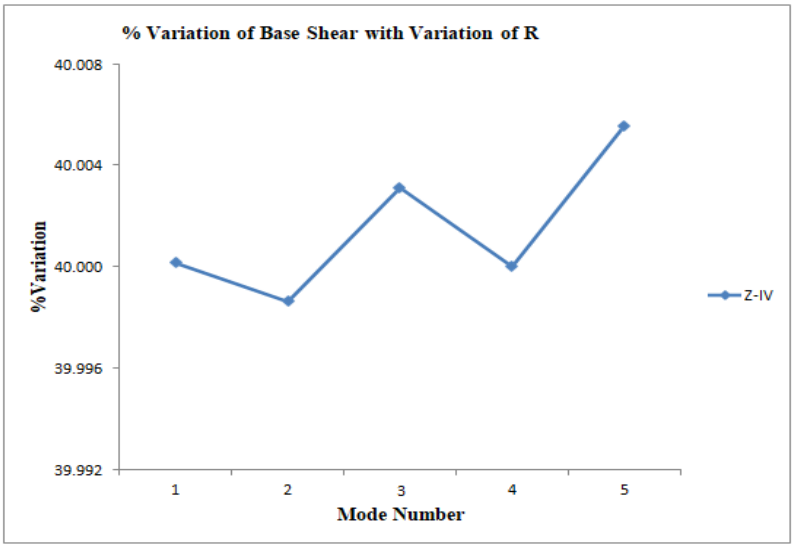


**Figure 4: Percentage variation of Base Shear for Zone IV for hard soil**

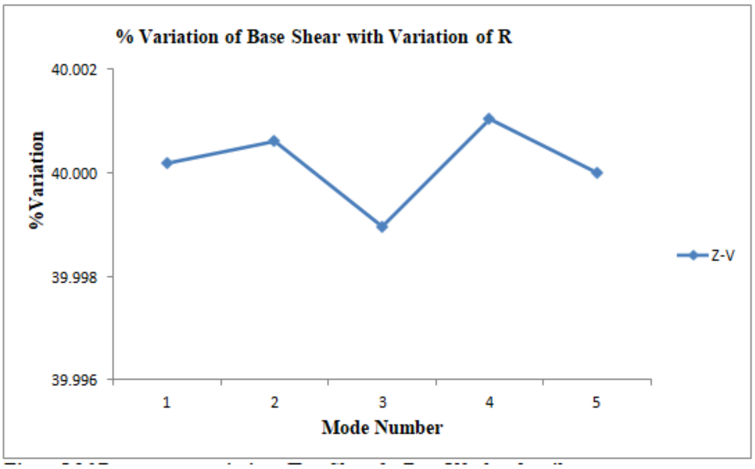


**Figure 5: Percentage variation of Base Shear for Zone V for hard soil**

The base shear (x direction) in each mode for different response reduction factors are shown below. These base shears correspond to medium soil strata for various zone factors.

**Table 4: Base Shear corresponding to medium soil for R=3**

| Mode | Base Shear in kN (Zone II) | Base Shear in kN (Zone III) | Base Shear in kN (Zone IV) | Base Shear in kN (Zone V) |
|---|---|---|---|---|
| 1 | 789.53 | 1263.19 | 1894.72 | 2842.11 |
| 2 | 246.14 | 393.77 | 590.69 | 885.91 |
| 3 | 72.82 | 116.59 | 174.82 | 262.39 |
| 4 | 159.72 | 255.60 | 383.47 | 575.19 |
| 5 | 29.92 | 47.96 | 71.92 | 107.95 |

**Table 5: Base Shear corresponding to medium soil for R=5**

| Mode | Base Shear in kN (Zone II) | Base Shear in kN (Zone III) | Base Shear in kN (Zone IV) | Base Shear in kN (Zone V) |
|---|---|---|---|---|
| 1 | 473.79 | 757.93 | 1136.81 | 1705.39 |
| 2 | 147.61 | 236.25 | 354.31 | 531.51 |
| 3 | 43.79 | 69.95 | 104.91 | 157.31 |
| 4 | 95.89 | 153.36 | 230.09 | 345.09 |
| 5 | 17.91 | 28.77 | 43.11 | 64.79 |

**Table 6: Percentage variations in Base Shear for medium soil**

| Mode | %Variation in Base Shear | %Variation in Base Shear | % Variation in Base Shear | % Variation in Base Shear |
|---|---|---|---|---|
| | ZoneII | ZoneIII | ZoneIV | ZoneV |
| 1 | 39.991 | 40.000 | 40.009 | 40.009 |
| 2 | 40.009 | 40.002 | 40.009 | 40.009 |
| 3 | 40.009 | 40.003 | 39.991 | 40.009 |
| 4 | 40.009 | 40.000 | 40.009 | 40.009 |
| 5 | 40.001 | 40.013 | 40.001 | 40.005 |

The percentage change is calculated as change in base shear corresponds to R=3 and R=5with base shear corresponds to R=3 response reduction factor. The percentage variation of base shear in x direction with variation of R for different zones (Zone II, Zone III, Zone IV and Zone V) for medium soil has been plotted graphically as shown below

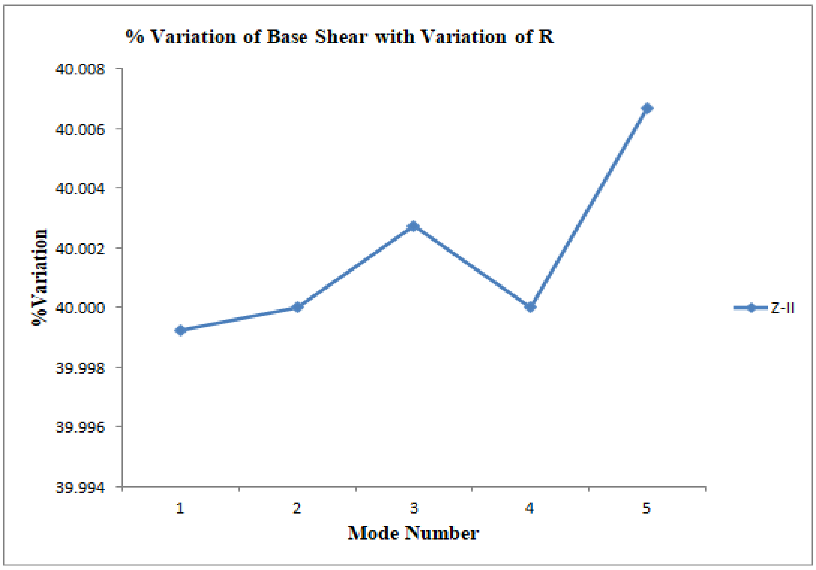


**Figure 6: Percentage variation of Base Shear for Zone II for medium soil**

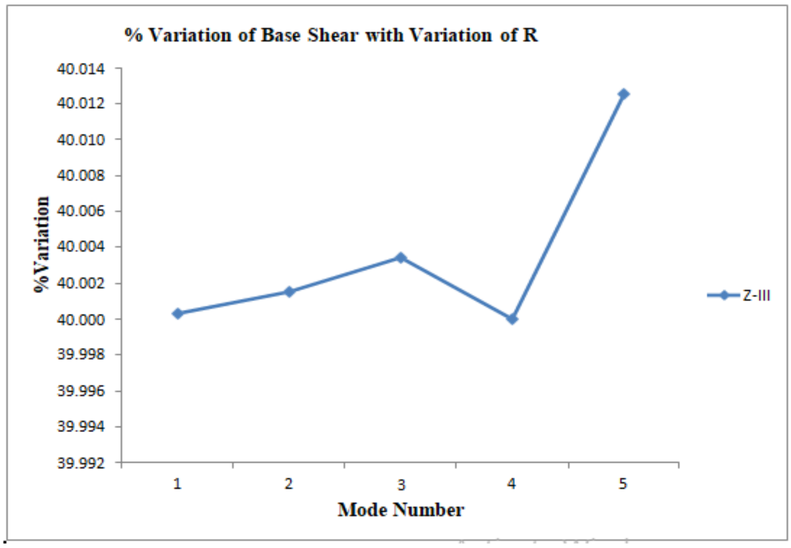


**Figure 7: Percentage variation of Base Shear for Zone III for medium soil**

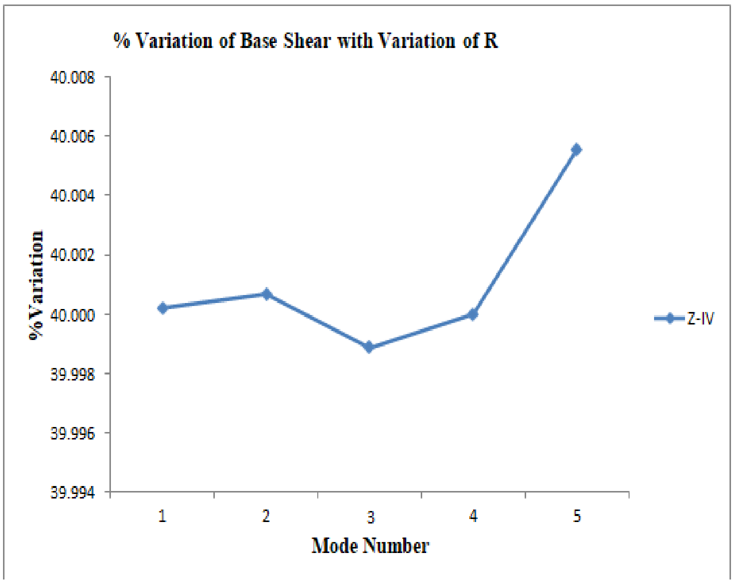


**Figure 8: Percentage variation of Base Shear for Zone IV for medium soil**

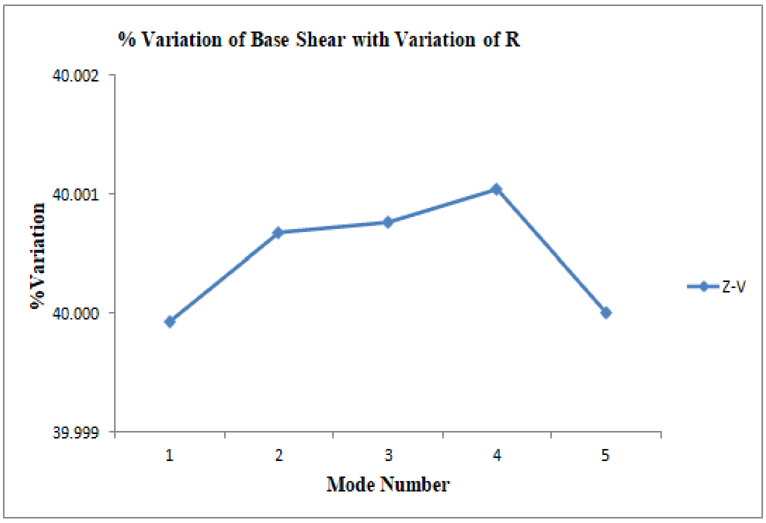


**Figure 9: Percentage variation of Base Shear for Zone V for medium soil**

The base shear (x direction) in each mode for different response reduction factors are shown below. These base shears correspond to soft soil strata for various zone factors.

**Table 7: Base Shear corresponding to soft soil for R=3**

| Mode | Base Shear in kN (Zone II) | Base Shear in kN (Zone III) | Base Shear in kN (Zone IV) | Base Shear in kN (Zone V) |
|---|---|---|---|---|
| 1 | 969.47 | 1551.15 | 2326.14 | 3490.65 |
| 2 | 302.85 | 483.56 | 725.25 | 1087.98 |
| 3 | 89.96 | 143.17 | 214.36 | 322.32 |
| 4 | 159.41 | 255.62 | 383.47 | 575.12 |
| 5 | 29.52 | 47.97 | 71.58 | 107.45 |

**Table 8: Base Shear corresponding to soft soil for R=5**

| Mode | Base Shear in kN (Zone II) | Base Shear in kN (Zone III) | Base Shear in kN (Zone IV) | Base Shear in kN (Zone V) |
|---|---|---|---|---|
| 1 | 581.78 | 930.68 | 1396.25 | 2094.78 |
| 2 | 181.89 | 290.12 | 435.14 | 652.45 |
| 3 | 53.45 | 85.91 | 128.36 | 193.25 |
| 4 | 95.56 | 153.37 | 230.85 | 345.14 |
| 5 | 17.12 | 28.78 | 43.74 | 64.65 |

**Table 9: Percentage variations in Base Shear for soft soil**

| Mode | % Variation in Base Shear | % Variation in Base Shear | % Variation in Base Shear | % Variation in Base Shear |
|---|---|---|---|---|
| | ZoneII | ZoneIII | ZoneIV | ZoneV |
| 1 | 40.032 | 40.068 | 40.035 | 40.031 |
| 2 | 39.956 | 39.991 | 40.015 | 40.021 |
| 3 | 39.985 | 39.991 | 39.975 | 40.011 |
| 4 | 40.075 | 40.068 | 40.095 | 40.041 |
| 5 | 40.098 | 40.011 | 40.025 | 40.089 |

The percentage change is calculated as change in base shear corresponds to R=3 and R=5with base shear corresponds to R=3 response reduction factor. The percentage variation of base shear in x direction with variation of R for different zones (Zone II, Zone III, Zone IV and Zone V) for soft soil has been plotted graphically as shown below

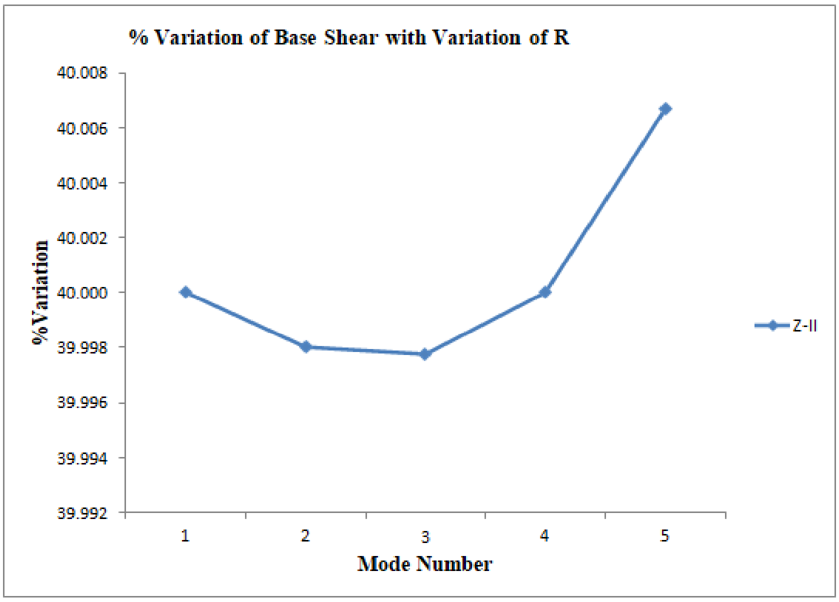


**Figure 10: Percentage variation of Base Shear for Zone IIf or soft soil**

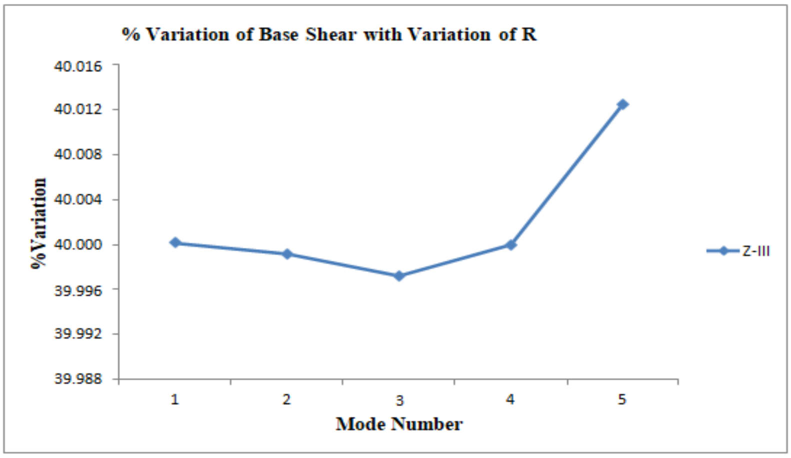


**Figure 11: Percentage variation of Base Shear for Zone III for soft soil**

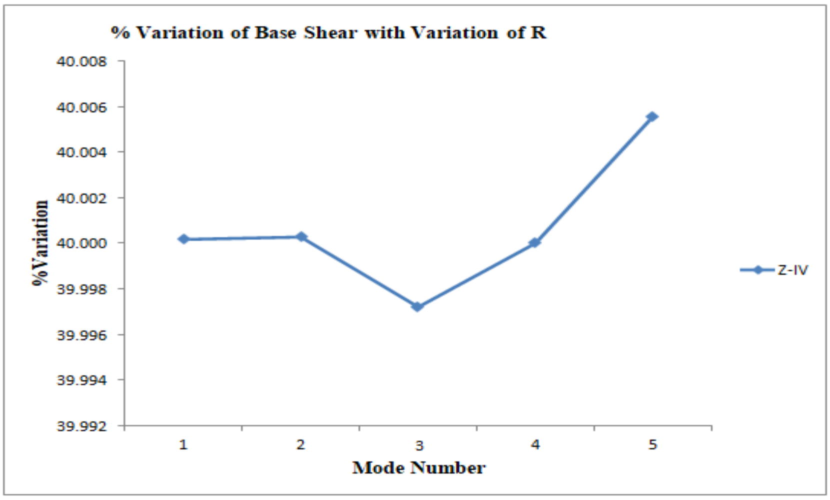


**Figure 12: Percentage variation of Base Shear for Zone IV for soft soil**

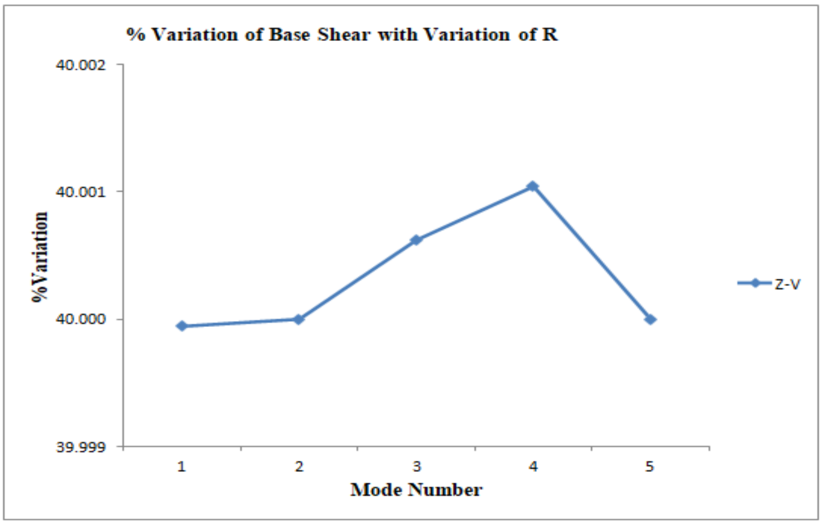


**Figure 13: Percentage variation of Base Shear for Zone V for soft soil**

## CONCLUSION

For Mode number 1, 2 & 3, almost 26-27% reduction in Base shear is achieved on constructing building on hard soil in place of medium soil while 18-19% reduction is achieved on constructing building on medium soil in place of soft soil irrespective of the building type but for mode number 4 & above, there is no change in base shear. The comparison of building responses between irregular buildings with regular one could be done for various response reduction factors, zone factor and soil strata. Multi storeyed building can also be analysed by time history method or by pushover analysis. Dynamic analysis of soft storey building could also be done and comparison of building responses could be done with that of an ordinary building.

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