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Evaluation of Seismic Performance of Building Resting on Plain and Sloping Ground Under Seismic Load

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Abstract--- The Greatest challenge for the structural Engineers in today's scenario is constructing the seismic resistant structures. Structures are generally constructed on the level ground; but due to scarcity of level grounds the constructions have been started on the sloping grounds. The behaviour of the buildings during earthquake depends upon the distribution of mass and stiffness. The buildings constructed on sloping ground are subjected to severe earthquake and are more prone to destruction. A study has been carried out by static and dynamic analysis on the building resting on a plain ground, set back building on plain ground, step back and set back resting on sloping ground and step back building on sloping ground. In the present study, Time history analysis for Bhuj, Nepal and Sumatra earthquakes is carried out by considering parameters such as Base Shear, Roof displacement, Torsional moment in beam, Axial force and moments for column. Earthquakes are applied at various angles to the buildings and most severe analysis is studied for each case.

Keywords – Dynamic analysis, Time history, Sloping grounds, Base shear, Static analysis

I. INTRODUCTION

An earthquake is what happens when two blocks of the earth suddenly slip past one another. The surface where they slip is called the fault or fault plane. The location below the earth's surface where the earthquake starts is called the hypocenter, and the location directly above it on the surface of the earth is called the epicenter. Sometimes an earthquake has foreshocks. These are smaller earthquakes that happen in the same place as the larger earthquake that follows. Scientists can't tell that an earthquake is a foreshock until the larger earthquake happens. The largest, main earthquake is called the mainshock. Mainshocks always have aftershocks that follow. These are smaller earthquakes that occur afterwards in the same place as the mainshock. Depending on the size of the mainshock, aftershocks can continue for weeks, months, and even years after the mainshock.

1.1 Four Virtue of Earthquake Resistant Building

A. At least smallest amount of Lateral strength in each of its plan direction to resist small intensity ground shaking with no damage, and not too strong to keep cost of construction in check, along with a minimum vertical strength to be able to continue to support the gravity weight.
B. At smallest amount minimum Lateral stiffness in each of its plan direction to resist so there is no distress to occupants of a buildings and no damage to contents of the building.
C. Good ductility in it to put up the imposed lateral deformation between the base and the roof of the building.
D. Good seismic configurations, with no choice of architectural form of the building that is harmful to better earthquake performance and that does not introduce newer complexity in the building performance than what the earthquake is already striking.

II. LITERATURE REVIEW

Extensive literature study has been carried out from national and international journals. These literatures are classified as journals, documents collected from web etc.

2.1 Lateral Stability of Multistorey Building on Sloping Ground" by Nagarjuna, Shivakumar B. Patil et al (2015)

In this literature, G+ 10 storeys RCC building and the ground slope varying from 10^0 to 40^0 have been considered for the analysis. A comparison has been made with the building resting on level ground (setback). ETABS is used to study the effect of varying height of the column in bottom storey and the effect of shear wall at different position during the earthquake.

2.2 Effect of Vertical Irregularity in RC Framed Buildings in Severe Seismic Zone by S Monish et al (2015)

This literature is based on study the effect of Seismic Performance of the buildings vertical Geometric irregularity and stiffness Irregularity with sloping ground. Different irregular models are considered as per mentioned irregularity in ETABS. From this study, the model that is most vulnerable to earthquake under severe seismic zone is found

2.3 Seismic Analysis of R.C.C. Building Resting on Sloping Ground" byDr. S. K. Deshmukh, Farooq et al (2015)
It has been studied that the earthquake actions are prone in hilly areas. Constructions in seismically prone areas make them exposed to greater shears and torsion. Buildings in hilly regions have experienced high degree of damage leading to collapse though they have been designed for safety of the occupants against natural hazards.

III. DESIGN METHODOLOGY

Four different types of buildings are considered in this work. Building with asymmetric plan resting on plain ground. Set back building with asymmetric plan resting on plain ground. Step back building re with asymmetric resting on sloping ground. Set back and Step back building with asymmetric plan resting on sloping ground are prepared in Sap-2000. Size of column is 450 mm X 450 mm, size of beam is 300 mm X 500mm and slab thickness is 115 mm. Slab is also loaded with floor finish of 1.5 KN/m^2. Live load on the floor slab is 3 KN/m^2 Materials are also kept constant for all building models. The above buildings are analyzed by Static, Response spectrum and Time history methods.

3.1 Static Analysis

Every design against earthquake effects must consider the dynamic nature of the load. However, for simple regular structures, analysis by equivalent linear static methods is often adequate. This is permitted in most codes of practice for regular, low- to medium-rise buildings and begins with an estimate of peak earthquake load calculated as a function of the parameters given in the code. Equivalent static analysis can, therefore, work well for low- to medium-rise buildings without significant coupled lateral–torsional modes, in which only the first mode in each direction is of significance. Tall buildings (over, say, 75 m), where second and higher modes can be important, or buildings with torsional effects, are much less suitable for the method, and both Euro code 8 and IBC require more complex methods to be used in these circumstances. However, it may still be useful, even here, as a 'sanity check' on later results using more sophisticated techniques given in the code.

3.2 Response Spectrum Analysis

By the means powerful desktop computers, this type of analysis has become the norm. It involves calculating the principal elastic modes of vibration of a structure. The maximum responses in each mode are then calculated from a response spectrum and these are summed by appropriate methods to produce the overall maximum response. The major advantages of using Response Spectrum analysis are listed below:-

- The size of the problem is reduced to finding only the maximum response of a limited number of modes of the structure, rather than calculating the entire time history of responses during the earthquake. This makes the problem much more tractable in terms both of processing time and (equally significant) size of computer output.
- Examination of the mode shapes and periods of a structure gives the designer a good feel for its dynamic response.
- The use of smoothed envelope spectra makes the analysis independent of the characteristics of a particular earthquake record.
- Response Spectrum Analysis can very often be useful as a preliminary analysis, to check the reasonableness of results produced by linear and non-linear time-history analyses.

Data which is used for the Response Spectrum analysis are used from IS: 1893-2016.

a) Zone factor – v
b) Soil type – Medium (II)
c) Importance factor – 1
d) Response reduction factor – 5

3.3 Time History Analysis

A linear time-history analysis overcomes all the disadvantages of Response Spectrum Analysis, provided that non-linear behaviour is not involved. The method involves significantly greater computational effort than the corresponding Response Spectrum Analysis and at least three representative earthquake motions must be considered to allow for the uncertainty in precise frequency content of the design motions at a site. With current computing power and software, the task of performing the number crunching and then handling the large amount of data produced has become a non-specialist task. Some key features of this method are as below: -

- The time history is the sequence of values of any time-changing quantity such as a ground motion calculated at a set of fixed times.
- In time history analysis the structural response is computed at a number of succeeding time instants.
- In other words, time history of the structural response to a given input is obtained as a result.

The time history which is used for analysis of above four types of buildings is Time Histories of Nepal and Sumatra.
Data used for Time history analysis is given below.

I. Sumatra Earthquake, 2007
   a) Name of time history: Sumatra
   b) Magnitude: 8.4
   c) Total no of acceleration records: 25799
   d) Time step: 0.005second
   e) Duration: 128.95 seconds

II. Nepal earthquake, 2015
   a) Name of time history: Nepal
   b) Magnitude: 7.8
   c) Total no of acceleration records: 64591
   d) Time step: 0.005 second
   e) Duration: 322.95 seconds

IV. ANALYSIS AND RESULTS

Analysis procedure and criteria for the analysis are in accordance with design basis. Analysis of building is done by SAP-2000 software in accordance with IS: 1893-2016 (Criteria for Earthquake resistant design of structures). Three methods are used for doing the analysis.

a) Static Method
b) Response Spectrum Method
c) Time History Method

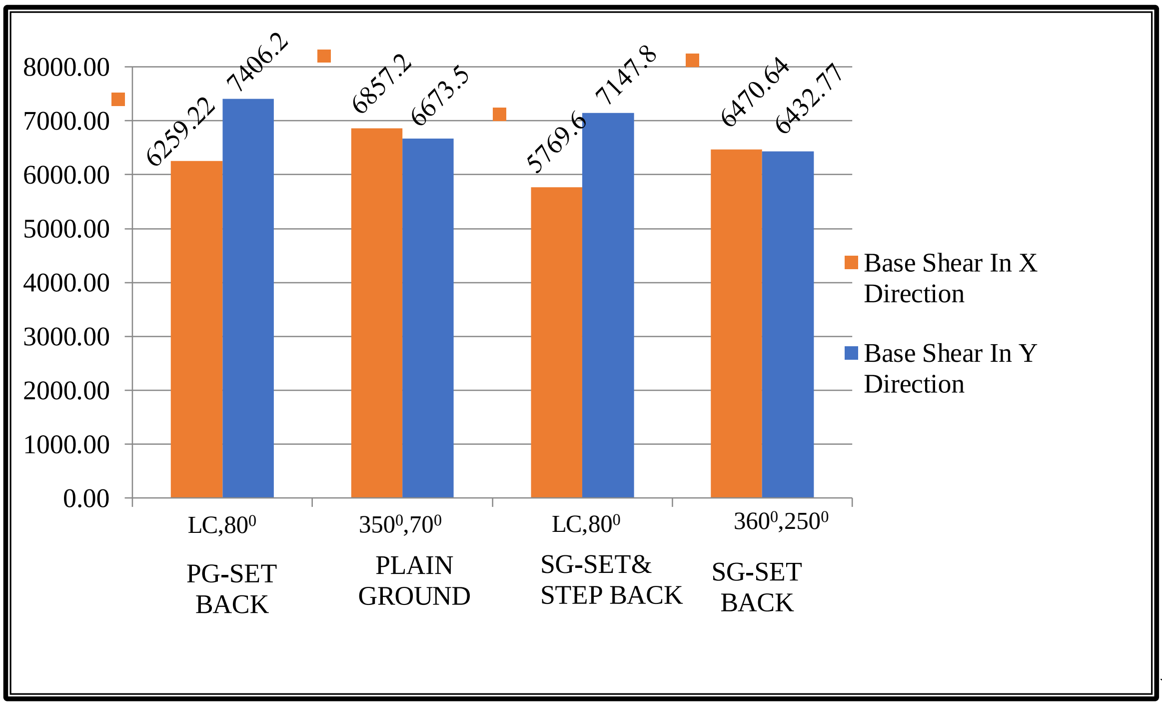

Figure 1. Base Shear for Nepal earthquake

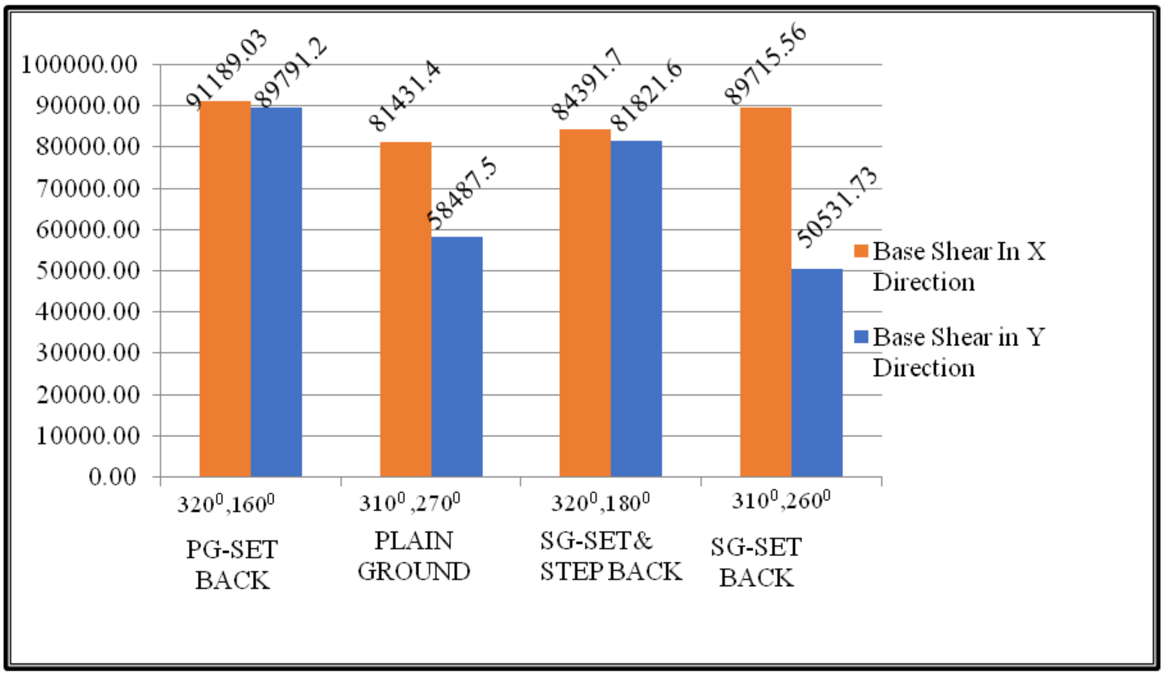

Figure 2. Base Shear for Sumatra earthquake

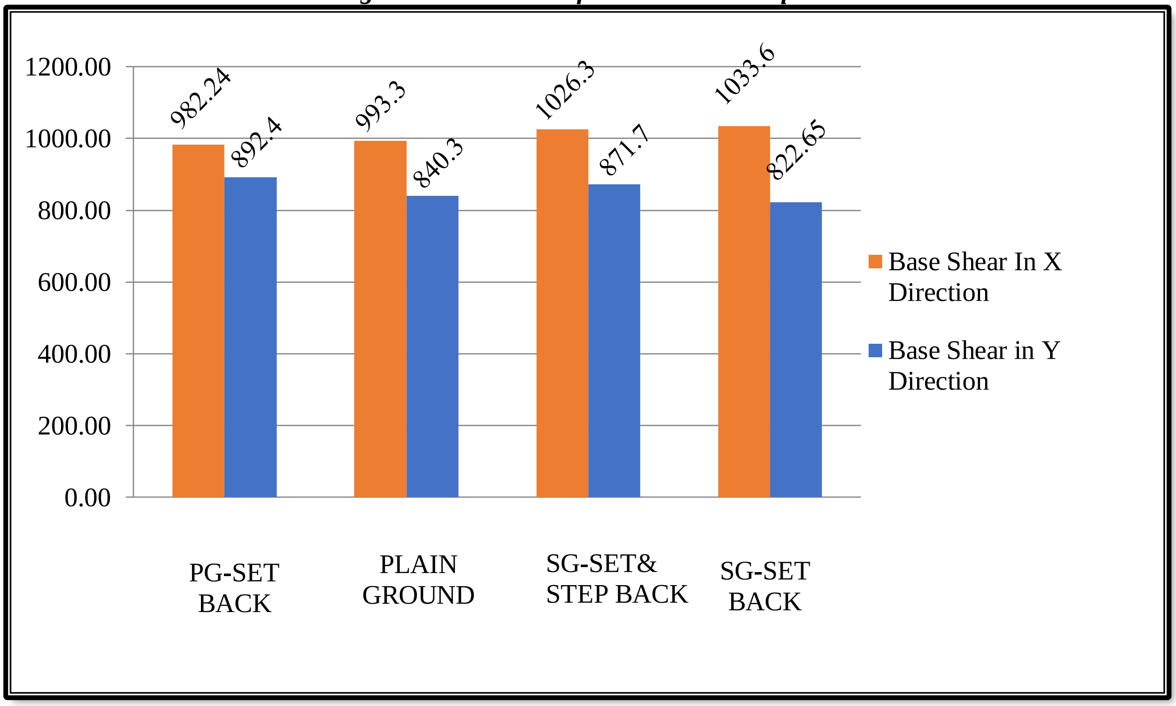

Figure 3. Base Shear for Response Spectrum zone-5

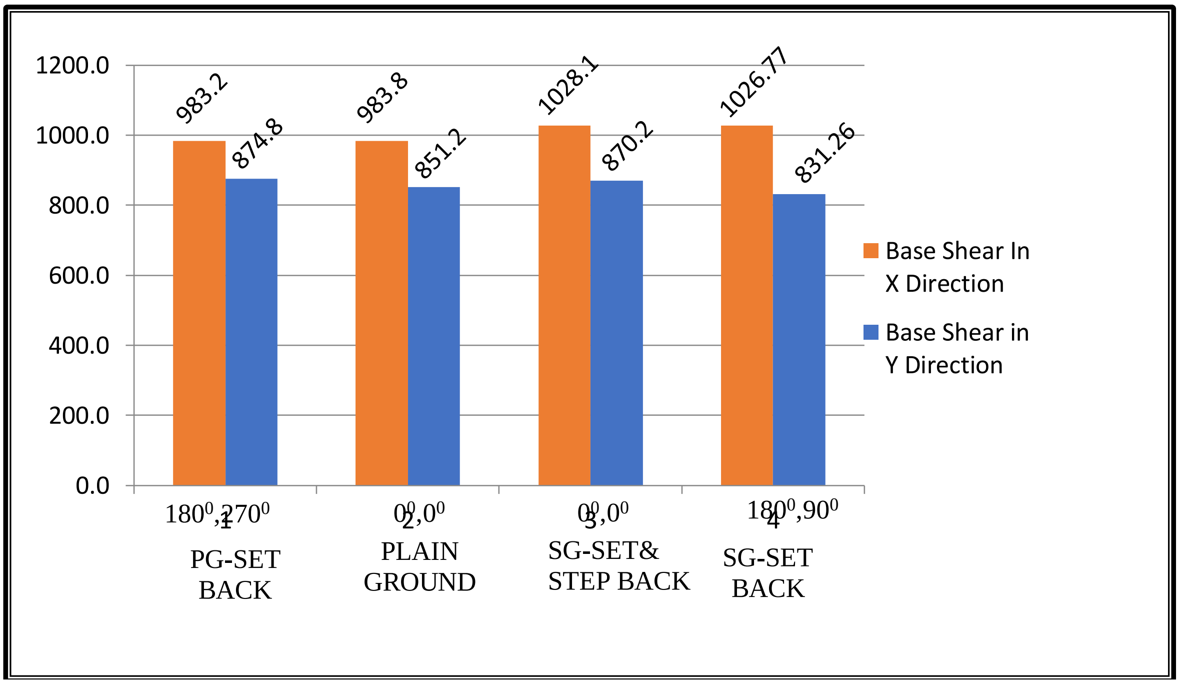

Figure 4. Base Shear for Static method zone-5

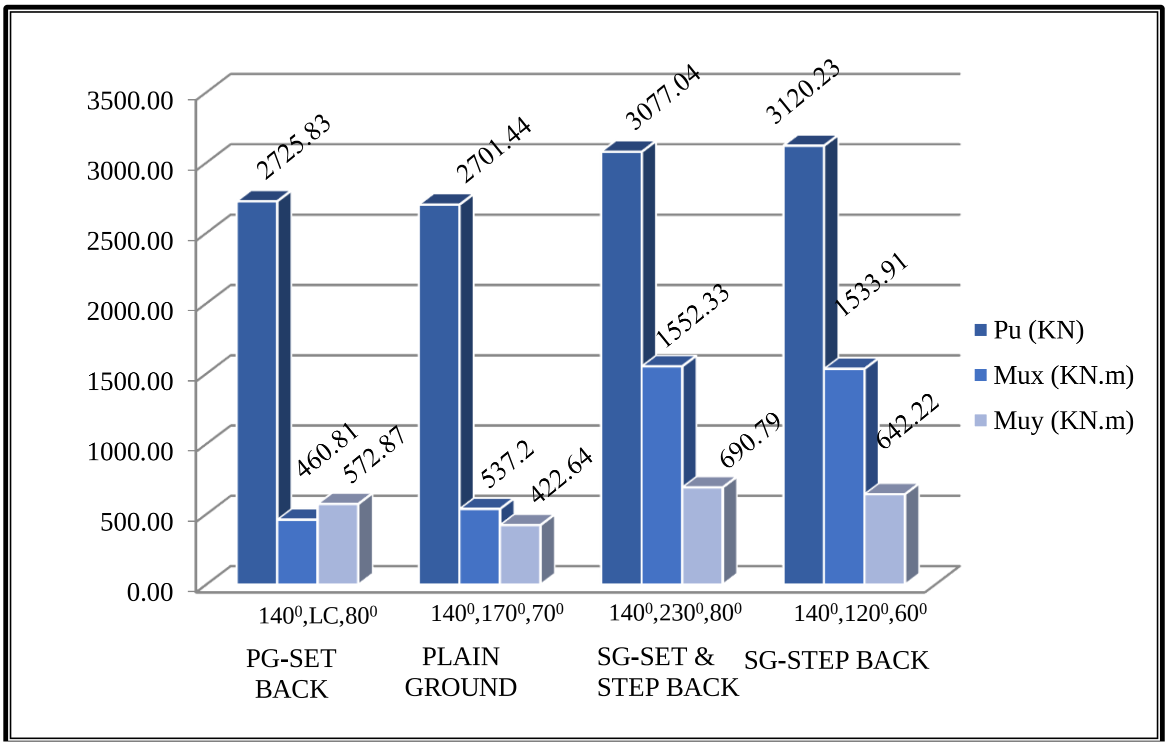

Figure 5. Axial force and moments for Nepal Earthquake

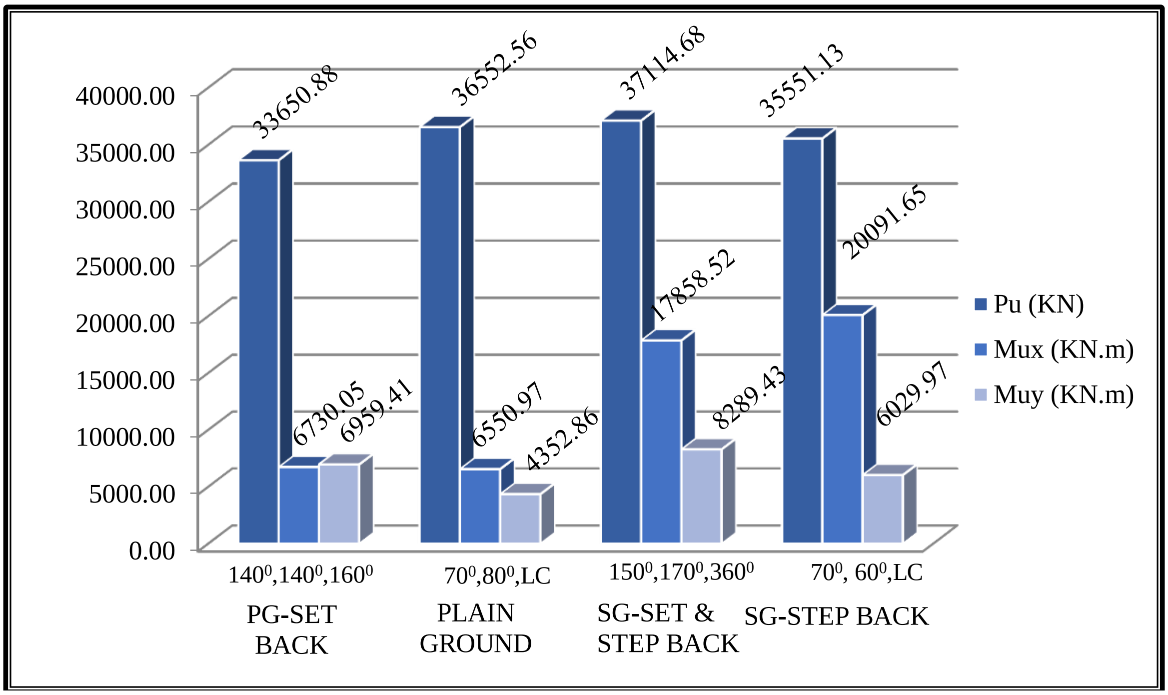

Figure 6. Axial force and moments for Sumatra Earthquake

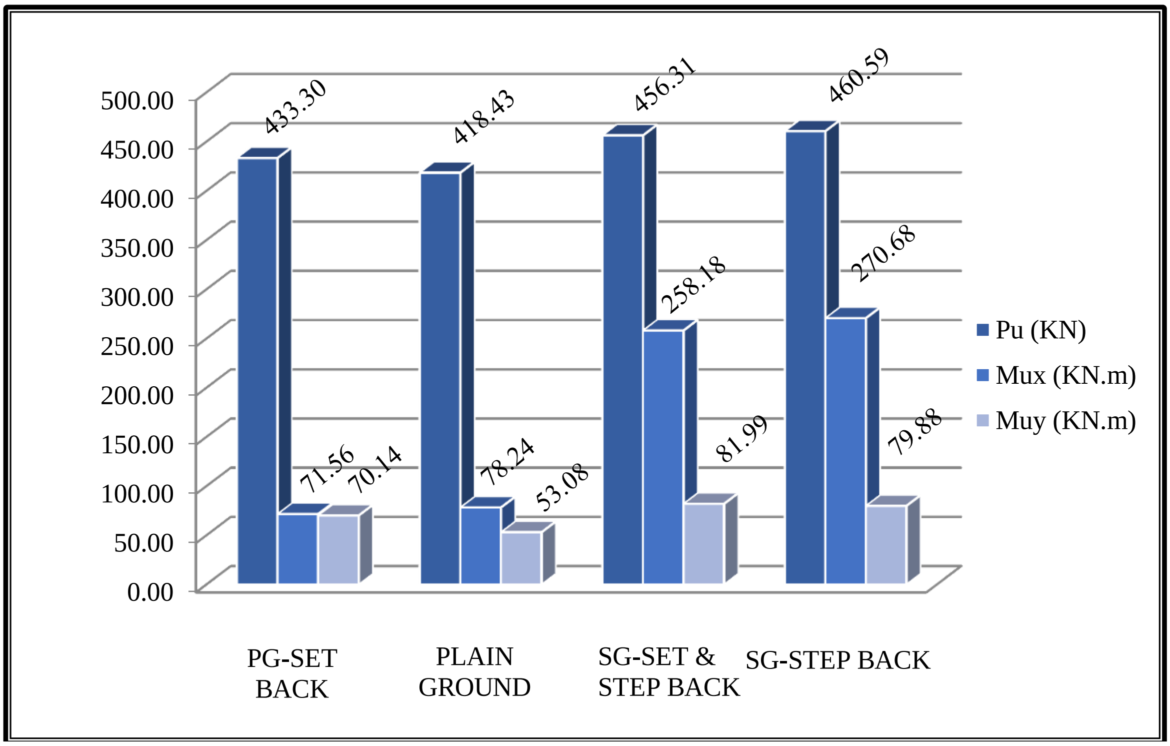

Figure 7. Axial force and moments for Response Spectrum zone-5

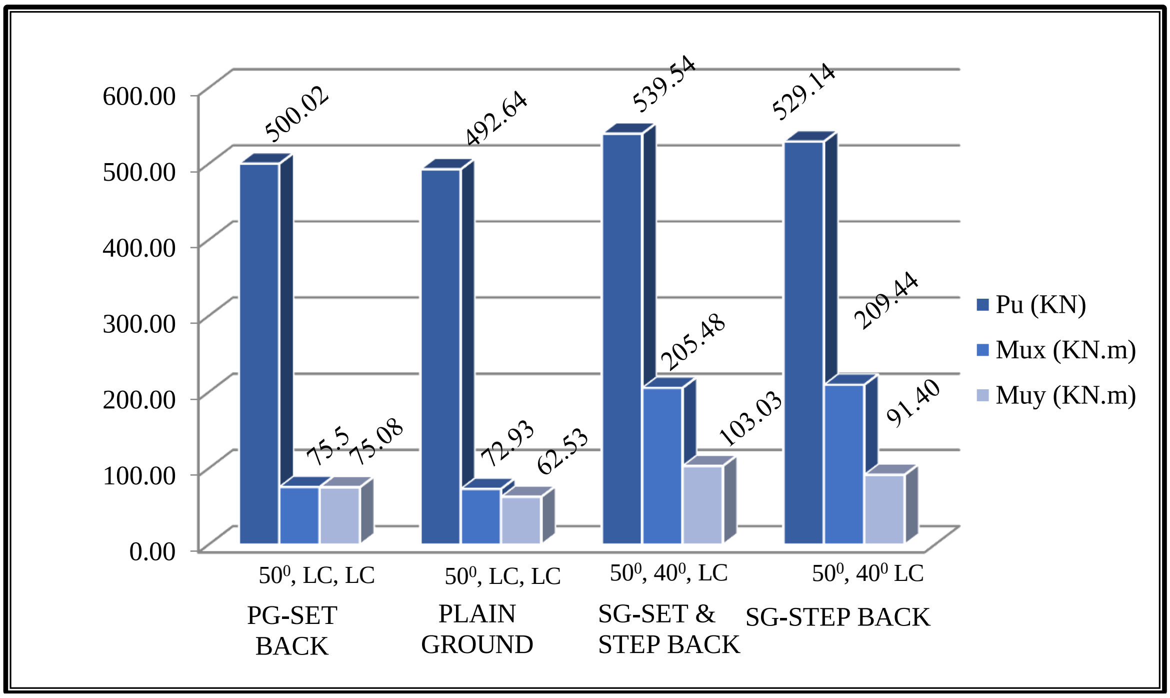

Figure 8. Axial force and moments for Static zone-5

V. CONCLUSIONS

- As per IS 1893-2016 clause 7.7.1 , Linear dynamic analysis shall be performed to obtain the design lateral forces for all buildings, other than regular buildings lower than 15 in Seismic Zone-2.We observed that in most of the practical case static method is used for the analysis, In this work Dynamic analysis is also done and what is observed that if Time history Analysis that is one of the methods of dynamic analysis is used then it was observed that there is increase of 68% in the lateral forces compared to static method of analysis. Hence it is essential that Dynamic analysis should be done to find out the responses in the structures.
- When the angle of seismic incidence is applied to the buildings other than 0^0 or 90^0 than it was observed that there is a rise of around 25-35% in the values of various responses.
- In the work carried out it is observed that, values of all considered parameters are high for Time History analysis compare to Response Spectrum analysis and Static analysis.
- From results it is concluded that only static analysis is not sufficient for irregular sloping ground building and dynamic analysis must be carried out to study response of building under earthquake forces.
- Time History analysis gives exact response of building if particular earthquake such as Nepal, and Sumatra will strike on building.
- Very important observations that in most of case critical angle of seismic incidence is different from 0^0 or 90^0.
- The recommendation of IS 1893:2016 in clause 6.3.4.1 underestimates the seismic response of the structure under different angle.
- It is very difficult to decide the critical angle of seismic incidence which gives peak response because we are getting different angles for various peak response such as Base shear, Roof displacement, Torsional moment, Axial force and moments for column.

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