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Seismic Analysis of Structures under Different Soil Conditions

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Abstract
In India, multi-storied buildings are usually constructed due to high cost and scarcity of land. In order to utilize maximum land area, builders and architects generally propose asymmetrical plan configurations. These asymmetrical plan buildings, which are constructed in seismic prone areas, are likely to be damaged during earthquake. Earthquake is a natural phenomenon which can generate the most destructive forces on structures. Buildings should be made safe for lives by proper design and detailing of structural members in order to have a ductile form of failure.
The concept of earthquake resistant design is that the building should be designed to resist the forces, which arises due to Design Basis Earthquake, with only minor damages and the forces, which arises due to Maximum Considered Earthquake, with some accepted structural damages but no collapse. This project report comprises of seismic analysis and design of an five-storied R.C. building with asymmetrical plan in different soil conditions. The building is modelled as a 3D space frame with six degrees of freedom at each node using the software SAP2000 v 14. Building is analyzed using Response Spectrum method. The Response Spectra as per IS 1893 (Part 1): 2002 for rocky or hard soil and soft soil is used.
Dynamic response of a structure resting on soft soils in particular, may differ substantially in amplitude and frequency content from the response of an identical structure supported on a very stiff soil or rock. However, data on many failure examples of rigid structures resting on flexible soils and intensive analytical studies in recent years have made considerable advances in the field of soil-structure interaction and analytical techniques are now available. This interaction phenomenon is principally affected by the mechanism of energy exchanged between soil and the structure.
Considering the soil – structure interaction effect which is mainly due to the fact that buildings with high stiffness on loose soils behave differently. Base shears have shown significant variation with high values for structures resting on loose soils and low values in case of hard rock. This attributes mainly due to more absorbing energy capacity of soils when compared to rock materials

I. INTRODUCTION

Earthquake is known to be one of the most destructive phenomenon experienced on earth. It is caused due to a sudden release of energy in the earth's crust which results in seismic waves. When the seismic waves reach the foundation level of the structure, it experiences horizontal and vertical motion at ground surface level. Due to this, earthquake is responsible for the damage to various man-made structures like buildings, bridges, roads, dams, etc. It also causes landslides, liquefaction, slope-instability and overall loss of life and property.
Most of the time earthquakes are caused by the slippage along a fault in the earth's crust. When the fault ruptures in the earth's crust, the seismic waves will travel away from the source known as focus, in all direction to the ground surface. As they travel through different geological materials, the waves are reflected and refracted. Throughout the whole journey from the bedrock to the ground surface, the waves may experience amplification.Seismic wave amplification may cause large acceleration to be transferred to the structures, especially when the resulting seismic wave frequencies match with the structure resonant frequencies. This phenomenon may result in catastrophic damages and losses. Thus, with respect to the possible risk of earthquake hazard, it is essential to estimate the peak ground acceleration at the ground surface in order to produce appropriate response spectra for the purpose of structural design and structural safety evaluation. An earthquake is a ground vibration due to the rapid release of energy.The vibration produced causing the ground to be in motion where such ground motion generates complicated transient vibrations in structures. The response of a structure under earthquake loading is directly associated with the response of soil to ground shaking. Thus, the extent and degree of damage during an earthquake is mainly influenced by the response of soil to ground vibrations. Therefore, it is vital to evaluate the response of soil due to ground vibration.

Though the structures are supported on soil, most of the designers do not consider the soil structure interaction and its subsequent effect on structure during an earthquake. Different soil properties can affect seismic waves as they pass through a soil layer. When a structure is subjected to an earthquake excitation,it interacts the foundation and soil, and thus changes the motion of the ground. It means that the movement of the whole ground structure system is influenced by type of soil as well as by the type of structure.Tall buildings are supposed to be of engineered construction in sense that they might have been analyzed and designed to meet the provision of relevant codes of practice and building bye-laws. IS 1893: 2002 "Criteria for Earthquake Resistant Design of Structures" gives response spectrum for different types of soil such as hard, medium and soft soil.

II. PROPOSED DESIGN

The building considered in the present report is G+4 storied R.C framed Guest house building, of asymmetrical plan configuration. The building is having following dimensions.

Length = 31.364 m
Width = 17.411 m
Height = 17.00 m

Typical elevation and plan of building is shown in Fig.

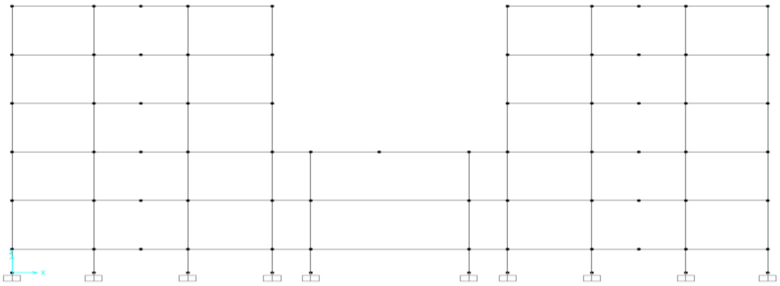

Figure 2.1:Elevation of building in x-z plane

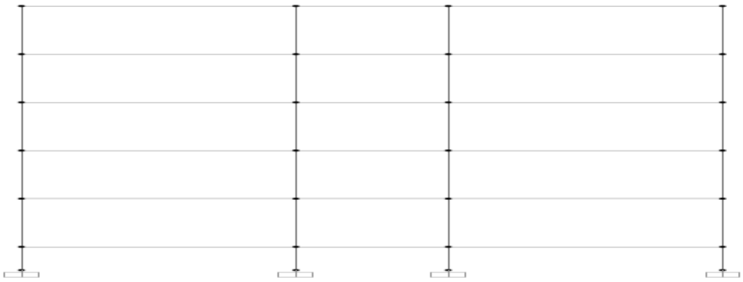

Figure 2.2 Elevation of building in y-z plane

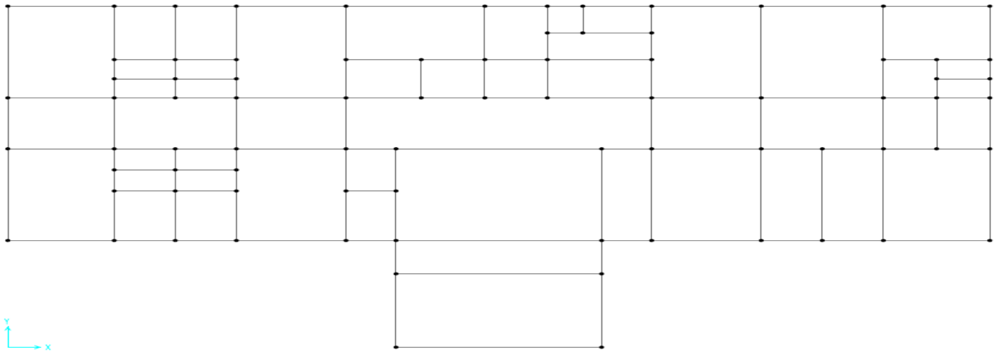

Figure 2.3 Plinth level beam plan

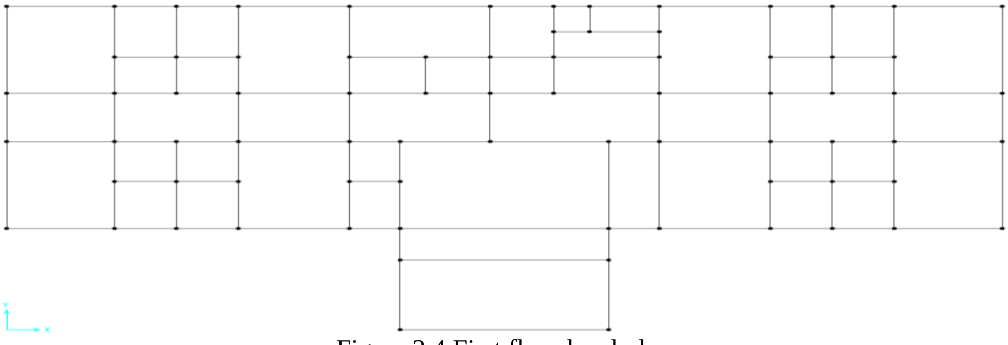

Figure 2.4 First floor level plan

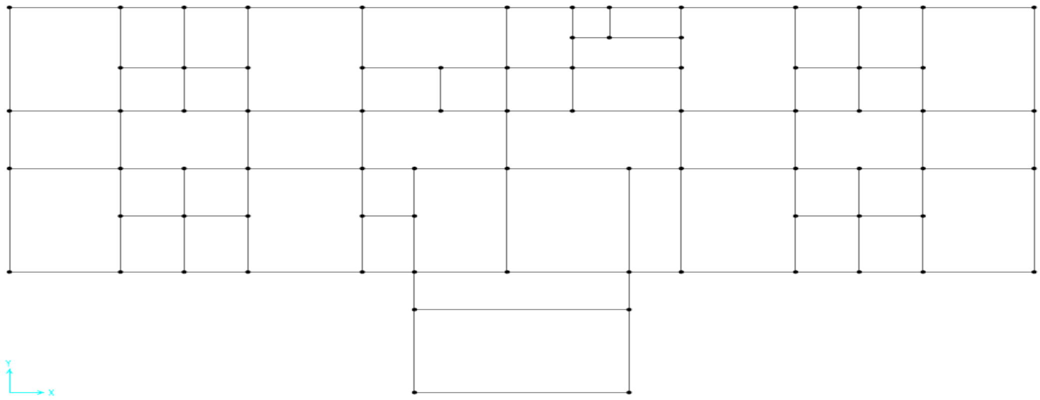

Figure 2.5 Second floor level plan

III. BUILDING PROPERTIES

3.1 Site Properties:
Location of building :: Amritsar Punjab
Seismic Zone :: IV

3.2 Geometric Properties of Components:
Beam section ::350 mm X 550 mm
Column section ::400 mm X 600 mm
Slab thickness :: 125 mm
External wall thickness ::230 mm
Internal wall (partition wall) ::115 mm
Height of parapet wall ::1.5 m
Thickness of parapet wall:: 230 mm

3.3 Material Properties:
Material property of Concrete, Masonry and Reinforcement are given in tabular form

Table 3.3.1 Material properties of concrete,masonry and reinforcement.

Material	Modulus of elasticity(kN/m^2)	Unit Weight (kN/m3)	Yield Stress MPa	Compressive strength (MPa)
Concrete	25 X 10^6	25	-	25000
Masonry	2 X 10^6	20	-	
Reinforcement	2 X 10^8		415	-
Reinforcement (column)	2 X 10^8		500	-

3.4 Loading Types:
The structure should be safe against all possible loads which are expected to come during its lifetime. The load cases should be considered for design of structural component of building.

3.5 Primary Loads
Dead load: It includes dead weight of beam column, floor slab, Floor finish roof finish, roof slab wall.
Self weight of beam and column
Weight of slab =3.125kN/m^2
Dead Weight of wall =14.26kN/m
Dead Weight of Internal wall (partion wall) =7.13kN/m
Dead Weight of parapet wall =6.9kN/m
Floor finish =1kN/m^2
Roof treatment =1.5kN/m

Live Loads
Live load (Bed room) =2kN/m^2
Live load (passage) =3kN/m^2
Live load on roof =1.5kN/m^2

3.6 Earthquake Load

The earthquake load is considered as per IS:1893 (Part I):2002,for the zone IV and hard rock type and soft soil with importance factor 1.5 and Reduction factor 5.

Seismic zone factor Z for Zone IV =0.24

Scale factor = (Z/2)*(I/R)*g
= (.24/2)*(1.5/5)*9.8=0.3532

3.7 Load Combinations

Load combinations that are to be used for Limit state Design of reinforced concrete structure are listed below.

1. 1.5(DL+LL)
2. 1.2(DL+LL±EQ-X)
3. 1.2(DL+LL±EQ-Y)
4. 1.5(DL±EQ-X)
5. 1.5(DL±EQ-Y)
6. 0.9DL±1.5EQ-X
7. 0.9DL±1.5EQ-Y

3.8 Seismic Load

Table 3.8.1 Load calculated by SAP and by manual calculation.

Load type	SAP result (kN)	Manual Calculation(kN)
DEAD WALL	15810.67	15810.67
DEAD SALB	5225.206	5225.206
DEAD FF	1262.695	1262.695
DEAD RT	614.056	614.056
LIVE	2816.216	2816.216
DEAD	13053.18	13053.18
Total load	38782.023	38782.023

The seismic load is calculated as per IS 1893(Part 1):2002.The building is analysed in two principal horizontal directions.

Fundamental time period of building are calculated as per IS 1893(Part 1):2002 cl.7.6.2 as given below

$T=0.09*h/\sqrt{d}$

h is height of building

d =Base dimension of building at plinth level.

For rocky or hard soil sites

$S_a/g = 1+15*T \quad 0.00 \le T \le 0.10$
$=2.5 \quad 0.10 \le T \le 0.40$
$=1.0/T \quad 0.40 \le T \le 4.00$

For soft soil sites

$S_a/g = 1+15*T \quad 0.00 \le T \le 0.10$
$= 2.5 \quad 0.10 \le T \le 0.67$
$= 1.67/T \quad 0.67 \le T \le 4.00$

3.9 Calculation of Base shear

$T_x = 0.09*15.5/\sqrt{31.364}$
$=0.25$ sec
$T_y = 0.334$ sec
$(S_a/g)_x = (S_a/g)_y = 2.5$
$A_h = (S_a/g)*(Z/2)*(I/R)$
$(A_h)_x = (A_h)_y = 0.09$
$V_B = A_h*W$

Base shear from manual calculation

$(\square_B)_X = (\square_B)_Y = 3490.38$kN

From SAP

$(V_B)_X = 1638.728$kN
$(V_B)_Y = 1732.327$kN

For soft soil sites

$S_a/g = 1+15*T \quad 0.00 \le T \le 0.10$
$= 2.5 \quad 0.10 \le T \le 0.67$
$= 1.67/T \quad 0.67 \le T \le 4.00$
$(S_a/g)_x = 6.68$
$(S_a/g)_y = 5$
$A_h = (S_a/g)*(Z/2)*(I/R)$
$(A_h)_x = 0.240$
$(A_h)_y = 0.180$
$V_B = A_h*W$

Base shear from manual calculation

$(\square_B)_X = 9307.68$kN
$(\square_B)_Y = 6980.76$kN

3.10 Base Shear Correction ($\square_B/V_B$)

Scale factor = $(\square_B/V_B)_X *(Z/2)*(I/R)*g$
$= 2.13*0.3532$
$= 0.7523$

Scale factor = $(\square_B/V_B)_y *(Z/2)*(I/R)*g$
$= 2.01*0.3532$
$= 0.7116$

$V_B = A_h*W$

Base shear from manual calculation

$(\square_B)_X = (\square_B)_Y = 3490.38$kN.

OBSERVATIONS

1.The fundamental time period of the building,calculated as per IS 1893 (Part 1): 2002, is 0.25sec in longitudinal direction.

2.The fundamental time period of the building,calculated as per IS 1893 (Part 1): 2002, is 0.334 sec in transverse direction.

3.The modal mass participation percentage is 0.63% along X (longitudinal) directions of the building.

4.The modal mass participation percentage is 0.006465% along Y (transverse) direction of the building.

5.Maximum modal mass participation is in mode no.10 is 91% in the longitudinal direction and 90% in transverse direction.

6.In a typical beam, shear force obtained from applied loads is 271.46kN for member.

7.The Base shear from manual calculation is $(\square_B)_X$ = $(\square_B)_Y$ =3490.38 kN for hard soil condition.

8.The Base shear from SAP is $(V_B)_X$ =1638.728 kN and $(V_B)_Y$ =1732.327 kN.

9.The Base shear from manual calculation is $(\square_B)_X$ =9307.68 kN $(\square_B)_Y$ =6980.76 for soft soil condition.

10.Base shear correction $(\square_B/V_B)_{X,}$ of 0.7523 is applied in longitudinal directionBase shear correction $(\square_B/V_B)_Y$ of 0.7116 is applied in transverse direction.

IV. CONCLUSION

In the present project report seismic design analysis of a asymmetrical plan building is carried out.Building is modelled as a 3D frame using SAP2000v14 which is analysed by Response Spectrum method. Following conclusions have been drawn from the seismic analysis and design of the building

- The modal mass participation percentage are 0.63% and .006465% along X and Y directions of the building, respectively. This is because of low torsional rigidity of the building.
- From the manual design of a typical beam and column, it has been found that the required flexure and shear reinforcement as obtained from SAP2000 is in reasonable agreement with manual calculations.
- Special confining reinforcement in potential plastic hinge zone has to be provided because SAP2000 does not provide any such special confining reinforcement.
- Out of the different load combinations the governing load cases consist of different combinations with earthquake load.
- The period of vibration as calculated from the empirical formula of IS: 1893(Part1)-2002 comes out to be 0.25 sec in the longitudinal direction and 0.334 sec in the transverse direction. The period of the structure as obtained from the software is 0.6099 sec and 0.60991sec in longitudinal and transverse directions, respectively. So correction for base shear $(\square_B/V_B)$ is considered for the capping on time period prescribed by IS: 1893 -2002.
- Considering the soil – structure interaction effect which is mainly due to the fact that buildings with high stiffness on loose soils behave differently. Base shears have shown significant variation with high values for structures resting on loose soils and low values in case of hard rock. This attributes mainly due to more absorbing energy capacity of soils when compared to rock materials.
- Time periods of the structure invariably decrease with the increase of soil stiffness.
- Due to earthquake forces, base shear decreases with increase of soil stiffness.
- In general, it is seen that the displacement values increase with the decrease of soil stiffness, which is mainly attributed due to the rocking effect of the soil.
- It is also observed that there is a wide variation in the decrease of displacements from loose soil to hard rock at ground floor level when compared with the displacements.
- The soil damping normally ranges from low value for flexible structure on rigid foundation to a high value for rigid structures on flexible foundations. Particularly for structures like nuclear power plants, which are more rigid than high rise buildings, the influence of soil-structure interaction is more significant.
- It is necessary to consider soil-structure interaction effect when structures rest on loose soils.

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