https://dx.doi.org/10.22161/ijaers.6.6.89 ISSN: 2349-6495(P) | 2456-1908(O)

Performance Based Analysis of RC Buildings with Underground Storey Considering Soil Structure Interaction

Taha A. Ansari[1], Sagar Jamle[2]

[1]M. Tech. Scholar, Department of Civil Engineering, Oriental University, Indore (M. P.), India
Email: taha.amilansari@gmail.com
[2]Assistant Professor, Department of Civil Engineering, Oriental University, Indore (M. P.), India
Email: sj.sagarjamle@gmail.com

***Abstract*— *Several researches on past earthquakes reveal that dynamic loading affects earthquake parameters of building. Due to interaction of soil and structure unexpected distress and failures has been observed in structures. Soil structure interaction increases shear forces in lowermost storey of building and building becomes less stiff which leads to increase in lateral displacements parameters like storey drift ,inter storey drift and roof displacements. Objective of study is to understand the effect interaction of soil and structure on building with underground storey. In this study seismic response of ten storey building with fix base and underground storey are compared using nonlinear static analysis for the parameters like pushover curve, performance point and hinges formation.*

Keywords*— *Demand Capacity, Hinge formation, Performance point, Pushover, SAP2000, Soil Structure Interaction.

I. INTRODUCTION

The Pushover Analysis of a structure is a static non-linear analysis under vertical loads and lateral loads which are increasing gradually. A graph between base shear and top displacement in a structure is obtained which represents weakness in structure. In this method beams and columns which will reach to yielding are identified. A pushover analysis is applied on a building by increasing lateral load patterns due to which stiffness in structural elements decreases. Pushover analysis proves to be an efficient compared to static analysis methods. The accurate prediction of the target displacement is important parameter for studying seismic demand predictions. Capacity curve response to the lateral load pattern is sensitive and it is very critical for predicting target displacement. In developing country like India, building with underground storey is important part of such high rise multi storey building for parking and other services. Sometimes due to rapid growth in infrastructure and lack of land of hard strata soil, designers are forced to deigns and construct building over soft strata. Response of building with shear wall and underground storey due to structure and soil interaction is a topic of research for the engineers. In recent practice, mostly standard codes treat low stiff soil in underground storey and shear wall building with guidance opted to design fixed base regular structure.

II. OBJECTIVE

Objective of this research is to study effect on seismic response of regular ten storey building with underground storey due to interaction of soil and structure using linear analysis and nonlinear static analysis along with following heads:-

1) To show the soil parameters and how to relate the Clayey Fine Sand (ML) and Clay of High Compressibility (CH) parameters in SAP software.
2) To demonstrate the Pushover Curve obtained between Base Shear and Displacement.
3) To find and illustrate the Hinge Formation in ML and CH soil.

III. MODELING

3.1 Building Modeling

A 10-storey reinforced concrete building has been modeled in SAP2000 V14 with conventional fixed base model and flexible base model considering SSI. For conventional building fix base is considered at lowermost storey. For soil structure interaction two medium stiff and low stiff soil has been considered as per IS code. Building is considered to be situated in Zone V as per IS 1893(Part I):2002. Building height is considered as 35 m with 3.5 m floor to floor height. Raft foundation is selected for the analysis with 1.2 m thickness. The length of beam in transverse direction X and longitudinal direction Y is 5 m

https://dx.doi.org/10.22161/ijaers.6.6.89 ISSN: 2349-6495(P) | 2456-1908(O)

respectively In SAP2000, dead load is program calculated as per the density of material and dimension of element used in modeling. Load of brick masonry on external beam is 15.4 KN/m and 7.7 KN/m on internal beams. M25 grade of concrete is used RCC members.

Table 1: Geometric Properties of Building Frame and Foundation

S. No.	Structural Element	Dimension
1	Beam	600 x 250 mm
2	Column	600 x 250 mm
3	Slab	150 mm (Thickness)
4	Raft	1200 mm (Thickness)
5	Retaining Wall	400 mm (Thickness)

3.2 Soil Modeling

Linear elastic continuum is the most suitable method to idealized soil response and behavior of supporting soil medium. In Elastic Continuum or finite element model, the finite soil mass is considered based on convergence study, with boundary far beyond a region where structural loading has no effect. Indrajit Chowdhary et. al (2009), suggests expressions to calculate the mesh size of soil. Clayey fine sand (ML) and Clay of high Compressibility (CH) is selected for this analysis as per IS 1893. Engineering properties of soils used are given in table 2. Soil is modeled by using solid element with a depth of which is about 2.5 times more than the width of the building. In this case depth of soil is calculated as 50 m. Interface element is provided between structure and soil. These elements are provided to avoid no tensile forces will be transmitted between soil and structure. Interface element is provided between soil-raft and soil – retaining wall. For modeling of vertical interface element spring is taken and the stiffness is calculated. Stiffness of building is calculated using empirical formula developed by M.H Rayhani et. al, (2008). For Clayey fine sand (ML) and Clay of high Compressibility (CH) values of spring stiffness is calculated as 215382 KN/m and 21534 KN/m respectively.

Table 2: Soil Properties

S. No.	Structural Element	Dimension
1	Beam	600 x 250 mm
2	Column	600 x 250 mm
3	Slab	150 mm (Thickness)
4	Raft	1200 mm (Thickness)
5	Retaining Wall	400 mm (Thickness)

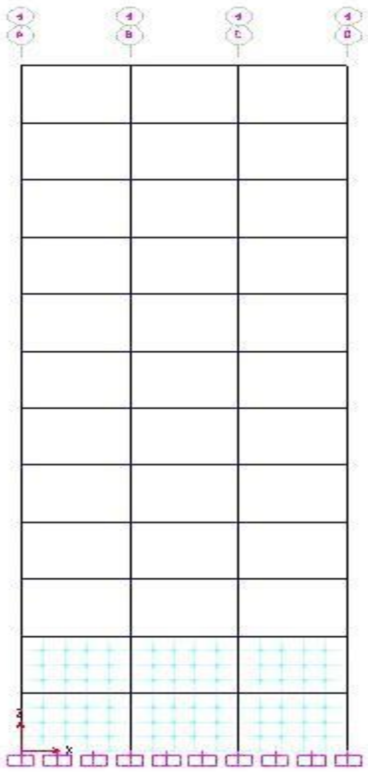


Fig.1: Fix Base Building Model

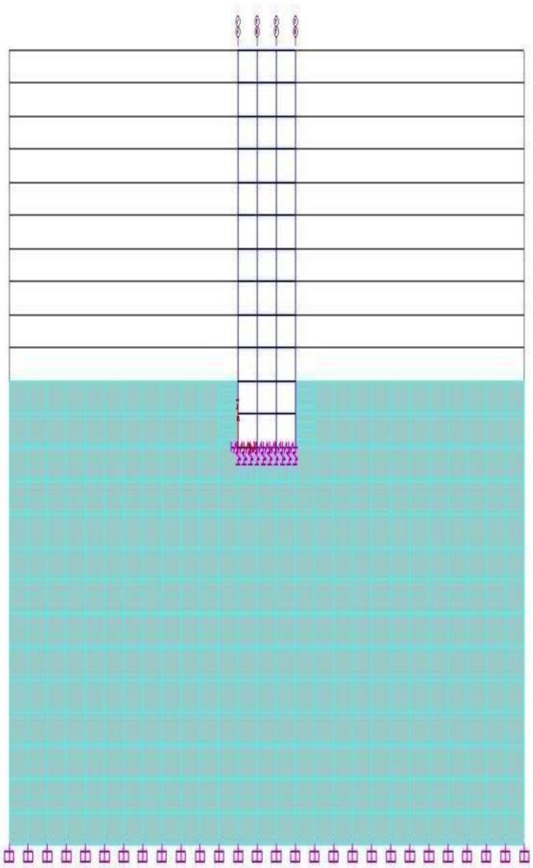


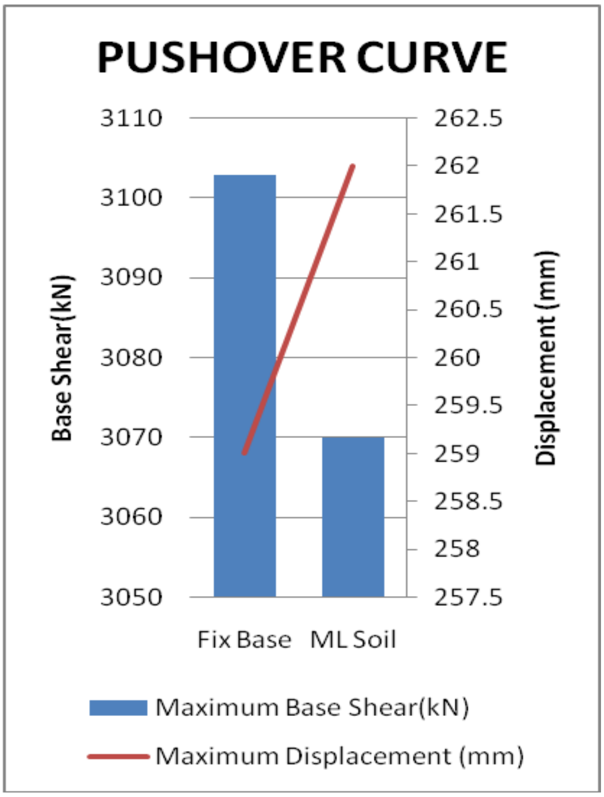
Fig. 2: Building with Soil Structure Interaction

IV. RESULTS AND DISCUSSION

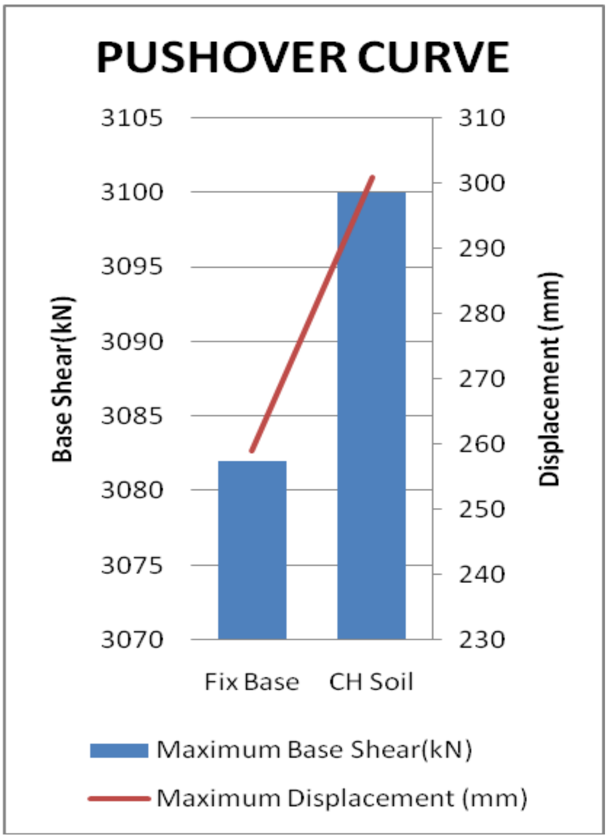
Nonlinear static analysis has been done in SAP 2000 V14 FEM software for X and Y directions. Hinges are assigned as per FEMA 356. For beam hinge property is assigned for M3 and for column P-M2-M3. Seismic responses for pushover analysis are discussed in terms of displacement, base shear, performance point and hinge formation. Seismic responses considering SSI effect are compared for building with underground floors.

4.1 Pushover Curves

Pushover curves have been plotted between base shear and displacement obtained from SAP 2000. Maximum base shear and displacement for fixed base and flexible base building has been compared in figure 3 and 4. From the obtained value it has been found that for regular building base shear is more than base shear for building with flexible base. Also maximum displacement increases due to SSI effect by 10%.



Graph 1: Pushover Curve ML Soil



Graph 2: Pushover Curve CH Soil

4.2 Performance Point

In Pushover Analysis, a pushover gives relation between capacity spectrum, performance point and demand spectrum. It also helps in determining the performance level of the building components. Performance point for underground building with regular building and SSI effect is shown from Figure 5 and 6. Performance point is evaluated using shear force value obtained from SAP 2000, ATC 40 Capacity spectrum for X direction. Demand capacity curve has been drawn for each building with fix base and flexible base building.
Following observations have been concluded from the analysis.

1. For all the cases i.e. fix base and SSI effect, demand capacity curve have been formed at second zone of pushover curves.
2. From the results it is found that on incorporating SSI in nonlinear static analysis a more detailed response of the building can be maintained.
3. Performance point of building with underground storey with or without SSI effect is nearly same.

4.3 Hinge Formation

Hinge results are shown in form of total hinges formed in specific zone of force displacement curve. Hinge formation in all models has been compared in table

https://dx.doi.org/10.22161/ijaers.6.6.89 ISSN: 2349-6495(P) | 2456-1908(O)

below. In force displacement curve hinge formation at different levels suggests condition of building during seismic force excitation.

1. For Ml and CH soil flexible base underground storey building 100% hinges are formed up to D and 89% hinges are formed up to CP.
2. For ML soil fix base underground storey building about 2% hinges are formed near to point E.
3. For CH soil fix base underground storey building about 5% hinges are formed near to point E.

Table 3: Hinge Formation in ML Soil

Building Type	ML Soil Fix Base	ML Soil Flexible Base
A -B	1502	1172
B - IO	226	356
IO -LS	136	120
LS -CP	8	62
CP -C	0	0
C - D	10	210
D - E	38	0
E	0	0
Total	1920	1920

Table 4: Hinge Formation in CH Soil

Building Type	ML Soil Fix Base	ML Soil Flexible Base
A -B	1216	1268
B - IO	372	336
IO -LS	176	172
LS -CP	12	60
CP -C	0	0
C - D	48	84
D - E	96	0
E	0	0
Total	1920	1920

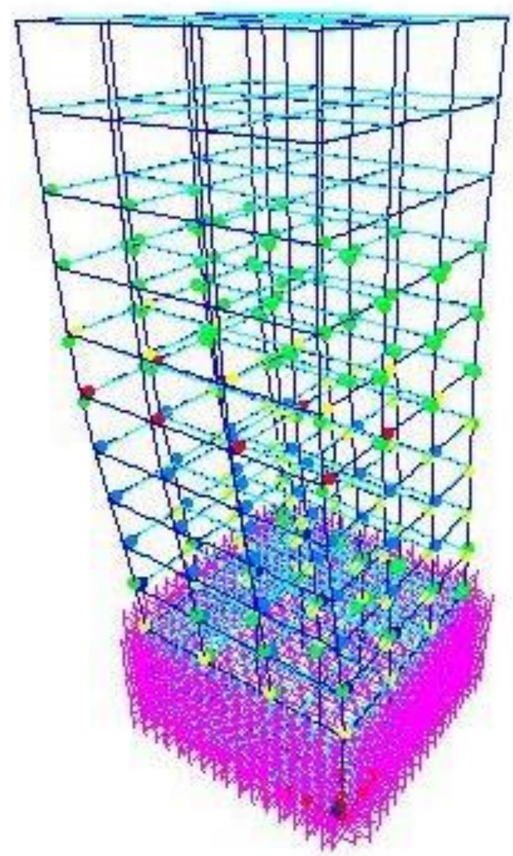


Fig. 3: Hinge Formation in ML Soil Fix Base

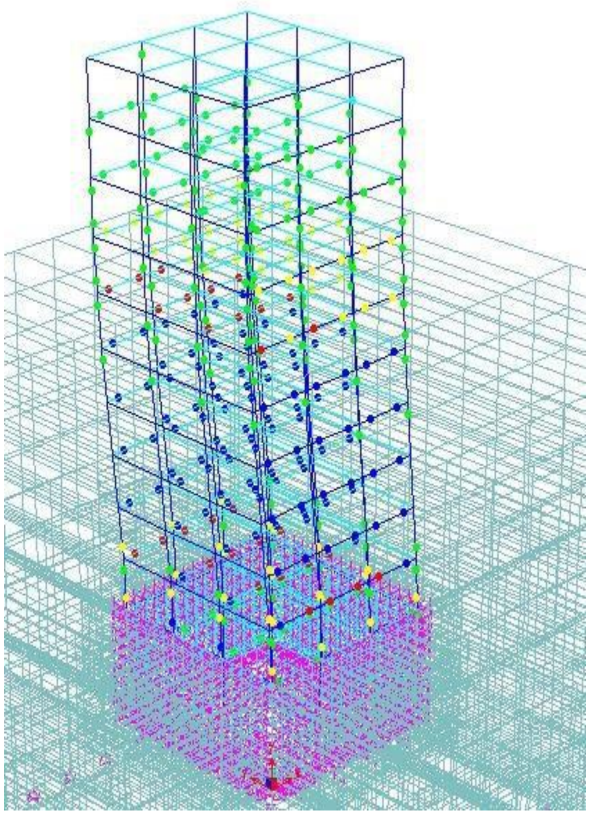


Fig. 4: Hinge Formation in ML Soil

https://dx.doi.org/10.22161/ijaers.6.6.89 ISSN: 2349-6495(P) | 2456-1908(O)

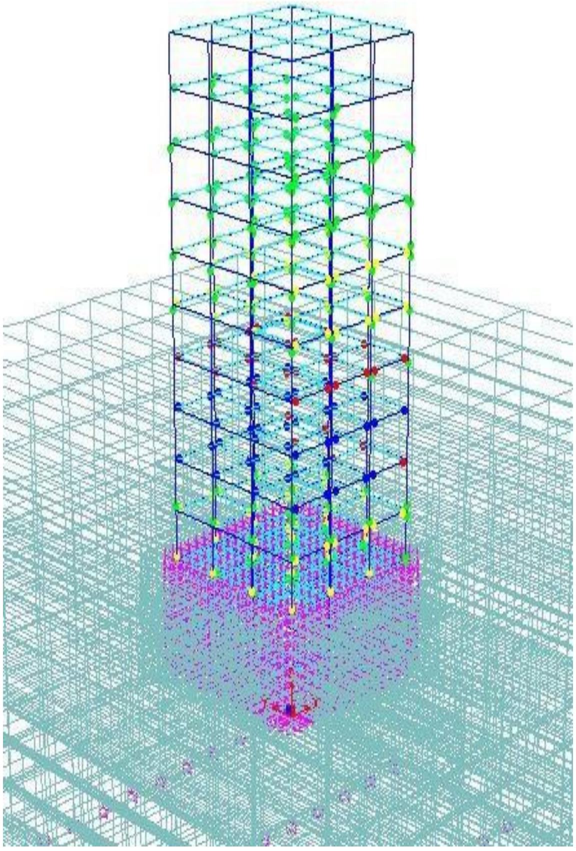


Fig. 5: Hinge Formation in CH Soil

V. CONCLUSION

Seismic response of structure is difficult to find because soil shows nonlinear behavior. Comparison of seismic analysis parameters in linear and nonlinear static have been studied in this study considering SSI effect for medium stiff ML Soil and low stiff CH Soil.

1. For regular 10 storeys building with underground storey building considering SSI effect it is observed that design storey shear forces are lower as compare to fix based building for both ML and CH Soil.
2. For underground storey building, demand capacity curves shows that the performance point of the building is nearly same.
3. For underground building more number of hinges are formed in fix base building is formed near to ultimate point of building.

ACKNOWLEDGEMENTS

I would like to thank Mr. Sagar Jamle, Assistant Professor, Department of Civil Engineering, Oriental University, Indore for his continuous efforts and dedication to my entire work.

REFERENCES

[1] FEMA-356 (Federal emergency management agency, November 2000) ASCE, American Society of Civil Engineers.

[2] Gokhan Dok, Osman Kırtel, (2018), Soil-Structure Interaction in Nonlinear Pushover Analysis of Shear Wall-Frame RC Structures: Non homogeneous Soil Condition, Natural Hazards and Disaster Management, pp. 741-748.

[3] Halkude S.A, Kalyanshetti M.G, Kadlag V. A (2015), Pushover Analysis of R.C Frames Considering Soil Structure Interaction, International Journal of Current Engineering and Technology, Vol.5, Issue 1, pp. 167-171.

[4] Joy P.V., Bennet Kuriakose, Mini Mathew (2016), Pushover Analysis of Buildings Considering Soil-Structure Interaction, Applied Mechanics and Materials, Vol. 857, pp. 189-194.

[5] Prajakta Barsinge, L. R. Wankhade (2017), Pushover Analysis over a Structure with Vertical Irregularities Using Soil Structure Interaction, ICLTESHM, ISBN 9789386171313, pp. 327-333.

[6] Tabatebaiefar HR, Fatahi Behzad, (2013), Seismic behavior of building frames considering dynamic soil structure interaction, Int. J. Geomech.; Vol. 13, Issue 4, pp. 409-20.

[7] Yang Lu, Iman Hajirasouliha, Alec M. Marshall (2016), Performance-based Seismic Design of Flexible-Base Multi-Storey Buildings Considering Soil-Structure Interaction, White Rose University Consortium, Vol.108, pp. 90-103.