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Performance Evaluation of Open Ground Storey Building with Soil-Structure Interaction by Pushover Analysis

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***Abstract*:** Open ground storey is typical and unavoidable feature in modern multi-storey construction in many countries like India. Studies of the building failed in past Earthquake shows that, open ground storey building are most vulnerable. In industrial practice, it is common to ignore the presence of infill wall for analysis of framed building but presence of infill wall alters the behavior of structure. Flexibility of soil also affects the behavior of structure, failing of consideration of effect of soil-structure interaction under-estimates the drift and strength demand in open ground storey column, resulting in incorrect design of building. In present paper, an extensive computational study has been conducted with soil-structure interaction, to find out the behavior of open ground storey building and their seismic vulnerability. Four different models are considered and comparative study is carried out. Infill stiffness is modeled using diagonal strut approach and soil stiffness is calculated as per FEMA. The models are analyzed for earthquake loads by both linear analysis and non-linear analysis by using commercial ETABS software.

Keywords: *Open ground storey, Linear Analysis, Pushover Analysis, Soil-structure interaction.*

I. INTRODUCTION

Open ground storey building is one of an example of vertical irregularity in the building. Open ground storey building is also called as 'soft storey'. As per IS:1893(Part-1) : 2002, "A soft storey is one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average lateral stiffness of three stories above".[7] Masonry infill walls are present in all but the first storey, hence it alters the behavior of the building under lateral loads. The lateral load transfer mechanism is changes from the predominant frame action to predominant truss action when we introduced the masonry infill wall to the RC frames. The upper stories moves almost like a rigid body during earthquakes and remain undamaged, so damage mostly occurs in the ground storey columns which is called as Soft-Storey Collapse.[4]

A performance based design is necessary for the structures which are situated in earthquake-prone zones. Pushover analysis is non-linear static procedure under permanent vertical loads in which magnitude of lateral loading is incrementally increased in accordance with certain pattern. The response of structure is affected by the interaction between the structure (i.e. foundation of structure) and the underlying soil.[5] Soil-structure analysis evaluates the collective response of the structure, the foundation and the geologic media underlying & surrounding the foundation to the free field ground motion.[6]

Pushover analysis is carried out on open ground storey buildings by many scholars. Comparative parametric study is done. From previous study, the conclusion drawn is that, the open ground storey buildings perform poorly during strong earthquake shaking. In present study, the pushover analysis is carried out on open ground storey building considering the soil-structure interaction. This paper highlights the effect of soil flexibility on open ground storey building through different parameters.

II. STRUCTURAL MODELLING AND ANALYSIS

To evaluate the performance of open ground storey structure, the present work involves performing linear and non-linear analysis with soil-structure interaction of the following structural forms: Bare Frame (B-F),Fully-infilled Frame (FI-F), Open Ground Storey Frame(OGS-F), Open Ground Storey Frame with Stiffer Columns (OGS-SC).

Structure considered consists of 10 storey plan symmetric RC frames consisting of 4x4 bays. The height of each storey is 3.2m and depth of foundation is 3m.The structural details of the four models are as follows: Size of Beam-230mmx450mm, Size of Column-450mmx450mm, Size of Stiffer Column-750mmx750mm, Thickness of Slab -130mm, Width of Diagonal Strut - 770mm.

For the study of RC structures, the grade of materials adopted and their properties are as follows: Grade of concrete - M30, Modulus of elasticity of concrete – 30GPa, Density of Reinforced concrete – 25kN/m3, Poisson's ratio – 0.2, Coefficient of thermal expansion – 5.5 x $10^6/^oC$; Grade of steel – Fe415; Modulus of elasticity of steel– 200 GPa [8]. Loads and load combinations on the structure is considered as per the IS provisions: Live load on the structure at floor level- 4kN/m^2, at roof level- 2kN/m^2 is considered [9]. Earthquake load is considered in both X and Y directions. The building is assumed to be situated in zone V with the soft soil. [7]

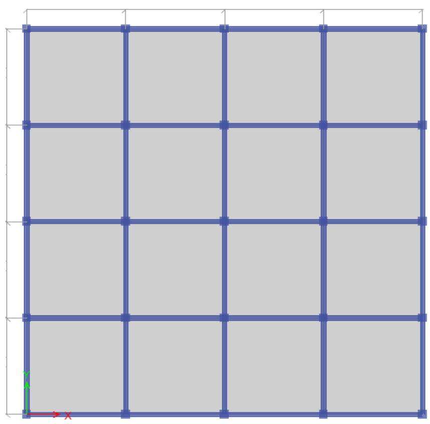

Fig.2.1: Typical Floor plan

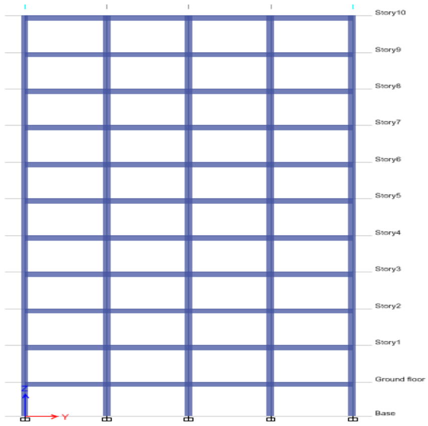

Fig 2.2: Elevation of (B-F)

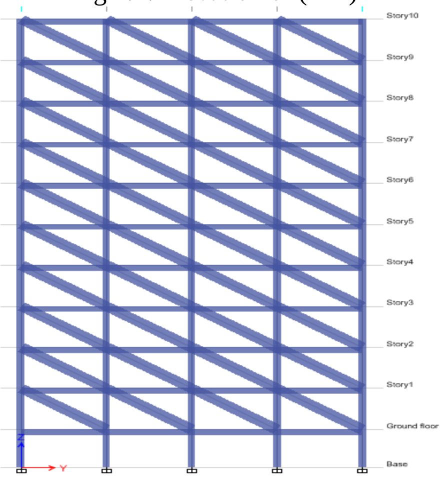

Fig 2.3: Elevation of (FI-F)

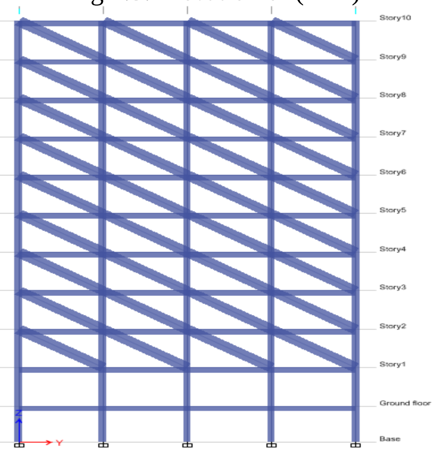

Fig.2.4: Elevation of (OGS-F)

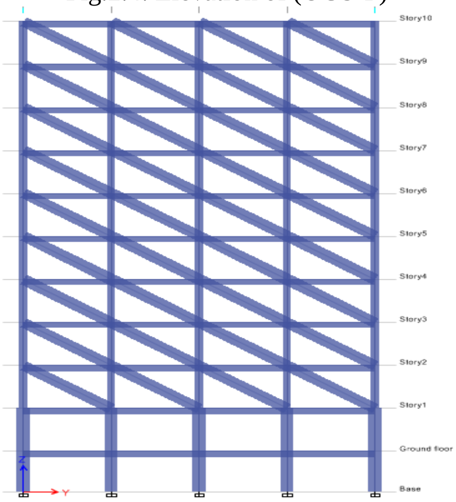

Fig.2.5: Elevation of (OGS-SC)

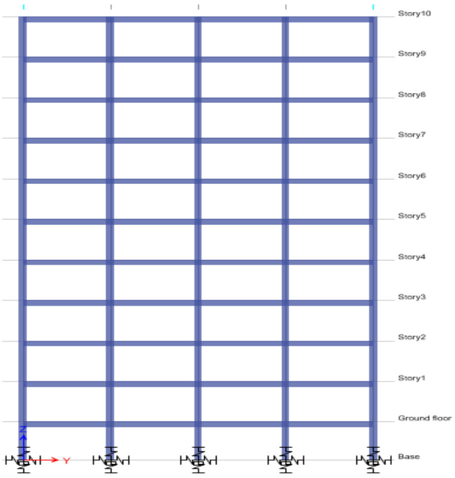

Fig.2.6: Elevation of Bare Frame Model with Flexible Base

III. RESULT AND DISCUSSION

The results are obtained by the analysis of different structural forms in ETABS. The results are in the form of graphs. In this section, based on the results obtained for different structural forms, parametric comparison is made.

A. Base Shear

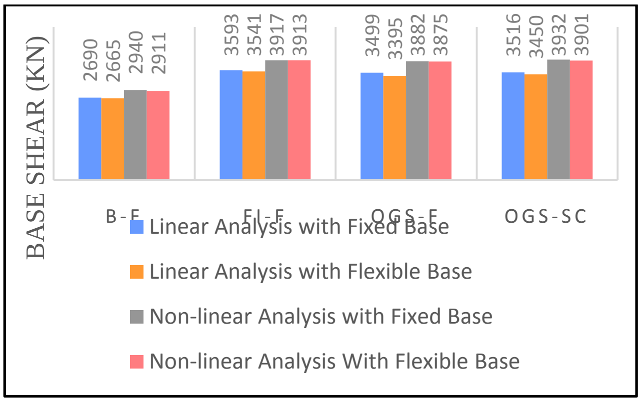

Fig. 3.1: Base shear for different structural forms and analysis.

For all four structural forms, base shear obtained by pushover analysis is higher than base shear obtained by linear analysis and Base shear for frames with flexible base is 1.79% lower in linear analysis and 0.5% in non-linear analysis than the corresponding values for frames with fixed base.

B. Top Storey Displacement

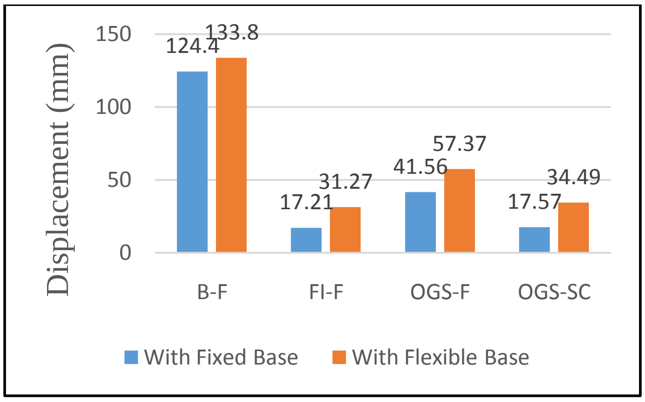

Fig.3.2: Top storey Displacement for different Structural forms

Top storey displacement for frames with flexible base is higher than corresponding top displacement values for frames with fixed base. The average increase in top displacement is about 32.25%.

C. Maximum Storey Drift

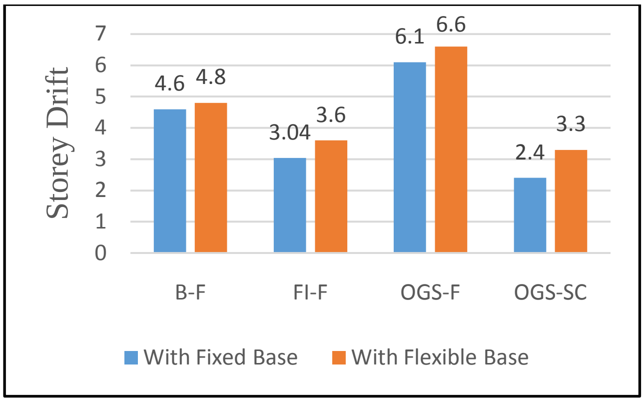

Fig.3.3: Maximum Storey Drift for different Structural forms

Drift demand is largest in open ground storey frame. Maximum storey drift increases by average 14% when soil-flexibility is added.

D. Modal Time Period

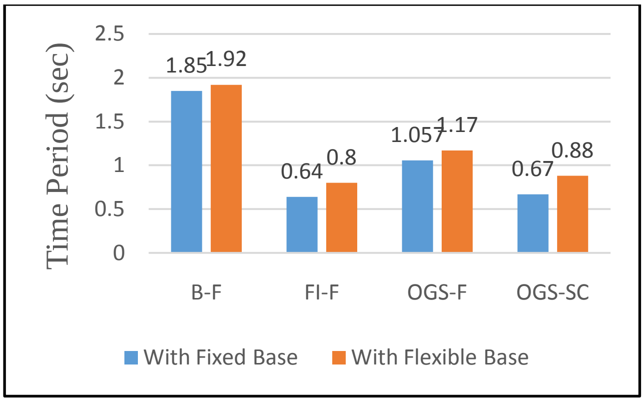

Fig.3.4: Modal Time Period for different structural forms

Modal time period is maximum in bare frame and it goes on decreasing as stiffness increases. Modal time period for frames with flexible base is higher than frames with fixed base. The average increase in time period is about 14.27%.

E. Performance Point :

Table 5.1: performance Point for different structural forms

A	B	C	D	E
1.	B-F (i)	2940.23	227	2.433
	B-F (ii)	2911.40	236	2.488
2.	FI-F (i)	3916.87	331	3.685
	FI-F (ii)	3913.32	348	3.765
3.	OGS-F(i)	3881.69	327	3.656
	OGS-F (ii)	3875.60	343	3.731
4.	OGS-SC(i)	3932.04	352	3.333
	OGS-SC(ii)	3900.67	364	3.401

(A) Sr. No.(B)Models (C)Base Shear (D) Monitored Displacement (E)Effective time period (i) Fixed Base (ii) Flexible Base.

Performance point for frames with flexible base is lower than corresponding values for frames with fixed base. The monitored Displacement values are increases when soil-flexibility is added.

CONCLUSION

In present study, different structural forms are modelled and analyzed with different methods considering the effect of soil-structure interaction. Based on parametric results and comparison, the following conclusions are made :

Linear Analysis:

- Base shear of bare frame is minimum and fully infill frame is maximum.
- Top storey displacement of OGS frame is 58% more than top storey displacement in fully infill frame.
- Storey drift is approximately doubled for OGS frame compared to infill frame. It is because ductility demand is largest in open first storey column.
- Modal time period of OGS frame is increased by 38% as compared with fully infill frame due to decrease in stiffness at soft storey.

Pushover Analysis:

- Frames are analysed by pushover analysis in X and Y directions. The base shear value is 10% higher for the pushover analysis as compared to equivalent static method
- The performance point for FI-F and OGS-SC is almost same. Due to the provision of stiffer column, OGS-SC frame behaves same like infilled frame. Hence damage get reduced.

Soil-structure interaction:

- Base shear values are marginally decrease for all models in linear analysis as well as non-linear analysis when soil-structure interaction is considered.
- Top storey displacement is 32.25% increased when soil flexibility is added to models.
- Soil-flexibility increases the force and drift demands in columns by 14%.
- Monitored displacement is increases while base shear is decreases in pushover analysis by adding the soil-flexibility.

On basis of structural parameters studied, the general conclusions are:

- Provision of stiffer columns provides the adequate strength to open ground storey columns hence it improves the behavior of structure.
- Soil flexibility need to examine before finalizing the design of structure.

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