Nonlinear performance assessment of bareframe and bareframe with shear wall resting on flexible 3D soil base (Continuum method)

[1]Deepa S, [2] S.V.Venkatesh,[3] I.R.Mithanthaya
[1]Senior scale Lecturer,[2] Professor,[3]Professor
[1]Department of Civil Engineering,
[1]DACG Government Polytechnic, Chickkamagalore, Karnataka, India

Abstract : The principle objective of this paper is to assess the behavior of a regular bare frame with Lateral load resisting system (LLRS) resting on flexible 3D soil base analyzed by Nonlinear analysis. Considering fixed base and performing linear analysis is conventional method of analysis. But subjecting the same building to nonlinear analysis and studying the response of the building is very necessary. This is because the behavior of the building when subjected to any load is usually nonlinear. A 3D model of ten storey building with flexible soil base is selected. The building is of 25mx25m with base resting on 3D soil base [Continuum method] and is analyzed for nonlinear pushover analysis. The 3D model is modeled using SAP 2000 V.19.2.1 software. The second model is bare frame with LLRS resting on 3D soil base. The LLRS adopted is a shear wall. In this the shear wall is modeled as shell elements layered with nonlinear material behavior. The nonlinearity is incorporated by applying reinforcement to shear wall. The shear wall is provided at ends and the model is subjected to nonlinear analysis to study the behavior of hinges. The results obtained of both bare frame and bare frame with LLRS is compared and tabulated. The results in case of displacement, base force, number of hinges and time period are studied. The results indicate that shear wall provided at ends shows better performance.

Index Terms – **Nonlinear Pushover analysis, Hinges, Shear wall, Continuum method.**

INTRODUCTION

Nonlinear analysis: Material non-linearity in frame sections is by frame non-linear hinge properties. Hinges are the points on a structure where one expects cracking and yielding to occur in relatively higher intensity so that they show high flexural or shear displacement, as it approaches ultimate strength. Hinges can be of various types. It can be an uncoupled flexural, shear or axial hinge or can be a coupled hinge (like PMM). Basically a hinge represents localized force-displacement relation of a member through its elastic and inelastic phases under seismic loads. For example, a flexural hinge represents the moment rotation relationship for a beam section
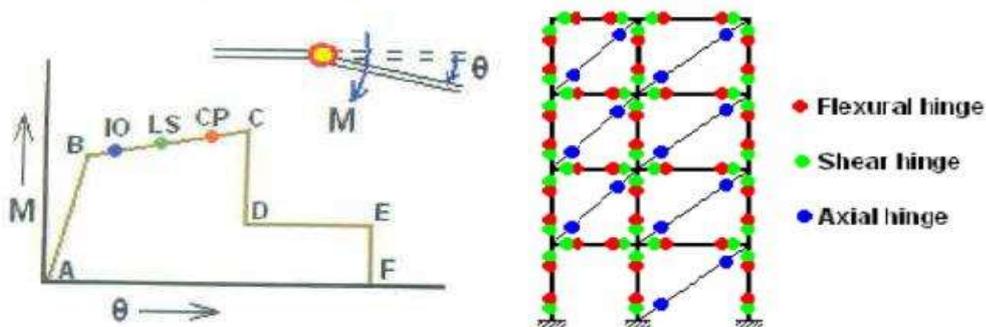

Fig. 1.1 : A typical flexural hinge (Courtesy taken from Ref. 51)

A typical flexural hinge is shown in Fig.1.1 where "AB" represents the linear range from the unloaded state (A) to its effective yield (B), followed by an inelastic but linear response of reduced stiffness from B to C. CD shows a sudden reduction in load

resistance, followed by the reserve capacity DE and finally, total loss of resistance from E to F. These hinges have non-linear states defined as "Immediate Occupancy" (IO), "Life Safety" (LS) and "Collapse Prevention" (CP) within the ductile region (BC).Default hinge properties can be selected from the charts of average value included in the standards ASCE 41-13 which are rough estimates.

Backbone Curve (Action vs. Deformation) In case of each material, hinge, or link degree of freedom, a uniaxial action vs. deformation curve defines the nonlinear behavior under monotonic loading in the positive and negative directions. For materials, stress vs. strain, for hinges and multi-linear links, force vs. deformation or moment vs. rotation, depends upon the degree of freedom to which it is applied. In case of each model, the uniaxial action-deformation curve is specified by a set of points that you describe. This curve is called the backbone curve, and it can take on almost any shape. The given curve defines the action-deformation relationship under monotonic loading. The first slope on either side of the origin is elastic, the remaining segments define plastic deformation

Soil Structure Interaction: "SSI is the phenomenon that involves the analysis of the relationship between the structure and the soil, and how it affects the motion of the structure during earthquake. Many design codes have suggested that the effect of SSI can be neglected for the seismic analysis of the structures. This false apprehension about SSI actually stems from the opinion that SSI reduces the overall seismic response of a structure. This overview is valid for certain class of structures and soil conditions, such as light structures in stiff soil. The SSI can have a harmful effect on the structural response, and neglecting SSI in the analysis may lead to unsafe design. Soft soil sediments can significantly elongate the period of seismic waves and the increase in natural period of structure which may lead to the resonance with the long period ground vibration. Additionally, few study showed that ductility demand can drastically increase with the increase in the natural period of the structure due to SSI effect. The permanent deformation and failure of soil may further worsen the seismic response of the structure. The effect of soil flexibility is generally ignored in seismic design of building and the design is usually carried out based on the results of dynamic analysis considering the column ends to be fixed or rigid. However as the column foundation rest on soil system which is flexible, it is necessary that the dynamic inter relationship between soil and structure has to be taken into account in the seismic analysis of the structure. Using thorough numerical analyses, Mylonakis and Gazetas shows that increase in natural period of structure due to SSI is not always beneficial as suggested by the simplified design spectrums. Soft soil sediments can significantly elongate the period of seismic waves, and the increase in natural period of structure may lead to the resonance with the long period ground vibration."

"Continuum method (CM) Is a 3D-elastic half-space discretized using FE as solid elements). The flexibility of soil is modeled by CM of soil which is considered as isotropic, homogenous elastic half space (3D) for which dynamic shear modulus and Poisson's ratio are the inputs. The finite element idealization of CM model is carried out using eight nodded element (SOLID) having three degrees of freedom of translation in the respective co-ordinate directions at each node. In order to fix the region of soil below and around the foundation which influence the soil behavior it is necessary to consider pressure Isobars based on the Boussinesq equation (Bowles 1988). Based on this, CM model for soil is represented by considering breadth equal to twice the width of the foundation along the plan dimension and thrice the width of foundation along the depth of foundation. Trial analyses with few variations with respect to above considerations of size of soil medium were carried out in order to fix the region of soil below and around the foundation to realistically represent continuum model. Finally region of soil thickness of 2.5 times the least width below and around the foundation was considered to represent the continuum model. During analysis, bottom boundary is fixed while lateral translation is arrested at vertical boundaries of the soil medium".

Shear wall: "Shear walls are used as rigid, shear tolerating walls. These walls can be external or internal walls around lift. They are classified as short, squat or cantilever according to their height to depth ratio. The shape and plan location of the shear wall affects the performance of the structure. The best location for the shear wall is in the centre of each half of the building. This is not often sensible, however, since it consumes the space, they are positioned at the ends. The shape and location of the walls give excellent flexural stiffness in the short direction, but depends on the stiffness of the frame in the other direction. The location provides good flexural stiffness in both directions, but may cause problems from restraint or shrinkage.

PRESENT PROBLEM: A 3D model of ten storey building with flexible soil base is selected. The building is of 25mx25m with base resting on 3D soil base [Continuum method] and is analyzed for nonlinear pushover analysis. The 3D model is modeled using SAP 2000 V.19.2.1 software. The second model is bare frame with LLRS resting on 3D soil base. The LLRS adopted is a shear wall. In this the shear wall is modeled as shell elements layered with nonlinear material behavior. The nonlinearity is incorporated by applying reinforcement to shear wall. The shear wall is provided at ends and the model is subjected to nonlinear analysis to study the behavior of hinges.

RESULT & DISCUSSION:

1.1 Bare frame with flexible soil base: The results of BF is as discussed below.

Pushover Capacity curve: The Fig.1.2 shows Pushover capacity curve and Table 1.1 gives values of capacity of the building. The Fig. 1.1 shows capacity curve which is linear indicating it is in elastic state up to a certain point and then it changes shape with increase in displacement and Base force. It is observed that the curve doesn't drop down which indicates the capacity of the building is more. The Table 1.1 shows results of the capacity curve. Initially the building is in elastic state till step 2, with a displacement of 0.01m, load of 1308.97kN and 1920 hinges lying in A-B state. From step 3 to step 24 the building is in B-IO state with 444 hinges showing a displacement of 0.0135m and a load of 7466kN. From step 25 to step 56 the building is in IO-LS failure state with a displacement of 0.333m and base force of 13586.48kN. From step 57 to step 70 the building reaches LS-CP and C-D state. The building terminates at C-D state with a displacement of 0.44m and Base force of 16295.33kN. Overall it is observed that there is no sudden change in the shape of the curve
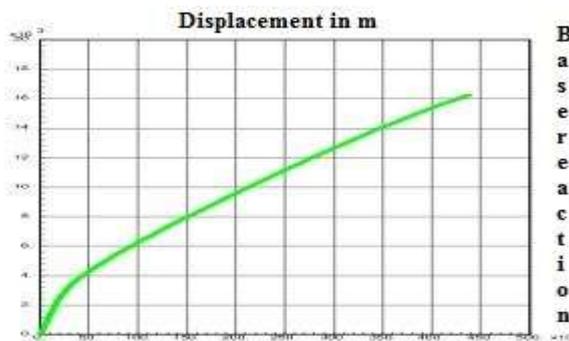
Fig. 1.2 Pushover Capacity curve

|											
Table1.1 Pushover Capacity curve
Step	Displace 'm'	"Base .Force 'kN'"	"AB"	"B IO"	"IO LS"	"LS CP"	"CP C"	"CD"	"DE"	"Bey E"	Total
0	0.000	0	1920	0	0	0	0	0	0	0	1920
1	0.005	654	1920	0	0	0	0	0	0	0	1920
2	0.010	1309	1920	0	0	0	0	0	0	0	1920
3	0.012	1622	1917	3	0	0	0	0	0	0	1920
24	0.135	7466	1476	444	0	0	0	0	0	0	1920
25	0.140	7631	1476	440	4	0	0	0	0	0	1920
56	0.333	13586	1348	284	288	0	0	0	0	0	1920
57	0.341	13829	1322	306	290	2	0	0	0	0	1920
59	0.355	14208	1302	306	308	4	0	0	0	0	1920
60	0.362	14387	1280	324	312	2	0	2	0	0	1920
61	0.370	14616	1268	336	312	0	0	4	0	0	1920
70	0.440	16295	1174	402	246	0	0	98	0	0	1920

Deformed shape of building
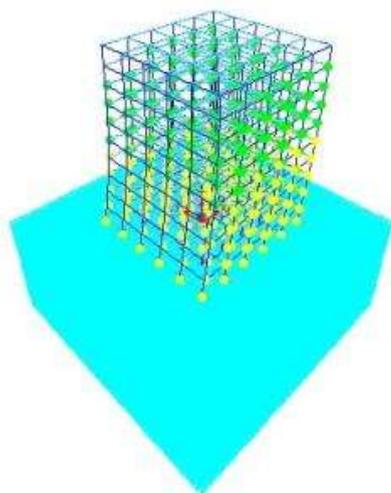
Fig.1.3 Step 56 IO-LS state   Fig. 1.4 Step 70 C-D state
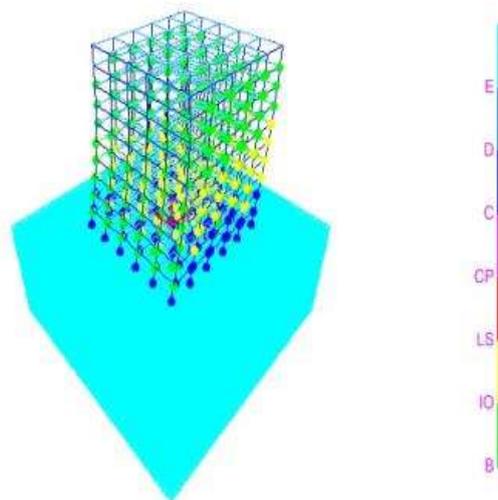
The Fig.1.3shows deformed shape of the building at step 56 where the building reaches IO-LS state indicated by yellow colour. The Fig.1.4 shows that step 70 the building reaches C-D state indicated dark blue colour. The diagram indicates that the failure state is observed at bottom floors. This indicates that the building has be retrofitted to shift the failure state to Life safety state.

1.2 Bare frame with shear wall at end & flexible soil base: The results of BF is as discussed below.

Pushover Capacity curve The Fig. 1.5 shows the capacity curve of the building. The Table 1.2 indicates the results of analysis at different failure stages when the building is pushed for a monitored displacement of 4.0m. The curve is linear and shows that the building has more capacity and does not drop the load.
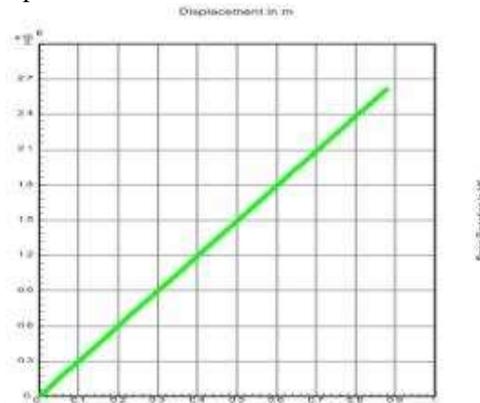

Fig.1.5 Pushover Capacity curve

From Table 1.2 it is seen that from step 0 to step 9, the building is in B-IO failure state with displacement of 0.190m and load of 571667.294kN. From step 10 to step 13 it reaches IO-LS state with a displacement of 0.283m and load of 847209kN. From Step 14 to step 42 the building reaches LS-CP and C-D state. The building reaches last step 42 at C-D state with a displacement of 0.881m and base force of 2625686kN. It is observed that along with increase in displacement the base force of the building also increases without drop in the load carrying capacity.

Step	Displace 'm'	Base force 'kN'	'AB'	'B IO'	'IO LS'	'LS CP'	'CP C'	'C D'	'D E'	'Bey E'	Total
0	0.000	0.00	1808	112	0	0	0	0	0	0	1920
1	0.022	66846.91	1780	140	0	0	0	0	0	0	1920
9	0.190	571667.29	1122	798	0	0	0	0	0	0	1920
10	0.212	635143.56	1098	816	6	0	0	0	0	0	1920
13	0.283	847209.67	1018	782	120	0	0	0	0	0	1920
14	0.308	922122.51	982	768	166	4	0	0	0	0	1920
15	0.331	989783.09	956	750	200	10	0	4	0	0	1920
16	0.354	1058213.02	918	758	222	6	0	16	0	0	1920
42	0.881	2625686.31	548	562	556	2	0	252	0	0	1920

Table: 1.2 Pushover Capacity Curve-200 Steps

Deformed shape of building :
The Fig 1.6 shows the deformed shape of the curve at step12, IO-LS state which is indicated by dark blue colour. Fig.1.7 at step 42, C-D state which is indicated by yellow colour.
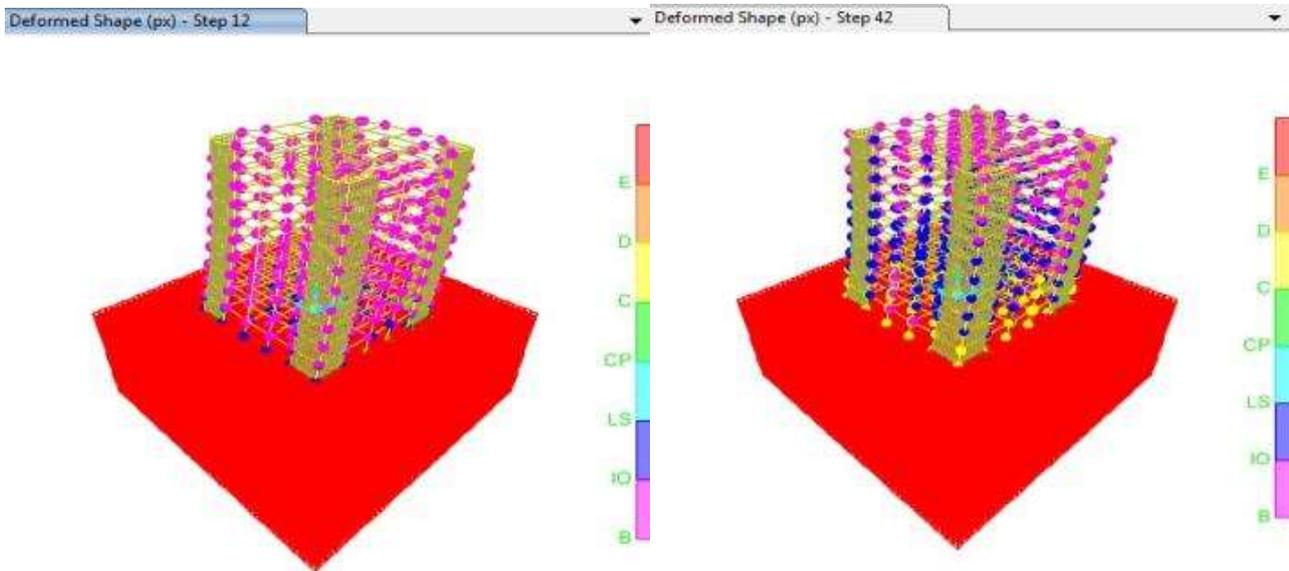
Fig. 1.6 Step 12, IO-LS state   Fig. 1.7 Step 42, C-D state

CONCLUSION:

1. The Capacity curve of BF- with shear wall at end is very stiff compared to BF. Capacity curve indicates the strength and stiffness of the building is high.

2. The deformed shape of BF shows the necessity to provide Shear wall.

3. BF with shear wall at end carries greater base force and minimum displacement compared to BF alone.

REFERENCES:

[1] Rutvij Kadakia, Vatsal Patel and Ansu Arya, "Modelling and analysis of irregular geometrical configured RCC multi-storey building using shear wall", ICRISET2017, International Conference on Research and Innovations in Science Engineering & Technology, Volume 1, 2017, PP 388-397

[2] Omar K.Al-Kubaisi, Aqeel Fadhil, Salah R.Al-Zaide, " Using Finite Element to Modify Winkler Model for raft foundation supported on dry granular soils" , IJSR :2319-7064 Index Copernicus value (2015) :78.96 Impact factor (2015):6. Vol 6 Issue 4, April 2017, pp130-135

[3] Mohammed zubair and B R Shilpa, " A Parametric study of soil structure interaction of raft foundation by using dynamic analysis", International Journal of Engineering Science Invention Research & Development , www.ijesird.com, e-ISSN: 2349-6185, Vol. III, Issue I July 2016/68

[4] Kolaki A I, Gudadappanavar B M "Analysis of performance point of the 15- storey framed structure considering soil structure interaction" International Journal of Engineering research and technology, Vol5, Issue-7, July 2016, PP 405-410

[5] Vinayak Garag, Mrs. S Karuna, "Effect of Soil-Structure Interaction on Regular and Irregular, Medium RC Framed Structure", International Journal of Science, Engineering and Technology Research (IJSETR) Volume 5, Issue 5, May 2016

[6] M.N.Bajad, Mr. Rahul Sawant, "Effect of Soil structure Interaction on High rise RC building", IOSR Journal of Mechanical and Civil engineering, ISSN:2320-334x, Vol13, Issue1 Ver.irr (Jan-Feb2016) , PP 85-91