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Pushover Analysis of G+20 Building with Strut and without Strut

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Abstract*—Pushover analysis is an approximate analysis method in which the structure is subjected to monotonically increasing lateral forces with an invariant height wise distribution until a target displacement is reached. Pushover analysis consists of a series of sequential elastic analysis, superimposed to approximate a force displacement curve of the overall structure. A two or three dimensional model which includes bilinear or tri-linear load-deformation diagrams of all lateral force resisting elements each first created and gravity loads are applied initially. A predefined lateral load pattern which is distributed along the building height is then applied. The lateral forces are increased until the some members yield. The structural model is modify to account for the reduced stiffness of yielded members and lateral forces are again increased until additional members yield. The process is continued until a control displacement at the top of building reaches a certain level of deformation or structure becomes unstable. The roof displacement is plotted with base shear to get the global capacity curve. In present study, analysis performed using ETABS nonlinear version 9.7.2. A three dimensional model of the structure has been define as a frame element. Define plastic hinges at both ends of beams and column. The nonlinear properties of plastic hinges are to be given as ETABS 9.7.2. A strut is a structural component designed to resist longitudinal compression. Struts provide outwards facing support in their lengthwise direction, which can be used to keep two other components separate, performing the opposite function of tie. Frequently struts are found in roof framing from either a tie beam or a king post to principal rafter. In this project we are providing strut to the G+20 building and analyzing the building by pushover analysis. Earthquake causes the random ground motions in all directions, radiating from epicenter. These ground motions causes structure to vibrate and induces inertia forces in them. In India majority of the existing RC structure do not meet the current seismic code requirements as these are primarily designed for gravity loads only so it is important to construct building with the consideration of earthquake load.

Keywords—radiation; conductivity;carbonation; corrosion; Euro-code

I. INTRODUCTION

Pushover analysis can be performed as force-controlled or displacement-controlled. In force-controlled pushover procedure, full load combination is applied as specified, that is, force-controlled procedure should be used when the load is known. Also, in force-controlled pushover procedure some numerical. Problem that affect the accuracy of results occur since target displacement may be associated with a very small positive or even a negative lateral stiffness because of the development of mechanism and P-delta effect. Pushover analysis is the preferred tool for seismic performance evaluation of a structure by the major rehabilitation guideline and codes because it is conceptually and computationally simple. Pushover analysis allows tracing the sequence of yielding and failure on member and structural level as well as the progress of overall capacity curve of the structure.[3]from localized surface spilling to major structural deterioration depending on the nature of combustible material and duration of exposure. Visual assessment of pattern of concrete provides valuable information by which an assessment can be made. One of the advantages of concrete over other building materials is its inherent fire-resistive properties. Fire resistance can be defined as the ability of structural elements to withstand fire or to give protection from it. However, concrete structures must still be designed for fire effects structural components must still be able to withstand dead & imposed loads without collapse even though the rise in temperature causes a decrease in the strength & modulus of elasticity for concrete & steel reinforcement. There is an urgent need to gather additional information about performance of R.C.C. under fire in order to create a general awareness & improve the existing practices & Codal provisions.

Pushover analysis is an approximate analysis method in which the structure is subjected to monotonically increasing lateral forces with an invariant height wise distribution until a target displacement is reached. Pushover analysis consists of a series of sequential elastic analysis, superimposed to approximate a force displacement curve of the overall structure. A two or three dimensional model which includes bilinear or tri-linear load-deformation diagrams of all lateral force resisting elements each first created and gravity loads are applied initially. A predefined lateral load pattern which is distributed along the building height is then applied. The lateral forces are increased until the some members yield. The structural model is modify to account for the reduced stiffness of yielded members and lateral forces are again increased until additional members yield. The process is continued until a control displacement at the top of building reaches a certain level of deformation or structure becomes unstable. The roof displacement is plotted with base shear to get the global capacity curve.

The innovative and revolutionary new ETABS is the ultimate integrated software package for the structural analysis and design of buildings. Incorporating 40 years of continuous research and development, this latest ETABS offers unmatched 3D object based modeling and visualization tools. Finite element method is a numerical method that can be used to solve different kind of engineering problem in stable, transient, linear or nonlinear cases. Among finite element software method, ETAB is one of the most precise and practicable software in industry and university researches. It is used for dynamic analysis such as earthquake and water wave loading structures. ETAB is a stand-alone finite element based structural program for analysis and design of civil structures. It offers an intuitive yet powerful user interface with many tools to aid in the quick and accurate construction of models, along with the sophisticated analytical techniques needed to do the most complex projects [1-3].

The nonlinear analysis of a structure is an iterative procedure. It depends on the final displacement, as the effective damping depends on the hysteretic energy loss due to inelastic deformations, which in turn depends on the final displacement. This makes the analysis procedure iterative. Difficulty in the solution is faced near the ultimate load, as the stiffness matrix at this point becomes negative definite due to instability of the structure becoming a mechanism. Extended Three Dimensional Buildings Systems (ETABS) and Structural Analysis Program finite element program that works with complex geometry and monitors deformation at all hinges to determine ultimate deformation. It has built-in defaults for ACI 318 material properties and ATC-40 and FEMA 273 hinge properties. The analysis in ETABS 9.7 involves the following four steps.1) Modeling, 2) Static analysis, 3) Designing, 4) Pushover analysis.

Steps used in performing a pushover analysis of a simple three-dimensional building. ETABS 9.7 general purpose, three-dimensional structural analysis program, is used as a tool for performing the pushover.

The following steps are included in the pushover analysis.

• Creating the basic computer model in the usual manner.

• Define properties and acceptance criteria for the pushover hinges. The program includes several built-in default hinge properties that are based on average values from ATC-40 for concrete members. These built in properties can be useful for preliminary analyses, but user defined properties are recommended for final analyses.

• Locate the pushover hinges on the model by selecting one or more frame members and assigning them one or more hinge properties and hinge locations.

• Define the pushover load cases. In ETABS 9.7 more than one pushover load case can be run in the same analysis. Typically a gravity load pushover is force controlled and lateral pushovers are displacement controlled.

• Run the basic static analysis and, if desired, dynamic analysis. Then run the static nonlinear pushover analysis.

• Display the pushover curve and the table.

• Review the pushover displaced shape and sequence of hinge formation on a step-by step basis.

A step-by-step procedure for modeling and analysis of frame structure using ETABS is explained through a simple example. Subsequently an example of seismic analysis of regular frame structure and irregular frame structure are solved through ETABS.

A plan of G+20 storey reinforced concrete (RC) frame structure is considered for modeling and analysis using ETABS [1].

II. PUSH-OVER ANALYSIS

In this paper, two models of building (G+20) storey without strut, (G+20) storey with strut, RC two models of building (G+20) storey without strut, (G+20) storey with strut, RCC structure are considered for analysis. Building has plan 30m x 20m as shown in Figure 1.1 slab is modeled as rigid diaphragm. Building is symmetric with respect to stiffness and mass. Nonlinear time history analysis is carried out in ETAB software. The Plan is depicted in the elevation of 20-storey with and without strut are shown. C structure are considered for analysis. Building has plan 30m x 20m as shown in Figure 1.1 slab is modeled as rigid diaphragm. Building is symmetric with respect to stiffness and mass. Nonlinear time history analysis is carried out in ETAB software. The Plan is depicted in the elevation of 20-storey with and without strut are shown.

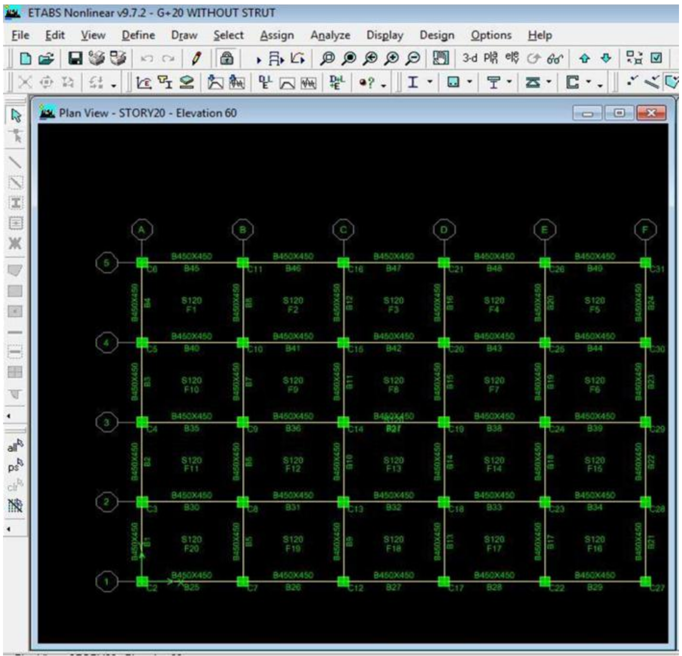

Fig. 1. Plan of Building Frame

A generic plan of a typical building has been selected. The plan in one direction has large number of bays i.e., 5 and in other direction it has 4 bays. This type of plan has been selected to simulate different behaviour in longitudinal and transverse direction. In longitudinal direction there are 5 bays which indicate sufficient redundancy. Where as in transverse direction there are only 4 bays which represent comparatively lesser redundancy. The distance between each column on X direction is taken as 6m while the distance between each column in Y Direction is taken as 5m. The plan area of building is 30 x 20 m with 3m as height of each typical story In addition to this, the effect of infill walls will be prominent in longitudinal direction than in transverse direction. The comparative study of with strut building and without strut building is carried out.

The description of frame provided above include: No. of bays along X axis : 5, No. of bays along Y axis : 4, Spacing along X axis : 6m, Spacing along Y axis : 5m, Story height :

3m, No. of floor : G+20, Size of column : 600x600mm, Size of beam : 450x450mm, Slab thickness : 120mm.

III. PUSH-OVER ANALYSIS METHODOLOGY

Pushover analysis is a static, nonlinear procedure in which the magnitude of the lateral force is incrementally increased, maintaining the predefined distribution pattern along the height of the building. With the increase in the magnitude of the loads, weak links and failure modes of the building are found. Pushover analysis can determine the behaviour of a building, including the ultimate load and the maximum inelastic deflection. Local Nonlinear effects are modelled and the structure is pushed until a collapse mechanism gets developed. At each step, the base shear and the roof displacement can be plotted to generate the pushover curve. It gives an idea of the maximum base shear that the structure was capable of resisting at the time of the earthquake. For regular buildings, it can also give a rough idea about the global stiffness of the building [4-5].

Response characteristics that can be obtained from the pushover analysis are summarized as follows:

1) Estimates of force and displacement capacities of the structure. Sequence of the member yielding and the progress of the overall capacity curve.

2) Estimates of force (axial, shear and moment) demands on potentially brittle elements and deformation demands on ductile elements.

3) Estimates of global displacement demand, corresponding inter-storey drifts and damages on structural and non-structural elements expected under the 20 earthquake ground motion considered.

4) Sequences of the failure of elements and the consequent effect on the overall structural stability.

5) Identification of the critical regions, when the inelastic deformations are expected to be high and identification of strength irregularities (in plan or in elevation) of the building. Pushover analysis delivers all these benefits for an additional computation effort (modeling nonlinearity and change in analysis algorithm) over the linear static analysis.

A displacement-controlled pushover analysis is basically composed of the following steps:

1) A two or three dimensional model that represents the overall structural behavior is created.

2) Bilinear or tri-linear load-deformation diagram of all important members that affect lateral response are defines.

3) Gravity loads composed of dead loads and a specified portion of live loads are applied to the structural model initially.

4) A pre-defined lateral load pattern which is distributed along the building height is then applied.

5) Lateral loads are increased until some member(s) yield under the combined effects of gravity and lateral loads.

6) The structural model is modified to account for the reduced stiffness of yielded member(s).

7) Gravity loads are removed and a new lateral load increment is applied to the modified structural model such that additional member(s) yield. Note that a separate analysis with zero initial conditions is performed on modified structural model under each incremental lateral load. Thus, member forces at the end of an incremental lateral load analysis are obtained by adding the forces from the current analysis to the sum of those from the previous increments. In other words, the results of each incremental lateral load analysis are superimposed.

8) Similarly, the lateral load increment and the roof displacement increment are added to the corresponding previous total values to obtain.

9) Steps 7, 8 and 9 are repeated until the roof displacement reaches a certain level of deformation or the structure becomes unstable [5].

IV. TIME HISTORY ANALYSIS

Static procedures are appropriate when higher mode effects are not significant. This is generally true for short, regular building. Therefore, for tall Buildings, building with torsional irregularities, or non-orthogonal systems, a dynamic procedure is required. There are two types of dynamic analysis; response spectrum analysis and linear dynamic analysis i.e. time history analysis. Although the spectrum method, outline in the previous section, is a useful technique for the elastic analysis of structure, it is not directly transferable to in elastic analysis because the principle of superposition is no longer applicable. Also, the analysis is subject to uncertainties inherent in the model superposition method. The actual process of combining the different model contribution is a probabilistic technique and, in ascertain cases, it may lead to result not entirely representative of the actual behaviour of the structure. The THA technique represents the most sophisticated method of dynamic analysis for buildings. In this method, the mathematical model of the building is subjected to acceleration from earthquake records that represent the expected earthquake at the base of the structure. The method consist of step by step direct integration over a time interval; the equation of motion are solved with the displacements, velocities, an acceleration of the previous steps serving as initial functions [5-8].

The time history method is applicable to both elastic and inelastic analysis in elastic analysis the stiffness characteristic of the structure are assumed to be constant for the whole duration of the earthquake. In the inelastic analysis, however, the stiffness is assumed to be constant through the incremental time only. Modification to structural stiffness caused by cracking, formation of plastic hinges etc., are incorporated between the incremental solutions. [9] Even with the availability of the sophisticated computer, the use of this method restricted to the design of special structure such as nuclear facilities, military installation, and base isolated structures [10-12].

V. RESULTAND DISCUSSION

Results obtained for (G+20) Storey Building with Strut and without strut are as follows:

1. Base shear

Base shear in X direction in building with strut = 4256.785 KN and in building without strut = 2512.456 KN

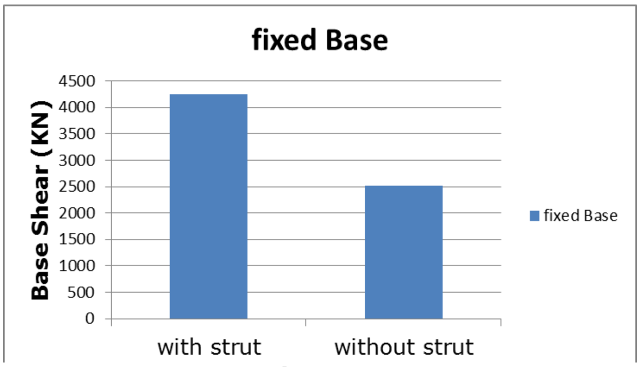

Fig. 2. Base Shear in X-Direction

Base shear in X direction in building with strut = 4987.4564 KN and in building without strut = 3125.8542 KN

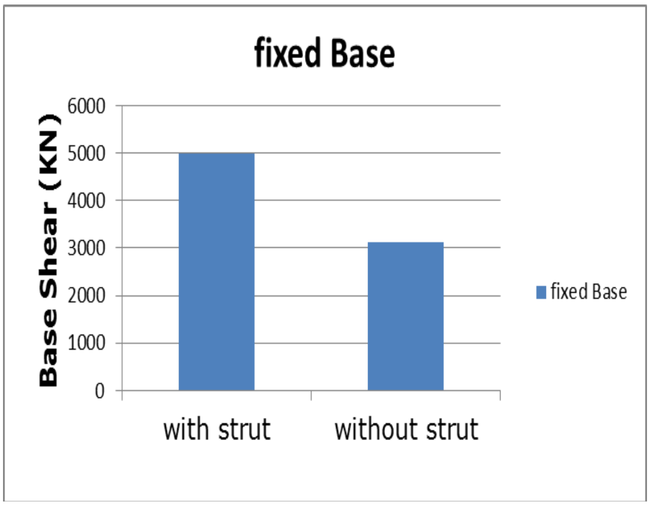

Fig. 3. Base Shear in Y-Direction

2. Storey Displacement

Storey displacement in X direction in building with strut = 72 mm and in building without strut = 167.5 mm

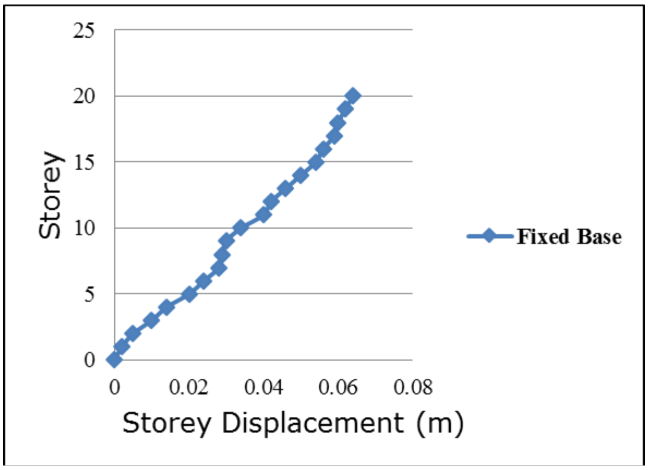

Fig. 4. Base Shear in Y-Direction

Storey displacement in Y-direction in building with strut = 52 mm and in building without strut = 128 mm

It has been clearly observed from the chart for the symmetric structure with strut it started with the immediate occupancy stage with the formation of 20 element hinges in this performance level. The structure remains in this "immediate occupancy" performance level till the displacement reached 52mm than that of the structure without strut with the displacement of 128mm [4].

3. Time Period Comparisons

The effective Time Period for (G+20) Structure with Strut at the performance point is 2.42 sec.

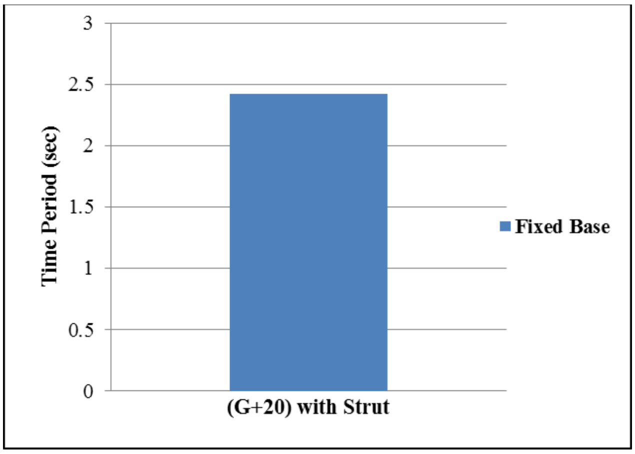

Fig. 5. Time Period for (G+20) Storey Structure with Strut

The effective Time Period for (G+20) Structure without Strut at the performance point is 3.83 sec.

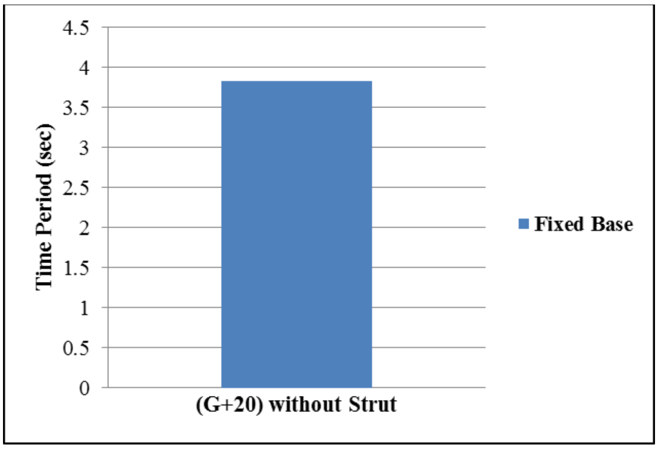

Fig. 6. Time Period for (G+20) Storey Structure without Strut

3.Pushover Curve

The Structure has been given in a Pushover curve x-direction for the Structure was graphically generated for both the symmetric building with strut and without strut.

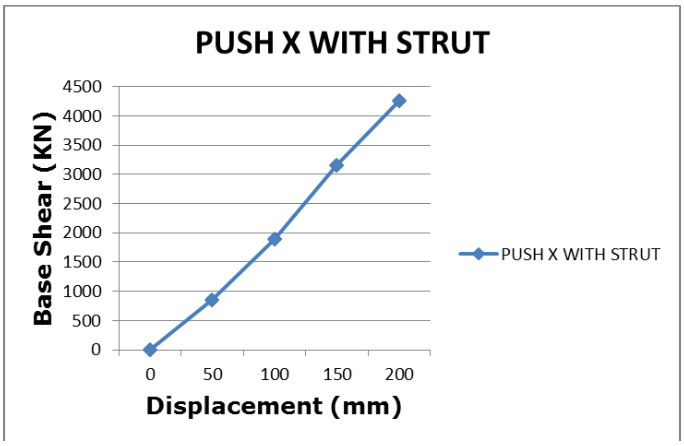

Fig. 7. Pushover curve in with strut

The Structure has been given in a Pushover curve Y-Direction for the Structure was graphically generated for both the symmetric building with strut and without strut.

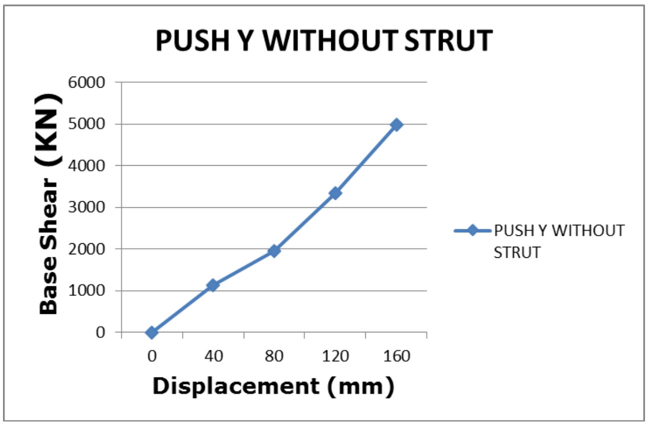

Fig. 8. Pushover curve in without strut

VI. CONCLUSION

After having perform the pushover analysis on two different building with strut and without strut following conclusion are drawn

1) In symmetrical building based on the performance point obtained from pushover curve and same building with strut the value of base share is found increased by 41% and the amplitude and displacement found by reduced by 36%.

2) The result of the present study shows that the strut in building have very important effect on structural behavior under earthquake effect.

3) The pushover analysis proves to be efficient tool for studying the behavior of the structure in non-linear zone.

4) Based on the above study it is felt that introduction of strut is one proven method of structural retro fitting.

VII.SCOPE FOR FUTURE WORK

1) Single strut model for infills can accurately predict the lateral stiffness and strength of RCC infill RC frame. However use of single strut can only take into account its compressive failure; it can't predict local failure in frame member. Single strut models underestimate the force resultant in frame member.

2) In the present study, opening were not considered in infills. Presence of opening in infills significantly reduces the stiffness and strength of the unfilled framed. Suitability of the proposed strengthening schemes must be verified for masonary infilled frames with openings with walls.

3) Also for future work, nonlinear dynamic analysis (time history analysis is best method for analyzing the strengthening methods like friction dampers.

4) The experimental work should be carried out on reduced scale 20 storey with first story without infilled wall under gradually increased cyclic lateral displacements to further verify the effectiveness of proposed strengthening schemes.

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