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AN ASSESSMENT OF SAFETY OF A REAL SIX STORIED R.C.C FRAME STRUCTURE BY NON LINEAR STATIC PUSHOVER ANALYSIS

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ABSTRACT

Though elastic analysis gives a good indication of the elastic capacity of the structures, it cannot predict the failure mechanisms when subjected to major earthquake where it is assumed that the elastic capacity of the structure will be exceeded. So, This paper aims to analyze a real six storied RCC building using non linear static pushover analysis to assess the safety of this building. A commercial software ETABS was used for non linear static analysis. From the analysis it had been found that the structure remained in the allowable limit for serviceability, Design and maximum Earthquake as per ATC-40. So, the analyzed building was safe in case of major earthquake. If the hinges formed in the frame during analysis crossed the collapse prevention (CP) then the appropriate retrofitting application would be required .

Keywords: *major earthquake, pushover Analysis, capasity spectrum, demand spectrum, safety.*

1. INTRODUCTION

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 (Oguz, 2005). It is the preferred method for seismic performance evaluation of structures by the major rehabilitation guidelines and codes because it is conceptually and computationally simple. It 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.

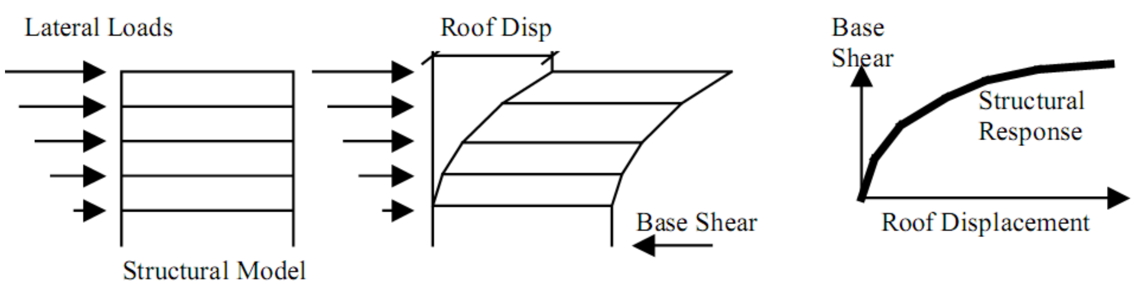

Figure 1: Static approximation used in the pushover analysis (Santhosh, 2014)

A major portion of state and local government RCC buildings in Dhaka are designed and constructed before and mid to late 1970s. The seismic performance of these older buildings has been observed to be relatively poor compared to the performance of modern, post 1970s concrete buildings (Sarfin, 2013). Accordingly a growing number of these buildings have been evaluated and retrofit in recent years and many more will be retrofit in the near future. So, This paper aims to analyze a real six storied RCC building using non linear static pushover analysis to assess the safety of this building considering of major earthquake in our country.

2. METHODOLOGY

A commercially available software ETABS 9.7.4 was used to model a existing building in Dhaka. Then the model was analyzed and designed as per BNBC code. Finally pushover analysis was carried out for that model according to ATC 40 with the help of ETABS. From the pushover analysis peak responces of the model for Seviceability, Design and Maximum earthquake were determined. Finally from the pushover curve and peak responces the performce of the model was judged.

3. ILLUSTRATIONS

3.1 Description Of The Frame Structure

The building used here for pushover purpose is a six storied R.C.C. building located at Plot No-1/E/1, Ring Road, Shyamoli, Dhaka-1207. All columns except lift column are 20 x 20 inch^2. The lift core column are of 17.5 x 17.5 inch^2. Again all beams are of 15 x 20 inch^2. Three dimensional model of the building is used for analysis. Building is designed as bare frame structure with strong column-weak beam condition. All supports are considered as fixed support. Slabs are assumed not to carry any moments from beams. Building is assumed to be intermediate moment resisting frame. Beams, columns and slabs are modeled as reinforced concrete members having the following material properties:

Concrete strength, f'_c=4000 psi

Yield strength of steel, f_y=60000 psi

Modulus of elasticity of concrete, E_c=3600 ksi

Modulus of elasticity of steel, E_s=29000 ksi

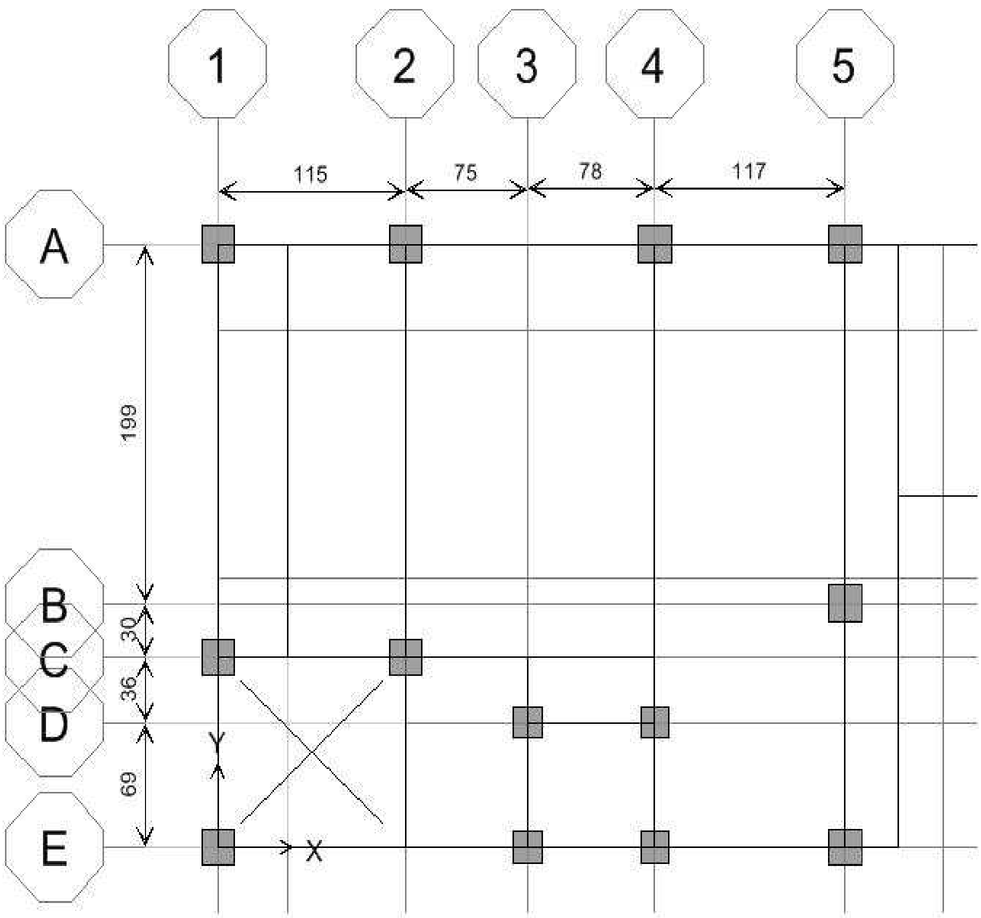

Figure 2 : Column and beam layout of the building (Faysal, 2013)

3.2 Loading:

Loading condition of the structure are provided in this section. Loading condition means assignment of dead, live, wind and earthquake load on the structure in additional of self weight. BNBC(2006) is followed for defining loads.

3.2.1 Dead Load

Self weight of different members of the building was calculated by the program itself. In addition to the self weight, 55 psf are considered for partition walls and floor finish. On the beams at the perimeter , 10″ thick brick wall is assumed and assuming 10% opening, 1.00 klf loads is considered. To calculate seismic weight full dead load is considered.

3.2.2 Live Load

40 psf live loads are considered in each floor specified for residential building as per BNBC. To calculate seismic weight no live load is considered in this study.

3.2.3 Wind Load

To strictly concentrate on the earthquake resisting capacity of the structure, wind load is not considered in this study.

3.2.4 Earthquake Load

Earthquake load is calculated as per BNBC (2006). Earthquake load is manually calculated and then added to the model as user defined load. The following factors and co-efficient are used -
Response Reduction Factor, R=8 (for IMRF structure)
Seismic Zone Co-efficient Z=0.15
Importance Factor, I=1.0
Soil Type=SC
Site Depended soil Factor, S=1.5

3.3 Assumptions for Pushover Analysis

For pushover analysis of the bare frame reinforced concrete structure , several assumptions have been made. These assumptions (Sarfin, 2013) are as follows:

- Pushover analysis is done using load pattern of equivalent static earthquake as per BNBC(2006) calculated manually.
- Gravity Load is considered as the previous case for each analysis.
- Unload entire structure is selected for distribution of loads when local hinges fail.
- Geometric nonlinearity effect (P-Delta effect) each analysis.
- Full DL and LL is considered.
- Horizontal displacement of topmost corner node has been selected for monitoring roof displacement.
- Moment (M_3) hinges and shear (V_2) are considered at each end of the beam and axial (P-M-M) hinges are considered at each end of columns.

3.4 Pushover Analysis

The pushover analysis involves following steps-

3.4.1 Define hinge properties

Frame nonlinear properties are used to define nonlinear force-displacement and/or moment rotation behavior that can be assigned to discrete locations along the length of frame elements. These nonlinear hinges are only used during static nonlinear analysis. For all other types of analysis, these hinges are rigid and have no effect on the linear behavior of element. There are three types of hinge properties in the software: Default hinge property, User defined hinge property and generated hinge property. Only default hinge property and user defined hinge property can be assigned to the frame elements. When a default or user defined hinge property is assigned to any frame element, it will automatically creates a new generated hinge property for each hinge. Default hinge properties are as per ATC-40 and FEMA 273.

3.4.2 Assigned hinge properties:

To assign hinge properties, after selection the frame elements, click the Assign menu > Frame/Line > Frame Nonlinear hinges. In this study default M_3 and Default V_2 hinges were assigned on beams whereas default P-M-M hinges was assigned to column.

3.4.3 Define static push over cases

Pushover analysis is a powerful feature available with the software. To add a static pushover cases, click the Define menu > Static Nonlinear/Pushover cases command. Then a Define static Nonlinear Cases form will be displayed. Select the Add new case button on the form. In ETABS 9.7 more than one pushover load case can be run in the same analysis. Also a pushover load case can start from the final conditions of another pushover load case that was previously run in the same analysis. Typically the first pushover load case is used to apply gravity load and then subsequent lateral pushover load cases are specified to start from the final conditions of the gravity pushover. Pushover load cases can be force controlled, that is, pushed to a certain defined force level, or they can be displacement controlled, that is, pushed to a specified displacement. Typically a gravity load pushover is force controlled and lateral pushovers are displacement controlled. ETABS 9.7 allows the distribution of lateral force used in the pushover to be based on a uniform acceleration in a specified direction, a specified mode shape, or a user-defined static load case. In this study Push 1 has done for gravity load and used in push 2 and push 3 respectively for subsequent lateral push over cases. But only data of push 2 has represented later as it governed over Push 3.

3.4.4 Run static nonlinear analysis

To run static nonlinear analysis, click the Analyze menu > Run static nonlinear analysis.

3.5 Earth Quake Ground Motion

It is the level of shaking that has a certain probabilityof occuring. There are three levels of shaking , namely Serviceability Earthquake (SE) , Design Earthquake (DE) and Maximum Earthquake (ME) as per ATC 40.

3.5.1 Serviceability earthquake (SE)

The Seviceability Earthquake (SE) is defined probabilistically as the level of ground shaking that has a 50 percent chance of being exceeded in a50-year period.

3.5.2 Design earthquake (DE)

The design Earthquake (DE) is defined probabilistically as the level of ground shaking that has a 10 percent chance of being exceeded in a 50-year period.

3.5.3 Maximum earthquake (ME)

The Maximum Earthquake (ME) is defined probabilistically as the level of ground shaking that has a 5 percent chance of being exceeded in a 50-year period.

3.5.4 Demand spectra

To establish the demand spectra for Serviceability Earthquake (SE) , Design Earthquake (DE) and Maximum Earthquake (ME) following parameters are considered .These parameters are calculated as per ATC-40(1996) .

Location of site	Dhaka city
Soil profile type	s_D (SC as per BNBC, 2006)
Near source factor	N_A=N_V=1 (as >15Km)
Seismic source type	C
Seismic zone factor	0.15 (Dhaka)
Earthquake hazard level	1
Structural behavior	Type B (that means average existing building and 5% effective damping)
Pushover procedure	Procedure B
Shaking Intensity (ZEN):	0.15 × 0.5 × 1 = 0.075 (for Serviceability Earthquake) 0.15 × 1.0 × 1 = 0.15 (for Design Earthquake) 0.15 × 1.5 × 1 = 0.23 (for Maximum Earthquake)
Seismic co efficient , C_A	0.12 (for Serviceability Earthquake) 0.22 (for Design Earthquake) 0.30 (for Maximum Earthquake)
Seismic co efficient , C_V	0.18 (for Serviceability Earthquake) 0.32 (for Design Earthquake) 0.44 (for Maximum Earthquake)

3.6 Performance Level And Objective

As per ATC 40 there are three performance levels, namely Immediate occupancy (IO) , Life safety (LS) and Collapse prevention (CP). The immediate occupancy performance level corresponds to low damage in a structure and small reduction on lateral stiffness and strength. The life safety performance level corresponds to important damage in a structure and a likely loss of initial stiffness; however, after this performance level, the structure has some lateral deformation capacity before reaching the collapse stage. The collapse prevention performance level is associated to the onset of total or partial collapse, and at this level the corresponding structural damage is important, but with enough resistance to gravity loads. The basic safety performance objective is to remain in life safety level at design earthquake and is to remain in structurally stable at Maximum earthquake (ATC 40,1996).

3.7 Force Deformation Behaviour of Hinges

The behaviour of hinges is represented in the following figure. There point A corresponds to unloaded condition whereas point B represents yielding of the element. Again, the ordinate at C corresponds to nominal strength and abscissa at C corresponds to the deformation at which significant strength degradation begins. But the drop from C to D represents the initial failure of the element and resistance to lateral loads. Beyond point C is usually unreliable. Again, the residual resistance from D to E allows the frame elements to sustain gravity loads. But, beyond point E, the maximum deformation capacity, gravity load can no longer be sustained.

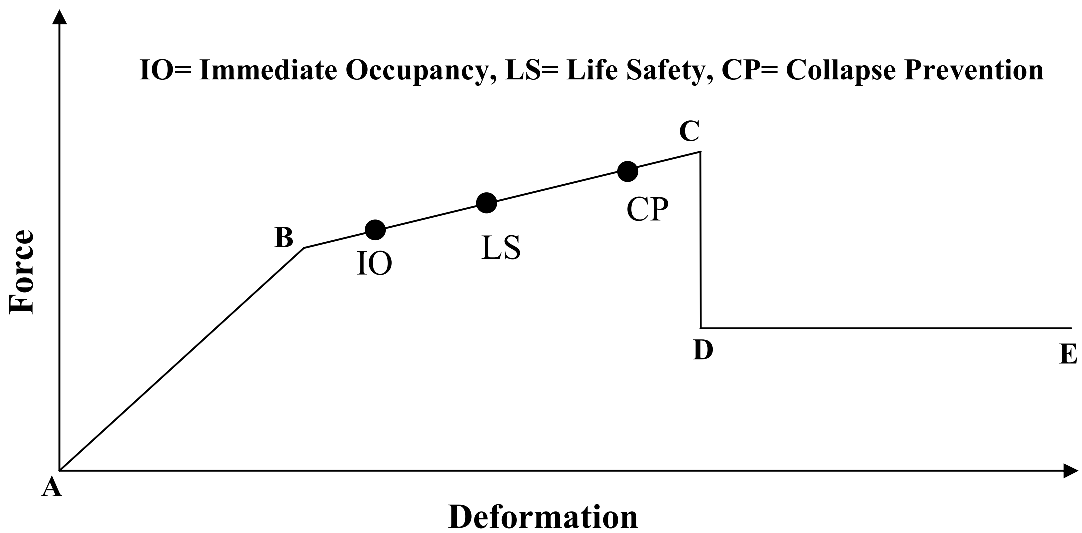

Figure 3 : Force deformation behaviour of hinges (Seo et al, 2015)

4. RESULT AND DISCUSSION

The mischelleneous of push 2 are given below :

Table 1: The mischelleneous of push 2

STEP	DISPLACEMENT (INCH)	BASE FORCE(KIPS)	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
0	0.0727	0	489	1	0	0	0	0	0	0	490
1	0.7078	138.8423	433	57	0	0	0	0	0	0	490
2	1.7702	361.06	311	150	29	0	0	0	0	0	490
3	5.0093	599.7928	284	103	99	4	0	0	0	0	490
4	7.058	676.3737	490	0	0	0	0	0	0	0	490

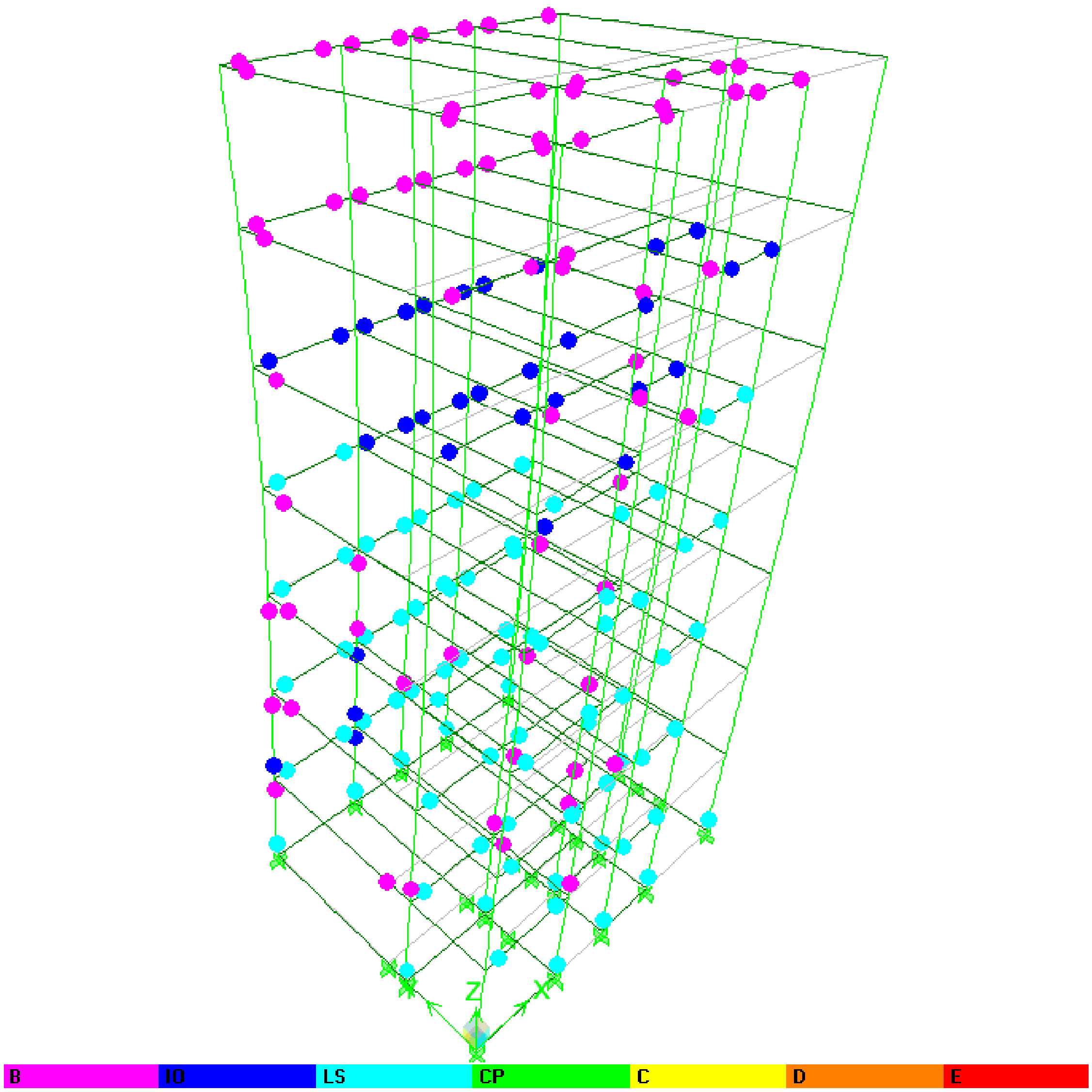

Figure 4 : Location of nonlinear hinges in the deformed three dimensional model by push 2.

The base shear and displacment related to performance point at different level of earth quakes are given below:

Table 2: Base shear and displacment related to performance point at different level of earth quakes

	BASE SHEAR (KIPS)	DISPLACEMENT (INCH)
Serviceability Earthquake	347.47	1.816
Design Earthquake	460.01	3.113
Maximum Earthquake	538.48	4.177

From the above tables It is evident that at the performance point for Seviceability Earthquake , no hinges crossed B-IO range . The requirement for serviceability earthquake is that ,no plastic hinge crosses the IO limit. Again in the same manner It can be rationally decided that at the performance points for Design Earthquake and maximum EarthQuake, no hinges crossed IO-LS and LS-CP ranges respectively. So, The basic safety performance objective (that is to remain in life safety level at design earthquake and is to remain in structurally stable at Maximum earthquake) has met.

5. CONCLUSIONS

Pushover analysis can identify weak elements by predicting the failure mechanism and account for redistribution of forces during progressive yielding. It may help engineers take action for rehabilitation work. It has found that number of plastic hinges formed in the structure does not cross the specified limits for serviceability, Design and maximum Earthquake. So, the structure has met the requirements which were mentioned in ATC-40. From the above discussion it can be concluded that, this building , properly designed as per BNBC(2006), is safe.

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