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Non-linear static analysis of steel Framed Structures

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Abstract

This paper aims to evaluate the zone Ⅱ.selected steel framed building to conduct the non-linear static analysis (Pushover Analysis). The pushover analysis shows the pushover curves, capacity spectrum, plastic hinges and performance level of the existing building. The non-linear static analysis gives better understanding and more accurate seismic performance of buildings as progression of damage or failure can be traced.The proposed building is the regular shaped three-storeyed steel structure.Its height is 9.8m above the ground level. The structure is composed of steel moment resisting frame and it is designed out by SAP-2000 Version 18 software. There are 204 hinges in the building to present the capacity curve and performance level. And also, it can get the knowledge of FEMA_356 usage in pushover analysis.

Keywords: Seismic zone, Pushover Analysis, capacity spectrum, FEMA_356, SAP-2000

1. Introduction

As an engineer, the buildings are considered to be safe at first and to be aesthetic from the architectural view.

Most of the existing buildings are in seismically active zones and are designed for gravity loads only. A large number of existing buildings in zone Ⅱ. is need seismic evaluation due to various reasons such as, noncompliance with the codal requirements, updating of codes, design practice and change the use of the building. However, the existing structure in the earthquake region Zone Ⅱ has to be provided by some rehabilitation to sustain

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the expected performance level. Before rehabilitation work, it is necessary to understand the capacity of the existing building to check if it meets the intended performance level. The purposed of the pushover analysis to evaluate the expected performance of a structural system by estimating its strength and deformation demands in design engineering earthquakes by means of a static inelastic analysis, and comparing these demands to available capacities at the performance level of interest.

2. Pushover Methodology

A pushover analysis is performed by subjecting a structure to a monotonically increasing pattern of lateral loads, representing the inertial forces which would be experienced by the structure when subjected to ground shaking. Under incrementally increasing loads various structural elements may yield sequentially. Consequently, at each event, the structure experiences a loss in stiffness. Using a pushover analysis, a characteristic non-linear force displacement relationship can be determined [3].

3. Pushover Analysis

After assigning all properties of the models, the displacement –controlled pushover analysis of the models are carried out. The models are pushed in monotonically increasing order until target displacement is reached or structure loses equilibrium; whichever occurs first. For this purpose, target displacement at roof level and number of steps in which this displacement must be defined. In this study, target displacement is taken 4% of building height. Pushover curve is a base shear force versus roof displacement curve. The peak of this curve represents maximum lateral load carrying capacity of the structure. The initial stiffness of the structure is obtained from the tangent at pushover curve at zero load level. The collapse is assumed when structure losses its 75% strength and corresponding roof displacement is called “maximum roof displacement”.

It is a plot drawn between base shear and roof displacement. Performance point and location of hinges in various stages can be obtained from pushover curve as shown in Fig.1. The range AB is elastic range, B to IO is the range of immediate occupancy IO to LS is the range of life safety and LS to CP is the range of collapse prevention. The Different Building performance levels are shown in table 1.

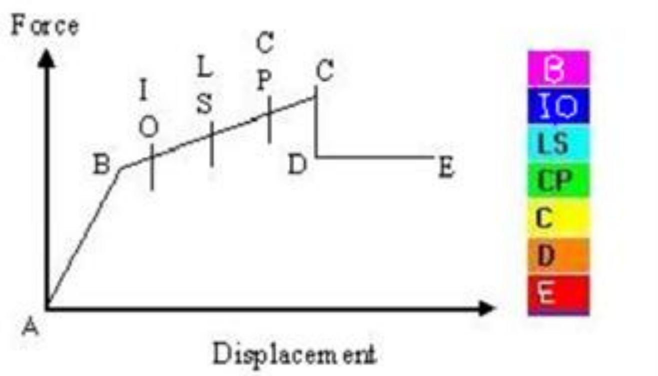

Fig.1 Different stages of plastic hinge

When a hinge reaches point C on its force-displacement curve that hinge must begin to drop

load. The way load is dropped from a hinge that has reached point C is that the pushover force (base shear) is reduced until the force in that hinge is consistent with the force at point D. As the force is dropped, all elements unload, and the displacement is reduced. Once the yielded hinge reaches the Point D force level, the pushover force is again increased and the displacement begins to increase again.

If all the hinges are within the CP limit then the structure is said to be safe. However, depending upon the importance of structure the hinges after IO range may also need to be retrofitted.

4. CASE STUDY

A. Design Parameters of Proposed Steel Viewing Tower This structure is designed based on Standard 2800 under seismic Zone2. The proposed building is four storeyed steel structural building as shown in following figure. Total height of the building is 12.80m. The structure is designed with average moment resisting frame design and the value of response modification factor R is 5. SAP 2000-software is used to analyze the structure.

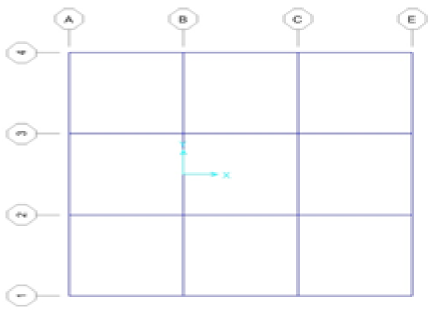

Fig.2 plan of building

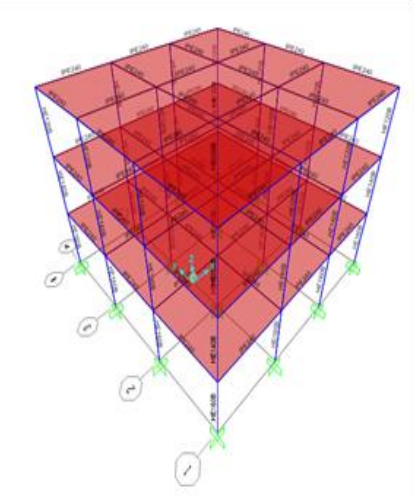

Fig.3 3D View of Proposed Building.

-Total height = 9.8m
-Length of the building =12m
-Breadth of the building =12m
-Location = Zone-2
-Type of structure = Regular Shaped Steel Structure

B. Material Properties

The strength of a structure depends on the strength of the made.

- Weight per unit volume = 7849.057kgf
- Modulus of elasticity for steel = 2.1×10^{10}kg/m
- Poisson's ratio = 0.3
-Coefficient of thermal expansion = 1.17×10^-5 m/mper°c

Design property data

- Yield stress, F_y = 24000000kg/m
- Tensile stress, F_u = 37000000kg/m

DESIGN OF COLUMN FOR PROPOSED BUILDIN

Story	section
Gf	HE160B
1	HE140B
2	HE120B

DESIGN OF BEAM FOR PROPOSED BUILDING

Section for all story is IPE240

5. Element Description of SAP2000

In SAP2000, a frame element is modelled as a line element having linearly elastic properties and nonlinear force-displacement characteristics of individual frame elements are modelled as hinges represented by a series of straight line segments. A generalized force-displacement characteristic of a non-degrading frame element (or hinge properties) in SAP2000 is shown in Figure 3.

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

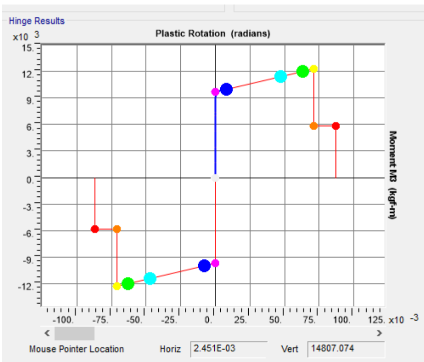

Fig 3. Force-displacement characteristic of a non-degrading frame element

6. Result and Discussion

The resulting pushover curve for this building is shown in here. The curve is initially linear but starts to deviate from linearity as the beams and columns undergo inelastic actions. When the building is pushed well into the inelastic range, the curve become linear again but with a smaller slope. The curve could be approximated by a bilinear relationship.

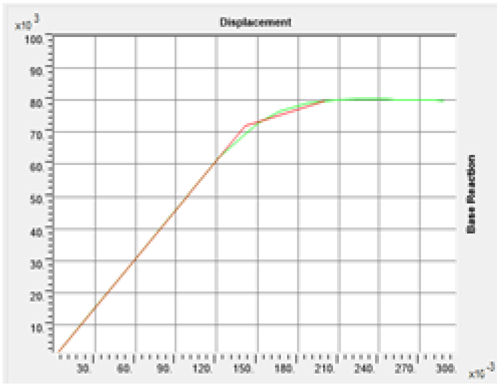

Fig4. Capacity curve FEMA-356

6.1. Plastic hinges mechanisms

Plastic hinges formation for the building mechanisms have been obtained at different displacement levels. The hinging patterns are plotted at different levels. Plastic hinges formation starts with beam ends and base columns of lower stories, then propagates to upper stories and continue with yielding of interior intermediate columns in the upper stories. But since yielding occurs at events B, IO and LS respectively, the amount of damage in the building will be limited.

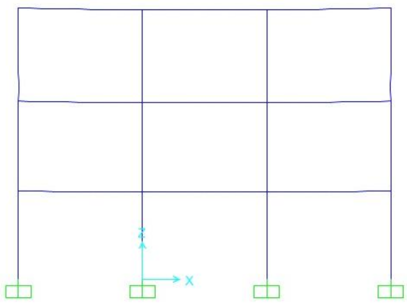

Fig5. Deformed shape of the frame at Step0

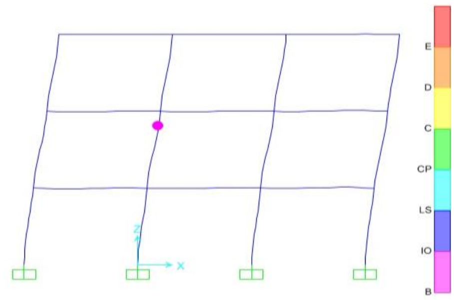

Fig7. Deformed shape of the frame at Step5

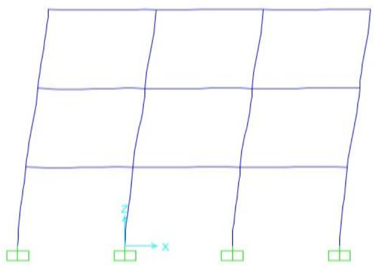

Fig6. Deformed shape of the frame at Step2

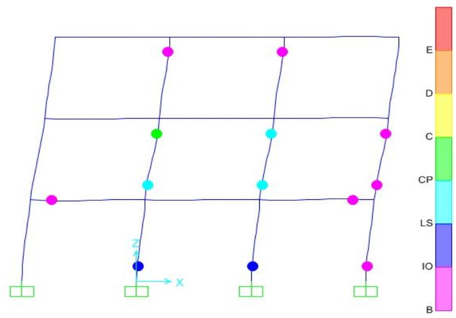

Fig8. Deformed shape of the frame at Step7

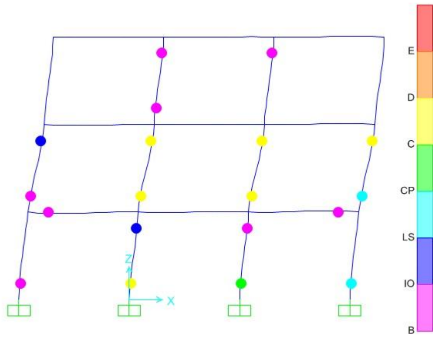

Fig9. Deformed shape of the frame at Step9

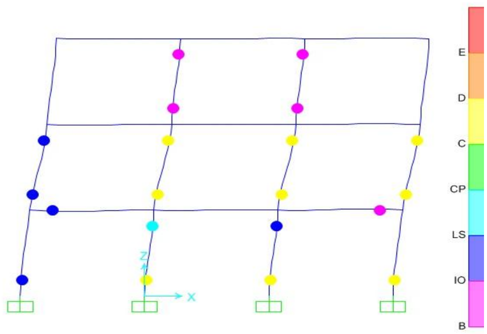

Fig10. Deformed shape of the frame at Step11

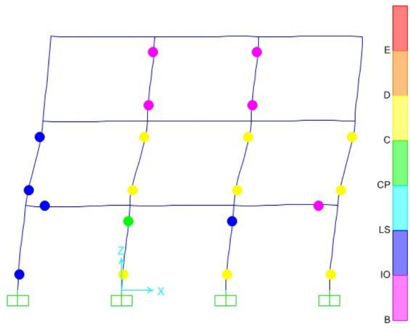

Fig11. Deformed shape of the frame at Step13

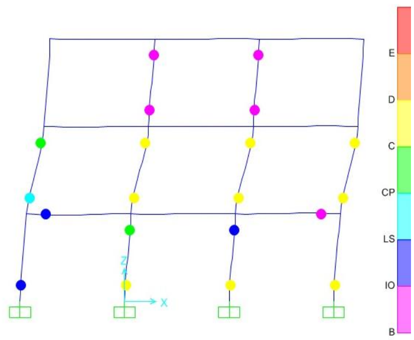

Fig12. Deformed shape of the frame at Step15

7. CONCLUSIONS

The performance of steel frames was investigated using the pushover Analysis.The pushover analysis is a relatively simple way to explore the non-linear behaviour of buildings

The structure is analyzed and designed according to SAP-2000 Version 18 software.The structure is located in seismic zone-2 and static approach procedure was analyzed according to STANDARD2800, and then it was analyzed by pushover analysis. By using pushover analysis, there are various steps until C-D level in capacity curve by giving push load in displacement control from x-direction. And , by seeing the hinge formations, most of the hinges are found in column. Column hinges are found mostly at the story2. So, it is the weak point when the lateral loads are affected in a building. It is hoped that the study here will get some knowledge to build a safe structure in severe earth-quake zone.

It would be desirable to study more cases before reaching definite conclusions about the behaviour of reinforced concrete frame buildings.

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