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Seismic Evaluation of Steel Frame Structure by Non-Linear Static Analysis

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Abstract: Earthquake is the disturbance that happens at some depth below the ground level which causes vibrations at the ground surface. The buildings which do not designed for seismic force, may suffer extensive damage or collapse if shaken by a severe ground motion. The Pushover analysis first came into practice in 1980's, but the potential of the pushover analysis has been recognized for last two decades years. In this procedure mainly estimate the base shear and its corresponding displacement of structure. Pushover analysis is a very useful tool for the evaluation of New and existing structures. In the present study we are evaluating the behaviour of steel frame structure when it subjected to seismic forces. The method we are using to evaluate seismic performance of structure is non-linear static method which is gives the progressive behaviour of steel structure at each stage of analysis. For the study we modelled two frame structures of G+12 and G+15 respectively by using E tabs 2018. Main purpose of the study is to check the progressive failure of structure especially after elastic region by non-linear static analysis.

Keywords: Non-linear static analysis, Steel frame structure, plastic hinge formation, IS 1893:2016

I. INTRODUCTION

An earthquake is that devastating natural disaster due to which every small and big structure gets fail if it is not design and analysed by taking seismic loading into account. A lack of steel availability was the subject of concern few decades ago, but now India is one of the second largest steel producers with 101.4MT per annum so it is readily available. It is very stiff and possesses high strength to weight ratio which shows great integrity against the seismic loading. In the present study Pushover analysis method is used for analysis of steel frame structure after at each step till it collapses. Nonlinear static pushover analysis is used to evaluate the seismic performance of the structures under incremental loadings. In the present study G+12 and G+15 steel frames structure are modelled in the ETABS2018 and then it set to run with pushover analysis by using IS 1893:2016 which is used to investigate the seismic behaviour of both structure under same seismic forces.

II. STEEL FRAME STRUCTURE

Steel Structure which includes structural steel framing, describes the creation of a steel skeleton made up of vertical columns and horizontal beams. This skeleton provides the support for the roof, floors and walls of the structure. There are three main types of structural steel framing systems. Structural steel members vary in depth, height, length, thickness, profile and cross-section, with each of these characteristics affecting performance and load capacity.

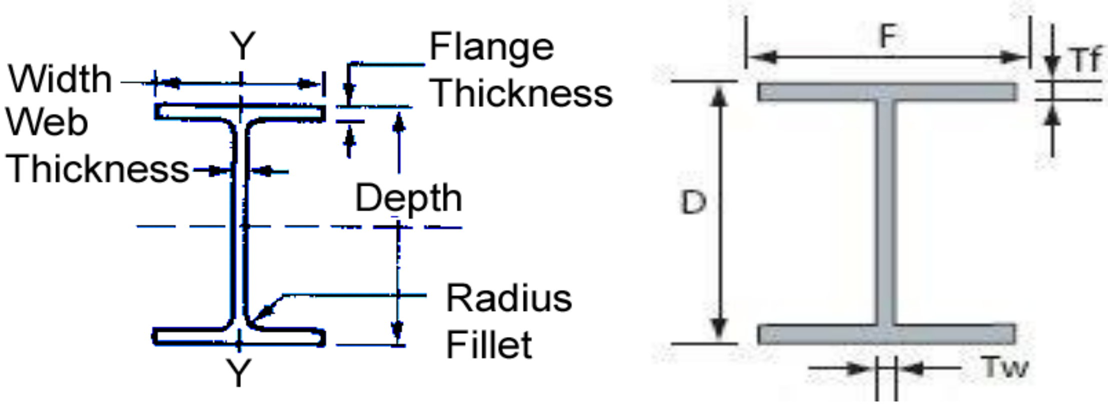

Fig. No.1.1 Typical cross section steel I section

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The web resists shear forces, while the flanges resist most of the bending moment experienced by the beam. Beam theory shows that the I-shaped section is a very efficient for carrying both bending and shear loads in the plane of the web. On the other hand, the cross-section has a reduced capacity in the transverse direction, and is also inefficient in carrying torsion, for which hollow structural sections are often preferred. High ductility and ability to absorb seismic energy are key advantages to steel which makes it superior than other regular material like RCC and composite**.**

Objective of Study

The objective of this work is to evaluate through an analytical study, the seismic performance of three-dimensional G+12, G+15 storey symmetric steel building. following are the main objective.

- To analyse the seismic performance of the steel structure with more degree of accuracy with E tabs 2018 software by using Non-linear Static Analysis Method.
- To understand the behaviour of steel frame structure when subjected to earthquake forces.
- To understand the progressive failure of steel structure by pattern and sequence of plastic hinge formation.
- To decide the need of retrofitting for which member it needed the most by analysing from level of damage.

Scope of Present study

In the present study, modelling of the G+12 and G+ 15 steel frames under the lateral loads has been designed and analysed by using ETAB 2018 software. The frame is analysed using ETAB software up to the failure and the load deformation curves. The results are shown in the form of base shear, displacement and plastic hinge formation.

III. PUSHOVER ANALYSIS

Pushover analysis is a static non-linear procedure in which the magnitude of the structural loading along the lateral direction of the structure is incrementally increased in accordance with certain pre-defined pattern. It is generally assumed that the behaviour of the structure is controlled by its fundamental mode and the predefined pattern is expressed either in terms of story shear or in terms of fundamental mode shape. With the increase in magnitude of lateral loading, the progressive non-linear behaviour of various structural elements takes on, and weak links and failure modes of the structure are identified. After this progressive post elastic analysis of the structure the designer can make necessary changes in the design configuration in order to obtained required plastic hinge sequence under the applied lateral loads.

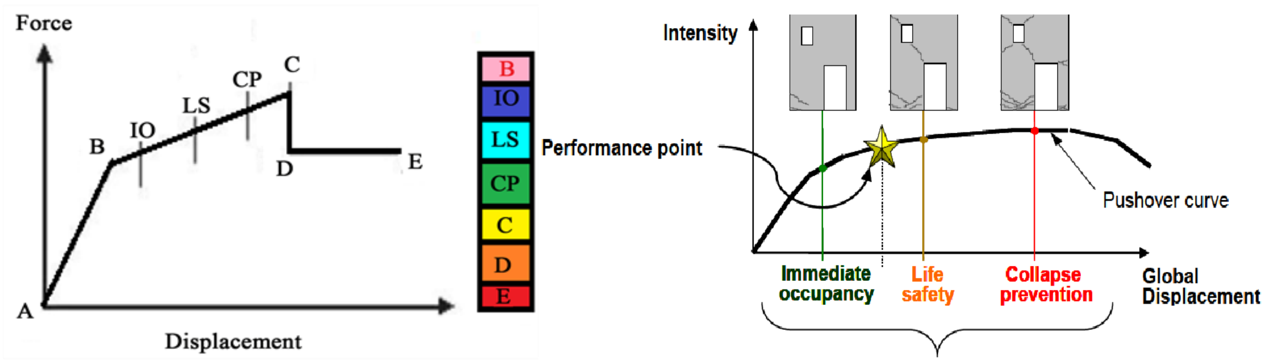

Figure 2: **Performance levels with pushover curve**

The pushover analysis is more convenient than full dynamic analysis because of computational time. Thus, pushover analysis is more practical for use in a design office. After the structure has been designed or retrofitted using appropriate codes or design guidelines, is that it yields additional information on the limit states, the plastic hinge sequence and the force redistribution caused by a seismic event. As shown in fig no 2 these levels are discrete points on a continuous scale describe the buildings expected performance or alternatively how much damage, economical loss and destruction may occur in the earthquake. In order to obtain performance points as well as the location of hinges in different state of damage, we can use the pushover curve. In this curve, the range AB being the elastic range, B to IO is being the range of instant occupancy, IO to LS being the range of life safety and LS to CP being the range of collapse prevention.

IV. METHODOLOGY

For analysis work, models of building G+12 and G+15 floors are made to know behaviour of building during earthquake. Typical bay width is taken 5m in both X and 4m in Y. Number of bays in both directions are not same. Storey height (Floor to Floor) 3 m were considered. Designing of steel structure is done by IS 800:2007 and structure analysed by FEMA 356. All the joints of beam, column is rigid. The models were analysed as per Indian standard Code IS 1893:2016. All the columns are fixed from base for foundation.

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Building Description

PARTICULARS	STEEL G+12	STEEL G+15
TOTAL STORY HEIGHT 39m 39m	39m	39m
BEAM SIZE	ISMB300	ISMB 350
COLUMN SIZE	ISMB 450	ISWB 600
SLAB	100mm Deck	100mm Deck
SECONDARY BEAM	ISLB200	ISLB200
Zone	V	V
Soil type	Type II medium soil	Type II medium soil
Importance factor	1.0	1.0
Response reduction	5.0	5.0
Damping ratio	5%	5%
Seismic zone factor	0.36 For zone V	0.36 For zone V

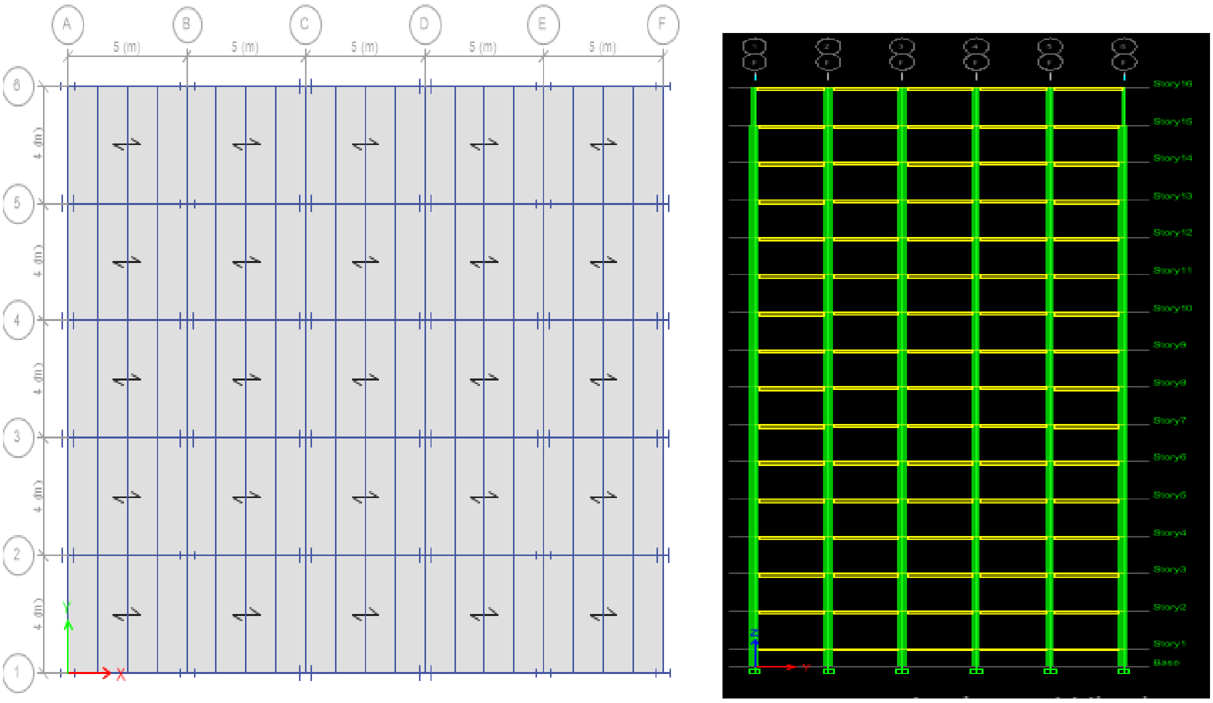

Figure 3: **General Plan Elevation of G+ 15 Steel frame structure**

Floor finish, basic geometry of building, materials used for the building such as concrete steel and rebar are similar. All other changes in case dimensions of members are as per design.

V. RESULT AND DISCUSSION

After the pushover analysis of both the G+12 and G+ 15 steel structures we obtained result as follows.

Hinge Formation at different levels

Table no 2: Sequence of Hinge Formation for G+12 steel frame.

Step	Monitored Displ mm	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
32	150.30	5123.36	2027	1	0	0	0	2028	0	0	0	2028
45	233.61	7259.25	1939	89	0	0	0	2022	6	0	0	2028
153	788.44	1266.18	1719	309	0	0	0	1726	291	11	0	2028
168	1039.36	13201.01	1591	433	4	0	0	1624	385	19	0	2028

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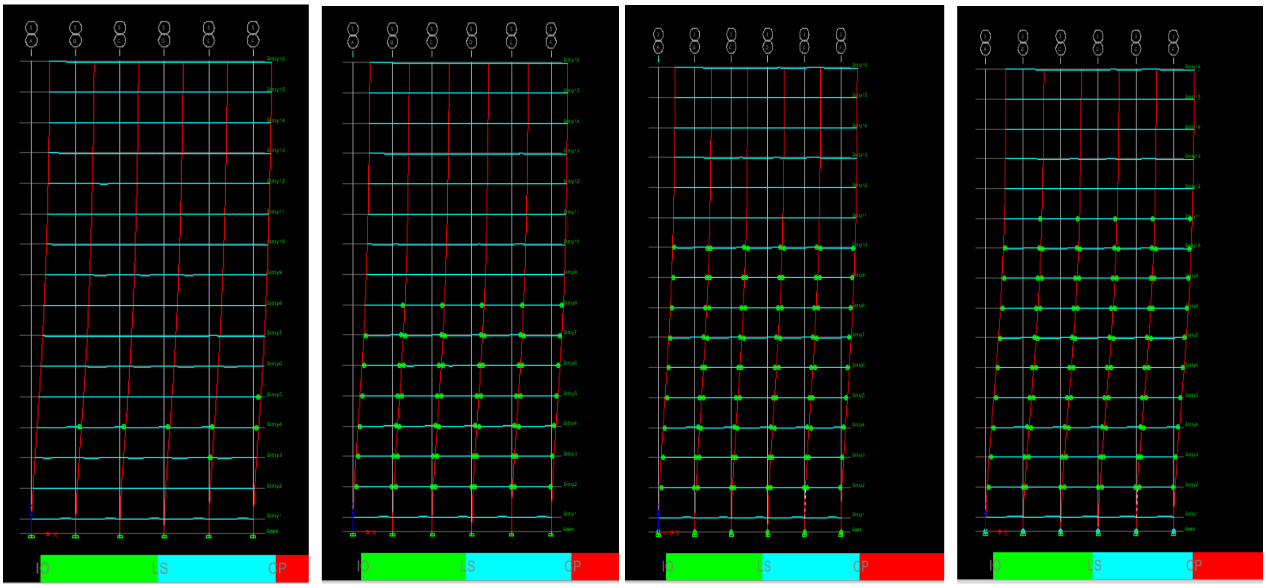
Table no 3 : Sequence of Hinge Formation for G+15 steel frame.

Step	Monitored Displ mm	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
41	270.62	7274.83	2492	4	0	0	0	2496	0	0	0	2496
56	406.43	9860.90	2194	302	0	0	0	2486	10	0	0	2496
183	1291.96	15046.01	1788	708	0	0	0	1896	584	16	0	2496
196	1377.76	15329.05	1762	730	4	0	0	1886	574	36	0	2496

Table no. 2 indicate that the formation of initial and ultimate hinge take place at a displacement of 150.30 mm and 1039.36mm in G+12 Steel structure, whereas table no. 3 shows in Steel frame, the earliest and latest hinge taken place at the 270.62mm and 1377.76 mm respectively. To understand sequence of failure or progressive failure we define 4 colours here such as yellow, blue, green and red are defined to understand the progressive failure pattern of the structure at different stages.

Each colour has its own significance. Yellow colour symbolizes yielding started; blue colour indicates that one member crosses CP. Similarly green colour shows that maximum members are still lies between A-IO and only few more have crossed the CP and finally red colour indicates that deformation reaches to its ultimate point and maximum members crosses the life safety limit and structure collapsed.



Step No.32 Step No.45 Step No.153 Step No.168

Figure 4: Steps of Progressive Failure of G+12 Steel Frame Structure

So, it clearly understands that steel structure has more flexibility so it can go for greater displacement during when earthquake occurs.

Base Shear

From the obtained graph Base Shear for G+15 frame structure is on higher side as it has more seismic weight because of maximum number of story. It means due to maximum self-weight of steel in G+15 story it has greater value of base shear.

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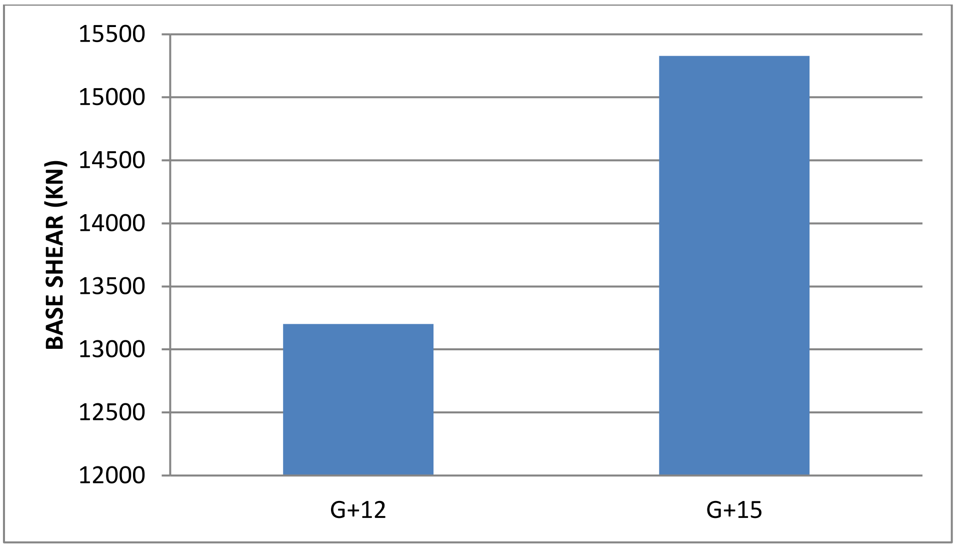

Figure 5: Base Shear of G+12 and G+15 Steel Structure

VI. CONCLUSION

From the obtained result we can conclude that Non-linear static analysis gives the better result than any other method as it gives failure members at each step even after building crosses elastic state. From table number 2 and 3 it is clear that steel structure behaves well under seismic forces and as the story height will be more then max member are susceptible to failure. But eventually steel structure has more ability to deform under seismic excitation due to its higher flexibility. From figure number 5 we can also conclude that base shear for the G+12 is comparatively lesser than G+ 15 steel structure just due to more number of storey with its corresponding displacement value. We can also make the conclusion that for by pushover analysis we can get the exact member which is being failed and it will be easy to retrofit that member alone as per need. After analysis we can conclude one should prefer steel structure for the construction and in higher seismic zones specially. And for seismic analysis non-linear static method is most accurate and feasible.

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