# Pushover Analysis of G+15 Steel and Steel-Concrete Composite Frame Structure

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**Abstract -** *Reinforced concrete construction is normally preferred for low-rise buildings. However, for medium to high-rise buildings, they are no longer economical due to increased dead load, span restriction, and hazardous formwork. In the present work the attempt has been made to compare Steel and RCC-steel composite frame structure when they are subjected to similar lateral loading by nonlinear static pushover analysis in which it compares performance of G+ 15 storey for steel and composite (steel-concrete) when earthquake load incrementally increases on the structure. Both steel and Steel-concrete composite construction has gained wide acceptance worldwide as an alternative to pure steel and pure concrete construction. Composite construction combines the best of both steel and concrete along with lesser cost, speedy construction, fire protection etc. whereas steel has high strength to weight ratio. It is observed that the performance of steel structure is on higher side than that of the steel-concrete composite frame structure. This study focuses on how steel frame structure can be veteran and most economical over the RCC at its seismic performance.*

***Key Words*: Pushover analysis, Performance point, Ultimate Displacement, ETABS, FEMA-356.**

## 1. INTRODUCTION

Concrete (RCC) is very predominant material which is being used in every residential as well as commercial project in Indian infrastructural development over the decades. Though it possesses an inherent heaviness, mass and strength but one can opt for steel and composite as core construction material as they have proved themselves as one of the finest material which responds to the lateral forces with less damage as compare to conventional RCC. With Proper design, engineering and construction the seemingly rigid structure built with steel can exhibit increased ductility and give better performance in earthquake prone areas. The advancement in building, Information, modeling has integrated design, detailing, and fabrication of steel which will result in high performance under earthquake loading. In the present study, modeling of the steel and composite frame under the lateral loads has been designed and analyzed using ETAB software up to ultimate collapse condition the and the load deformation curves are plotted. The analysis has been done with the parameter such as pushover curve and plastic hinge formation, performance point, Time period, Base shear and displacement at performance point.

### 1.1 STEEL 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. The horizontal elements of the "I" are known as flanges, while the vertical element is termed the "web". I-beams are usually made of structural steel and are used in construction and civil engineering. I sections are widely used in the construction industry and are available in a variety of standard sizes and these section may be used both as beams and as columns. The typical cross-section of Steel I section is shown in figure 1.

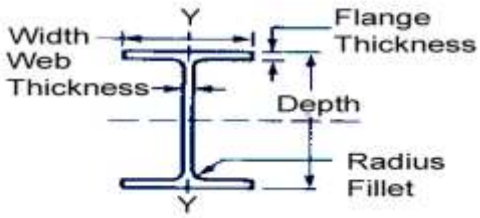



**Fig -1**: Typical cross section steel I section

### 1.2 COMPOSITE STRUCTURE

The structure in which sections are made up of two different materials such as structural steel and concrete for the structural framing system is called as a composite structure. A composite structure is formed when a steel component, such as an I-beam, is attached to a concrete component, such as a floor slab or bridge deck. Steel concrete composite structure combines the compressive strength of concrete with the tensile strength of steel to evolve an effective and economic structural system. The typical cross-section of composite member is shown in figure 2. The designing method in this paper is based on the code of AISC 360-10, which incorporates the latest research on composite construction. Indian standard for composite construction IS 11384-1985 does not make any specific reference to composite structure design and analysis.

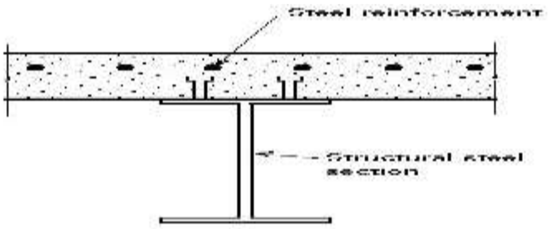



**Fig -2**: Typical composite cross section

In composite construction it is very necessary to use the shear connectors as the total shear force at the interface between concrete slab and steel beam is about eight times the total load carried by the beam. Use of these mechanical shear connectors transmits the longitudinal shear along the interface and it also prevents the separation of steel beam and concrete slab at the interface. The commonly used type of shear connector as per IS: 11384-1985. There are three main types of shear connector; Rigid, Flexible and anchorage shear connectors. For this study rigid type shear connectors are used.

## 2. OBJECTIVE OF THE STUDY

1. To investigate the progressive failure of multi-story steel and composite frame structure when subjected to identical seismic condition.
2. To compare the performance of steel and composite building under seismic loading by pushover analysis.
3. To compare the maximum capacity of deformation that structure can undergo against lateral forces without failure.
4. To decide feasibility of the structure from its performance point by using pushover analysis.

## 3. METHODOLOGY

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 a certain pre-defined pattern. With the increase in magnitude of lateral loading, the progressive non-linear behaviour of various structural elements is captured, and weak links and failure modes of the structure are identified.

In the Present work building model G+15 Steel and Composite are situated in zone V with subsoil type medium -II were analyzed in ETAB software. All the sections are design by LSM from respective codes using trial and error method. All earthquake forces are considered as per IS 1893:2002. The basic planning and loading for the steel and Composite structures are kept similar for the study. The details of steel and composite frame structure are as shown in Table No.[1] Codes used for design of structural members mentioned in below table No.1:
Steel design: IS 800:2007
Composite design: AISC LRFD 99

### 3.1 FRAME STRUCTURE DETAILS

**Table -1:** Details of G+15 Steel & composite Frame Structure

| PARTICULARS | STEEL FRAME | COMPOSITE FRAME |
|---|---|---|
| BEAM SIZE | ISMB350 | ISMB350 |
| COLUMN SIZE | ISWB 600 | ISMB450 Encased in 700*700mm |
| SLAB/DECK | 100mm DECK | 100mm DECK |
| TOTAL STOREY HEIGHT | 46.5m | 46.5m |
| TYPICAL STOREY HEIGHT | 3m | 3m |
| PLAN | 25x20m | 25x20m |
| CONCRETE GRADE | M-25 | M-25 |
| Rebar | HYSD415 | HYSD415 |
| STEEL | FE345 | FE345 |
| ZONE | V | V |
| IMPORTANCE FACTOR | 1 | 1 |

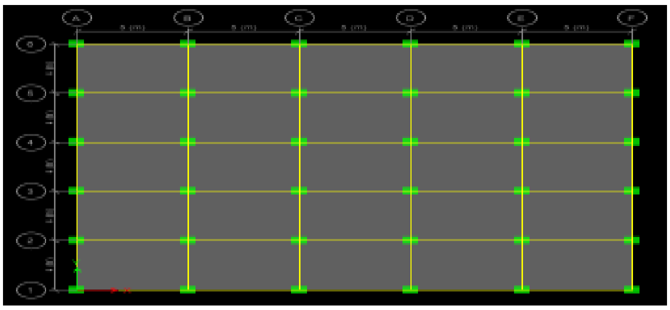


**Fig -3**: General plan view of frame structure

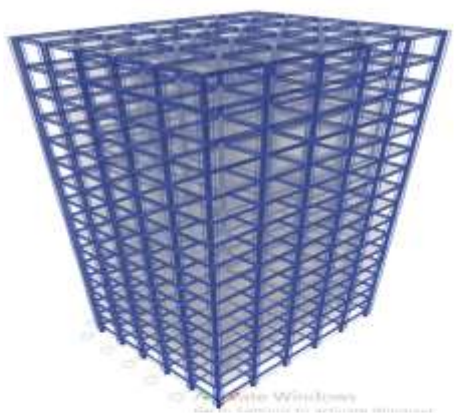


**Fig-4:** General 3D view of frame structure

## 5. RESULT AND DISCUSSION

### 5.1 PUSHOVER CURVE

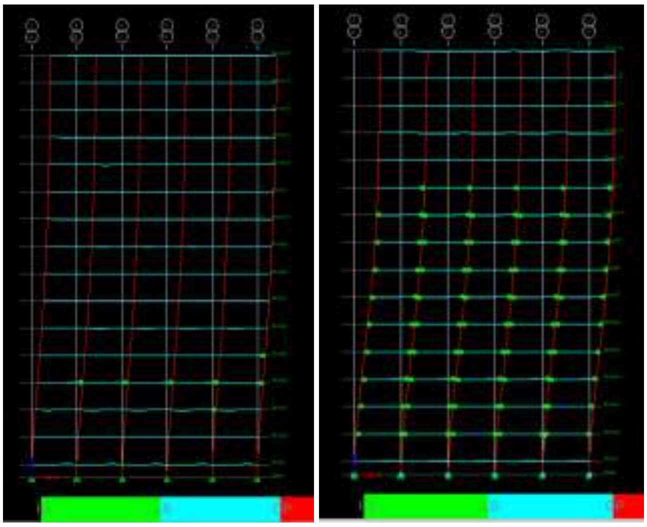
**Table -2:** Yield point of steel and composite structure

| Type of Structure | Yield Displacement in mm | Yield Base Shear in kN |
|---|---|---|
| Steel | 316.57 | 8400.22 |
| Composite | 223 | 7717.14 |


**Chart -1**: Yield Displacement and Base Shear

Table no.2 shows the yield displacement and its corresponding base shear for steel and composite frame structure. This is the progressive post elastic behavior of both the structures forming a Pushover curve as shown in chart 1.

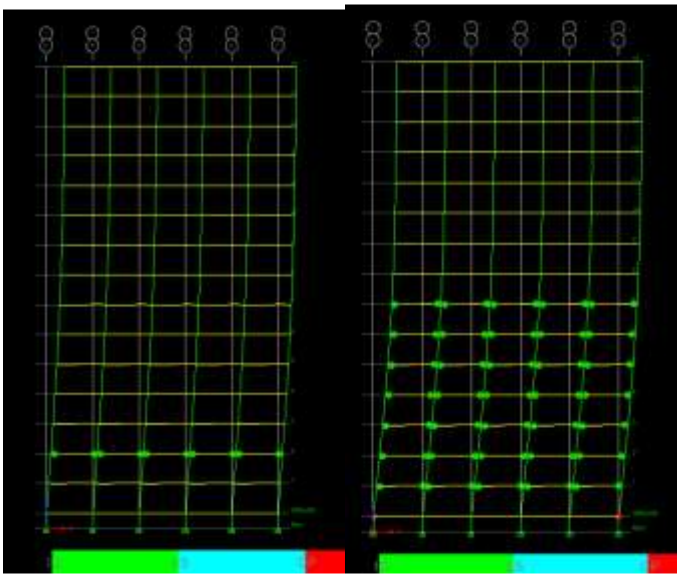
### 5.2 PLASTIC HINGE FORMATION



**(a) 126th step** **(b)416th step**

**Fig-5: (a) and (b)** Formation of hinges for G+15steel frame Structure

Figure No. 5 shows that the hinge formation of steel structure at step number 126th in which it can be seen that, the formation of plastic hinges taking place and they are in immediate occupancy level as it is in green color similarly in figure No. 5 (b) it can be observed that it is the ultimate (416th) stage of hinge formation for steel in which no members are near CP level.



**(a) 56th** **(b) 117th**

**Fig-6: (a) and (b)** Formation of hinges for G+15composite frame Structure

Figure No.5 (a) and (b) shows the formation of plastic hinges in G+ 15 composite frame structures in which figure no. 5 (a) indicates that at the step number 56th plastic hinges just started to developed means structure is in early stage where hinges are just in between B-C and as the load on the structure increases incrementally by the principle of displacement control in pushover analysis and finally reaches to its ultimate (117th) stage of state where number of plastic hinges are near the collapse prevention as some of hinge points are in red mark.

### 5.3 PERFORMANCE POINT

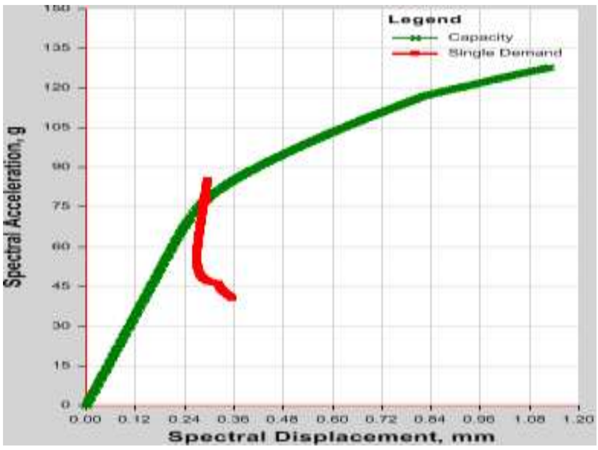



**Fig-7:** performance point of G+15 Steel Structure

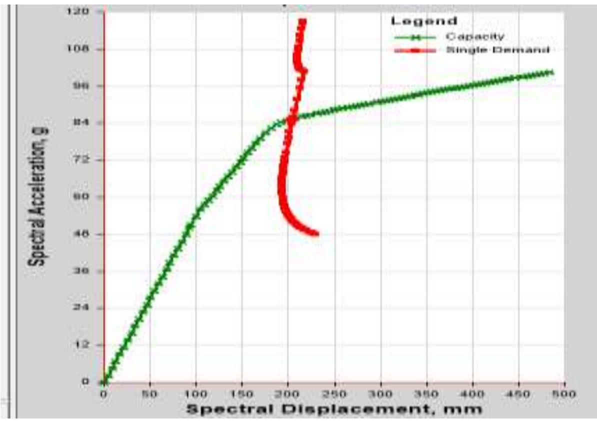



**Fig-8:** performance point of G+15 composite Structure

Fig-6 shows that the demand curve intersecting capacity curve of steel frame structure at the IO(immediate occupancy) whereas fig-7 indicates that composite structure achieved performance point after IO level. So it can be clearly state that from obtained result steel structure shows more reserved strength than that of the composite structure before its ultimate collapse state.

### 5.4 BASE SHEAR AND DISPLACEMENT

**Table -3:** Base shear and Displacement at performance point

| No. of story | Steel | | Composite | |
|---|---|---|---|---|
| | Displacement in mm | Base shear in kN | Displacement in mm | Base shear in kN |
| (1) | (2) | (3) | (4) | (5) |
| G+15 | 367.13 | 9342.8 | 258.9 | 8222.06 |

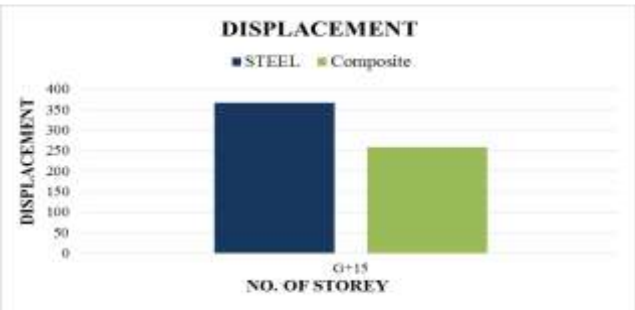



**Chart -2**: Displacement at Performance point

Table No-4 shows the displacement and corresponding base shear of steel and composite frame structure at performance point. The graph obtained from the values of displacement symbolizes that due to high ductility of steel section steel structure can go under maximum displacement before its failure whereas composite structure is able to show less deformation against the lateral forces. The base shear value of steel structure is less as compare to composite structure due its less self-weight which responsible for the greater performance of steel structure than that of composite against the seismic forces.

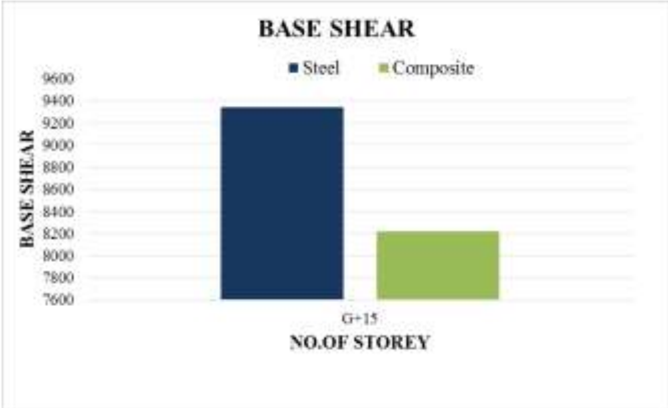



**Chart -3**: Base Shear at Performance point

### 5.5 TIME PERIOD AT PERFORMANCE POINT

**Table -4:** Time period at performance point

| No. of Storey | Steel | Composite |
|---|---|---|
| | Time period in sec | Time period in sec |
| (1) | (2) | (3) |
| G+15 | 3.876 | 3.104 |


**Chart -4**: Time period at Performance point

Table No. 4 shows that time period of G+ 15 steel structures is 3.876sec whereas in case of composite it is 3.104sec which indicates that steel structure takes more time to start oscillating back an fourth after application of lateral forces due to its higher flexibility in comparison with composite frame structure.

## 6. CONCLUSIONS

From the obtained results the following conclusions are made:

1. In case of composite frame, yielding starts at the displacement at 223mm which is 29.55% lesser than

the yield displacement of steel frame in pushover curve.

2. Base shear of composite frame structure is more than that of steel structure as the steel possesses less self-weight.

3. Plastic hinges are forming in early stage of deformation in case of composite structure due to its less ductility than that of steel.

4. From the performance point obtained in the fig-6 and 7, it can be concluded that steel structure has greater reserve strength to resist against lateral forces in comparison with composite structure.

5. From the obtained performance point it is concluded that due to high ductility and less weight Steel structure behaves well in seismic excitation.

6. After comparing both structures, steel structure resists the forces for longer time as compared to composite structure.

7. So from the comparative study it can be concluded that steel structure are more feasible in seismic excitation as it has been proved better than composite in every result parameter considered for the study.

8. Pushover analysis concludes that the steel frame structure proved itself as a one of the safe choice for construction in seismic zone.

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## REFERENCES

[1] Inel M and Ozmen H. B., “Effects of plastic hinge properties in nonlinear analysis of reinforced concrete buildings”, Department of Civil Engineering, Pamukkale University, 30 March 2006, pp.1494-1502.

[2] Martino R and Kingsley G, “Nonlinear Pushover Analysis of RC Structures”, Advanced Technology in Structural Engineering, Vol.2, 2004, pp.256-262.

[3] Tedia A and Maru S, “Cost, Analysis and Design of Steel-Concrete Composite Structure R.C.C Structure”, IOSR Journal of Mechanical and Civil Engineering, Vol.11, Issue 1,Version(II), Jan 2014, pp.54-59.

[4] Raut A and Prasad R, “Pushover analysis of G+3 reinforced concrete building with Soft Storey”, Journal of mechanical and civil engineering, Vol.11, Issue 4,JulAug2014, pp.25-29.

[5] Anuj Domale and Kalurkar L.G, “analytical study of RCC and Steel Frame Structure by Static Nonlinear Snalysis”, International Journal of Engineering Technology science and Research (IJETSR) Vol. 5, Issue 3, June 2018.

[6] Mwafy A.M. and Elnashai A. S., "Static Pushover versus Dynamic Collapse Analysis of RC Buildings", Engineering Structures, Elsevier Science Direct, Vol. 23, 2001, pp. 407–424.

[7] Panchal D.R. and Marathe P.M., “Comparative Study of R.C.C, Steel and Composite (G+30 Story) Building”, Institute of Technology, Nirma university, Ahmedabad – 08-10 December, 2011, pp382-481.

[8] Mohd. Amir Khan, “Comparative Study of R.C.C & Structural Steel -Concrete Composite Frame for Linear and Non-Linear Analysis”, International Research Journal of Engineering and Technology (IRJET), Vol.4, Issue 7, July 2017.

[9] FEMA, “NEHRP Guidelines for Seismic Rehabilitation of Buildings”, Developed by Building Seismic safety Council for Federal Emergency and Management Agency No. 356, Washington D.C.,2000.

[10] IS: 800, “Code of practice for general construction in steel”, Bureau of Indian Standards, New Delhi, 2007.

[11] IS: 11384, “code of practice for composite construction in structural steel and concrete”, Bureau of Indian Standards, New Delhi, 1985.

[12] IS: 1893, “Criteria for earthquake resistant design of structures – general provisions for buildings, Part 1”, Bureau of Indian Standards, New Delhi, 2002.

## BIOGRAPHIES

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