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Performance Assessment of the Steel Moment Resisting Frame Structures

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Abstract - *The steel structures are widely used in the construction industry, due to its various elegant advantages like high strength to weight ratio, reduction in the dead load of the structure, high ductility, high resistance against the lateral loads, high-speed construction, reuse and recycle of material. Earthquake is a transfer mechanism that initiates form ground motion travels in all directions. When the structure subjected to ground vibration, it induces inertial forces on the structure. The structure situated in the seismic areas has to resist not only gravity load but also lateral load that induces high stresses on the structure. It is essential to design a structure to perform well under seismic loads. The capacity of structure and yielding of the structure found by the elastic analysis but the redistribution of the forces beyond the elastic range and mechanism of structural failure cannot predict by elastic analysis. To examine the behavior of the structure beyond the elastic limit, the nonlinear static analysis is a popular method widely used. The present work deals with the assessment of the seismic response of the structure using the linear dynamic analysis and nonlinear static analysis. The parametric study carried out for various regular steel moment-resisting frames considering variation in the base dimension and height of the structure. The results obtained from the response spectrum analysis and displacement controlled pushover analysis, the performance of the structure is significantly influenced by the change in the base dimension and height of the structure.*

Key Words: *Seismic response, Moment resisting frames nonlinear static analysis, linear dynamic analysis.*

1. INTRODUCTION

The Concept of seismic design is to provide structure with sufficient strength and deformation capacity to sustain seismic demands imposed by ground motion with an adequate margin of safety. Even if the probability of occurrence of earthquake within the life span of structures were very less, the strong ground motion would generally cause greater damage to the structure. Steel has high resilience for dynamic loads, which implies that the ability of steel to absorb energy when it is deformed elastically and release that energy upon unloading. The ability of the steel to undergo significant plastic deformations before rupture makes it more ductile and hence increases its probability of use in earthquake resistant design of structures, where ductility plays a major role in the behaviour of the structure. The steel moment resistance frame consists of two key elements. The first key element is a horizontal member that resists the external load by generating the shear forces and flexural moments and second is the vertical member that withstand external load by generating axial load and bending moments. The rigid joint between horizontal and vertical members of the moment-resisting frame provides essential resistance to the lateral force. The flexural strength and rigidity of the vertical and horizontal members are the fundamental source of the complete frame for the lateral stiffness and strength.

The linear dynamic analysis gives only the elastic capacity and yielding of the structure. However, the redistribution of the forces and failure mechanism cannot be predicted from the linear dynamic analysis. The nonlinear static analysis becomes very useful because of the various aspects like effortlessness, easy to assess the deformation demands of the structure without any complexity in the modeling and computation [1]. The displacement demand will be the target displacement for the MDOF system which equivalent shape vector of the SDOF. The seismic response during the earthquake, the selection of invariant load pattern will define the response of the structure. The single load pattern will not influence load variations required for bound the inertia force distribution so use at least two load patterns [2]. To estimate the seismic demands of the high-rise building used upper-bound pushover analysis procedure. The nonlinear time history analysis procedure s are more complicated as compared to the nonlinear static procedures because of that the pushover analysis procedure is widely used in the tall building structures. The conventional procedure contains some drawbacks in predicting the inelastic seismic demands of high-rise buildings to overcome from this problem recently improved procedures developed. The new improved procedure considered higher mode effects of the applied loads. The target roof displacement can be determined using the applied lateral load and the absolute sum of the modal combination rule [3], [4]. Force distribution and target displacements are controlled by the fundamental natural mode, which remains unchanged after the yielding of the structure. On this assumption, the pushover analysis is work. Due to the above, assumption, invariant load distribution does count the effect caused by the plastic deformation and change in the stiffness property. The adaptive pushover analysis method is more effective to evaluate the seismic induced dynamic demands of the structure when subjected to earthquake loads [5], [8]. Most of the design procedures derived based on the elastic analysis of the structure. This procedure does not consider nonlinear behavior that occurs due to the material and geometry. The seismic design codes for building s use the phenomenon of the response reduction factor to count the nonlinear response of the structure when it is subject to high ground vibration due to the earthquake. The performance of the frames in the nonlinear state will define the value of the response reduction factor. The nonlinear behavior depends on the member rotation that is the function moment-curvature characteristics and length of plastic hinge. The comparative study carried out between the RC frame structure and steel frame structure. The response of the steel frame structures is more effective than the RC frame structure [9]. Performance-based design based on the response of the structure during the nonlinear static analysis. There are two key elements of the performance-based design of the earthquake-resistant structure. The first key element is the demand that is the function of shaking of the structure due to ground motion and it represents the deformation of the structure during the shaking of the ground. The second key element is the capacity of the structure to resist the lateral load. The nonlinear static analysis involves the series of the sequential elastic analysis that developed the approximate a force-displacement curve for the overall performance of the structure. A predefined load pattern assigned to the structure that distributed along with the overall height of the building. Then this predefine load increased up to the yielding of the structural members. The process of the increasing load continued until the structure becomes stable. Then plot made between roof displacement and base shear to form a global capacity curve of the structure [10].

2. OBJECTIVES AND SCOPE

To study the linear dynamic characteristics and nonlinear static characteristics of the steel moment-resisting frame structure subjected to lateral earthquake load by performing the response spectrum method and displacement controlled pushover analysis.

3. PROBLEM STATEMENT

In this work, several frame geometries are select as a part of the study. All the frames are regular steel moment-resisting frames. Only two-dimensional analytical models are used so that the results could be studied properly. The analysis and design confirm to the Indian code provisions as given in IS 800:2007 and IS 1893:2016. The following details are used.

Table -1: Input Parameters

Name of Parameter	***Specification***
Type of structure	Moment resisting frames
Seismic Zone	5
Soil type	Medium stiff
Story height	4m
Bay width	4m,5m,6m
Zone Factor	0.36
Importance factor	1.2
Support condition	Fixed
Damping	5%
Grade of steel	Fe 500
Height of structure	36m

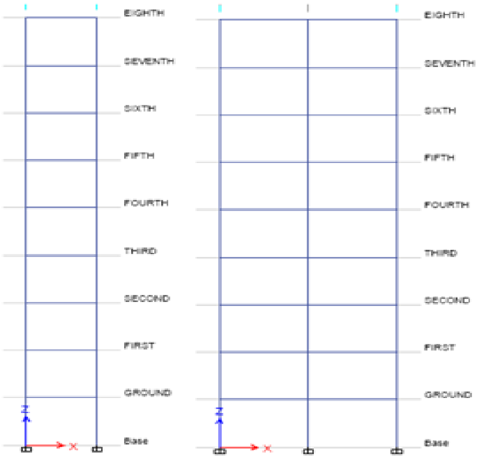

Fig -1: Steel moment-resisting frames models used in the study

4. METHOD OF ANALYSIS

To evaluate the seismic response of the steel moment-resisting frames by performing different analysis as mentioned below

4.1 EQUIVALENT STATIC ANALYSIS:

It is the most fundamental and simplest method for calculating the base shear of the structure. It requires less computational efforts because the base shear force is the function of the fundamental period and total seismic weight of the structure. The equivalent static method used to estimate maximum lateral load going to act on the structure. This method considers the only fundamental period of vibration. This method applies to regular buildings with restricted for less height.

4.2 RESPONSE SPECTRUM METHOD:

To know the peak response of the structure at the time earthquake is obtained from the response spectrum method. This method gives the earthquake response spectrum based on the type of soil condition. This method gives an approximate response but it is very useful for the structural design aspect. This method reflects the distribution of the forces up to the elastic range efficiently and shows the effect of the higher modes of vibration. This method is applicable for the regular and irregular building without any height restrictions.

4.3 PUSHOVER ANALYSIS:

The target displacement applied to the structure to show the maximum probable force to be experienced during the earthquake. The capacity curve is the plot of normalized base shear and normalized roof drift. The capacity curve is also known as the pushover curve.

4.3.1 TYPES OF PUSHOVER ANALYSIS:

Depending upon the target parameter, there are two types of the pushover analysis.

1) Displacement controlled pushover analysis:

When the lateral displacement is applied to the structure along with specified displacement to determine equilibrium force is known as displacement controlled pushover analysis.

2) Force-controlled pushover analysis:

The specified lateral force is applied to the structure to estimate the equilibrium displacement of the structure is known as Force controlled pushover analysis.

4.3.2 SIGNIFICANCE OF DISPLACEMENT CONTROLLED PUSHOVER ANALYSIS:

The displacement controlled pushover analysis provides more relevant than the forced controlled pushover analysis for determining the full capacity of the structure beyond the elastic limit. The analysis performed up to the failure limit to determine the ductile capacity and collapse load of the structure. The pushover curve is the graph plotted between the base shear coefficient and roof drift for the progressive increments in the lateral load till failure of the structure.

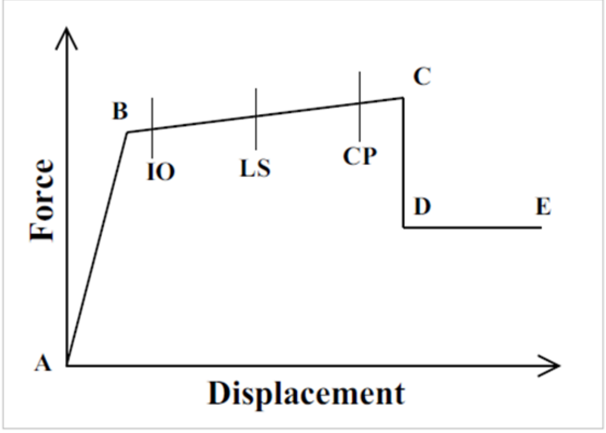

Fig -2: Idealised Force deformation curve

5. RESULT AND DISCUSSION

5.1 FUNDAMENTAL NATURAL PERIOD:

The fundamental natural period is a key parameter in the earthquake-resistant design that plays a vital role in the computation of base shear of the structure. The present work focuses on the seismic response of steel building considering variation in the base of the structure. For variation in the base of the structure is 4m, 5m, and 6m for the single bay, two bays, and three-bay structures respectively. The results obtained from response spectrum analysis for different steel models shown below

Table -2: Fundamental natural period

	Period for G+8 structure in seconds			
Span	***Single***	***Two***	***Three***	***IS code***
4m	1.974	1.977	1.98	1.477
5m	1.772	1.787	1.975	1.477
6m	1.706	1.728	1.738	1.477

The fundamental natural periods obtained from the analysis are not following the natural periods obtained from the empirical expression of code for the bare frame structure. The results show that as the base dimension of the structure increase then the fundamental natural period of the structure decrease. In the case of the bare frame structure, the effect of change base dimension should be considered.

5.2 PUSHOVER CURVE:

The displacement controlled pushover analysis performed, up to the failure limit to determine the ductile capacity and collapse load of the structure. The results obtained from the analysis of different steel models shown below.

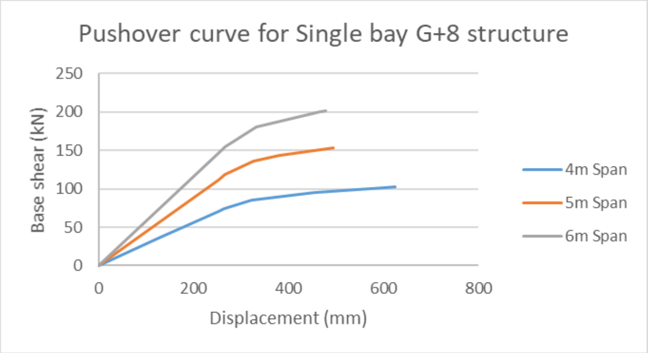

Fig -3: Pushover curve for single bay G+8 structure

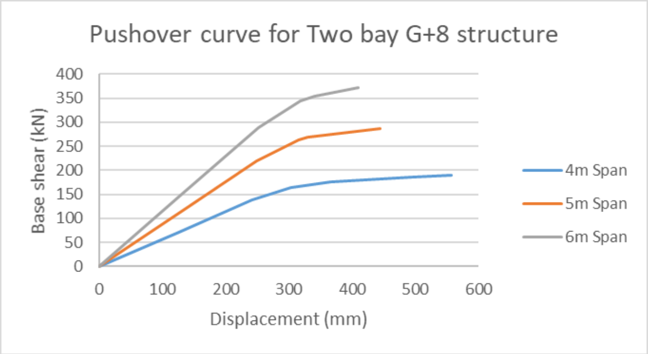

Fig-4: Pushover curve for two-bay G+8 structure

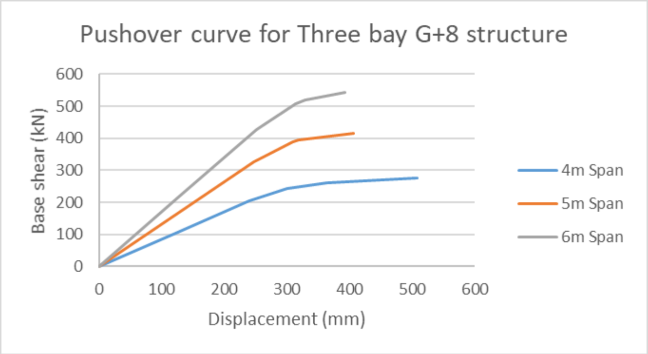

Fig -5: Pushover curve for three bay G+8 structure

5.3 PERFORMANCE POINT:

The point at which the capacity curve of the structure intersects the demand curve known as the Performance point of the structure. The performance point indicates the real behavior of the structure. The results obtained from displacement controlled pushover analysis for different steel models shown below.

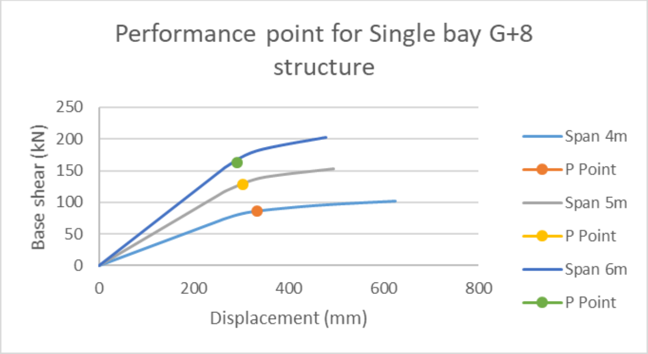

Fig- 6: Performance point for single bay G+8 structure

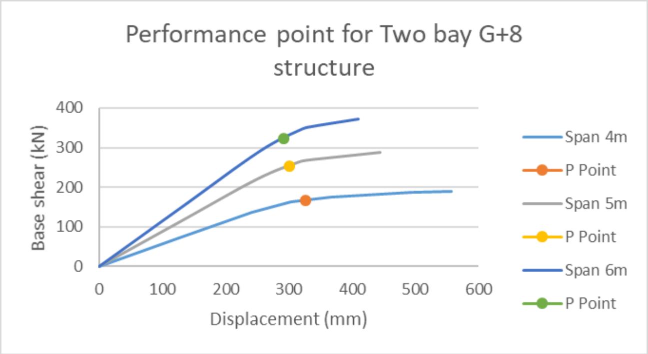

Fig-7: Performance point for two-bay G+8 structure

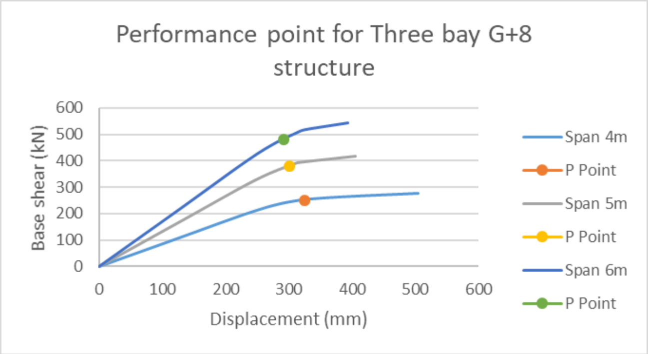

Fig- 8: Performance point for three bay G+8 structure

It is inferred that, as the base dimension increased the aspect ratio of the structure change, result in a change in the diaphragm action of the structure. As the change in diaphragm action, the stiffness of the lateral load-resisting element decrease with an increase in the base dimension. The capacity of the structure gets reduce as the base dimension of the structure increased.

6. CONCLUSIONS

[1] From the linear dynamic analysis, the natural period of the bare frame model is more than the value predicted by the empirical expression of code. This shows that results obtained for the bare frame model did not show the correct response of the structure when subjected to a seismic load.

[2] The base dimension of the structure increase then the fundamental natural period of the structure decrease. In the case of the bare frame structure, the effect of change base dimension should be considered.

[3] As the base dimension increased the aspect ratio of the structure change, this results in a change in the diaphragm action of the structure. The stiffness of the lateral load-resisting element decrease with an increase in the base dimension. The capacity of the structure gets reduce. The analysis performed up to the failure limit to determine the ductile capacity and collapse load of the structure.

[4] The capacity and performance of the structure get reduce as the base dimension of the structure increased.

[5] The results obtained from the linear dynamic analysis and nonlinear static analysis, the aspect ratio of the structure significantly influence the seismic performance of the structure.

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