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CODEN: IJRSFP (USA)

International Journal of Recent Scientific Research
Vol. 9, Issue, 2(K), pp. 24588-24592, February, 2018

ISSN: 0976-3031

International Journal of Recent Scientific Research

DOI: 10.24327/IJRSR

Research Article

PERFORMANCE EVALUATION OF STEEL BRACED BUILDING BY LINEAR STATIC AND TIME HISTORY ANALYSIS

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DOI: http://dx.doi.org/10.24327/ijrsr.2018.0902.1689

ARTICLE INFO

Article History:

Received 17th November, 2017
Received in revised form 12th December, 2017
Accepted 04th January, 2018
Published online 28th February, 2018

Key Words:

Time history analysis, linear static method, Bracing and Concrete filled steel tube etc.

ABSTRACT

Performance evaluation of different bracing system has been done by using linear static method and Time history method. A total 5 steel building (one SMRF and 4 different bracing system) and has been analyzed by Linear static and time history method. All 5 models are having 12 storey each with a storey height 3.2m. Four bracing system used are V-Bracing, Inverted bracing, diagonal bracing and X bracing, all bracing are made up of CHS filled with concrete. EL Centro Earthquake data has been used in time history analysis. After analysis results in the form of time period, Story shear, Story drift and story displacement has been tabulated and plotted. After comparing the results conclusion has been made and it has been found that Inverted bracing system is the mostly effective bracing system among the studied four type of bracing. Second effective system is X bracing and third effective system is V bracing system and fourth effective system is diagonal bracing system and the least effective system is SMRF.

INTRODUCTION

Design of high-rise and mid high rise building is generally governed by lateral load due to Earthquake or wind loads. Lot of structural systems re available to carry lateral loads effectively. In this paper 4 type of bracing system namely V, Inverted V, X and Diagonal bracing has been compared with SMRF system by time history analysis and linear static analysis. 5 models has been made in ETABS with above mentioned system and analysis and design has been done. For time history analysis El centro Earthquake data has been used for time history analysis and base shear modification factor for time history analysis has been used such that time history will give equal base shear as linear static method. This equal base shear has been maintained to compare the two methods. Result in the form of time period, Storey shear, Storey drift, Storey displacement has been extracted and presented in graphical and tabulated form. All the results has been compared to get the most effective bracing system.

LITERATURE REVIEW

Steel moment resistant frame previouslydamged in north ridge earthquake has been studied by Aixa Vazquez *et al* (2005). Author has analyzed 4 storey buildings by nonlinear static and nonlinear dynamic analysis, it has been found that NDP is more reliable than NSP. Mahmoud R. Maheri *et al* evaluated R factor for X bracing Knee bracing for RC building and it has been found that higher the height of building lesser the R value of building. Varoius method of performing seismic analysis like Adaptive pushover analysis and force based pushover analysis has been studied by MohseenIzadinia, Mohmd *et al*. 15 steel building has been analyzed by nonlinear static pushover having bracings like Single, Diagonal, K, V, inverted V and chevron bracings by Mohammed Idrees Khan *et al*. Results of seismic analysis of high rise steel building with different pattern of bracing system and without bracing system by using time history analysis for Northridge earthquake has been done by KK Sangle *et. al*. Importance of response reduction factor has been stated by Apurba Mondal. Dhanraj m Patil *et al* has been evaluated seismic behaviors of different bracing system by nonlinear static pushover analysis

Structural Systems for High Rise Building

Different structural system has been used to resist the lateral load and drift. Here only two system has been mentioned.

Special moment resistance frame: In rigid frame structures the columns and girders are joined together by moment resistant connections. The lateral stiffness of a rigid frame depends on the bending stiffness of the columns, girders and connections in-plane.

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Bracing System: In braced frames the lateral resistance is given by diagonal members that, together with the girders, form a web of vertical trusses, where the columns acting as chords. Bracing systems are highly efficient of resisting lateral loads. This due to the horizontal shear in the building is resisted by the horizontal components resulting in tensile and compressive actions in the web members. The bracing system is an almost steel exclusive system since the diagonals are inevitably subjected to tension for one or the other direction of the lateral loading. Braced systems are able to produce a very stiff lateral structure for a minimum of additional material which makes it economically efficient for any height. In this work four type of bracing has been studied namely V, Inverted-V, X and Diagonal bracing.

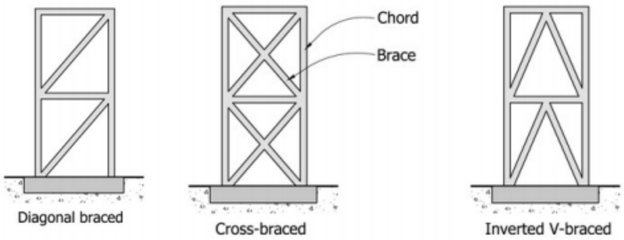

Fig 1 Daigonal, X bracing and Inverted V bracing system

The bracing system is an almost steel exclusive system since the diagonals are inevitably subjected to tension for one or the other direction of the lateral loading. Braced systems are able to produce a very stiff lateral structure for a minimum of additional material which makes it economically efficient for any height.

Concrete Filled Steel Tube AS bracing (CFT)

Braces are extremely effective in increasing the horizontal stiffness and strength of steel frame as discussed above but braces buckles and rapidly losses strength when subjected to compression force. Compressive strength of the tabular member decreases radically in post buckling stage because the section is easy to change in shallow ellipse. If these braces will be filled by concrete it will prevent the local buckling and will provide more energy absorption, due to which damage of column and beam which are carrying permanent load will be less due to earthquake.

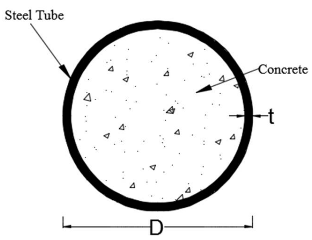

Fig 2 Steel Filled pipe bracing cross section

The concrete-filled steel tube (CFT) bracing system has many advantages compared with the ordinary steel or the reinforced concrete system. One of the main advantages is the interaction between the steel tube and concrete local buckling of the steel tube is delayed by the restraint of the concrete, and the strength of concrete is increased by the confining effect of the steel tube.

Methods of analysis

Two methods of analysis namely Linear Static (LSM) (Equivalent lateral load method) and Time history analysis (TH) has been used in this work. For Equivalent load method Procedure of IS1893-1 has been followed. For time history analysis El Centro Earthquake data has been used for analysis. Base shear modification factor for time history has been used such that it will give equal base shear of equivalent lateral load methods. Time history analysis has been done in ETBAS software.

Fast Nonlinear Analysis (FNA) is a modal analysis method useful for the static or dynamic evaluation of linear or nonlinear structural systems.FNA is well-suited for time-history analysis, and often recommended over direct-integration applications.

Geometric and loading data for 5 steel building models

Total 5 buildings which included 1 Special moment resistance frame building and remaining 4 Braced buildings with different bracing system has been modelled and analyzed. All 5 models are having 12 storey each with 5 bays in each direction. The bay width is 6 m. All the input data has been mentioned in below table. Model 1-SMRF, Model 2-V bracing, Model 3-Inverted V, Model 4 – Diagonal and Model 5-X bracing.

Table No 1 Geometric and Loading data for 5 Steel building models

Description	**Model1**	**Model-2**	**Model-3**	**Model-4**	**Model 5**
Material	Fe 345	Fe 345	Fe 345	Fe 345	Fe 345
Deck thickness (mm)	110	110	110	110	110
Concrete Density (kN/m^3)	25	25	25	25	25
Floor Finish load (kN/m^2)	2	2	2	2	2
Live load (kN/m^2)	2	2	2	2	2
Zone Factor	0.36	0.36	0.36	0.36	0.36
Total height of building (m)	38.4	38.4	38.4	38.4	38.4
Time history data	EL Centro	EL Centro	EL Centro	EL Centro	EL Centro
Time history factor	83.45	79.126	79.76	80.21	81.04
Bracing type	NA	V bracing	Inverted V	Diagonal	X bracing
Bracing section (pipe filled with M20 concrete)	NA	200x16	200x16	200x16	200x16
Secondary beams	ISLB 250	ISLB 250	ISLB 250	ISLB 250	ISLB 250

Modeling in etabs

Modelling of steel building has been done in ETABS software. After loading application steel section has been designed. After complete design two types of analysis has been performed one is Equivalent lateral load another is time history analysis. The modelling all models has been explained as below.

Model 1 (SMRF): This model is having Structural system of rigid frame. Beam and column joints are assumed at rigid.

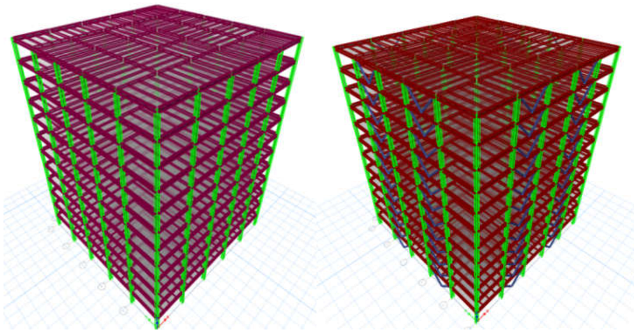

Fig 3 D view of Model 1 and Model 2

Model 2 (V bracing): This model is having rigid frame with Bracing. Beam and column joints are assumed as rigid and bracing ends has been considered as pinned.

Model 3 (Inverted V bracing): This model is having rigid frame with Inverted V Bracing. Beam and column joints are assumed as rigid and bracing ends has been considered as pinned.

Model 4 (Diagonal bracing): This model is having rigid frame with Diagonal Bracing. Beam and column joints are assumed as rigid and bracing ends has been considered as pinned.

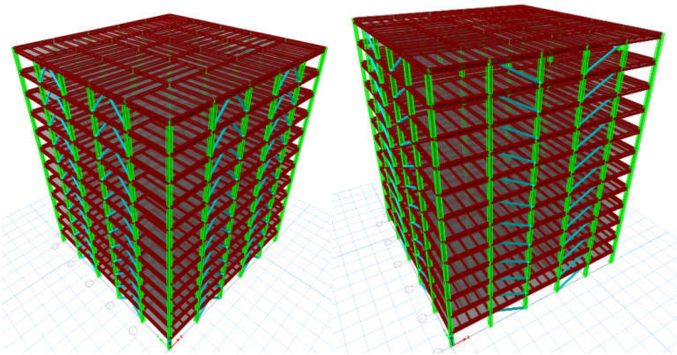

Fig 4 3-D view of Model 3 and Model 4

Model 5 (X bracing): This model is having rigid frame with X Bracing. Beam and column joints are assumed as rigid and bracing ends has been considered as pinned.

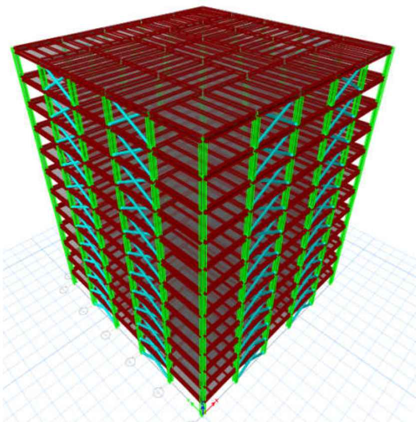

Fig 5 3-D view of Model 5

Analysis results

After analysis results in the form of Storey shear, Storey displacement, Storey drift and time period of building has been evaluated and plotted as below.

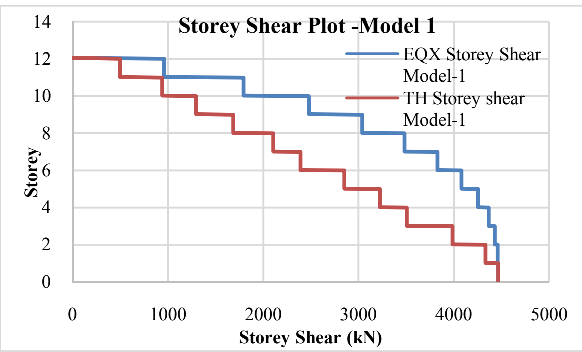

Fig 6 Storey Shear plot for Model-1 (EQX and TH)

Storey Shear: Storey shear plot for all five models has been plotted below. The concept of keeping Base shear for both method of analysis same is to compare static and dynamic method of analysis.

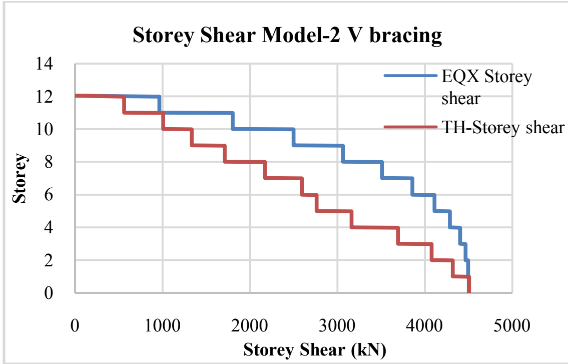

Fig 7 Storey Shear plot for Model-2 (EQX and TH)

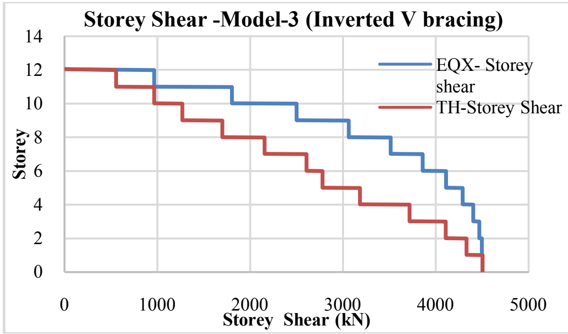

Fig 8 Storey Shear plot for Model-3 (EQX and TH)

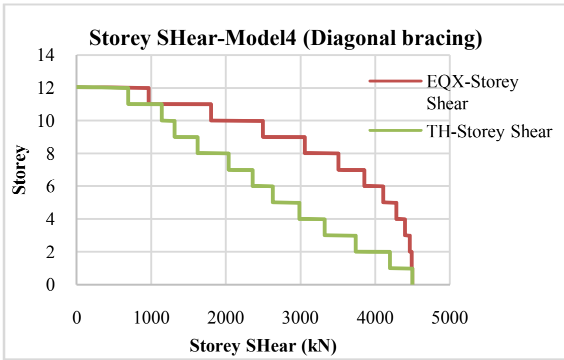

Fig 9 Storey Shear plot for Model-4 (EQX and TH)

Storey Drift: Storey drift for all 5 models has been plotted on two graphs one graph is having EQX method another graph is having TH.

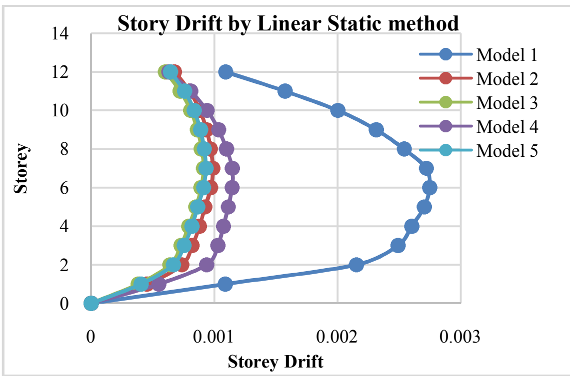

Fig 10 Storey drift plot for All Model by EQX

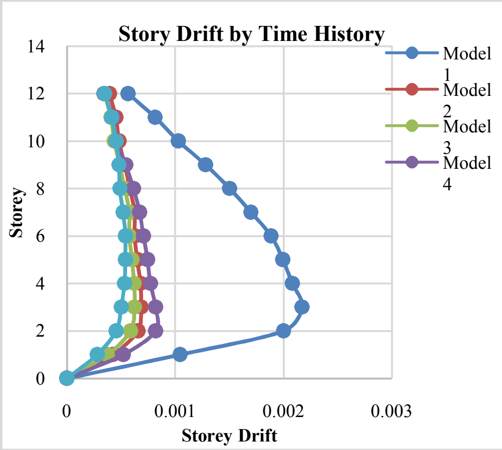

Fig 11 Storey drift plot for All Model by TH

Storey Displacement: Storeydisplacement for all 5 models has been plotted on two graphs one is for QX another for TH analysis method

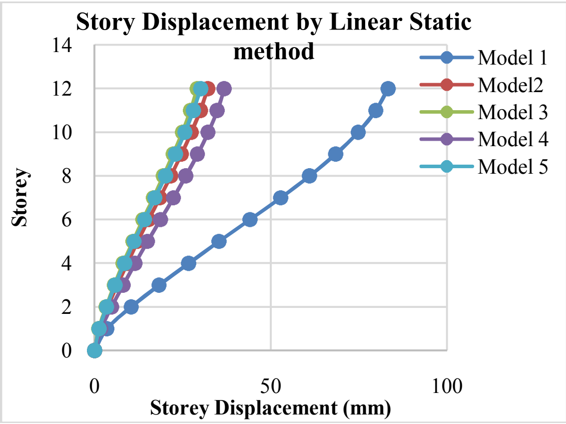

Fig 12 Storey displacement plot for All Model by EQX

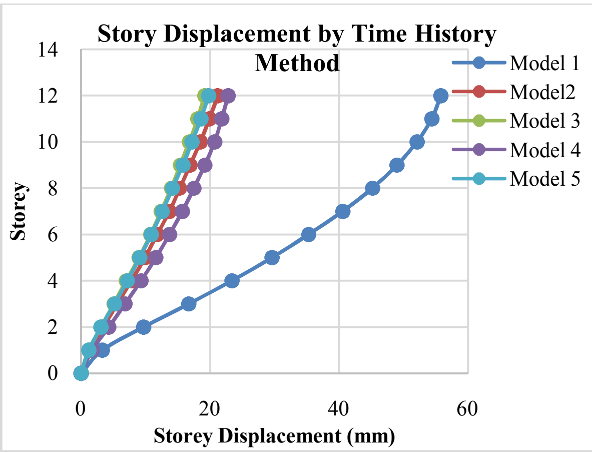

Fig 13 Storey displacement plot for All Model by TH

Time periods of buildings: For all five buildings programme calculated time period has been obtained from ETBAS and tabulated as below

Table 2 Time periods of 5 Models

Model	Time period (Sec)	Remark
Model 1	2.128	SMRF system
Model 2	1.28	V bracing
Model 3	1.217	Inverted V bracing
Model 4	1.396	Diagonal Bracing
Model 5	1.235	X bracing

RESULTS AND DISCUSSION

Result and discussion based on the plotted graphs and table has been mentioned as below:

Discussion on Storey Shear Plot: For comparing the two methods of analysis base shear for both the analysis methods has been kept equal. It has been observed that, equivalent Storey forces by equivalent lateral load(EQX) method is higher at top stories and lesser at lower story and by Time history method the equivalent lateral storey load is almost uniform throughout the height of the building.

Discussion on Storey Drift

- Out of 5 building studied none of the building drift has been exceeded the allowable limit of IS1893-1 (0.004).
- Model-1 (SMRF) building is having maximum Drift among all the studied model, the drift in building with bracing is very less as compare to building without bracing.
- Linear static method overestimates the Drift as compare to time history for the same Base shear.
- By time history maximum drift has been observed at storey 2 and 3 but by Linear static method maximum drift has been observed at mid height of building.

Discussion on Storey Displacement

- Maximum Story displacement has been observed for model 1 among all five cases studied. By linear static method and time history method story displacement of top story observed is 83.3 and 55.8 mm respectively.
- There is a much difference in story displacement between Model-1 (SMRF) building and all braced buildings (Model 2-4).
- The minimum observed story displacement is for the model-3. By linear static and time history method observed story displacements are 29.1 mm and 19.2 mm respectively.
- For Model 3 and model five the Storey displacement plot is almost overlapped.
- Linear static method of analysis overestimates the storey displacement as compare to time history analysis.

Discussion on time periods of Building: By observing the table of time period it has been observed that, maximum time period is for model-1 (SMRF) 2.128 sec while minimum time period has been observed for model -3(Inverted v bracing). The second minimum time period obtained is for model -5 (X bracing building).

CONCLUSION

Five steel buildings one with Special moment resistance frame and remaining four with 4 type of bracing system has been studied. The bracing section used is Circular pipe section filled with concrete. All studied model are having storey height of 3.2 m each with total 12 storey. There are total 5 bays in each direction of 6 m each. The four bracing system used are V bracing (Model-2), inverted V bracing (model -3), Diagonal bracing (Model-4) and X bracing (model-5). The all 5 building has been modelled in ETABS software and loads has been applied as per chapter 4. Two methods of analysis namely Linear Static method (LSM/EQX) and time history analysis (TH) has been used. EL Centro earthquake data has been used for time history analysis. The scale factor for time history has been used such that base shear for Linear static method is equal to Time history method. After analysis results in the form of time period, Story shear, Story drift and story displacement has been tabulated and plotted as graph. Final conclusion has been made as per obtained result as below:

- Linear Static method of analysis over estimates the response of structure like Storey drift/ Storey displacement as compare to Time history analysis method.
- By observing the lateral drift and displacement of building it can be concluded that SMRF (Model-1) is having less lateral stiffness (more displacement as compare to all braced building) as compare to the all bracing system building.
- As factor has been used to maintain equal story shear by both the analysis method, the observed Storey shear for different building and analysis method is not varying too much.
- It has been observed from story shear plot that Storey forces by linear method of analysis has higher values at top story and lower value at lower story while by time history analysis the lateral load values are almost uniform along the height of building.
- For the 5 models observed storey drift is less than the Allowable drift as per IS1893-1 (0.004) by both the methods of analysis.
- By comparing the results in the form of Store drift, Story shear, Story displacement and time period of building it can be concluded that the most effective structural system among all studied structural system is Inverted V bracing system (Model-1) because it's having minimum story drift, story displacement and time period as compare to all studied structural system.
- After Inverted bracing second effective system is X bracing (Model5) which is having all storey drift and storey displacement curve nearly overlapped with Inverted bracing.
- The third effective system bracing system is V bracing (Model-2) and fourth effective system is diagonal bracing (Model-4). And the least effective structural system among studied structural system is Special moment resistance frame (model-1).

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How to cite this article:

Rupa Walunj and Kalwane U.B.2018, Performance Evaluation of steel Braced Building by Linear Static and Time History Analysis. *Int J Recent Sci Res.* 9(2), pp. 24588-24592. DOI: http://dx.doi.org/10.24327/ijrsr.2018.0902.1689

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