Dynamic Analysis of Industrial Steel Structure by using Bracings and Dampers Under Wind Load and Earthquake Load

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Abstract* - The structural system of the building has to support the lateral loads due to earthquake and wind in addition to gravity loads. A lateral load develops high stresses and produces sway causing vibration and drift. If the industrial steel structures are not designed to resist the lateral loads, then they may be collapse resulting into the loss of life or its content. Therefore it's important for the structure to have not only sufficient strength against gravity loads but also the adequate stiffness to resist lateral forces. Literature review reveals that LLRSS (Lateral load Resisting structural system) is provided in the form of devices like base isolation and dampers which controls the seismic vibration and lateral drift. But these devices are very costly and effective only for high rise buildings. Hence there is a need to study the LLRSS or technology suitable for a particular breadth of building. The objective of this research is to propose simple but innovative and effective LLRSS or structural technology and methodology for the seismic control which can be used in new as well as old industrial steel structures.. In spite of increasing popularity, analytical study of braced industrial steel structure and its detailed requirement to control the seismic responses limited in India. Also industrial steel structure involves heavy dead load due to large member size which intern is more prompt for seismic loss. Hence, it is proposed to study the response of steel buildings/frames with different types of steel bracings configurations and dampers as a LLRSS to control the vibration lateral displacement and storey drift. The structural response parameters selected for the study are time period, natural frequency, and roof displacement. The research work deals with the parametric study of response of Non-linear time history analysis (NLTHA) of 3D industrial steel structure braced with different bracing configurations and dampers with different mass ratios using software (Sap-2000) under Bhuj earthquake. The bracing configuration used are X-bracing, ECCENTRIC bracing, DIAGONAL bracing to suggest suitability of particular bracing configurations for the stability of the building structure under seismic loading. Modals with x bracing and damper with mass ratio 2% are found to improve the performance of the building under earthquake load and wind load.

Key words: LLRSS, bracings, dampers, time history analysis, time period, base shear, lateral displacement, BHUJ EARTHQUAKE,SAP 2000 software.

1. INTRODUCTION

Earthquakes are perhaps the most unpredictable and devastating of all natural disasters. They not only cause great destruction in terms of human casualties, but also have a tremendous economic impact on the affected area. An earthquake may be defined as a wave like motion generated by forces in constant turmoil under the surface layer of the earth (lithosphere), travelling through the earth's crust. It may also be defined as the vibration, sometimes violent, of the earth's surface as a result of a release of energy in the earth's crust. This release of energy can cause by sudden dislocations of segments of the crust, volcanic eruption, or even explosion created by humans. Dislocations of crust segments, however, lead to the most destructive quakes. In the process of dislocation, vibrations called seismic waves are generated. These waves travel outward from the source of the earthquake at varying speed, causing the earth to quiver or ring like a bell or tuning fork.

The concern about seismic hazards has led to an increasing awareness and demand for structures designed to withstand seismic forces. In such a scenario, the onus of making the building and structure safe in earthquake-prone areas lies on the designers, architects, and engineers who conceptualize these structures. Codes and recommendations, postulated by the relevant authorities, study of the behavior of structures in past earthquakes and understanding the physics of earthquake are some of the factors that helps in the designing of an earthquake resistant structure.

Earthquakes create vibrations on the ground that are translated into dynamic loads which cause the ground and anything attached to it to vibrate in a complex manner and cause damage to buildings and other structures. Civil engineering is continuously improving ways to cope with this inherent phenomenon. Conventional strategies of strengthening the system consume more materials and energy. Moreover, higher masses lead to higher seismic forces. Alternative strategies such as passive control systems are found to be effective in reducing the seismic and other dynamic effects on civil engineering structures.

PLAN BRACING:

Plan bracing is perhaps the most obvious way to prevent lateral buckling of a compression flange. This is because plan bracing provides lateral restraint, i.e. it stops the compression flanges of beams from moving sideways.

Plan bracing takes the form of diagonal members, usually angle sections, connecting the compression flanges of the main beams, to form a truss when viewed in plan. This makes a structure that is very stiff in response to lateral movement. With lateral movement of the compression flanges thus resisted, the half wave length for buckling is reduced to the length between bracings.

Most plan bracing will be at top flange level. For steel composite bridges, this allows plan bracing to be cast within the deck slab, so it does not need to be painted and the underside of the bridge will have a clean, bracing-free appearance. However, where there are hogging moments in the main girders, there may need to be bracing on the bottom flange.

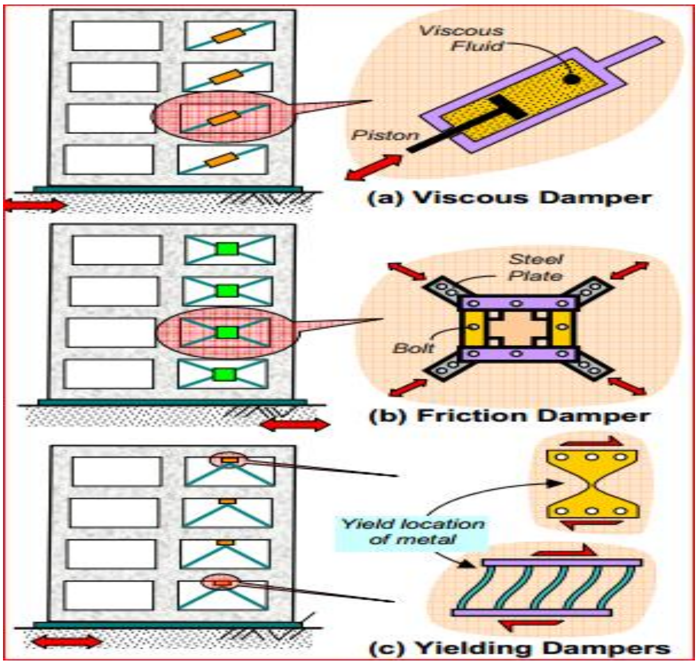
Plan bracing is not common in modern steel composite bridges. The main reason it is not used is because the plan bracing above the top flange conflicts with deck permanent formwork. It is, however, possible to position the plan bracing below the deck slab.

If plan bracing is not cast within the deck and is going to remain in the structure on completion, the performance of the bracing in service needs to be verified. Because the bracing is spanning partly in the longitudinal direction, longitudinal stresses will be induced in the bracing. Stresses can be determined by calculating the global displacements of the structure and imposing them on the bracing, or by adding the bracing to a comprehensive 3D structural model. No checks are needed for bracing within the deck slab, because the extra stiffness of the steel will be insignificant and concrete restrains the bracing against buckling.

Plan bracing can be used to form a "virtual box" girder. This is an alternative to the box girder which avoids the health and safety risks associated with the confined space interiors of box girders . The virtual box uses the deck slab or deck plate and plan bracing between the bottom flanges of two adjacent I girders to form a shape with torsional stiffness which can be used instead of a box girder.

SEISMIC DAMPERS

Another approach for controlling seismic damage in buildings and improving their seismic performance is by installing seismic dampers in place of structural elements, such as diagonal braces. These dampers act like the hydraulic shock absorbers in cars much of the sudden jerks are absorbed in the hydraulic fluids and only little is transmitted above to the chassis of the car. When seismic energy is transmitted through them, dampers absorb part of it, and thus damp the motion of the building. Dampers were used since 1960s to protect tall buildings against wind effects. However, it was only since 1990s, that they were used to protect buildings against earthquake effects. Commonly used types of seismic dampers include viscous dampers (energy is absorbed by silicone-based fluid passing between piston-cylinder arrangement), friction dampers (energy is absorbed by surfaces with friction between them rubbing against each other), and yielding dampers (energy is absorbed by metallic components that yield)



II. METHODOLOGY

For seismic performance evaluation, a structural analysis of the mathematical model of the structure is required to determine force and displacement demands in various components of the structure. Several analysis methods, both elastic and inelastic, are available to predict the seismic performance of the structures.

2.1 STRUCTURAL IDEALIZATION

The objective of the present work is to

- Study the use of bracings and dampers placed at different locations subjected to wind and earthquake load.
- The design of wind load was calculated based on IS 875 (Part-3) and the earthquake load obtained using IS1893(Part-1):2002.
- The location of bracings and dampers for reducing the lateral displacement, lateral drift are evaluated
- The sap-2000 software program is selected to perform analysis.

In the present context of study an steel structure is taken into consideration and the analysis is done as per the Indian standards. This building will not represent a particular real structure that has been built or proposed. the structure is assumed to be located in zone 5 of India. however, the dimensions, general layout and other characteristics have been selected to be representative of a building for which the use of bracings and dampers would be plausible solution. here the studies has been performed on steel structure with different height to breadth ratio.

The modal considered for the study is a 12.6m height steel structure. The plan of the structure is 57.6 x 86.4m ,

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57.6 x 100.8m , 57.6 x 129.6m , 57.6 x 172.8m with column spaced at 7.2m centre to centre. a building is assumed to be located at zone 5 of India.

In the present study a total of 4 different arrangements of bracings and 2 models with and without damper are analysed using SAP2000 software are as fallows.

1. Structural modal without bracing.
2. structural modal with X bracing(12 bay)
3. structural modal with diagonal bracing(12 bay)
4. structural modal with eccentric bracing (12 bay)
5. structural modal with X bracing(14 bay)
6. structural modal with diagonal bracing(14 bay)
7. structural modal with eccentric bracing (14 bay)
8. structural modal with X bracing(18 bay)
9. structural modal with diagonal bracing(18 bay)
10. structural modal with eccentric bracing (18 bay)
11. structural modal with X bracing(24 bay)
12. structural modal with diagonal bracing(24 bay)
13. structural modal with eccentric bracing (24 bay)
14. structural modal without damper
15. structural modal with damper.
16. all steel columns are identical that is ISMB225 and its property is mentioned in the table4.1. the bracings width and lenth is 0.31m and 12.32m.the tie beam are 0.45m wide and 0.45m deep.
17. the method of analysis carried out here is dynamic analysis. torsional effects are not considered,the material behavior is in linear elastic range.

Table 4.1 shows the sectional properties of steel structure:

ALL DIMENSIONS IN MM	Outside height(in mm)	Flange width(in mm)	Flange thickness(in mm)	Web thickness(in mm)
BEAMS				
ISMB 225	225	110	11.8	6.5
RAFTER				
ISMB 225	225	110	11.8	6.5
PURLIN INTERMEDIATE				
ISMB 225	225	110	11.8	6.5
PURLIN AT ENDS				
PIPE	Dia=30mm			
BRACINGS	Outside horizontal leg	Outside vertical leg	Horizontal and vertical leg thickness	
BR1-CA225x225x30	225	225	30	

III MODELING:

In the present study, dynamic analysis of industrial steel structure using dampers and bracings under wind load and earthquake load is investigated. Considering steel structure keeping height constant the breadth of the structure has been varied (H/B RATIO 1, 2 and 3). The dampers mass ratio has been varied by 1%, 1.5% and 2%. The research work deals with the parametric study of response of Non-linear time history analysis (NLTHA) of 3D industrial steel buildings braced with different bracing configurations and dampers using software (Sap-2000) under Bhuj earthquake.

Table 4.2 shows the general description of steel structure.

No of bays	X direction	Y direction
Model 1	8	12
Model 2	8	14
Model 3	8	18
Model 4	8	24
Height of frame	12.6	
Yield strength of steel	Fe500	
Grid to grid spacing in x dir	7.2m	
Grid to grid spacing in y dir	7.2m	

Wind Coefficient

Coefficients	Values
Basic wind speed	50
Terrain category	3
Structural classes	C
Risk coefficient k1	1
Terrain,height and structure size factor k2	1
Topography factor k3	0.85
Design wind speed vz	42.5

Seismic Coefficients

Coefficients	VALUES
Response reduction factor R	5
Importance factor I	1
Zone factor Z	0.36
Time period T	0.568

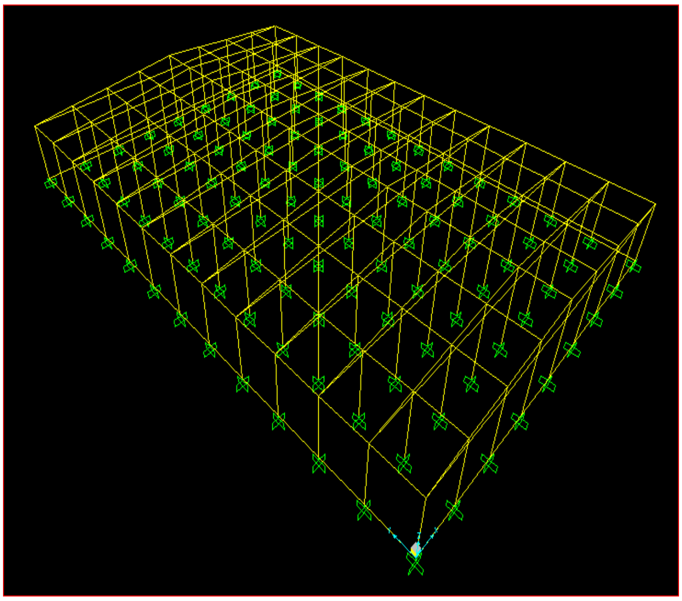

Fig: 12 bay fixed modal

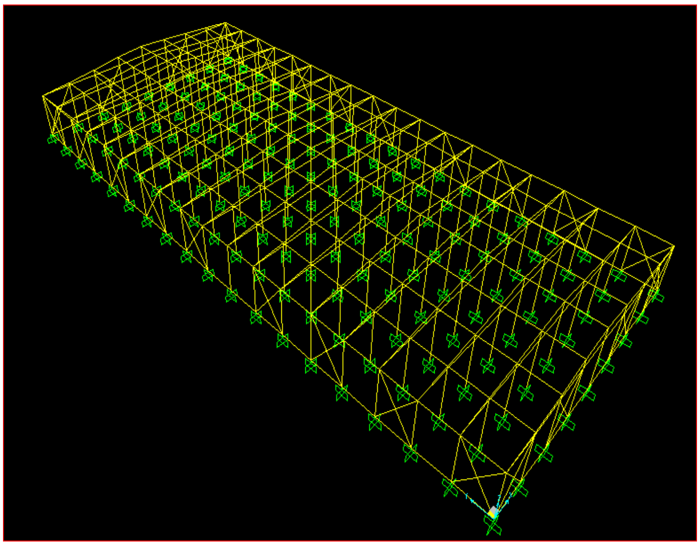

Fig :18 bay x bracing modal

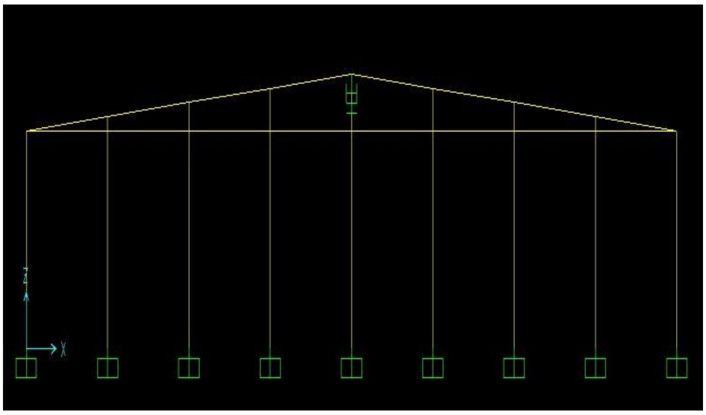

Fig :18 model with damper

IV RESULT AND DISCUSSIONS

The forces and displacements developed in each of the member of a structure are obtained from the analysis. These results obtained from the analysis have been discussed in detail in this chapter. Further these results have been used for the understanding of behaviour of the structure between the steel structure with bracing and dampers under the effects of lateral loads.

4.1 VARIATION OF NATURAL TIME PERIOD:

The variation of natural time period is studied for model with and without bracing , and with and without dampers. The values of natural time period (mode 1, mode 2 and mode 3

EFFECT OF BRACINGS:

The variation of base shear is studied for a steel structure with different number of bays (12,14,18,24) implemented with different bracings is compared with fixed base modal. the values of base shear of a (12,14,18,24) bay modal with and without bracings .

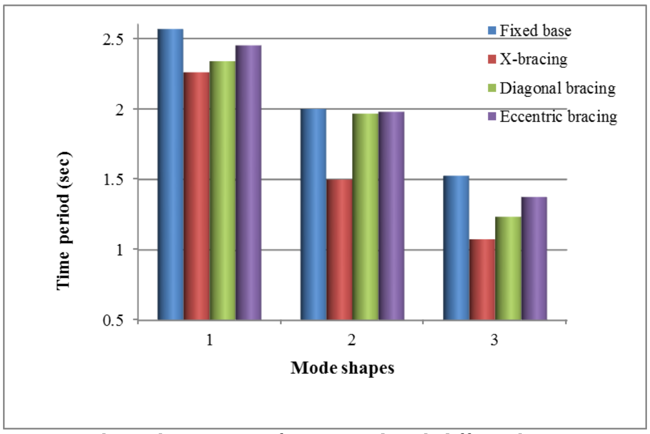

Fig : shows the variation of time period with different bracings.

From the above figure it can be seen that there is decrease in time period with the implementation of bracings and x-bracing is found out to be more effective in reducing time period than other bracings.

4.2 VARIATION OF BASE SHEAR:

The variation of base shear is studied for model with and without bracing , with and without dampers . the values of base shear of the member .

EFFECT OF DAMPERS:

The variation of base shear is studied for a steel structure with different number of bays(12,14,18,24) implemented with damper is compared with fixed base modal. the values of base shear of a (12,14,18,24) bay modal with and without dampers .

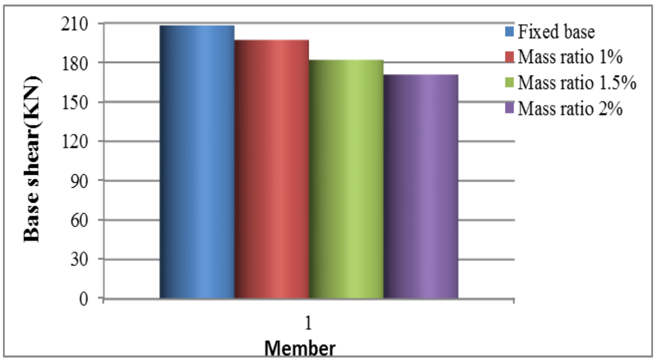

Fig : shows the variation of base shear with different mass ratio.

From the above figure it can be seen that there is decrease in base shear with the implementation of dampers and damper with mass ratio 2% is found out to be more effective in reducing base shear than other dampers with mass ratio(1%,1.5%).

4.3COMPARISION OF LATERAL DISPLACEMENT

The variation of lateral displacement is studied for a steel structure with different number of bays(12,14,18,24) implemented with different bracings and dampers is compared with fixed base modal. the values of lateral displacement of a (12,14,18,24) bay modal with and without bracings and dampers.

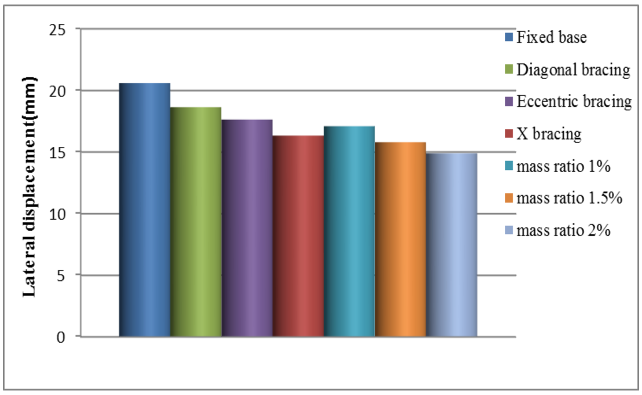

Fig 5.35: shows the variation of lateral displacement with different mass ratio and bracings.

From the above figure it can be seen that there is decrease in lateral displacement with the implementation of dampers and bracings.

5.5 TIME HISTORY ANALYSIS:

Analysis of structure, applying data over increment time step as function of acceleration, force, moment or displacement. Earthquake ground acceleration records namely NW bhuj components of bhuj earthquake records have been selected the records are defined for the acceleration points. with respect to a time interval of 0.05secs,time history analysis has been carried out for the modals with fixed base and different bracings(diagonal,eccentric,x) and damper with different mass ratio (1%,1.5%,2%).

EFFECT OF BRACINGS:

VARIATION OF BASE SHEAR:

The variation of base shear is studied for a steel structure with different number of bays (12,14,18,24) implemented with different bracings is compared with fixed base modal and it is subjected to bhuj earthquake data. The values of base shear of a (12,14,18,24) bay modal with and without bracings are showed in below graphs.

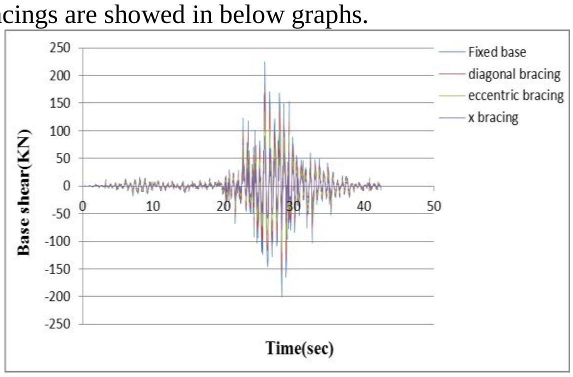

Fig : shows the variation of base shear with different bracings.

From the above figure it can be seen that there is decrease in base shear with the implementation of bracings and x-bracing is found out to be more effective in reducing base shear than other bracings.

VARIATION OF JOINT DISPLACEMENT:

The variation of joint displacement is studied for a steel structure with different number of bays (12,14,18,24) implemented with different bracings is compared with fixed base modal and it is subjected to bhuj earthquake data. The values of joint displacement of a (12,14,18,24) bay modal with and without bracings are showed in below graphs.

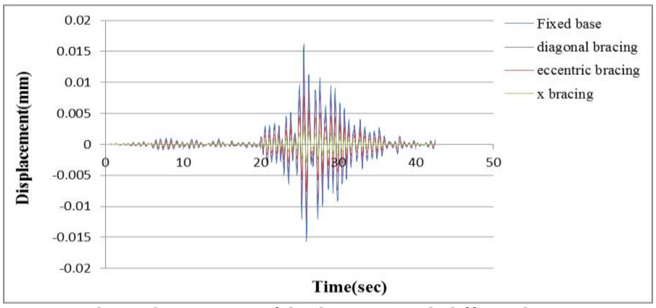

Fig : shows the variation of displacement with different bracings.

From the above figure it can be seen that there is decrease in joint displacement with the implementation of bracings and x-bracing is found out to be more effective in reducing joint displacement than other bracings.

5.5.2 EFFECT OF DAMPERS:

VARIATION OF BASE SHEAR:

The variation of base shear is studied for a steel structure with different number of bays(12,14,18,24) implemented with damper is compared with fixed base modal and it is subjected to bhuj earthquake data. The values of base shear of a (12,14,18,24) bay modal with and without dampers are showed in below graphs.

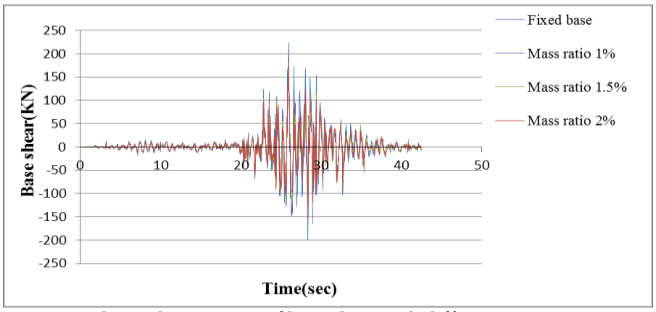

Fig : shows the variation of base shear with different mass ratio.

From the above figure it can be seen that there is decrease in base shear with the implementation of dampers and damper with mass ratio 2% is found out to be more effective in reducing base shear than other dampers with mass ratio(1%,1.5%).

VARIATION OF JOINT DISPLACEMENT:

The variation of joint displacement is studied for a steel structure with different number of bays(12,14,18,24) implemented with damper is compared with fixed base modal and it is subjected to bhuj earthquake data. The values of joint displacement of a (12,14,18,24) bay modal with and without dampers are showed in below graphs.

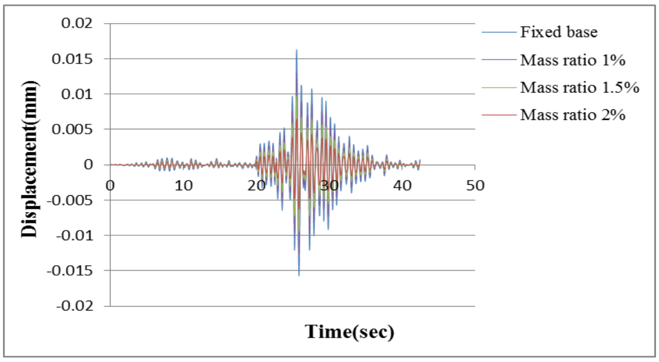

Fig : shows the variation of displacement with different mass ratio.

From the above figure it can be seen that there is decrease in joint displacement with the implementation of dampers and damper with mass ratio 2% is found out to be more effective in reducing joint displacement than other dampers with mass ratio(1%,1.5%).

V CONCLUSION:

The thesis attempts to study the effect of bracings and dampers under earthquake and wind loads for industrial steel structures. This study has been mainly carried out to determine the change in various dynamic parameters due to consideration different bracings, dampers with different mass ratio and height by breadth ratios. on the basis of results obtained, some of the important conclusions are presented here.

Modals with bracings are more effective in reducing structural parameters than dampers. Modals with damper are most effective in reducing systematic parameters than bracings. The usefulness of dampers is observed when the mass ratio of damper is 2%. In bracings x bracing is found out to be more economical.

1. Time period decreases with the increase in stiffness of building.
2. In comparison to the structure with bracing and damper the time period decreases up to 12.06% for bracing and 19.82% for damper.
3. Base shear decreases with the increase in stiffness of building.
4. In comparison to the structure with bracing and damper the base shear decreases up to 21.82% for bracing and 23.10% for damper.
5. Lateral displacement decreases with the increase in stiffness of building.
6. In comparison to the structure with bracing and damper the lateral displacement decreases up to 20.72% for bracing and 28.38% for damper.
7. Effective stress ratio decreases with the increase in stiffness of building.
8. In comparison to the structure with bracing and damper the effective stress ratio decreases up to 71.50% for bracing and 17.30 % for damper.
9. Time history analysis (base shear) decreases with the increase in stiffness of building.
10. Time history analysis (joint displacement) decreases with the increase in stiffness of building.
11. From the study it has been found that Dampers are more economical than bracing

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