Parametric Analysis of a Steel Industrial Building Frame Considering Wind Load, Dampers and Bracings Using ETABS

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ABSTRACT

In addition to gravity stresses, the building's structural structure must handle lateral loads caused by earthquakes and wind. A lateral load causes significant stresses and instability, which results in vibration and drift. If industrial steel structures are not designed to withstand lateral loads, they may collapse, resulting in the death or destruction of people or property. As a result, the structure must not only be strong enough to withstand gravity loads, but also stiff enough to withstand lateral forces. According to a review of the literature, LLRSS (Lateral load Resisting structural system) components such as base isolation and dampers are used to manage seismic vibration and lateral drift. This research compares the performance of a G+4 steel frame building with and without a damper. It is a rectangular structure with an industrial operation. The planned building's structural frame is a unique steel moment resisting frame (SMRF). ETABS is used to perform structural analysis and design. The structure's dynamic behaviour under wind and seismic loads is investigated using response spectrum analysis. Wind and earthquake vibrations are reduced by the usage of dampers. Engineers can improve the building's resilience by employing dampers. Fluid viscous dampers are investigated in depth in this research.

The parametric investigation of Dynamic analysis of 3D industrial steel structure braced with varied bracing configurations and dampers with different mass ratios utilising software (ETABS). For the structural stability of the building structure under seismic loads, X-bracing bracing configurations were adopted.

A comparison with a general steel construction was done, and the bracing structure and dampers were examined.

Keywords - Steel Frame Building, Viscous Damper, Bracing System Storey Drift, Displacement, Base Shear, ETABS

I. INTRODUCTION

Steel Worldwide different types of RC and steel structures with various floor systems are being used for multi-storey buildings. In the past, masonry structures were widely used for building construction. Day by day technology has developed. Later, steel structural systems were started for multi-storey buildings. RC structural techniques for multi-story building construction started with the establishment of reinforced concrete. Non-composite RC floor systems supported on steel beams have been used in the past. It became necessary to form mechanical shear connectors to consider composite action after the invention of welding. Because many multi-story and low-rise RC and masonry buildings have failed due to earthquakes, structural engineers are seeking for alternate construction methods. The use of composite or hybrid materials is very intriguing. The fire resistance of a bare steel structure is low. Different fireproofing systems have advanced greatly in recent years. In India, masonry and RC constructions were the most common. Steel structural technologies have become increasingly popular during the previous decade. As a result, alternative structural systems are gradually gaining ground on RC structural systems. The use of stone structures is now extremely limited. In India, RC constructions predominate, with steel structures gradually making their way into multi-story building structures. As a result, a comparison analysis is required to determine the most effective structural system for a given structure.

II. Review of Literature Survey

Chao Gong et al (2022) research paper presented the seismic performance of structures subjected to earthquake mainshock-aftershock sequences. There is comparison of two types of the additional BRB elements, and also there is comparison between them and the original steel frame to show the effect of using BRB and SCBRB elements. To compare the seismic performance of BRBF and SCBRBF, the same mainshock-aftershock sequences were used in this part. Because of the flag-shaped hysteretic curve of the SCBRB elements, big amount of the energy was dissipated during the motion.

Results stated that structure with SCBRB elements subjected to earthquakes have smaller responses than ones without it. Amount of the energy which was dissipated is increased. Using SCBRB and BRB elements increase frequency of the structure. Residual deformations of the SCBRBF in more than 6.6 times smaller than ones of SF, residual deformations of the BRBF more than 2.11 times smaller than ones of SF. Conclusion stated that using SCBRB elements can decrease the damage of the structure during earthquakes, and also lead to improvement of characteristics of the building such as maintainability and service life in the seismic region.

Zhe-Xi Zhang et al (2022) in the research paper, a novel type of self-centering brace, namely the self-centering SMA-viscoelastic hybrid brace (SCVEB) was proposed. The energy dissipation was provided by the SMA cables, as well as the viscoelastic dampers (VEDs), whilst the self-centering capacity was provided by the former. The fundamental mechanical behavior of individual SMA cables and viscoelastic dampers was first investigated, followed by a more comprehensive experimental study on a proof-of-concept SCVEB specimen.

Results stated that the SMA cable exhibits typical flag-shaped hysteretic loops with a large recovery strain. Reasonable cyclic pre-training is suggested before anchoring to SCVEB, since this process was shown to help stabilize the hysteretic response. The VED is capable of providing reliable energy dissipation. The rubber in the test did not show rate-dependence property, such as typical viscoelastic material, and this may be due to the differences in their compositions. The frames using the intended SCVEB fulfilled peak inter-story drifts under the MCE and had nearly no residual interstory drifts, according to the system-level analysis. More crucially, the SCVEB can reduce the frames' peak floor acceleration even more. These positive results show that the suggested SCVEB could be a cost-effective self-centering solution by reducing boundary frame member size while using less SMA.

III.Objectives of the research

- To study the wind performance of multi storey steel building with and without damping system.
- To compare the response of the structure under dynamic loading with dampers and bracing system.
- To Study the behaviour of Steel Structure subjected to lateral loadings.
- To understand the performance of steel structure for bracing system and damper.
- Study is carried out to observe the behaviour of Structure dynamic time history and wind loadings.
- The parameters such as base shear, displacement, storey drift, are compared and discussed in detail.

IV.Methodology

Step 1 Steel structuring is complex and heavy duty structure. Numerous authors were researching seismic analysis of self centering concentrically braced frame using different analytical application.

Step 2: the first step in ETABS is model initialization where the metric units are defined besides assign steel design code as per IS 800:2007 and concrete Design code as per IS 456:2000.

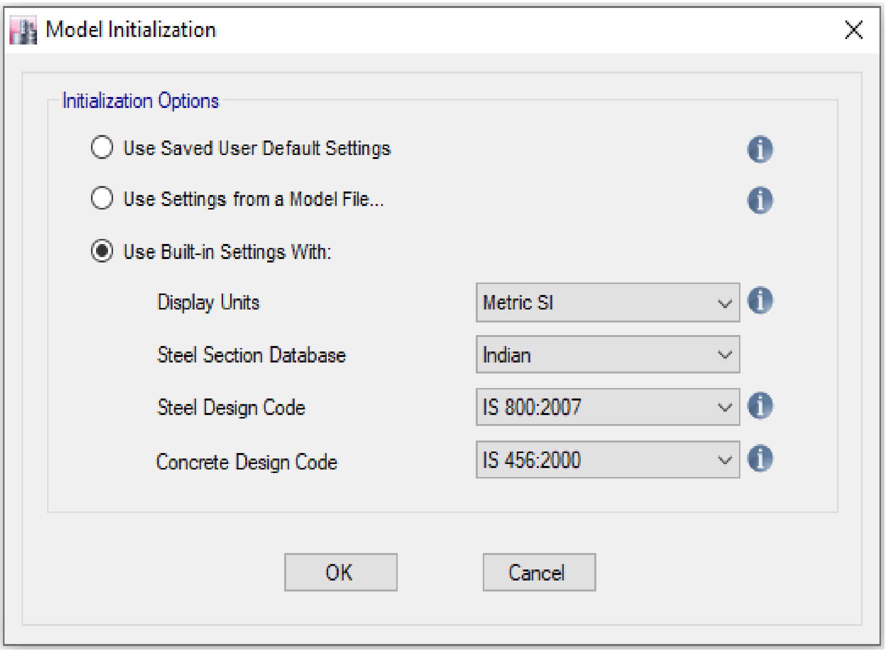


Fig 1 Initialization of Model

Step 3 Defining Grid system data for X and Y direction, X direction is defined with variables as A, B, C, D……. and Y DIrection is defined with variables as 1, 2, 3, 4…..

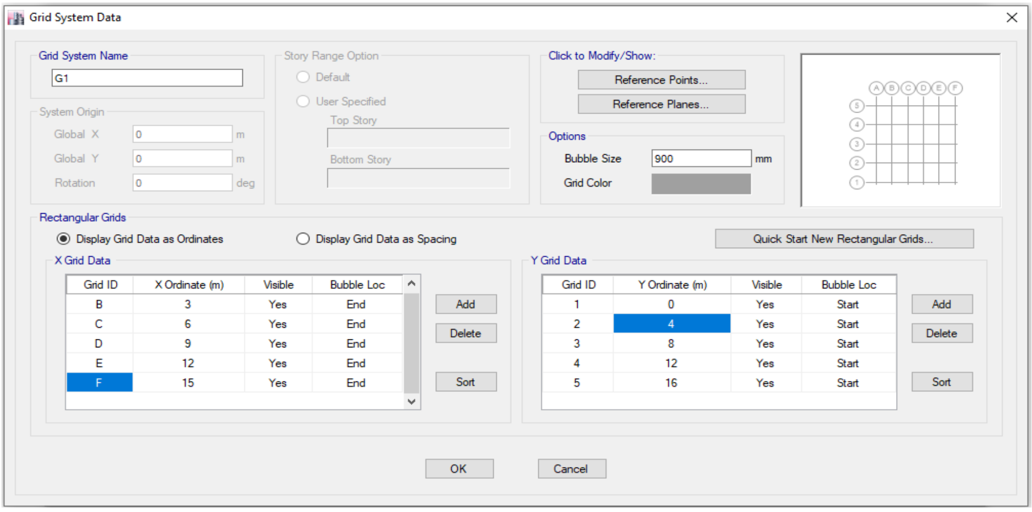


Fig 2 Grid System Data

Step 4 Adding material properties for steel as an industrial structure in considered in the analysis.

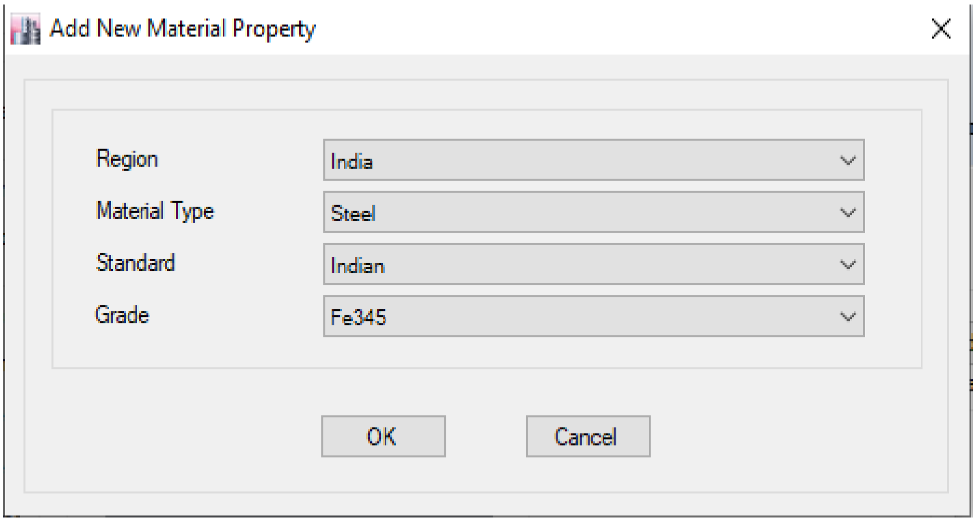


Fig 3 Adding new material properties

Step 5 Defining Material properties data

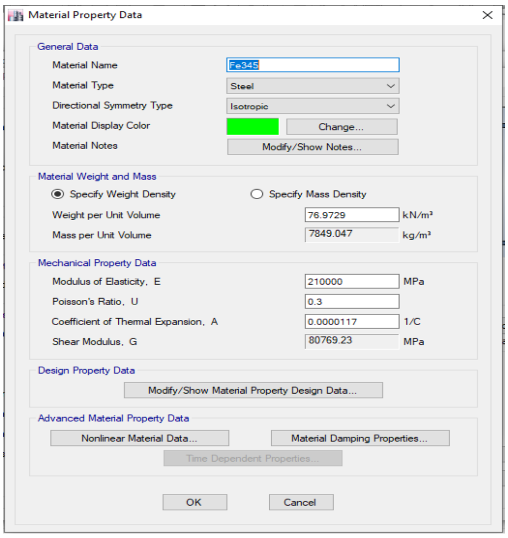


Fig 4 Defining Material Property Data

Step 6 Defining Section Properties

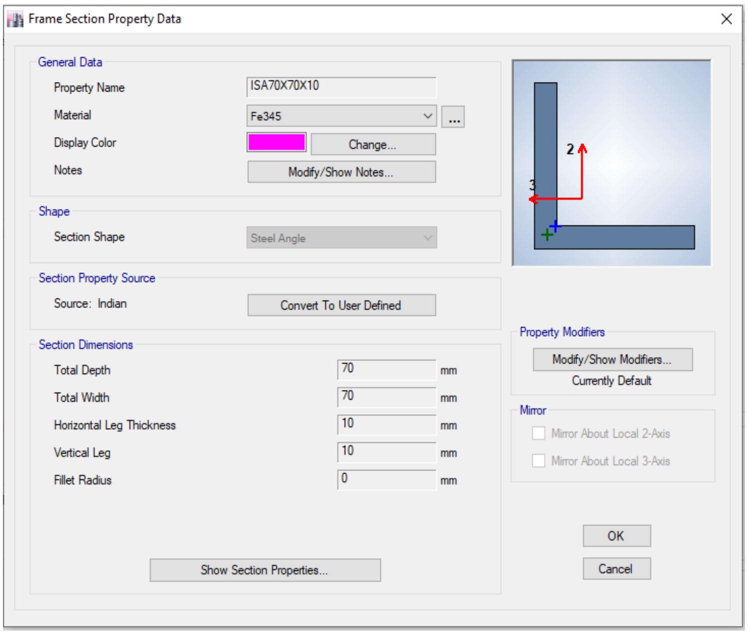


Fig 5 Defining Frame Section

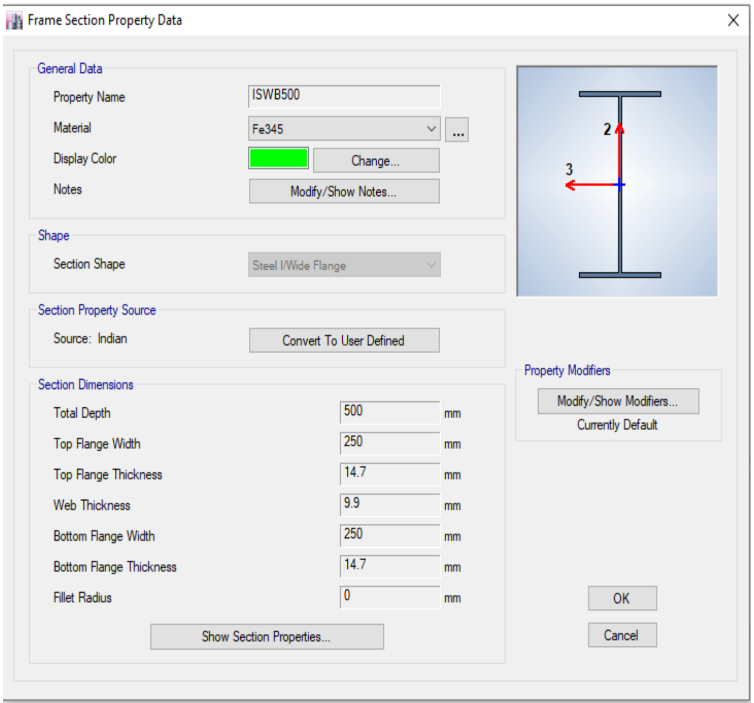


Fig 6 Defining Column Section

Step 7 Defining Point Spring Property data for damping system

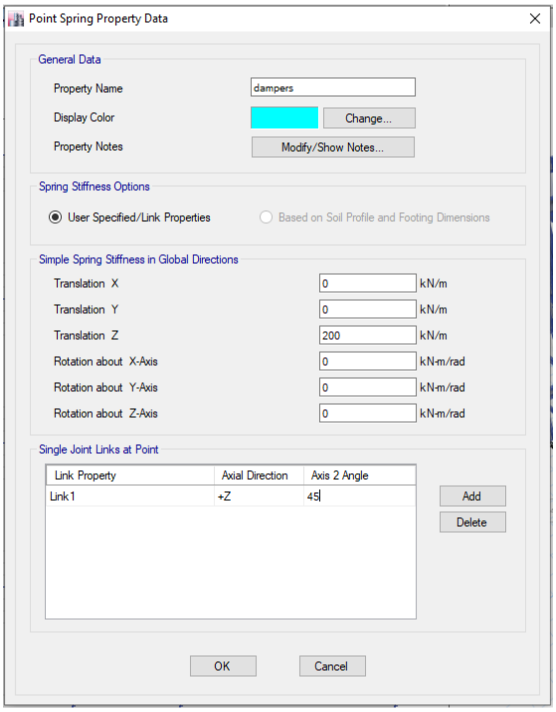


Fig 7 Point Spring Data

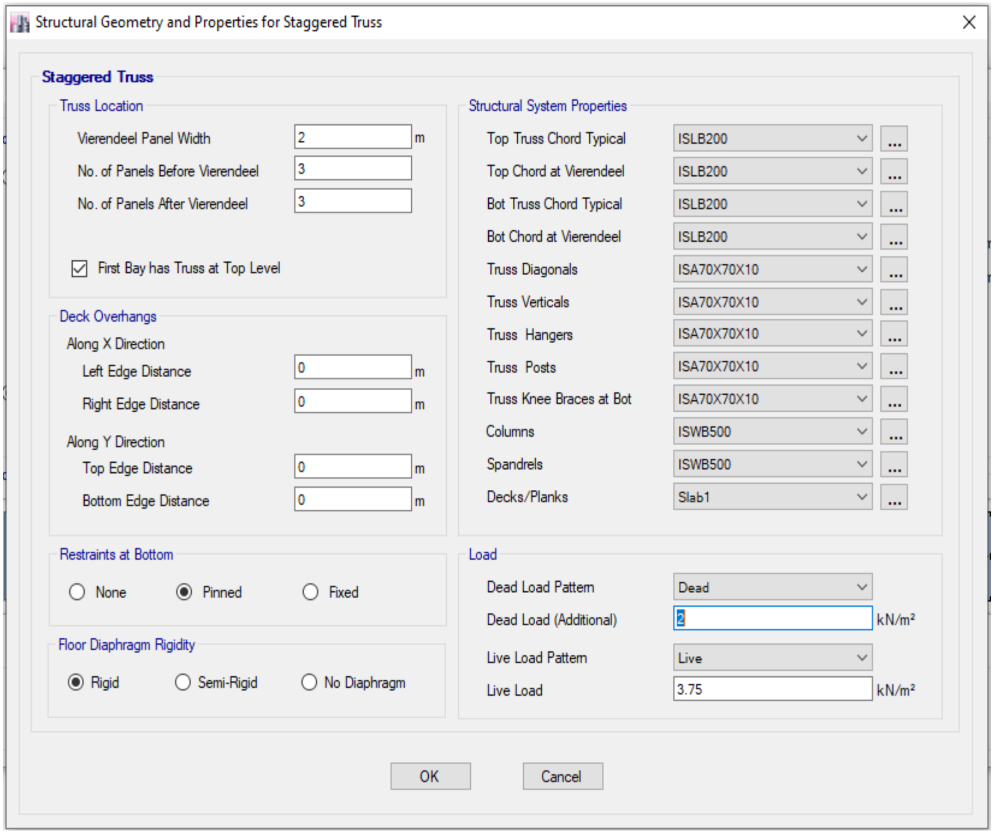


Fig 8 Structural Geometry and Properties of Staggered Truss

Step 8 Defining Load cases on the considered industrial structure for live load, dead load and wind load.

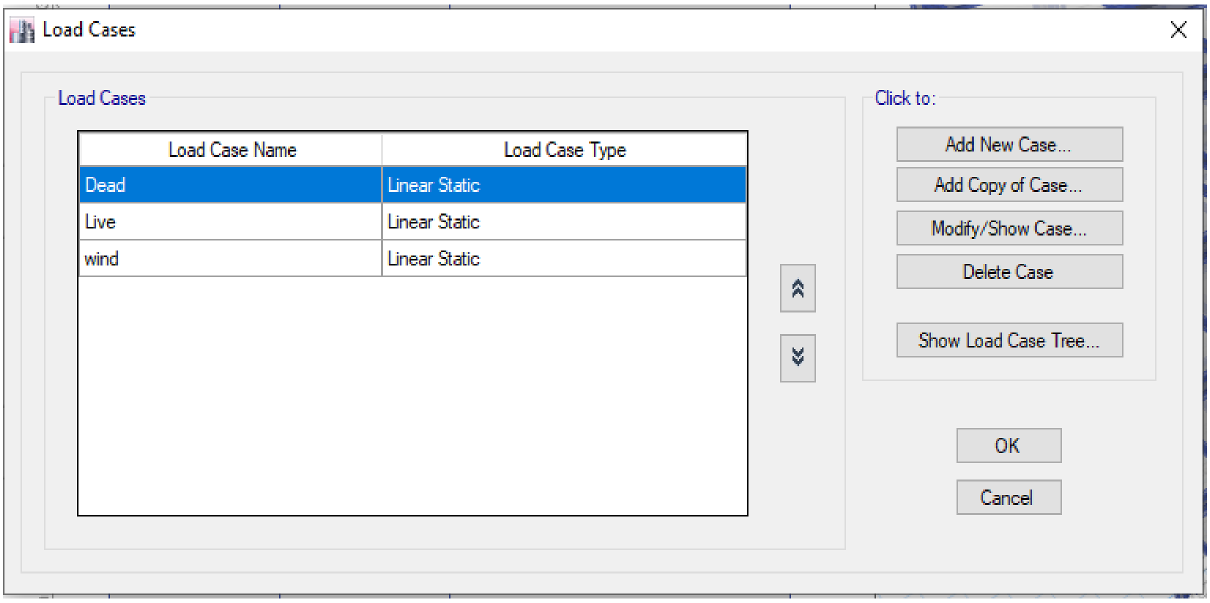


Fig 9 Defining load cases

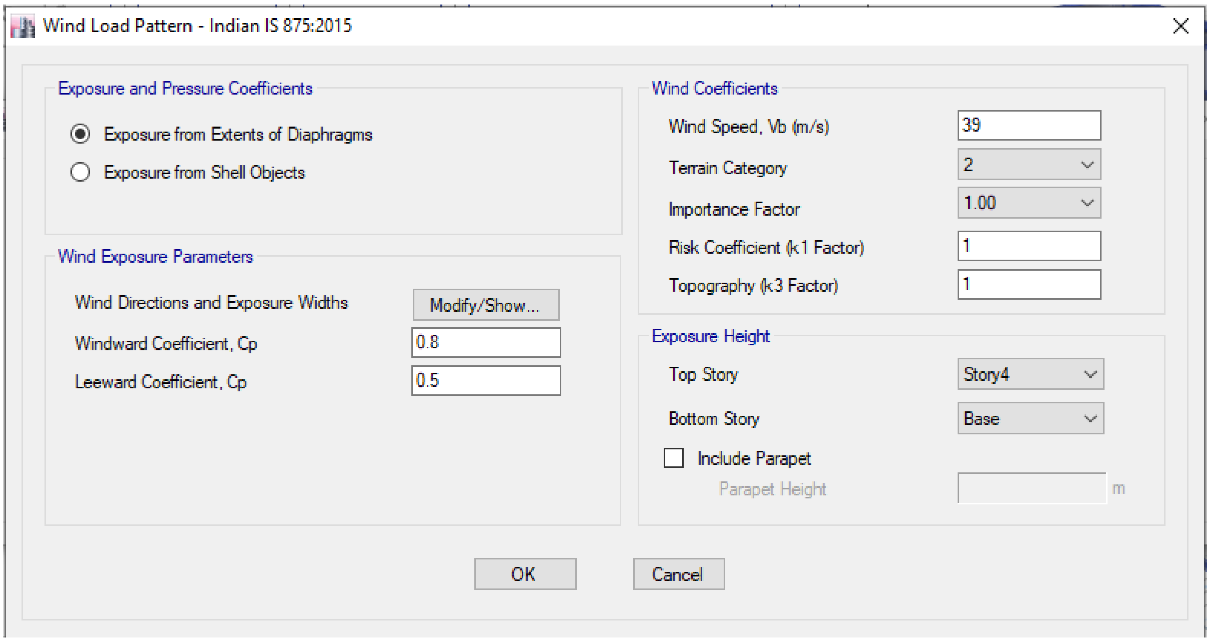


Fig 10 Defining properties of Wind load as per IS 875:2015

Step 9 Analyzing the model for dead load, live load and wind load in terms of deflection, displacement.

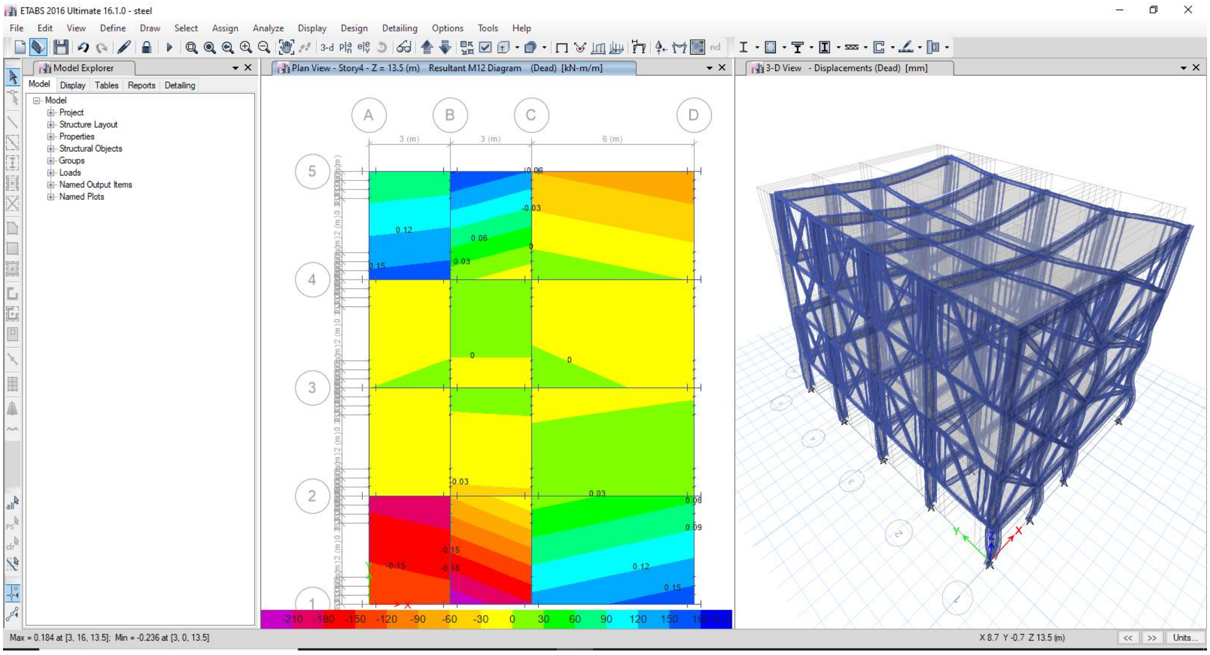


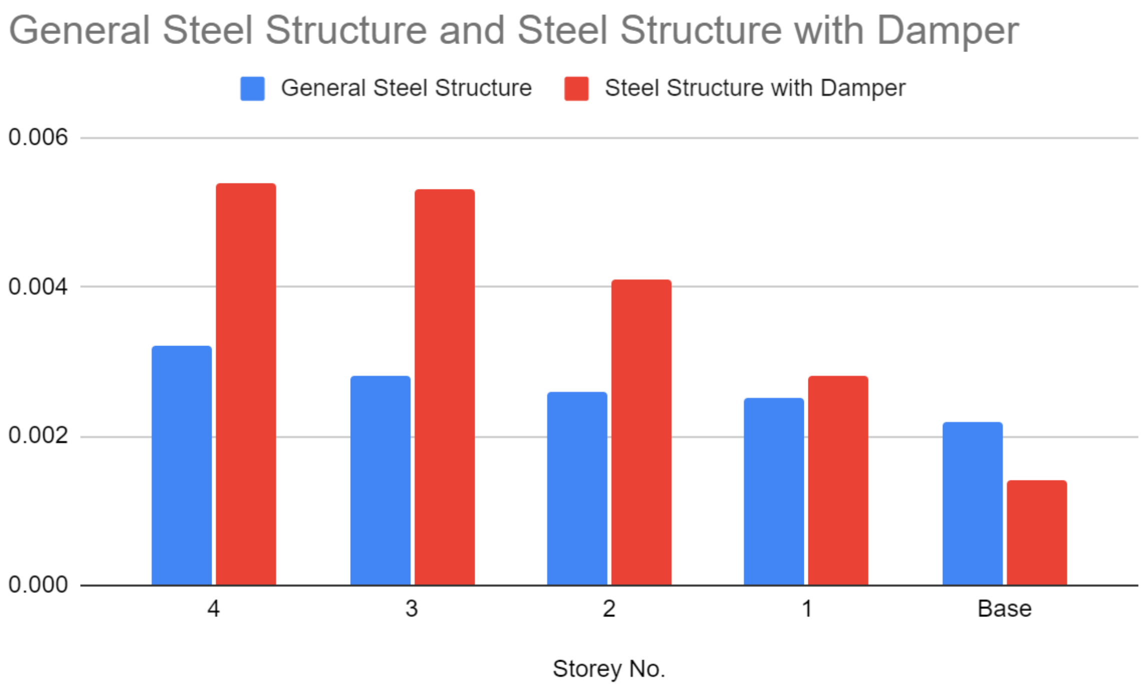
Fig 11 Analyzing the structure

Table 1 Geometrical Description

Geometry of Building	
Utility of Building	Industrial Building
No of Bays in X Direction	4 bays
No of Bays in Y Direction	5 bays
Width between bays in Y Direction	2m
Width between bays in X Direction	3m, 6m
Height of Each storey	3.4m
Height of Bottom Storey	3m
Wind Speed (m/s)	39 m/s
Terrain category	II
Wind Coefficient	0.8
Soil Type	Medium
Column used	ISMB
Thickness of Slab	125mm

V. ANALYSIS RESULT

Drift:



Displacement

Storey Displacement in X-Direction (in)		
Storey No.	General Steel Structure	Steel Structure with Damper
4	2.615	2.006
3	1.936	1.642
2	1.258	1.17
1	0.546	0.695
Base	0.4	0.305

VI.CONCLUSION

The parametric investigation of response of Non-linear Dynamic analysis of 3D industrial steel structure braced with distinct bracing configurations and dampers with different mass ratios utilising software is the focus of this research (ETABS). For the structural stability of the building structure under seismic loads, X-bracing bracing configurations were adopted. Modals with x bracing and a damper with a mass ratio of 1.5 percent have been discovered to increase the building's performance under earthquake and wind loads. A comparison with a general steel construction was done, and the bracing structure and dampers were examined.

Storey Drift

The storey shear and storey drift graphs are useful when analysing the effect of lateral loading on a multi-story building due to seismic or wind loads. The storey drift ratio is the storey drift divided by the storey height. Storey drift is the lateral displacement of a floor relative to the floor below. The storey drift ratio is a valuable metric that can be directly compared to the code requirements because seismic loading rules often impose limits on storey drift as a percentage of the storey height. A storey drift ratio graph will reveal whether certain floors are drifting more than others, indicating that they may require stiffening. Storey Drift was measured in the X and Z directions, and it was discovered that Case I, a general structure, had 7% more storey drift than Case II, a steel structure with dampers and concentric bracing.

Storey Displacement

Story displacement is the lateral displacement of the story relative to the base. The lateral force-resisting system can limit the excessive lateral displacement of the building. The acceptance lateral displacement limit for wind load case could be taken as H/500 (some may take H/400). Store Displacement was valuated for X and Z Direction for G+5 storey steel structure considering both the cases. Variation of 3% was seen in X direction when comparing both the structures and 5% variation was seen in Z direction when compared both the structures.

Base Shear

Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity. It is calculated using the seismic zone, soil material, and building code lateral force equations. Base shear was maximum in general steel structure. Base shear was least in Z direction in both the cases. By comparing base reactions which are obtained by with and without damper, usage of dampers shows considerable effects on increase in base shear. As the base shear increase the building will be able to resist the lateral loads.

The result shown that, adding fluid viscous damper to the structure reduces not only deformation but also the storey drift and displacement. It can be concluded that wind response of steel frame is considerably reduced with added fluid viscous damper placed by bracing.

VII. REFERENCES

[1]. D. Roke, R. Sause, J.M. Ricles, and N. Gonner, [DESIGN CONCEPTS FOR DAMAGE-FREE SEISMIC-RESISTANT SELF-CENTERING STEEL CONCENTRICALLY-BRACED FRAMES], The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China.

[2]. Zhe-Xi Zhang, Yiwei Ping and Xiuzhang He, [Self-Centering Shape Memory Alloy-Viscoelastic Hybrid Braces for Seismic Resilience], Materials 2022, 15, 2349.

[3]. Pei Chi, Jun Dong, Wenlong Tian and Dafu Cao, [Nonlinear Seismic Response of Multistory Steel Frames with Self-Centering Tension-Only Braces], Appl. Sci. 2020, 10, 1819.

[4]. Chao Gong, MingMing Jia, XuanHao Cheng and Mishel Gritcuk, [Seismic performance of buckling-restrained braced steel frames subjected to earthquake mainshock-aftershock sequences], 2022 International Conference on Applied Mechanics and Advanced Materials.

[5]. Masruri Anwar and Budi Suswanto, [Analysis of Eccentrycally Braced Frame (EBF) Structure With Self Centering System Modification], International Journal of Science and Research (IJSR), Volume 8 Issue 1, January 2019.

[6]. Patrick McCready, Yadong Jiang, Suhaib Salawdeh, Hatim AlWahsh, Brian Broderick and Jamie Goggins, [Performance validation of a self-centring steel structure using robust data sets from shake table testing], Civil Engineering Research in Ireland 2020.

[7]. G.J. O'Reilly, J. Goggins and S.A. Mahin, [Behaviour and Design of a Self-Centering Concentrically Braced Steel Frame System], 15 WCEE LISBOA 2012.

[8]. Ergang Xiong, Kun Zu, and Qian Zhang, [Seismic Performance Analysis of Self-Centering Concentrically Braced Steel Frame Structures], Hindawi Shock and Vibration Volume 2020, Article ID 8826272, 13 pages.

[9]. Richard Sause, James M. Ricles, David Roke, Choung-Yeol Seo, and Kyung-Sik Lee, [DESIGN OF SELF-CENTERING STEEL CONCENTRICALLY-BRACED FRAMES], 4th International Conference on Earthquake Engineering Taipei, Taiwan October 12-13, 2006.

[10]. Dario De Domenico and Iman Hajirasouliha, [Multi-level performance-based design optimization of steel frames with nonlinear viscous dampers], Bulletin of Earthquake Engineering (2021) 19:5015–5049.

[11]. Hamed Jabbari, Reza Vahdani, Mohsen Gerami and Hossein Naderpour, [Seismic Performance of Steel Moment Frames Containing Concentric Bracing Equipped with Shape Memory Alloys], The Open Civil Engineering Journal, 2019, Volume 13.

[12]. Jagadeesh B N and Dr. Prakash M R, [SEISMIC RESPONSE OF STEEL STRUCTURE WITH MEGA BRACING SYSTEM], INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY, International Journal of Engineering Sciences & Research Technology, ISSN: 2277-9655, September, 2016.

[13]. E. Tahmasebi, R. Sause and J. M. Ricles, [Probabilistic Seismic Damage Analysis of Steel Self-Centering Concentrically Braced Frame Systems], 16th World Conference on Earthquake, 16WCEE 2017.

[14]. Habib Ghasemi Jouneghani, Abbas Haghollahi, Hassan Moghaddam and Abdolreza Sarvghad Moghadam, [Study of the seismic performance of steel frames in the elliptic bracing], INTERNATIONAL LTD.JOURNAL OF VIBROENGINEERING. AUG 2016, VOL. 18, ISSUE 5. ISSN 1392-8716.

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