COMPARATIVE STUDY OF BRACED STEEL STRUCTURE WITH UNBRACED STEEL STRUCTURE

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Abstract - In modern construction, steel structures are used for almost every type of structure including heavy industrial building, high-rise building, equipment support systems, infrastructure, bridges, towers, heavy industrial plant, etc. This study investigates as well as compares the performances of braced steel system & unbraced steel system. To perform the analysis ETABS is used to get the output using dynamic analysis (Response Spectrum). The performances of structures are evaluated with the help of base shear, deflection, story drift, story displacement, natural time period, Structure is stabilized by providing brace frame in both longitudinal and transverse direction, Semi Rigid diaphragm of concrete metal deck is considered in each story is provided to ensure proper lateral load transfer to vertical brace hence providing stability and controlling the deflection while analysing and designing the structures. By considering various parameters such as storey displacement, drift, stiffness, lateral force, and base shear, you're able to comprehensively assess the effectiveness of bracing in resisting seismic forces. Using two different models, we can compare how buildings with different structures handle earthquakes.

Key Words: Base shear, Time period, storey drift, Storey displacement, Bracing, Response spectrum.

1. INTRODUCTION

A steel structure is a metal structure which is made of structural steel components connected to each other to carry loads and provide rigidity. Because of the high strength of steel, these structures are reliable and require less raw material than some other types of structure such as concrete. Braced frames are known for their ability to provide efficient lateral stiffness. It's now widely acknowledged that bracing systems can offer the necessary stiffness to withstand moderate earthquakes and similar dynamic forces, while also serving as a source of energy dissipation through post-buckling hysteresis behaviour of braces.

Bracing systems are broadly classified into two categories: concentric bracing and eccentric bracing. In eccentric schemes, preventing brace buckling is crucial to confining inelastic deformation to a short segment of the girders acting as shear hinges bracing systems, braces undergo cyclic deformations beyond buckling and yielding due to severe dynamic excitation. Understanding the cyclic inelastic behaviour of bracing members is essential for. In concentric evaluating the dynamic response of concentrically braced structures. Previous researchers have developed several analytical models to represent the cyclic behaviour of steel braces. These models incorporate important phenomena observed during inelastic cyclic loading, such as compression strength deterioration, residual elongation due to plasticity, and local buckling.

1.1 MODEL CONFIGURATION

The general software E-TABS has been used for the modelling. It is more user friendly and versatile program that offers a wide scope of features like static and dynamic analysis, non-linear dynamic analysis and non-linear static pushover analysis, response spectrum analysis, time history analysis etc. ETAB. Software is used in modelling of building frames and it is general purpose software for performing the analysis and design of a wide variety of structures. G+ 7 story two regular steel building are considered, one with vertical bracing and the other without bracing. The beam length in (x) transverse direction and longitudinal direction is shown in the Figure having 12 bays in x-direction and 5 bays in y-direction. Story height of each building is assumed 4.5 m. Figure 1.2 shows the 3D frame building of unbraced building and figure 1.3 shows the 3D frame of braced building.

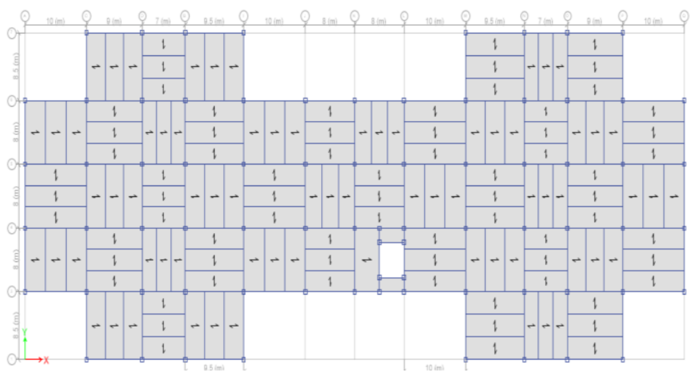

Fig: 1.1 PLAN OF BOTH BUILDING.

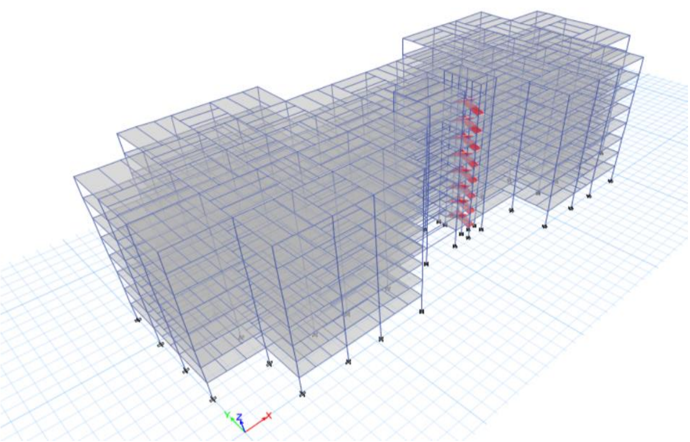

Fig:1.2 3D VIEW OF UNBRACED BUILDING

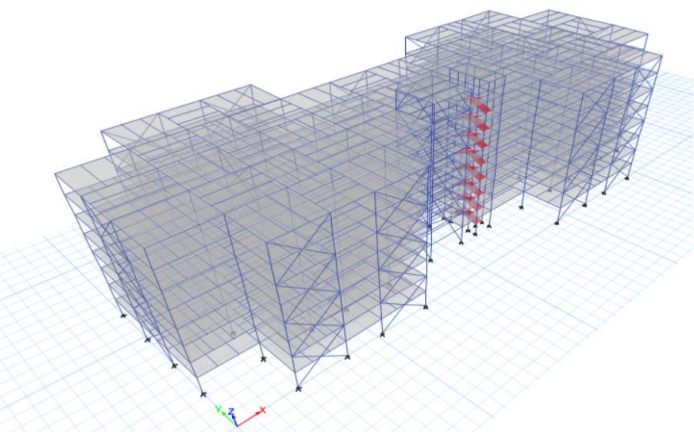

Fig: 1.3 3D VIEW OF BRACED BUILDING

1.2 STRUCTURE MODEL DATA

The G+7 story steel building was analysed for gravity, seismic and wind loads in Etabs. For the comparative study, beam and column dimensions are kept same in both the buildings. Height of the story is 4.5 m and beam length in longitudinal and transverse direction is shown in Fig: 1.2.1 and Fig: 1.2.2

No. of Stories	G +7
Story Height	4.5 m
Grade of concrete	M30
Grade of steel	Fe 345
Width of building in X-direction	107m
Width of building in Y-direction	41 m
Height of the building	40.5m

Table: 1.2.1

Structural Element	Cross section	Length (m)
Beam in (x) direction.	W24x94 W24x104 W24X117 W24X131	7,8,9,9.5,10 7,8,9,9.5,10 9.5 10
Beam in (y) longitudinal direction	W24x94	8.5,8
Column	HSS20X20X7/8	4.5
Brace	HSS16X12X5/8	6.5

Table: 1.2.2

2. RESULTS

TIME PERIOD: - Time period of a building is the duration it takes for one complete cycle of vibration. Bracing can significantly affect the building's stiffness, thereby altering its natural frequency & hence the time period of vibration.

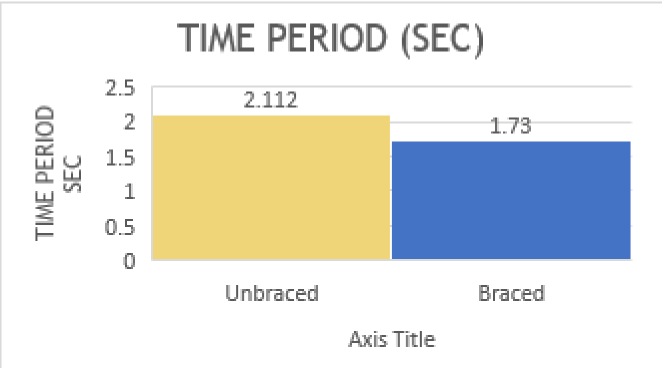

Fig 2a

The decrease in the natural period of a structure with bracing compared to one without indicates that the presence of bracing modifies the structural dynamics. When bracings are integrated into the structural system, they enhance the overall stiffness of the building and establish a more efficient path for lateral loads. Consequently, the structure tends to respond more swiftly to dynamic loading, resulting in a shorter natural period and typically a stiffer system.

BASE SHEAR: - Base shear is the total lateral force acting at the base of the structure due to seismic or wind loads. Bracings play a crucial role in determining the distribution of this base shear throughout the structure.

Fig 2b

If structure without bracing has less base shear compared to structure with bracing, it suggests that presence of bracing redistributes lateral force within structure.

STOREY DRIFT: - Storey drift is defined as the relative displacement between the top and bottom of any storey. It is calculated by considering the difference in displacements between the top and bottom of each storey due to lateral forces. According to IS 1893-2016, clause 7.11.1.1 Storey drift in any story shall not exceed 0.004 times the storey height, under the action of design base shear with no load factors mentioned in 6.3 of Is 1893-2016, story drift is a critical parameter that governs the design and seismic performance of buildings. Engineers adhere to stringent guidelines to ensure that structures can withstand lateral forces while maintaining safety and functionality during seismic events.

COMPARISON OF STOREY DRIFTS OF TWO BUILDINGS

MAX. STOREY DRIFT					
BRACED (SPECX)			UNBRACED (SPECX)		
Story	Elevation m	X-Dir	Story	Elevation m	X-Dir
MUMTY	**40.5**	**0.00074**	MUMTY	40.5	0.000291
Terrace	36	0.000631	Terrace	36	0.000398
Story7	31.5	0.000669	Story7	31.5	0.000627
Story6	27	0.000677	Story6	27	0.00078
Story5	22.5	0.000625	Story5	22.5	0.000893
Story4	18	0.000621	Story4	18	0.000995
Story3	13.5	0.000496	Story3	13.5	0.000993
Story2	9	0.00047	**Story2**	**9**	**0.00102**
Story1	4.5	0.000268	Story1	4.5	0.000656
Base	0	0	Base	0	0

MAX. STOREY DRIFT (X-Dir)

MAX. STOREY DRIFT					
BRACED (SPECY)			UNBRACED (SPECY)		
Story	Elevation m	Y-Dir	Story	Elevation m	Y-Dir
MUMTY	40.5	0.000838	MUMTY	40.5	0.000423
Terrace	36	0.000978	Terrace	36	0.000532
Story7	**31.5**	**0.00103**	Story7	31.5	0.000852
Story6	27	0.001024	Story6	27	0.001063
Story5	22.5	0.000938	Story5	22.5	0.001201
Story4	18	0.000916	Story4	18	0.001314
Story3	13.5	0.000731	Story3	13.5	0.001309
Story2	9	0.000701	**Story2**	**9**	**0.001337**
Story1	4.5	0.00042	Story1	4.5	0.000843
Base	0	0	Base	0	0

MAX. STOREY DRIFT (Y-Dir)

Bracings significantly reduce peak earthquake & wind displacements in both X & Y directions, as well as peak earthquake story drifts, highlighting their effectiveness in enhancing lateral stiffness & structural stability under lateral force.

STOREY DISPLACEMENT: - Storey displacement" refers to the vertical displacement or movement of each floor level in a building structure. When analysing the behaviour of a building under various loads such as gravity loads, wind loads, or seismic forces, engineers often calculate the displacement at each storey to understand how the building responds to these loads.

COMPARISON OF STOREY DISPLACEMENT OF TWO BUILDINGS

MAX STOREY DISPLACEMENT (X-DIR)					
BRACED (SPECX)			UNBRACED (SPECX)		
Story	Elevation m	X-Dir (mm)	Story	Elevation m	X-Dir (mm)
MUMTY	**40.5**	**21.453**	**MUMTY**	**40.5**	**26.758**
Terrace	36	19.291	Terrace	36	26.468
Story7	31.5	16.508	Story7	31.5	25.064
Story6	27	13.612	Story6	27	22.781
Story5	22.5	10.68	Story5	22.5	19.764
Story4	18	7.939	Story4	18	16.097
Story3	13.5	5.242	Story3	13.5	11.857
Story2	9	3.087	Story2	9	7.497
Story1	4.5	1.205	Story1	4.5	2.952
Base	0	0	Base	0	0

MAX. STOREY DISPLACEMENT (X-Dir) SPECX

MAX STOREY DISPLACEMENT (X-DIR)					
BRACED (WINDX)			UNBRACED (WINDX)		
Story	Elevation m	X-Dir (mm)	Story	Elevation m	X-Dir (mm)
MUMTY	**40.5**	**7.262**	MUMTY	40.5	14.631
Terrace	36	6.641	**Terrace**	**36**	**15.418**
Story7	31.5	5.777	Story7	31.5	14.758
Story6	27	4.868	Story6	27	13.622
Story5	22.5	3.912	Story5	22.5	11.999
Story4	18	2.974	Story4	18	9.9
Story3	13.5	2.012	Story3	13.5	7.36
Story2	9	1.259	Story2	9	4.682
Story1	4.5	0.526	Story1	4.5	1.87
Base	0	0	Base	0	0

MAX. STOREY DISPLACEMENT (X-Dir) WINDX

MAX STOREY DISPLACEMENT (Y-DIR)					
BRACED (SPECY)			UNBRACED (SPECY)		
Story	Elevation m	Y-Dir (mm)	Story	Elevation m	Y-Dir (mm)
MUMTY	40.5	27.812	MUMTY	40.5	27.162
Terrace	**36**	**28.798**	**Terrace**	**36**	**35.485**
Story7	31.5	24.545	Story7	31.5	33.496
Story6	27	20.208	Story6	27	30.268
Story5	22.5	15.871	Story5	22.5	26.098
Story4	18	11.849	Story4	18	21.18
Story3	13.5	7.936	Story3	13.5	15.562
Story2	9	4.713	Story2	9	9.773
Story1	4.5	1.89	Story1	4.5	3.794
Base	0	0	Base	0	0

MAX. STOREY DISPLACEMENT (Y-Dir) SPECY

MAX STOREY DISPLACEMENT (Y-DIR)					
BRACED (WINDY)			UNBRACED (WINDY)		
Story	Elevation m	Y-Dir (mm)	Story	Elevation m	Y-Dir (mm)
MUMTY	**40.5**	**36.569**	**MUMTY**	**40.5**	**41.232**
Terrace	36	32.558	Terrace	36	39.722
Story7	31.5	28.617	Story7	31.5	38.042
Story6	27	24.261	Story6	27	35.025
Story5	22.5	19.705	Story5	22.5	30.654
Story4	18	15.118	Story4	18	25.027
Story3	13.5	10.507	Story3	13.5	18.283
Story2	9	6.445	Story2	9	11.732
Story1	4.5	2.739	Story1	4.5	4.978
Base	0	0	Base	0	0

MAX. STOREY DISPLACEMENT (Y-Dir) WINDY

3. CONCLUSIONS

Economic Efficiency: Bracing structures with vertical geometric regularity experience minimal lateral deformation during seismic events, making them economically favorable due to reduced material usage & construction costs.

Lateral Stability Enhancement: The use of slender bracings enhances the lateral stability of the structure, leading to a significant reduction in self-weight. This reduction in load contributes to more efficient seismic analysis & overall structural design.

Deformation & Drift: The max. storey deformation & drift due to earthquake force are within safe limits according to IS guidelines, indicating structural stability & safety of building under seismic loading.

Seismic Performance: Bracing buildings demonstrate the capability to absorb max. lateral force from earthquake events, resulting in a more economical design compared to other building types. The addition of bracings increases stiffness of building, leading to reductions in peak earthquake displacements & story drifts in both X & Y directions, enhancing overall seismic performance.

Impact on Time Period & Base Shear: Introduction of bracings decreases time period of building by 22% but increases the base shear by 20% to 26% compared to buildings without bracings, reflecting the influence of bracings on building stiffness & response to seismic force.

Reduction in Displacements & Drifts: Bracings significantly reduce peak earthquake & wind displacements in both X & Y directions, as well as peak earthquake story drifts, highlighting their effectiveness in enhancing lateral stiffness & structural stability under lateral force.

Increased Stiffness: Bracing contribute significant lateral stiffness to the structure, enhancing its resistance to lateral loads. This increased stiffness leads to a shorter natural period of vibration, thereby reducing the overall time period

Stiffness & Resistance: Bracing increase overall stiffness of structure, making it more resistant to lateral movement. This increased resistance means that more of the lateral force is resisted directly by the bracing, leading to higher base shear values.

Restriction of Lateral Deformation: Bracing restrict the lateral deformation of the building, thereby reducing its flexibility. This restriction in flexibility results in a shorter time period for the structure's vibrational response

Lateral Force Distribution: Bracing are designed to resist lateral force such as those from seismic or WL. When these force act on the building, bracing help distribute them more efficiently throughout the structure. As a result, the overall base shear is likely to be higher in buildings with bracing

Overall, the findings suggest that incorporating bracings in building design improves seismic performance, reduces deformations & drifts, & enhances structural stability, ultimately leading to more economical & resilient structures in seismic-prone regions.

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[7] ETABS VERSION 21.0