ANALYZING THE EFFECT OF STEEL BRACING IN PLAN IRREGULAR STEEL STRUCTURE SUBJECTED TO LATERAL LOADS

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Abstract - *Tall building steel structural system consists of vertical and horizontal structural elements made of structural steel which resists both gravity and lateral loads efficiently. Present Work focuses on the effect of steel bracing in plan irregular steel structure under equivalent static and dynamic time history loads as per IS 1893-2002. Five bracing systems are adopted in this work i.e. X,V, inverted V and two types of diagonal bracing. Key results like modal time period, maximum drifts, stiffness and displacements and base forces are extracted from equivalent static and dynamic analysis using ETABS. The use of X bracing shows good performance in resisting lateral loads since displacements and drifts are found to be less than that of other bracing system.*

***Key Words*: Bracing system, Tall building, Steel moment resisting frame, Storey drift, Storey stiffness, Peak acceleration, Peak displacement**

1. INTRODUCTION

Tall steel building structural system consists of vertical and horizontal structural elements with floor systems made of structural steel which resists both gravity and lateral loads efficiently. In most of the steel structures, floor is made of both concrete and steel decks which acts as a composite component, and in addition columns and beams can be composite in nature which are called composite tall buildings which uses both steel and concrete acting compositely in primary structural elements. High rise steel structures can be utilized to develop multi storey structure from 25 meters to 150 meters in elevation(apartment buildings) and building above 150 m (skyscrapers). For skyscraper basic frameworks are provided with bolted structure made off site (from production line) utilizing beam joist cold form deck slab and steel columns or composite columns. The frame structures are the structures that have the beam, column and slab to hold gravity loads and lateral loads. They overcome the large moments developed due to the applied loading.

1.1 BRACING

A braced frame is a structural system that is usually used as part of structures that are subject to horizontal loads, such as wind and seismic loads. Typically, the members are made in a braced frame are of structured steel, and they can work successfully in both tensions and compression. The beams and columns that create the vertical load support frame and the bracing system carries the lateral load. The position of the braces, on the other hand, can be challenging because they can interfere with the facade design and the location of openings. Structures that adopt these high-tech or post-modern styles responded to bracing as an element of internal or external design. Different types of bracing such as Single diagonal bracing, Cross bracing, V bracing, Inverted V bracing, Eccentric bracing.

1.2. IRREGULAR BUILDINGS

In general, Special moment frame buildings are expected to resist inelastic deformation when subjected to the forces from the motions of design earthquake. In fact, many SMF steel buildings are irregular due to commercial or residential needs. Earthquake experiences show that the seismic behavior of irregular buildings can be much more different than the regular building. The irregularities in the building structures may be due to irregular distributions in their mass, strength and density along the height of the building. At the moment when such structures are built in high seismic zones, the analysis and design are more complex. There are two types of irregularity:
1. Plan Irregularities
2. Vertical Irregularities

2. METHODOLOGY AND MODELLING

In this study analysis is carried out on static and dynamic analysis i.e. equivalent static and linear response time history analysis in ETABS ver.16.

2.1 METHODOLOGY

1. A structure with G+10 asymmetrical storey having L Shape in plan was considered, having overall dimension 30 m x 30 m in X and Y direction with a bay size of 5 m in both the direction.
2. Five Structural systems is adopted in this work i.e., conventional steel moment resisting frames without and with bracings.
3. ISWB 600-2 and ISMB 600 sections is used for columns and beams for conventional steel moment resisting frames and for bracing ISA 200X200X25 section was provided along the face of wind.

4. ISWB 600-2 and ISMB 600 section beams is considered for modeling the steel bracing structure and bracing with ISA 200X200X25 section are provided along the face of wind and also concrete deck was modelled as floor element.
5. Modeling and analysis is carried out using ETABS Ver. 2016.
6. Equivalent static and dynamic analysis is carried out for all the five models.
7. Key results like modal frequency and time period, maximum drifts and displacements are extracted from equivalent static analysis, Peak acceleration and displacements are extracted from dynamic analysis from all the structural systems.
8. Relevant conclusions are made based on the discussion of results

2.2 MODELLING

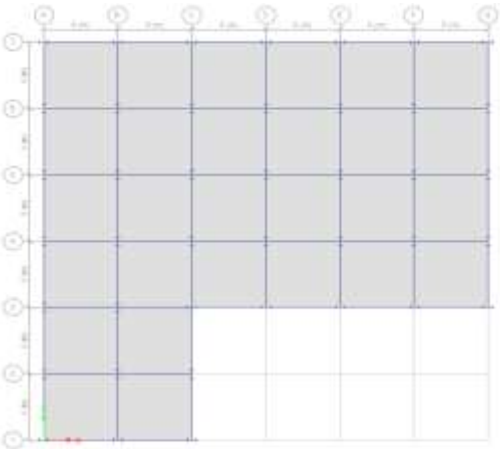

Fig. 2.1 The plan of steel moment resisting frame(SMRF)

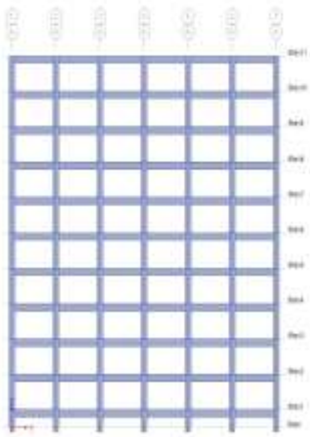

Fig. 2.2 elevation of SMRF

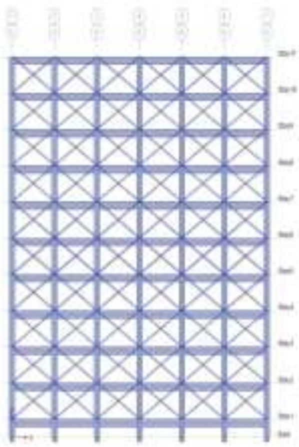

Fig 2.3 X bracing

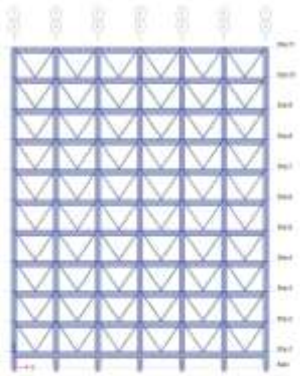

Fig.2.4 V Bracing

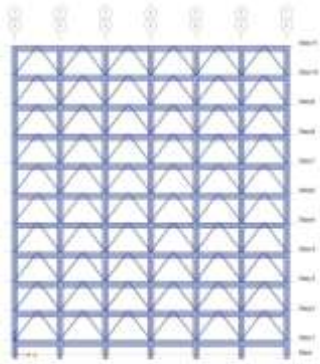

Fig.2.5 Inverted V bracing

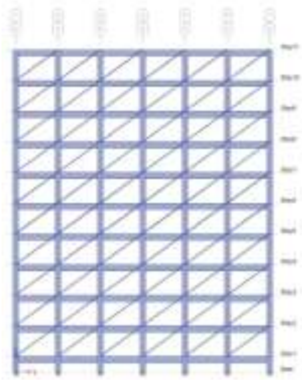

Fig.2.6 Diagonal type 1

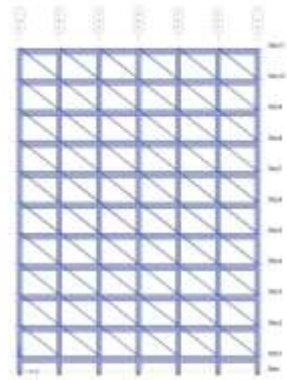

Fig.2.7.Diagonal type 2 bracing

3. ANALYSIS

The effects of the design of the seismic loads applied to the structures can be classified into two types, namely:

1. Equivalent static method
2. Dynamic analysis method

3.1 DYNAMIC TIME HISTORY ANALYSIS

Every structure is subject to dynamic loads. Dynamic analysis can be used to find:

1. Natural frequency and Dynamic displacements
2. Time history results and Modal analysis

The performance of the buildings depends mainly on the resistance, as well as on the deformability of the building elements, which is more closely linked to the members' interior design forces. The internal design forces depend sequentially on the accuracy of the method that works in its analytical purpose.

Time history analysis provides a linear or non-linear evaluation of the dynamic structural response under load which may vary depending on the specified time function. The equations of dynamic equilibrium are solved using modal methods or direct integration. The initial conditions can be established by continuing the structural state from the end of the previous analysis. In the present study, the historical data of ELCENTRO are considered based on the following specifications.

Location; "Imperial Valley"
Date; 19th May 1940
Time; 4:39am
Station; "El Centro Array #9"
Direction: Horizontal, 180°
Units of acceleration;
g= 9.81 m/s2 (acceleration of gravity)
Number of time instants; 4,000
Sampling time; Δt= 0.01 s (f= 100 Hz)

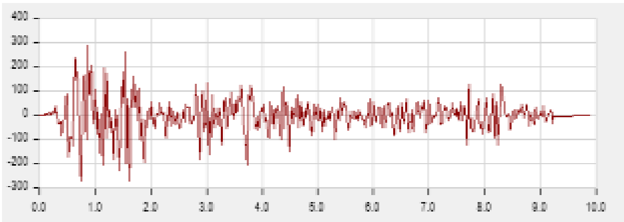

Fig.3.1 Time History Input – El-Centro(From ETABS)

4. RESULTS

4.1 MODEL ANALYSIS

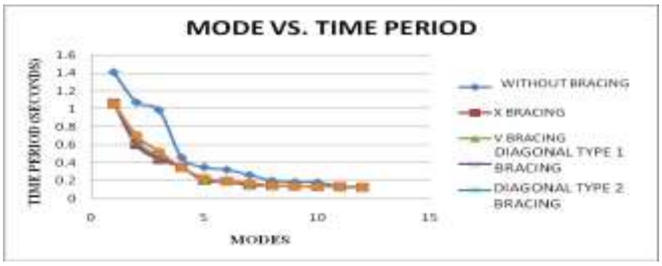

Fig 4.1 Mode vs. Time period

From the 4.1 it is observed that the time period is more in case of conventional steel moment resisting frame (MRF) in comparison with steel braced structure. (Fig.4.1) There is a significant decrease in time period if the structural system changes from steel MRF to braced structures. There is no much difference in time period when compared along the different types of braced steel structures.

4.2 STORY DISPLACEMENTS

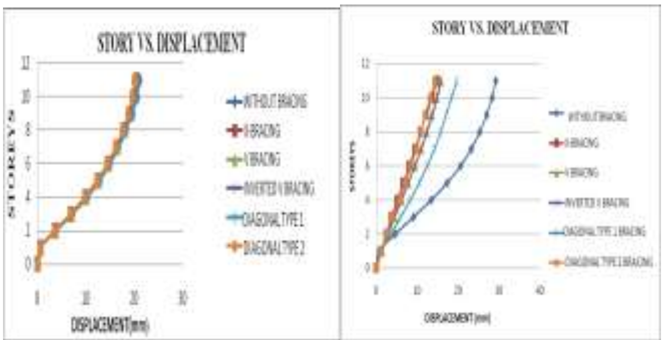

Fig. 4.2 Story vs. Displacements along THX and THY

Storey vs. Storey displacement along THX and THY (fig 4.2) direction is shown in above graphs. Along THX direction displacement in steel MRF and steel braced structure is more or less same since there is no bracing provided along the x-direction. While, along THY direction steel MRF have more displacement compared to other steel braced structure and by use of X-bracing and diagonal type 2 bracing the displacement have reduced and also other type of bracing have increased by 3% which is found to be less.

4.3 STOREY DRIFTS

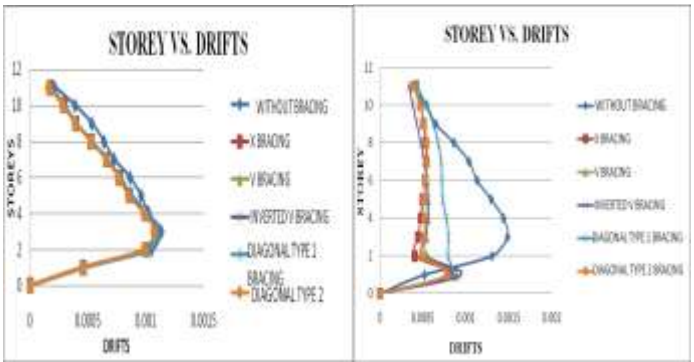

Fig 4.3 Storey vs. Storey Drifts along THX and THY

The above graph shows the storey vs. storey drifts graph along THX and THY (fig 4.3) direction. Along x direction there is no significant change in drifts as there is no bracing provided in that direction. A significant decrease in the reduction of story drifts is found along THY direction in steel bracing structures in comparison with conventional steel MRF. Maximum story drifts is found to be at story 4 in steel MRF.

4.4 BASE FORCE

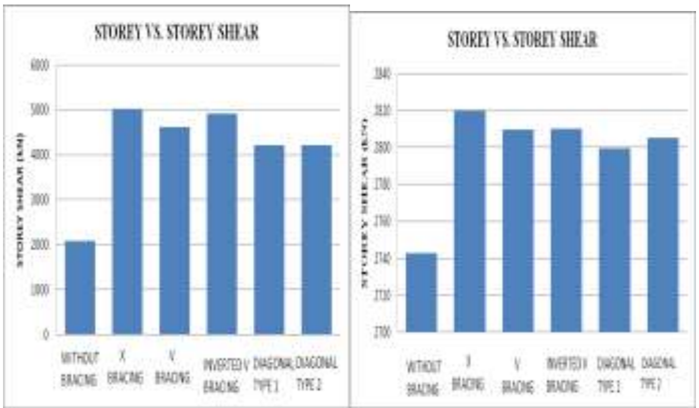

Fig 4.4 Story vs. Story Shear – THX and THY

From the dynamic time history analysis storey shear vs. storey values is extracted for both x and y direction. The values obtained from both the direction is more or less same and the model i.e. steel MRF without bracing have less storey shear when compared to other steel braced structure and steel structure with X bracing have more storey shear than other steel braced structures.

4.5 PEAK ACCELERATION AND PEAK DISPLACEMENT

The peak acceleration is shown in below table 4.1 for steel moment resisting frame without bracing and with different types bracing system for both the x and y direction.

Table 4.1 Time History Response Summary Chart - ELCENTRO

Models	Peak Acceleration (m/s^2)		Peak Displacement (mm)	
	X Dir.	Y Dir.	X Dir.	Y Dir.
Steel MRF	2.59	2.62	197.35	200.36
Steel MRF - X bracing	2.70	2.95	199.28	143.60
Steel MRF- V bracing	2.62	2.77	200.36	150.40
Steel MRF- Inverted V bracing	2.64	2.80	198.76	148.65
Steel MRF- Diagonal Type 1 bracing	2.66	2.78	196.06	150.98
Steel MRF- Diagonal Type 2 bracing	2.67	2.81	199.82	149.32

Time history response summary chart presents the peak values of acceleration and displacements along both X and Y direction. From the maximum base force values it can be seen that, values are found to be almost equal for X direction for all the structural systems and along Y direction steel MRF with X bracing have maximum base force. Also the peak acceleration is found to be more in steel X bracing along Y direction. Steel structure without bracings has maximum displacement compared to all other steel braced structural systems and by use of steel X bracing the displacement can be reduced

6. CONCLUSIONS

Following conclusions are made from results and discussion from modal, equivalent static and dynamic time history analysis.

1. Providing steel bracing or retrofits is one of the useful method to strengthen the structures.
2. It can be concluded that after application of bracing system the displacement of the structure decreases. The use of X bracing and diagonal type 2 bracing shows the maximum decrease in the horizontal displacement.
3. Steel structure with X bracing have more stiffness compared to other steel MRF structure.
4. It can be concluded that use of bracings increased the base shear of the frame compared to the steel MRF.
5. From dynamic time history analysis it can be concluded that steel structure with X bracing has high peak acceleration due to high stiffness and also less displacement compared to conventional steel moment resisting frame.
6. Overall it can be concluded that for the resistance of the lateral loads use of X bracing is more effective than other bracing system.

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