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SEISMIC BEHAVIOR OF STEEL BRACED FRAME STRUCTURES

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Abstract - The progress of steel usage has provided a significant growth in construction industry. It is well established that steel provides better ductility ,stability and strength to the structure. The structure should be good enough to withstand seismic loads as well as lateral loads. This study aims to determine that the steel braces is one of the best method to reduce seismic forces specifically knee bracing which gives most of the lateral stiffness and flexural yielding. In this context a 6 storey knee steel frame structure with a plan of 9 m *9 m is utilized. To test the results that the knee braced framed structure gives better results than the bared frame. A 6 storey knee braced steel structure has been analyzed using ETABS software based on IS 1893:2002 guidelines. Equivalent static analysis method used for calculating base shear and lateral force on each storey and compared with bare frame. ETABS software results are compared with manual results.

Key Words: Seismic performance, steel braces, ETABS software , Equivalent static analysis.

1.1 INTRODUCTION

Earthquakes are natural phenomenon which cause the ground to vibrate. It causes movement in both horizontal and vertical directions respectively. Earth interior is hot and lava comes out to the surface. As the lava comes out, it gets cooled and new land is moved which is continuously moving. Earthquake arise due to the constantly moving plates which either gets collide at their boundaries. The areas which are near the boundaries of the plates are more prone to earthquakes. The structure made should be able to withstand gravity forces as well as seismic forces and safety of structure. In addition, Structure are prone to lateral loads which exhibit more stresses causes bending and deflection of the structure. Structures are subjected to various loads wind load, earthquake load and gravity loads. The gravity load which are dead and live load acting on a given structure. Structure should be well enough to accept all type of loads. When structures are provided to horizontal loads mainly building structures, structures show greater deflection. Braces and shear walls are the most common lateral load resisting systems to reduce the displacement. The areas subjected to earthquakes, tall building structures cannot bear large deflections. Bracings are mostly used in structure subjected to wind and earthquake loads. It resist forces with the brace members both in compression or tension. This makes the bracing system highly efficient in resisting the horizontal loads. The braced frame make system efficient and structure laterally stiff. With the addition of the material to the bare frame and it forms efficient structure to a greater heights .

1.2 BRACINGS TYPES

Bracing systems are defined depending on the usage and the usage is based on the connection of beam and column. Braces are connected at two different joints i.e. column beam joint and away from column beam joint. Braces are classified into various types

Material based :-

a) Reinforced Cement Concrete brace- The Cross section of this brace is of a beam or column. These braces are strong in compression as concrete is strong in compression also as their construction is hard they are not used. These braces can be used once due to seismic excitations and hence these are expensive.

b) Steel brace: These braces are made up of steel and types of steel sections are used such as angle sections, channel sections, tubular sections for steel braces. The steel braces mostly resist large tension force and fail in buckling. The benefit of steel braces is they can be used again and again after the damage and generally not expensive.

Based on the connection to the frames:-

a) Concentric: These are joined to beam or column connectivity. The examples of concentric braces on the basis of their configuration are as follows such as K type, V type and X type bracing.

b) Eccentric: These are connected to separate point of the given section. The section connected to members link aid in transfer energy from seismicity through plastic drift. These Bracings improve the lateral stiffness and increase the energy dissipation capacity. In eccentric braces, the lateral stiffness of the frame depends upon the bending deformation.

Design of steel buildings for seismic loads are based on below objectives:

a) Elastic response

b) Collapse prevention

To meet above objectives, structures are typically designed with greater lateral stiffness.

Following above objectives to control large deflections during moderate earthquakes and with proper ductility to survive large inelastic deformations.

The objectives can be achieved using ductility. Ductile braced frame structures have high lateral stiffness and ductility. The lateral stiffness is achieved by bracing element. The ductility is usually provided by an inelastic mechanism to overcome overloading in structures

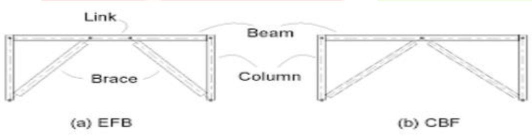
The mostly used ductile braced frame systems are

a) Eccentrically braced frames

b) Buckling restrained braced frames

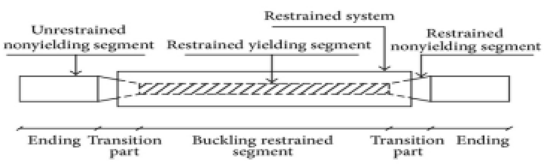
c)Eccentric Braces Frames (EBFs):

In this type of system, the bracing element is connected to beam as shown in figure. It consists of a small connecting link called ductile link. This link provides enough ductility and the energy dissipation to the structure. They are constructed by providing an eccentricity between the bracing tip and in between the brace and the column tip.



(a)eccentric brace frame (b) concentric brace frame

Buckling Restrained Braces (BRBs): In this type of framework, they are utilized to decrease the buckling steel support during serious seismic loadings. It compromise of a steel centre encased with mortar secured with a steel packaging. Under seismic excitations the steel centre yields and the mortar covering forestalls further change in shape. The composite activity performs and forestalls shape under extreme conditions. The segment of BRB are as shown.



Components of BRB

2. LITERATURE REVIEWS

1.Jinko Kim, Junhe Paret. al (2009) The seismic conduct of framed structure with chevron buckling restrained braces was examined and conduct factors like over strength, ductility, and response modification factor were assessed. The kind of structures for example building frame system and dual system framework with 4, 8, 12, and 16 stories were planned. Nonlinear static pushover analyses utilizing the distinctive loading designs and gradual powerful analysis using twenty earthquake records were administrated to figure conduct factors. Time history analyses were likewise led with 20 earthquake tremors getting dynamic reactions. The dual systems structured with the little seismic load indicated prevalent static and dynamic performances.

2.Lelataviwat.S, Dung.P, Prof. Jenda. E, Chanan.W. et. al (2017). This paper shows the behavior and style idea of a proficient basic structural steel systems based on creative uses of knee brace support. knee braced frames incorporate moderately straight forward associations of basic development after an earthquakes and less block when contrasted with standard bracing systems. Different arrangement of KBFs are frequently planned and definite for different degrees of strength, stiffness, and ductility. They all are designed all together that all inelastic exercises are limited to the knee braces and assigned yielding components. A plan ideas to assure sure ductile behavior of knee frame are first summed up.The outcomes show that KBFs can give practical options in contrast to standard structural systems

3.Lugi DI Saro, Amr Elnshai. et. al (2004) This investigation shows the seismic performance of steel moment resisting frames retrofitted with various braces system frameworks. A tall steel structure with steel border MRF was planned with horizontal stiffness in zones with high seismic perils. Most storey drifts of MBFs are 70% and about 50 % lower than SCBFs. The territory designs with buckling restrained braces have seismic execution barely better to MBF regardless of their mass. This measures steel for basic components and their associations in designs with mega braces is less than in uncommon concentrically braced frames. This decreases the expense of development and renders mega braces frames are appropriate for seismic retrofitting applications.

4.Mahnud Mri, Abas Zdeh. et. al Frames comparable measurements however different heights in systems are structured predictable with Iranian code of practice for seismic resistant design of building and afterward dependent on nonlinear push over static analysis. A seismic factors like factor behavior and execution level are looked at. Considering tables related with seismic data it demonstrated regardless of stages expanded the strength factor diminished and furthermore the ductility expanded. A amount of dispersing and energy absorbed in chevron knee brace framework is very customary knee braces system framework which shows high ductility of chevron knee braces system against of solidness knee braces system

5.Viswnath K.G, Prof. Praket. al (2016). The idea utilizing steel bracing is one of the useful ideas can be utilized to fortify the current structures. Steel bracing utilized as a substitute to the next fortify or fitting procedures absolute load on the current structure won't change fundamentally. Steel bracings typically lessen shear requests on beam and columns and move horizontal loads through axial load component. The lateral displacement building contemplated are decreased by X bracing. This examination presume that the X bracing decrease the lateral deflection fundamentally.

6.Sara Raphl, Prof. Soni Syed, et. al (2016) In this exploration paper a relative investigation of various knee bracing system is introduced. Pushover analysis performed on steel frames outlines with double knee bracings. It demonstrated excellent conduct during a seismic activity with less directional disfigurement and stress. Four knee braced steel outlines with differing points are displayed and broke down for an edge investigation of knee part. From the nonlinear examination the total deformation for relating extreme burden load are obtained. This paper reasons that the steel frames with double knee bracings shows awesome conduct during a seismic movement and the degree of inclination of the knee member with more noteworthy than 350 shows maximum stiffness.

7.J. Sakar, E.V. Ragha Rao, N. Chamakesavulu. Et. al (2016) A main role of the project being remarked upon is to discovers forces on components of a structure as required for configuration purposes. For buildings, Earthquake force is format with supporting elements from which the forces get moved to the system. This task provides values of bending moments, shear forces, storey drifts for an assortment of cases covered and shows storey drift increment from base to top. The examination showed that storey drift will be expanded from zone II to zone V in both the directions X and Z separately. The measure of storey drift relies up on the extent of earthquake tremor and furthermore on the displacement of the storey. Bending moment and shear force values shifts starting with one zone to another zone and hence subsequently will expanded from zone II to zone V.

8.Arthi Thamrkshan, Arunema .S et. al Steel bracing is efficient, simple to raise, consumes less space and has adaptability to structure for getting the ideal quality and solidness. There are various sorts of steel bracings accessible as indicated by wanted need. This paper contrasts steel frame outline consequences of the pushover method. The paper examining recommending the suitable setups. Steel braced frame is the auxiliary frameworks oppose earthquake loads in st Antha M, Diva K.K. et. al (2015) A knee supporting ordered by Finite element method to decide specific assurance in specific methodology. In this the 2D outline thought about and most part consider a bit of data to record it a frame structure to figure external body. A single diagonal frame is thought of and the double knee bracing has taken. Because of solidarity to mass proportion the properties of material, ductility, 7 nature of structure is taken. The fundamental point contrast Knee supporting frame with eccentric with Nonlinear static examination and non linear time history investigation dictated utilizing computer software. Analysis is identify the means of earthquake information. a definitive load were determined.

9.K.K.Sgle V.Mhalngkr (2012) An examination chip away at seismic analysis of skyscraper steel building with and without Bracing and study think about the after effects of seismic analysis of skyscraper steel building with various arrangements of bracing framework. The time history examination of the paper shows that bracing element will have exceptionally unmistakable impact on structural behavior under seismic burdens.

10.Tremblay et al. (2008) An analytical study is evaluated to contrast the Buckling restrained braced casing having self focusing energy dissipation. This outcomes shows the remaining distortion of self focusing fatality disseminating support outline frame systems is unimportant under low and moderate danger level and is reduced up to enormous degree under greatest considered seismic tremor level.

11.Chudhari V., et. al (2015). The journal explains the significant idea of earthquake opposing frames of X supported frame, V and Knee braced outlines in steel structures. In this journal Sap software has been utilized. The G+4 storey with steel uncovered was thought of and analyzed in various bases. As the plotted outcomes were taken from accompanying computer data. The pushover investigation showed distinguish the base shear and performance point.

12.Ratnsh Kumar, Prof. K. C. Bswal, et.al. The investigation of braced steel frame structure data is generally concentrated in engineering. Numerous analyst profoundly reading these structures for their more noteworthy limit of conveying external factors. Model one was a Steel Moment Resisting Frame concentric supports in which they utilized Cross bracing and an un bracing frame is considered. Model two compromises two Steel Moment Resisting Frame with comparative V type and Inverted V bracing with different height.

13.Christopoulus et al. (2008) A Self centering energy dissipating frames is utilized in cross bracing framework. Buckling reinforced braced frames are additionally utilized and disperse vitality due to their self focusing capabilities which helps in reducing building deflection after prominent seismic excitations.

14.C.C. Jecob et.al (2009) The earthquake behavior of less ductile steel framework intended for medium seismic regions have created enthusiasm with financially savvy structure of malleable framework for areas. anyway eccentrically braced frames (EBFs) which shows high ductility systems and can possibly offer practical arrangement in moderate seismic regions. Eccentrically Braced Frames (EBFs) offers a blend of high elastic stiffness and unrivaled inelastic execution qualities.

15.GhorahA. et al., (1997) This paper shows that the inter story drift can moreover be considered as an approach to give uniform flexibility over the parts of the building. A story drift may achieve function of a slight story that may cause cataclysmic structure breakdown in an seismic function. Uniform story adaptability over all records is generally need in seismic arrangement.

16.K.G.Vishwath(2010) A paper was introduced on seismic reaction of Steel supported fortified solid edges in International diary of common and auxiliary designing. A four story building was taken in zone four as shown to IS code 1893. The presentation of the structure is assessed by story float . X sort of steel propping is found to be beneficial.

3. METHODOLOGY

MATERIAL AND SPECIFICATIONS

3.1 INTRODUCTION OF MODELED STRUCTURES.

A Model structure of 6 storey steel frame structure with X bracing system with floor plan of9m x 9 m is taken. The various analysis i.e. Response Spectrum , Time history is performed in ETABS software based on IS 1893:2016 guidelines.

Depending on the complexity in the problem for bracing models had utilized ETABS softwareso as to find lateral and base shear.

The outcomes were plotted as even structures of tabular forms and chart for different storeydrift and displacement.

3.2 CODE, STANDARDS AND SPECIFICATIONS

The specifications and software used are listed below:

1- The Loading i.e. Dead, Live and Earthquake were received utilizing IS codes.

2- Spectral analysis and seismic loading were surveyed by IS 1893:2002. [1]

3- The structure were planned according to IS 800:2007 & IS 456:2000.

4- ETABS 2018 was used for the investigate and plan of basic components.

3.3 PROPERTIES OF MATERAIL

Steel properties in this thesis depend on data recorded in Table 3.3.1

Density -780 kg/m3

Specific Weight 7800 kg/m3

Poisson's ratio 0.3

Yield stress,(fy)- 2400 kg/cm2

Ultimate strength, (fu)- 4000 kg/cm2

Elasticity modules- 2.01*10^6 kg/cm2

Concrete Values

Concrete data are shown in Table 3.3.2

Density - 240 Kg/m3

Specific Weight - 2400 Kg/m3

Elastic Module- 21882 Kg/m3

3.4 MODEL STRUCTURES LOADING PARAMETERS

Assessment of Floor Dead Load

a) Dead Load Calculation

For assessment of loads- unit tables from IS code are utilized in the software so that the densitycan be determined by the program.

b) Live Load Calculation

Live load calculation is done using IS code 1893:2002 and IS 456:2000 and IS code 800:2007.Half of the moving load is burdened at the floors.

c)Design Load Criteria

Various load combinations are as follows

1.5 (DL+LL)

1.2 (DL+LL+ELY)

1.2 (DL+LL+ELY)

1.5 (DL+ELX)

1.5(DL+ELY) 0.9DL+1.5ELX 0.9DL+1.5ELY DL:-DeadLoads,

LL:-LiveLoads

EL:- Earthquake Loads In X And Y Direction.

Earthquake Load

IS 1893 is used to calculate the earthquake loads. Earthquake acts in two directions x and y directions.In the solving of seismic loads on the structure can be linked with number of methods

Base shear is calculated using the IS code guidelines As we know from IS code.

VB = Ah*W

A = Seismic coefficient for a structural building.

W = Seismic weight of structure considered.

The design horizontal seismic coefficient for a given structure A and various parameters aregiven as

A = Z*I*Sa / 2*R*G

A =

Z = zone factor.

I- importance factor.

R -response reduction factor.

Sa / g -coefficient of response acceleration for rock and soil sites

T- The fundamental naturalperiod for buildings obtained

Ta = 0.075*h *0.75 for RC frame resisting structure

Ta = 0.09 * h/√d for building of moment resisting frames and structures. h = The height of the building from the base foundation to tp roof (m).

4. ANALYSIS AND DESIGN

In this chapter, the various manual calculations used in this study are calculated with all therequired formulae.

4.1 Equivalent Static Analysis for Calculating the Base Shear and Lateral Shear

Specification of a 6-storey steel residential building Given data,

Stories = 6

Live load = 3kN/m2

Columns = ISHB250-2

Beams = ISLB200

Bracing = ISMB175

Thickness of Deck = 110mm

Thickness of wall = 120mm

Importance factor = 1.0 Zone=3

4.2- Seismic Weights Computations

1- Unit weight of concrete as 25kN/m3 and 20 kN/m3 for masonry

2- Slab: Dead load of Deck = Volume of Deck*unit weight of concrete **=** (9*9*0.11) * 25 = 222.75kN

3 -Coloumn: from steel table ISHB250-2 = 54.7kg/m = 547N/m

Dead load due to self-weight (16 no's) =No.of columns * self-weight * length of column. =16 * 0.547 * 3 = 26.26kN

4 -BEAMS - ISLB200 = 19.8kg/m = 198N/m

Dead load to self-weight (18 no's) = 0.198 * 18 * 3 = 10.7kN

5 -WAL - Weight of wall per unit length = 0.12 * 3 * 20 Dead load due to weight = (9+9+9+9) * 7.2 = 259.2kN. 5) Live Load (25%) = unit weight * area of deck = (0.25*3) * (9*9) = 60.75kN.

Load on all Floors
W1 = W2 = W3 = W4 = W5 = DECK + COLUMNS + BEAMS + WALLS + LIVE LOAD =222.75 + 26.26 + 10.7 + 259.2 + 60.75 = 579.66kN

6- Fundamental Time Period Ta = 0.09 * √h/d = 0.09 * √18/9 = 0.54 s

7- Moment Frame with in Fill Walls Medium soil takenTa = 0.54 s

Sa/g = 2.5

Zone factor- Zone 3, Z = 0.16 Importance factor (I) = 1.0

Response Reduction factor(R)= 3.0

Horizontal acceleration coefficient (Ah)

Ah = $Z/2 * Sa/g * IR$

= 0.16/2∗ 2.5 ∗ 1.0/2.0

= 0.0667

4.3 Shear at base (VB)

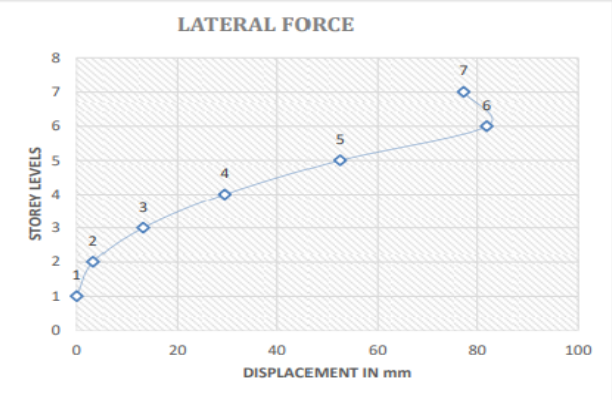
VB = Ah*W = 0.0667 * 3860VB = 257.47kN

Storey shear forces are calculated as follows (last column of the table),

V6 = Q6 = 77.27kN

V5 = V6 + Q5 = 77.27 + 81.90 = 159.17kN

V4 = V5 + Q4 = 159.17 + 52.42 = 211.59kN



V3 = V4 + Q3 = 211.59 + 29.49 = 241.08kN

V2 = V3 + Q2 = 241.08 + 13.11 = 254.19kN

V1 = V2 + Q1 = 254.19 + 3.28 = 257.47KN

Lateral Force and Shear Force Distribution 4.3.1

Floor Level (L)	WI (KN)	Hi (m)	$w_i h_i^2$ (kN-m²)	Storey Forces $Q_i = VB \frac{w_i h_i^2}{\sum_{i=1}^{n} w_i h_i^2}$	Storey shear forces (vi) (kN)
6	380	18	123,120	77.25	77.25
5	580	15	130,500	81.88	159.13
4	580	12	83,520	52.46	211.56
3	580	9	46,980	29.43	241.02
2	580	6	20,880	12.11	253.13
1	580	3	5,220	3.26	256.39
			$\sum W_i h^2$ = 410,220		

Lateral Force and shear Force Distribution in Fig 4.3.2

DISCUSSION

Storey Drifts in X-Direction:
The values shows the storey level, storey displacement and inter storey drift for steel bare frame and types of bracing patterns which are bare frame, knee bracing in X- direction by response spectrum analysis

Storey Drifts in Y-Direction:
The values shows the storey level, storey displacement and inter storey drift for steel bare frame types of bracing patterns which are bare frame, knee bracing in Y- direction by response spectrum analysis.

3. CONCLUSIONS

From the above study, the following conclusions were made:

- The seismic behavior on G+5 structural model with bare frame and knee frame bracing arrangements for analysis.
- The inter storey drift in X-direction is more compared to permissible drift ratio as per IS code 1893:2002.
- The knee braced frame system is significant to reduce the effect on lateral displacement by spectral acceleration (Sa).
- The inter storey drift in Y-direction is far compared to permissible drift.
- The knee bracing frame structural inter storey drift is acceptable as per IS code 1893:2002

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