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COMPARATIVE ANALYSIS OF BRACING SYSTEMS USING SHAKE TABLE

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Abstract

From last few decades steel structures plays an important role in construction industry. Steel is a essential material for building construction. Steel structures are ductile in nature and carries good strength and stability, they gives prior warning before failure by means of deformation. The design of structure should be such that it can sustain earthquake load. This report contains analysis of G+5 building using different types of bracing systems. The building is designed for cross bracing(X), diagonal bracing, Y bracing and K bracing and comparision is made between them using shake table.and results are cross checked using ETABS software. Bracing in steel structures are used because they give good strength against lateral loads like earthquake, wind etc. and are provided to minimize lateral deflection of structure.

KEYWORDS: Steel structure , Bracing , Shake table.

1.INTRODUCTION

Earthquake are most l damaging and destructive natural calamities. Basically they are generated by releasing large amount of energy in earth crest causing seismic waves appears with different intensities at different instant of time. Bracing in steel structure are commonly used to withstand loads from earthquake , wind etc. Bracings are economical , need no any skilled work to set up and can be easily designed for required strength and stability. Braced frames are provided to give strength and stability to structures in earthquake prone areas.

There are various ways to provide bracing to the structure like Crossbracing(X),diagonal bracing , y type bracing , k type bracing. In my research work I am going to consider analysis of the above bracing types in G+5 story structure using shake table and going to cross check results using ETABS software.

1.SHAKE TABLE

Shake table are an essential tool for assessing the behavior of structural components, the whole system works similar to those induced in real earthquake. Shake table are used to study the dynamic effects on the performance of specimens. There are two shaking tables in the world which are large enough to test the full – scale structures, one jumbo shaking table in JAPAN and the one in USA.

1 Horizontal Shake Table

In horizontal shake table the cam is connected to a variable speed motor with the help of a shaft and a fly wheel. A circular mounting plate is placed on a vibrating plate so that the test structure can be mounted at any desirable angle. The table is able to generate harmonic motions of different amplitude. Horizontal shake table will produce horizontal base motions. The amplitude of base motion can varied by changing the eccentricity of the cam. By varying the speed of motor, the frequency content of the base motion can be varied.

Fig -1 Horizontal shake table

2 Vertical Shake Table

Vertical shake table will produce vertical base motion. Vertical shake table will consist of a connecting rod, avibration table and a cam. The cam will beconnecting to a variable speed motor with the help of bearing assembly. The vibration table will be mounted on springs and the roller supports prevent wobbling. Frequencycontrol 5% accuracy . A screw mechanism will be presents to vary the amplitude of base motion. By varying the speed of motor, thefrequency content of the base motion can be varied

3 Servo Electric Shake Table

Servo electric shake table will consist of a Servo Actuator is controlled through computer. Various base motions such a sine, square, random, etc. will be given to Actuator and accordingly the top table will vibrate. A circular mounting plate will be placed on the vibrating plate.

Fig -2 Servo Electric Shake Table

4. Servo Hydraulic Shake Table

Servo hydraulic shake table is a closer look control based actuation mechanism. Servo based direction control valve is the heart of the entire system. Servo valve basically governs the flow and pressure of the oil to the Actuator. Accordingly the Actuator moves forward and backward and hence the shake table The Actuator has a Position Feedback Sensor (PFS) which sand the signal of the motion controller. Controller verifies the position and if there is any difference with respect to initially fade Valve and corrects it by moving the Actuator front or back.

Fig -3 Servo Hydraulic Shake Table

USES OF SHAKE TABLE

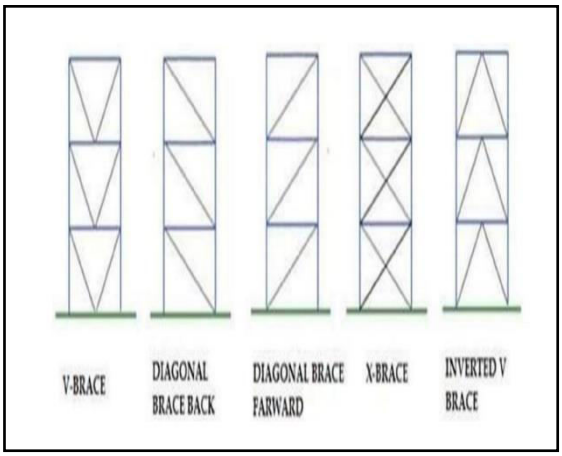
1. To check the stability of Building models

2. To check the stability of Bridge models

3. Assessment of dynamic and seismic behavior of civil engineering structures

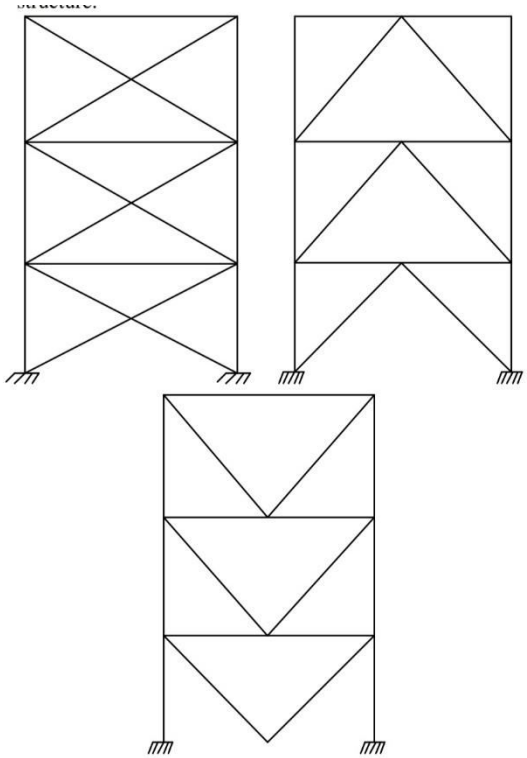
2. BRACING SYSTEMS

As steel bracing is economical, easy to set up, occupies minimum space and also have flexibility in nature to design for meeting the required strength and stiffness. Braced framed structures are usually considered to resist the lateral forces and also earthquake loads. Braced systems provide due to their strength, stiffness to the structures. They provide more stiffness against the horizontal shear because the diagonal member elements work in axial stress.



DESCRIPTION OF BRACING SYSTEM

Braced frames are a very common form of construction, being economic to construct and simple to analyse. Economy comes from the inexpensive, nominally pinned connections between beams and columns. Bracing,which provides stability and resists lateralloads, may befrom diagonal steel members or, from aconcrete 'core'. In braced construction, beams and columns are designed under vertical load only, assuming the bracing system carries all lateral loads. A Braced Frame is a structural system which is designed primarily to resist wind and earthquake forces. Members in a braced frame are designed to work in tension and compression, similar to a truss. Braced frames.are almost always composed of steel members. Following fig. show the different types of bracing system use to braced the structure.



OBJECTIVE OF STUDY:

1.To find out seismic stability of the model by using shake table and compare the results using ETABS software.

2.To find out effects on various parameters of building which undergoes earthquake due to presence of bracing system.

3To find out which bracing system is superior compared another in higher earthquake zones.

4.To carry out the analysis of structure as per IS1893:2002(PART1) and to study the behaviour of structure under earthquake.

5.To decrease the story drift and story displacement during earth quake.

ADVANTAGES OF SHAKE TABLE

1. As it tests the resistance of structures in earthquake which becomes helpful from destructions.

2. Dynamic structural behavior can be done which helps to understand the situations of the structures.

3. Various types of ground vibrations and seismic research can be done by using shake table.

LITERATURE REVIEW

GENERAL-

During the last three decades, a substantial research work has been done on the selection and scaling of earthquake records for use in dynamic analysis of structures. . Based on the literature review, there are two main approaches in this research. One approach is on the selection and scaling of real records, and the other approach is on the use of ETABS software. The objectives of both approaches are to provide earthquakeground motions which are compatible with the specified design .

Literature available on the topic itself is comprehensible enough to that earthquake analysis of structure can be easily carried out by using different methods of analysis but the key point is to do it with realistic approach such as shake table analysis. Instead of assumed input earthquake data for assessment shake table make use of the ground acceleration data of actual earthquake that happened somewhere. By using the same data, a realistic analysis of structure can be found out by this method.

LITERATURE REVIEWS

1) *Trembly et al:*
He carried out the experimental study on seismic performance of braced steel frames with rectangular bracing systems. The main study area of his experiments is X bracing and diagonal bracing systems. He performed non linear dynamic analysis of typical braced frames. To obtain results cyclic loading is used and results are used to charactorise the hysteretic response , including energy dissipation capabilities of the frame. Using different earthquake ground loading the ductile behaviour of bracing is studied and used for design applying the code procedure. He obtain simplified models of the structure to predict plastic hinge failure and local buckling failure of the bracing as ductility failure mode. As the result of experiment inelastic deformation capabilities are obtained before failure of moment resisting frame and bracing members.

2) *Seismic response of Steel braced reinforced concrete frames by K.G.Vishwanath in International journal of civil and structural engineering (2010)*
A four storey building was taken in seismic zone 4 according to IS 1893:2002 . The performance of the building is studid according to story drift. Then the further study is done as extension of the first to eight story and twelve story and results are concluded as X type of steel bracing is most efficient.

3) *Seismic response assessment of concentrically braced steel frame buildings (The 14th World conference on earthquake engineering October 12-17, 2008, Beijing, China)*
A performence based Improvement of design and analysis procedure for complete understanding of conventionally used concentrically braced frame and buckling restrained braced frames is discussed.

4) *Kartik Prashar, Jagdeep singhGahir(2018)(Seismic behaviour of RC frame structure with different types of bracing)*

He studidthe the different bracing system (diagonal type, V type ,inverted and k type) and arrangement of bracing system . To build the seismically safe structure with adequate lateral resistance .Bracing system is installed between column member to resist the lateral load. Bracing system is easy to installed , economical and occupies less space. The structure is analyzed for seismic zone V with different types of bracing system and compared with the bare frame with the using of ETAB software. The load condition is applied as per IS 1893 :2002. Bracing system improve the displacement capacity of the structure.

5) *Pratik Patel,Sandeep Patel, Tejasvee Patel ,Kamlesh damdoo(2019)(comparative study of bracing systems using STAAD.pro)*

Their study gives a solution to reduces the effects of earth quake due to the discontinuity in load path and non-uniformity of stiffness and to hold the structure under the bracing system using with other strengthening systems. This feature is useful in provision of open storey at the ground floor or first floor and to eliminate the internal columns which are hindering in open space. To resist the lateral load acting on building, different types of steel or RCC bracing systems are provided. The use of RCC bracing has potential advantages than any other bracings like higher stiffness and stability. This study aimed the comparison of normal building and building with different RCC bracing system under seismic behavior in high rise buildings. The bracing systems provided on periphery of the building. The frame models are analyzed as per IS: 18932000 using STADD.ProV8i. The parameters which will be considered in this paper for comparing seismic effect of buildings are base shear and storey displacement. The probable results showed that X-braced frames are more efficient and safe at time of earthquake when compared with moment resisting frames and V-braced frames.

6) *A.P.Kulkarni, M.K.Savant, M.S.Shindepatil(2017)(Experimental study using earthquake shake table)*

This paper consist of the stability of a three storey building is considerd for various conditions under two different scenarios, with and without the use of base isolation technique in the form of dampers. As shake table are used in many research work as it produces the same effects that earthquake produces. Using horizontal shake table analysis of deflection of building is done for different cases. Designing of shake table is done considering the

factors and specifications of earthquake produced. Type of Payload is set according to the building characteristics and frequency is to be set according to the earthquake produced various uses and advantages of shake table are also studied during our analysis work. Also different types of base isolation materials are mentioned. By using springs as a base isolating material analysis is done.

7) *Ali Hemmati and Ali Kheyroddin*

Studied 20 story steel frame with different arrangement of bracing systems and Linear and static nonlinear (push-over)analyses are carried out. As a result Analytical results show that, the use of bracing is more adequate system under the lateral loads.

8) *A Rahimi and Mahmoud R. Maher*

Analysed the Behaviour of RC columns before and after retrofitting with steel X bracing and observed possible complications, increased demands and side effects of such a retrofitting method. The effects on the level of column shear and axial force, as well as, column performance level and low cycle fatigue life are investigated.

9) *Ratnesh Kumar (2014, Seismic analysis of braced steel frames)*

The study is based on basically on linear time history analysis of steel frames with concentric bracing models. Different configurations of frames are selected such as cross bracing, diagonal bracing and V and inverted V bracing and analyzed. This paper presents a summary of various parametres defining the computational models, the basic assumptions and the steel frame geometry considered for this study. He investigate the seismic performance of a multi-story steel frame building When unbraced and then with different bracing arrangement such as cross bracing 'X' and diagonal bracing using Equivalent Static analysis, Response Spectrum analysis and linear Time History analysis. Under different earthquake loading and loading combinations. Also concluded about seismic response of a multi story steel frame building Undersame bracing configuration but with varying number of story i.e. with varying height of the building.

10) *Priyanka T. , Shilpa V.B.(2016)(Seismic analysis of of unsymmetrical building with different bracing systems)*

Their study consist of unsymmerical building plans constructed for aesthetic purpose. These building includes discontinuity in mass, geometry and stiffness of structure, which leads to destruction during earthquake. In the current work concerns with study of the dynamic behaviour of regular building in comparison with irregular buildings with different bracing system using IS 1983-2002 (Part 1) code recommended response spectrum method. Analysis of building has been carried out using ETABS software. The structure is anlysed as per IS 1893-2002(Part I) code and studied about response of braced and unbraced for symmetrical and unsymmerical buildings. The study of seismic analysis is carried out by ETBS .

11) *ShahrzadEghtesadi ,DaneshNourzadeh , Khosrow Bargi (2011)*

(Comparative study on different type of bracing systems in steel structures)

They Choose an appropriate lateral force resisting system which has a considerable effect on performance of the structure in steel frames. So this paper is concern about investigating and comparing various types of bracing systems. They use four types of bracing systems including X-bracing, Diagonal bracing, Inverted chevron CBF and Inverted chevron EBF, in four different height levels. The model is prepared and analysedand are compared in different aspects, such as economy point with evaluating the weight of the structure, the maximum top story displacement under seismic loading and the energy absorption. The result of experiment shows that diagonal bracing systems increase the energy absorption capacity of the structure, but because of its less rigidity it leads to increasing the buildings weight. So in order to optimize the amount of steel consumption and obtain the light weight structure,

best solution is to apply the Inverted chevron CBF bracing systems in steel frames.

12) *K.S.S.Karthik Reddy , SaiKalaKondepudi ,Harsha Kaviti (2015)(A comparative study on behaviour of multistory building with different type and arrangement of bracing systems)*

Their study concern with the tall building subjected to lateral or torsional deflections under the action of lateral loads, the resulting oscillatory movement can induce a wide range of responses in the building. As a result, lateral stiffness is a major consideration in the design of tall buildings. Bracing is a highly efficient and economical method of resisting lateral forces in a frame structure because the diagonals work in axial stress and therefore call for minimum member sizes in providing the stiffness and strength against horizontal shear. In this research study, four different types of bracing systems have been investigated for the use in tall building in order to provide lateral stiffness. The use of bracings has potential advantage over other scheme, the bracings are provided for peripheral columns. A sixteen story (G+15) building is situated at seismic zone 2 and is subjected to a wind speed of 220kmph. The building models are analyse by equivalent static analysis as per IS 1983:2002 using Staad ProV8i software and wind loads are calculated as per IS:875(part 3)-1987. The main parameters consider in this paper to compare the seismic analysis of buildings are lateral displacement, story drift, axial force, base shear. It is found that the x-type of bracings significantly contributes to the structural stiffness and reduces the maximum inter storey drift of R.C.C building than other bracing system. The peripheral column moments are also reduced as compared to the column moments to unbraced structure. The axial force on the columns for x king of bracings and minimum for system without any bracing similarly the base shear is more compared to any type of bracings. A comparative study between behaviour of concrete and steel bracings was also done performance of steel x bracing was 2.15% more efficient than that of reinforced concrete bracing, the complete weight of the structure was increased by 3.5% on using concrete bracings.

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MODELLING-

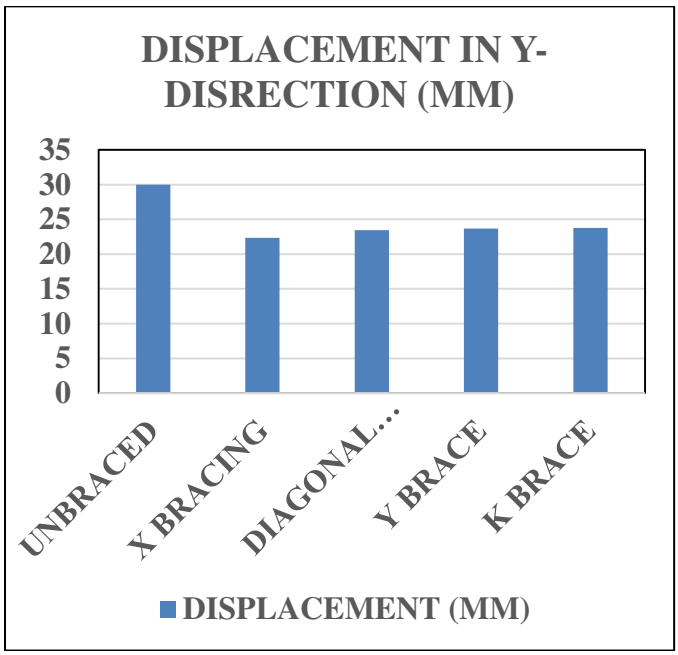
SR.NO	BUILDING DETAILS	
1	TYPE OF BUILDING	G+5
2	PLAN DIMENSIONS	10MX10M
3	TOTAL HEIGHT OF BUILDING	18M
4	NO.OF STIRIES	6 STORIES
5	HEIGHT OF TYPICAL STOREY	3M
6	HEIGHT OF GROUND STOREY	3M
7	GRADE OF STEEL	Fe345
8	SIZE OF BEAMS	ISMB 200

9	SIZE OF BEAMS	ISWB600
10	SIZE OF BRACINGS	ISA 150X150X12 DOUBLE ANGLE

SR NO	DETAILS	
1	ZONE	V
2	ZONE FACTOR	0.36
3	IMPORTANCE FACTOR	1
4	RESPONSE REDUCTION FACTOR , R	5
5	TYPE OF SOIL	II
6	DAMPING RATIO	5%
7	DEAD LOAD	3KN/M^2
8	LIVE LOAD	3KN/M^2

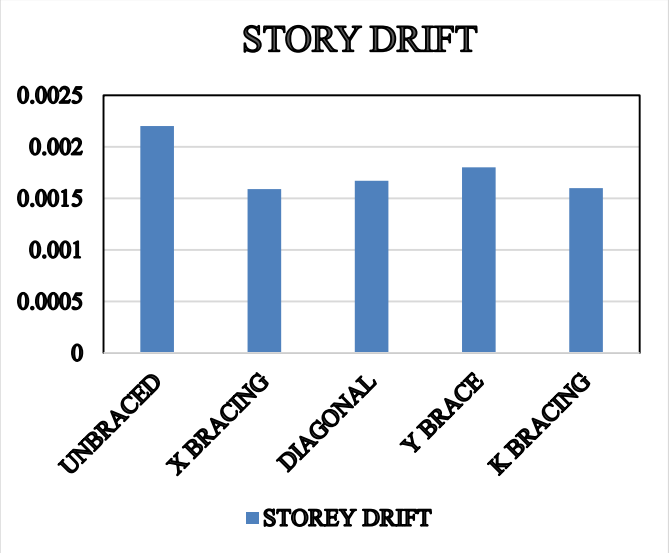
RESULTS

DISPLACEMENT-



The maximum displacement is seen in bare frame , and the lesser values are seen for X-bracing i.e 25.55%. In case of other types of bracing like diagonal,Y bracing and K type bracing it is seen that there is reduction of 21.84% ,21.12%,20.76% reduction indisplacement respectively. The displacements are reduced significantly because of the stiffness provided by the respective types of bracings.

STORY DRIFT-



The results shows that ,there is reduction of 27.73% in case of X bracing compared to bare frame and 27.27% in case of K bracing , 23.18% for diagonal and 18.18% for Y-bracing.

BASE SHEAR-

SR.NO	TYPE OF BUILDING	BASE SHEAR (KN)
1	UNBRACED BUILDING	38.6588 KN
2	BUILDING WITH X-BRACING	87.229 KN
3	BUILDING WITH DIAGONAL BRACING	61.6365 KN
4	BUILDING WITH K-BRACING	49.7368 KN
5	BUILDING WITH Y-BRACING	56.9049 KN

The values shows that the base shear are maximum for X-bracing. This is because of all bracings , X-bracing structure provide more stiffness

CONCLUSION

The study of (G+5) building model is done in the research and analysis results are prepared. The study of all structures by both methods i.e Shake table and ETABS software is done and the conclusion is drawn on that basis . For the study purpose 5 models are prepared , unbraced frame , Model with X- bracing , diagonal bracing ,K bracing and Y bracing , The concluding reark is as follows

1) Shake table can be successfully and effectively used to study the stability of building by providing ground motions similar to seismic forces.

2) From the results of analysis from both the methods it is seen that , use different type of steel bracings help to reduce the lateral forces on building.

3) It is seen ,using different types of bracings to buildings drastically reduces the lateral displacement of the structure. From all the bracings I studied it is seen that X -bracing works more effectively than others . It helps to reduce the lateral forces about 25.55% compared to bare frame (unbraced frame).

4) The study also shows that there is considerable reduction in storey drift. From all the models. Model with X-bracing shows more positive results, and reduction in drift about 27.73%.

5) In comparision with all types of bracing it is seen thet X-bracing works more effectively than K,Y and diagonal bracings.

6)From weight comparision it is seen that , model with X bracing is more heavy compared to other which leads to uneconomy and unnecessary heavy design. So for good results with economy from overall my study I suggest the use of 'Y-Bracing ' is also an good and convenient option.

SCOPE OF FUTURE WORK

1) By using bracings it is seen that the displacement and drift can be reduced in case of buildings square in plan hence further study with buildings with uneven plan or buildings with architectural view can be studied.

2) apart from K,Y,X, and diagonal other types of bracings can be studied like Z,N,V, inverted v shape, W shape etc.

3) We can also study on behaviour of building in other seismic zones apart from zone V.

4) We can also study about material of the bracing apart from steel. The composite materials like use of BFRP (Basalt Fibre Reinforced Polymer), CFRP(Carbon Fibre Reinforced Polymer) on lighter steel structures can also be done to reduce the weight of steel bracings.

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