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DYNAMIC ANALYSIS OF COMPLETELY BRACED STEEL FRAME IN COMPARISON WITH PARTIALLY BRACED FRAME WITH OUTRIGGERS

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Abstract – *Due to Industrial upheaval, accessibility of occupations and offices, populace from country zone is relocating towards urban areas. In light of this metro urban communities are thickly populated. Accessibility of land continues diminishing and arrives at cost increments. To conquer this issue the utilization of multistoried structures is must. Yet, such arrangements expand dead load and live load of the structure. Multi-story structures are intended to convey gravity stacks and in addition, tremor loads and their mixes. I.S. codes giving these stacking mixes to which structure should be investigated and outlined. The examination is gone for finding the inside powers in segment of structures to discover removals created in the structure prompting the improvement of strains. Structure must be sheltered from both quality perspective and serviceability. Uncovered edges are observed to be more adaptable and have huge area necessity to withstand powers. The same can be limited by making the structure stiff. In this volume, utilization of propping to build the firmness of structure has been carried out to premise the past work done. The cross-sort, askew kind of supporting framework has been utilized. Various structures with same height and width with and without props have been investigated. The reactions of propped edges of various designs have been contrasted with each other and the same has been contrasted with unbraced edge. For all sort of structures, which are serving more economy for specific sort, it was discovered that the horizontal removals are well within the limit as far as possible according to IS 1893:2002.*

***Key Words*: Dynamic Analysis, ETABS, Braced Steel Frames, Outriggers, Partially Braced Frames.**

1. INTRODUCTION

A building is an enclosed structure that has walls, floors, a roof, and usually windows. A tall building is a multi-story structure in which most occupants depend on elevators [lifts] to reach their destinations. The most prominent tall buildings are called high-rise buildings in most countries and tower blocks in Britain and some European countries.

The Egyptian Pyramids, one among the seven miracles of world, built in 2600 B.C. are among such antiquated tall structures. Such structures were built resistance and to show pride of the populace in their human progress. The development in present day multi-storied building development, which started in late nineteenth century, expected to great extent for business and private purposes. The outline of tall structures includes a theoretical plan, surmised investigation, preparatory outline and streamlining, to securely convey gravity and horizontal burdens. The plan criteria are quality, serviceability, strength and human solace. Quakes have turned into a regular occasion everywhere throughout the world. It is exceptionally hard to anticipate the force, area, and time of event of tremor. Structures sufficiently intended for normal burdens like dead, live, wind and so on may not essentially protected against quake stacking. It is neither down to earth nor monetarily reasonable to configuration structures to stay inside flexible farthest point amid quake.

The outline approach embraced in the Indian Code IS 1893(Part I): 2002 'Criteria for Earthquake Resistant Design of Structures' to guarantee that structures have no less than a base quality to withstand minor seismic tremor happening much of the time, without harm oppose direct quakes without noteworthy auxiliary harm however, some non-basic harm may happen and points that structures withstand significant seismic tremor without fall. Structures need appropriate tremor safe elements to securely oppose vast parallel strengths that are forced on them amid incessant quakes. Common structures for houses are generally worked to securely convey their own particular weights.

1.1 Bracing Systems

Steel supporting is an exceedingly productive and efficient technique for opposing flat powers in a casing structure. Propping has been utilized to settle along the side most of the world's tallest building structures and one of the significant retrofit measures. Supporting is effective because the diagonals work in pivotal anxiety and along these lines call for least part sizes in giving solidness and quality against flat shear. Various analysts have researched different systems, for example, infilling dividers, adding dividers to existing segments, encasing sections, and adding steel propping to enhance the quality as well as pliability of existing structures. A propping framework enhances the seismic execution of the edge by expanding its horizontal solidness and limit. Through the expansion of the supporting framework, load could exchange out of the casing and into the props, bypassing the frail sections while expanding strength.

Steel-propped edges are proficient auxiliary frameworks for structures subjected to seismic or wind parallel loadings. Along these lines, the utilization of steel-propping frameworks for retrofitting fortified solid edges with insufficient sidelong resistance is alluring. The primary approach acknowledged with the presentation of steel supports in steel structures and of RC shear dividers in RC structures. Be that as it may, the utilization of steel propping frameworks for RC structures may have both viable and monetary points of interest. Specifically, this framework offers preferences, for example, the capacity to oblige openings and the insignificant included weight of the structure. Moreover, on the off chance that it is acknowledged with outer steel frameworks (External Bracing) the base interruption to the full operationality of the building is gotten. There are two sorts of supporting frameworks, Concentric Bracing System and Eccentric Bracing System are appeared in Fig-1.

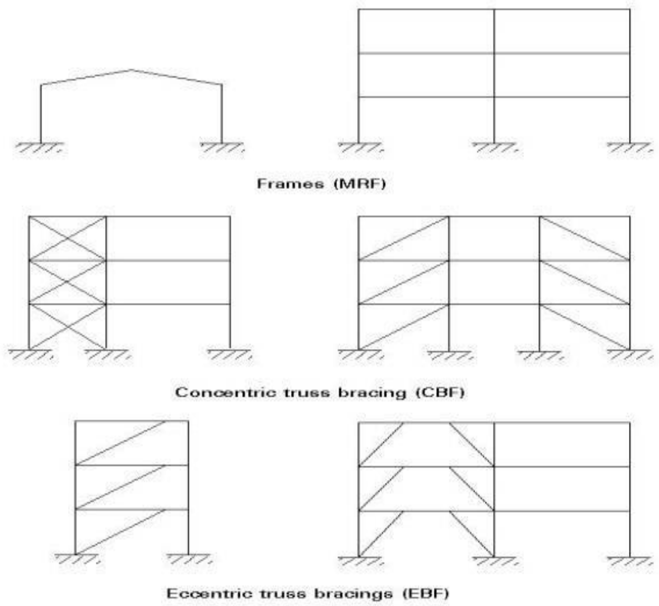

Fig-1: Bracing Systems

1.2 Types of Bracing System

1.2.1 Vertical Bracing System

In a propped multi-story building, the planes of vertical supporting normally given by corner, corner supporting between two lines of sections, as appeared in the figure beneath. Either single diagonals given, as appeared, in which case they should be intended for either strain or pressure, or crossed diagonals are given, in which case thin supporting individuals conveying just strain might be given

Take note of that when crossed diagonals are utilized and it is accepted that the ductile diagonals give resistance, the floor bars take an interest as a component of the propping framework (as a result a vertical Pratt truss is made, with diagonals in strain and posts – the floor shafts – in pressure). The vertical supporting must have intended to oppose the strengths because of the accompanying:

- Wind loads
- Equivalent level powers, speaking to the impact of starting defects
- Second, arrange impacts because of influence (if the edge is touchy to second request impacts).

Direction on the assurance of equal even powers and on the thought of second request impacts in examined in the areas beneath, and a Frame steadiness configuration instrument is additionally accessible.

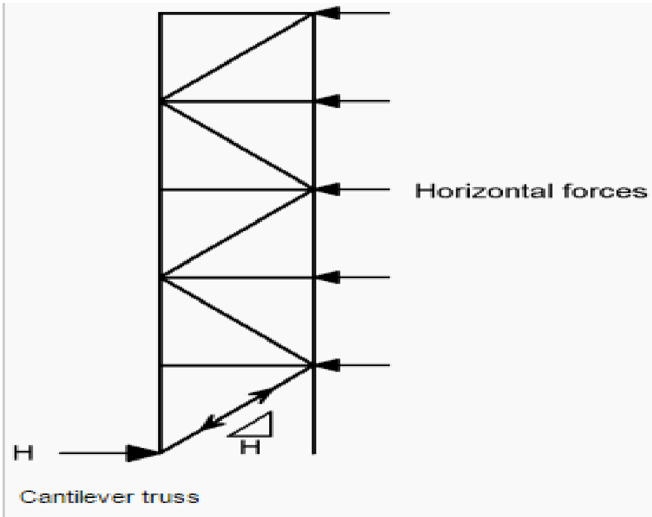

Fig-2: Vertical Bracing System

1.2.2 Horizontal Bracing System

A flat propping framework is required at each floor level, to exchange even powers (mostly the strengths exchanged from the edge segments) to the planes of vertical supporting that give imperviousness to even powers.

Two sorts of even supporting framework utilized as a part of multi-story propped outlines:

1. Diaphragms
2. Discrete triangulated propping.

More often than not, the floor framework will be adequate to go about as a stomach without the requirement for extra steel supporting. At rooftop level, supporting, regularly known as a wind brace, might be required to convey the flat powers at the highest point of the segments, if there is no stomach. See figure on the privilege.

The supporting at each floor level (in flat planes) gives stack ways to the transference of even strengths to the planes of vertical propping. Even propping is required at each floor level; nevertheless, the floor framework itself may give adequate resistance. Rooftops may require propping.

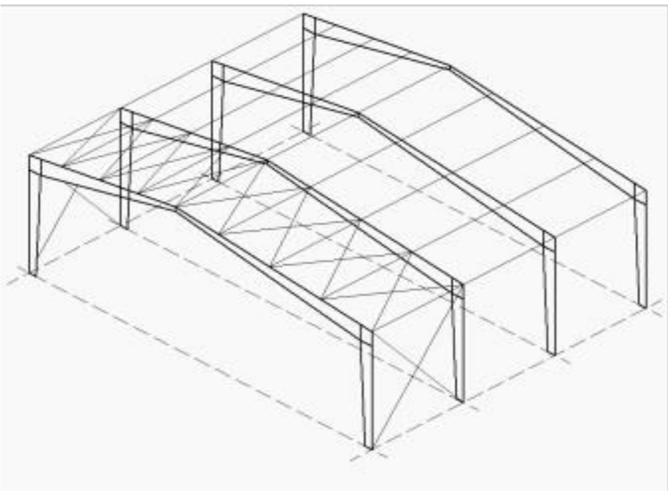

Fig-3: Horizontal Bracing System

1.3 Types of Bracings

In view of the sorts of props utilized in this review, propping frameworks characterized relying upon whether the supports are associated at section pillar joint or far from segment bar joint. Props assembled into different classes, as takes are follows,

1.3.1 Based on the material utilized as a part of supports

1. **RCC support:** These are the props, which are comprised of fortified bond concrete. The Cross-area of solid prop is like RCC bar or segment. These sorts of supports are solid in pressure however are once in a while utilized in view of their development troubles and furthermore another drawback is, these props can't be supplanted once harmed because of seismic burdens and thus it winds up noticeably uneconomical.

2. **Steel support:** in Steel props diverse sorts of steel segments can be utilized, for example, channel areas, point segments, I segment and so on or tubular segment. These props as a rule oppose huge strain compel and bomb in clasping. Supplant the fundamental favorable position of steel prop scan after the harm consequently making it conservative.

1.3.2 Based in transit supports are associated with the edges

Concentric: In a concentrically propped outline, supporting individuals are associated with pillar or segment intersection. Diverse sorts of concentric props can be additionally characterized relying upon their design. Cases for concentric props are V sort, X sort, K sort and so on.

Eccentric: In an erratically propped outline, supporting individuals are associated with partitioned focuses on the bar or segment. The portion or connection exhibit between shaft individuals help in retaining vitality from seismic activity*through plastic miss happening. Offbeat Bracings enhance the horizontal solidness and increment the vitality dissemination limit. In unusual association of the supports to shafts, the horizontal solidness of the casing relies on the flexural firmness. This is regularly utilize as a part of seismic locales and considers entryways and passageways in the supported narrows. It is like V-propping yet rather than the supporting individuals meeting at a middle point there is space between them at the top association. Propping individuals interface with isolated focuses on the bar or brace. This is so that the "connect" between the propping individuals assimilates vitality from seismic movement through plastic twisting. Unconventional single diagonals can likewise be utilizing to prop a casing.

1.3.3 Based on the props arrangement

Single Bracing: Trussing, or triangulation, shaped by embedding corner-to-corner basic individuals into rectangular zones of an auxiliary edge, settling the casing. In the event that a solitary support utilized, it must be adequately impervious to pressure and pressure.

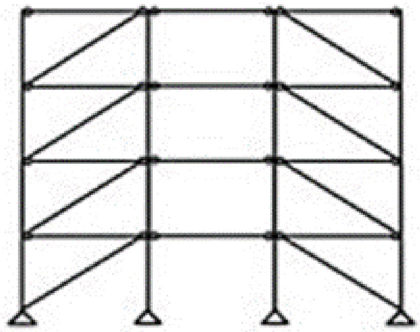

Fig-4: Single Bracing

V Bracing: Supporting where a couple of props joins at a solitary point on the bar traverse. Reversed V props that type of chevron propping that*terminates at point on pillar from beneath. This includes two slanting individuals stretching out from the main two corners of an even part and meeting at a middle point at the lower flat part, in the state of a V. Rearranged V-supporting includes the two individuals meeting at a middle point on the upper flat part. Both imply that the clasping limit of the pressure support is probably going to be altogether not as much as the strain yield limit of the strain prop. This can imply that when the props achieve their resistance limit, the heap should rather have opposed in the bowing of the level part.

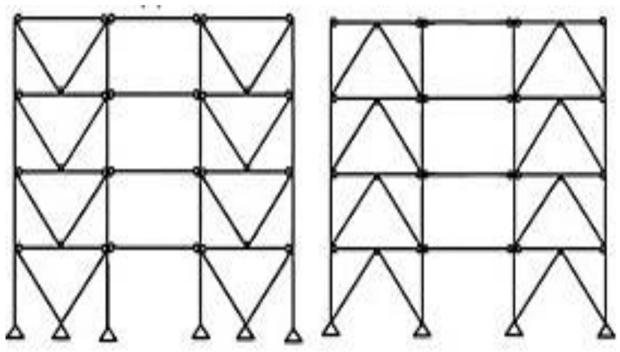

Fig-5: V Bracing

X Support: Supporting where two inclining props crosses close mid-length of the propping individuals. Cross supporting (or X-propping) utilizes two askew individuals crossing each other. These exclusive should be impervious to strain, one prop acting to oppose sideways strengths at once relying upon the heading of stacking. Accordingly, steel links can likewise have utilized for cross supporting. In any case, this gives the slightest accessible space inside the façade for openings and results in the best bowing in floor shafts.

Fig-6: X Bracing

K Support: Supporting where a couple of props associated on one side of a section joins at a solitary point on another leg of segment. Props interface with the segments at mid- tallness. This edge has greater adaptability for the arrangement of openings and results at all twisting in floor pillars. K supporting is largely disheartened in seismic locales due to the potential for section disappointment if the pressure prop clasps.

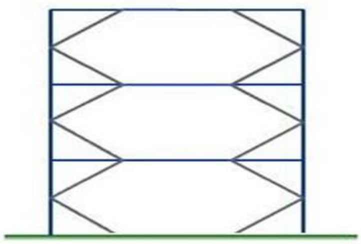

Fig-7: K Bracing

1.4 Outrigger i.e. Partially Braced Frame

A propped outline with outrigger is appeared in Figure the structure contains a casing with focal straight supported clubbed with an arrangement of two equivalent length outriggers. Such outriggers indicate even more solidifying impact for general structure. The instigated pressure and strain drives in the sections make a huge opposing minute to connected level stacking. The edge with blend i.e. external straight supported all through the structures with 600 mm pillar profundity structure was utilized. For different cases, economy classified beneath. The example of supporting with normal straights and level variety, which gives an ideal outcome, appeared.

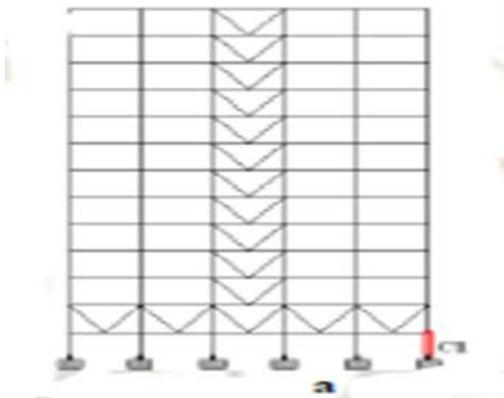

Fig-8: Partially braced frame

1.5 Concept of Outrigger Frames

At first, the possibility of outrigger used in the cruising ship with a particular true objective to extend the unfaltering quality and the nature of the shafts subjected to wind qualities. Beginning here of view, a tall building could be seen as for all intents and purposes equal to the post of a ship in proximity of further parts near in direct to the spreaders and remains. Thusly, the planners fathomed that it was possible to couple within focus of the working with the outside sections. The fundamental thought that impacts the framework of tall structures is its affectability to the sidelong load. One of the basic criteria for the arrangement of tall structures is sidelong buoy at top. The satisfactory buoy bind (best redirection in tall working) for wind stack examination (according to the IS code) is 1/500 of the building height. The usage of focus divider structure has been a particularly practical and capable helper system used as a piece of decreasing the buoy in view of parallel load. In any case, as and when the stature of the building extends, the middle does not have the adequate immovability to hold the buoy down beyond what many would consider possible. For such lifted structure structures, helper system known as outriggers may be displayed.

2. LITERATURE REVIEW

E.M. Hines and C.C. Jacob [2009] displayed a paper on Eccentric propped outline framework execution. The seismic execution of low-malleability steel frameworks intended for direct seismic districts have produced new enthusiasm for the financially savvy plan of flexible frameworks for such areas. Albeit unusually propped outlines (EBFs) have an entrenched notoriety as high-flexibility framework and can possibly offer savvy arrangements in direct seismic districts, their framework execution has not been broadly talked about. Whimsically Braced Frames (EBFs) known for their alluring mix of high versatile solidness and predominant inelastic execution attributes (AISC 2005). The University of California, Berkeley (UCB) under the course of Professors Popov and Bertero led a trial of two separate 0.3-scale shake table trial of Concentrically Braced Frame (CBF) and EBF double frameworks (Uang and Bertero 1986, Whittaker et al. 1987, Whittaker et al. 1990). The plan of shear connections for the tower of the San Francisco-Oakland Bay Bridge East Bay self-secured suspension traverse (McDaniel et al. 2003).

S.H. Chao and M.R. Bayat et.al [2008] considered on execution based plastic plan of steel concentric propped outlines for upgraded certainty level in China. Concentrically supported edges (CBFs) for the most part thought to be less malleable seismic safe structures than different frameworks because of the prop clasping or break when subjected to huge cyclic relocations. This is credited to less complex outline and high effectiveness of CBFs contrasted with different frameworks, for example, minute casings, particularly after the 1994 Northridge Earthquake. Be that as it may, late explanatory reviews have demonstrated that CBFs planned by ordinary versatile outline technique endured extreme harm or even fall. The three-and six-story Chevron sort CBFs initially planned (Sabelli, 2000) as SCBF as per 1997 NEHRP outline spectra (FEMA, 1997) and 1997 AISC Seismic Provisions (AISC, 1997) utilized as a part of this review.

R. Leon & R. DesRoches [2006] has done an exploration take a shot at Behavior of Braced Steel Frames with Innovative Bracing Schemes. Ordinary propping frameworks incorporate commonplace askew and chevron supporting arrangements, and in addition imaginative ideas, for example, strut-to-ground and zipper propped outlines (Khatib et al. 1988, Bruneau et al. 1998). Seismic controls and rules for the seismic outline of CBFs can be found in the Structural Engineers Association of California (SEAOC) Recommended Lateral Force Requirements (SEAOC 1996), the International Building Code (IBC 2000), the NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings (BSSC 2000), and the AISC Seismic Provisions for Structural Steel Buildings (AISC 2002). Inclining and chevron frameworks can give huge horizontal quality and unbending nature yet don't give incredible pliability as clasping of the diagonals prompts quick loss of quality without much drive redistribution (Goel 1992). In chevron support the lopsided vertical strengths that emerge at the associations with the floor bars because of the unequal pivotal limit of the props in strain and pressure.

P. Uriz and S.A. Mahin [2004] displayed a paper on Seismic execution evaluation of concentrically propped steel outlines. The general examination incorporates frameworks that use customary props, clasping controlled supports and props fusing thick damping gadgets. In the initial segment an indistinguishable unwavering quality system from used to evaluate Special Moment Resisting Frame (SMRF) structures amid the FEMA/SAC Steel Project was utilized to survey the certainty with which Special Concentric Braced Frames (SCBF) and Buckling Restrained Braced Frames (BRBF) may accomplish the seismic execution expected of new SMRF development. In the second section, a test program to help enhance displaying of SCBF frameworks is portrayed, including the plan of an about full-measure, two-story SCBF test example. The certainty that a three story SCBF outlined by the 1997 NEHRP arrangements can accomplish the fall aversion execution objective was under 10% for all definitions limit and a seismic risk relating to a 2% likelihood of exceedance in 50 years. A correspondingly planned six-story BRBF exhibited to be a great deal more dependable. The execution based assessment approach for describing and enhancing the execution of steel propped outlines joining customary supporting, clasping controlled supports, rubbing and hysteretic gadgets, and thick dampers.

C.Y. Ho and G.G. Schierele [1990] distributed a diary paper Effect of arrangement and horizontal float on High-ascent space outlines. Over the top parallel float in skyscraper edges can harm auxiliary frameworks, for example, segments dividers; produce optional section worry because of P-δ minutes; and make inconvenience building tenants under delayed repeating float. Harm to auxiliary framework can be controlled by decreasing float. The P-δ impact is most serious in minute opposing edges; the Uniform Building Code permits littler seismic float for minute opposing casings (0.3% story float versus 0.5 % for different frameworks). Outline for wind or seismic strengths are typically in light of goals to limit sidelong float. To lessen sidelong float of tall structures is an imperative outline thought in regions of high wind or potentially seismic movement. The examination introduced here demonstrates that choosing the most suitable supporting framework can considerably lessen float with just minor cost contrasts. An affectability investigation, multiplying cross-segment ranges of top and belt truss supports, uncovered just minor float decreases. The diminishments run from at least 1 % for the 20 story K- propped outline with top truss, to a most extreme of 7.6% for a similar edge-consolidating top and belt trusses. Seismic strengths tend to increment with the firmness of a building. For instance, in the proportional static equation for seismic base shear V=ZICW/R, the R element is 12 for Special Moment Resisting Frames yet shifts in the vicinity of 4 and 8 for different supporting plans. More research expected to decide the impact of different surrounding designs on parallel strengths and float in seismic circumstances.

Shan – HauXu& Di – Tao Niu [2003] had chipped away at seven strengthened cement (RC) propped outline, one fortified solid casing and one strengthened solid shear divider are tried under vertical stacking and turned around cyclic stacking. They concentrated fundamentally on the disappointment system, quality, and corruption in solidness, and hysteresis circle of the RC propped outline. As indicated by their review, in supported casings, sidelong resistance and firmness improved, as well as vitality dispersal sum expanded fundamentally.

A.R. Khaloo and M. Mahdi Mohseni [2008] had chipped away at nonlinear seismic conduct of RC Frames with RC Braces. This review concentrates on assessment of quality, firmness, flexibility and vitality retention of strengthened cement supported casings and examination with comparative minute opposing edges and edges with shear divider.

J. P. Desai, A. K. Jain and A. S. Arya [1987] had chipped away at two-sound, six- story outline planned by breaking point state strategy subjected to simulated seismic tremor and bilinear hysteresis model was accepted for supports, elasto-plastic model was expected for sections and straightforward triangular hysteresis model was expected for fortified solid propping. It is inferred that the inelastic seismic reaction of X and K supported solid casings with transitional propping individuals is agreeable.

Tremblay et al. [2003] Tremblay et al. plays out an exploratory review on the seismic execution of concentrically propped steel outlines with frosty framed rectangular tubular supporting framework. Examination performed on X supporting and single inclining propping framework. One of the stacking grouping utilized is a relocation history acquired from non-straight unique examination of run of the mill supported steel outlines. Results were gotten for various cyclic stacking and were utilized to portray the hysteretic reaction, including vitality scattering capacities of the edge. The pliable conduct of the props under various tremor ground stacking examined and utilized for configuration applying the codal methodology. Rearranged models were gotten to anticipate plastic pivot disappointment and neighborhood clasping disappointment of supporting as a flexibility disappointment mode. At last, inelastic disfigurement abilities gotten before disappointment of minute opposing edge and supporting individuals.

3. REVIEW ANALYSIS

Objectives: Tall building advancements have been quickly expanding around the world. The development of multistory working over the most recent quite a few years is viewed as the piece of need for vertical extension for business and also living arrangement in real urban areas. It is watched that there is a need to concentrate the basic frameworks for confined structure, which opposes the parallel loads because of seismic impact. Security and least harm level of a structure could be the prime necessity of tall structures. To meet these prerequisites, the structure ought to have satisfactory horizontal quality, sidelong solidness and adequate malleability. Among the different basic frameworks, shear divider outline or propped solid casing could be a state of decision for originator. Hence, it draws in to survey and watch the conduct of these auxiliary frameworks under seismic impact. Subsequently, it is proposed to concentrate the dynamic conduct of fortified solid casing with and without shear divider and steel supported casing. The reason for this review is to think about the seismic reaction of above auxiliary frameworks. Pivotal powers and minutes in individuals and floor relocations will be analyzed. The best and viable technique for upgrading the seismic resistance is to build the vitality assimilation limit of structures by consolidating propping components in the casing. The supported casing can assimilate a more prominent level of vitality applied by seismic tremors. To examine a multi-storied RC encircled building considering diverse seismic tremor powers II, III, IV and V by reaction spectra technique and locate the base shear an incentive for various structures. Seismic examination of RC edge with exposed and distinctive position of shear divider and supported casing is done utilizing linear static investigation technique according to IS 1893 (Part I): 2002 by utilizing ETABS programming. For this examination diverse sorts of models are considered and correlation of seismic execution is done.

1. To comprehend the conduct of the tall steel structures under various seismic zones.
2. To review the impact of supported steel outline under the activity of sidelong loads.
3. To review the impact of fractional supported with outrigger and completely propped steel outlines along the external fringe of the steel structures
4. Analysis is completed utilizing proportionate static technique utilizing IS 1893- 2002 and dynamic time history examination utilizing ETABS.
5. Efficiency of halfway supported with outrigger and completely propped steel structures as for the base shear, dislodging, float and speeding up are discovered for every single geometric arrangement

4. MODELLING

4.1 Summary

In this section, the common step by step procedure for modeling the basic regular structure is explained. The related modeling procedure is used to model the different other types, to study the seismic performance of different structural configuration of steel structure.

a. Base model
b. Steel Moment resistance frame – Type 1
c. Steel frame with partially braced – Type 2
d. Steel frame with partially braced with outrigger – Type 3
e. Steel fully braced frame- Type 4

4.2 Material Properties

The material considered for analysis RC is M-30 grade concrete and Fe-500 grade reinforcing steel:

Young's Modulus - steel, Es = 2, 10,000 MPa
Young's Modulus - concrete, EC =27,386 MPa
Characteristic strength of concrete, fck = 30 MPa
Yield stress for steel, fy = 500 MPa
Ultimate strain in bending, Ɛcu =0.0035

4.3 Model Geometry

The Building is a 50-storied, 7 bays along X-direction and 7 bays along Y- direction, Steel frame with properties as specified below. The floors are modeled as rigid deck section. The details of the model are given as follows:

Number of stories = 50.
Number of bays along X Dir. = 7- Bays, Y-Dir. = 7- Bays
Storey height = 3.0 mts. at Ground Floor & Remaining Floors.
Bay width along X Dir.= 5 mts, Y Dir. = 5 mts.

4.4 Plan View Of Building

The plan - view of building plan is indicative in the Fig:9. The bay width, columns and beams positions are shown below:

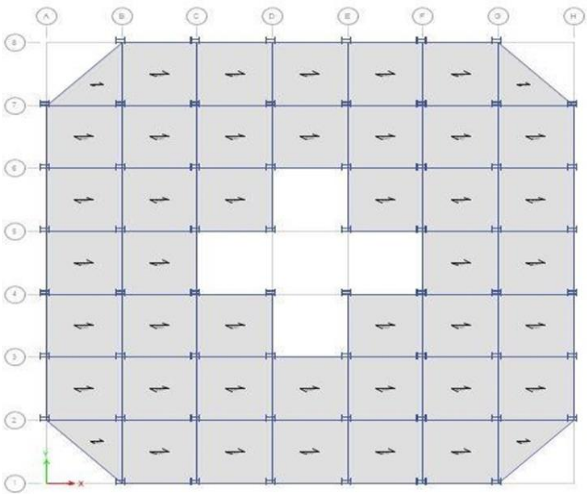

Fig-9: Plan view of Building

4.5 Elevation of Building

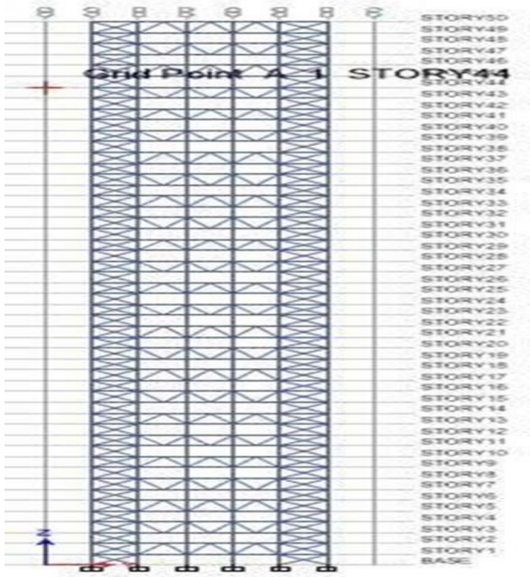

Fig-10: Elevation of Building

4.6 BASE MODEL

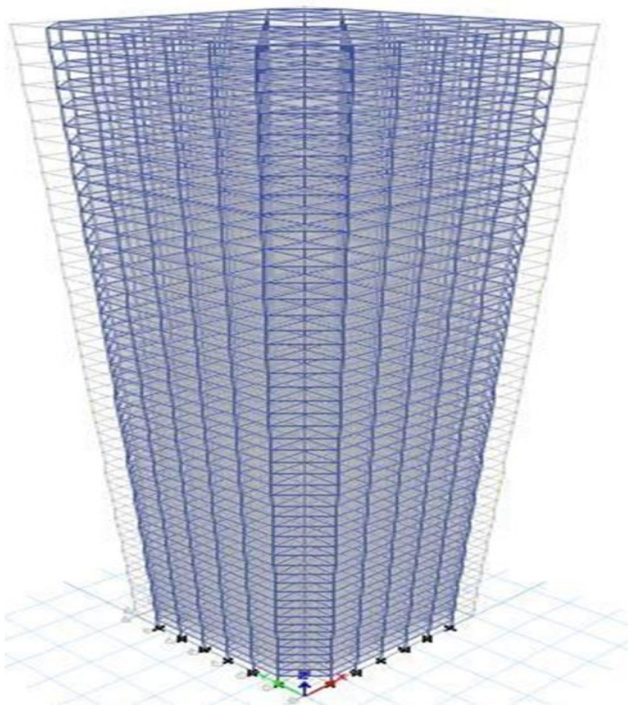

Fig-11: 3D view of model 1

4.7 STEEL MOMENT RESISTANT FRAME (Type 1)

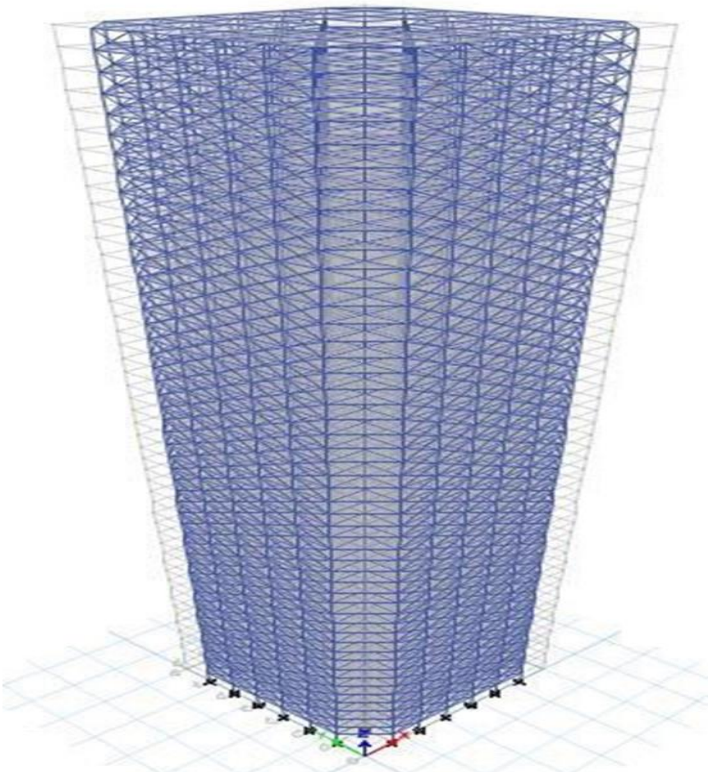

Fig-12: 3D view of model 2

4.8 STEEL FRAME WITH PARTIALLY BRACED

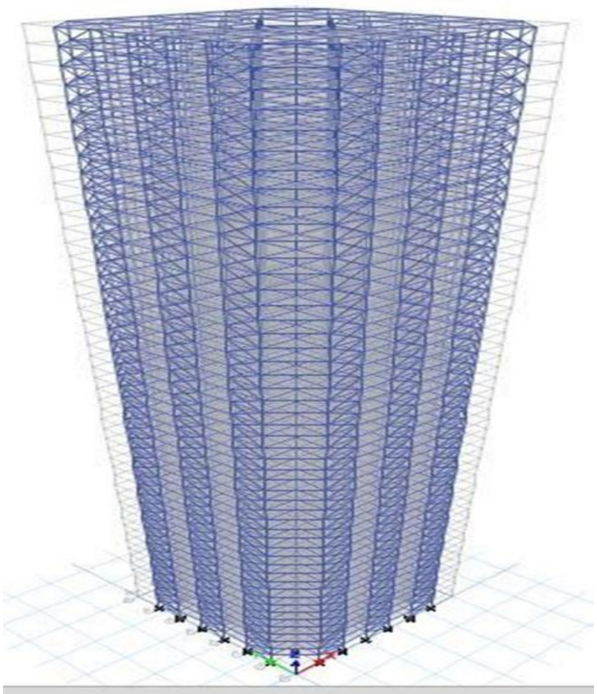

Fig-13: 3D view of model 3

4.9 STEEL FRAME WITH PARTIALLY BRACED WITH OUTRIGGER

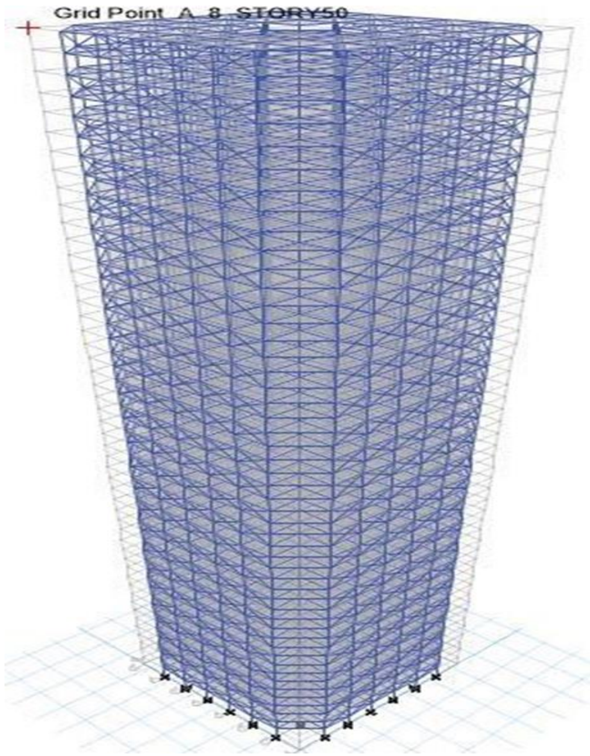

Fig-14: 3D view of model 4

4.10 STEEL FULLY BRACED FRAME

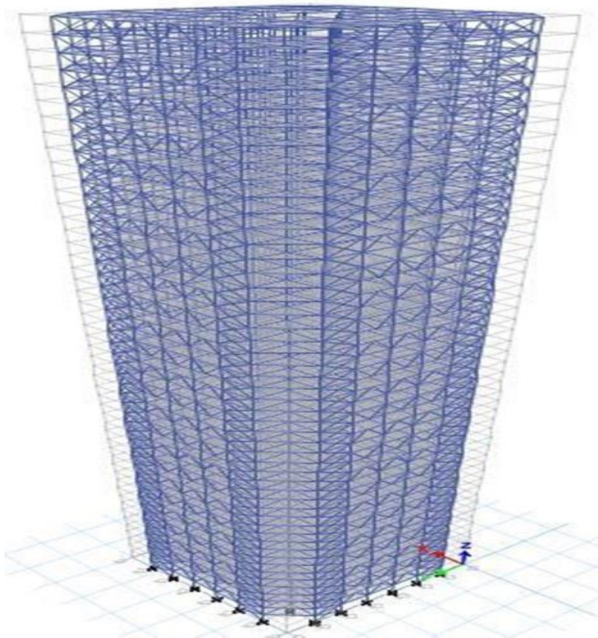

Fig-15: 3D view of model 5

5. RESULTS AND DISCUSSION

From the modal analysis variation of time period and frequency has been studied and results are presented in the below table and graphs. From the below results it is clear that for high rise steel moment resisting frame without bracings, time period is found to very high of about 11.41 sec. With the incorporation of bracings into the steel frame, time period came down to 5.78 sec which is about 49% decrease in case of steel frame with full bracings on outer periphery of the structure.

5.1 TIME PERIOD

Table-1: Mode vs Time Period

	Time Period (Seconds)				
Mode No.	Model 1	Model 2	Model 3	Model 4	Model 5
1	11.41	5.78	8.91	6.81	6.21
2	10.98	5.73	8.77	6.51	6.05
3	9.83	3.36	6.25	4.17	3.84
4	3.75	1.57	2.59	2.09	1.85
5	3.56	1.53	2.54	1.95	1.79
6	3.24	0.96	1.78	1.32	1.17
7	2.17	0.77	1.29	1.12	0.96
8	2.02	0.75	1.26	1.02	0.93
9	1.90	0.51	0.86	0.77	0.64
10	1.52	0.49	0.80	0.72	0.62
11	1.38	0.48	0.78	0.70	0.61
12	1.32	0.43	0.56	0.59	0.48

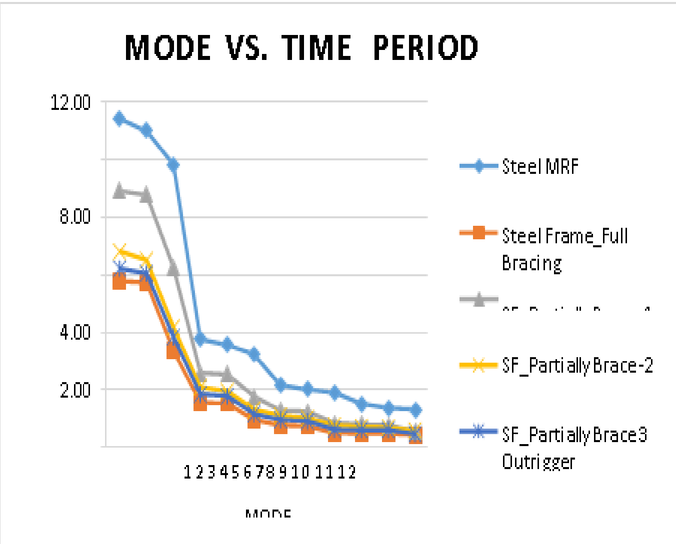

Chart 1: Mode vs Time Period

Time period is more in partially braced steel moment resisting frame compared to full braced frame. From the Table 2. below, maximum frequency is observed in steel frame will full bracing system which is about 0.17 Hz. Frequency of partially braced frame is found to be less than that of fully braced frame which is about 35.26% for partially brace 1 and 15% for partially brace 2 and only 7% for partially brace 3 with outrigger.

5.2 FREQUENCY

Table-2: Mode vs Frequency

	Frequency (Cycles/sec)				
Mode No.	Steel MRF	Steel Frame_Full Bracing	SF_Partially Brace -1	SF_Partially Brace -2	SF_Partially Brace 3 Outrigger
1	0.088	0.173	0.112	0.147	0.161
2	0.091	0.175	0.114	0.154	0.165
3	0.102	0.297	0.160	0.240	0.261
4	0.267	0.638	0.386	0.478	0.540
5	0.281	0.653	0.393	0.513	0.558
6	0.308	1.042	0.561	0.760	0.858
7	0.461	1.296	0.776	0.895	1.038
8	0.496	1.336	0.794	0.978	1.078
9	0.525	1.976	1.160	1.296	1.567
10	0.658	2.041	1.251	1.388	1.623
11	0.726	2.071	1.287	1.435	1.645
12	0.756	2.303	1.784	1.700	2.103

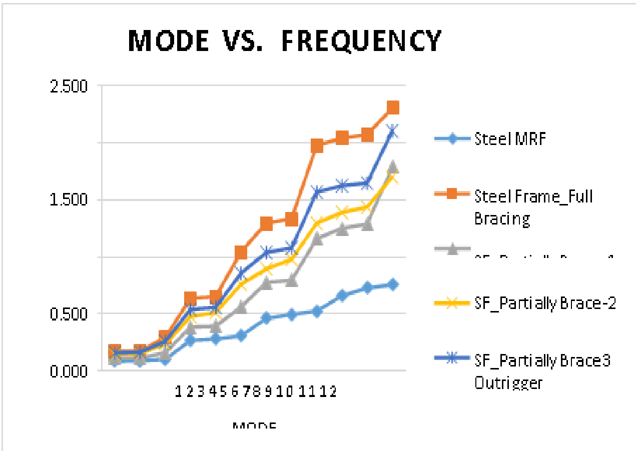

Chart 2: Mode vs Frequency

5.3 STORY SHEAR

Table-3: Base shear

Base Shear (kN)				
Steel MRF	Steel Frame_Full Bracing	SF_Partially Brace -1	SF_Partially Brace -2	SF_Partially Brace 3 Outrigger
3109	3158	3138	3134	3146

From the above table it is clear that, steel moment resisting frame with bracings and without bracings also, the partial bracings will do not have significant effect on variation of base shear. Only about 1.5% increase in base shear is found due to the incorporation of racings in to steel moment resisting frame and comparatively maximum base shear is found to be frame with full bracings

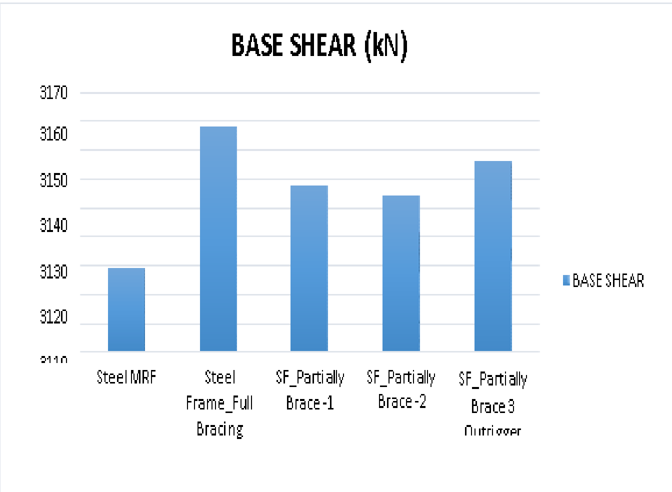

Chart 3: Base Shear

5.4 STORY DISPLACEMENT

From the results presented below, it is evident that, for steel moment resisting frame without bracing systems, displacements are reaching and goes beyond the limiting value (H/500). Due to the presence of bracings on the periphery of the structure, displacements are significantly reduced as shown in the below table.

Displacement in steel frame with full bracings along the entire width and height of the building is found to be 190 mm which is about 67% less than that of Steel MRF. Further with the study of partial bracings systems, the displacements are increased in partially bracing 1 and reduced further in partial bracing 2 and it is found that, SF with partially brace 3 with outrigger is almost have same resistance as that of fully braced frame which is found to be 201 mm, which is about 65%.

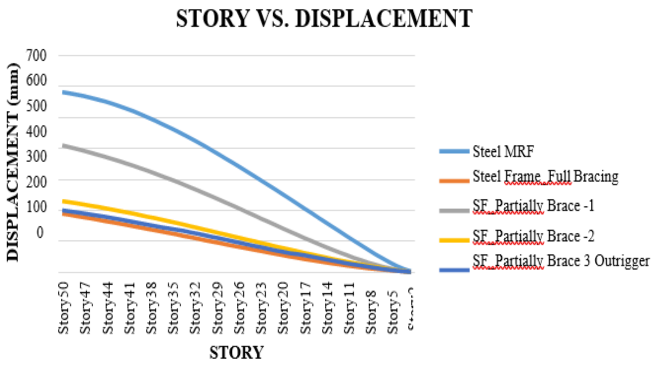

Chart 4: Story vs Displacement

5.5 STORY DRIFT

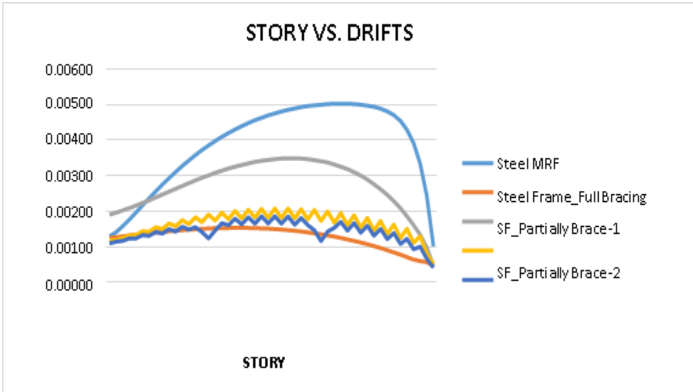

Chart 5: Story vs Drifts

From the above Figure, It is evident that, partial bracing systems will have better control over story drifts and with the presence of outrigger system story drifts are less than that of fully braced system.

5.6 STORY STIFFNESS

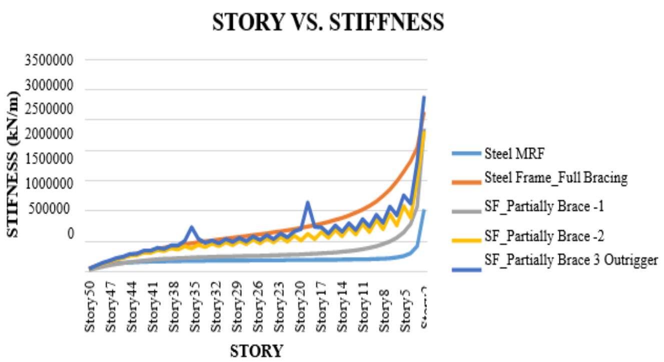

Chart 6: Story vs Stiffness

From the above Fig, the variation of stiffness is observed, and it is found that, maximum stiffness is found to be in partially braced frame with presence of outrigger.

5.7 COLUMN FORCE

Table-4: Column Forces

Column Force (kN)				
Model 1	Model 2	Model 3	Model 4	Model 5
Steel MRF	Steel Frame_Full Bracing	SF_Partially Brace -1	SF_Partially Brace -2	SF_Partially Brace 3 Outrigger
1404	2844	2874	2663	2836

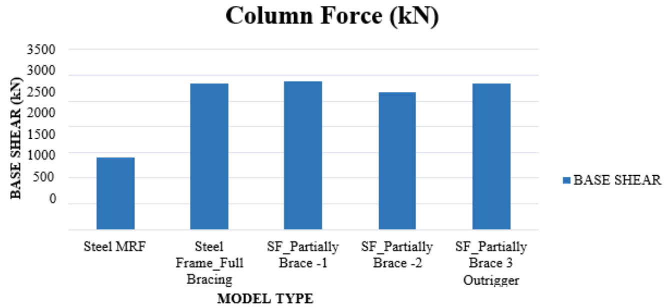

Chart 7: Column Forces

From the results above, the column axial forces are observed to be high in case of braced frame in comparison with the frame without bracings systems. And it found to be 102% higher than that of steel moment resisting frame. And within the bracing systems, partially bracing – 1 system is found to be carry maximum axial force of 2874 kN.

5.8 Story vs. Displacements – Time History

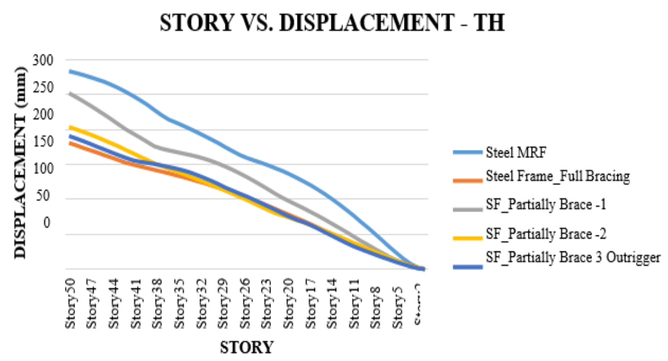

Chart 8: Story Displacement – Time History

5.8.1 Typical Time history response

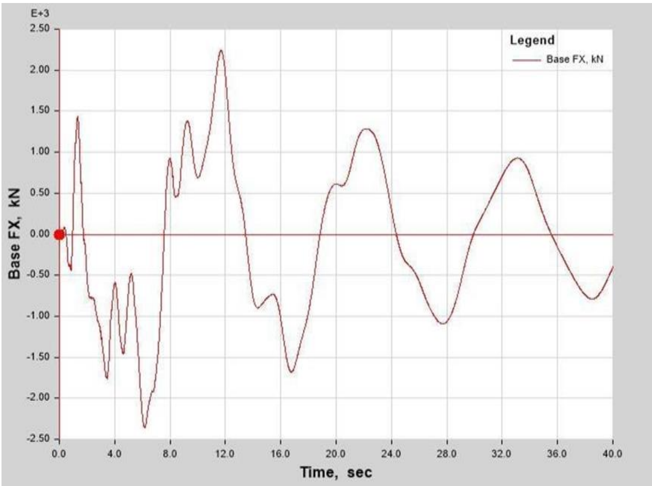

Chart 9: Base Force

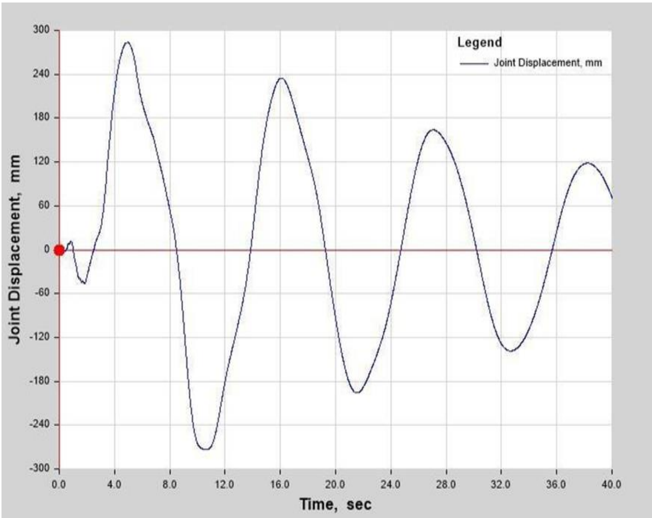

Chart 10: PeakDisplacement

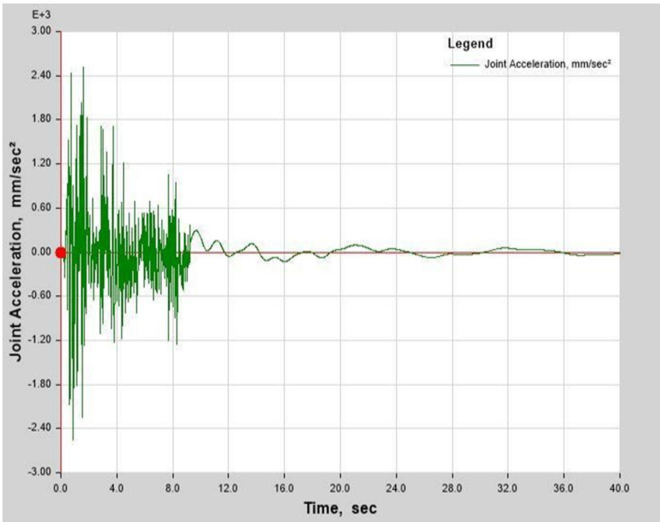

Chart 11: Peak Acceleration

Table 5: Time History Summary

Models	Base Force (kN)	Peak Displacement (mm)	Peak Acceleration (m/s^2)
Steel MRF	2358	283.59	2.56
Steel Frame Full Bracing	6926	180.84	2.69
SF_Partially Brace - 1	3674	252.02	2.61
SF_Partially Brace - 2	4001	203.67	2.68
SF_Partially Brace 3 Outrigger	4472	190.85	2.97

From the above summary of table, time history results are summarized for maximum base shear, peak displacement and acceleration. Maximum base shear is found to be in fully braced steel frame that is about 65% more than steel MRF. And minimum peak displacements are found to be in fully steel brace and partially brace frame with outrigger, that is 36% lesser than steel mrf also is having almost same peak displacement as that of fully braced frame and maximum acceleration is found to be in partially brace frame with outrigger that is 13.8% larger than steel mrf.

6. CONCLUSIONS

From the analysis of steel moment resisting frame in comparison with the fully bracings and partial bracing systems following conclusions are made from modal, equivalent static and dynamic time history analysis.

- From the modal analysis it can be concluded that, time period and frequency can be controlled using bracing systems.
- Frequency of partially braced frame is found to be less than that of fully braced frame which is about 35.26% for partially brace 1 and 15% for partially brace 2 and only 7% for partially brace 3 with outrigger.
- Displacements and story drifts can be greatly controlled by using the fully braced and partially braced systems.
- In this study of partially braced system it can be concluded that, instead of providing the bracings fully on the outer peripheral of the building, partial bracings can be provided with addition of outrigger, which will increase the stiffness of the steel structure there by limiting the story drifts and displacements.
- Also by providing the bracings, columns will carry more axial loads due to the distribution of lateral forces from bracings to main columns of the structure.
- From the dynamic time history analysis, it can be concluded that, partial bracings with outrigger system performs better as that of fully bracing systems.
- Hence partial bracing system with outriggers is preferred over fully bracings system from the present study.

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