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THE BEHAVIOR OF OUTRIGGER STRUCTURAL SYSTEM IN HIGH-RISE BUILDING: REVIEWS

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***Abstract*—The development of Tall building has been rapidly increasing worldwide introducing new challenges that need to be met through structural design by proper engineering judgments. In modern tall buildings, lateral loads induced by wind or earthquake are often resisted by a system of coupled shear walls. But when the building increases in height say 90 m, the stiffness of the structure becomes more important as height of the building increases, the stiffness of the building reduces then the lateral load resisting system is used to provide sufficient lateral stiffness by providing outrigger beams between the core and external columns is often used to provide sufficient lateral stiffness to the structure. The outrigger with Belt truss is used as one of the structural system to effectively control the excessive drift due to lateral load. Thus, it will improve the performance by preventing the structural and non-structural damage of the building under seismic loading and wind loading. The objective of this paper is to study the outrigger structural system in high rise RC building under the action of laterals loads such as seismic loads and wind load. In this paper, study of literature is reviewed on various aspect of outrigger structural system as : Behaviour of different lateral load resisting structural system, Behaviour of outrigger structural system in High-Rise RC building, Behaviour of Outrigger structural system in High-Rise Steel and composite Building, Behaviour of outrigger structural system with vertical irregularities and mass irregularities in the structures. After summarized the reviews, gaps are also encountered in this study are listed in this paper.**

***Index Terms-* Belt Truss, High-Rise RC Building, Lateral Loads, Outrigger System.**

1.GENERAL

Tall Building as a skyper has always been a vision of dreams and technical advancement with new types of equipment leading to the progress of construction in the world. Nowadays, Tall building has become a more convenient option for residential and commercial housing due to rapid growth in urbanization. Tall buildings are designed for Residential and office use. These are the primary reaction to the rapid growth of urban population and demand by business activity. A large portion of our country is susceptible to damaging levels of seismic hazards due to earthquake Hence, it is necessary to consider the seismic load for the design of high-rise structure. The different lateral load resisting systems are used in high-rise building . These lateral forces can produce critical stresses in the structural and non structural member in building, inducing undesirable stresses in the structure, and undesirable vibrations or cause excessive lateral sway of the structure.

2. STRUCTURAL SYSTEM

In the past years, structural members of the building were assumed to carry primarily the gravity loads. Today, however, by the advancement in structural systems and high strength materials, building weight has reduced, in turn increasing the slenderness, which necessitates taking into account majorly the lateral loads such as wind and earthquake. Specifically for the tall buildings, as the slenderness, stiffness and flexibility are important parameters as buildings are severely affected from the lateral loads resulting from wind load and earthquake load.
Hence, it becomes more important to identify the proper structural system for resisting the lateral loads depending upon the height of the building. There are many types of structural systems that can be used for the lateral resistance of tall buildings shown in (fig.01).
Types of Structural systems.
Type 1 : Shear frames
Type 2 : Interacting frames Systems
Type 3 :Partially Tubular Systems
Type 4 : Tubular systems

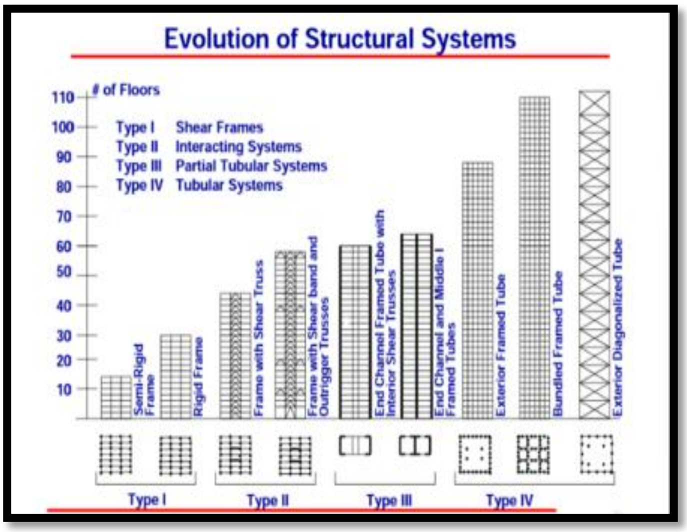

Fig. 01 Types of structural systems

3.INTRODUCTION OF OUTRIGGER

The structural design of high rise structures with the provision of limiting the drift due to seismic load and wind load to acceptable limits without paying extra cost on steel. The saving of steel and cost reduction can be done by adopting certain techniques in this regard; one such is an Outrigger System, The outrigger beam and belt truss system is one of the lateral loads resisting system in which the central core is tied to the external columns with very stiff outriggers beam and belt truss at one or more levels. The belt truss tied the peripheral column of the building while the outriggers engage them with main core or central shear wall. The core may be centrally located with outriggers extending on both sides (Fig. 02) or it may be located on one side of the building with outriggers extending to the building columns on one side (Fig . 03). The outrigger and belt truss system is commonly used as one of the structural systems to effectively control the excessive drift due to lateral load and the risk of structural and non-structural damage can be minimized.

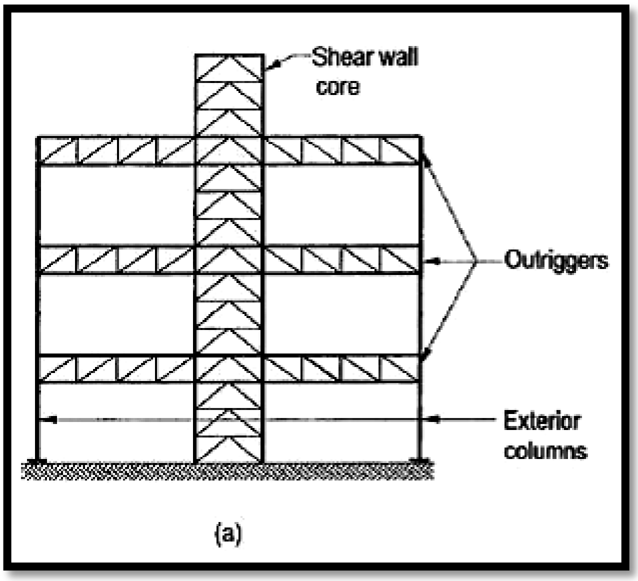

Fig. 02 Outrigger With Central Core

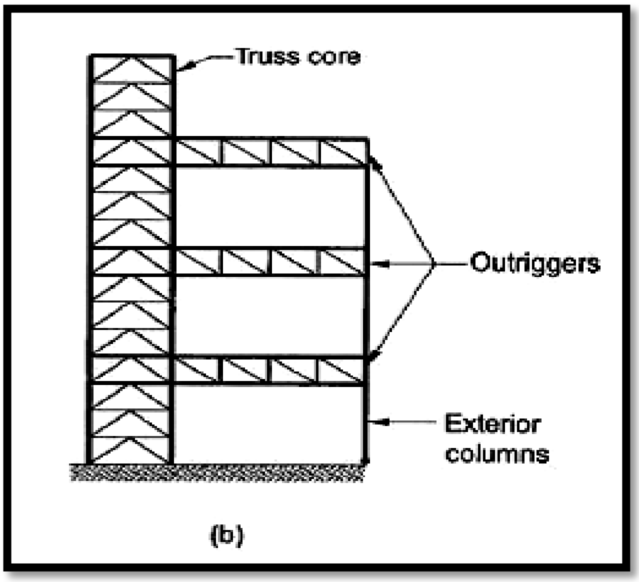

Fig. 03 Outrigger With Offset Core

3.1 Behaviour Of Outrigger System

The arrangement of members for this structural system consists of the main concrete core or braced core connected to exterior columns by relatively stiff horizontal concrete or braced members commonly referred to as outriggers having a depth of one or two-story-deep walls. The basic structural response of the system is quite simple. As outrigger act as a stiff horizontal members connected to outer columns, when central core tries to tilt its rotation at outrigger level induced a tension in windward side column and compression in leeward side columns and acting in opposite to that moment.(Fig. 04) The result is the Type of restoring moment acting on the core of the building at the level of outrigger. As a result, the effective depth of the structure for resisting bending moment is increased when the core bend as a vertical cantilever by the development of tension in the windward columns and by compression in the leeward columns. In addition to those columns located at the ends of the outriggers, it is usual to also mobilize other peripheral columns to assist in restraining the rotation of outriggers. This is achieved by including a deep spandrel girder, or a "belt truss," around the structure at the levels of the outriggers. Typically the outriggers and belt truss are at least one, and often three-to-four-stories deep.

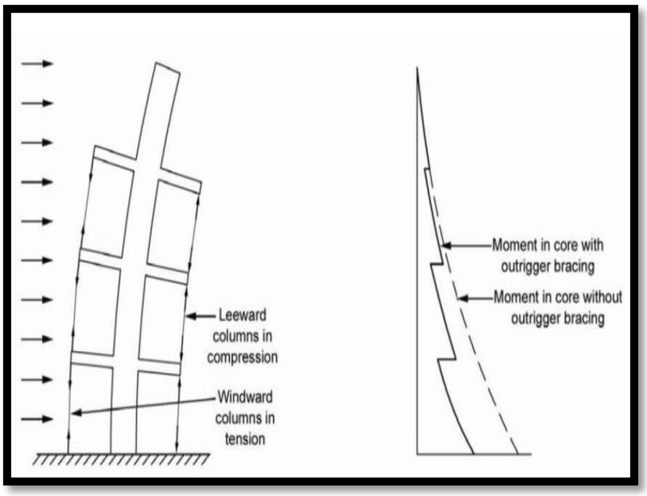

Fig. 04Behaviour Of Outrigger structural System

3.2 Types Of Outrigger Structural System

On the basis of connectivity to the core there are two types of outrigger system:

A) Conventional outrigger system.

B) Virtual outrigger system.

CONVENTIONAL OUTRIGGER SYSTEM

In the type of Conventional outrigger system, the outrigger beam or outrigger trusses are joined directly to the braced frame or shear walls at the core and to outrigger columns located outboard of the core. Mostly but it is not necessary, the columns are at the outer edges of the building. The outrigger trusses, which are connected to the columns, outboard of the core and to the core, prevent rotation of the core and convert part of the moment in the core into a vertical couple at the columns (Fig.05). The number of outriggers above the height of the building can vary from one-three or more. Deformation of the trusses and shortening and elongation of the columns will allow some rotation of the core at the outrigger. In most designs, the rotation is small enough that the core undergoes reverse curvature below the outrigger.

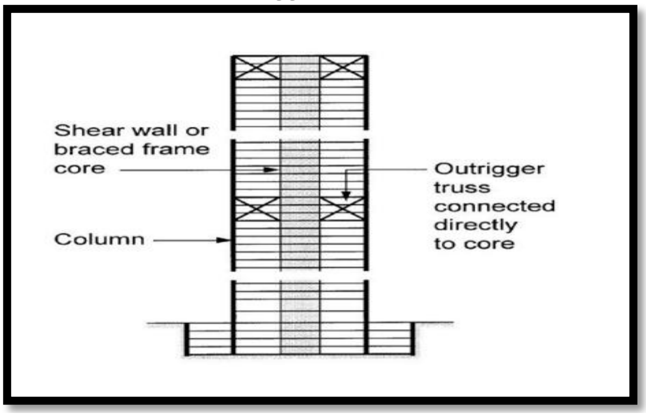

Fig. 05Conventional Outrigger System

VIRTUAL OUTRIGGER SYSTEM

In the virtual outrigger system, outrigger trusses are not connected directly to the core and to outboard columns but the same transfer of overturning moment from the core to element outboard of the core is obtained. The removal of direct connections avoids many of the problems associated with the use of outriggers. The fundamental idea behind the virtual outrigger system is to use rigid floor diaphragms, which are very stiff and stronger in their own plane, to transfer moment in the form of a horizontal couple moment from the core to trusses and trusses to exterior column. Basement walls and belt trusses are appropriate to use as virtual outriggers (Fig.06) The way in which overturning moment in the core is converted into a vertical couple at the exterior columns in case of conventional outrigger, rotation of the core is resisted by the floor diaphragms at the top and bottom of the belt trusses; thus, part of the moment in the core is converted into a horizontal couple in the floors. The horizontal couple, transferred through the two floors to the truss chords, is converted by the truss into vertical forces at the exterior columns.

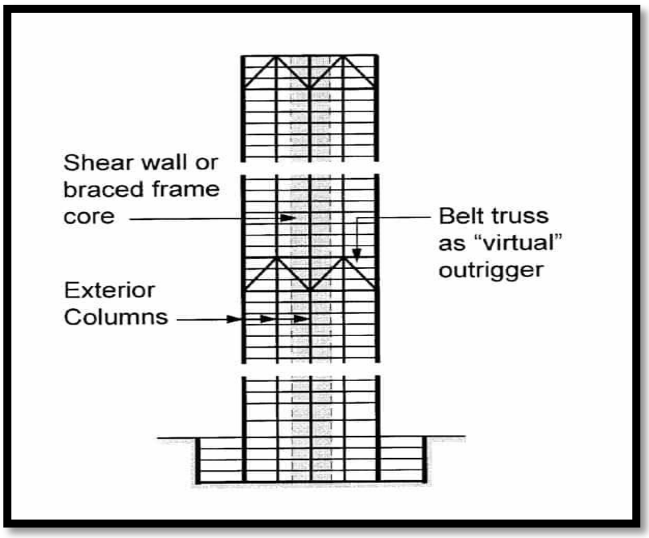

Fig. 06Virtual Outrigger System

3.3 Factors Affecting The Effectiveness Of Outrigger System From the studies, it has become evident that the behaviour of Outrigger structural system is dependent upon many factors. Some of the major factors of influence are:

1. The stiffness and location of the outrigger truss system.
2. The stiffness and location of the Belt truss system.
3. Geometry of the tall building.
4. Stiffness of the central core.
5. Floor-to-floor height of the tall building.

3.4Benefits Associated With Outrigger Systems:

1. The outrigger systems may be constructed in any combination of steel, concrete, or composite construction.
2. Core overturning moments and their associated induced deformation can be reduced through the "reverse" moment applied to the core at each outrigger intersection.
3. Significant reduction and possibly the complete elimination of uplift and net tension forces throughout the column and the foundation systems.
4. The exterior column spacing is not driven by structural considerations and can easily mesh with aesthetic and functional considerations.
5. Exterior framing can consist of "simple" beam and column framing without the need for rigid-frame-type connections, resulting in economies.

3.5Problems Associated With Outrigger Systems:

1. At the floor where the outrigger is located that place cannot be used especially the outrigger in diagonal in shape.
2. Architectural and functional limitation may prevent placement of large outrigger columns where they could most conveniently be engaged by outrigger beam extending out from the core.
3. The connections of the outrigger trusses to the core can be very complicated, especially when a concrete shear- wall core is used.
4. The core and the outrigger columns will not shorten equally under gravity load. The outrigger trusses, which need to be very stiff to be effective as outriggers, can be severely stressed as they try to restrain the differential shortening between the core and the outrigger columns.

4. LITERATURE REVIEW

4.1 Review Of Literature On Study Of different Lateral Load Resisting Structural System

M.R.Suresh And Shruti Badami (2014) has been carried out to investigate the most familiar structural systems that are used for reinforced concrete tall buildings under the movement of gravity and wind loads. These systems include "Rigid Frame", "Shear Wall/Central Core", "Wall-Frame Interaction", and "Outrigger". This relative analysis has been aimed to select the optimal structural system for a certain building height. The structural efficiency is measured by the time period, storey displacement, storey drift, lateral displacement, base shear values and core moments. For their research work they considered seismic zone III, medium soil type, basic wind speed 50m/sec, terrain category is III, structure class is B, risk Co-efficient is one, topography is one and the different stories (G+15; G+30; G+45; G+60) having regular shaped symmetrical plan of 49 X 49 m. The researchers have drawn the conclusion that limiting the wind drift in tall building into something more rigid and stable to confine the deformation and increase stability. Shear wall/central core system is more economical than rigid frame system and increases the flexural stiffness with respect to the rigid frame and outrigger system. Outrigger structural system is proficient in controlling top displacement and also reducing inter-storey drifts. Flexural stiffness is increased by Outrigger structure but it does not increase its resistance to shear which has to be carried by core.

Amol V. Gorle, Shubham P. Dhoke and Bhavini V. Ukey (2017) have carried out information about various lateral load resisting system while designing any multistory building. Researchers have considered three types of lateral resisting system, Beam Column system, Frame Tube System and Diagrid System under the action of earthquake loading by using Response Spectrum Method on the basis of the various parameter such as storey force, storey drift, storey displacement and modal time period. A modal of 40 stories located in Nagpur city having plan area 36 X 36 m2 with each storey height 3m.After the investigation of these research paper have found that modal time period depends on the stiffness of structural member that show modal time period is minimum in diagrid system. The stability of considered models increases with the increase in column stiffness, thus diagrid system having stiffness relatively higher than Frame tube system and Beam-Column system. Due to stiffness increase, storey displacement and modal time period are reduced that show damping of the structure is increased. On the basis of results, it concludes the diagrid system give good result than Beam-Column system and Frame tube system in case of modal time period, storey force, storey stiffness and storey displacement.

Thejaswini R. M. and Rashmi A. R. (2015) have carried out analysis and comparison of different lateral load resisting structural systems to observe the performance of the building during earthquake loading and wind loading as well as to select structural system of the tall building to stay in good condition with the effect of gravity, live load and external lateral load. For this research work they have modelled a geometrically irregular 14 storey RCC high rise building length and width of the building is 48.641 X 42.1244 m size of each block is taken as 20mX14m with different forms of structural system, such as Rigid frame structure, Core wall structure, and Shear wall structure with different configurations of shear wall location, Tube structure and outrigger structure. Results of the analysis show that the values of displacement were less in tube structure and outrigger structural system. The authors have also stated that in geometrically irregular structure the columns sway can be reduced by implementing L-shaped shear wall along the corners of the structure. A major point that must be concluded from this research is that when outrigger structural system is provided at a story which has maximum drift, it can perform as a maximum drift controller.

4.2 Review Of Literature On Behavior Of Outrigger Structural System In High Rise RC Building.

Akash Kala, Madhuri Mangulkar & Indrajeet Jain (2017) have worked on 60storey reinforced concrete building subjected to wind loading to find the optimum outrigger and belt truss location. The value of wind loading was calculated based on IS 875 part III. The building models have 60storey with storey height of 3.5meters. The plan of a structure was L-shaped with column spaced at 6meters from centre to centre. The location of the building at Pune, thus basic wind speed as per code IS 875 part III Vb is equal to 39 m/s. For research work, the location of outrigger beam and belt truss was changed from top floor to the first floor in the building model and wind load analysis was carried out for each model having a different location of outrigger beam and belt truss. After analysis, it concluded lateral behaviour of the structure under wind load critically influenced by the location of the outrigger. The results show when only core is employed that show maximum drift at the top of the structure is around 493mm that reduced to 385mm by placing the outrigger at 20th storey. The optimum location of the outrigger for high rise RCC building under the action of wind load is between 0.25-0.33 times the height of the building.

Po Seng Kiran and Frits Torang Siahaan (2001) have worked for increasing the stiffness and make the structure more stable under both wind and seismic load by initiating outrigger and belt truss system joining core to an exterior column. In this study authors have studied the application of outrigger and belt truss with different arrangements. They have carried out the investigation on a 40 storied 2-dimensional models with eight different arrangements subjected to wind load by introducing outrigger and belt truss systems by fluctuating the location of the outrigger. Similarly 60 storied 3- dimensional models with 5 different configurations subjected to earthquake load by including outrigger and belt truss system by different Locations, height and numbers of diagonal outrigger beam and belt truss. A relative study has been carried out to examine the decrement in lateral displacement. Authors have also focused on to find out the optimum location of the outrigger. From the study, it has found that 65% maximum decrement in displacement is obtained in the 40 storied 2-dimensional models subjected to wind load by providing two outriggers. The first and second outrigger is assigned at the top and the mid-height of the structure. Moreover, about 18% maximum decrement in displacement is obtained in 60 storied 3-dimensional model subjected to earthquake load by providing the optimum location of outrigger truss at the top and 33rd level.

N. Herath et al. (2009)carried out the research based on the understanding that earthquake ground motion can occur anywhere in the world and the risk associated with tall buildings, especially under severe earthquakes, should be given special attention since tall buildings often accommodate thousands of inhabitant. When the height of building increases, the consideration of stiffness is essential in the tall building. In these case, outrigger beam is proposed to be provided in between the shear wall and external columns to improve adequate lateral stiffness to the structure. The main purpose of this research was to optimize the location of Outrigger for safety against Earthquakes and Economy in design. For this aim, researchers have considered 9 previous earthquake records and based on acceleration to velocity ratios (A/V Ratio) namely, Spitak (7 Dec 1988), Park field (28 June 1966), Friuli (6 may 1976), Gazli (17 may 1976), Patras (29 Jan 1974), El Centro (18 May 1940), Mexico City (19 Sep 1985), Tabas (13 Sep 1978), San Fernando (9 Feb 1971). The performance of high rise building has been examined by studying different design of outrigger structural system. A model of 50 stories was examined for three different ratios of peak ground acceleration to peak ground velocity. In each category of an earthquake, records were incorporated in this research study to provide a uniform level of approach. Response spectrum analysis was conducted to determine the behaviour of the building considering parameters such as lateral displacement and inter-storey drift. It was demonstrated from this study that the structure is optimized when the outrigger is placed between 22-24 levels. Therefore it can be concluded that the optimum location of the structure is between 0.44-0.48 times of its height (taken from the bottom of the building).

Alpana L. Gawate and J. P. Bhusari (2015) have the main objective of their research is to enhance the lateral stiffness of tall buildings, because due to the increase in the height of the building the core alone is not ample to keep the drift within permissible limit. Therefore for drift, some other structural element is to be added to that building. Outriggers are the structural system, which helps in decreasing the lateral drift increasing the stiffness of the structure by the enormous amount. In this research, optimum location of the outrigger is found by considering few constraint conditions. The lateral drift and formation of the soft storey are the parameters on which the conclusions are made. A soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above. It is also considered that the change in results due to changes in sizes of cross sections of columns and shear walls. For the analysis of this problem, researchers have chosen a 30 storied three dimensional model with various alignments of outrigger such as a system with single and double outrigger by changing cross-sectional dimensions of columns and thickness of a shear wall. This model was analyzed by response spectrum analysis as per Indian standard codes and draw following conclusions. The system was not effective as concerning of drift due to a provision of only one outrigger. There was an astonishing change observed in the drift profile when two outriggers were provided. One important conclusion deducted from this research is no story was found as a soft story for all 9 trials made in the model with two outriggers with changes in cross-sectional dimensions of columns and thickness of the shear wall.

Kiran Kamath et al. (2012) contended the study of efficient Outrigger Structural System in a high rise reinforced concrete building. Their research examined the behaviour of a reinforced concrete structure with central core wall with various configurations of outrigger system by varying relative flexural rigidity. The fundamental thought behind this study was to increase the stiffness and make the structural form effective under the lateral load acting on the structure due to wind load as well as earthquake loads. In this research optimum location of outrigger system in tall buildings by considering the relative height of outrigger beam i.e. (ratio of a height of outrigger to the total height of the building) is also focused by the authors. In this study, article researchers have considered 40 stories three-dimensional models of 6 different configurations of outrigger of varying Hs/H ratio and varying relative flexural rigidity between 0.25 - 2 for modelling of a structure. An equivalent static analysis was performed for both static and dynamic behaviour purpose. Time history analysis is done by considering the previous earthquake data of peak ground acceleration of California region as per Indian standard codes was carried out. A comparative study for the analysis of various parameters, such as lateral deflection, peak acceleration and inter-story drift has been performed. From the analysis, it is observed that by considering the criteria for reduction in top displacement, the optimum position of the outrigger is at mid-height of the building with a relative flexural rigidity of 0.25 by static and dynamic analysis. It is also concluded by the authors that in time history analysis the response of structure does not show any particular trend with peak acceleration, though for all earthquake histories of California region the top lateral displacement was minimal for outrigger structure with relative height of 0.5.

Manohar B C And Vijaya Kumari Gowda M R (2015) have worked on lateral load resisting structural system by initiating belt truss at the top and mid-height of the building. Belt truss came out to be cost effective to improve the performance of building subjected to earthquake load. The peripheral columns of the structure at a certain height of building uses Belt truss generally to improve the stiffness and firmness of lateral loads. A comparative study by using different types of belt truss which includes X, V, inverted V diagonal etc. for different seismic zone criteria to understand the importance of belt truss is also carried out by researchers. To accomplish this study researchers have modelled 30 storied 3-dimensional models by applying different types of belt truss and analyzed the model by equivalent static analysis and response spectrum method as per the Indian Standard codes. A relative study has been performed based on percentage reduction of displacement and story drift at the different seismic zones. It is found from the study that Concrete belt truss is more efficient for reducing lateral displacement and story drift as compared to structural steel belt truss as it gives negligible results. There are different results for different seismic zones by each of the trusses, therefore inverted V-type of belt truss is one of the ideal types of belt truss in all seismic zones to increase the efficiency of the building based on economical conditions.

A.S. Jagadheeswari and C Freeda Christy (2016), have study Performance of the various models of the three-dimensional 40-storey building with 3 bays along with an x-direction and 3 bays along y-direction having storey height is the 3.5m and total height of 140m. The depth for the outrigger beam is considered as a height of the one storey. For belt truss and outrigger bracing ISLB 250 structural steel section is considered with X-shaped bracing.A total of 9 different arrangements of outriggers has been modelled and analyzed using SAP2000 software. The analysis has been carried out for a lateral load that is wind load was calculated according to IS-875-Part 3 (1987) and equivalent static analysis for seismic in accordance with IS 1893 (Part-I) 2002.For dynamic behaviour purpose Time History analysis is carried out for Nepal earthquake time histories. After considering results for lateral displacement for wind load there is a reduction about 15.73% by using outrigger in 20th and a 26th storey of the building. On considering Nepal Earthquake time history data for the time history analysis for the building model, the lateral displacement found to be 0.0138mm for building without outrigger and the value is reduced to 0.01342mm when one outrigger at 20th storey and second outrigger at 26th storey. There is the considerable reduction in the lateral deflection, storey drift while adding a multi outrigger system in the structure. The use of multi outrigger structural systems not only controlling the top storey displacement but also helps in reducing the inter-storey drift. It is concluded that the 20th and 26th storey of the building is considered as the optimum location of the building.

P.M.B. Raj Kiran Nanduri, B.Suresh, MD. Ihtesham Hussain (2013) has done their research to find the optimum position of outrigger system for High Rise reinforced concrete building for lateral loads by considering three type of the model with the central core, the central core with and without belt truss having height 90m which represents a 30 storied office building. The plan area of models is 38.5 X 38.5 m with column spaced at 5.5m from centre to centre. The location of the building is assumed to be at Hyderabad. Wind load was calculated with IS 875(part 3-Wind loads) The Basic wind speed as per the code is Vb=44m/s. The value of coefficients K1 and K3 are taken as 1.0 and the terrain category 4 with structure class C Using the above parameter the software automatically interpolates the coefficient K2 and eventually calculates lateral wind load at each storey. Same wind load is also applied to positive and negative X & Y axis one direction at a time to determine the worst loading condition. Earthquake load was calculated by use of IS 1893(part 1)-2002 seismic zone z =0.10. The importance factor (I) of the building is taken as 1.0 and soil type is assumed to be a hard/rocky site (Type I). The value of response reduction factor R is taken as 3.0 for all frames. The use of outrigger and belt truss system in high-rise buildings increase the stiffness. The maximum drift at the top of a structure when the only core is employed is 50.63 mm and this value is reduced by suitably selecting the position of outrigger at the top storey as a cap truss is 48.20 mm and 47.63 mm with and without belt truss respectively. It also concludes that there are not much reductions in the drift with belt truss. Using the second outrigger gives the reduction of 18.55% and 23.06% with and without belt truss in a drift of top storey. The optimum location of the second outrigger is 0.5times height of the building.

Kiran Kamath ,Shashi kumar Rao And Shruti. (2012) By using Outrigger structural system the author have worked on the differential column shortening due to long-term effect in the tall building. The basic purpose of this research is that the cumulative differential shortening of columns causes the slabs to lean with the resulting rotation of partitions. Inappropriate functioning of elevators, deformation, or damage to pipelines, cracking of partitions and finishes, and many other service problems can appear in the building due to differential shortening of columns. Therefore it is essential to study the effect of column shortening and need special consideration in design. The main objective of this research was to find out the optimum location of outrigger in high-rise RC building to decrease differential column shortening. In this study, researchers have analyzed a 60 storied 3-dimensional model with various configurations of outriggers with different H/h1 ratios. From the analytical study it is observed that the differential shortening was reduced by 34% when one outrigger system was introduced at H/h1 = 1.715, as well as the same model, was analyzed by keeping one outrigger fixed at its optimum position with H/h1=1.715 and second outrigger optimum position is found to be at H/h2=1.33 which will further decrease the differential shortening by a whole of 58% so this research conclude that differential shortening of columns was decreased to a great extent by establishment of outriggers.

Prateek N. Biradar, Mallikarjun S. Bhandiwad (2015) have carried out research on the performance of outrigger structural system for the tall building. In this study staic and dynamic behaviour of 40-storey building models were examined under lateral loads such as wind loads and earthquake loads. The three-dimensional 40th-storey building having plan 27 X 24 m is assumed to be located at Hyderabad. These models were analysed with core shear wall only, eight models with a concrete shear wall with concrete outrigger and similarly eight models with a concrete shear wall with X shape bracing in outrigger along with belt truss. For analysis, wind load was considered as per IS 875 part III with basic wind speed Vb=44 m/s. and seismic loads as per IS 1893:2002 for seismic zone III in medium soil type II. Dynamic time history analysis was carried out by Bhuj earthquake data, the peak ground acceleration was around 0.38g. it can be observed from the result of the analysis, the maximum lateral displacement for building without outrigger is 126.5mm and with outrigger is 107.5mm for positioning of the first outrigger at 20th storey and second outrigger at a 26th storey for earthquake loads. Due to wind load along X-direction, the percentage reduction was found to be 15.77%. There was around 35% reduction for maximum storey drift in outrigger bracing with belt truss when compared with a concrete outrigger for the same positioning. Outrigger bracing with belt truss show 3% reduction in displacement and weight of the structure is also get reduced. Thus outrigger bracing system is more economical and give better result.

Mohd Abdus Sattar, Sanjeev Rao, Madan Mohan, Dr. Sreenatha Reddy (2014) has been carried out the study to find the effect of building displacement in a lateral direction with a shear core, stringer beam and floor rigidity under the gravity load and lateral loads such as wind load and Earthquake load. Wind load was considered as per IS 875 part III with basic wind speed is equal to 44 m/s. The value of coefficient K1 and K2 are taken as 1.0 with terrain category 4 structural class-C. and earthquake load was calculated as per IS 1893 part I:2002 for seismic zone II on the site is assumed to be hard/rocky site. The value of Importance factor(I) and Response reduction factor (R) are 1.0 and 3.0 respectively. For this study, models were 15,20,25 storey L-shape high rise RCC building frame having height 40,60,75 meters respectively and plan area of the structure is 40 x 40m with a height of each storey is 3.00 m. Building frame with Double Core arrangement of the shear wall, Stringer beams and floor rigidity.is a stiffer structure Due to the presence of the additional stiffness in terms of double core shear wall, stringer beam and floor rigidity. Building frame with Double Core arrangement of shear wall and Stringer beam show column forces and moments are minimum for which drift and displacement are also comparatively less. The value of moments in Corner column are less compared to the middle column.

4.3 Review Of Literature On Behavior Of Outrigger Structural System In High Rise Steel Building.

Dhanaraj M. Patil and Keshav K. Sangle (2016) have study for the behaviour of different bracing systems under the application of dynamic wind load is investigated for high rise 2-D steel building. For this purpose, a two-dimensional dynamic wind load analysis was carried out on different five structural configurations of braced frames: moment resisting frames (MRF), chevron braced frames (CBF), V-braced frames (VBF), X-braced frames (XBF), and zipper braced frames (ZBF). of 10, 15, 20, 25, 30, and 35 storeys to capture the structural response. Dynamic wind analysis is carried on total 30 high rise 2-D steel buildings using gust factor method according to IS 875 part III: 1987. Finally, the behaviour is compared based on the fundamental period of vibration, storey displacement, and inter-storey drift ratio by using SAP2000v 16 software. The conclusions of this study MRF 2-D buildings show higher storey displacement and inter-storey drift ratios that representing MRF building are more flexible than CBF, VBF, XBF and ZBF systems. CBF and ZBF show similar behaviour under dynamic wind load and lower top storey displacements than other systems in steel buildings under gust factor method. This representing CBF and ZBF are stiffer than other systems. Strength, stiffness and stability requirements are main criteria to control in high rise 2-D steel buildings, so from this study one can choose a bracing system so as to increase strength, stiffness and stability of the MRF high rise steel buildings.

Abbas Hangollahi , Mohsen Besharat Ferdous and Mehdi Kasiri (2012) have worked to optimize the location of outrigger on high rise steel framed building subjected to earthquake load. The fundamental concept of this research work was to carry out the relative study of outcomes obtained for the lateral displacement and story drift by response spectrum and non-linear time history technique for optimum outrigger location. In this research, 20 and 25 story models had been analyzed by considering ground accelerations of various actual earthquakes in the past to study displacement and drift. Total 7 earthquakes were taken into consideration for this study that is Northridge 17/1/1994, Tabas 16/09/1978, Victoria Mexico 9/6/1980, San Fernando 9/02/1971, Cape Mendocino 25/04/1992, Chi Chi 20/09/1999 and Loma Perieta 18/10/1990. Researchers have concluded that by engaging response spectrum analysis method, optimum location of outrigger and belt truss in 20 and 25 story model was at story 10 and story 14 (i.e. 0.44 and 0.5 times the height of structure from top). Correspondingly by employing Non-linear Dynamic Time History analysis optimum location of outrigger and belt truss was at story 14 and story 16 (i.e. 0.3 and 0.36 times the height of structure from top). So according to an author, it may be safe to claim that outrigger optimum location at actual status should be located in upper level.

K.K.Sangle, K.M.Bajoria, V.Mhalungkar (2012) has done the work by considering the different type of bracing that can extensively modify the seismic behaviour of the framed steel building. In this research linear time history analysis is carried out on high rise steel building with the different pattern of the bracing system for Northridge earthquake data as per guideline is given in IS-1893 part I. maximum acceleration is applied at the base of building. There are six type of structural configuration considered, G+40 steel framed without bracing and G+40 steel framed with a different bracing pattern such as diagonal brace-A, X-brace, K-brace, knee brace and diagonal brace-B. time period as per IS 1893 part I:2002 is equal to 3.52 sec. during modal analysis, around 64.76% difference observed in between without brace system and with brace system. Base shear increase up to 38% due to bracing in both direction. The top storey displacement of steel frame building with the different bracing pattern is reduced from 43% to 60%. The diagonal brace-B shows highly effective and economical design of bracing pattern.

Z. Bayati, M. Mahdikhani and A. Rahaei (2008)in this paper presents an investigation on the reduction of top storey displacement in uniform belted structures with rigid outriggers, through the analysis of a sample structure were built in Tehran's Vanak Park. An 80-story steel-framed office tower will be used to investigate the effectiveness of belt trusses as virtual Outriggers. Designs with conventional outriggers and virtual outriggers will be compared. The floor-to-floor height is 4 meters. The building has three sets of 4-story deep outriggers and the floor area is 45 meters square and has a 15 meters square core at the center. Inverted V type of bracing is used for the core .Analysis and Design loads are in accordance with Iranian Building Code. The lateral displacement at the top storey of the building for the design with conventional outriggers and with belt trusses as virtual outriggers was found to be 700 mm and 950 mm respectively due to wind loading. The structure was also analyzed with no outriggers at all lateral displacement increased to 2750 mm. Researcher have been proposed use of Belt trusses as virtual outrigger as it avoids most of the problems associated with conventional outriggers. Basements used as outriggers can create a wider effective base for resisting overturning. All exterior columns participate in resisting overturning moment.

4.4Review Of Literature On Behavior Of Outrigger Structural System With Vertical Irregularities And Mass Irregularities In RC Building

Shivshankar k, ChandraKala S and Karthik N M (2015) his research involves study of the action of outrigger structural system in Tall vertical irregularity structure. Vertical geometric irregularity shall be examined to exist where the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey. In this research, 30-storey models having vertical irregularity were selected. The building plan changes at 11th and 21st story. These models were analyzed with only bare frame and bare frame with one outrigger and belt truss for 6 arrangement of outrigger beam by changing their place. Likewise bare frame with two outriggers and belt truss for 5 non-identical arrangements and the response of the structure was estimated under the different parameters i.e. Lateral displacement, building drift, maximum story shear and an axial load of various columns. For evaluating the behaviour of vertical irregularity of outrigger structural system, linear static analysis has been carried out as per the Indian standard. It was identified through this study that around 28.58% and 27% lateral deflection and building drift was prevent by providing outrigger structural system in high rise vertical irregularity structure when it is provided at 0.67 times its height compare to bare frame as well as 37.7% and 36.11% of the Deflection and drift is controlled by providing outrigger with belt truss at 0.67 times its height and when compared with bare frame it is 0.5 times. The optimum position of outrigger was between 0.5 times of its height in tall vertical irregularity structure came out from this research.

Mr Gururaj B. Katti and Dr Basavraj Baapgol (2014) have focused on the effect of the floor which has different loads or may be termed as mass irregularity in multi-storeyed reinforced concrete building. The aim of this research work was to study the seismic response of high-rise building by executing different seismic analysis methods, such as Equivalent static analysis, Time History Analysis and Response Spectrum analysis by considering Earthquake data of KOYNA Earthquake (Dec 11, 1964) and BHUJ Earthquake (Jan 26, 2001) to determine the realistic behavior throughout earthquake So in this study authors have modelled 10 storied RCC Building and executed seismic analysis as per Indian Standard Code by different methods as mentioned above to examine the performance of multi-story building by taking parameters such as base shear and story displacement. The complete comparative analysis imparts that, for determining the non linear behavior of irregular structure time history analysis must be performed.

Dr S.A. Halkure et al. (2014) have studied the effect of seismicity on irregular shape structure in the high rise reinforced concrete building. This research is carried out to study the seismic response of irregularly shaped structure which will decrease displacement by incorporating shear walls to enlarge stiffness of the structure. In tall building, it is prime concern to identify the effective, efficient and ideal location as well as a position of the shear wall. In this research 11 story, an irregular and unsymmetrical building that is in s C- shape in plan is relatively analyzed by executing Equivalent lateral force method as per Indian Standard Code practice, by instigating shear wall with 14 different layouts by varying percentage length of the shear wall with feasible combination of location of shear wall. Correspondingly, the model which gives a good seismic response when subjected to earthquake load by examining parameters, such as top displacement, base shear, beam moment and column moment, story drift and torsion is figured out. From the complete research, authors have found that application of shear wall about 23-31% of perimeter structure was found very much effective in controlling displacement.

Abdul Karim Mulla and Shrinivas B.N (2015)had carried out research for both regular and vertically irregular structure to increase axial stiffness with exterior columns to oppose the overturning moment by initiating Outrigger structural system with steel bracing. An irregular structure has an interruption in mass, stiffness and geometry of the structure. According to author the main reason for the earthquake was vertical irregularities though it can be avoided by providing outrigger to enlarge lateral stiffness. In this research, authors have conducted the relative analysis of 3 dimensional regular and vertically irregular shaped symmetrical plan 20-storey structures with and without providing outrigger beam subjected to earthquake load. The analysis of structure was done by identical static method and response spectrum method as per the Indian standard code practice. For measuring the effectiveness of the structure authors have taken some parameters that are base shear, lateral displacement, story drift and fundamental natural period. Authors have also investigated the response of the structure with different seismic zones as well as the behaviour of outrigger by equivalent static and response spectrum method by engulfing concrete and steel outrigger. They have also focused on the determination of the optimum location of outrigger beam to underneath the lateral displacement. It was noticed through this research that there is a considerable decrease in Time period when outrigger was introduced in a regular and irregular building structure which will upgrade the overall stiffness of the structure. Base shear will decrease and minimize the inter-story drift by incorporating outrigger. The geometric vertical irregularity was more successful due to the reduction of self-weight compared to well-organized building and Concrete outrigger are more effective than steel outrigger with X bracing type in decreasing lateral story displacement.

Piyush Mandloi and Prof. Rajesh Chaturvedi (2017) have carried out the study of seismic response with real time history to prevent seismic effect by designing structure to withstand against earthquake. This paper includes four different G+20 storey models which are vertically irregular and each model was analyzed for without mas irregularity, with mass irregularity increase from bottom to top and with mass irregularity decrease from bottom to top. These models were analyzed against five different time history which was Chichi (1999), Petrolia (1992), Friulli (1976), Northridge (1994) and Sylmar respectively. Models were considered as special RC moment resisting frame in seismic zone – V in medium soil. After analysis, it concluded that in the result of time history analysis for different models, displacement decrease after 8th storey in chichi time history whereas in Sylmar time history after 9th-storey displacement is sudden increase and after 15th storey it decrease.as discussion that outcomes varies from time history to time history. The designers must considered time history data while analyzing and design vertical and mass irregular building.

Karthik N.M, Narayana G and Chandrakala S (2015) have represented research involving the behaviour of vertical irregularities on 30storey models to find the optimum position of outrigger system and belt truss by using lateral loads. According to IS 1893:2002 part I vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral force resisting system in any storey is more than 150 % of that in its adjacent storey.The building plan considered for vertical irregularities of 30th storey of 7 X 7 bay for 1st to the 10th storey and 7 X 6 bay for 11th to the 20th storey and 7 x 5 bay 21st to the 30th storey at the location of Bhuj. Research work carried by considered location at Bhuj having basic wind speed 50 m/s (terrain category III, Class-B) and for earthquake loads seismic zone –V in medium soil types with the value of importance factor and reduction factor is equal to one and five respectively. These models were analyzed with only bare frame, bare frame with one outrigger and belt truss for 6 different configurations of outrigger beam by changing their location and bare frame with two outrigger beam and belt truss for 5 different configurations. After analysis, it was observed that 29.8% and 36.9% of deflection was controlled by providing one position outrigger at 0.67 height compared to bare frame. 45.1% and 40% of deflection was controlled by providing outrigger with belt truss at 0.67 and 0.5 when compared with bare frame. This study concluded that the optimum position of outrigger was between 0.5 times its height in tall vertical irregular structure.

Sampath Nagod, Prof. A.J.Zende (2017) have carried out research to determine the seismic response of building by dynamic non-linear analysis which is one of the important techniques for seismic analysis when the structural response is non-linear in nature. To perform an analysis 12 storey RC building having mass irregularity and without mass irregularity with the fixed base and lead rubber bearing for base isolators. By comparing the response of the structure, the researcher observed the Base shear is decreased by 40% in the base isolated building when compared to the fixed base building and the Base shear is increased by 30% in mass irregular building compared to the regular building. The value of base shear is minimum in the regular building with base isolators as compared to all four models. Time period increase by 27% by the use of base isolators in building and mass irregular building has about 8% increased time period compared to the regular building. By considering at the base, fixed base buildings have zero translational displacement whereas base isolated building have a considerable amount of translational displacement. Storey displacement was increased by 25% in the buildings with base isolators compared to the building with a fixed base and Displacement is reduced by 7% in mass irregular building compared to regular building.

5. GAPS IN LITERATURE

Based on the literature review after study of various National and International Researches Papers with reference to the outrigger structural system, there is certain absence of research work which is not studied earlier, as mentioned below:

1. The analysis of the models has done in grid models only. No researchers have done by taking actual plan of the building.

2. Most of the researches are done by conventional outrigger system and outrigger with belt truss, but very few researches are done with taking only “Virtual Outrigger”.
3. In the earlier research work, Outrigger structural system is done up to 60 storey building model. However, it can be extended to super high rise building having height up to 300 to 350 m (80-90 Stories).
3. There is absence of research work considering Multi-outrigger approach. By adopting three different outrigger levels or outrigger with double storied depth.
4. There is absence of research work considering Damped outrigger approach. By adopting various damping system with outrigger, we can study the performance of tall building.

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