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Comparative Analysis of Wall Belt Systems, Shear Core Outrigger Systems and Truss Belt Systems on Residential Apartment : A Review

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ABSTRACT

Multi-story buildings have attracted people since the dawn of civilization, with their construction serving first as a means of defence and then as a means of ecclesiastical worship. Because of their height, tall buildings are susceptible to lateral pressures such as wind and earthquakes, which can cause the building to shatter in shear and bend. Rigidity (i.e. resistance to lateral deflection) and stability (i.e. resistance to overturning moments) become more significant in general. Shear walls (structural walls) have an important role in lateral stiffness, strength, ductility, and energy dissipation. Due to numerous functional requirements such as accommodating doors, windows, and service ducts, a regular pattern of apertures must be provided in many structural walls. Depending on the shape and size of the opening, this type of opening affects the rigidity of the shear wall to some extent. The purpose of this parametric study is to investigate and critically assess the effects of various sizes of shear wall apertures on the responses and behaviours of multi-story buildings. The present review articles deals with the research based on the Outrigger Wall, Wall Belt Supported System, shear core and truss belt support by different researchers. The observation includes based on the reviews in that inputs of various arrangement for the building to increase the performance of building in terms of stability, stiffness, strength & cost.

Introduction

Outriggers are defined as the members who consist of the beams or contact plates from the centre to the outside of the posts on both sides that block the structure and operation of the connecting links. The core was provided as a detachable bar holding the entire structure firmly to accommodate loads and moving equal loads out of poles. Greater stiffness is accomplished in this type of structure than conventional frame. An outrigger combines the two elements adding a strong solid that interferes with emergency power. If an outrigger-reinforced building under wind or seismic loads deflection, the outrigger connects the main wall to and away from the posts, a unit to resist lateral loads is act on replaced the full structural system.

The best technique used in huge-story houses is to maintain the body whether it is a bar belt or a truss belt system. It representatives to the structural nodal points & communicate through it. They are termed as belt support systems the reason is the belt is usually made of trusses or bolts, connecting the structure line. The load departs from each member being distributed equally housing. In order to adapt to the force of the wave and to maintain the stability of the structure, the outer straps and straps are used. The Policy is that the outer poles are fitted with the centre of the bar with the braces and straps in one or more positions. The truss straps are attached to the outside pillar of the house while the outside holds them to the main or central vertical wall. The reason behind is this approach due to reduction value is occurs in interference structure with respect to the conventional method.

The outrigger structural system is a lateral load resisting system in which the external peripheral columns are tied to the central core with very stiff outriggers and belt truss at or more levels. The outriggers engage with the main or central shear wall, while the belt trusses are attached to the building's perimeter columns. This structural system is often employed as one of the structural systems to efficiently control excessive drift due to lateral load, such that the danger of structural and non-structural damage is minimised during minor or medium lateral load due to either wind or earthquake. The tension-compression relationship created in the outer columns determines the structural response of an outrigger system. The outrigger engages the outer columns and centre core like a strong arm. The outriggers distribute the lateral force created in the central core to the periphery columns, reducing the overturning moment.

Tall constructions are designed to meet four criteria: strength, serviceability, stability, and human comfort. Nonetheless, the factors that determine how tall buildings are designed are always human comfort and maximum space between columns. When lateral stresses are applied to a tall building, the effect of rhythmic movement causes a complex chain of responses in the structure and its occupants. The chosen structural system must be strong enough to withstand predicted loads without failure and stiff enough to resist lateral movement and horizontal load-induced motions within limitations with the least amount of money spent. Multistory buildings use cores and shear walls as horizontal resistance elements against wind and seismic loads.

Background:

Shear wall and core wall are components applied in the high story structures to resist lateral force in high seismic zones, now utilized in zone II and also zone III to restrain against earthquake loads. Shear wall and core wall both are similar. Shear wall is considered as a linear wall which is provided at the edges of buildings. Core wall is provided at the center of the building. Core wall is combination of shear walls.

Materials and Methods:

In this paper study of 10 story, 15 story and 20 story building analyzed with different lateral resistance applied with similar structural parameters and dimensions with linear static method and comparison of analysis results with shear wall, core wall and concrete frame building.

Results:

The mean difference is in terms of maximum story displacement, story drift in each model. The variation of results can be seen core wall in the middle has less deformation compared to other models. Conclusion: Core wall provided in the center of model is more convenient with compare to shear wall at the edge of the model

The floor stomach activity limits the revolution of the center is opposed by the floor stomachs at the best and base of the belt brackets which results in transformation of minute in center into a flat couple in the floor, which thusly is exchanged to the slanted bracings which at that point move their powers to the vertical segments supporting it. There are no bracket diagonals reaching out from the center to the outside of the building . The need to find outrigger segments where they can be helpfully connected by brackets stretching out from the center is disposed of the muddled support to-center association is disposed of differential shortening or settlement between the center and the detachable segments does not influence the virtual outrigger framework since the floor stomachs, however solid in their very own plane, are truly adaptable in the vertical, out-of-plane heading.

Literature Review Summary:

The subsequent literature papers are premeditated for the learning and comprehension of behavior of multi-storey building under various support system. The investigator work on Comparative analysis of Wall Belt Systems, Shear Core Outrigger Systems and Truss Belt Systems on Residential Apartment the main emphasis on the various building support system for enhancing the performance of building under seismic loading.

1) A. Rutenberg., D. Tal (1987)

This paper presents the results of an investigation on drift reduction in uniform and non-uniform belted structures with rigid outriggers under several lateral load distributions which are likely to be encountered in practice. Design aids in the form of graphical presentations of the somewhat complex solutions are provided to assist the practicing engineer in the preliminary design stages. The belted truss system is an efficient means for reducing the lateral displacements and bending moments in tall building structures. Several buildings having this type of bracing were built during the last twenty years in North America and Japan, t most of them being in the height range of 180-260 metres (30-65 storeys) as predicted in the early 1970s by Khan.

2) Abbas Haghollahi, Mohsen Besharat Ferdous & Mehdi Kasiri.(2012)

The outrigger system consist of a main core element connected to the external columns by outrigger beams at one or several floors and resists against core's rotation and storey drift. When using outrigger beams in building design, their location in the optimum position for an economic design is necessary. Despite different strategies to identify the optimum locations of these outrigger beams under lateral loads, there is a dearth of research dealing with optimum outrigger location under earthquake loads. The aim of this paper is to compare optimum outrigger locations obtained by response spectrum and nonlinear time-history analysis. Two models of 20 and 25 story models have been investigated and response spectrum and time-history analyses have been carried out against seven ground motions. The finding of this study shows that the optimized location of outrigger with nonlinear time-history is different from response spectrum analyses and it has been located in upper levels.

3) Akshay A. Khanorkar & S. V. Denge (2016)

Tall building construction has been rapidly increasing worldwide. It is creating impact on innovative development of structur al system for tall building. Recently, structural systems like braced tube, dia-grid, outrigger and belt truss providing great approach for development of tall building. This paper presents a review on uses of belt truss as lateral force resisting system for tall building. Belt truss is emerging as efficient structural system for tall building. It is concluded that belt truss can be used as lateral force resisting system in tall building rather than using it with outrigger due to some problem related with outrigger. Belt truss can control nearly same amount of deflection with increased in stiffness as that of outrigger.

4) Abeena mol N M & Rose mol K George (2016)

The development of tall building has been rapidly increasing worldwide. In typical structural design practice, the performance of lateral-load-resisting systems is the main focus of lateral analysis. . One of the lateral load resisting solutions that can provide significant drift control for tall buildings is outrigger structural systems. The research is being carried out on a 30-story high-rise core wall structure. The analysis is based on a standard floor plan of 38.5m x 38.5m. There are two forms of analysis: time history analysis and push over analysis. The parameter - maximum storey displacement – is taken into account when calculating the results. ETABS software was used to examine the performance of several outrigger structural systems in this work.

5) Hassan Beiraghi (2018)

The responses of reinforced concrete core-wall structures in tall buildings connected to the outer columns by Buckling-Restrained Brace (BRB) outriggers were explored in this study. Ground motions of forward directivity Near-Fault (NF) and ordinary Far-Fault (FF) were applied to the structures. The response spectrum analysis process was used to study and construct the buildings according to the existing DBE level codes. The reinforced concrete core-walls were modelled using a nonlinear ber element technique. At the MCE level, nonlinear time history analysis was performed utilising 14 NF and 14 FF data. The results showed that the mean moment demand envelope and mean shear demand envelope obtained from NF records were nearly identical to the equivalent demand envelopes acquired from FF records in the core-wall. The reason was that the RC core-wall, which was subjected to both sets of records, was extending plasticity all over it. For both NF and FF earthquakes, the overall reactions of the reinforced concrete core-wall with BRB outrigger system were within acceptable limits. The highest curvature ductility demand in the reinforced concrete core-wall occurred right above the outriggers in this investigation.

6) Hoenderkamp, J.C.D. (2008)

This study proposes a graphical technique of analysis for the preliminary design of horizontally loaded tall buildings with vertical trussed frames and horizontal off-set riggers positioned in the outside or façade skeletal frame structures in the lateral loading direction. The two floor constructions close to the top and bottom cords of the riggers interact with the trussed frames and these facade riggers. The bending and shear stiffness of the vertical trussed frames, the horizontal off-set riggers, and the floor structures, as well as the bending stiffness of the outer skeletal frame structures that support the riggers, are all calculated using the method of analysis. The method enables a graphical procedure for determining the optimal level of the facade riggers, as well as a quick assessment of the impact of the floor structures and facade riggers on the high-rise structure's performance, such as the reduction in lateral deflection at the top and the overturning moment at the base of the trussed frames. Figure depicts a braced frame with outriggers, as well as its deflected shape as a result of lateral loading. A vertical trussed frame with two equal length outriggers attached to outside columns reaching to the foundation makes up the structure. The stiffening effect of the outriggers may be seen in the deflected forms of the vertical and horizontal components. The outside columns resist outrigger rotation by creating a large resistive moment to the applied horizontal loading due to the produced compression and tension forces in these columns.

7) Hoenderkamp, J.C.D. (2011)

For the preliminary design of high-rise structures subjected to horizontal loading, this work proposes a graphical approach for identifying the best position of outriggers on shear walls with basement fin extensions. At the top of the building, this location for the outrigger will result in the greatest reduction in lateral deflection. The approach involves the input of seven structural parameters: shear wall, outrigger, and fin-wall bending stiffnesses, outrigger racking shear stiffness, total bending stiffness contribution from the outer columns, and shear wall and column foundation rotational stiffnesses. These characteristics enable the creation of two rotation compatibility equations at the intersections of the shear wall's neutral lines with the outrigger and foundation structures. They give expressions for restraining moments at the outrigger and foundation levels, which work in the opposite direction of the bending moment caused by horizontal stress on the structure. The ideal location of the outrigger structure is determined by maximising the influence of the restraining moments on the horizontal deflections. The optimisation technique for this type of structure can be depicted by a single graph that immediately yields the optimum level of the outrigger by combining all stiffness parameters into two non-dimensional distinctive structural characteristics. It also provides for a quick assessment of the impact of various structural components on the overall behaviour of a high-rise structure during the design phase.

8) Lee, Kang-Kun, Loo, Yew-Chaye, Guan, Hong (2001)

An orthotropic box beam analogy approach is used to analyse a framed-tube system with several internal tubes, in which each tube is independently simulated by a box beam that accounts for flexural and shear deformations, as well as shear-lag effects. The tubes-in-tube construction is idealised as a system of equivalent multiple tubes, each made up of four orthotropic plate panels capable of sustaining axial loads and shear stresses. The structural analysis is reduced to the solution of a single second order linear differential equation by reducing the assumptions in regard to the patterns of strain distributions in external and interior tubes. The suggested method can be used to analyse framed-tube constructions with single and multiple internal tubes, as well as those without internal tubes, and is meant to be used as a tool for early design. The suggested method's simplicity and correctness are illustrated by the analysis of three framed-tube constructions (of various heights) without interior tubes. The comparison study also includes a 3-D frame analysis tool and two existing approximate approaches. In addition, three different framed-tube systems with single, two, and three internal tubes are examined to ensure that the proposed method is applicable and reliable. The tube-tube contact, combined with the presence of negative shear-lag in the tubes, makes estimating structural performance and performing accurate tube analysis in a framed-tube system difficult. Existing approximate analysis models not only ignore the internal tubes' contribution to overall lateral stiffness, but also the tubes' negative shear-lag effects. As a result, these models solely evaluate the external tube's structural analysis and ignore the inside tube's shear-lag phenomenon. As a result, they fall short of accurately describing the true behaviour of these structures.

9) Kiran Kamath, N. Divya, Asha U Rao (2012)

In this research, the behaviour of many alternative 3D models for reinforced concrete structures with central core wall with outrigger and without outrigger was investigated using ETABS software by increasing the relative flexural rigidity from 0.25 to 2.0 with 0.25 step. The position of the outrigger has also been modified along the height of the building by using a relative height of outrigger parameter ranging from 0.975 to 0.4. Variation of bending moments, shear force, lateral deflection, peak acceleration of the core; inter-storey drifts for static and dynamic analysis for a 3-dimensional model for various values of relative rigidity and relative height are among the parameters examined in this work. The performance of the outrigger is most efficient when the relative height of the outrigger is equal to 0.5, according to the analysis of the findings obtained. The adoption of a core-wall system has proven to be a very effective and efficient structural technique for avoiding lateral load drift (wind and earthquake loads). However, as the building's height rises, the core lacks the necessary rigidity to maintain wind drift to a minimum. Outriggers, a type of structural system, may be used to support such tall constructions. Outriggers are a deep, rigid beam that connects the central core to the columns on the outside, helping to maintain the columns in place and reducing sway.

10) Kwang Ryang Chung, Dong Yang (2015)

Outrigger systems, like tubular systems, are highly efficient because they use the perimeter zone to withstand lateral stresses. Because of the system's substantial lateral strength, the overall structural weight can be lowered. As a result, it is the structural system of choice for tall and supertall buildings constructed in recent years. The differential shortening effect during the construction of the outrigger system, as well as the special joints used to solve these issues, will be discussed in this paper. There will also be a brief discussion of the features of wind and seismic loading in Korea. Finally, buildings in Korea that use an outrigger as their primary structural system will be discussed, as well as the structural importance of the system. The employment of mega columns around the outer border of the central core is widely employed to minimise torsion caused by plan defects, as structural efficiency occupies a substantial percentage of the planning of super-tall buildings. Various solutions for supporting this type of structure have been developed, and the outrigger system has recently gained popularity. Through the use of advanced construction and design technologies, the industry has been able to maximise the performance of structural systems with outriggers, making them more applicable.

11) Mohd Abdus Sattar, Sanjeev Rao,Madan Mohan, Dr. Sreenatha Reddy (2014)

'Tying the exterior columns to the core at one or several levels with one or two storey stiff horizontal outriggers trusses can result in a significant increase in stiffness and subsequent decrease in lateral drift in structures that don't rely on shear wall-frame interaction to resist lateral loads, in which girders are essentially pin-connected to the columns. Outriggers trusses are typically found at mechanical levels near the middle or top of a building for architectural reasons. To mobilise the increased axial rigidity of many columns while also providing torsional stiffness At the outrigger levels, a belt truss can be used. A reinforced concrete or braced steel frame main core is joined to outside columns by flexural stiff horizontal cantilevers in an outrigger-braced high rise construction. The core can be positioned between column lines with no outriggers extending on both sides, or on the side of the building with cantilevers connecting to the columns on the other side. When the building is subjected to a horizontal force, the columns-restrained outriggers prevent the core from rotating. As a result, lateral deflections and moments in the core are less than if the core stood alone and resisted the loading. As a result, when the structure bends as a vertical cantilever, tension in the windward columns and compression in the leeward columns increase the effective depth of the structure. The goal of the research is to determine the impact of lateral building displacements using shear core, outrigger, and belt truss.

12) Naveen.P.Vijay, Jerison Scariah James, Nimmy Kurian (2020)

Tall buildings are vulnerable to a variety of lateral loads, particularly wind and seismic loads, which have an impact on their design. Tubular structures, core supported outriggers with bracings, diagrid structures, and other lateral load resisting structural systems were introduced for the analysis and design of these high-rise buildings. The core supported outrigger with bracings is one of the most commonly used structural systems to control the risk of structural and nonstructural damage due to lateral load, so that the risk of structural and nonstructural damage can be minimised during small or medium lateral loads due to earthquake or wind load. The basic goal of outrigger design is to keep the outriggers in place. The optimization of the outrigger in this study is based on the depth of the outrigger as well as the position of the outrigger. The top deflection in an outrigger braced structure is first calculated using existing approximation methods. The relationship between variables that impact the top deflection in an outrigger braced structure is then determined using a statistical method known as regression analysis. The regression-based equation gave favourable findings, with a factor of safety of 0.88 and 0.99, respectively.

13) P.M.B. Raj Kiran Nanduri, B.Suresh, MD. Ihtesham Hussain

Tall building construction is quickly rising around the world, posing new issues that must be addressed by engineering judgement. A system of connected shear walls commonly resists lateral loads produced by wind or earthquake in modern tall buildings. However, when the building rises in height, the structure's stiffness becomes more crucial, and outrigger beams between the shear walls and external columns are frequently utilised to give sufficient lateral stiffness. The outrigger and is often employed as one of the structural systems to successfully control excessive drift owing to lateral load, so that the risk of structural and non-structural damage can be minimised during small or medium lateral load due to either wind or earthquake load. This system can be considered as an acceptable structure for high-rise buildings, particularly in seismic active zones or wind load dominant areas. The goal of this thesis is to investigate outrigger behaviour, outrigger site optimization, and outrigger efficiency when three outriggers are used in the construction. Nine 30-story three-dimensional models of outrigger and belt truss systems are subjected to wind and earthquake loads, examined, and compared in order to determine the lateral displacement reduction associated to outrigger and belt truss system position. By placing a first outrigger at the top and a second outrigger in the structural height, a maximum displacement reduction of 23 percent can be achieved for a 30-story model. The impact of the second outrigger system is investigated, and key findings are recorded and drawn.

14) Shivacharan K, Chandrakala S , Karthik N M(2015)

The structure is analysed to determine the outrigger's behaviour and efficiency in order to determine its best position at the first and second locations. Wind and earthquake loads are applied to three-dimensional models of outrigger and belt truss systems, which are then studied and compared to determine the lateral displacement reduction associated to the outrigger and belt truss system position. The purpose of this research is to look into the use of outrigger and belt truss in various locations that are subjected to wind and earthquake loads. IS 875 (Part 3) was used to compute the wind load, while IS 1893 (Part-1): 2002 was used to determine the seismic load. Outrigger and belt truss positioning to reduce lateral displacement and building drift. A linear static analysis was performed using ETABS2013.5 to evaluate the performance of vertical irregularities of outrigger structure. Vertical uneven buildings of 30 stories were used to achieve this goal. 7X7bay from the first to the tenth floor, 5x5bay from the eleventh to the twentieth floor, and 3x3bay from the twenty-first to the thirty-first floor with outriggers and belt truss at various stories were investigated. The displacement and drift of the structure are evaluated in compression. Axial Axial Axial Axial Axial Axial Axial Axial A The construction with the first and second position of the outrigger has a load of distinct columns.

15) Siddhaling S. Khanapur and Visuvasm J.(2016)

A research for a tall slender building to determine the outriggers' ideal location and behaviour under lateral loads, as well as to represent modelling and analysis of the 30 storey structure using a mathematically 3D model. To examine the behaviour of outriggers, different plan ratios and positions of outriggers are considered. The project's major goal is to reduce lateral displacement and inter-storey drift by comparing the maximum % reduction of these variations with and without outriggers. According to the linear static analysis, the ideal position of the outrigger, in addition to the one on the top level, is at the intermediate structure. High-rise constructions are becoming more popular in this era, therefore skyscrapers, megaframes, tube structures, and tall buildings with high slenderness are all possibilities. In comparison to a conventional size column from the bottom top storey, the increase in structural height with reduced column sizes causes human discomfort owing to deflection of top stories. In order for structures to grow more intricate in any direction where deflection occurs owing to gravity and horizontal load imbalances, causing the structures to become faulty. To take into consideration the most cutting-edge concept outrigger system, which plays a critical role in tall constructions. The three primary reasons for adding outriggers to a structure's outer column are shorter column elongation, bending, and racking shear. The outrigger is a horizontal stiff arm that connects the cores to the column's periphery, while the central core tries to rotate and bends at the outrigger level, causing strain and compression. They supply resistance forces to the movement, allowing movement forces to readily resort. We learned that adding outriggers to a structure is safe, and that its primary purpose is to prevent deflection and inter-storey drift. However, determining the best location for outriggers is more difficult in the case of taller buildings, because as the height of the building rises, the column sizes become smaller, resulting in maximum deflection.

16) Vaibhav R. Kubde Rahul M. Phuke(2018)

A system of multi-outriggers commonly resists lateral loads caused by wind or seismic forces in modern tall buildings. The shear walls are connected to the outer columns by an outrigger, which is a stiff beam. When the structure is subjected to lateral forces, the outrigger and columns prevent the core's rotation, reducing the lateral deflection and base moment that would otherwise occur in a free core. Numerous studies on the analysis and behaviour of outrigger constructions have been conducted during the last three decades. However, the topic of how many outriggers are required in tall buildings remains unanswered. To optimise the structural system, the behaviour of a 37-story RC structure will be investigated using conventional structural software for displacement and base shear at various outrigger levels. The rapid rise of the urban population and the resulting demand on limited space has had a significant impact on the city's residential development. The high cost of land, the need to avoid ongoing urban sprawl, and the necessity to protect important agricultural production all contributed to the upward trend in residential construction. As a building's height rises, the lateral load resisting system takes precedence over the structural system that resists gravity stresses. The susceptibility of tall structures to lateral loads is a fundamental aspect that influences their design. One of the most essential design factors for tall buildings is lateral drift near the top.

17) Wensheng LU And Xilin LU(2000)

The shaking table tests of numerous scaled multi-tower high-rise building models are summarised in this publication. The assumption of a rigid floor is clearly inappropriate for multi-story building research. A novel analytic model is proposed that takes into account the effect of a flexible transfer floor. The test findings are compared to the theoretical dynamic behaviour. This work also discusses the connection floors connecting towers at higher levels, as well as the influence of foundation stiffness to structural dynamic behaviour. A number of recommendations and conceptual guidelines are made. High-rise buildings are well-known for playing a significant role in modern cities.First of all, tall buildings can be effectively used to meet the requirements of modern society and solve the problem of limitation of construction site resources. On the other hand, they are the signals of economic properties and civilization. Nowadays high-rise buildings rise higher and higher, with more and more complex and individual plan and elevation, such as multi-tower buildings.

Conclusions

The following conclusions are made based on the above research papers

- The shear core, truss belt support system, belt truss & outrigger system most conventional method for withstanding under seismic loads.
- The maximum investigation is based on the most favourable tallness, shear wall position and tallness, variations in outrigger deepness etc.
- Mostly used bracing & Outriggers System is more priority in it and reduces the effect of laterals loads.
- The main aim of the investigators is to increases the strength and durability of the building used, hence growth is pragmatic by diverse researchers.
- The checks made by different researches are Seismic performance, Impact of various support system in high rise structure with different parameters.

Future Scope

The following future worked as carried out to get the knowledge of truss belt and wall in the structure and to find deeper concept and new considerable idea through it. There are as follows

- Outputs based on the efficiency of outrigger.
- Use of different types of structural form such steel, bundled tube, bracing etc and comparisons between them.
- Dimensional analysis: variations in the depth, size of the belt truss and wall.
- Locations based assessment of the structure to get optimises location for earthquake resisting building.
- Use of different type's base isolation in the truss belt and outriggers system.

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