# Review on Comparative Analysis of Outrigger Braced System with Different Lateral Load Resisting System in Multistorey Building

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*Abstract*— The advancements in engineering and technology, development of high strength structural materials, rise in population and lack of land area available due to the increase in land prices and rapid urbanization have led to the development of high-rise buildings in the modern era. The high-rise buildings are the most susceptible to the lateral loadings due to the wind and seismic forces. The trend of taller and slender structures makes it necessary to develop the structural system which can resist the lateral loads effectively with minimum cost. In this study we compared two lateral load resisting system for dynamic analysis of flat slab multistory building one system is outrigger bracing system and other is Shear wall system. The outrigger bracing system provides the solution to control excessive drift and displacement in high rise buildings. It consists of the outrigger bracings or the outrigger trusses which connects the central core of the building with the peripheral columns and the peripheral columns relate to one another through the belt trusses. The studies afford the precis of different research work & conclude with identified gaps in the research in addition to recognize the object of required work.

***Keywords:*** Dynamic Analysis, Flat-Slab, Outrigger Bracing, Shear Wall

## I. INTRODUCTION

It has been found through various research that the shear wall when used alone provides resistance effectively only upto a certain height and beyond that it becomes uneconomical when compared with the benefit it provides. Thus, there is necessity of some other more efficient structural system offering more stiffness and strength to the high-rise structures against wind and seismic loadings and considering the economy criteria. The outrigger bracing system provides more stiffness to tall buildings against the lateral displacement and drifts without paying any extra cost on the steel and proves to be very economical solution for the drift control.

The outrigger system consists of the outrigger bracings or the outrigger trusses which connects the core of building with the columns on periphery and the peripheral columns relate to one another through the belt trusses.

## II. CONTRIBUTION OF RESEARCHERS IN FIELD OF FLAT SLAB & LATERAL LOAD RESISTING SYSTEM.

To analyses and design of flat slab for a different shape such as rectangular and square with and without the drop, pushover analysis (statics analysis) and earthquake analysis (seismic co-efficient method) with the help of ETABS software. After the evaluation of the result, the maximum strip moment was almost same for rectangular and square slab and the value of base shear was higher in square flat slab without the drop. The storey displacement seems to be higher in rectangular slab and the storey drift value for rectangular and square was also the same, the natural period value was almost the same for both shapes. (Kaulkhere R.V, Prof. G.N Shete, (2017).[1]

In this work, to analyze and model of G+3 regular frame structure with shear wall and G+3 flat slab with the shear wall in Seismic Zone 3 done with SAP-2000. The plan area is (24 x 24) m, the height of plinth 1.8 m and floor height is 3.6 m. After the result comparison regular frame building has better performance as compared to the flat slab. To enhance the performance of flat slab building, shear wall can be provided. (Imran Mohammed, et.al 2017).[2]

Flat-slab building structures possess major advantages over traditional slab-beam-column structures because of the free design of space, shorter construction time, architectural –functional and economical aspects. Because of the absence of deep beams and shear walls, the flat-slab structural system is significantly more flexible for lateral loads then traditional RC frame system and that make the system more vulnerable under seismic events. The critical moment in the design of these systems is the slab-column connection, i.e., the shear force in the slab at the connection, which should retain its bearing capacity even at maximal displacements. The behaviour of flat slab building during an earthquake depends critically on 'Building Configuration'. This fact has resulted in to ensure safety against earthquake forces of tall structures hence, there's got to determine seismic responses of such building for designing earthquake-resistant structures. Response spectrographic analysis is one among the important techniques for structural seismic analysis. In the present work, dynamic analysis of 15 models of multi-storied RCC Flat slab structure is administered by response spectroscopic analysis. (Renuka Ramteke 2017) [3]

Comparison of flat slabs and grid slabs and compare them with normal slab using STAAD pro, to get the optimum design. The design involves load calculations and analyzing the whole structure by STAAD pro. The design methods used in STAAD pro analysis are Limit State Design conforms to an Indian Standard Code of Practice. STAAD pro options a progressive computer program, visualization tools, powerful analysis and design engines with advanced finite element and dynamic analysis capabilities. From model generation, analysis design to visualization and result verification, STAAD pro is that the professional's choice. STAAD pro has a very interactive user interface which allows the users to draw the frame and load the input values and dimensions. Then consistent with the desired criteria allotted it analyses the structure and styles the members with reinforcement details for RCC frames. (Bhatia Navjot Kaur., Golait Tushar,2016).[4]

In this study, for the strengthening of flat slab against punching shear, the use of post-installed shear reinforcement after the completion of construction work. It is also known as post shear reinforcement, used to improvement of punching shear strength of flat slab. The critical shear crack theory has used to design the post-installed shear reinforcement. The main conclusion of this work was that the inclined shear reinforcement was simpler to enhance punching shear strength. (Devtale M. K. et.al 2016).[5]

The work is done in this kind of approach, the analysis of flat slab in earthquake loading condition has drawn out. In this research, the flat slab is designed with the help of direct design method, equivalent frame method (for gravity load only) and finite element method (for irregular geometry and irregular layout). Contrasting the result, it has been found that in IS Code 456-2000, there aren't any provisions related to the flat slab for seismic loading, it is only based on the gravity loading conditions. If the designing has not done properly, then cracks are evolved near the support which concluding the drastic results when any structure considered during construction. (Srinivasulu P., Dattatreya Kumar A 2015).[6]

In this work, the discovery of the actual performance of R.C.C. flat slab building under earthquake loading has been done. It was determined that due to seismic loading, the effect on the flat slab in terms of storey displacement, frequency, base shear, storey level acceleration and also the effect of punching shear in all types of flat slab i.e. flat slab not including drop, flat slab with drop, flat slab with only shear wall, flat slab with drop and shear wall have also concluded. The response spectrum method is used with the help of ETABS software. After the result was compared, the fundamental mode of frequency is 20% increase in a flat slab with a drop and to enhance stiffness property with the shear wall the value was increased with 96%. The value of fundamental frequency was high on the bottom floor and less at the top floor and the value of the fundamental time period increased on the top floor to the bottom floor. The storey shear value seems comparatively high on the bottom floor and less at the top floor. Hence concluding this, the flat slab with drop and shear wall is a better option to overcome the displacement in the X direction, also base shear increased when weight increases. If the drop has provided in the interior panel then punching shear gets reduced by 25%. (More R. S., Sawant V. S. (2015).[7]

The effect of with and without the shear wall of flat slab building on the seismic behaviour of high rise building with different position of shear wall studied. For that, 15 story models are selected. To study the effect of different location of the shear wall on high rise structure, linear dynamic analysis (Response spectrum analysis) in software ETABs is carried out. Seismic parameters like period of time, base shear, storey displacement and storey drift are verified. (Walvekar Anuja, Jadhav H.S. 2015).[8]

The effect of RC flat slab with shear wall at a different location for various heights of the building. Shear wall with flat slab provides stability to structure further because it improves lateral load resistance. The effectiveness of RC flat slab and shear wall building is studied with the help of three different models. Model one is a conventional building with regular slabs, beams & column framing. Model two is a conventional building with various shear wall location and model three with flat slab and shear wall. Time history analysis is carried out for the structure using ETABs software. (Patwari K. G. L. G. Kalurkar 2016), [9]

As per IS code 1893:2002 analysis carried out by considering regular and irregular buildings with brick infill and modified building with strong column and shear wall at the corner of the soft storey. For linear and nonlinear analysis five, 10, and 15 storey buildings modelled by using ETABS software considering Response reduction factor, Importance factor, Zone factor, damping ratio, loads as per code Lateral displacement, base shear and hinge reactions were obtained consistent with code provision. (Ravindra B N, Mallikarjun S. Bhandiwad 2015).[10]

Six number of conventional RC frame and Flat Slab buildings of G+3, G+8, and G+12 storey building models are considered. The performance of the flat slab and therefore the vulnerability of pure frame and purely flat slab models under different load conditions were studied and for the analysis, seismic zone IV is considered. The analysis is done using E-Tabs software. It is necessary to investigate the seismic behaviour of the building for various heights to examine what changes area unit about to occur if the peak of standard RC Frame building and flat slab building changes. Therefore, the characteristics of the seismic behaviour of flat slab and traditional RC Frame buildings recommend that extra measures for guiding the conception and design of those structures in seismic regions are required and to boost the performance of building having standard RC building and flat slabs below seismic loading, The object of the present work is to compare the behaviour of multi-storey industrial buildings having flat slabs and traditional RC frame thereupon of getting 2 approach slabs with beams and to review the result of height of the building on the performance of those 2 varieties of buildings below seismic forces. Present work provides an honest supply of knowledge on the parameter's lateral displacement, storey drift, storey shear, column moments and axial forces, time period. (Navyashree K et al 2014) [11]

Behaviour of the flat slab with old traditional two-way slab along with the effect of shears walls on their performance. The parametric studies comprise of maximum lateral displacement, storey drift and axial forces generated in the column. For these case studies we have created models for two-way slabs with shear wall and flat slab with a shear wall, for each plan size of 16X24 m and 15X25 m, analysed with Staad Pro. 2006 for seismic zones III, IV and V with varied height 21m, 27 m, thirty-three m and thirty-nine m. This investigation also told us about the seismic behaviour of the heavy slab without ends restrained. For stabilization of the variable parameter, a shear wall is provided at the corner from bottom to top for calculation. Results comprise of study of 36 models, for each plan size, 18 models are analysed for varying seismic zone. (Pawah Sumit.et al 2014). [12]

for determining the most economical slab between flat slab with the drop, Flat slab without a drop and grid slab. The proposed construction site is Nexus point opposite to Vidhan Bhavan and beside NMC office, Nagpur. The total length of the slab is 31.38 m and width are 27.22 m. the total area of the slab is 854.16 sqm. It is designed by exploitation M35Grade concrete and Fe415 steel. Analysis of the flat slab and grid slab has been done each manually by IS 456-2000 and by using code additionally. Flat slab and Grid slab have been analysed by STAAD PRO. Rates are taken consistent with N.M.C. C.S.R It is observed that the FLAT slab with the drop is more economical than Flat slab without a drop and Grid slabs. (Sathawane Amit A., Deotale R.S. 2014) [13]

In this proposed work, comparison between a flat slab and post-tensioned flat slab for seismic Zone 2, 3 with taking various types of multi storied building like G+9, G+11, G+14. The different model cases have different geometry along with different material properties. To analyse the different model cases using linear time history analysis method in STAAD Pro, some conclusions drawn are shown.Post tensioned flat slab was more effective under seismic loading. (Fernandez Ruiz Miguel et.al 2013).[14]

In this analytical work, the researcher obtained the most economical slab among flat slab without the drop, flat slab with finished by using STAAD Pro. In the grid slab system, the quantity of concrete required is more drop and grid slab based on manual analysis as well as software analysis. They used the direct design method and equivalent frame method to analyze the flat slab. The approximate method and plate theory method were used to analyze grid slab since manual analysis process and software analysis was being as compared to the flat slab. Steel quantity seems to be more required in the flat slab exclusive of drop as compared to flat slab added inclusive of drop and grid slab. As per economy, the flat slab added with the drop is better as compared to Grid slab and flat slab exclusive of the drop. (Sathawane Amit A., Deotale R.S 2012).[15]

In this proposed work to compare the flat slab with drop attached shear wall and without the shear wall in seismic loading condition for Zone 3, 4 and 5 using STAAD Pro software. For this work, they took six models which are as follows:

Plan area (16x24) m2 with 7 storey with shear walls at plinth floor only

Plan area (16x24) m2 with 9 storey with shear walls at plinth floor only

Plan area (20x30) m2 with 7 storey with shear walls at plinth floor only

Plan area (20x30) m2 with 9 storey with shear walls at plinth floor only

Plan area (20x30) m2 with 11 storey with shear walls at plinth floor and 1st floor

Plan area (20x30) m2 with 13 storey with shear walls at plinth floor only

After result comparison the storey drift values are high at mid-height of the structure. In flat slab added with drop has more drift values for short span and are lesser in the longer span. There are not any effects on storey drifts with or without shear wall added in building. For a shorter span, the master-slave option could be used but for longer span realistic approach adopted. (Dr Gupta Uttamasha, 2012).[16]

*1) Documentation on Shear wall*

Analyze R.C structures (regular and irregular structure) with the and without shear wall by response spectrum analysis and wind analysis using CYPE software. A parameter such as time period, the centre of mass and centre of stiffness, base shear, mode shapes and drifts are calculated and compared. Comparing the amount of analysis of various models is additionally done. The model analysis is conducted to know the response of a structure with a shear wall. (Sharma Prabesh et al. 2016).[17]

The lateral behaviour of the multi-storey building designed according to the IS-456 and IS-1893 part-I is evaluated using dynamic analysis of framed structures using Response Spectrum Method. The inadequacies of multi-storied frame shear wall building are discussed comparing the lateral behaviour, building drift, axial force, and seismic base shear. Two important parameters of zone factor and Soil-structure interaction (SSI), which influence the lateral behaviour of the building is also considered in this study. Software STAAD-ProV8i is used for this purpose. In this study variety of stories, zone factor and soil condition are varying parameters. (Chouhan Maikesh., Makode Ravi Kumar,2016).[18]

The non-linear analysis of frame for various positions of shear wall up a building frame. In this present study, the focus is to identify the effective location of the shear wall in a multi-storey building. Considering model, one is the bare frame structural system and the other three models are the dual-type structural system. An earthquake load is applied to a building of eight stories is in zone II, zone III, zone IV and zone V as per Code Provision IS1893-2002. The analysis has been distributed exploitation ETABS software package. Pushover curves are developed and compared for varied models. It has been observed that structure with shear wall at the appropriate location is more significant in case of displacement and base shear. (Mr LovaRaju.K et.al 2015).[19]

This paper represents the shear-wall frame behaviour in a multi-storey building subjected to wind loading. The different cases are prepared with a different configuration of the shear wall. Comparative graphical illustration totally different from various} models (cases) supported different parameters like lateral deformation, level drift index, most bending moment and shear forces are mentioned. Seismic analysis of G+15 building stiffened with bracings and shear wall. The performance of the building is analysed in Zone II, Zone III, Zone IV, and Zone V. The study includes underneath, standing the most thought issue that leads the structure to perform poorly throughout an earthquake, to attain their acceptable behaviour under future earthquakes. The analysed structure is symmetrical, G+15, standard RC moment-resting frame (OMRF). Modelling of the structure is completed as per standard professional. V8i software. The time period of the structure in both the direction is retrieved from the software and as per IS 1893(part 1):2002 seismic analysis has undergone. The Lateral seismic forces of RC frame are carried out using the linear static method as per IS 1893(part 1): 2002 for different earthquake zones. The scope of gift work is to know that the structures got to have appropriate Earthquake resisting options to soundly resist massive lateral forces that are obligatory on them during the Earthquake. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing earthquake damage within the structure. Also, the braced frames can absorb a great degree of energy exerted by an earthquake. The results of the performance and the analysis of the models are then graphically represented and in tabular form and is compared for determining the best performance of building against lateral stiffness by the arrangement of three different types of bracings with three different orientation of bracings and shear wall. A comparative analysis is completed in terms of Base shear, Displacement, Axial load, Moments in Y and

Z direction in columns and shear forces, maximum bending moments, max Torsion in beams. (Atif Mohd et.al 2015).[20]

The improvement location of shear walls in a symmetrical high-rise building. Position of shear walls in symmetrical buildings has due considerations. In symmetrical buildings, the centre of gravity and centre of rigidity coincide, in order that the shear walls are placed symmetrically over the outer edges or inner edges (like box shape). So, it's terribly necessary to seek out the economical and ideal location of shear walls in symmetrical buildings to attenuate the torsion impact. In this work, a high rise building with completely different places of shear walls is considered for analysis. The multi-storey building with 14 stories is analysed for its displacement, strength and stability using ETABS-2013 software. For the analysis of the building for seismic loading with two different Zones (Zone-II & Zone-V) is considered with soil I & soil III types. The analysis of the building is done by using an equivalent static method and a dynamic method. The results from the analysis obtained from both the methods are presented in tabular form and the results are compared using the graphical form. (Reddy N. Janardhana et.al 2015) [21]

The opening in Shear walls is generally located at the sides of buildings or arranged in the form of the core that houses stairs and lifts. Due to practical necessities like doors, windows, and alternative openings, a shear shut in a building contains several openings. The size and location of openings may vary from an architectural and functional point of view. In most of the apartment building, size and location of openings in the shear wall are made without considering its effect on the structural behaviour of the building. This study is administered on 6- story frame-shear wall buildings, using linear elastic analysis with the assistance of finite element software, STAAD PRO under earthquake loads in equivalent static analysis. The results reveal that stiffness, as well as seismic responses of structures, is affected by the size of the openings as well as their locations in the shear wall. It is also explored that top lateral drift of the system can also be reduced thickening the element in the model around the opening of the shear wall. (Bhruguli H. Gandhi 2015).[22]

Mukundan (2015) found shear wall provision in the building has been effective and economical. A 10-storey building in Zone IV is tested to reduce the effect of an earthquake using reinforced concrete shear walls in the building. The results are presented after analysing model using ETABS software and RSA method is used. Researchers also studied results in varying thickness of shear walls. It is concluded that shear walls are more resistant to lateral loads in regular/Irregular structure and for safer design, the thickness of the shear wall should range between 150mm to 400mm. [23]

Sagar et al. (2015) analysed the performance on various sort of irregularity Considered i.e.(a) Horizontal Irregularity. Plan irregularity (b) Vertical Irregularity. Mass Irregularity. To achieve the objective of the project Time history Analysis & Response spectrum analysis method was carried out.[24]

The effects of openings in the shear wall on the seismic response of structures. For parametric study 6 and 12 storied 7x3 bays apartment buildings with the typical floor plan of 35mx15m and floor height of 3m with different openings size and location in shear walls were modelled in STAAD Pro. An equivalent static analysis for three-dimensional models of the buildings was performed as per IS 1893 (part 1): 2002. Seismic responses of the analysed structures were compared. The results reveal that for gap space < 2 hundredths, the stiffness of the system is additionally littered with the scale of openings than its arrangement. However, for gap space >20%, the stiffness of the system is considerably littered with openings configuration in shear walls. (Vishal A. Itware., Dr Uttam B. Kalwane 2015).[25]

An irregular high-rise building with shear wall and without a shear wall was studied to understand the lateral loads, story drifts and torsion effects. From the results, it's inferred that shear walls are additionally immune to lateral masses in an associate irregular structure (Ravi Kanth Chittiprolu et.al 2014).[26]

Performance of structures under frequently occurring earthquake ground motions leading to structural damages also as failures has repeatedly demonstrated the seismic vulnerability of existing buildings, due to their design supported gravity masses only or inadequate levels of lateral forces. This necessitates the need for design based on seismic responses by suitable methods to ensure the strength and stability of structures. Shear wall systems are one among the foremost commonly used lateral load resisting systems in high rise buildings. This study aims at comparing various parameters such as store drift, storey shear, deflection, reinforcement requirement in columns etc. of a building under lateral loads based on the strategic positioning of shear walls. Based on linear and nonlinear analysis procedures adopted, the effect of shear wall location on various parameters is to be compared. Pushover analysis is employed to gauge the expected performance of the structure by estimating its strength and deformation demands in style earthquakes by means that of static dead analysis and comparing these demands to on the market capacities at the performance levels of interest. The capability spectrum methodology is employed to get the performance level of a structure. The software used is ETABS 9.5 and SAP 2000.V.14.1(Lakshmi K.O. et.al 2014).[27]

A study has been carried out to determine the optimum Structural configuration of a multi-storey building by changing the shear wall locations radically. Four different cases of shear wall position for a 10-storey residential building with keeping zero eccentricity between the mass centre and hardness centre have been analysed and designed as a space frame system by computer application software system, subjected to lateral and gravity loading in accordance with IS provisions. (Sejal Bhagat 2014).[28]

The seismic responses of the ten-storey RC shear wall building with and without opening. Developed mathematical modelling and analysed the concrete shear wall building by exploitation totally different nonlinear strategies (time history and pushover method). These strategies dissent about accuracy, simplicity, transparency and clarity of theoretical background. Non-linear static procedures were developed with the aim of overcoming the insufficiency and limitations of linear methods, whilst at an equivalent time maintaining the relatively simple application. All procedures incorporate performance-based ideas paying more attention to brake management. The analysis is administered by exploitation commonplace package SAP2000. The comparison of those models for various parameters like displacement, story drift and base shear has been given by RC shear wall building with and without opening. (Satpute S G., and D B Kulkarni 2013).[29]

This paper discusses the importance of the lateral stiffness of a building on its wind and seismic design. To reduce damage in the event of wind and an earthquake, it's desirable to possess large lateral stiffness. Shear walls contribute significant lateral stiffness, strength, and overall ductility and energy dissipation capacity. Therefore, we have introduced shear walls at a different location on the plan of the building like side centre shear wall, corner shear wall, the shear wall at near to the centre of the building plan. The effect of the shear wall on deflection is studied in A1, B1, C1& D1 models of 30 storied building. (Prajapati Rajesh et. al 2013).[30]

An organized research programme to assess and strengthen existing concrete walls that were designed using older seismic codes. The main object of the paper is to examine the behaviour of RC shear walls that do not comply with modern seismic codes and compare their experimental performance with the provisions for assessment of reinforced concrete members. For this purpose, a series of six shear walls were designed and tested under static cyclic loading. The wall specimens were characterized by many types of reinforcement arrangement, focusing on varying amounts of shear reinforcement. The experimental outcomes are compared with the provisions included in modern codes, which predict the shear strength, the chord rotation ductility and the effective stiffness of RC shear walls. (Christidis 2013).[31]

The finite element modelling in analysing and exploring the behaviour of shear wall with an opening under seismic load actions. In modern tall buildings, shear walls are commonly used as a vertical structural element for resisting the lateral loads which will be induced by the effect of wind and earthquakes. Shear walls are usually set at the perimeters of buildings or organized within the form of a core that homes stairs and lifts. Due to purposeful needs like doors, windows, and other openings, a shear wall in a building contains many openings. The size and placement of openings might vary from bailiwick and purposeful purpose of reading. In most of the apartment building, size and location of openings in the shear wall are made without considering its effect on the structural behaviour of the building. This study is administered on 6- story frame-shear wall buildings, using linear elastic analysis with the help of finite element software, ETABS under earthquake loads in equivalent static analysis. The results reveal that stiffness additionally as seismic responses of structures are plagued by the dimensions of the openings additionally as their locations in the shear wall. It is additionally explored that prime lateral drift of the system also can be reduced thickening the component within the model round the gap of the shear wall. (Chowdhury Sharmin Reza., et.al 2012).[32]

*2) Documentation on Outrigger Braced System*

Taranath (1975) [33] worked on finding the optimum location of the belt-truss along the height that reduced the lateral sway under the wind loadings and found the mid location of building as optimum for single outrigger. He also proposed a very simple method of analysis for the outrigger structural system.

McNabb (1975) [34] carried the study of Taranath ahead and used two outriggers for finding out the reduction in lateral drift and verified the work done by Taranath. He suggested that most suitable location of outrigger considering the drift and displacement control is nearly 0.445 times the height of structure from the top.

Chan and Kuang (1988) [35] started the studies on stiffening the structure by employing stiff beams at arbitrary locations in the structure. They stated that location of stiff beams affects the performance of high-rise structure against lateral loads.

Qi and Chen (1996) [36] worked with two-dimensional models to study the suitability of outriggers. Their model comprised of the core in form of channel and two columns connected with the series of outriggers beams to the core. They found that three outriggers reduce lateral displacement significantly.

Po Seng Kiran and Frits Torang Siahaan (2001) [37] have worked on increasing the stiffness to make the structure capable of resisting the lateral loads such as wind load and seismic load by using the diagonal outrigger and belt truss system. The researchers have used eight two-dimensional models of 40 storey height and five three-dimensional models of 60 storey height with different configurations of the outriggers for the analysis. The two-dimensional models are analysed under the wind load and the three dimensional models are analysed for the seismic load as per the British standards. Different locations as well as height of outriggers are considered for performing a comparative study of the roof displacement. The researchers have found that in the case of two-dimensional models, a single outrigger provided at the middle height of the structure reduces the lateral displacement by around 56% while two outriggers, one at the top and the other one at the mid height of structure reduces the lateral displacement by around 65%. In case of three-dimensional models, the optimum location of outriggers is at the top and the 33rd storey (nearly mid height) for which the reduction in lateral displacement is found to be 18%.

Hoenderkamp and Baker (2003) [38] presented a graphical method based on five non-dimensional parameters for the preliminary design of the outrigger-braced structure with truss core and shear wall. Flexible foundation effect is considered, and central core is a shear wall, and wind load distribution is assumed to be uniform. By evaluating benchmark example, it was proved that the more precise models, the more alteration of the optimum location. Optimum location was found to be on 0.3 and 0.4 of the structure heights, respectively.

Zeidabadi et al. (2004) [39] method is derived based on continuum method. The method analyzes structural behavior of coupled shear walls stiffened by internal beams and outrigger. Results of analysis showed that, the effect of laminar shear on the optimum location of outrigger is substantial. Including laminar shear in the analyses yielded the optimum location of the outrigger to be on 0.4 height from the bottom, leading into the minimization of laminar shear. Optimum location to maximize resistant moment, occurred when the outrigger was placed from 0.2 to 0.4 height of the structure.

K.K. Sangle et al. (2012) [40] studied performance of steel framed structures under seismic loadings by incorporating different types of bracings. Northridge earthquake data was used in this study for performing time history analysis. Research considered six different configurations in this study which are G+40 bare frame model (without bracing) and G+40 models with various bracing patterns – diagonal bracing, X- bracing, K- bracing and knee bracing. The displacement at top of steel framed building with the different bracing patterns investigated is decreased by 43% - 60% which means flexural stiffness increases by using different bracing systems. A reduction in time period is observed by using different types of bracings. Diagonal bracing is found to be the most efficient in this study.

Junais Ahmed AK and Yamini Sreevalli (2014) [41] have worked on investigating the change in fundamental time period of the building with outriggers placed at different locations of structural models. For this purpose, structural models of 30, 40, 50 & 60 storeys are created in FEM based ETABS software. The lateral loads are applied as per IS 1893(PART 1) – 2002 for earthquake loads and IS 875(PART 3) -1987 for the wind loads. The maximum reduction in the fundamental time period of the building is obtained by placing the outriggers at one-third the building height from top as well as from the bottom. The results indicate that plan dimension plays a role in stability of the structure. Increasing the structural height with same plan dimensions leads to increase in the fundamental time period of the building. Thus, lateral stability of the structure is inversely proportional to the height of the structure.

M.R. Suresh and Shruti Badami (2014) [42] have worked on investigating the most suitable structural configuration for structures of different heights subjected to gravity loads and wind loads. The researchers have considered “Rigid Frame”, “Shear Wall/Central Core”, “Wall-Frame Interaction”, and “Outrigger” systems. This study was aimed at finding out the most suitable structural system for the building of certain height. They considered models of G+15, G+30, G+45 and G+60 storeys with symmetrical plan. They have found that for buildings upto 40 storeys height Rigid Frame with Shear wall system is suitable but for the building over 40 storeys height, outrigger structural system is very much efficient in controlling excessive displacement at the top of building and the inter storey drift values.

Abdul Karim Mulla and Shrinivas B.N (2015) [43] worked by considering the regular as well as vertically irregular structures also. For this study, the researchers used 20 storey building models having the vertical irregularity but symmetrical in plan. They used linear static method and the response spectrum method according to IS codes. Further they studied the behavior of structural models in different seismic zones for concrete as well as the steel outriggers. Time period and base shear were reduced considerably in models with outriggers. Outriggers upgraded the stiffness of the vertically irregular building efficiently and controlled the displacement effectively. They found concrete outriggers more efficient than steel outriggers in controlling the lateral displacement.

H.S. Sukesh et al. (2017) [44] worked on outrigger systems with varying relative stiffness at various locations in 35 storey building model. They used outriggers at different levels along the height(H) of building at 0.25H, 0.5H, 0.75H and H and varied the relative stiffness of outrigger beams at all these locations by changing dimensions. The dimensions of outrigger beam for different cases were taken as 300x600mm, 300x1200mm, 300x 1800mm, 300x2400mm and 300x3000mm. Six different models are used for the comparative study. Model 1 comprised of bare frame without shear walls and outriggers. The remaining five models comprised of the shear wall and outrigger concrete beams having varying stiffness. Analysis was performed for seismic zones 2 to 5 using the ETABS software and it was found that lateral displacement decreases, and base shear increases with increase in relative stiffness of the concrete beams in all the seismic zones.

Prajyot A. Kakde and Ravindra Desai (2017) [45] studied the difference in performance of the structures with steel outriggers and concrete beam outriggers. They considered a tall building with plan dimensions of 30m x 30m and 70 storey height having a central core. Wind load is considered for analyzing the models in ETABS 2016 based on parameters like displacement, drift and base shear. They found steel outriggers to be more efficient in controlling lateral displacement and storey drift. Base shear is also less with steel outriggers than with the concrete outriggers. The outrigger system along with the peripheral belt made up of structural steel is more effective than concrete deep beams.

Sajjad Baygi and Amin Khazaee (2019) [46] determined the optimum number of outriggers for reduction in top storey displacement. They used MATLAB program for formulating the base moment in the core and top displacement of the structural model under lateral loadings. They stated that the optimum number of outriggers in a structure depends upon numerous factors such as the axial rigidity of columns, bay length, height of structure and most essentially the stiffness of outriggers provided. Optimum number of outriggers is changed on changing any of these factors. They also found that using four or more outriggers in a structure does not reduce lateral displacement beyond a limit and rather leads to uneconomical configurations.

*3) Documentation on Dynamic Analysis*

The important objective of earthquake engineers is to style and build a structure in such how that damage to the structure and its structural component during the earthquake is minimized. This report aims towards the dynamic analysis of a multi-storey RCC building with symmetrical configuration. For the analysis purpose model of ten storey’s RCC with the asymmetrical floor plan is considered. The analysis is carried by exploitation finite element based mostly computer code SAP 2000. Various response parameters like lateral force, base shear, story drift, story shear can be determined. For dynamic analysis time, history method or response spectra method are often used. The time-history analysis is a step-by-step analysis of the dynamical response of a structure to a specified loading that may vary with time. The analysis may be linear or non-linear. The dynamic analysis may be performed for symmetrical yet as unsymmetrical building. The dynamic analysis may be within the form of nonlinear dynamic time history analysis. In this paper, a nonlinear time history analysis is performed on a ten storey RCC building frame considering time history of El Centro earthquake 1940 using SAP2000. The main parameters of the seismic analysis of structures ar load-carrying capability, ductility, stiffness, damping and mass. The various response parameters like base shear, level drift, level displacements etc are calculated. The storey drift calculated is compared with the minimum requirement of storey drift as per IS 1893:2002. (Ahmad Akil 2015).[48]

Soundarya R et. al (2014) studied the dynamic behaviour of high. Rise building using IS1893.2002 code recommended response spectrum method and time history method. Base shear, Response Spectra at different story levels, Bending Moment Diagram and Shear Force Diagram variations are considered to study and analyses in the present study. STAAD Pro software is used to analyse the building models and it is found that the base shear obtained from Time history analysis is higher than Response Spectrum analysis. This is because of the variation in amplitude and frequency content of the ground motions.[49]

Seismic performance evaluation of the behaviour of frame-wall irregularity on established existing concrete (RC) structures that were subjected to the 1999 Kocaeli Earthquake in Turkey. In explicit, reference is formed to the nonlinear static analysis and nonlinear dynamic analysis of ferro-concrete (RC) structures containing shear walls. The layered shell model has been chosen due to its advantages. The damage observed after reconnaissance studies have been captured using the 3D model. (Koçak Ali et. al 2014) [50]

Patil and Kumbhar (2013) considered ten-story building and tested against nonlinear dynamic response under seismic effect. SAP 2000 is used as a software application tool in this paper. Five number of seismic time histories are used to compare results of considered cases. Similar variation patterns are for displacement and base shear values are noted with different intensities and it is suggested and concluded that the high. Rise RCC buildings must be tested using time history method to confirm safety against seismic effects.[51]

## III. Summary of Literature Review and Research Gaps

This is not enough to study the nonlinear behavior of the structure. A great amount of research in nonlinear static analysis i.e., push over-analysis is in progress and at the same time, a great focus is also on the direction of nonlinear dynamic analysis.

To know the complete behavior of the Flat slab Multistory structure with different lateral load resisting system from the linear stage to the collapse stage, nonlinear dynamic analysis study is done. Now a day, complex-shaped buildings are becoming popular, but they carry a risk of sustaining damages during earthquakes. Therefore, such buildings should be designed properly taking care of their dynamic behavior.

The literature review reveals that some work has been done for analysis of multi-storied buildings having a flat slab with comparison of two lateral load resisting system under seismic loading conditions.

From the Literature survey, it has been pointed out that very less work had been done in the analysis of the same topic. Since no author has done the comparison of the results of such cases. Therefore, after summarizing the literature survey, these cases are taken and needed to be studied as per Indian Code of Practice.

## IV. Conclusion

Since various papers were studied and what the authors have been found in the way but not comparable. The only way to find the optimum result parameters is to obtain by comparing various building cases of multi storied buildings. So, for that, total of 4 building cases are prepared with one optimum case of a flat slab to find the result parameters. After then the load is to be taken as dead load, live load, earthquake load and as per IS 1893-2002, various load combinations are considered. Results hence obtained based upon the different cases analyzed, will be compared and the suitable case where least value will obtain be the conclusion of the work. The main purpose is to find the optimum building case to counteract earthquake forces and analysis is done using software STAAD Pro. So, for this, different loads applied, and parametric values obtained are considered and point of comparison of different building models is as follows:

Node displacement
Peak Storey shear in All Models
Max Von Mis stresses in Flat slab
Principal Stresses on Flat slab
To obtain optimum building case among all building cases by observing and comparing their parameter values.

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