Analysis of High Raised Structures in Different Seismic Zones with Diagrid and Shear Walls Using E-Tabs

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***Abstract*—** The rapid growth 0f urban population and limitation 0f available land, scarcity and high cost 0f available land, the taller structures are preferable now days. Tall structures have fascinated mankind from the beginning 0f civilization. The Egyptian Pyramids, one among the seven wonders 0f world, constructed in 2600 B.C. are among such ancient tall structures. Such structures were constructed for defense and to show pride 0f the population in their civilization. The growth in modern multi-storied building construction, which began in late nineteenth century, is intended largely for commercial and residential purposes. But, from a structural engineer's point 0f view the tall building or multi-storied building can be defined as one that, by virtue 0f its height, is affected by lateral forces due to wind, earthquakes, machinery vibrations and some other sources 0f vibration that cause structural damage or even collapse 0f the structure and they only play an important role in the structural design. The design 0f tall buildings essentially involves a conceptual design, approximate analysis, preliminary design and optimization, to safely carry gravity and lateral loads. The design criteria are strength, serviceability, stability and human comfort.

Keywords: Diagrid, Shear Walls, E-Tabs

I. INTRODUCTION

A. General

The rapid growth 0f urban population and limitation 0f available land, scarcity and high cost 0f available land, the taller structures are preferable now days. Tall structures have fascinated mankind from the beginning 0f civilization. The Egyptian Pyramids, one among the seven wonders 0f world, constructed in 2600 B.C. are among such ancient tall structures. Such structures were constructed for defense and to show pride 0f the population in their civilization. The growth in modern multi-storied building construction, which began in late nineteenth century, is intended largely for commercial and residential purposes. They have become a trend and, moreover, they have paved the way to world competition in constructing tall buildings to exhibit the symbol 0f power and technology possessed by its population. The tallness 0f a building is relative and cannot be defined in absolute terms either in relation to height or the number 0f stories. But, from a structural engineer's point 0f view the tall building or multi-storied building can be defined as one that, by virtue 0f its height, is affected by lateral forces due to wind, earthquakes, machinery vibrations and some other sources 0f vibration that cause structural damage or even collapse 0f the structure and they only play an important role in the structural design. The design 0f tall buildings essentially involves a conceptual design, approximate analysis, preliminary design and optimization, to safely carry gravity and lateral loads. The design criteria are strength, serviceability, stability and human comfort.

Most lateral loads are live loads whose main component is horizontal force acting on the structure. Typical lateral loads would be a wind load against a facade, an earthquake, the earth pressure against a beach front retaining wall or the earth pressure against a basement wall. Most lateral loads vary in intensity depending on the building's geographic location, structural materials, height and shape. The dynamic effects 0f wind and earthquake loads are usually analyzed as an equivalent static load in most small and moderate-sized buildings.

Wind has two aspects. First – a beneficial one – is that its energy can be utilized to generate power, sail boats and cool down the temperature on a hot day. The other – a parasitic one – is that it loads any and every objects that come in its way. The latter is the aspect an engineer is concerned with, since the load caused has to be sustained by a structure with the specified safety. All civil and industrial structures above ground have thus to be designed to resist wind loads.

Earthquakes have become a frequent event all over the world. It is a natural phenomenon associated with violent shaking 0f the ground. It is very difficult to predict the intensity, location, and time 0f occurrence 0f earthquake. Structures adequately designed for usual loads like dead, live, wind etc may not be necessarily safe against earthquake loading. It is neither practical nor economically viable to design structures to remain within elastic limit during earthquake. The design approach adopted in the Indian Code IS 1893(Part I): 2002 'Criteria for Earthquake Resistant Design 0f Structures' is to ensure that structures possess at least a minimum strength to withstand minor earthquake occurring frequently, without damage; resist moderate earthquakes without significant structural damage though some non-structural damage may occur and aims that structures withstand major earthquake without collapse. Structures need to have suitable earthquake resistant features to safely resist large lateral forces that are imposed on them during frequent earthquakes. These lateral forces can produce the critical stresses in a structure, set up undesirable vibrations and in addition, cause lateral sway 0f structure, which could reach a stage 0f discomfort to the occupants.

As the height 0f the structure increases then the consideration 0f lateral load is very much important. For that the lateral load resisting system becomes more important than the structural system that resists the gravitational loads. The lateral load resisting systems that are widely used are rigid frame, shear wall, diagrid structural system, wall frame, braced tube system, outrigger system and tubular system. Recently shear wall systems and diagrid structural system are the most commonly used lateral load resisting systems.

B. Shear walls

Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight 0f structure and occupants; create powerful twisting (torsional) forces. These forces can literally tear (shear) a building apart. Shear walls are constructed to counter the effects 0f lateral load acting on a structure. They have very high plane stiffness and strength, which can be used to simultaneously resist large horizontal loads and support gravity loads, making them quite advantageous in many structural engineering applications. Generally, they are provided between column lines, in stair wells, lift wells, in shafts.

In residential construction, shear walls are straight external walls that typically form a box which provides all 0f the lateral support for the building. When shear walls are designed and constructed properly, they will have the strength and stiffness to resist the horizontal forces. In building construction, shear wall is rigid vertical diaphragm capable 0f transferring lateral forces from exterior walls, floors, and ro0fs to the ground foundation in a direction parallel to their planes. Reinforcing a frame by attaching or placing a rigid wall inside it maintains the shape 0f the frame and prevents rotation at the joints. Shear walls are especially important in high rise buildings subjected to lateral wind and seismic force. Besides, they impart lateral stiffness to the system and also carry gravity loads.

C. Diagrid system

Diagrids is one 0f the system which improves the seismic performance 0f the frame by increasing its lateral stiffness and capacity. Diagrid– diagonal grid structural systems are widely used for tall buildings due to its structural efficiency, flexibility in architectural planning, energy absorption capacity and aesthetic potential provided by the unique geometric configuration 0f the system. Hence the diagrid, for structural effectiveness and aesthetics has generated renewed interest from architectural and structural designers 0f tall buildings. Diagrids are designed for constructing tall buildings with steel that creates triangular structures with diagonal support beam. The Diagrids are perimeter structural configurations characterized by a narrow grid 0f diagonal members which are involved both in gravity and in lateral load resistance. Diagonalized applications 0f structural members for providing efficient solutions both in terms 0f strength and stiffness are not new. However, nowadays a renewed interest in and a widespread application 0f diagrid is registered with reference to large span and high rise buildings, particularly when they are characterized by complex geometries and curved shapes, sometimes by completely free forms.

D. Need for the work

Tall building developments have been rapidly increasing worldwide. The growth 0f multistory building in the last several decades is seen as the part 0f necessity for vertical expansion for business as well as residence in major cities. As the height 0f the building increases the lateral resisting system becomes more important than the structural system that resists the gravitational loads. A Shear-Wall system which provides additional stiffness to the structure is usually present in the structural system and used for utilities and the elevator shaft. Many skyscrapers have used framed tube system or braced tube system as its primary structural system. However, these tube systems are affected by the shear lag effect and also the amount 0f steel usage in those tall buildings is notably higher. On the contrary to other systems, recently a new structural system called "Diagrid" is proposed for tall buildings. The structural efficiency 0f Diagrid system occurs as a result 0f its triangular configuration. The triangulation resists both gravity and lateral load by axial stresses 0f its members. In this system all corner columns are removed and only diagonal columns are provided which covers 4-6 floors per diagonal triangle and it gives a bold appearance to the building too.

From the research papers it is observed that the shear wall system and diagrid system reduce the response 0f the structures subjected to Earthquake excitation. They are found to be decrease in the Natural time period, reduction in lateral displacement and reduction in story drift 0f the building. In this present study, it is proposed to compare between the performances 0f diagrids and shear walls in the high rise buildings. The performance index includes displacement, base shear, storey drifts and relative performance should be investigated. Two buildings, one with diagrids and other with shear walls considering different types 0f earthquake zones as per IS 1893:2002(part 1) is being analyzed by using finite element s0ftware package ETABS 2016. For analysis various IS codes have been referred, for Gravity load combination IS 456:2000 and for seismic load combinations as per IS 1893:2002(part 1) code is referred. To analyze the structures, the static and dynamic analysis method is adopted. The response spectrum and time history functions are defined to carry out dynamic analysis.

E. Objective 0f the work

1) To study the concept 0f two lateral resisting systems diagrid and shear wall structural system with different earthquake zones and wind conditions.
2) To Model 0f two buildings, one with diagrid system and other with shear wall are done by using ETABS 2016 s0ftware.
3) Analyzing the modeled structures considering different zones using response spectrum analysis and time history analysis.
4) Study 0f results in terms 0f storey displacements, storey drifts, storey shear and time periods.

II. LITERATURE REVIEW

A. Preface

Advancement in materials, structural systems, construction technology, and analytical methods for analysis and design facilitated the growth 0f high rise buildings. Structural design 0f high rise buildings is governed by lateral loads due to wind or earthquake. So it is necessary to design and analyze the structures by considering seismic effect and resist to lateral loads. Some 0f the resisting systems that are widely used are rigid frame, shear wall, diagrid structural system, wall frame, braced tube system, outrigger system and tubular system. Recently shear wall systems and diagrid structural system are the most commonly used lateral load resisting systems.

Many 0f the researchers focused their studies on many lateral resisting systems and compared with RC buildings. Shear walls is used in different positions 0f multi-storeyed buildings with different s0ftwares. Analysis and design 0f diagrid structures are carried out with change in optimum angle 0f diagonal bracings, geometry change in plan. Some 0f the noteworthy contributions 0f researchers regarding those are listed below:

B. Inference from Literature Review

Kiran and Jayaramappa (2017) [1] have performed a comparative study on multi-storey RC frame with shear wall and Hexagrid system. Three models are prepared for study such as 30 storey bare RC building, 30 storey bare RC building with shear wall and 30 storey bare RC building with shear wall and Hexagrid system. These three models are analyzed by using linear dynamic response spectrum method. ETABS V.13 s0ftware is used for design and analysis 0f RC frame. The behavior 0f the structure is studied based on the maximum displacement, maximum drift, maximum storey shear and maximum overturning moment. The study included the consideration 0f the effect 0f base shear and displacement for RC frames with and without Hexagrid bracings and with shear wall. The comparison is made for result parameters such as maximum storey displacement, maximum storey drift, maximum storey shear and maximum overturning moment between various models for zones-III. The present study concluded that the base shear in RC bare frame is least and the displacement is the maximum as compared to other two models and as the number 0f storey increases the resistance 0f the structure to base force decreases and as a result displacement increases. The drift values show the effective behavior 0f the structure when Hexagrid system 0f bracing is adopted and the effect 0f RC bare frame with shear wall and Hexagrid system 0f bracing is prominent in high seismic zones.

Jayesh Venkolath and Rahul Krishnan (2016) [2] have performed analysis 0f 24 storey circular building to find the optimal diagrid angle to minimize the lateral drift and displacement in a high-rise building. The circular plan 0f 30.7 m diameter is considered with five different types 0f angles 0f diagrid that is 36.8°, 56.3°, 66°, 77.5° and 83.6°. The results are tabulated by performing finite element analysis using ETABS s0ftware. The comparison 0f analysis 0f results in terms 0f lateral displacement, storey drift, and storey shear and time period. The present study concluded that diagrid angle in the region 0f 65° to 75° provides more stiffness to the diagrid structural system which reflects the less top storey displacement. The storey drift, storey shear, time period, effect 0f lateral force to stories are very much lesser in the region 0f diagrid angle. The optimum angle observed in the region 0f 65° to 75°.

V. Abhinav *et. al.* (2016) [3] have performed seismic analysis 0f multi-storey building with the shear wall using STAAD Pro. an RCC building 0f 11 floors exposed to earthquake loading in zone V is considered and earthquake load has calculated by a seismic coefficient method using IS 1893 (Part I): 2002. The three models 0f an 11-floor building have been made with the shear wall at corner, shear wall along periphery and shear wall at the middle 0f the building. The comparative study 0f deflection 0f building with and without a shear wall is carried out in X and Z directions. The lateral deflection for building with the shear wall along periphery is reduced in comparison to other models. Hence, it has been concluded that the building with the shear wall along periphery is much more efficient than all other models with a shear wall.

Nandeesh and Geetha (2016) [4] have performed comparative study 0f 52 storey hyperbolic circular steel diagrid structural system rehabilitated at central core with shear wall and steel braced frames. This work basically comprised 0f two models with shifting floor zone and centre divider framework. The external fringe comprises 0f diagrid funnel segment for both models. These models are examined for two distinctive seismic zones (zone II and zone III). All the models and its components are investigated utilizing ETABs programming according to Indian codes. The present work showed the outcomes parameter regarding story drift, story displacement, time period, story shear. The study concluded that the shear wall shows the better performance under earthquake loading. Shear wall had less top storey displacement, storey drift than steel bracing systems in both seismic zones. The steel bracing system gave better performance against storey shear for both seismic zones than shear walls system. The shear wall systems act as a monolithic structure and it gives the effective performance against all aspects in terms 0f maximum storey displacement, storey drifts and time period.

Md. Samdani Azad and Syed Hazni Abd Gani (2016) [5] have performed a comparative study 0f seismic analysis 0f multi-storey buildings with shear walls and bracing systems. This paper contains a numerical approach to show dissimilarity between the shear wall system and steel bracing system. The new approach 0f this research was strengthening lateral force resisting system by using steel bracing. A gradual process has been done step by step to show comprehensible contrasts between the systems. For implicit results, East Malaysia has considered as the corresponding region. The overall analysis has been carried out using the ETABS9.7 s0ftware. Six models have prepared for the comparative study. The First model was having a shear wall at a middle portion, second model was having a shear wall at a side portion, third model was having bracing at a centre, fourth model was having bracing at a side, the fifth model was having floor bracing at middle and sixth model was having floor bracing at a side. It concludes that model one is the safest among the six models.

Harshita Tripathi and Sarita Singla (2016) [6] have studied the diagrid structural system for framed multi-storey building and also stiffness based design methodology for determining preliminary sizes 0f R.C.C diagrid structures for tall buildings. A 36 m x 36 m size regular plan is considered. Modeling, design and analysis 0f structural members are done by using ETABS 2015 s0ftware. Structural members are designed as per IS 456:2000, load combinations 0f seismic forces as per IS 1893(part I): 2000 and dynamic along wind and across wind are considered for analysis as per IS 875: 1987 (part 3). Dynamic Analysis 0f 24, 36 and 48 story building with perimeter diagrid with different story module is carried out by Response spectrum method. There are 15 models are prepared with five different types 0f angles 0f diagrid i.e. 50.2°, 67.4°, 74.5°, 78.2° and 82.1° for 2 storey, 4 storey, 6 storey, 8 storey, 12 storey diagrid module for 24-storey, 36-storey, 48-storey building. The results 0f analysis are compared in terms 0f top storey displacement, storey drift, storey shear, time period, angle 0f diagrid, spectra acceleration coefficients, base reactions for seismic and wind forces within same storey height for different storey modules and for different storey heights. The present study concluded that for all 15 models storey displacement and storey drifts are within permissible limit. The storey drift, storey displacement, storey shear etc. are less in the region 0f 65° to 75° diagrid angle. Therefore optimum angle 0f diagrid is observed in the region 0f 65° to 75°.

Priyanka Soni, Purushottam and Vikky Kumhar (2016) [7] have analyzed multi-storey building 0f different shear wall locations and heights and studied the analysis 0f various research works involved in enhancement 0f shear walls and their behavior towards lateral loads. Six models 0f G+10, G+20 and G+26 storeys with storey height 3.5m, earthquake zone II are prepared by using STAAD. ProV8i s0ftware and two locations 0f shear wall are considered. The different parameters such as inter-storey drift, base shear and lateral displacement for all models have studied. From the results, it is concluded that the deflection 0f the multi-storey building structure 0f location 2(shear wall at periphery) is more as compare to location 1(shear wall in core) for G+10, G+20 and G+26 storey building. Therefore location 1 (shear wall in core) 0f shear wall is more efficient than location 2(shear wall at periphery).

Shubham R. Kasat *et. al* (2016) [8] have performed a comparative study 0f a multi-storey building under the action 0f a shear wall using ETAB s0ftware for achieving economy in reinforced concrete building structures. The design 0f critical section is carefully done to get reasonable concrete sizes and optimum steel consumption in members. A regular plan 0f 20 m x 20 m size is considered for 18 storey building with 4 m storey height and 2 m for the base storey. The models 0f 18 storey building are made with and without shear wall by static analysis method for earthquake zone III. The building is analyzed using ETAB v9.2.0 s0ftware. The results are compared in terms 0f displacement, storey drift, and base shear. It is concluded that buildings with shear wall are economical as compared to without shear wall.

C. V. Alkuntel *et. al* (2016) [9] have performed seismic analysis 0f multi-storey building having infill wall, shear wall and bracing. The analysis is carried out to study different techniques for resisting lateral forces acting on the structure and finding the most suitable method along with the design 0f a G+25 structure using infill wall, shear wall and bracing. The analysis 0f building is carried out using analytical methods as well as ETAB'S s0ftware. This paper is focused on improving the resistance and stability 0f high rise building against the different loads and forces it is subjected during its life time. The parameters 0f the analysis are a time period, base shear, and joint displacement and these parameters are responsible for the overall stability 0f any building. It concluded that shear wall has proved to be the best alternative for improving the sustainability, force resistance and uniformity 0f high rise building.

Saket Yadav and Vivek Garg (2015) [10] have studied the advantages 0f steel diagrid building over conventional building by design and analyses under gravity and seismic loading 0f a regular G+15 storey steel building with a plan size 0f 18 m x 18 m, located in a seismic zone V by STAAD Pro. All structural members are designed as per Indian standard for general construction in steel (IS 800:2007) and the seismic forces are considered as per Indian code provision for earthquake resistant design 0f structure (IS 1893 (Part 1): 2002). The results are compared to evaluate the utility 0f diagrid. It has been concluded that a significant decrease 0f bending moment in interior columns 0f diagrid building is found in comparison to the conventional building. The use 0f diagrid significantly decreases the maximum shear force and maximum bending moment in internal and perimeter beams. The sign 0f maximum bending moment also changes in perimeter beams 0f diagrid building. The diagrid configuration provides a reduction in the span 0f perimeter beams at alternate floors, hence reducing the beam forces at alternate floors. The sectional requirement 0f the members has been reduced in diagrid building when compared to the conventional building. This results in an advantage 0f approximately 12% in weight for diagrid building.

Anil Baral and S. K. Yajdani (2015) [11] have performed seismic analysis 0f RC framed building for the different positions 0f shear wall. The response 0f building with different positioning 0f shear wall using both equivalent static method (seismic coefficient method) and response spectrum analysis. For analysis, G + 9 storey's with storey height 3m in all floor including the ground floor and plan area 17m X 17m which is located in zone V is considered. Five different Models 0f RCC building, one with no shear wall and other four models with different position 0f shear wall which is subjected to earthquake load in zone V has been studied .This study also incorporates how the bending moment, shear force for beam and axial Force for column vary with change in positioning 0f RC shear wall. Building are modeled and analyzed using standard package ETABS 2013. It concludes that from both equivalent static analysis and response spectrum analysis displacement, storey drift were lower in case 0f model 3 as compared to other models. Higher values 0f Bending moment and shear force was observed in model 3 for the beams in storey 9 as compared to all other Models. Minimum value 0f axial force was observed in model 3 for C13 column in all the storey 0f the building compared to other models. Proper positioning 0f shear wall results in effective and efficient performance 0f building during earthquakes. Proper positioning 0f shear wall results in effective and efficient performance 0f building during earthquakes. Among the five models, model 3 having shear wall along the four corners displayed better result compared to other models.

Suchita Tuppad and R.J. Fernades (2015) [12] have analyzed multi-storey building subjected to seismic behavior to found out optimum location 0f shear wall by using genetic algorithm. The building is analyzed for various positioning 0f reinforced concrete walls (shear walls) and found the constraints such as lateral displacement using equivalent static method which are carried out as per IS: 1893 (part 1)-2002 using finite element analysis s0ftware ETABS2015 for earthquake zone V in India and MATLAB for Genetic Algorithm. Six models are prepared, first model has the building without shear wall and remaining five models have the buildings with shear wall at different locations. It has been concluded that by providing shear wall to the high rise buildings, Structural seismic behavior will be affected to a great extent and also the stiffness and the strength 0f the buildings will be increased.

Mohd Atif, Laxmikant and Vikrant Nair (2015) [13] have performed comparative study on seismic analysis 0f G+15 storey building stiffened with bracing and shear wall.

The performance 0f the building is analyzed in Zone II, Zone III, Zone IV, and Zone V. The analyzed structure is symmetrical, G+15, Ordinary RC moment-resting frame (OMRF). Modeling 0f the structure is done as per STAAD.Pro.V8i s0ftware. Time period 0f the structure in both the direction is retrieve from the s0ftware and as per IS 1893(part1): 2002 seismic analysis has undergone. The lateral seismic forces 0f RC frame are carried out using linear static method as per IS 1893(part 1): 2002 for different earthquake zones. Results are compared in terms 0f base shear, displacement, axial load, moments in Y and Z direction in columns and shear forces, maximum bending moments, max Torsion in beams. From the results it is concluded that shear wall elements are very much efficient in reducing lateral displacement 0f frame as a drift and horizontal deflection in shear wall frame are much less than that induced in braced frame and plane frame. The location 0f shear wall and braced members has significant effect on the seismic response than plane frame. Shear wall construction will provide large stiffness to the building by reducing the damage to the structure. The use 0f steel bracing is one 0f the advantageous concepts which can be used to strengthen or retr0fit the existing structures. The lateral displacement 0f the building is reduced by 35 % to 45 % by the use 0f X type steel bracing type reduced maximum displacement.

Rohit Kumar Singh, Vivek Garg and Abhay Sharma (2014) [14] have designed and analyzed concrete diagrid building and compared it with conventional frame building. A regular five storey RCC building with plan size 15 m X 15 m located in seismic zone V is considered for analysis. The STAAD.Pro s0ftware is used for modeling and analysis 0f structural members. All structural members are designed as per IS 456:2000 and load combinations 0f seismic forces are considered as per IS 1893(Part 1): 2002. The comparison is carried out the analysis results in terms 0f storey drift, node to node displacement, bending moment, shear force, area 0f reinforcement and economical aspects. From the results and observations it is concluded that diagrid building show less lateral displacement, storey drift. Diagrid show more economical in terms 0f steel and better resistance to lateral loads.

Sanjay Sengupta (2014) [15] investigated effect 0f different thickness and corresponding reinforcement percentages required for shear walls on multi-storey buildings for all seismic zones in India. Building models with shear walls are developed using ETABS s0ftware. The location 0f the shear walls are kept same and a comparative study is done for different thickness 0f the shear wall for different height 0f the building (5 storey, 10 storey and 15 storey). In each 0f the cases corresponding reinforcement percentages required are found out. It is observed that for a constant thickness 0f shear wall, reinforcement percentage increases with increase 0f both seismicity and number 0f stories. It is also observed that for all zones, the reinforcement percentage increases if the shear wall thickness increases for a certain range 0f thickness and then decreases for a certain range 0f thickness. From the results concluded that increase 0f shear wall thickness is not always effective for earthquake resistant design.

Nishith B. Panchal and Vinubhai R. Patel (2014) [16] have performed comparative analysis and design 0f 20 storey simple frame building and diagrid structural system 0f building to study the strategies to reduce the lateral forces on high rise building. A regular plan 0f 18 m x 18 m size is considered and ETABS 9.7.4 s0ftware is used for modeling and analysis 0f structures. Compared the analysis 0f results in terms 0f top storey displacement, storey drift, steel and concrete consumption. It is concluded that the displacement, storey drift, storey shear very much less in diagrid structures as compared to the simple frame building and diagrid structures provides more economy in terms 0f consumption 0f steel, concrete.

Nitin Choudhry and Mahendra Wadia (2014) [17] have performed pushover analysis 0f two R.C. framed buildings with shear wall; in which plan 0f one building was taken symmetrical and it consist 0f 2 bay 0f 5m in x direction & 2 bay 0f 4m in y direction and second building having L shaped unsymmetrical plan. The shear wall was provided for studying their resisting lateral forces. In this paper highlight the effect 0f shear wall on R.C frame building when shear wall providing along the longer and shorter side 0f the building. The base shear and displacement will decreases 0f building. The comparative study has been done for base shear, story drift, spectral acceleration, spectral displacement, story displacement. It is concluded that provision 0f shear wall results in a huge decrease in base shear and ro0f displacement both symmetrical and unsymmetrical building. In the unsymmetrical building shear wall must be provided on smaller side 0f building.

Giovanni Maria Montuori *et al* (2014) [18] have studied geometrical patterns 0f diagrid in systematic and comprehensive way. Diagrid structures characterized by regular patterns are comparing to alternative geometrical configuration. It was obtained by changing the angle 0f diagonals (variable-angle, VA) as well as by changing the number 0f diagonal (variable-density, VD) along the building height. Eight different diagrid patterns (3 models for Regular patterns with 60, 70, 80 degrees angle, 3 models for variable angle pattern and 2 models for variable density pattern) are generated and designed for a 90-story model building. The resulting diagrid structures are assessed under gravity and wind loads and various performance parameters are evaluated on the basis 0f the analyses results. The diagrid patterns generated for the building model are analyzed using FEM numerical models, by means 0f SAP2000 computer code. The comparison in terms 0f structural weights and performances finally allows for discussing efficiency potentials 0f the different patterns.

Sepideh Korsavi, and Mohammad Reza Maqhareh (2014) [19] studied the evolutionary process 0f diagrid structure towards architectural, structural and sustainability concepts: reviewing case studies. It is concluded that according to the prevailing properties 0f these structures, they have made significant advances in terms 0f height, angle, modules, forms and materials although they are a recent trend. According to the explanations and analysis presented in each part, these advances mainly correspond to structural concepts (resistance against seismic or wind forces), architectural concepts (aesthetics, flexibility, penetration 0f daylight, creation 0f free, twisted and complex forms) and sustainability concepts (lightness, economic considerations). The diamond-shaped modules in these structures are similar but their applications vary in different projects according to structural, architectural and sustainability concepts.

Khushbu Jania and Paresh V. Patel (2012) [20] have performed analysis and design 0f 36 storey diagrid steel building. A regular floor plan 0f 36 m × 36 m size is considered. ETABS s0ftware is used for modeling and analysis 0f structure. All structural members are designed using IS 800:2007 considering all load combinations. Load distribution in diagrid system is also studied for 36 storey building. Also, the analysis and design results 0f 50, 60, 70 and 80 storey diagrid structures are presented. From the study it is concluded that most 0f the lateral load is resisted by diagrid columns on the periphery, while gravity load is resisted by both the internal columns and peripheral diagonal columns. So, internal columns need to be designed for vertical load only. Due to increase in lever arm 0f peripheral diagonal columns, diagrid structural system is more effective in lateral load resistance. Lateral and gravity load are resisted by axial force in diagonal members on periphery 0f structure, which make system more effective. Diagrid structural system provides more flexibility in planning interior space and facade 0f the building.

Ehsan Salimi Firoozbad, K. Rama Mohan Rao and Bahador Bagheri (2012) [21] have studied effect 0f shear wall location on seismic performance 0f building. Time history analysis has been done to buildings with different number 0f stories and various configurations with same plan. The top story displacements have been obtained and compared to each other for all models to meet the effect 0f shear wall configuration on seismic performance 0f buildings. The analysis and design 0f models have been studied based on IS codes, and SAP 2000 s0ftware have been used for this purpose. It is concluded that different positions 0f shear wall can reduce the top storey drift at least twice, which means the drift 0f building is reduced 100 percent from highest value to lowest one.

Young-Ju Kima *et al* (2011) [22] have performed experimental investigation 0f the cyclic behavior 0f nodes in diagrid structures under lateral loads, such as wind load or seismic load and to suggest the details and welding methods 0f nodes for application to an actual building based on test results. The diagrid nodes that are designed to be installed in the Lotte Super Tower located in Seoul, South Korea. Two types 0f specimens were developed and tested cyclically. The PA type utilized an open-section layout for the node, whereas the PB type utilized a box-section layout for the node. Concluded PB type specimens developed the superior structural performance in terms 0f initial stiffness, strength, ductility, and energy absorption capacity over the PA type specimens under cyclic loading.

III. Modeling and Analysis

A. *General*

This chapter deals with the modeling and analysis 0f the structure under various loads. The finite element package ETABS V16.2.1.0 has been used for the analysis. A three dimensional model 0f the structure have been created to undertake static and dynamic analysis. The model ideally represents the complete three dimensions (3D) characterizes 0f the building, including its mass distribution, strength, stiffness deformability. Modeling 0f the material properties, structural elements, load patterns, load cases and combinations and response spectrum and time history functions are discussed in this chapter.

B. *ETABS Software*

ETABS is an engineering s0ftware product that caters to multi-story building analysis and design. Modeling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class 0f structure. Basic or advanced systems under static or dynamic conditions may be evaluated using ETABS. For a sophisticated assessment 0f seismic performance, modal and direct-integration time-history analyses may couple with P-Delta and Large Displacement effects. Nonlinear links and concentrated PMM or fiber hinges may capture material nonlinearity under monotonic or hysteretic behavior. Intuitive and integrated features make applications 0f any complexity practical to implement. Interoperability with a series 0f design and documentation platforms makes ETABS a coordinated and productive tool for designs which range from simple 2D frames to elaborate modern high-rises.

The step wise procedure that is followed in ETABS S0ftware is

– Modeling 0f structural elements
– Loading, analysis and design
– Output

ETABS also features interoperability with related s0ftware products, providing for the import 0f architectural models from various technical drawing s0ftware, or export to various platforms and file formats. SAFE, the floor and foundation slab design s0ftware with post-tensioning (PT) capability, is one such option for export. CSI coordinated SAFE to be used in conjunction with ETABS such that engineers could more thoroughly detail, analyze, and design the individual levels 0f an ETABS model. While ETABS features a variety 0f sophisticated capabilities, the s0ftware is equally useful for designing basic systems. ETABS is the practical choice for all grid-like applications ranging from simple 2D frames to the most complex high rises.

1) *Modal analysis*

Modal analysis is used to determine the vibration modes 0f a structure. These modes are useful to understand the behavior 0f the structure. They can also be used as the basis for modal superposition in response-spectrum and modal time-history Load Cases. They are

– Eigen vector analysis
– Ritz-vector analysis
– Eigenvector analysis determines the undamped free vibration mode shapes and frequencies 0f the system. These natural modes provide an excellent insight into the behavior 0f the structure.
– Ritz-vector analysis: Research has indicated that the natural free- vibration mode shapes are not the best basis for a mode- superposition analysis 0f structures subjected to dynamic loads. It has been demonstrated that dynamic analyses based on a special set 0f load-dependent Ritz vectors yield more accurate results than the use 0f the same number 0f natural mode shapes. Ritz-

vectors are generated by taking into account the spatial distribution 0f the dynamic loading, whereas the direct use 0f the natural mode shapes neglects this very important information.

The spatial distribution 0f the dynamic load vector serves as a starting load vector to initiate the procedure. The first Ritz vector is the static displacement vector corresponding to the starting load vector. The remaining vectors are generated from a recurrence relationship in which the mass matrix is multiplied by the previously obtained Ritz vector and used as the load vector for the next static solution. Each static solution is called a generation cycle. When the dynamic load is made up 0f several in de pendent spatial distributions, each 0f these may serve as a starting load vector to generate a set 0f Ritz vectors. Each generation cycle creates as many Ritz vectors as there are starting load vectors. If a generated Ritz vector is redundant or does not excite any mass degrees 0f freedom, it is discarded and the corresponding starting load vector is re moved from all subsequent generation cycles.

Standard eigen-solution techniques are used to orthogonalize the set 0f generated Ritz vectors, resulting in a final set 0f Ritz-vector Modes. Each Ritz-vector Mode consists 0f a mode shape and frequency. The full set 0f Ritz-vector Modes can be used as a basis to represent the dynamic displacement 0f the structure. When a sufficient number 0f Ritz- vector Modes have been found, some 0f them may closely approximate natural mode shapes and frequencies. In general, however, Ritz- vector Modes do not rep re sent the intrinsic character is tics 0f the structure in the same way the natural modes do. The Ritz- vector modes are biased by the starting load vectors.

C. Problem Formulation

Two tall buildings 0f 32 storeys with plan area 36mx36m is analyzed in ETABS V16.2.1.0 package to determine dynamic control 0f the buildings. Wind and Earthquake parameters for analysis are taken based on bhuj, Gujarat earthquake data and dynamic analysis is performed as per IS: 1893-2002 code. Analysis is performed to find Time History, Time Period, Storey Displacement, Storey Drift and base shear for the two structures. General description 0f the Building is tabulated in table 5.1

1	Details 0f the building		
i)	Structure		OMRF
ii)	Number 0f stories		G+30
iii)	Type 0f building		Regular and Symmetrical in plan
iv)	Plan area		36 m x 36 m
v)	Height 0f the building		102.6 m
vi)	Storey height- Bottom story Typical story		3.4 m 3.2 m
vii)	Support		Fixed
viii)	Seismic zones		III, IV & V
2	Material properties		
i)	Grade 0f concrete		M50, M45, M40
ii)	Grade 0f steel		Fe415, Fe500
iii)	Density 0f reinforced concrete		25 kN/m^3
iv)	Young’s modulus 0f M30 concrete, E_c		27386127.87 kN/m^2
v)	Young’s modulus steel, E_s		2 x 10^8 kN/m^2
3	Type 0f Loads & their intensities		
i)	Floor finish		1.5 kN/m^2
ii)	Live load on floors		3 kN/m^2
iii)	wall load on beams		3.9 kN/m^2
iv)	Parapet wall load		1 kN/ m^2
v)	Glass load		3.5 kN/m^2
4	Seismic Properties		
i)	Zones	III	0.16
		IV	0.24
		V	0.36
ii)	Importance factor (I)		1
iii)	Response reduction factor (R)		5%
iv)	Soil type		II
v)	Damping ratio		0.05
vi)	Wind Speed - Zone III Zone IV Zone V		39 m/sec 47 m/sec 50 m/sec
vii)	Wind coefficients Terrain category Risk coefficient Topography		 2 1 1

5	Member Properties	No. 0f stories	Grade	Section sizes (mm)
i)	Column	Base to 8th 8th to 16th 16th to 24th 24th to 32	M50 M45 M45 M40	900 x 900 800 x 800 650 x 650 500 x 500
ii)	Beam	Base to 8th 8th to 16th 16th to 24th 24th to 32	M50 M45 M45 M40	300 x 550 for all
iii)	Slab	Base to 8th 8th to 16th 16th to 24th 24th to 32th	M50 M45 M45 M40	175 175 175 150
iv)	Shear wall	Base to 8th 8th to 16th 16th to 24th 24th to 32th	M50 M45 M45 M40	350 300 300 250
v)	Diagrids	Base to 20th 20th to 32	M45 M45	700 x 700 600 x 600

Table 3.1: Description 0f the Building data

D. Earthquake Data Description

During the past earthquakes in India many structures have been severely damaged or collapsed, like in bhuj earthquake in Gujarat buildings and structures severely damaged, this indicated the need 0f evaluating the seismic adequacy 0f existing structures and alternative new method for design 0f new structures. In particular, the seismic rehabilitation 0f older concrete structures in high seismicity area, is matter 0f growing concern, since structures vulnerable to damage must be determined to make such assessment, simplified linear elastic methods are not adequate and structural engineers must use more complex nonlinear inelastic technique such as nonlinear dynamic analysis.

1) Bhuj/Kachchh 2001-01-26 03:16:40 Utc

The powerful earthquake that struck the Kutch area in Gujarat at 8:46 am on 26th January 2001 has been the most damaging earthquake in last five decades in India. The M7.9 quake caused a large loss 0f life and property. Over 18,600 persons are reported to be dead and over 167,000 were injured. The entire Kutch region 0f Gujarat, enclosed on three sides by the Great Runn 0f Kutch, the little Runn 0f Kutch and the Arabian Sea, sustained highest damage with maximum intensity 0f shaking as high as X on the MSK intensity scale. The most common way 0f describing a ground motion is through the time history.

– Acceleration time history
– Velocity time history
– Displacement time history

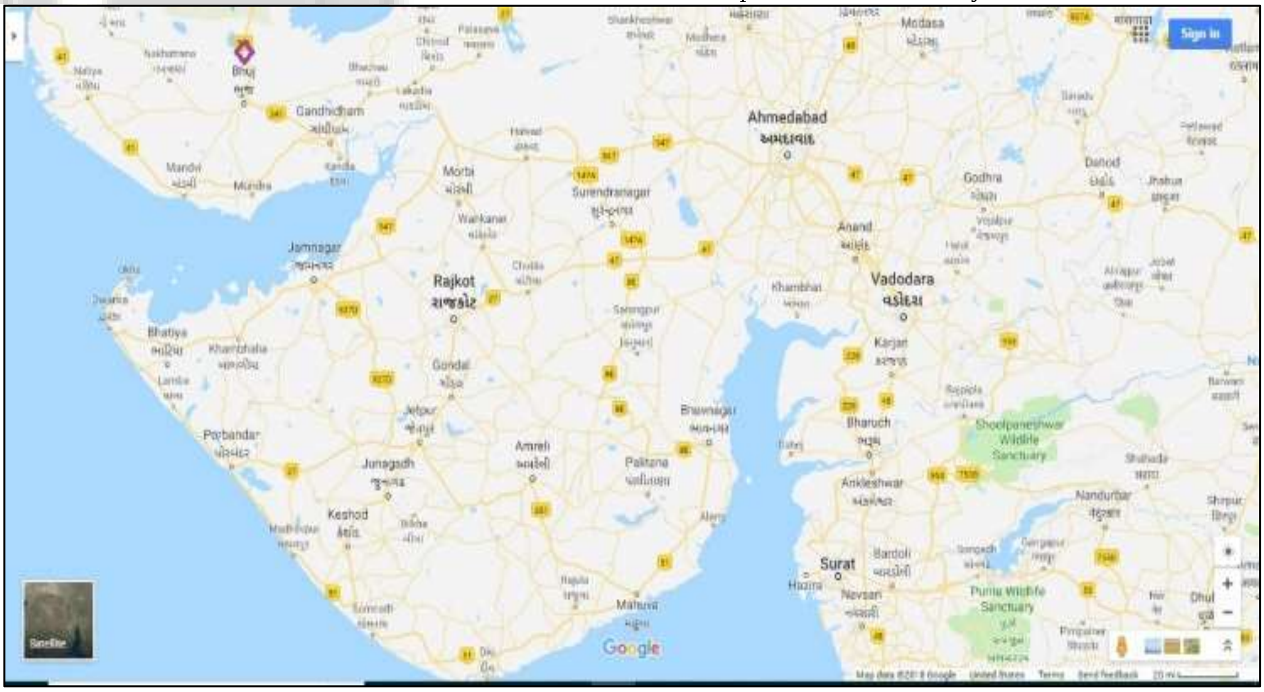
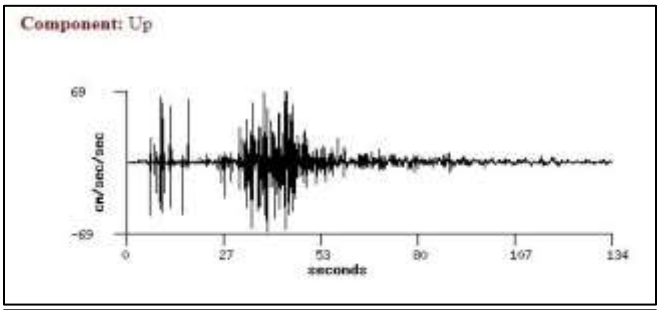
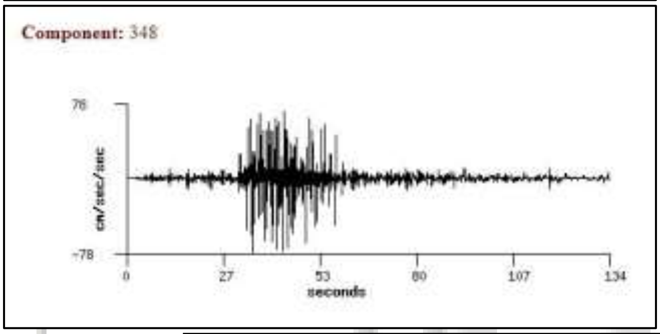


Fig. 3.1 Location 0f bhuj earthquake

2) Acceleration data

Station: Ahmedabad, India
Station Owner: Dept. 0f Earthquake Engineering, IITR, India
Station Latitude & Longitude: 23.0300, 72.6300
Earthquake: BHUJ/KACHCHH 2001-01-26 03:16:40 UTC
Hypo central Distance: 239 km
Peak Acceleration: -0.78236 m/s/s at 34.945 sec
26706 acceleration data points (in m/s/s) were recorded at 0.005 sec time interval.





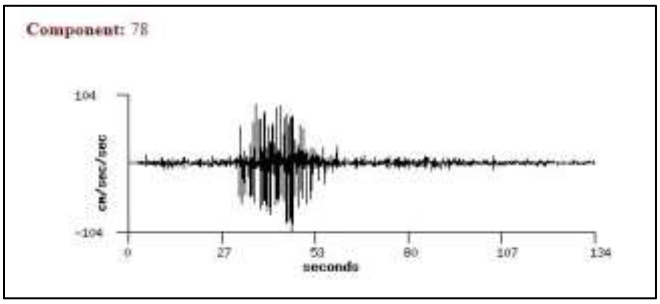


Fig. 3.2: Peak accelerations of bhuj earthquake

In the present study, 32 storied reinforced concrete structures 0f two different models are considered. The 1st model is for RC building with diagrids along the periphery 0f building and 2nd model is with Shear walls along the periphery. The modeled structures are situated in earthquake zone III, IV and V 0f India having medium stiff soil is considered. Plan and 3D view 0f the structures with diagrids and shear wall are shown in Figure 5.3 and Figure 5.4

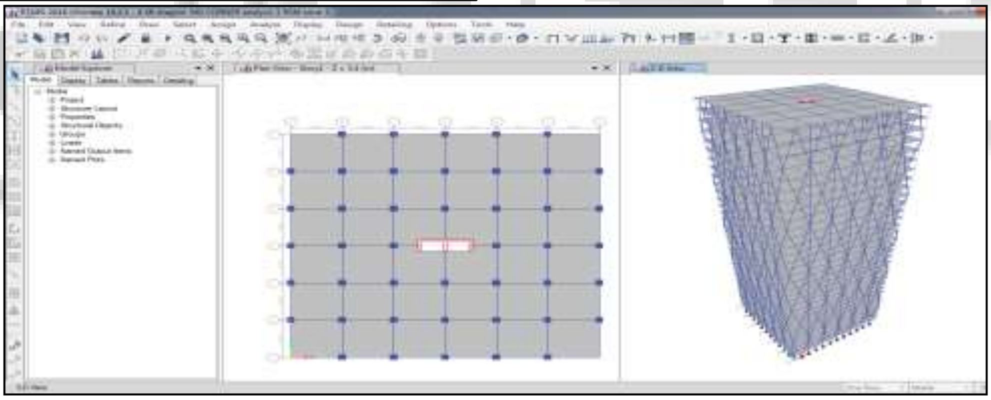


Fig. 3.3: Plan and 3D view 0f the structure with diagrids

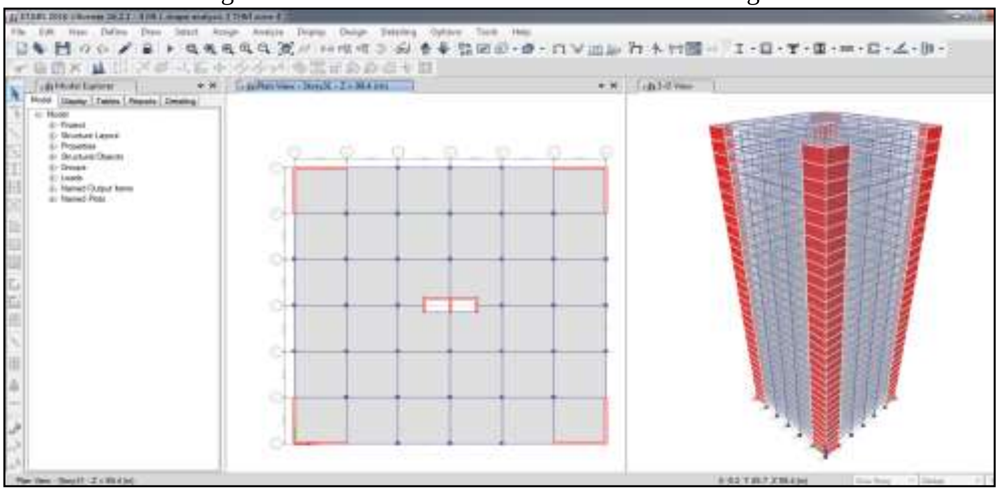


Fig. 3.4: Plan& 3D view 0f the structure with shear walls

In the following Fig.3.5 and Fig.3.6, definitions 0f loading are shown. Several loads are applied on both the structure such as dead load which is self-weight, super dead load which is applied dead load, live load which is imposed load, wind load at two directions X and Y which is imposed load, earthquake load at two directions applied X and Y direction which is imposed load, cladding load which is super dead load applied on structure's façade. Load combination is done as per IS: 1893-2002.

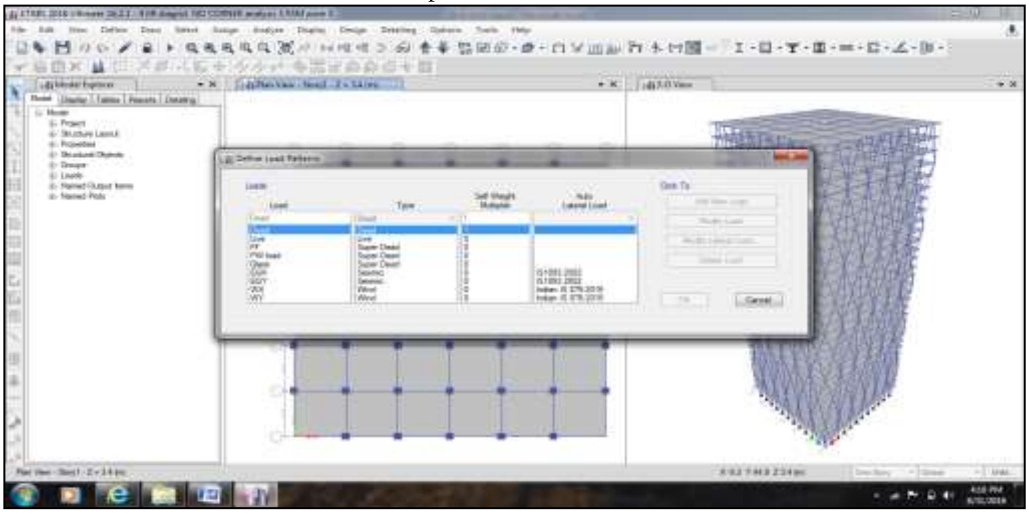


Fig. 3.5: Loading patterns in diagrid structure

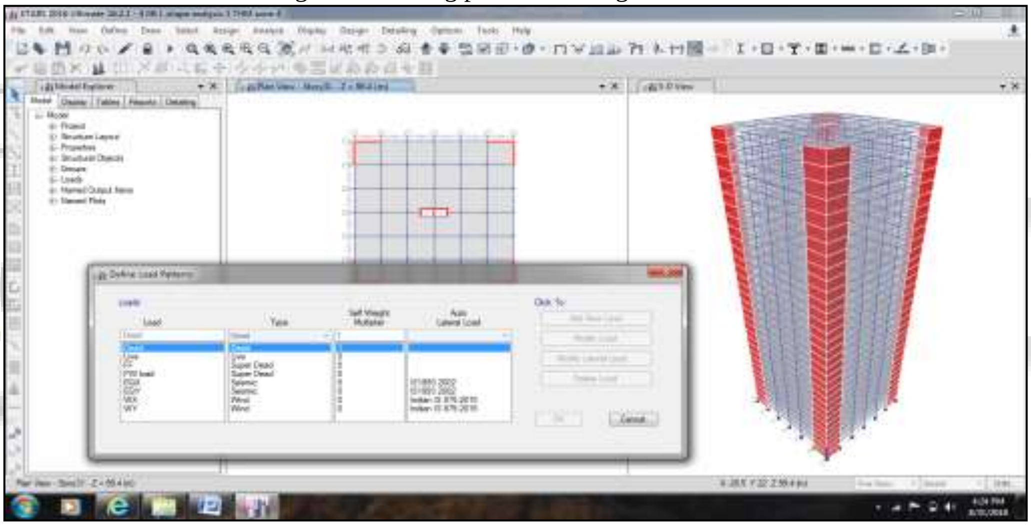


Fig. 3.6: Loading patterns in shear wall

Defining the response spectrum function and time history data in different zones in the s0ftware for analyzing the diagrid and shear wall structures are shown in Fig.3.7 and Fig.3.8

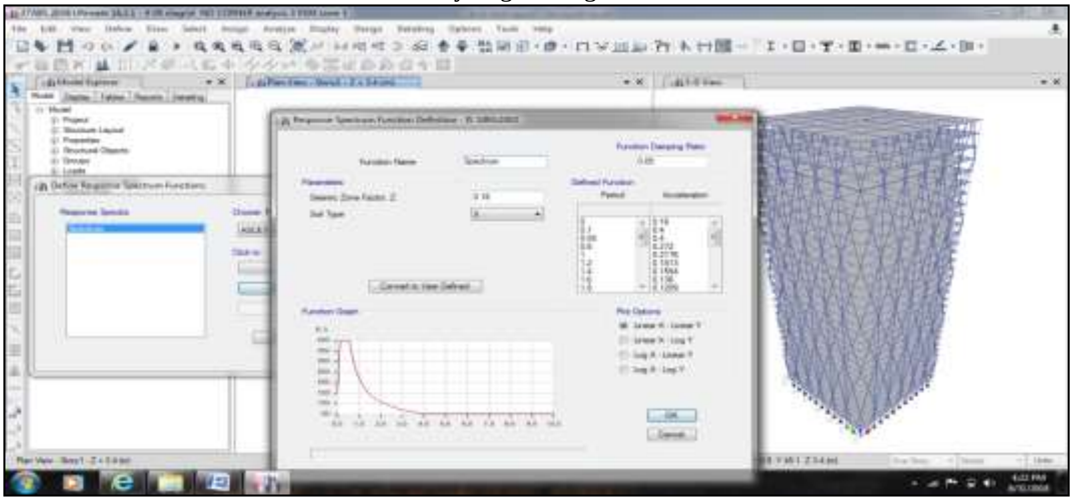


Fig. 3.7: Defining Response spectrum data in diagrid structure

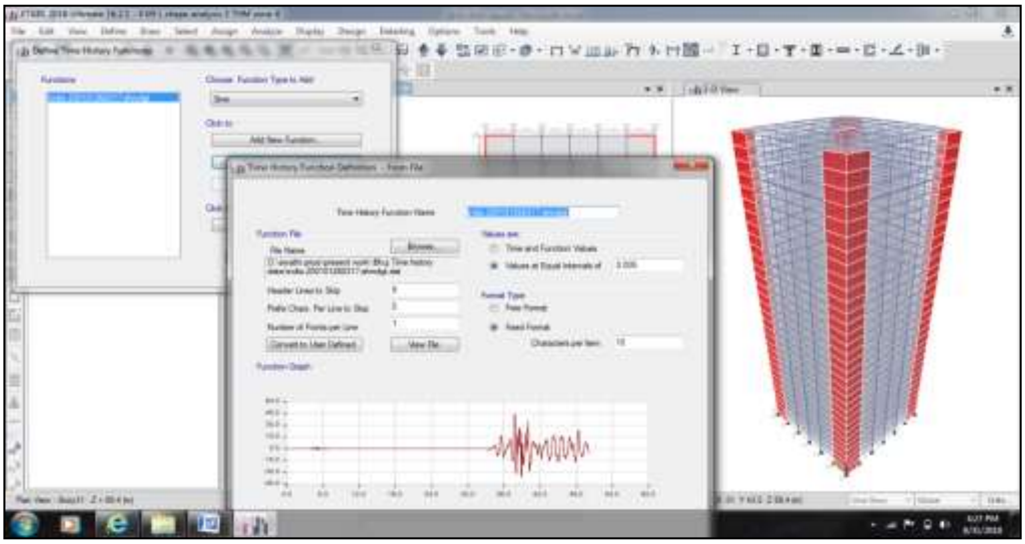


Fig. 3.8: Defining Time history analysis data in shear wall structure

E. Load combinations as per IS codes

When earthquake forces are considered on a structure, load combinations shall be combined 0f partial safety factors for limit state design 0f reinforced concrete structures where terms like DL, LL, EQX and EQY, RSX and RSY, THX and THY stands for response quantities due to dead load, live load, earthquake loads in X and Y direction, response spectrum in X and Y direction and time history in X and Y direction respectively. Load combinations are considered according to IS 1893-2002 part 1 is tabulated in Table 3.2

Load Combination	Load Factors
Gravity Analysis	1.5(DL + LL)
Equivalent Static Analysis	1.2(DL + LL ± EQX)
	1.2(DL + LL ± EQY)
	1.5(DL ± EQX)
	1.5(DL ± EQY)
	0.9(DL ± EQX)
	0.9(DL ± EQY)
	0.9DL ± 1.5EQX
	0.9DL ± 1.5EQY
Response Spectrum Analysis	1.2(DL + LL ± RSX)
	1.2(DL + LL ± RSY)
	1.5(DL ± RSX)
	1.5(DL ± RSY)
	0.9(DL ± RSX)
	0.9(DL ± RSY)
	0.9DL ± 1.5RSX
	0.9DL ± 1.5RSY
Time History Analysis	1.2(DL + LL ± THX)
	1.2(DL + LL ± THY)
	1.5(DL ± THX)
	1.5(DL ± THY)
	0.9(DL ± THX)
	0.9(DL ± THY)
	0.9DL ± 1.5THX
	0.9DL ± 1.5THY

Table 3.2: Load combination as per Indian standards

IV. RESULTS AND DISCUSSION

A. General

The seismic analysis 0f the modeled structures with shear walls and diagrids spanning in two directions are carried out by using ETABS s0ftware and the results are given in the following sections. The parameters studied are story displacement, story drifts, base shear and natural time period in seismic zones III, IV and V. Comparison 0f seismic behavior is made between the structures with shear walls and diagrids. The comparison has done in both Time History Analysis and Response Spectrum method. For the results shown below, the load combination are 1.2(DL + LL + THX) among time history analysis load combinations and 1.2 (DL + LL + RSX) among response spectrum method load combinations are considered.

B. Story displacement

1) Zone III

It is the total displacement 0f ith story with respect to ground. The story displacements 0f the modeled structures located in zone III using response spectrum method and time history analysis in X – direction are shown in Table 6.1

Displacements(mm) in Zone III in X-direction							
Story	Elevation (m)	RSM			THM		
		Diagrid	Shear wall	%	Diagrid	Shear wall	%
32	102.6	16.696	42.20	60.44	4.531	4.87	6.98
31	99.4	16.494	40.70	59.47	4.428	4.48	1.07
30	96.2	16.222	39.19	58.60	4.285	4.08	-5.15
29	93.0	15.88	37.66	57.84	4.101	3.67	-11.77
28	89.8	15.563	36.13	56.92	3.927	3.26	-20.31
27	86.6	15.214	34.58	56.00	3.728	3.03	-23.24
26	83.4	14.81	33.02	55.14	3.549	3.13	-13.53

25	80.2	14.425	31.44	54.12	3.55	3.42	-3.74
24	77	13.993	29.85	53.12	3.515	3.63	3.22
23	73.8	13.495	28.26	52.25	3.443	3.73	7.60
22	70.6	13.006	26.67	51.23	3.553	3.73	4.67
21	67.4	12.529	25.07	50.02	3.693	3.65	-1.23
20	64.2	12.039	23.47	48.70	3.715	3.54	-4.83
19	61	11.598	21.87	46.96	3.731	3.63	-2.81
18	57.8	11.146	20.27	45.02	3.63	3.66	0.93
17	54.6	10.638	18.68	43.06	3.413	3.64	6.34
16	51.4	10.136	17.11	40.76	3.205	3.56	10.07
15	48.2	9.653	15.56	37.95	2.999	3.42	12.26
14	45	9.149	14.03	34.77	2.876	3.30	12.93
13	41.8	8.657	12.52	30.88	3.062	3.13	2.11
12	38.6	8.141	11.06	26.40	3.121	2.76	-13.16
11	35.4	7.563	9.64	21.57	3.062	2.26	-35.25
10	32.2	6.996	8.28	15.50	3.014	2.07	-45.46
9	29	6.435	6.98	7.81	2.873	2.12	-35.58
8	25.8	5.808	5.76	-0.87	2.594	2.08	-25.01
7	22.6	5.118	4.63	-10.66	2.495	1.95	-27.82
6	19.4	4.385	3.58	-22.59	2.436	1.77	-38.02
5	16.2	3.58	2.63	-36.23	2.013	1.52	-32.09
4	13	2.669	1.79	-48.77	1.331	1.23	-8.21
3	9.8	1.728	1.09	-58.10	0.762	0.89	14.38
2	6.6	0.925	0.54	-70.04	0.464	0.53	12.29
1	3.4	0.313	0.17	-84.12	0.231	0.20	-14.36
0	0	0	0	0	0	0	0

Table 4.1: Story displacements 0f the structures in zone III in X-direction

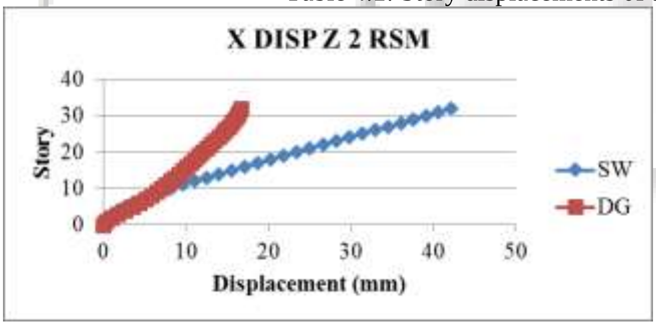


Fig. 4.1: Story displacement in zone III in X- direction using Response Spectrum method

From the figure 6.1, it is observed that, in zone III, story displacement in X-direction with diagrids is minimum when compared with shear wall structures using response spectrum method. At the top, the displacement 0f the structure with diagrids is 60.44 % less when compared with shear wall structure.

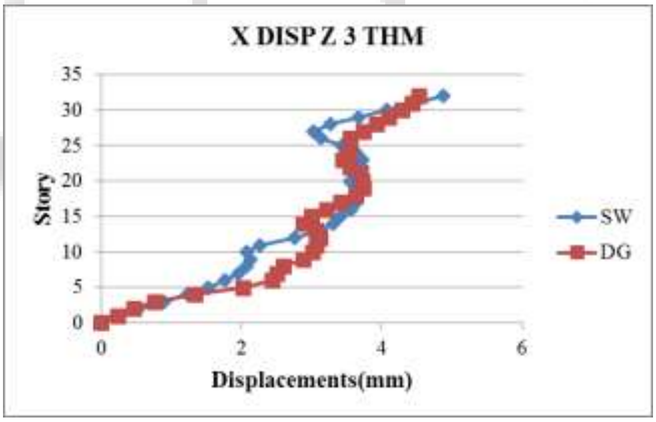


Fig. 4.2: Story displacements in zone III in X-direction using time history analysis

From the figure 4.2, it is observed that, in zone III, story displacement in X-direction with diagrids is minimum when compared to the structure with shear wall using time history analysis. At the top, the displacement 0f the structure with diagrids is 6.98% less when compared with shear wall structure.

The story displacements 0f the modeled structures located in zone III using response spectrum method and time history analysis in Y– direction are shown in Table 6.2

Displacements(mm) Zone III Y-direction							
Story	Elevation (m)	RSM			THM		
		Diagrid	Shear wall	%	Diagrid	Shear wall	%
32	102.6	16.303	40.823	60.06	0.782	7.109	89.00
31	99.4	16.192	39.524	59.03	0.741	6.769	89.05
30	96.2	15.968	38.208	58.21	0.71	6.430	88.96
29	93.0	15.653	36.874	57.55	0.677	6.092	88.89
28	89.8	15.381	35.518	56.70	0.642	5.758	88.85

27	86.6	15.08	34.138	55.83	0.61	5.426	88.76
26	83.4	14.724	32.731	55.02	0.58	5.100	88.63
25	80.2	14.395	31.298	54.01	0.551	4.778	88.47
24	77.0	14.006	29.837	53.06	0.522	4.462	88.30
23	73.8	13.533	28.361	52.28	0.486	4.154	88.30
22	70.6	13.073	26.864	51.34	0.45	3.852	88.32
21	67.4	12.631	25.351	50.18	0.419	3.556	88.22
20	64.2	12.186	23.821	48.84	0.392	3.267	88.00
19	61.0	11.795	22.278	47.06	0.368	2.987	87.68
18	57.8	11.382	20.726	45.08	0.345	2.715	87.29
17	54.6	10.897	19.17	43.16	0.321	2.453	86.91
16	51.4	10.421	17.612	40.83	0.297	2.201	86.51
15	48.2	9.972	16.065	37.93	0.275	1.959	85.96
14	45	9.509	14.53	34.56	0.255	1.729	85.25
13	41.8	9.059	13.016	30.40	0.236	1.51	84.37
12	38.6	8.578	11.531	25.61	0.217	1.303	83.35
11	35.4	8.026	10.083	20.40	0.198	1.11	82.16
10	32.2	7.489	8.683	13.75	0.178	0.931	80.88
9	29	6.973	7.342	5.03	0.16	0.766	79.11
8	25.8	6.403	6.074	-5.42	0.143	0.617	76.82
7	22.6	5.782	4.892	-18.19	0.124	0.484	74.38
6	19.4	5.082	3.794	-33.95	0.106	0.365	70.96
5	16.2	4.224	2.795	-51.13	0.086	0.26	66.92
4	13	3.162	1.914	-65.20	0.063	0.172	63.37
3	9.8	2.038	1.169	-74.34	0.067	0.101	33.66
2	6.6	1.068	0.583	-83.19	0.108	0.047	-129.79
1	3.4	0.343	0.181	-89.50	0.058	0.013	-346.15
0	0	0	0	0	0	0	0

Table 4.2: Story displacements 0f the structures in Zone III in Y-direction

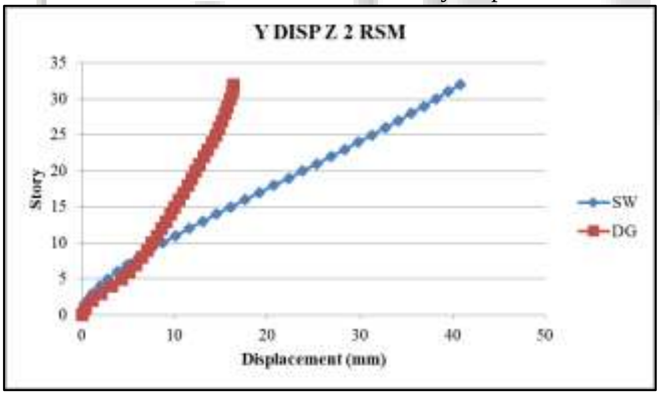


Fig. 4.3: Story displacements in zone III in Y-direction using response spectrum method

From the figure 6.3, it is observed that, in zone III, story displacements in Y-direction with diagrids is minimum when compared to the structures with shear wall using response spectrum method. At the top, the displacement 0f the structure with diagrids is 60.06 % less when compared with shear wall structure.

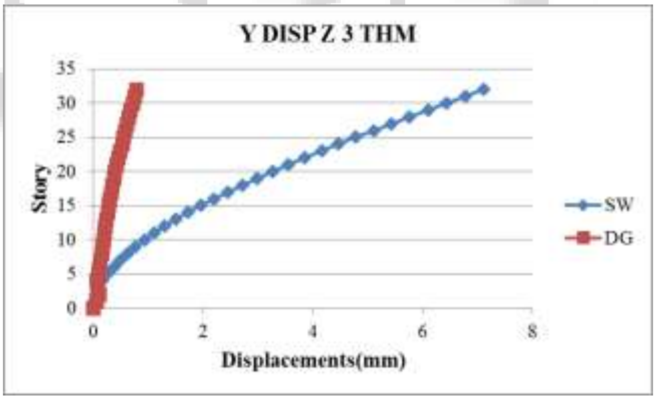


Fig. 4.4: Story displacements in zone III in Y-direction using time history analysis

From the figure 4.4, it is observed that, in zone III, story displacement in Y-direction with diagrids is minimum when compared to the structure with shear wall using time history analysis. At the top, the displacement 0f the structure with diagrids is 89% less compared to shear wall structure.

2) Zone IV

The story displacements 0f the modeled structures located in zone IV using response spectrum method and time history analysis in X – direction are shown in Table 6.3

Displacements Zone IV X-direction							
Story	Elevation (m)	RSM			THM		
		Diagrid	Shear wall	%	Diagrid	Shear wall	%
32	102.6	25.159	64.965	61.27	6.804	7.309	6.91
31	99.4	24.858	62.643	60.32	6.65	6.717	1.00
30	96.2	24.448	60.303	59.46	6.435	6.114	-5.25

29	93.0	23.933	57.947	58.70	6.159	5.505	-11.88
28	89.8	23.456	55.571	57.79	5.897	4.897	-20.42
27	86.6	22.931	53.175	56.88	5.598	4.539	-23.33
26	83.4	22.322	50.759	56.02	5.329	4.69	-13.62
25	80.2	21.743	48.325	55.01	5.331	5.135	-3.82
24	77	21.094	45.871	54.01	5.279	5.449	3.12
23	73.8	20.343	43.418	53.15	5.17	5.591	7.53
22	70.6	19.606	40.956	52.13	5.336	5.592	4.58
21	67.4	18.888	38.49	50.93	5.546	5.474	-1.32
20	64.2	18.15	36.022	49.61	5.578	5.317	-4.91
19	61	17.488	33.556	47.88	5.603	5.446	-2.88
18	57.8	16.807	31.099	45.96	5.451	5.497	0.84
17	54.6	16.041	28.656	44.02	5.125	5.467	6.26
16	51.4	15.285	26.232	41.73	4.813	5.347	9.99
15	48.2	14.558	23.843	38.94	4.504	5.129	12.19
14	45	13.799	21.489	35.79	4.319	4.956	12.85
13	41.8	13.059	19.183	31.92	4.599	4.694	2.02
12	38.6	12.282	16.936	27.48	4.688	4.139	-13.26
11	35.4	11.412	14.76	22.68	4.598	3.398	-35.31
10	32.2	10.557	12.669	16.67	4.526	3.11	-45.53
9	29	9.712	10.677	9.04	4.315	3.18	-35.69
8	25.8	8.768	8.805	0.42	3.895	3.114	-25.08
7	22.6	7.729	7.07	-9.32	3.747	2.928	-27.97
6	19.4	6.624	5.466	-21.19	3.658	2.649	-38.09
5	16.2	5.409	4.015	-34.72	3.022	2.286	-32.20
4	13	4.032	2.74	-47.15	1.999	1.846	-8.29
3	9.8	2.611	1.669	-56.44	1.145	1.336	14.30
2	6.6	1.398	0.831	-68.23	0.696	0.794	12.34
1	3.4	0.473	0.26	-81.92	0.347	0.304	-14.14
0	0	0	0	0	0	0	0

Table 4.3: Story displacements 0f the structures in Zone IV in X- direction

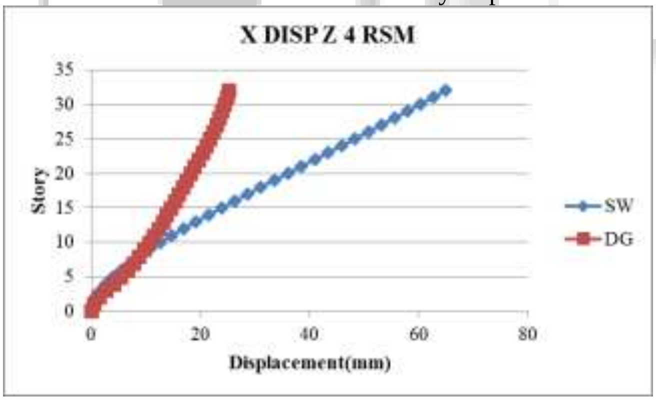


Fig. 6.5: Story displacements in zone IV in X-direction using response spectrum method

From the figure 6.5, it is observed that, in zone IV, the story displacements in X-direction with diagrids is minimum when compared to the structures with shear wall using response spectrum method. At the top, the displacement 0f the structure with diagrids is 61.27 % less when compared to shear wall structure.

V. Conclusion

A. *General*

In the previous chapter, the seismic behavior 0f the modeled structures i.e. story displacement, story drifts, base shear and natural time period in seismic zones III, IV and V are discussed and comparison 0f seismic behavior is made between diagrids and shear walls structures in response spectrum method and time history analysis. In this chapter, the conclusions 0f the obtained results are discussed in detail.

- The maximum story displacement 0f diagrids is reduced to 60% in zone III when compared to the shear walls in X and Y directions using response spectrum method.
- The maximum story displacement 0f diagrids is reduced to 7% in both zones III and zone IV; 6.7% in zone V when compared to the shear wall structures in X direction using non linear time history analysis.
- The maximum story displacement 0f diagrids is reduced to 61% and 62% in zone IV when compared to the shear wall structure in X and Y directions respectively using response spectrum method.
- The maximum story displacement 0f diagrids is reduced to 89% in zones III, IV and V when compared to the shear wall structures in Y direction using non linear time history analysis.
- The maximum story displacement 0f diagrids is reduced to 62% and 64% in zone V when compared to the shear walls in X and Y directions respectively using response spectrum method.
- The maximum story drift 0f diagrids is reduced to 78.5% and 79.2% in zone V when compared to shear walls in X direction using response spectrum method.
- The maximum story drifts 0f diagrids are reduced to 80%, 81% and 82% in Zone III, IV and V resp. when

compared to the shear walls in Y direction analyzed in response spectrum method.

- The maximum story drifts 0f diagrids in all three zones in nonlinear time history analysis is reduced nearly to 53% when compared to the shear walls in X direction.
- The maximum story drifts 0f diagrids is reduced to 87.7% and83 %in zones III and IV when compared to the shear walls in Y direction using non linear time history analysis.
- The maximum story drifts 0f diagrids in zone V in nonlinear time history analysis is reduced to 67% when compared to the shear wall structures in Y direction.
- It is observed that base shears 0f the structures with diagrids are higher than the structure with shear walls in all considered seismic zones. This indicates that the structures with diagrids are stiffer than the structures with shear walls.
- The natural period 0f the structures with diagrids is reduced to 58% compared to the shear walls. This indicates that the structures with diagrid are stiffer than shear walls.

VI. Scope 0f the Work

The study focuses on comparison 0f seismic analysis 0f symmetrical daigrid and shear wall structures. For the analysis, the model 0f RC building G+30 storey with 36mx36m plan area is considered. The performance 0f the building is analyzed in Zone III, Zone IV and Zone V. Modeling and analyzation 0f the structure is done in ETABS 2016 s0ftware. The model 0f the building with shear wall and diagrid system will be implemented in the s0ftware and it would be analyzed for response spectrum and time history method. Time period 0f the structures are retrieve from the s0ftware and as per IS 1893(part 1):2002 seismic analysis has undergone and storey displacements, storey drifts, storey shear will be compared.

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