COMPARATIVE STUDY OF DIAGRID STRUCTURE WITH CONVENTIONAL BUILDING HAVING DIFFERENT HEIGHTS

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Abstract - *Buildings in high-seismic areas must be designed with particular attention to their lateral stability during extreme earthquakes. A modern concept of shifting the vertical column's orientation to a diagonal column aids in the transformation of all forces into axial forces. Diagrid (Diagonal Grid of Columns) is a brand new structural system designed to improve a building's lateral stability. The diagrid structural system's aesthetics and structural advantages have made it a popular option for many buildings around the world, including many prominent high-rise structures constructed in recent years. The nonlinear behaviour and design of mid-to-high-rise steel diagrid structures are investigated in this paper. The results are compared to corresponding moment resisting frames and concentrically braced frames in terms of tale drift, time length, base share, and displacement in diagrids. Practical design guidelines are suggested using virtual work/energy diagrams and nonlinear seismic analysis using ETABs for G+7, G+11, and G+16 to improve nonlinear behaviour and increase collapse load potential of diagrid structures in high seismic regions.*

Keywords: Diagrid building, earthquake forces, time history analysis

1. INTRODUCTION

The word earthquake may be used to define any kind of seismic phenomenon that produces seismic waves, whether normal or caused by humans. Earthquakes are usually induced by seismic fault rupture, although they may also be sparked by volcanic activities, mine explosions, landslides, and nuclear testing. Many structures have primary construction systems that do not fulfill existing seismic standards and are severely damaged during an earthquake. India is divided into four zones based on seismic operations, according to the Seismic Zoning Map of IS: 1893-2002. Zones II, III, IV, and V are the four zones. Some companies construct full-scale models and do extensive research before mass-producing thousands of similar systems that have been studied and engineered with test outcomes in mind. Unfortunately, the construction industry may not have this choice, making large-scale creation unfeasible. Many current structures in India are built according to Indian standard code 456:2000, but in order to render buildings earthquake prone, IS 1893-2002 should be included.

In certain cases, the only loads acting on these systems are gravity loads, resulting in elastomeric structural behavior. However, in the case of a strong earthquake, a system can be exposed to forces that exceed its elastic limit. After the last earthquake in the last four decades, in which several concrete structures were severely weakened or destroyed, it has been essential to assess the seismic suitability of existing or planned structures. As a result, the structure's susceptibility to harm must be calculated. Simplified linear elastic approaches are not ideal for achieving or achieving this goal. As a result, structural engineers have devised a novel modeling approach and seismic protocol that incorporates performance-based structures and nonlinear techniques.

Linear static, linear dynamic, nonlinear static, and nonlinear dynamic analysis are the four types of analysis. The first two are only suitable if the systemic loads are minimal and the stress strains are below the elastic maximum. After an earthquake, structural loading may exceed collapse pressure, causing material stresses to exceed yield stresses. To obtain successful results in this situation, material nonlinearity and geometrical nonlinearity must be integrated into the study. Pushover analysis is a basic method for analyzing a building's nonlinear static nature. So, using output thresholds, the pushover curve, and the pushover analysis protocol, discuss pushover analysis in this project.

1.1 CONCEPT

The diagrid (a portmanteau of diagonal grid) is a structure for building and roof design that consists of diagonally intersecting metal, concrete, or wooden beams. In comparison to a traditional steel frame, it uses less structural steel. Diagrid structural system that may be characterized as trim components, how the bed was generated from the transition, different materials such as metal, concrete, or wooden beams used in the construction of the structure, and the roof are all discussed. Using steel pieces to construct diagonal constructions, you may quickly improve the C-power and stiffness properties of a structure. Today, however, it is commonly employed in diagrids found in large-span and high-rise structures, particularly when the forms are complicated or curved in nature. However, it is also the diagrid's diagonal element that is responsible for the shift and for the instant. Consequently, the height of the structure has an effect on the ideal exit angle for the diagonals. The ideal angle allocated to the greatest bending strength of a normal structure is 90 degrees diagonally, while the ideal angle allocated to the maximum shear strength of a normal structure is 35 degrees. It is thought that the ideal angle of the diagrid is located somewhere in the center of these two possibilities. As a general rule, temperatures are supposed to be in the range of 60 to 70 degrees Celsius. A building's ideal angle grows in proportion to its height.

1.2 BENEFITS

The diagrid system has a lot of benefits that can make it more favored be the designer against other systems. Some of those benefits are:
• Generally column free peripheral and internal.
• Generous amounts of day lighting due to dearth of internal columns and structure.
• Generally 1/5th saving in steel possible.
• Unsophisticated construction techniques (although they need to be perfected yet).
• Full utilization of the structural material.
• Similar design/construction tolerances as a typical moment frame construct (for instance: a type, columnar element would be created 1/8th of an inch longer than called for to allow for compression in the final product in a M.F. project. The same can be said for a Diagrid project).
• Open and clear, distinctive floor plans are possible.
• Aesthetically govern and significant.

1.3 OBJECTIVES

• To report the functioning of RC plane frames and Diagrid structure under seismic loads (Earthquake loads).
• To execute Non-Linear Analysis of diagrid structure with conventional building in ETABS.
• To analysis the performance of Diagrid structure with respect to different parameters such as story drift, story displacement, base shear.
• To report demand capacity curve of diagrid structure and conventional with pushover analysis.

2. LITERATURE REVIEW

Giulia Milana (2015) The aim of this research is to evaluate the robustness of a tall diagrid structure. The aim is to determine whether gains in terms of sustainability have a detrimental effect on the structure's structural robustness. Different failure conditions are compared numerically and the results are presented. The diagrid (diagonal grid) structural structure is one of the most evocative designs for tall buildings. Because of its aesthetics and structural efficiency, diagrid (with perimeter structural configurations) has emerged as a new design trend for tall-shaped complex structures. It is a more sustainable structure since it uses less structural steel than a traditional steel frame.

Seyed Saeid Tabaee (2015) The rising urban population and its demand on limited urban space has affected the construction of city dwellings, according to this paper. The high cost of property, as well as plans to discourage the construction of short buildings and modern architecture, has resulted in an increase in the number of tall buildings in urban areas. In comparison to the gravity load bearing mechanism, the resisting system against lateral forces becomes more critical as a structure rises. Moment frame, braced frame, dual frame, shear wall, outrigger system, and other lateral force resisting mechanisms are all commonly used. In recent years, designing engineers have embraced diagrid – diagonal networks – as a structural framework for tall buildings, owing to the structural efficiency and aesthetic architectural potential provided by the geometric configuration of the components. The diagrid system is a type of space truss that is unique. This structural framework is made up of triangular space trusses that form peripheral networks.

Kiran Kamath (2016) The efficiency characteristics of diagrid structures were investigated using nonlinear static pushover analysis in this research. The models investigated are circular in plan, with an aspect ratio of H/B ranging from 2.67 to 4.26 (where H is the overall height and B is the structure's base width). 59°, 71°, and 78° are the three different angles of external brace regarded. The structure's height is varied in accordance with the width of the foundation, which is held unchanged at 12m. Plastic hinges based on the moment-curvature relationship as defined in FEMA 356 guidelines are used to model the elements' nonlinear behaviour. Nonlinear static analysis was used to determine the seismic reaction of the system in terms of base shear and roof displacement corresponding to the output stage, and the findings were contrasted. All of the aspect ratios considered in the analysis indicate an improvement for the 71° brace angle model base shear at output. The brace angle and aspect ratio have an impact on the structure's efficiency.

Deepak Nathuji Kakade (2017) This paper presents an analysis of a 32-story diagrid structural structure without a vertical column across the periphery building. Here is a comparison of the study results in terms of storey displacement and storey drifts for them. Tall buildings have traditionally served as industrial office buildings. Since then, other uses such as retail, mixed-use, and hotel tower projects have exploded. Economic considerations, aesthetics, infrastructure, urban legislation, and politics all play a role in tall building growth. The most important governing principle has been economics. The structural architecture of a very tall building is normally controlled by its lateral stiffness.

U. A. Nawale (2017) In this article, ETABs and SAP software are used to compare storey drift and base shear of 32-story diagrid structural framework with or without vertical column around periphery building and simple frame building. Here is a comparison of the results of the study in terms of storey drift (As per IS 1893-2000) and base shear. The lateral loads caused by earthquakes and wind force have an effect on the design of high-rise buildings. Wall frame, shear wall, braced tube system, and outrigger system are examples of lateral load resistance systems. Because of its structural strength, the diagonal grid design is commonly used in steel buildings or tall buildings. It's a vertical bracing device with a triangulation configuration that transfers load. As far as the construction of a tall building is concerned, storey drift and displacement are the most significant factors.

Roham Afghani Khoraskani (2018) This research will assist architects in the shape generation process so that tall buildings have a better response to lateral loads and are structurally feasible. The interrelationships between architectural type and structural response of approximately 60 storey tall buildings with diagonal grid (Diagrid) structures are explored in this study using a parametric modelling strategy. The lower and upper floor plans' various geometries and dimensions, as well as the method of shape generation that determines the building's ascending development from base to top, resulted in 49 architectural schematic forms. The produced architectural forms are later mapped with Diagrid members of identical steel tubular section as the framework of the tall buildings. The structure is then subjected to lateral loads that reflect analogous static behaviour, and a static linear analysis is performed. Finally, the findings show that the structural behaviour of initial models is largely determined by the base floor plan rather than other parameters, and that architectural models with a higher side count have a higher structural performance.

Esmaeel Asadi (2018) This paper presents a detailed 12 investigation of the performance of steel diagrid structures in order to assess their core seismic 13 performance factors. Nonlinear static, time-history dynamic, and gradual dynamic are three types of dynamic. In a high 15 seismic zone, 14 analyses are used to evaluate diagrid output and collapse mechanisms. Four different methodologies are used to quantify seismic output factors such as reaction adjustment factor, ductility factor, over strength factor, and deflection amplification factor. Four archetype classes of diagrid buildings with heights ranging from four to thirty floors have been studied. For steel diagrid frames with 8 to 30 stories, a R factor of 4 to 19.5 is recommended unless 20 supplementary analyses are performed to find the optimal diagonal angle. An R factor of 3.5 to 4 is recommended for low-rise 21 steel diagrids (under 8 stories). 22 Furthermore, a 2.5 and 2 over strength and ductility is recommended. The groundwork for using steel diagrids in design provisions is laid out in this document.

Aida Mirniazmandan (2018) This is an academic paper. The diagrid structural system is currently very common among engineers and architects because of its structural efficiency and versatility in architectural planning. Since architects and engineers may use architectural and structural parameters to create more productive buildings, The aim of this study is to see how different geometric base and top plan configurations of tall buildings, as well as the angle of the diagrid framework, affect the total weight of structural elements per unit area and the horizontal displacement of the top floor in order to design efficient tall buildings (both minimized). To achieve this, the number of sides at the base and top plans are randomly increased, resulting in 64 parametric models with different cross-sectional shapes and a height of 180m. For varying angles of diagonal members, the created models are produced. Modeling is done with Rhino software and its plug-in Grasshopper, and structural analysis is done with Grasshopper's plug-in Karamba. Genetic algorithm-based optimization is used to find the best models. Finally, the optimum bound for diagrid angle is found to be between 53° and 70°, and the performance of buildings with diagrids that have the optimum diagonal angles increases as the number of polygonal cross-sections increases.

Yue Li (2018) Using static, time-history reactive, and gradual dynamic studies, this paper provides a thorough inquiry into the nonlinear performance of steel diagrid frameworks. The ASCE/SEI 41-13 and FEMA P-58 performance-based assessment approaches are used to establish a system for seismic performance assessment and loss estimation of steel diagrid buildings. The seismic failure of archetype diagrid buildings is estimated using illustrative and quantitative criteria for diagrid frame efficiency and damage assessment. The diagrids are found to have a high degree of lateral stiffness and collapse capability. However, the non-structural loss caused by stiff diagrid frames high maximum absolute floor acceleration can have an adverse effect on the estimated total loss. The corner diagonal members are the main elements in their action due to the shear lag effect. Building height, diagonal angle, and incomplete diagrid modules are also investigated for their impact on efficiency and loss.

Esmaeel Asadi (2018) The nonlinear behaviour and architecture of mid-to-high-rise steel diagrid structures was investigated in this article. Steel diagrids are analysed and compared to corresponding moment resisting frames and concentrically braced frames in terms of weight, storey drift, fundamental time, lateral stiffness, and sequence of plastic hinge forming. Practical architecture recommendations are suggested utilising simulated work/energy diagrams and nonlinear static analysis to enhance the nonlinear behaviour and increase the failure load potential of diagrid structures in high seismic regions. The diagrid method has mostly been used in the construction of tall buildings with a height of 20 to 100 metres. The diagrid system may also be a powerful and cost-effective structural system for mid-rise buildings in the 8-15-story range, according to the findings of this study.

Vimlesh V Agrawal (2019) In this article, land scarcity stifled horizontal progress, leading to the evolution of the town's vertical growth, which culminated in the construction of tall buildings. Fazlur Khan pioneered the design of tall buildings in the early 1960s. Tall buildings were able to get off the ground thanks to various structural systems, although advancements in material and building technology hastened their progress. The major force that influences the construction of tall buildings is the lateral load caused by wind and earthquakes, which is primarily resisted by either an exterior or an internal structural framework.

Alejandro Palacio Betancur (2020) The creation of various structural structures to ensure protection and serviceability against natural hazards has resulted from the study of high-rise buildings. Thanks to their high lateral stiffness and architectural potential, diagrid structures are a new trend in tubular high-rise buildings. Since the system's geometric flexibility allows for a wide range of element layouts that result in variations in the stiffness of each storey, determining an optimum configuration is critical for the design of these structures. Existing design codes and provisions do not provide precise guidance for diagrid structural structures, but there are many studies in the literature that use simplified calculation methods to provide design aids to engineers working with preliminary designs.

Vishalkumar Bhaskarbhai Patel (2020) The comparison of various forms of lateral load resisting systems is discussed in this article. The thesis is primarily concerned with evaluating the most efficient and cost-effective systems for resisting lateral loads such as wind and seismic loads. Conduct a comparative analysis of different lateral load resisting structures such as Shear wall, Belt Truss, Outrigger, Belt Truss + Outrigger, Diagrid, Staggered Truss, and Tube in Tube framework of a 10-story building with a plan size of 18m X 18m based on a literature examination. Static earthquake forces, dynamic earthquake forces (Response Spectrum analysis as per guidelines of IS: 1893-(Part 1) 2016), static wind forces as per IS: 875 (Part-3)-2015, and design based on IS: 800-2000 were all analysed using ETABs-2017. It was discovered that storey displacements and storey drifts are less in Diagrid systems in X-direction.

Snehal V. Mevada (2020) The main topics covered in this paper are the design of Core and Outrigger structural systems using ETABs tools, link design between RCC core and steel framework, seismic analysis compared with standard moment resisting framed RCC building, and cost efficiency analysis comparison with framed RCC building. This structure is built in such a way that more forces are drawn to the building's central core and fewer forces are borne by the building's perimeter. This device was often used for a building of medium height, in addition to tall structures.

3. SYSTEM DEVELOPMENT

In this paper, three G+7, G+11, G+16 diagrid building models for RCC were created and analysed in ETAB software for different positions of shear wall in zone V with subsoil Type medium -II. To confirm seismic activity with the same storey and storey height, both of the buildings are subjected to the same earthquake packing. Various seismic analysis techniques are used for the analysis of these simulations, but for this work, both linear static and non-linear static methods are used. The approaches are described in detail below.

METHOD OF ANALYSIS

Equivalent Static Method: The design lateral force due to earthquake is calculated as follow

- **Design horizontal seismic coefficient** :

The following expressions may be used to calculate the horizontal seismic coefficient Ah for a structure: - Ah = (Z/2) X (I/R) X (Sa/g) X (Z/2) X (Z/2) X (Z/2) X (Z/2) X (Z/2)

Assume that whatever the meaning of I/R, the value of Ah would not be less than Z/2 for any structure of T0.1 s.

What is the location?

Z is the zone aspect.

I = Importance factor, which is determined by the structure's practical application.

R=Response reduction factor, which varies based on the magnitude of the perceived seismic impact.

The structure's efficiency is a factor to consider.

Average reaction acceleration coefficient (Sa/g)

- **Design Seismic Base Shear** :

The total design lateral force or seismic base shear (Vh) along any principal direction is determined by the following expression:-

Vb = Ah .W

Where, W is the seismic weight of the building.

- **Distribution of design force** :

The design base shear (Vb) computed is distributed along the height of the building as below:

Qi=Vb (wihi2 / ∑wihi2)

Where,

Qi = Design lateral force at each floor level i

Wi = Seismic weight of floor i.

hi = Height of floor i measured from the base.

❖ Response Spectrum Method

The modal form, or modal superposition method, is another name for this method. The approach may be used on structures where modes other than the fundamental one have a major impact on the structure's reaction. It's especially useful for analysing forces and deformations in multi-story buildings caused by medium-intensity ground shaking, which results in a moderately significant yet basically linear reaction in the structure. The reaction continuum approach of seismic analysis has analytical advantages for predicting displacements and component forces in structural structures. Using smooth design spectra that are the average of many earthquake movements, the approach includes calculating only the maximum values of displacements and participant forces in each mode. Just one mode of vibration was considered in the seismic coefficient system (single mode method). The natural intervals and mode shapes obtained from free vibration analysis are used to calculate seismic force in the response spectrum process. During earthquake ground movements, the maximal reaction of an idealised single degree of freedom device with a given duration and damping is represented.

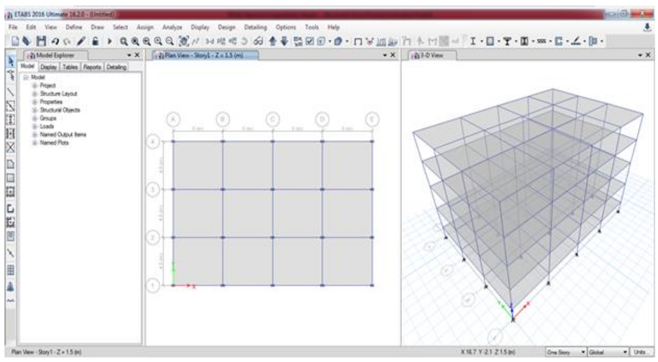


Fig. 1 - model structure of low rise building

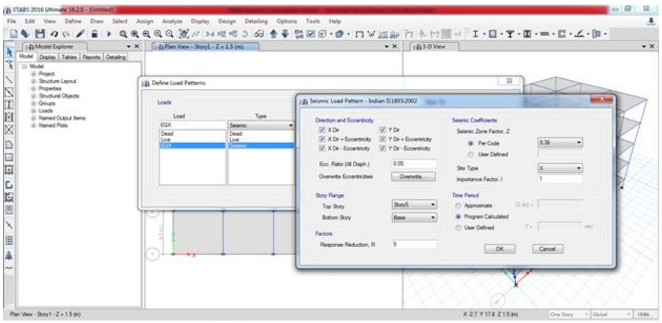


Fig. 2 - Implantation of IS 1893 provision in ETABs

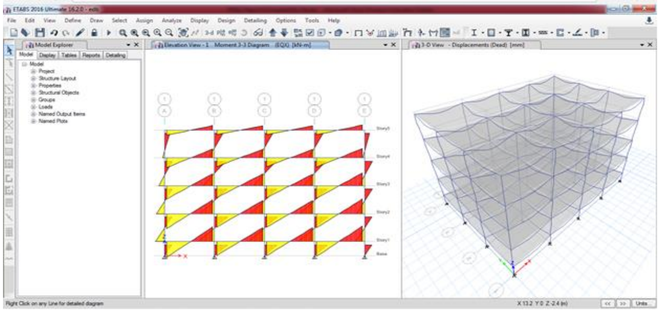


Fig. 3 - Shear force diagram due to earthquake load

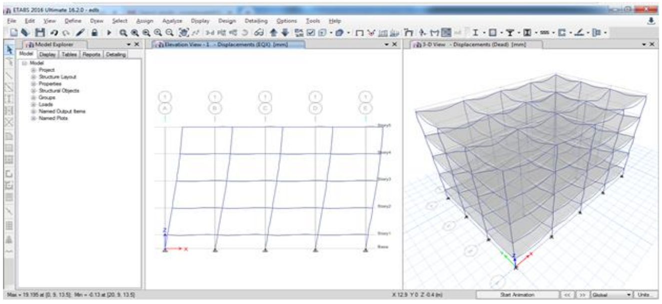


Fig. 4 - Deflection diagram due to earthquake load

4. METHODOLOGY

❖ Problem Statement

The considered design plan area is 18 x 18 m, with panels measuring 3x3 m for traditional with square diagrid buildings, and related areas considered for various levels G+7, G+11, and G+16.

Design parameters used for Study-

• Seismic Zones: III

• Models: G+7, G+11, G+16

• 3.6 m floor height

• Both configurations have the same grid configuration: a square 3 x 3 grid.

• Diagrid angle: 67.4°

• The plan is 18X18 m in dimension.

• Column dimensions: 500mm x 500mm

• Beam dimensions: 300mm x 500mm

• Slab thickness: 125 mm

• Diagonals Dimensions: 300X500 mm

• M30 is the concrete grade.

• Steel grade: Fe 500

❖ Methodology

There were two phases of the project investigation. The primary data was collected by a literature review that included online searches as well as a review of eBooks, guides, passwords, and journal articles. Following the evaluation, the issue statement is established, and the model is prepared for detailed research and examination. This research will be carried out according to the flow map below:

Software Analysis And Design Procedure

1. Describe Plan Grids and Story Data
2. Describe Material Properties
3. Describe Frame Sections
4. Describe Slab Sections
5. Describe Load Cases
6. Represent Beam Objects (Frame Members)
7. Represent Column Objects (Frame Members)
8. Allocate Slab Sections

9. Allocate Restrains
10. Allocate Slab Loads
11. View Input Data in Tabular Form
12. Run the Analysis
13. View Analysis Results Graphically
14. Design Concrete Frame Element

5. MODELING IN ETABs

Model 1 – G+7	Normal Building
	Diagrid Building
Model 2 – G+11	Normal Building
	Diagrid Building
Model 3 – G+16	Normal Building
	Diagrid Building

❖ Modeling G+7

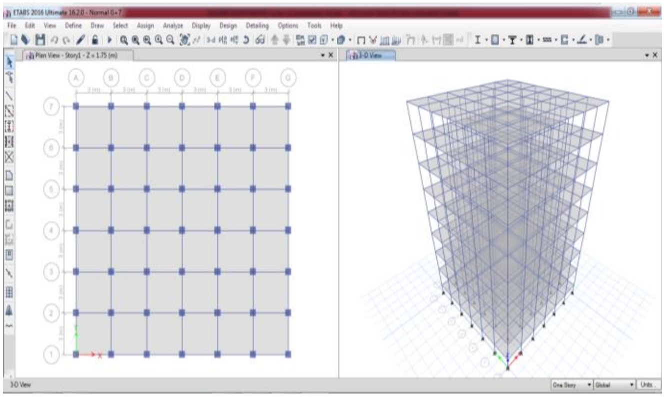


Fig. 5 – Normal Building G+7

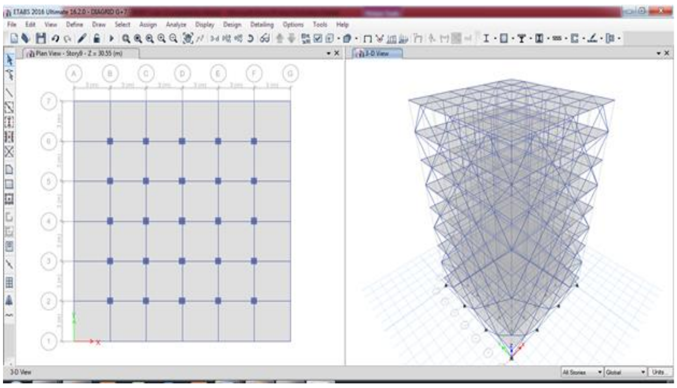


Fig. 6 – Diagrid Building G+7

❖ Modeling G+11

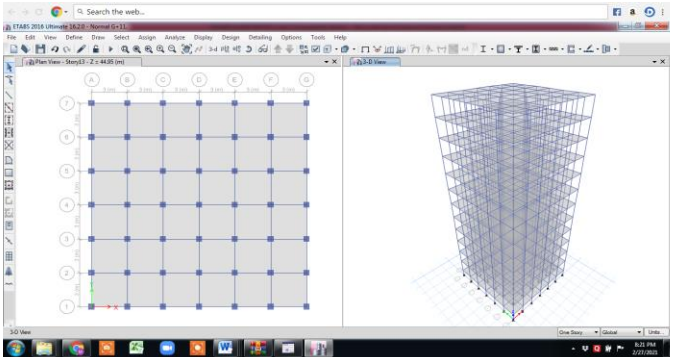


Fig. 7 – Normal Building G+11

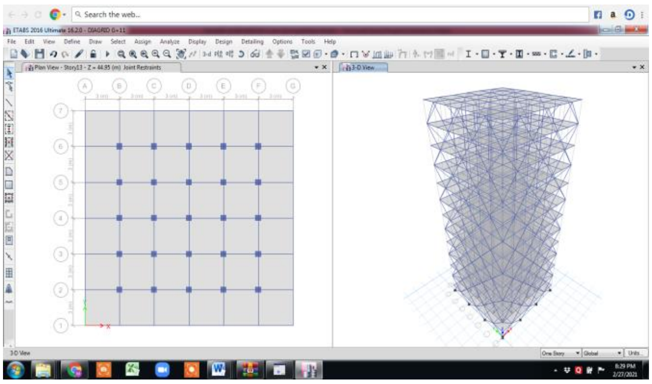


Fig. 8 – Diagrid Building G+11

❖ Modeling G+16

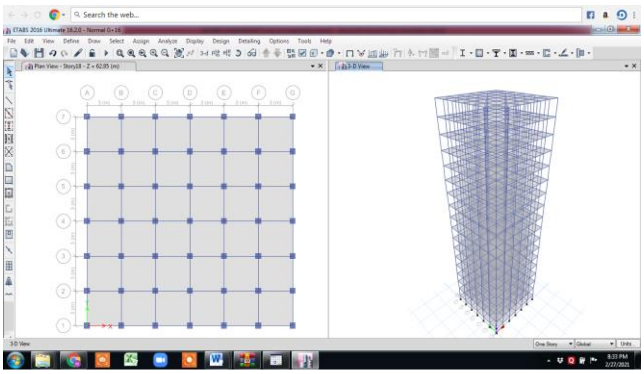


Fig. 9 – Normal Building G+16

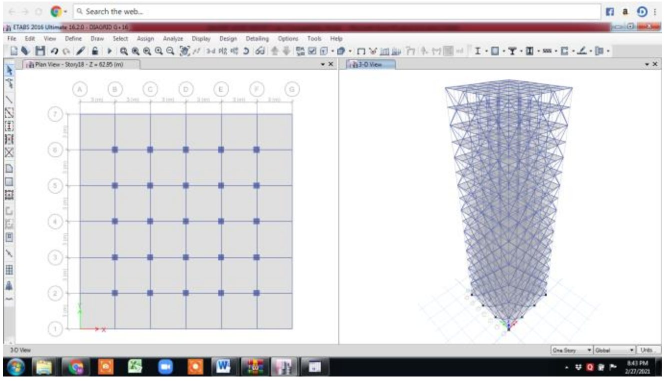
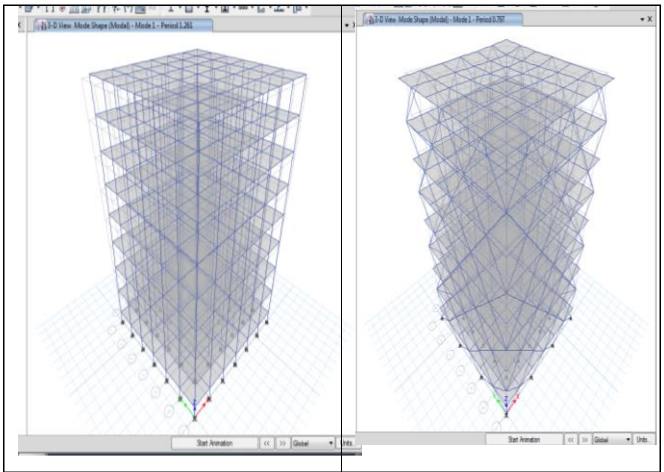


Fig. 10 – Diagrid Building G+16

1.8 RESULTS FOR THE MODEL 1

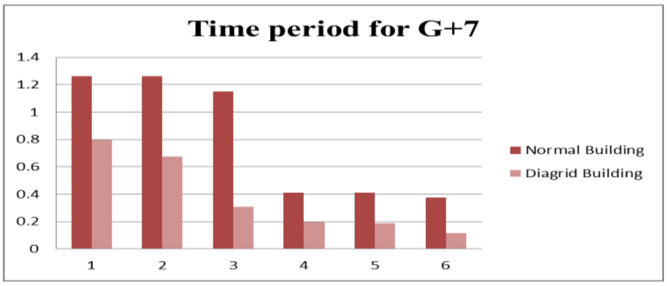


Mode Shape 1 For Normal G+7	**Mode Shape 1 For Normal G+7**

Fig. 11 – Mode shape for G+7

Mode	Normal Building	Diagrid Building
1	1.261	0.797
2	1.261	0.677
3	1.149	0.306
4	0.41	0.196
5	0.41	0.189
6	0.376	0.116

Table 1 - Time period result

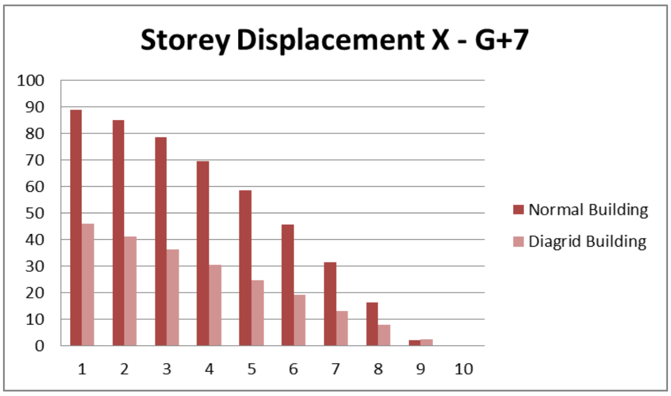


Graph 1 - Time period for G + 7

- **Storey Displacement for G+7**

Story	Normal Building	Diagrid Building
9	88.955	46.076
8	84.994	41.328
7	78.46	36.216
6	69.542	30.73
5	58.563	24.923
4	45.797	19.241
3	31.521	13.186
2	16.264	7.924
1	2.327	2.377
Base	0	0

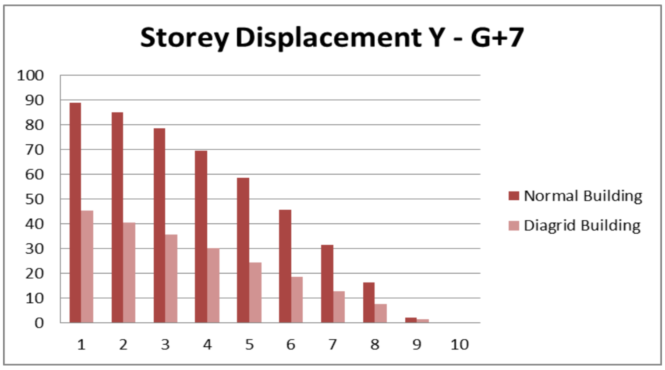
Table 2 - Storey Displacement result



Graph 2 - Storey displacement X for G + 7

Story	Normal Building	Diagrid Building
9	88.955	45.485
8	84.994	40.721
7	78.46	35.65
6	69.542	30.148
5	58.563	24.407
4	45.797	18.711
3	31.521	12.699
2	16.264	7.56
1	2.327	1.555
Base	0	0

Table 3 - Storey Displacement result

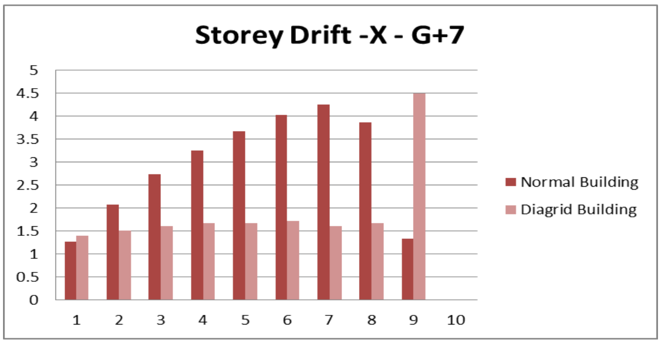


Graph 3 - Storey displacement Y for G + 7

❖ **Storey Drift for G+7**

Story	Normal Building	Diagrid Building
9	1.276	1.405
8	2.078	1.507
7	2.74	1.617
6	3.256	1.678
5	3.674	1.667
4	4.024	1.722
3	4.251	1.611
2	3.871	1.677
1	1.33	4.493
Base	0	0

Table 4 - Storey Drift result

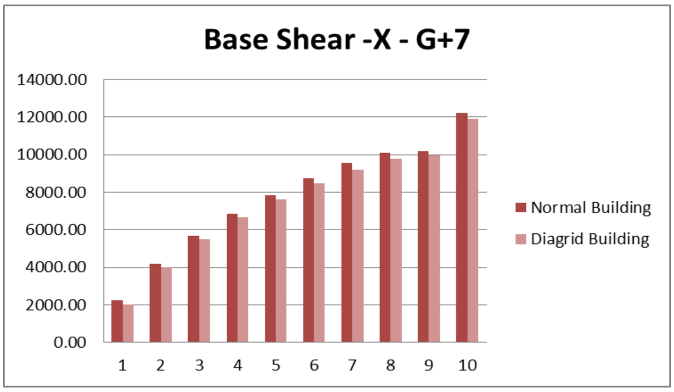


Graph 4 - Storey drift X for G + 7

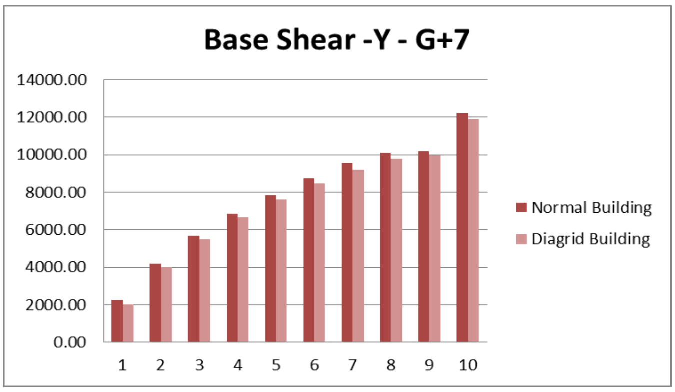
❖ **Base shear for G+7**

Story	Normal Building	Diagrid Building
9	2226.04	2038.61
8	4204.68	3994.51
7	5693.57	5482.46
6	6867.35	6650.40
5	7853.68	7618.07
4	8753.56	8467.34
3	9541.22	9203.62
2	10107.41	9765.56
1	10199.30	9985.79
Base	12203.76	11886.36

Table 5 - Base Shear result



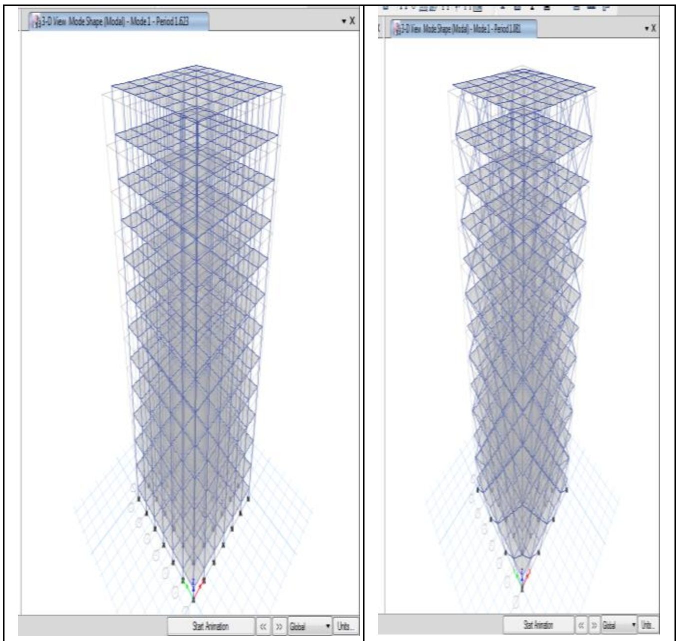
Graph 5 – Base shear X for G + 7



Graph 6 – Base shear Y for G + 7

1.9 RESULTS FOR THE MODEL 2 – G+11

❖ **Time period for G+11**

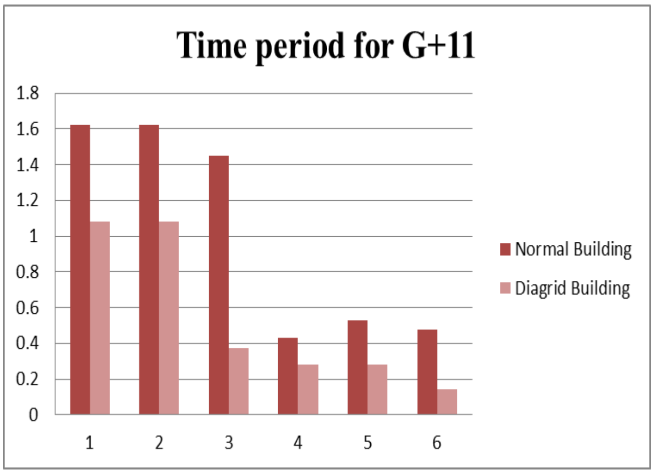


Mode Shape 1 For Normal G+11	Mode Shape 1 For Normal G+11

Fig. 12 – Mode shape for G+11

Mode	Normal Building	Diagrid Building
1	1.623	1.081
2	1.623	1.081
3	1.449	0.372
4	0.43	0.28
5	0.53	0.28
6	0.478	0.14

Table 6 - Time period result

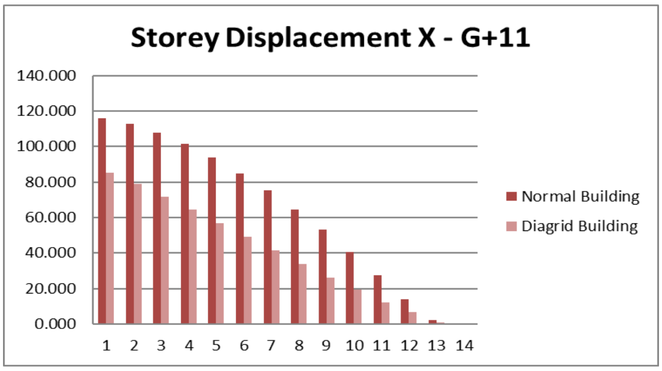


Graph 7 - Time period for G + 11

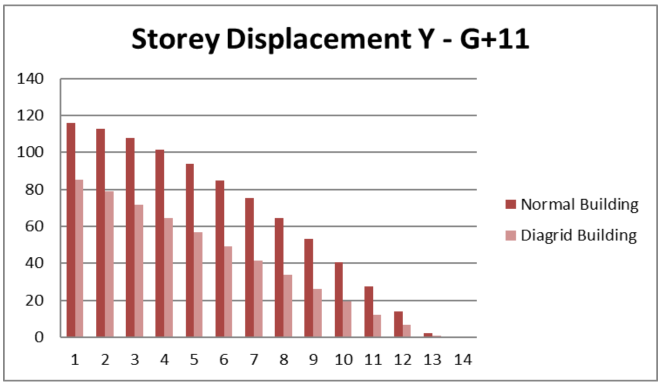
❖ **Storey Displacement for G+11**

Story	Normal Building	Diagrid Building
13	115.865	85.297
12	112.561	78.727
11	107.696	71.807
10	101.350	64.497
9	93.724	56.955
8	84.986	49.279
7	75.253	41.463
6	64.591	33.872
5	53.038	26.214
4	40.645	19.229
3	27.520	12.252
2	14.021	6.53
1	1.994	0.965
Base	0.000	0

Table 7 – Storey Displacement result



Graph 8 – Storey Displacement X for G+11

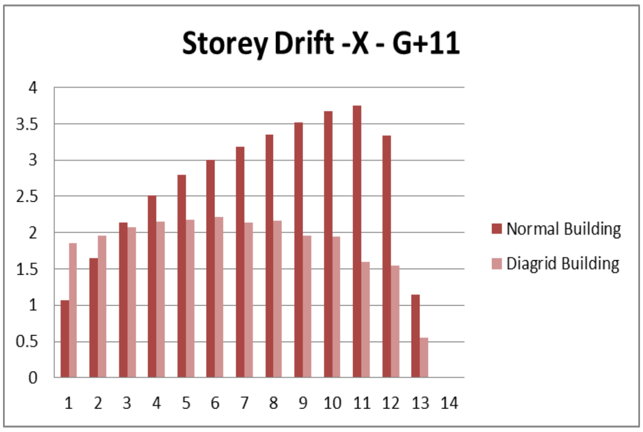


Graph 9 – Storey Displacement Y for G+11

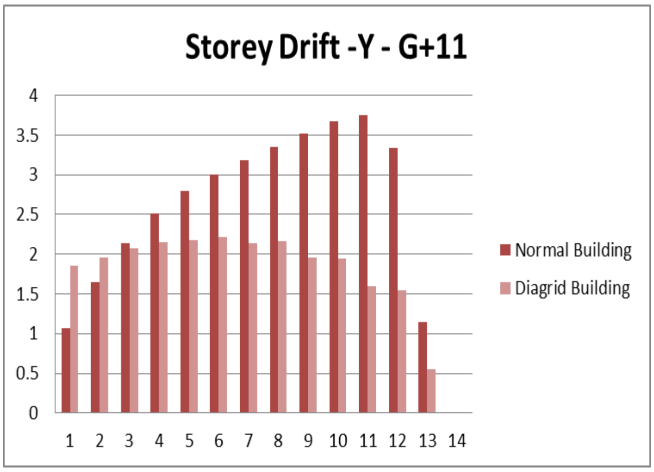
❖ **Storey Drift for G+11**

Story	Normal Building	Diagrid Building
13	1.074	1.85
12	1.643	1.963
11	2.134	2.079
10	2.508	2.153
9	2.791	2.18
8	3.007	2.222
7	3.187	2.14
6	3.356	2.158
5	3.523	1.953
4	3.676	1.95
3	3.755	1.591
2	3.341	1.548
1	1.139	0.552
Base	0	0

Table 8 – Storey Drift result



Graph 10 – Storey Drift X for G+11

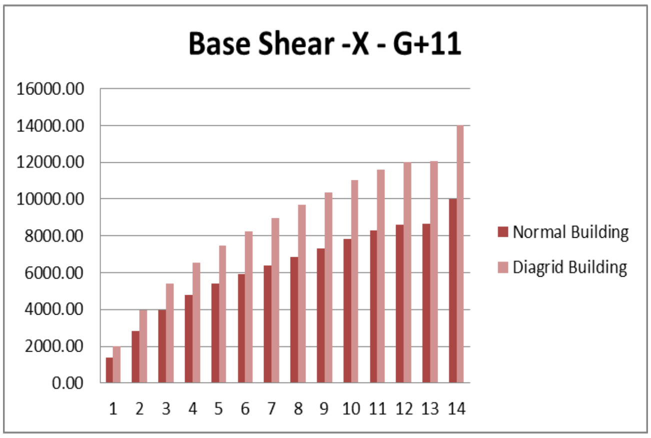


Graph 11 – Storey Drift Y for G+11

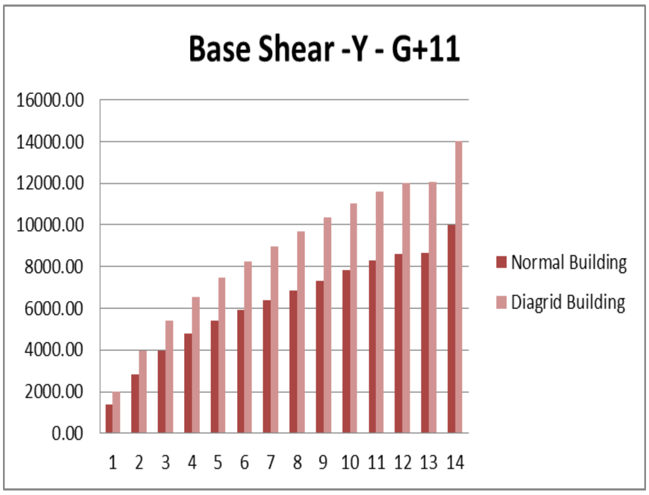
❖ **Base shear for G+11**

Story	Normal Building	Diagrid Building
13	1402.15	2025.83
12	2840.83	3959.88
11	3937.61	5426.93
10	4762.92	6558.83
9	5402.87	7460.37
8	5913.31	8237.24
7	6370.61	8956.49
6	6843.02	9672.14
5	7338.45	10380.82
4	7842.13	11045.47
3	8313.27	11615.04
2	8626.34	12002.25
1	8671.72	12080.20
Base	10023.71	14033.43

Table 9 – Base shear result



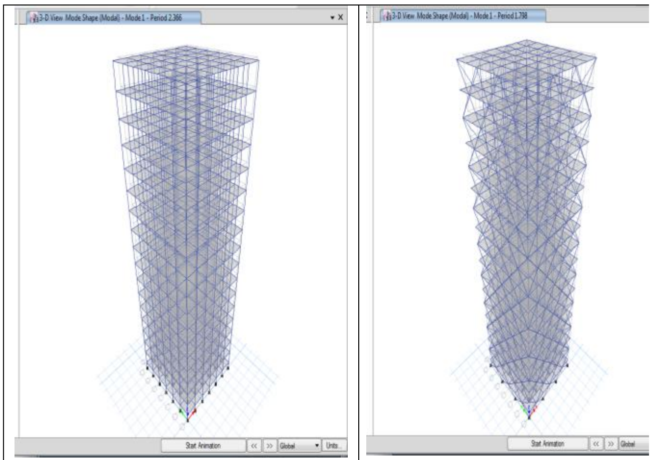
Graph 12 – Base shear X for G+11



Graph 13 – Base shear Y for G+11

1.10 RESULTS FOR THE MODEL 3 – G+16

❖ **Time period for G+16**

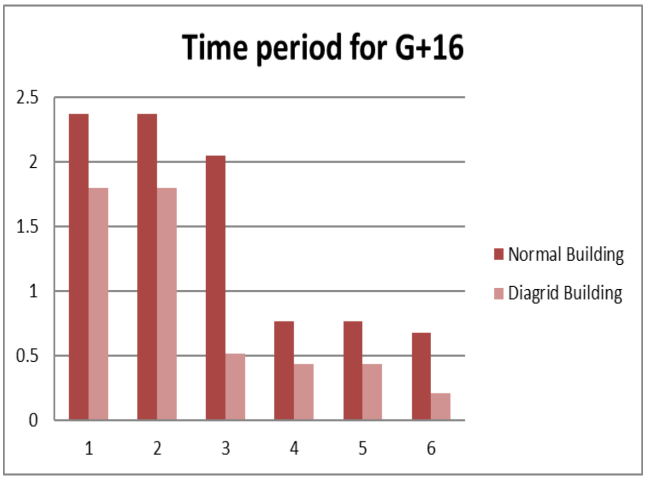


Mode Shape 1 For Normal G+16	Mode Shape 1 For Normal G+16

Fig. 13 – Mode shape for G+16

Mode	Normal Building	Diagrid Building
1	2.366	1.798
2	2.366	1.798
3	2.048	0.519
4	0.769	0.44
5	0.769	0.44
6	0.677	0.21

Table 10 - Time period result

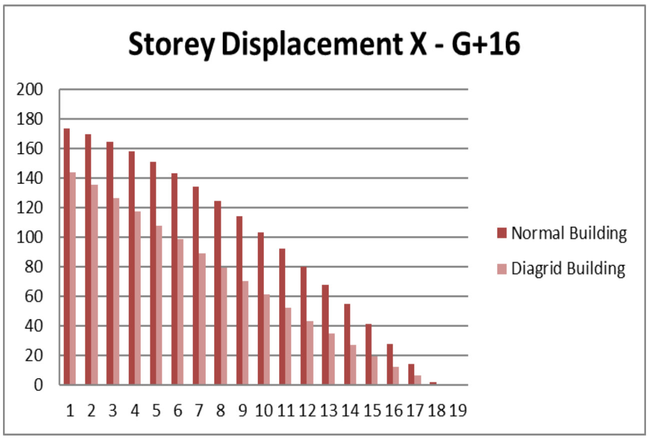


Graph 14 - Time period for G + 16

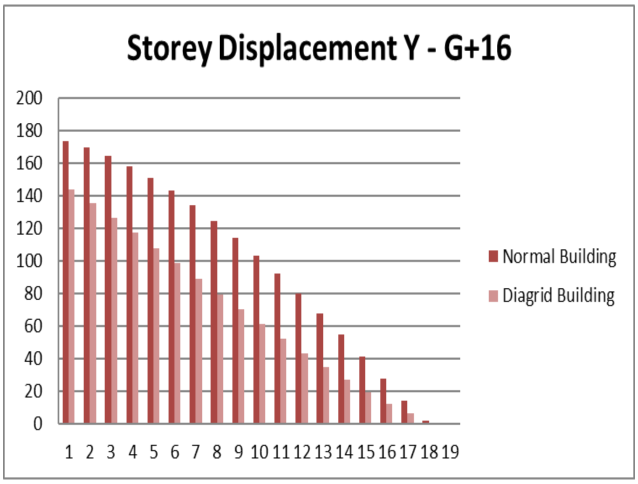
❖ **Storey Displacement for G+16**

Story	Normal Building	Diagrid Building
18	173.51	143.983
17	169.528	135.312
16	164.399	126.343
15	158.15	117.221
14	150.91	107.903
13	142.796	98.512
12	133.906	89.096
11	124.321	79.666
10	114.104	70.398
9	103.299	61.145
8	91.939	52.253
7	80.052	43.381
6	67.662	35.115
5	54.788	26.877
4	41.459	19.582
3	27.763	12.348
2	14.022	6.551
1	1.985	0.947
Base	0	0

Table 11 – Storey Displacement result



Graph 15 – Storey Displacement X for G+16

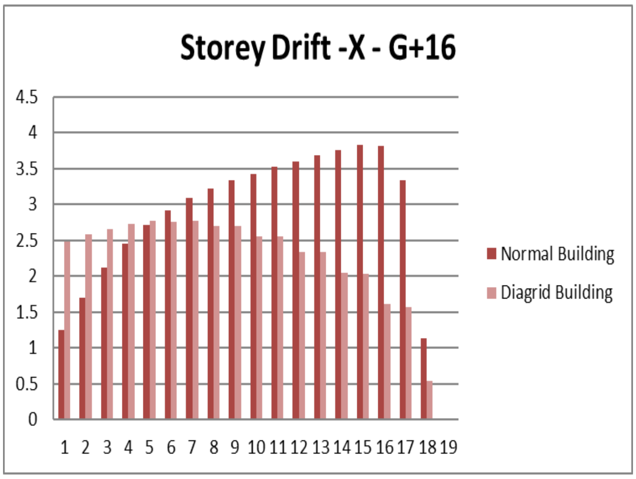


Graph 16 – Storey Displacement Y for G+16

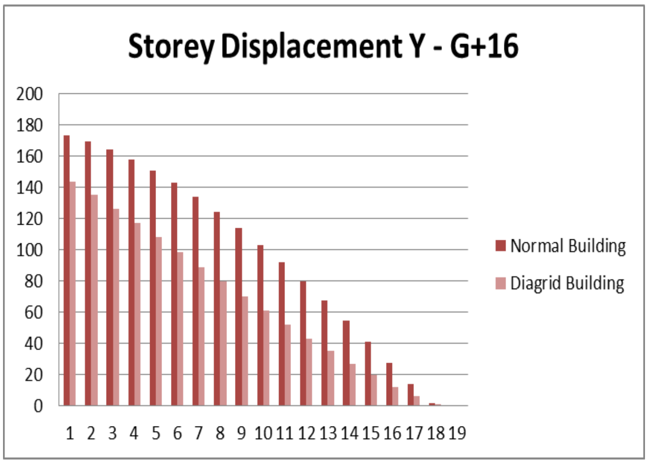
❖ **Storey Drift for G+16**

Story	Normal Building	Diagrid Building
18	173.51	143.983
17	169.528	135.312
16	164.399	126.343
15	158.15	117.221
14	150.91	107.903
13	142.796	98.512
12	133.906	89.096
11	124.321	79.666
10	114.104	70.398
9	103.299	61.145
8	91.939	52.253
7	80.052	43.381
6	67.662	35.115
5	54.788	26.877
4	41.459	19.582
3	27.763	12.349
2	14.022	6.553
1	1.985	0.948
Base	0	0

Table 12 – Storey Drift result



Graph 17 – Storey Drift X for G+16



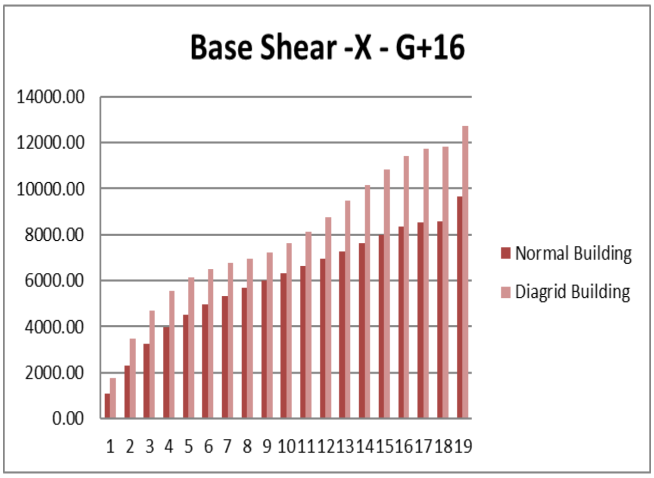
Graph 18 – Storey Drift Y for G+16

❖ **Base shear for G+16**

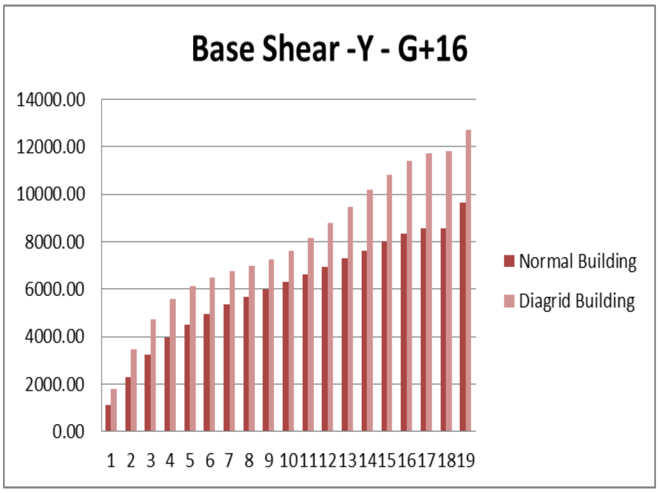
Story	Normal Building	Diagrid Building
18	1113.46	1782.91
17	2301.30	3479.69
16	3247.27	4722.61
15	3959.00	5574.75
14	4504.86	6145.44
13	4956.39	6508.00
12	5348.79	6758.18
11	5693.25	6974.79
10	6008.00	7249.21
9	6319.63	7630.10
8	6640.19	8141.83

7	6963.62	8774.29
6	7290.41	9472.11
5	7637.56	10182.19
4	8005.51	10843.08
3	8339.74	11395.11
2	8547.00	11748.64
1	8575.92	11816.79
Base	9652.76	12736.71

Table 13 – Base shear result



Graph 19 – Base shear X for G+16



Graph 20 – Base shear Y for G+16

❖ Pushover Analysis

Pushover analysis which is an iterative procedure is looked upon as an alternative for the conventional analysis procedures. Pushover analysis of multi-story RCC framed buildings subjected to increasing lateral forces is carried out until the present performance level (target displacement) is reached. The promise of performance based seismic engineering (PBSE) is to produce structures with predictable seismic performance.

The recent advent of performance based design has brought the nonlinear static pushover analysis procedure to the forefront. Pushover analysis is a static non-linear procedure in which the magnitude of the structural loading along the lateral direction of the structure is incrementally increased in accordance with a certain pre-defined pattern. If is generally assumed that the behavior of the structure is controlled by its fundamental mode and the predefined pattern is expressed either in terms of story shear or in terms of fundamental mode shape. With the increase in magnitude of lateral loading, the progressive non-linear behavior of various structural elements is captured, and weak links and failure modes of the structure are identified. After this progressive post elastic analysis of the structure the designer can make necessary changes in the design configuration in order to obtained desired plastic hinge sequence under the applied lateral loads. In addition, pushover analysis is also used to ascertain the capability of the structure to withstand a certain level of input motion defined in terms of a response spectrum.

❖ Pushover Analysis perform on G+16

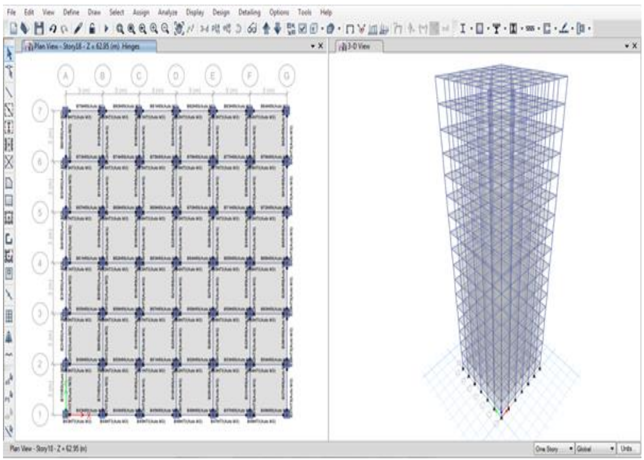


Fig. 14 – Normal Building for G+16

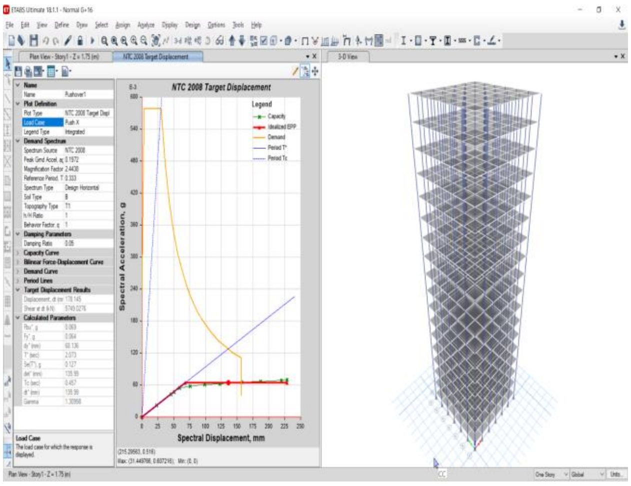


Fig. 15 – Normal Building for pushover analysis

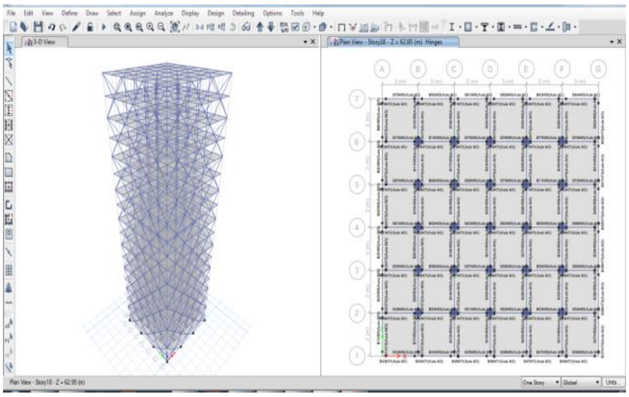


Fig. 16 – Diagrid Building for G+16

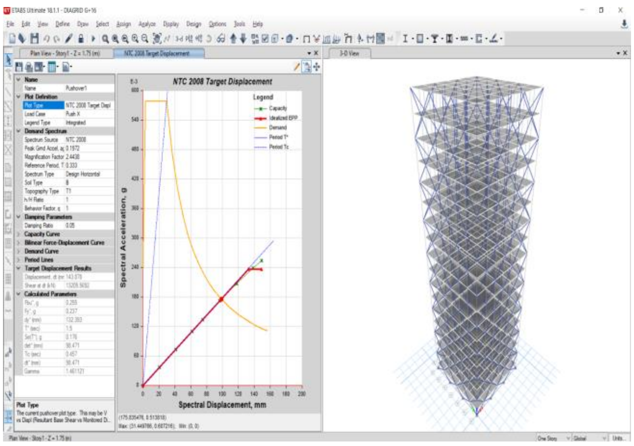
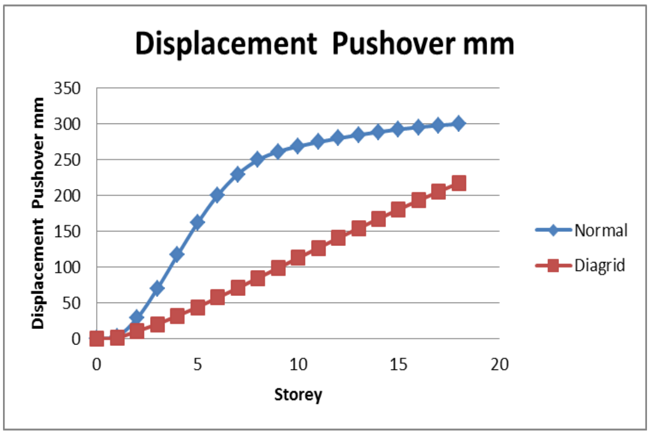


Fig. 17 – Diagrid Building for pushover analysis

❖ **Displacement after pushover analysis**

Displacement Pushover mm		
Storey	Normal	Diagrid
18	300	217.655
17	297.985	205.655
16	295.465	193.266
15	292.393	180.637
14	288.767	167.585
13	284.59	154.288
12	279.865	140.665
11	274.591	126.815
10	268.682	112.869
9	261.349	98.723
8	249.6	84.842
7	229.799	70.807
6	200.334	57.55
5	161.73	44.201
4	116.656	32.313
3	70.012	20.429
2	29.011	10.886
1	3.335	1.555
0	0	0

Table 14 – Displacement result



Graph 21 – Displacement Pushover

6. CONCLUSIONS

Built on the empirical review conducted in this test work, the diagrid and normal building structures are compared for nonlinear analysis of response spectrums for G+7, G+11, and G+16. The analysis concludes that the diagrid structure is more economical than normal structures up to the 11th floor, but G+16 less economical than the G+7 and G+11 structures. To ensure consistency in this study, we analyze G+16 for pushover analysis to determine the structure's capability. The analysis concludes that the diagrid structure has a greater capacity resisting force than the normal structure.

- Time Period for G+7 for normal and diagrid structure for the response spectrum analysis , the time period reduces of diagrid structure than normal structure by 30-40% .

- Results for storey displacement X for G+7 for normal and diagrid structure for the response spectrum analysis , the storey displacement reduces of diagrid structure than normal structure by 40-50%.

- Results for storey displacement Y for G+7 for normal and diagrid structure for the response spectrum analysis, the storey displacement reduces of diagrid structure than normal structure by 20-30%.

- Results for storey drift X for G+7 for normal and diagrid structure for the response spectrum analysis, the storey drift reduces of diagrid structure than normal structure by 30-40%.

- Results for Base Shear X for G+7 for normal and diagrid structure for the response spectrum analysis , the base shear reduces of diagrid structure than normal structure by 30-40%.

- Results for Base Shear Y for G+7 for normal and diagrid structure for the response spectrum analysis , the base shear reduces of diagrid structure than normal structure by 20-40% .

- Results for Time Period for G+11 for normal and diagrid structure for the response spectrum analysis , the time period reduces of diagrid structure than normal structure by 30-40% .

- Results for Storey Displacement X for G+11 for normal and diagrid structure for the response spectrum analysis , the storey displacement reduces of diagrid structure than normal structure by 20-30% .

- Results for Storey Displacement Y for G+11 for normal and diagrid structure for the response spectrum analysis , the Storey Displacement reduces of diagrid structure than normal structure by 10-30%.

- Results for Storey Drift X for G+11 for normal and diagrid structure for the response spectrum analysis , the Storey Drift reduces of diagrid structure than normal structure by 20-30%.

- Results for Storey Drift Y for G+11 for normal and diagrid structure for the response spectrum analysis , the Storey Drift reduces of diagrid structure than normal structure by 30-40% .

- Results for Base Shear X for G+11 for normal and diagrid structure for the response spectrum analysis, the base shear reduces of diagrid structure than normal structure by 30-40% .

- Results for Base Shear Y for G+11 for normal and diagrid structure for the response spectrum analysis , the base shear reduces of diagrid structure than normal structure by 20-30% .

- Results for Time Period for G+16 for normal and diagrid structure for the response spectrum analysis , the time period reduces of diagrid structure than normal structure by 30-40% .

- Results for Storey Displacement X for G+16 for normal and diagrid structure for the response spectrum analysis , the storey displacement reduces of diagrid structure than normal structure by 20-30% .

- Results for Storey Displacement Y for G+16 for normal and diagrid structure for the response spectrum analysis ,the storey displacement reduces of diagrid structure than normal structure by 20-30%.

- Results for Storey Drift X for G+16 for normal and diagrid structure for the response spectrum analysis , the storey drift reduces of diagrid structure than normal structure by 20-30%.

- Results for Storey Drift Y for G+16 for normal and diagrid structure for the response spectrum analysis , the storey drift reduces of diagrid structure than normal structure by 30-40% .

- Results for Base Shear X for G+16 for normal and diagrid structure for the response spectrum analysis , the base shear reduces of diagrid structure than normal structure by 20-30% .

- Results for Base Shear Y for G+16 for normal and diagrid structure for the response spectrum analysis , the base shear reduces of diagrid structure than normal structure by 30-40%.

7. REFERENCES

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12) Vimlesh V. Agrawal on 16 July 2020 et al. Parametric analysis of diagrid structures subjected to seismic forces.
13) On November 13, 2020, Alejandro Palacio Betancur will present his Hybrid Counter Propagation Neural Dynamic Model for Structural Design Optimization of Diagrid Structures.
14) Comparative analysis of diagrid structure with other structural systems for tall structures research gate 30 June, 2020.
15) On September 2, 2020, Snehal V. Mevada will present the Design and Analysis of Core and Outrigger Structural System.

BIOGRAPHIES

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