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# Comparative Analysis of Conventional RCC Structure and Diagrid Structure of U-Shape Plan

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**ABSTRACT-** Present trends show that the geometrical configuration of the diagrid structural system to be used for high-rise buildings provides aesthetic potential and structural efficiency. The construction of multi-story buildings is increasing worldwide. To counteract the lateral forces, one of the effective ways is to adopt a Diagrid Structural System which also sums up the aesthetics of the building. Lateral loads in diagrid buildings are resisted by inclined members which are placed at the exterior of the building. In this work, the concrete diagrid structure is analysed and compared with the conventional concrete building according to earthquake conditions. This paper considers G+3, G+11 and G+19 storey RC buildings with plan size 15 m x15 m located in zones II and III for analysis. ETABS 17 software is used for the study of structural members. This paper compares maximum storey displacement, maximum storey drift, storey stiffness, shear force and bending moment with different results.

**KEYWORDS-** RCC Structure, Conventional RCC Structure, Diagrid Structure, U-Shape Plan

## I. INTRODUCTION

The term “diagrid” may be a combination of the words “diagonal” and “grid” and uses triangulation to realize its structural integrity. Current trends show that the diagrid structural system is becoming popular within the design of tall buildings because of its inherent structural and architectural advantages. The unique geometrical configuration of the diagrid structural systems has driven them to be used for high-rise buildings providing aesthetic potential and structural efficiency also the construction of multi-story buildings is increasing all over the world Diagrids [1].

Diagrid structure can save about 20% of steel weight as compared to standard moment frame structure. By using this method high rise building is in-built in any geometric configuration as per architectural design. The diagrid makes the utmost use of the structural material is fully utilized. once glass material is properly utilized with the diagrid, it permits a generous quantity of light within the structure. These structures have majorly column-free exterior and interior, free and clear, and unique floor plans are enforced [2].

### A. *Steel Diagrid Structural System*

Steel is the most popularly used material in the construction of diagrids. The sections’ size and weight are made to resist the high bending loads.

### B. *Concrete Diagrid Structural System*

The most commonly used diagrid material is concrete. Both precast and cast in-situ types of concrete diagrids are used. It also protects from fire damages.

### C. *Timber Diagrid Structural System*

Timber is the least used material in diagrids’ construction as it has more disadvantages. This material's sole advantage is that the timber section is easily available in any shape and size. The installation cost is low. The most important disadvantages are that timber has lesser material strength.

## II. OBJECTIVE OF THE STUDY

To calculate the lateral design forces on conventional RCC buildings and diagrid buildings in Zone II and Zone III.

•To evaluate the response of buildings subjected to ground motions, namely low, intermediate, and high-frequency ground motion.

•To compare the analysis results of storey displacement, storey drift, storey stiffness, shear force, and bending moment values of the buildings.

•Dynamic analysis was done on the structures using ETABS software.

### A. *Effect of Structural Irregularities*

There are numerous examples of past earthquakes in which the cause of failure of the reinforced concrete buildings has been ascribed to irregularities in configurations.

Irregularities are mainly categorized as:

(i) Horizontal Irregularities

(ii) Vertical Irregularities

### B. *Horizontal Irregularities*

Horizontal irregularities refer to asymmetrical plan shapes (e.g., L-, T-, U-, F-) or discontinuities in the horizontal resisting elements (diaphragms) such as cut-outs, large openings, re-entrant corners, and other abrupt changes resulting in torsion, diaphragm deformations, stress concentration.

### *C. Vertical Irregularities*

Vertical irregularities, referring to sudden changes of strength, stiffness, geometry, and mass, result in irregular distribution of forces and/ or deformation over the height of the building.

## III. LITERATURE REVIEW

Shashi Kiran and N. Myogesh discusses the concrete diagrid structure is analysed and compared with the conventional concrete building. The structural design of tall buildings is governed by lateral loads i.e., wind or earthquake. Lateral loads in diagrid buildings are resisted by inclined members which are placed at the exterior of the building. G+16 storey RCC building is considered. ETABS 18 software is used for the analysis of structural members. A conventional structure is compared with a diagrid structure with a diagrid angle of 40 and a diagrid angle of 60. In this paper storey displacement, story drift, shear force, bending moment, axial load and reinforcement % of diagrid structures with different diagrid angles are compared with conventional structures [3]. Sameeran R. Takle (2021) et al. study a G+41 storey multi-storeyed R.C.C.C.C. building model is modelled using ETABS 2018 software. Response spectrum analysis is carried out by considering the building situated in zone III. Building models are analysed by ETABS 2018 software to study the effect of storey shear, base moments, maximum storey displacement and maximum storey drift etc [4]. This paper presents a state-of-art review of the effects of bracing angle he diagrid steel structures, the effects of aspect ratio, then a comparison between different shapes of diagrid structures and analysis of wind load and seismic load using E-Tabs software. Design, study and analysis of 36-storey steel buildings diagonally, taking into account the dynamic analysis along the wind and the lateral effects of the wind and all load combinations according to IS 800: 2007 standard for the buildings [5].

Aarthi Senthil Kumar, R. Umamaheshwari's paper will show the structural performance of diagrid and conventional structure using ETABS v.15. Various parameters like story displacement, story drift and story stiffness are obtained and compared in this study. Three-dimensional space frame analysis is carried out for diagrid and conventional structure under seismic loading. All the structural members are designed using IS 800:2007 and IS 456:2000. The main frame has the same area, number of stories and a concrete core wall at the Centre for both the structures. Model 1: Conventional Structure (Concrete), Model 2: Diagrid Structure (Steel) [6].

Optimization is a process which is used to make a structure fully perfect, effective, and functional as possible. Lateral load resistance of structural members plays an important role in the stability of a high-rise structure and research shows that slanted column patterns called diagrids are very effective system for the purpose of resisting lateral load. The axial action of slant-ed columns in diagrid will resist the overturning moment and of maximum storey drift in G+11 storey building in shear forces that develop on the structure. This paper aims to study the structural optimization of a 48-storey building with diagrid, analysed, and modelled using ETABS software [7].

## IV. THEORY AND FORMULATION

This section discusses the parameters and methodology adopted for the study.

In this paper G+3, G+11, and G+19 storey building with a plan size of 15m x 15m are considered for the study. Diagrid buildings and conventional buildings are analysed in the software ETABS 2017 taking all the codal provisions.

The properties considered for modelling of G+3, G+11 and G+19 storey building are shown in table 1 i.e., plan properties, table 2 i.e., material properties, table 3 i.e., load properties and in table 4 i.e., seismic properties.

Table 1: Plan Properties

| PLAN PROPERTIES | SPECIFICATIONS |
|---|---|
| Details of Building | G+3, G+11, G+19<br>RC Structure |
| Plan configuration | 15m x 15m |
| Floor-to-Floor Height | 3m |
| Building Height | 12m, 36m, 60m |

Table 2: Material Properties

| MATERIAL PROPERTIES | SPECIFICATIONS |
|---|---|
| Grade of concrete | M-25 for beams and slabs,<br>M-30 for columns |
| Grade of steel (Diagrids) | Fe345 |
| Size of Column | 300mm x 600mm |
| Size of Beam | 230mm x 450mm |
| Size of Slab | 125mm |
| IS-Code referred | IS 456:2000, IS 800:2007 |

The result analysis is carried out on ETABS software and the comparison of maximum storey displacement G+3 storey building is shown in table 5, the comparison of maximum storey drift of G+11 storey building is shown in table 6 and the comparison of maximum storey stiffness values of G+19 storey building shown in table 7.

Figure 1 and 6 shows the elevation and 3D view of the Diagrid building of G+3 and G+19, figure 2 and 3 shows the elevation and 3D view of a conventional building of G+3 and G+11, figure 4 shows the plan and 3D view of G+11 Diagrid building and figure 5 shows the plan and 3D view of G+19 conventional building.

Figure 7 and 8 shows the graphical representation of the comparison of maximum storey displacement of G+3 storey building in zone II and III, and figure 9 and 10 shows the graphical representation of a comparison zone II and zone III, figure 11 and 12 shows the graphical representation of a comparison of maximum storey stiffness in G+19 storey building in zone II and zone III.

Table 3: Load Properties

| LOAD PROPERTIES | SPECIFICATIONS |
|---|---|
| Live Load | 2 KN/M2 |
| Live Load on Roof | 1.5 KN/M2 |
| IS-Code referred | 1. IS-875 Part-1 for Dead Load<br>2. IS-875 Part-2 For Live Load |

Table 4: Seismic Properties

| SEISMIC PROPERTIES | SPECIFICATIONS |
|---|---|
| Soil Type | Medium Soil |
| Zone considered | Zone 2 and Zone 3 |
| Zone Factor | 0.1 and 0.16 |
| Importance Factor | 1.2 |
| Response Reduction Factor | 3 |
| Damping | 0.05 |
| Rock & Soil Type Factor | II |
| IS-Code referred | IS-1893 Part-1 (2002) |

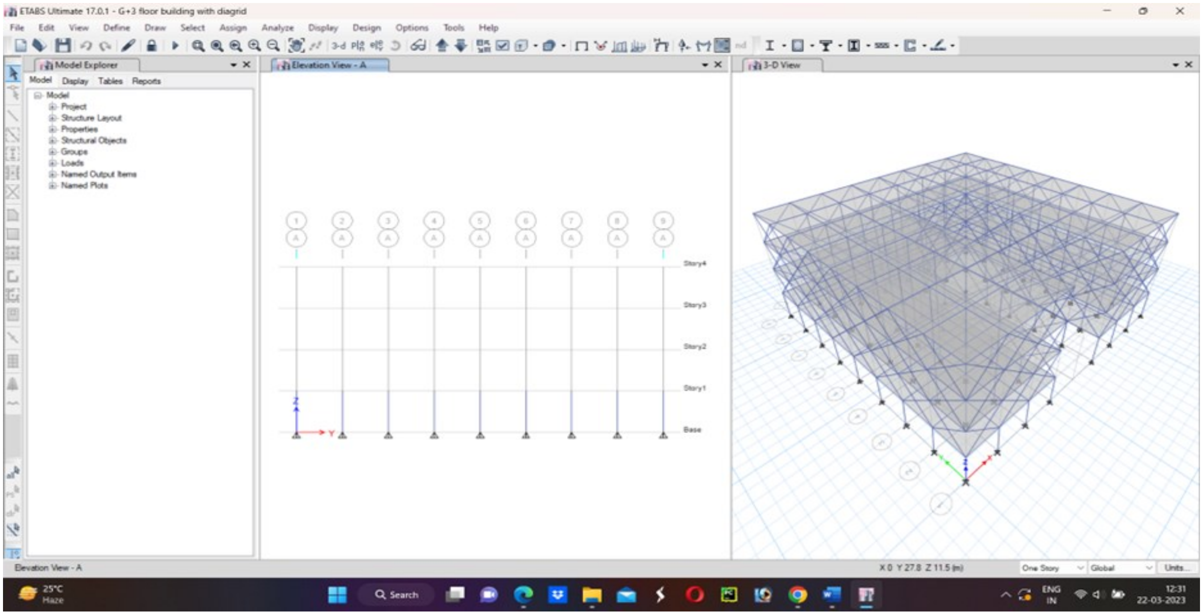


Figure 1: Elevation and 3D View of G+3 Diagrid Building

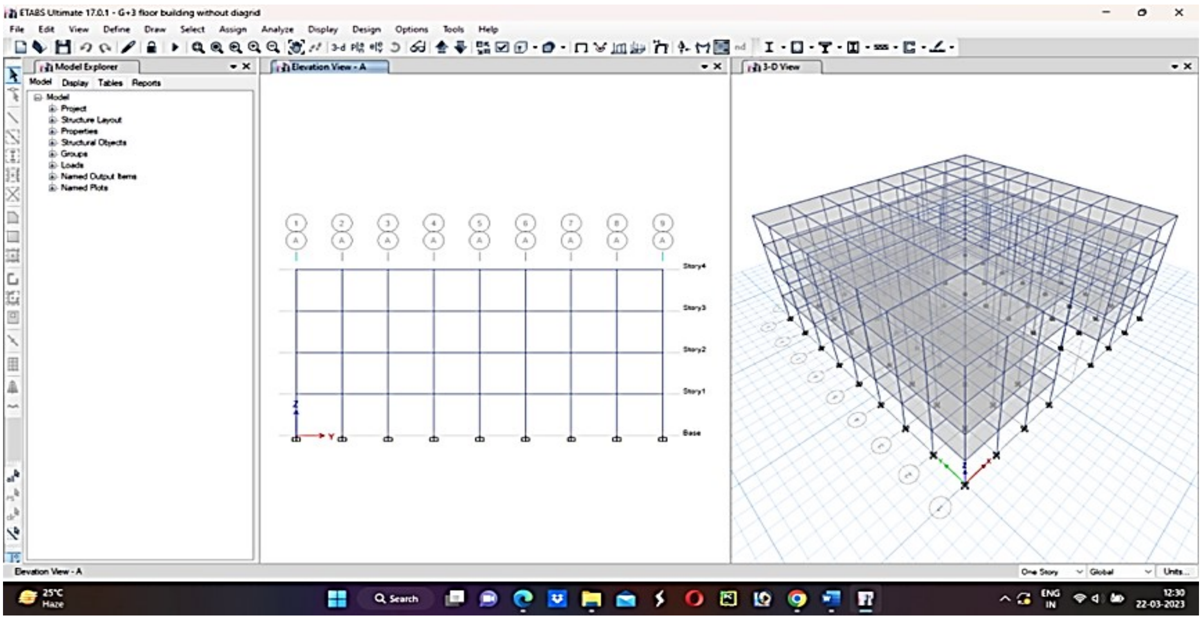


Figure 2:  Elevation and 3D view of G+3 Conventional Building

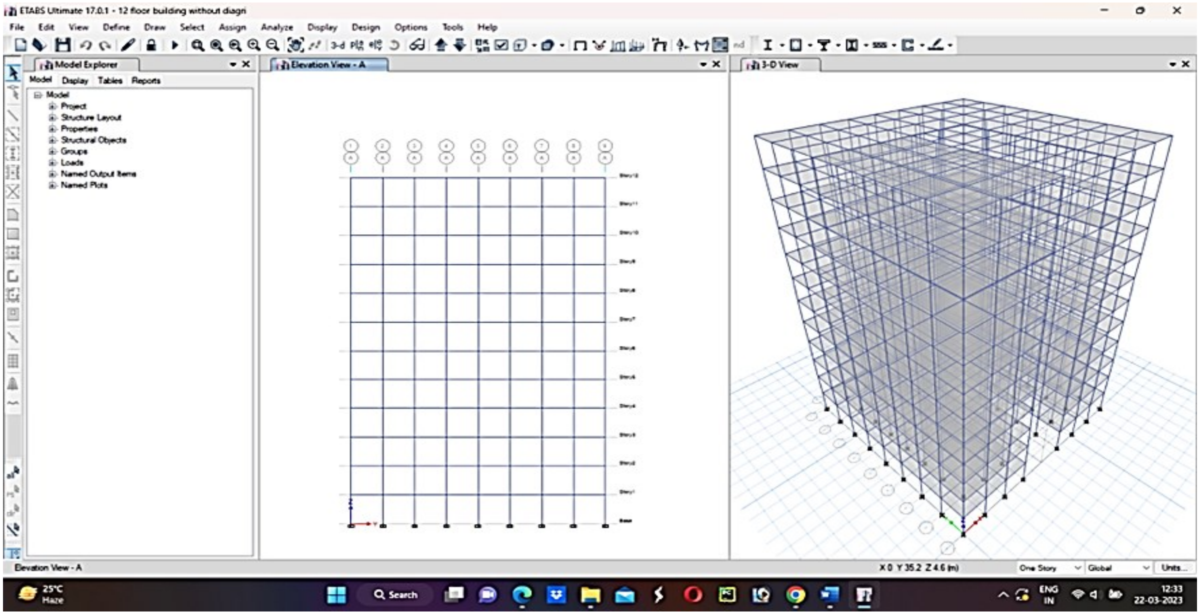


Figure 3: Elevation and 3D view of G+11 Conventional Building

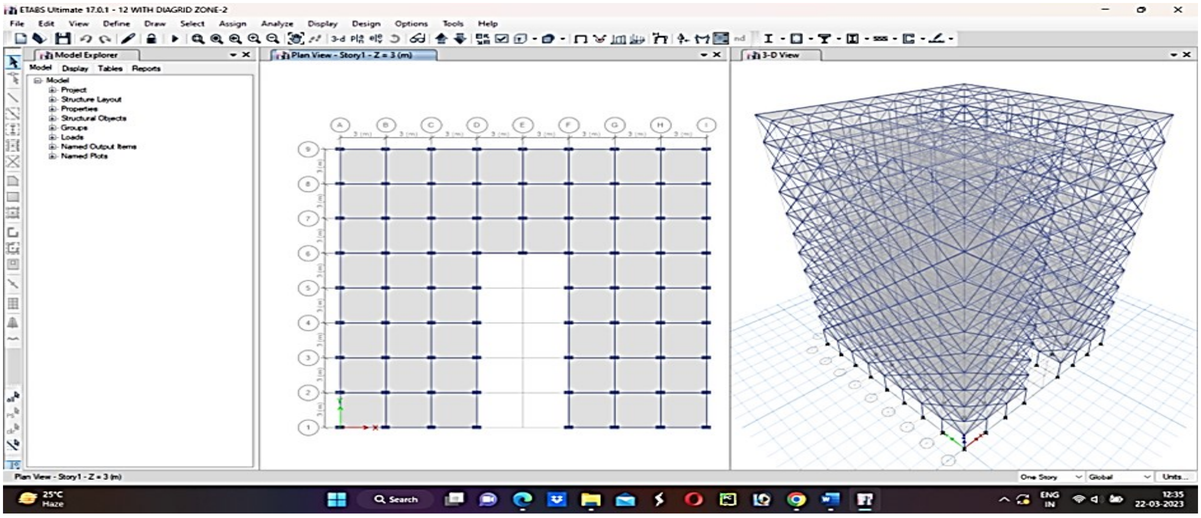


Figure 4: Plan and 3D view of G+11 Diagrid Building

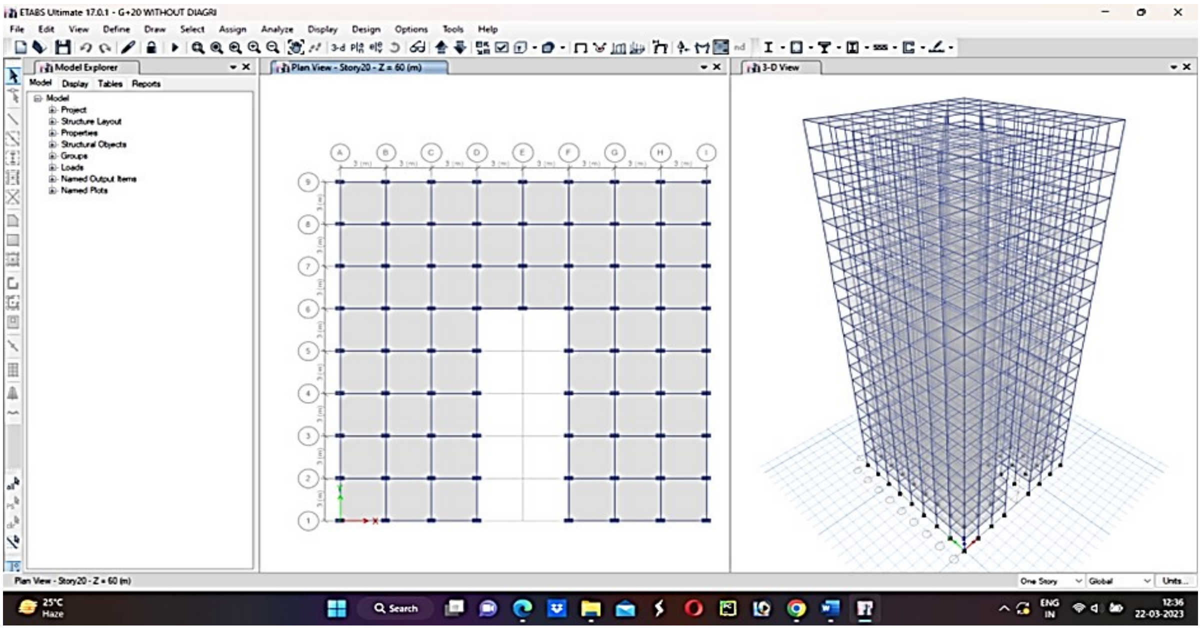


Figure 5: Plan and 3D view of G+19 Conventional Building

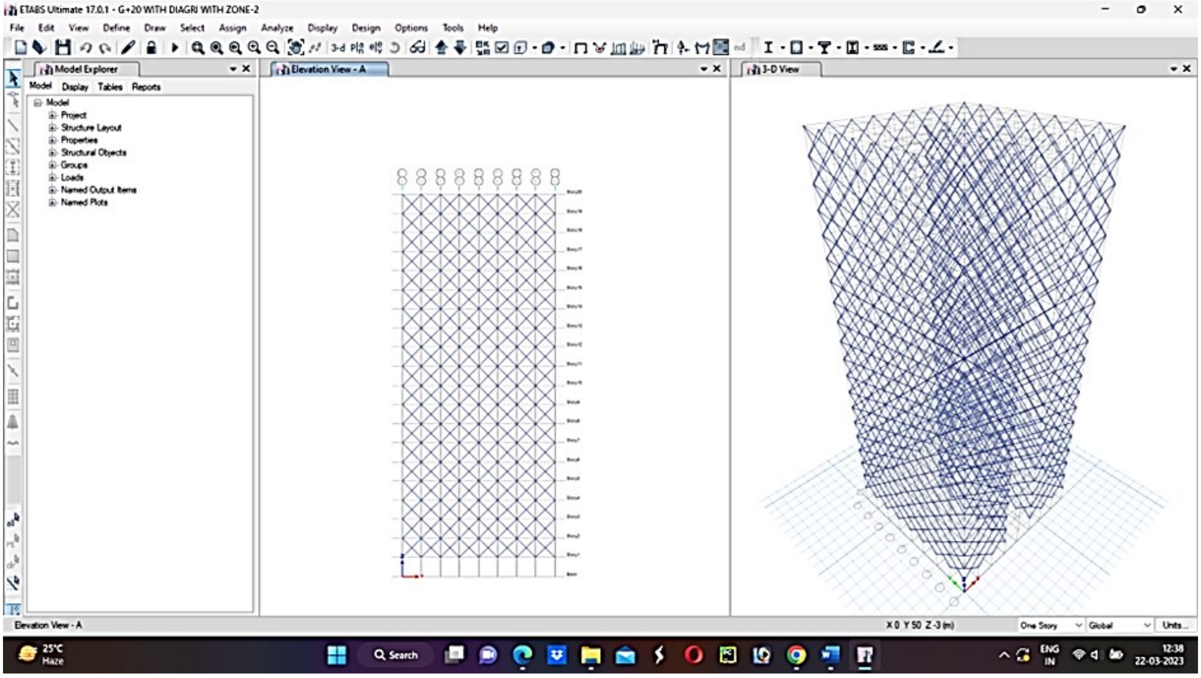

Figure 6: Elevation and 3D view of G+19 Diagrid Building

## V. RESULTS AND DISCUSSION

After the analysis from E-TABS, the results of 6 structures are noted. Results like maximum storey displacement, maximum storey drift, shear force, bending moments and storey stiffness are noted and compared among the 6 structures. The results obtained are discussed below:

***Comparison of Maximum Storey Displacement Values***

Table 5: Comparison of Maximum Storey Displacement Values in G+3

| Storey Number | Conventional Building | | Diagrid Building | |
|---|---|---|---|---|
| | Zone II | Zone III | Zone II | Zone III |
| 4 | 2.431 | 2.728 | .728 | 1.107 |
| 3 | 2.002 | 2.283 | .658 | 1.049 |
| 2 | 1.325 | 1.538 | .559 | .964 |
| 1 | 0.531 | 0.626 | .421 | .978 |

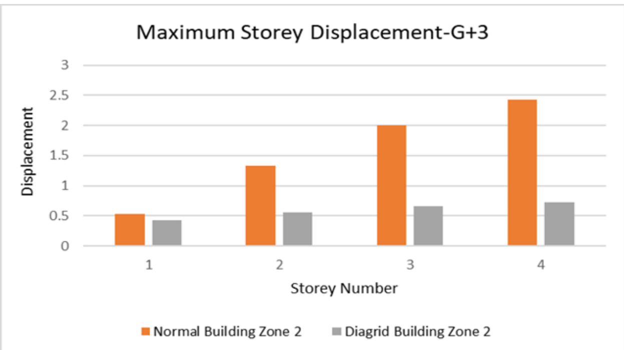


Figure 7: Graphical representation of maximum storey displacement in Zone II

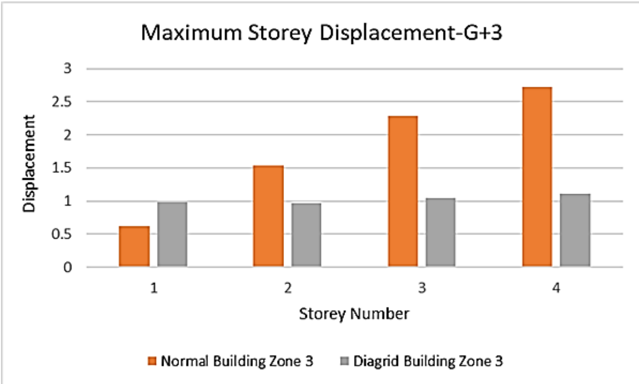


Figure 8: Graphical representation of maximum storey displacement in Zone III

From table 5 and figure 7 & 8, it is concluded that a diagrid building displaces less as compared to a conventional RCC building.

Table 6: Comparison of Maximum Storey Drift Values in G+11

| Storey Number | Conventional Building | | Diagrid Building | |
|---|---|---|---|---|
| | Zone II | Zone III | Zone II | Zone III |
| 12 | 0.612 | 0.624 | 0.482 | 1.147 |
| 11 | 0.803 | 0.839 | 0.522 | 1.19 |
| 10 | 0.985 | 1.045 | 0.562 | 1.23 |
| 9 | 1.134 | 1.213 | 0.595 | 1.26 |
| 8 | 1.255 | 1.349 | 0.617 | 1.273 |
| 7 | 1.355 | 1.46 | 0.628 | 1.268 |
| 6 | 1.436 | 1.581 | 0.624 | 1.241 |
| 5 | 1.5 | 1.693 | 0.603 | 1.19 |
| 4 | 1.545 | 1.787 | 0.562 | 1.112 |
| 3 | 1.55 | 1.845 | 0.494 | 0.995 |
| 2 | 1.435 | 1.776 | 0.397 | 0.892 |
| 1 | 0.833 | 1.105 | 1.022 | 1.28 |

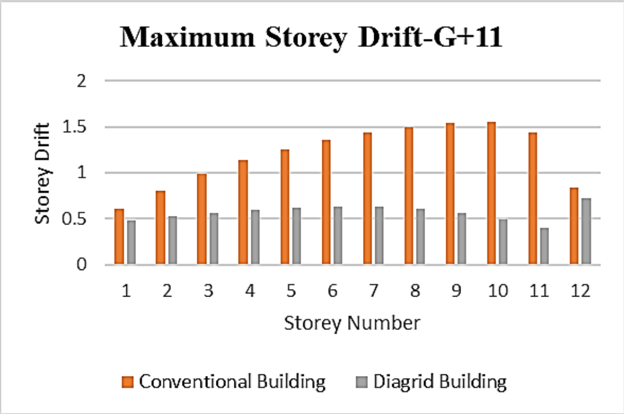


Figure 9: Graphical representation of maximum storey drift in Zone II

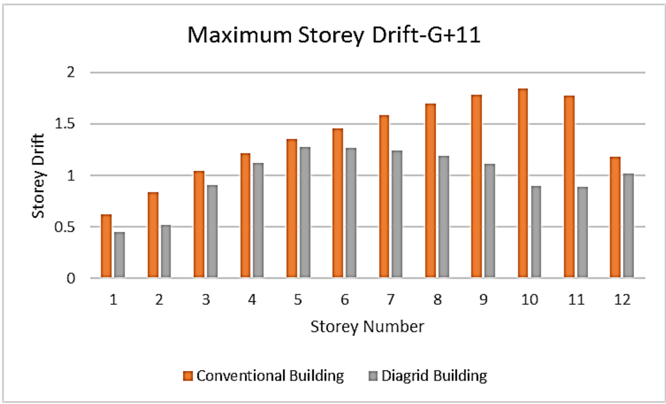


Figure 10: Graphical representation of maximum storey drift in Zone III

- From table 6 and figure 9 and 10, it is concluded that maximum storey drift is less in diagrid buildings.

Table 7: Comparison of Storey Stiffness Values in G+19

| Storey Number | Conventional Building | | Diagrid Building | |
|---|---|---|---|---|
| | Zone II | Zone III | Zone II | Zone III |
| 20 | 221221.75 | 221221.754 | 562991.622 | 373022.741 |
| 19 | 357040.13 | 357040.137 | 1080855.573 | 679830.92 |
| 18 | 427647.69 | 427647.695 | 1509119.836 | 903790.126 |
| 17 | 467643.60 | 467643.602 | 1863287.689 | 1066119.674 |
| 16 | 489598.99 | 489598.992 | 2161006.507 | 1186842.539 |
| 15 | 502950.09 | 502950.909 | 2419556.979 | 1281798.579 |
| 14 | 512035.51 | 512035.512 | 2656234.979 | 1363475.159 |
| 13 | 520741.82 | 520741.827 | 2888996.837 | 1442517.166 |
| 12 | 531089.14 | 531089.142 | 3159648.504 | 1528733.799 |
| 11 | 543441.65 | 543441.654 | 3403550.822 | 1637242.631 |
| 10 | 557302.36 | 557302.369 | 3708217.936 | 1842936.835 |
| 9 | 572322.29 | 572322.29 | 4013512.156 | 2100479.11 |
| 8 | 588875.24 | 588875.245 | 4371567.184 | 2294929.07 |
| 7 | 607863.05 | 607863.052 | 4804683.928 | 2523362.529 |
| 6 | 629967.29 | 629967.299 | 5344219.992 | 2808091.035 |
| 5 | 655117.49 | 655117.493 | 6041569.806 | 3175083.88 |
| 4 | 683290.28 | 683290.284 | 6989201.3 | 3677029.429 |
| 3 | 720874.08 | 720874.084 | 8428742.496 | 4471642.094 |
| 2 | 805268.93 | 805268.938 | 10300407.453 | 5243388.117 |
| 1 | 1380135.11 | 1380135.114 | 2423850.894 | 1237219.818 |

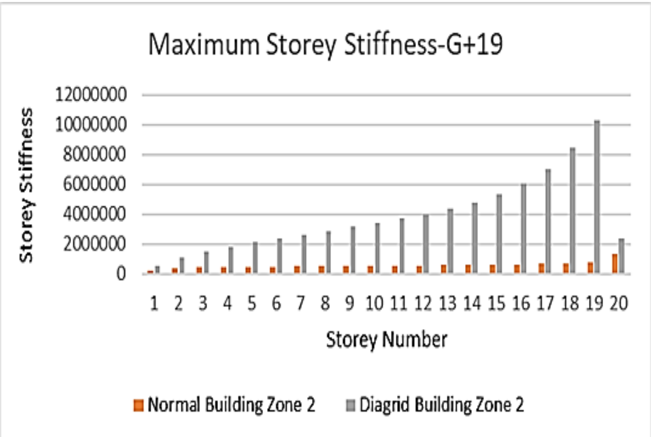


Figure 11: Graphical representation of storey stiffness in Zone II

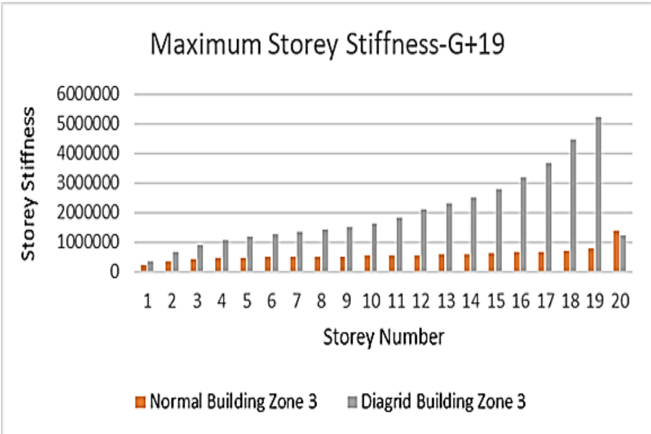


Figure 12: Graphical representation of storey stiffness in Zone III

- From table 7 and figures 11 and 12, it is concluded that the diagrid building is stiffer.

## VI. CONCLUSIONS

In the present study, the procedure for element damage assess mentin semi-rigid connected structures is presented. First, the methodology for the detection of element damages in semi-rigid connected structures is outlined. From the analysis report, it is concluded that displacement is less in zone 2 and zone 3 in the diagrid building. The diagrid structure is stiffer, and they displace less as compared to a conventional building. storey drift is found less in zone 2 which means relative displacement between two floors is also less i.e., more stability. Diagrid structure performs better in resisting lateral load and is superior in performance than a conventional building. It is observed that most of 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. Diagrid structure gives a more aesthetic look and gives more interior space. Due to a smaller number of columns, the façade of the building can also be planned more efficiently.

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