# SEISMIC PERFORMANCE ASSESSMENT OF CONCRETE DIAGRID STRUCTURES

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*Abstract:* The diagrid structure is widely used for RCC and steel buildings due to structural efficiency and flexibility provided in architectural planning. Under lateral loading diagrid columns mainly bear lateral loads and produce axial force in the direction of diagrid column which is useful to resist second order bending moment. In this paper a regular 9m x 9m size for G+11 storey with diagrid angle $45^0$is considered. For modelling and analysis of structure SAP 2000 software is used. IS 456:2000 is used for design of all structural members by considering all load combinations. Seismic load is used for analysis of building. Similarly, analysis and design of $63^0$, $76^0$ and $81^0$ diagrid angles are performed. Comparison of results in terms of shear force and bending moments in ground beams, interior and diagrid columns, Axial forces in interior and diagrid columns is carried out along with seismic parameters like storey drift, storey displacement and storey shear. Above results are used for finding optimal angle of diagrid. At last this optimal angled diagrid building results are again compared with conventional grid system.

***IndexTerms* - Diagrid Structure, Optimal Diagonal Angle, Rectangular Grid.**

## I. INTRODUCTION

The diagrid structure is consisting of special inclined column unlike vertical columns in conventional grid buildings. It is in the form of space truss which is stable without any vertical column on its periphery. Due to presence of inclined columns shear deformation produced due to presence of lateral loads is mainly resisted by axial action in diagrids in other hand this shear deformation is resisted by deflection of vertical columns in conventional grid systems. Diagrid system provides good aesthetic views along with structural efficiency which reduces the number of structural members required. Diagrids are mainly used in the form of concrete, steel and wooden. In recent years steel is widely used for diagrid structures because of steel is strong in both compression and tension as compared to concrete. There are lots of research are done on steel diagrid structures for wide range of diagrid angles and also gives the relation between height of building and angle of diagrids. But it is observed that these types of researches are not done in concrete diagrid structures. Due to behavior of diagrid structures there is limitations on height of buildings because tension produced in diagrids is depend on height of building and diagrid angles and concrete is weak in tension.

From history it is observed that for concrete also there are range of diagrid angles used for different heights some of them are Atlas building (Netherland) had diagrid angle of $45^0$ for G+6 storeys, Poly-Real estate head Quarters (China) had diagrid angle of $54^0$ for 33 storeys, Yellow building (England) had angle of $61^0$ for UG+G+6 storeys and O-14 Tower (Dubai) had randomly spaced 1326 openings for G+24 storeys. From different case studies it is observed that in case of steel buildings up to height 28 meters $33^0$ is optimal angle and height up to 556 meters optimal angle is in the range of $65^0$ to $79^0$. This height and angle relation is only found for steel diagrid structures and not for concrete diagrid structures.

Analysis and design of 36, 50, 60 70, 80 diagrid structures is carried out and compared a results in the term of time period, inter storey drift and top storey displacement [13]. 36 storey diagrid building with various slopes were designed and their seismic performance is evaluated nonlinear static and dynamic analysis [9]. For 15m x 15m RCC conventional and diagrid building seismic analysis is carried out and results are compared in the term of storey drift, node displacement, bending moment, shear force and area of reinforcement [4]. The application of topology for high rise building is performed and comparison of structural performance of some recent diagrid tall buildings, having different number of storeys and geometries are carried out along with some design remarks are derived [5]. Existing researches in diagrid structures for tall and super tall buildings are summarized and conclude that structure has good seismic performance and large lateral stiffness in case of diagrid structures [11]. Nonlinear performance of steel diagrid structures using static, time history dynamic and incremental dynamic analysis is carried out along with different building height and diagonal angle [1].

## II. PROPOSED WORK

### 2.1 Methodology

Regular plan of 9 m x 9 m is considered. The dimensions of building components are found by design according to IS 456-2000. Modeling and analysis of diagrid buildings is done with different angle of diagrids $45^0$, $63^0$, $76^0$, $81^0$ using finite element analysis software SAP 2000. By comparing different results like shear force bending moments, axial compression and tension, storey drift and storey displacement optimal angle of diagrid is found. In second part of paper this optimal angled diagrid building results are again compared with conventional grid system.

### 2.2 Configuration of Building

#### 2.2.1 Loading and Other Data

- Plan Area – 9m x 9m
- No of Storey – G+11
- Storey Height – 3m
- DL – 1 KN/m2
- LL – 4 KN/m2
- Wall Load – 11.76 KN/m
- Grade of Concrete – M25 and M30

#### 2.2.2 Section Properties

Table -1: Section Properties

| Angle of Diagrid | $45^0$ | $63^0$ | $76^0$ | $81^0$ |
|---|---|---|---|---|
| Beam Size (mm) | 230 x 380 | 230 x 380 | 230 x 380 | 230 x 380 |
| Column Size (mm) | 450 x 450 | 450 x 450 | 450 x 450 | 450 x 450 |
| Diagrid Size (mm) | 350 x 350 | 350 x 350 | 450 x 450 | 600 x 600 |
| Slab Depth (mm) | 125 | 125 | 125 | 125 |

#### 2.2.3 Seismic Parameters

Table -2: Seismic Parameters

| | |
|---|---|
| Zone Factor (Z) | 0.36 |
| Importance Factor (I) | 1 |
| Response Reduction Factor | 5 |
| Soil Type | II |

### 2.3 Modeling

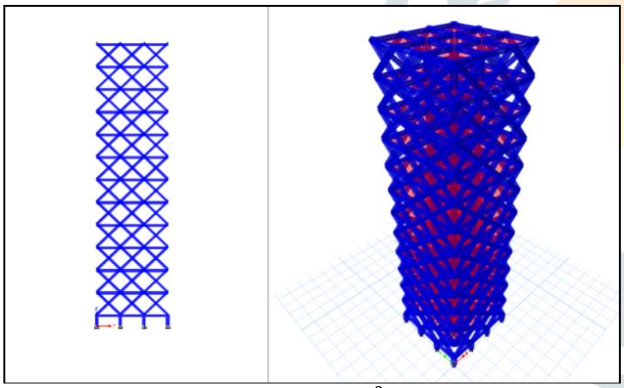

Fig -1: FEM modeling of $45^0$ diagrid building.

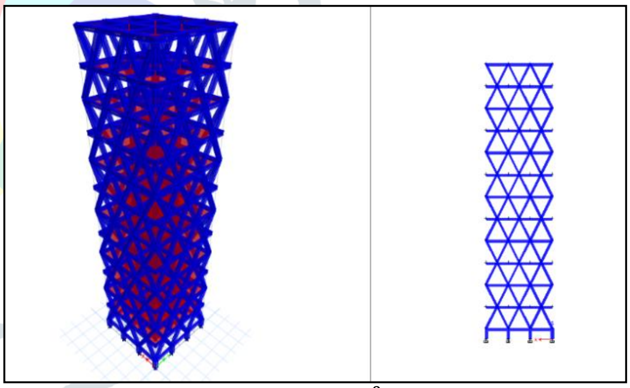

Fig -2: FEM modeling of $63^0$ diagrid building.

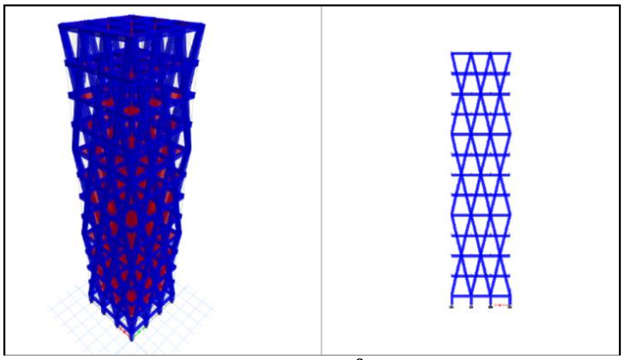

Fig -3: FEM modeling of $76^0$ diagrid building.

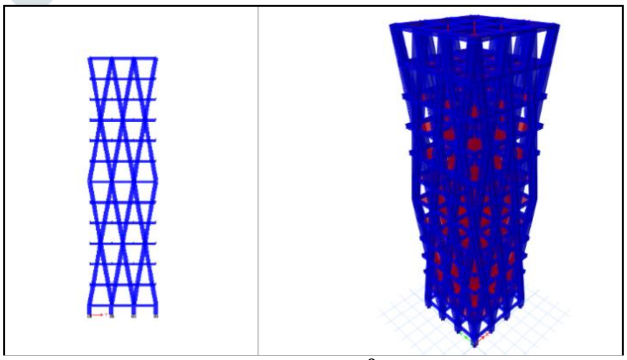

Fig -4: FEM modeling of $81^0$ diagrid building.

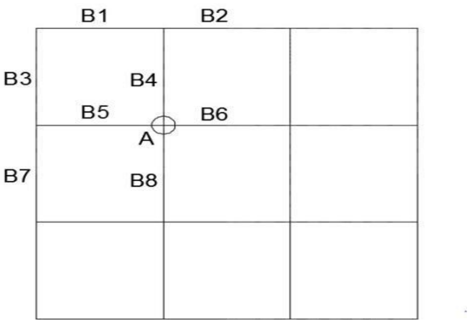


Fig -5: Location of beams and column considered for analysis.

## III. RESULTS

### 3.1 Results Comparison between Different Diagrid Angles

#### 3.1.1 Shear Force and Bending Moment at Ground Level Beams

From the results of shear force and bending moment present in ground beam it is observed that the most of bending and shear is resisted by exterior beams (B1, B2, B3, B7) than the interior beams (B4, B5, B6, B8)

The other observation show that as angle of diagrid increases from 45° to 76° values of shear forces and bending moment increases and then suddenly decreases for higher angles greater than 76° i.e. 81°.

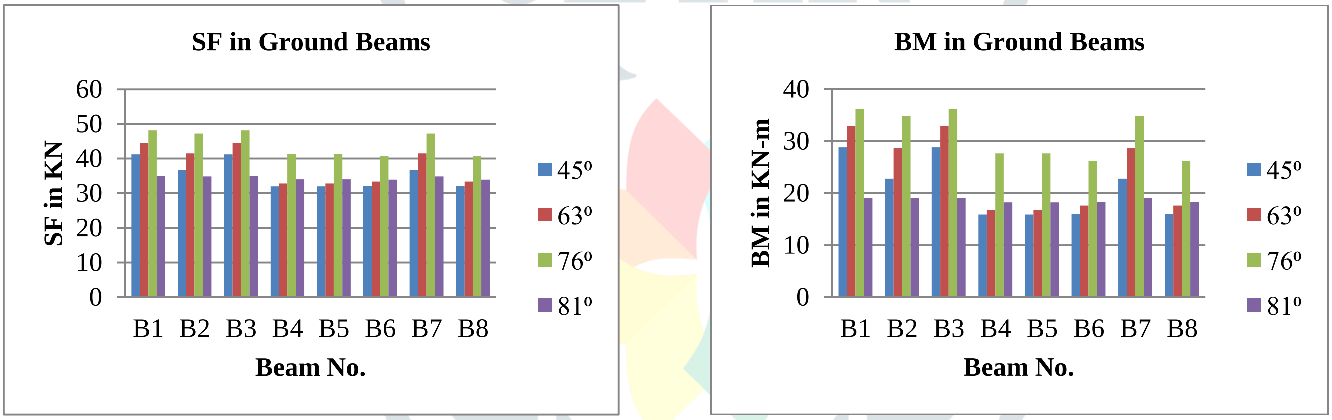


Chart -1 SF and BM at ground level beams.

#### 3.1.2 Axial Force in interior column

From below graph it is observed that as angle of diagrid increases from 45° to 76° the value of axial forces reduces and it again increases for angle 81°. Due to presence of diagrid on the periphery most of lateral load is resisted by diagrids so that interior column carry only gravity loads.

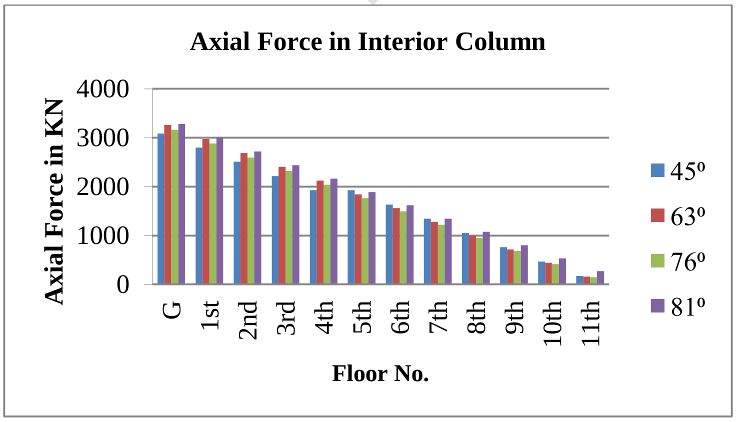


Chart -2 Axial Force in interior column.

### 3.1.3 Shear Force and Bending Moment in interior columns

From below graph it is observed that behavior of shear forces and bending moment in interior columns are complex in nature. For angle 45° there are less fluctuation of shear forces and bending moment but at the same time it shows maximum values.

For angle 63° the fluctuation of results are higher than 45° but at the same time values are much less than 45°. Diagrid angle 76° and 81° shows more fluctuation of results and values are lies between values obtained for 45° and 63°.

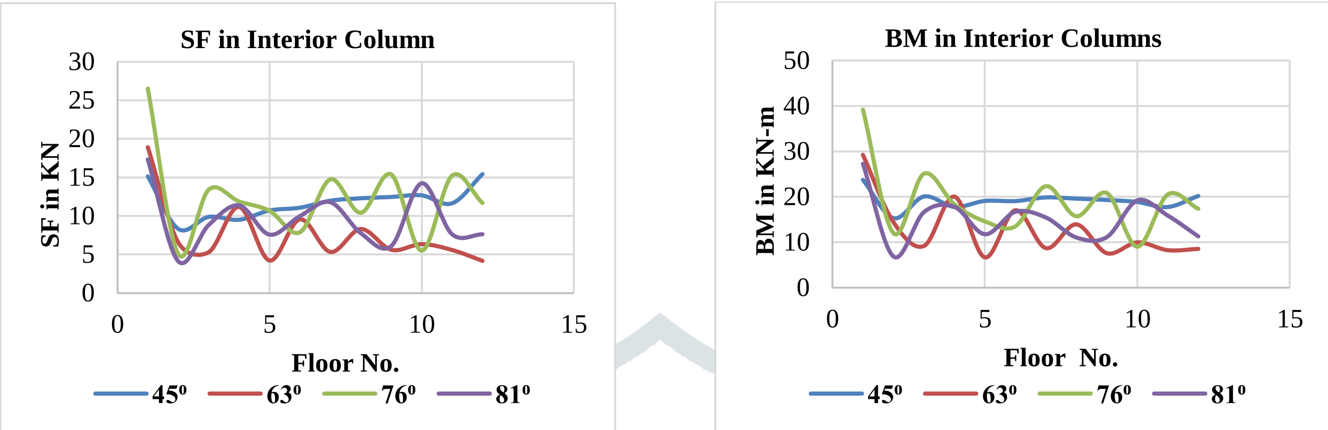


Chart -3 SF and BM in interior column.

### 3.1.4 Shear Force and Bending Moment in diagrid columns

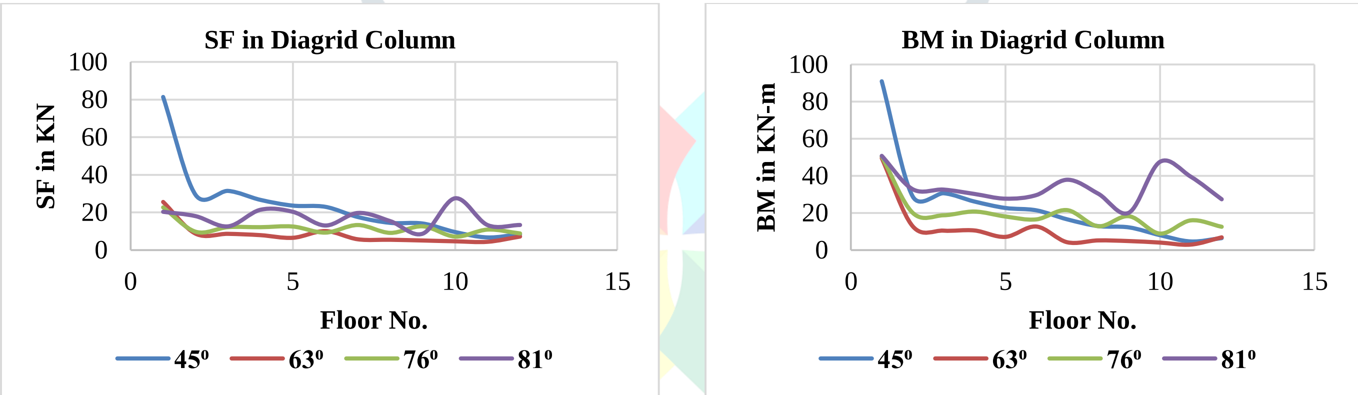


Chart -4 SF and BM in diagrid column.

45° diagrid angle shows maximum values of shear forces and bending moment present in diagrids on the other hand 63° shows very less values of shear and moment with very less fluctuation in values. The other two diagrid angles show more fluctuation and higher values than the 63°.

### 3.1.5 Axial Force in diagrid column

From above graphs it is clear that as angle of diagrid increases axial compression and tension in diagrid also increases.

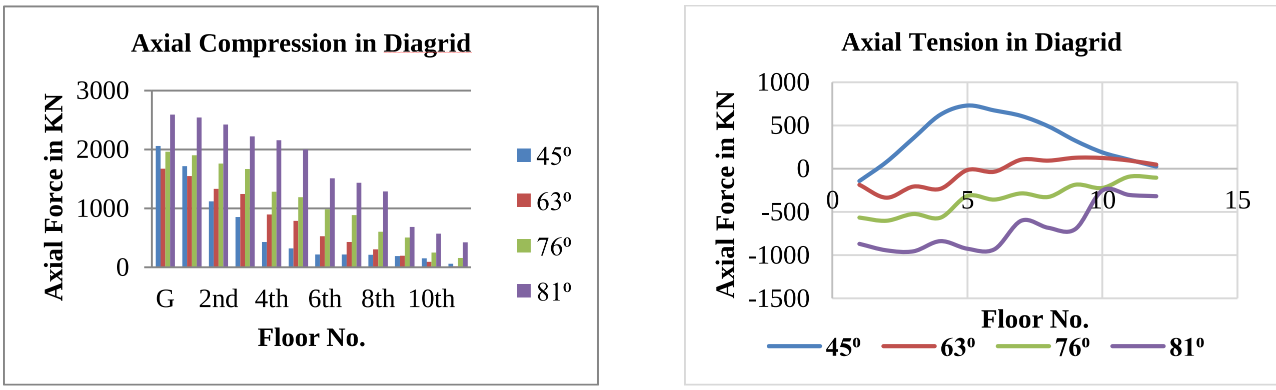


Chart -5 Axial compression and Tension in diagrid.

### 3.1.7 Storey Displacement and storey Drift

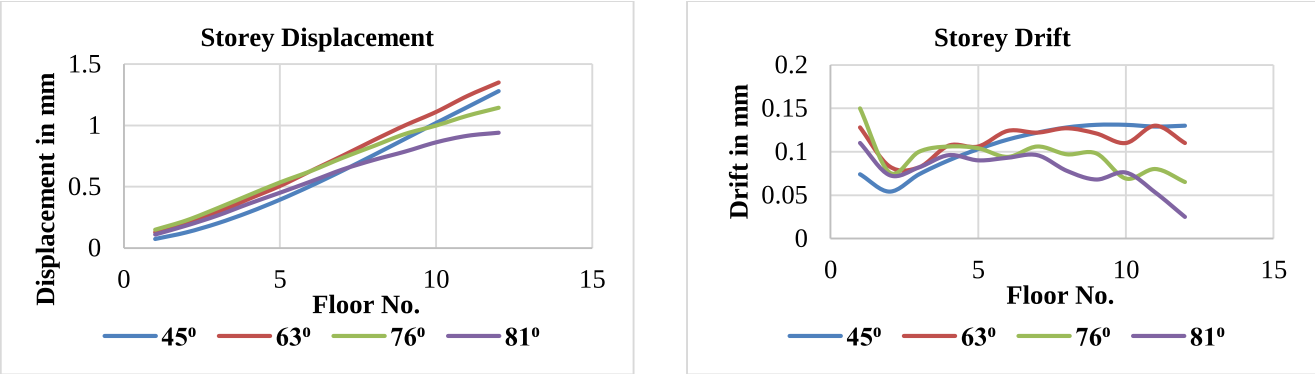


Chart -6 Storey displacement and storey drift.

### 3.2 Results Comparison between Diagrid and Conventional Grid Building

#### 3.2.1 Shear Force and Bending Moment at Ground Level Beams

From the results of shear force and bending moment present in ground beam it is observed that for conventional grids all beam carry same SF and BM but for diagrids exterior beams carry maximum SF and BM.

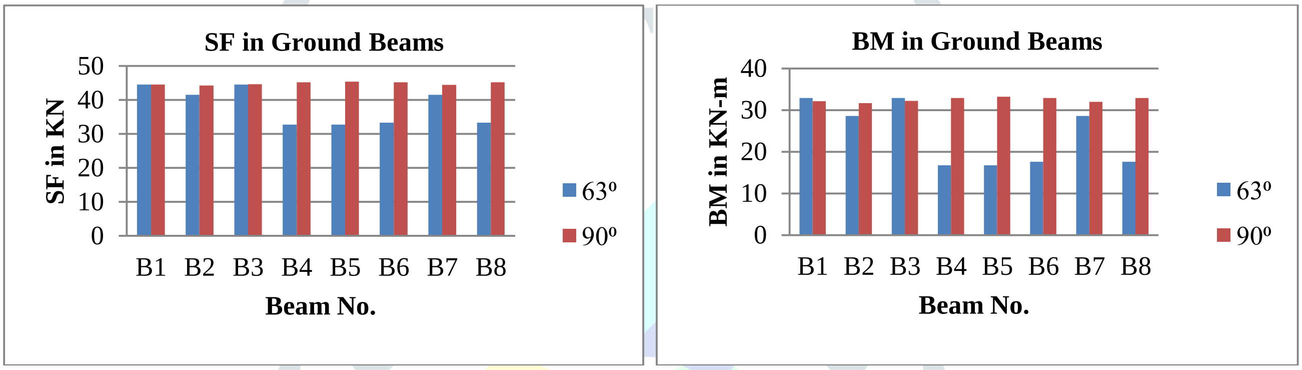


Chart -7 SF and BM at ground level beams.

#### 3.2.2 Axial Force in interior column

From above graph it is observed that diagrid structure has maximum axial forces in interior columns than the conventional grid system.

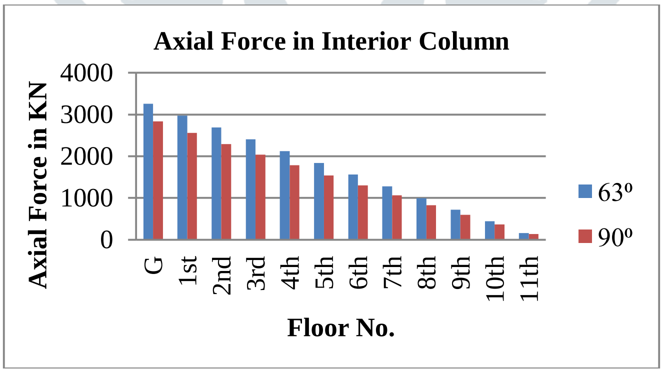


Chart -8 Axial Force in interior column.

#### 3.2.3 Shear Force and Bending Moment in interior columns

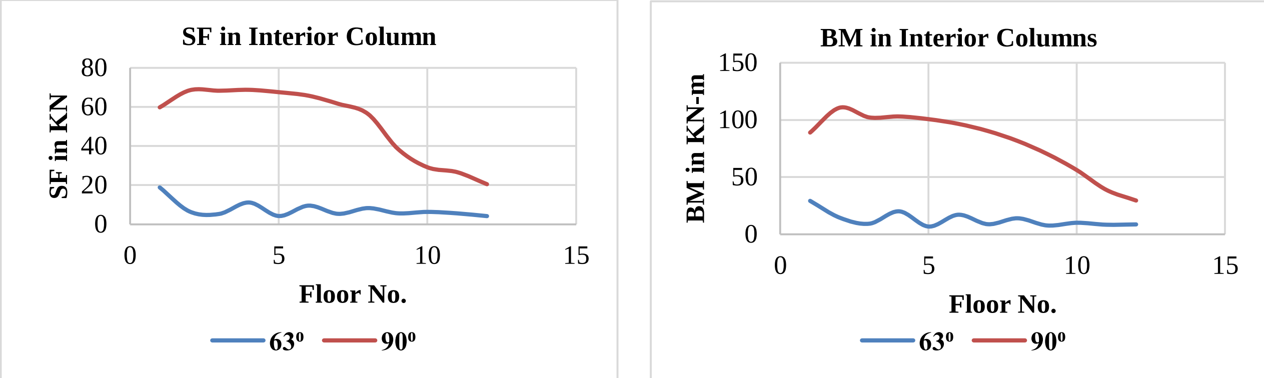

Chart -9 SF and BM in interior column.

From below graph it is observed that in conventional grid system interior columns carry maximum SF and BM than Diagrid structure.

### 3.2.4 Shear Force and Bending Moment in diagrid columns

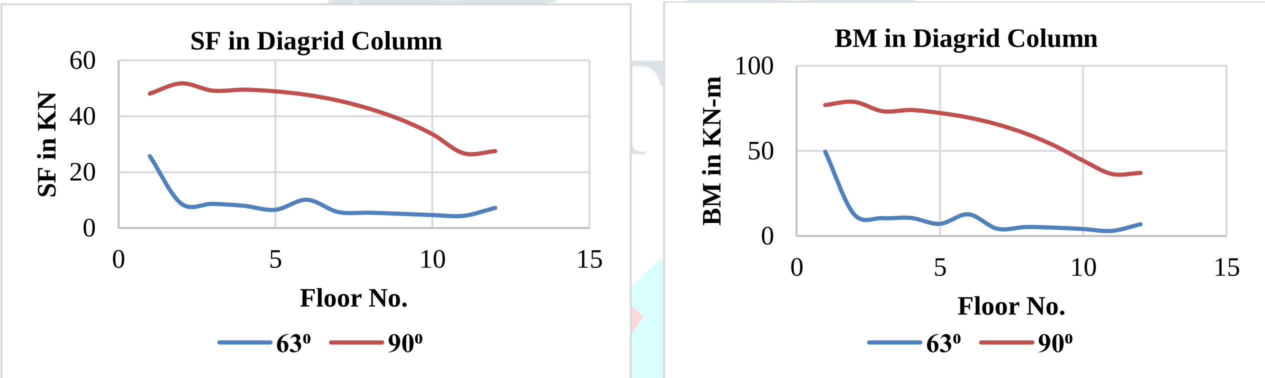

Chart -10 SF and BM in diagrid column.

From below graph it is observed that in conventional grid system interior columns carry maximum SF and BM than Diagrid structure.

### 3.2.5 Axial Force in diagrid column

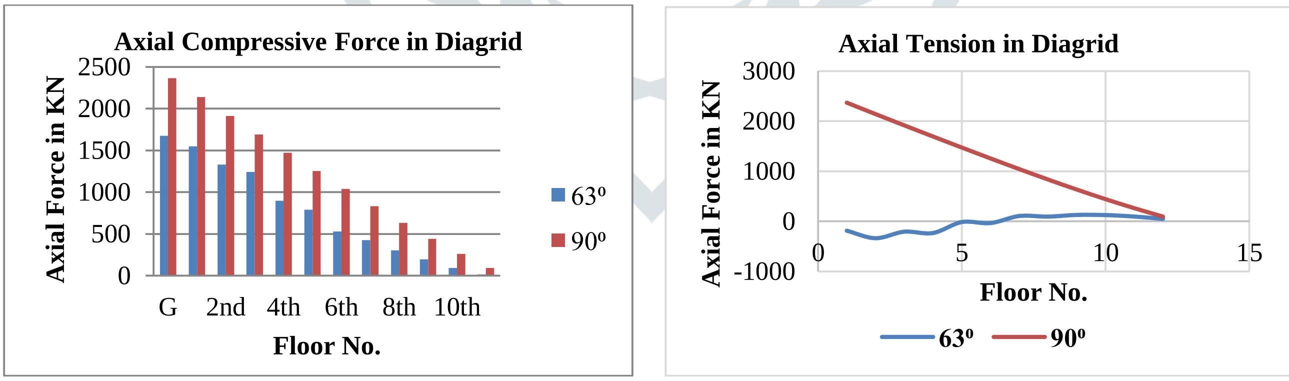

Chart -11 Axial compression and Tension in diagrid.

From above graphs it is clear that as angle of diagrid increases axial compression increases but in case of axial tension it is only present in the case of diagrid structures.

## IV. Conclusions

By analyzing different diagrid angles these are the conclusions of this study-

1. According to SF and BM present in different diagrids $81^0$ shows better results than other angles.
2. According to axial forces in interior columns present in different diagrids $45^0$ shows better results than other angles.
3. According to SF and BM present in interior columns present in different diagrids $63^0$ shows better results than other angles.
4. According to SF and BM present in diagrid columns present in different diagrids $63^0$ shows better results than other angles.

5. According to axial compression present in interior columns present in different diagrids $63^0$ shows better results than other angles.
6. According to axial tension present in interior columns present in different diagrids $45^0$ shows better results than other angles.
7. According to storey drift present in different diagrids $81^0$ shows better results than other angles.
8. From above conclusions it is observed that $63^0$ diagrid system performance is better than other diagrid angle buildings.
9. For axial forces in interior column and axial tension in diagrids, conventional grid system perform better than $63^0$ diagrid structure.
10. According to SF and BM in ground beams, interior columns and diagrid columns present in different diagrids $63^0$ shows better results than conventional grid system.
11. From above conclusions it is observed that $63^0$ diagrid system performance is better than conventional grid system.

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