"Diagrid Structural System - effect of Varying Angle Diagrid on the lateral force resisting capacity on tall structure On Etab Software"

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Abstract - *Advancement in technology, increasing population and limited availability of land has leaded towards the construction of tall structures. Structural design of high rise buildings is governed by lateral loads due to wind or earthquake. Lateral load resistance of structure is provided by interior structural system or exterior structural system. Usually shear wall core, braced frame and their combination with frames are interior system, where lateral load is resisted by centrally located elements. While framed tube, braced tube structural system resist lateral loads by elements provided on periphery of structure. Recently diagrid structural system is being adopted in tall buildings due to its structural efficiency and flexibility in architectural planning. Compared to closely spaced vertical columns in framed tube, diagrid structure consists of inclined columns on the exterior surface of building. Due to inclined columns lateral loads are resisted by axial action of the diagonal compared to bending of vertical columns in framed tube structure. Diagrids structures have emerged as one of the most innovative and adaptable approaches to structuring buildings. The advantages of this system thus even outweigh the disadvantages which are specifically complexity in design, construction of nodes and high cost of the structure. Therefore, studies related to a structure of this kind which has a huge scope in future are highly desired.*

***Key Words*: Diagrid, Varying angle diagrid, Time history analysis, Aspect Ratio**

1. INTRODUCTION

The term "Diagrid" is a blending of the words "diagonal" and "grid". The Diagrid structural system can be defined as a diagonal members formed as a framework made by the intersection of different materials like metals, concrete or wooden beams which is used in the construction of buildings and roofs. Diagrid is commonly used to describe a diagonal structural grid. The system is comprised of diagonal members, normally fabricated from structural steel, that are joined at nodal points. Diagrids or diagonal grids are a structural design strategy for constructing buildings that combine the resistance to gravity and lateral loads into a triangulated system of members the eliminates the need for vertical columns. This system is usually placed on the perimeter of the building.

The primary idea behind the development of the diagrid system was the recognition of the savings possible in the removal of (most of) the vertical columns. Vertical columns, engineered to carry gravity loads, are incapable of providing lateral stability, the diagonal grid, if properly spaced, is capable of assuming all of the gravity loads as well as providing lateral stability due to its triangular configuration. A pure diagrid structure does not require the traditional reinforced concrete or steel core to provide lateral stability.

2.LITERATURE REVIEW

1) Montuori et al. (2014) have studied geometrical patterns of 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 of diagonals (variable-angle, VA) as well as by changing the number of 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 of the analyses results. The diagrid patterns generated for the building model are analysed using FEM numerical models, by means of SAP2000 computer code. The comparison in terms of structural weights and performances finally allows for discussing efficiency potentials of the different patterns.

2) Jani et al. (2012) carried out analysis and design of 36 storey diagrid steel building. A regular floor plan of 36 m x 36 m size is considered in this paper. Modelling and analysis of structural members is done in ETABS. Both Dynamic along wind and across wind are considered for analysis and design of the structure. In a similar way, analysis and design of 50, 60, 70 and 80 storey diagrid structures is also carried out and Comparison of analysis results in terms of time period, top storey displacement and inter-storey drift is presented in this paper.

3. OBJECTIVES

The objectives have been specified as follows:

- To review the existing literatures related to diagrid structural system.
- To evaluate the performance of diagrid structure as a lateral load resisting system.
- To analyse the effect of variation of angles along the height of the building.
- To perform the linear static and linear dynamic analysis and compare responses obtained in terms of Base shear, Top Storey displacement, Inter-Storey drift.

4. METHODOLOGY

The present study is carried out to study different structural aspects related to diagrid structural system. To solve the stated problem, the following procedure is followed.

1)Modelling of various structures and different Angles of diagrid structures using ETABS 2016.

2)Linear Dynamic analysis of these structures by Time History Method.

The following steps have been followed in ETABS 2016 software for modelling and analysis purpose:

1)Defining material properties (In ETABS Define menu > Material Properties)

2)Defining different section for Interior columns and beams. (Define > Frame section)

- Sizes are assumed so as to satisfy safe displacement criteria.
- Section Designer is used specially to define built-up column.
- All beams and vertical columns are modelled as beams elements while inclined diagonal columns are modelled as truss elements by applying moment releases at the ends.

3)Defining Slab section as membrane element to transfer the loads. (Define > Define slab section)

4)Defining various load patterns as shown in the Fig. 3.1 (Dead load, live load, Floor Finish, Earthquake load, Wind load) (Define > Load patterns)

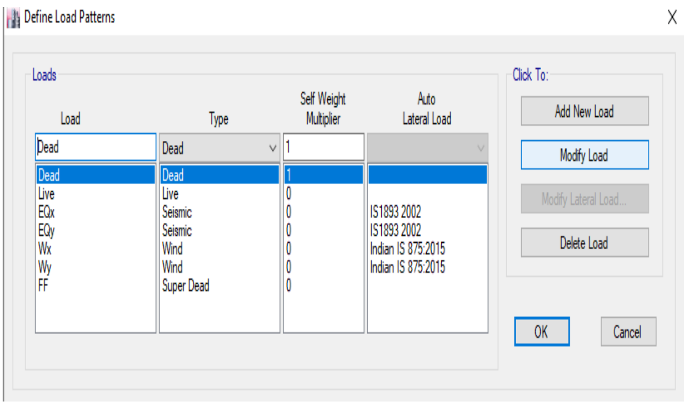

Fig. Load Patterns

5}Assigning support conditions (Assign > Joint > Restraints)
6)All slabs are selected and assigned diaphragms for rigid action (Assign > Shell > Diaphragms)
7)Assigning Live loads on all slabs(Assign > Shell loads)
8)Defining Mass source (Define > mass source command)
As per IS: 1893-2002, 25% live load (up to & equal to 3kN/m2) is considered on all floor of building except at roof level.

9)Defining Time History function. (Define > Function > Time History Function)

Input the values as per the earthquake as in fig below.

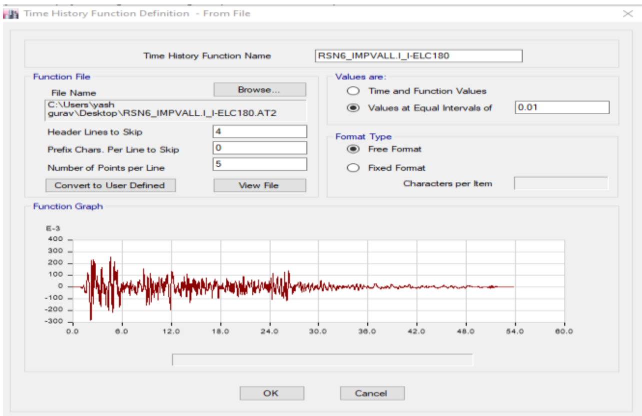

Fig . Time History Function Definition

Match the base shear and change the scale factor while entering the Load case data as shown in fig below.

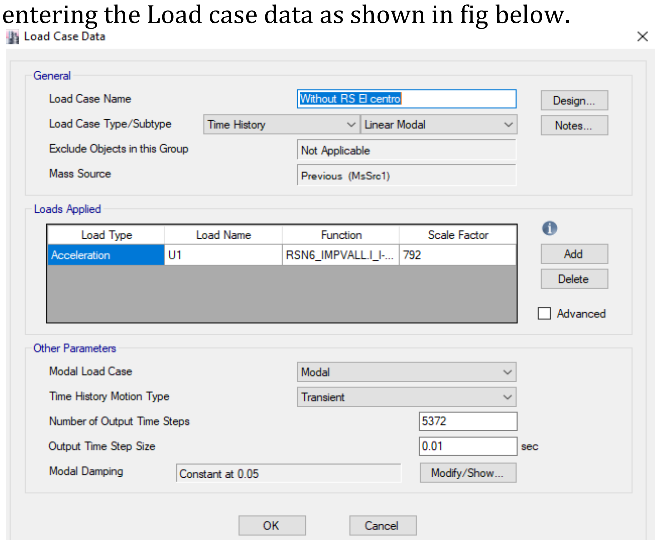

Fig.Time History Load case data.

9)Defining different load cases (Define > Load cases). 11)Processing to analyse the models (Analyse > Run Analysis). 12)Obtaining the results after analyses process (Display > Show Tables > Analyses)

Table. Building Details

Description	
Plan Area	1296m2
Size of the building	36x36m
Total height	129.6m
No. of stories	36
Storey height	3.6m
Module size	3-Storey Module
Slab thickness	100mm thick, M30 grade

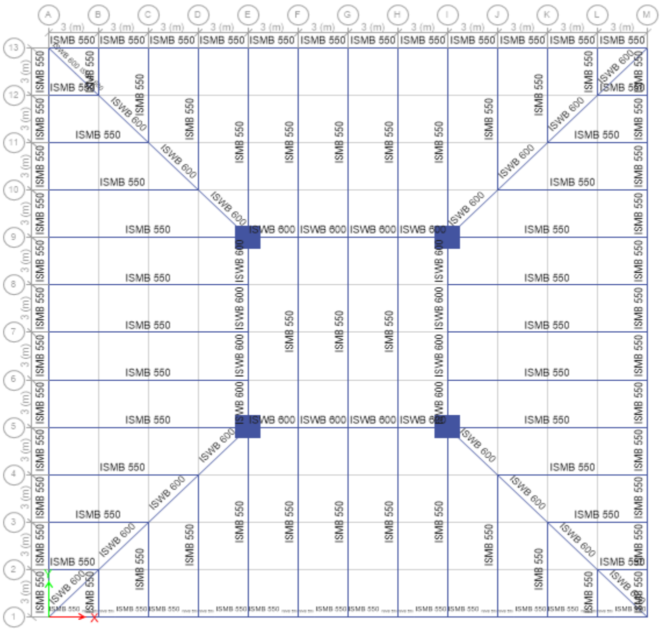

Fig. Floor Plan

3-Storey Module means the diagrid is covering 3 storeys and then a joint is placed as shown in fig.

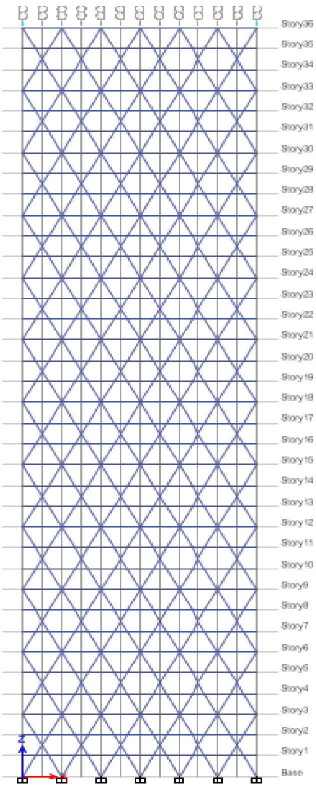

Fig. (a) 2D Elevation

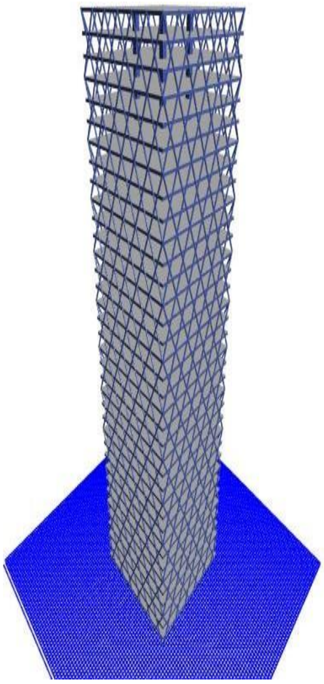

Fig .(b) 3D Elevation

Table. Input data for materials and loads

Grade of Concrete	M30
Grade of Steel	Fe250 (Mild steel)
Intensity of live load	2.5 kN/m2
Floor Finish load	1.0 kN/m2
Density of Concrete	24.992 6 kN/m^3
Density of Steel	76.972 9 kN/m^3
Modulus of Elasticity of Steel	21000 0 MPa
Modulus of Elasticity of Concrete	27386. 13MPa

Table. Seismic and Wind Parameters

Mass Source	DL+0.25LL
Importance Factor (I)	1.2
Response Reduction Factor (R)	5
Seismic Zone	III
Seismic Zone Factor(Z)	0.16
Soil Type	Medium Soil
Basic Wind Speed	39 m/s
Terrain category	III
Risk factor (k1)	1
Topography factor (k3)	1
Damping ratio	5%

The model of 36 storey diagrid structure with 6m spacing of diagrid is shown in fig..

There are 3 models, one for each case.

- In case-1 the angle is kept constant throughout the height i.e. 3 storey module (74.2 degrees).
- In case-2 variation of angle takes place from base to top. At the base 4 storey module (78.2 degrees) is used, in the middle portion 3 storey module is used and in the top potion 2 storey module (67.4 degrees) is used. Therefore, the angle becomes steeper as we go towards the base.
- In case-3 variation of angle is opposite of that in case-2. Here 2 storey modules are used at the base whereas 4 storey module are used in the top portion. Therefore, the angle becomes steeper as we go towards the top.

model of 36 storey diagrid structure with 9m spacing of diagrid is shown in fig..

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- In case-3 variation of angle is opposite of that in case-2. Here 2 storey modules are used at the base whereas 4 storey module are used in the top portion. Therefore, the angle becomes steeper as we go towards the top.

Table.Results for 36 Storey Diagrid building with 6m spacing, , Case-1- Uniform angle

Earthquake	**Top Storey Displacement (mm)**	**Inter Storey Drift (unit less)**	**Fundamental Time Period (sec)**
EQX/EQY	69.98	0.00065	2.542
ELCentro	54.58	0.000763	
Kocaeli shock-1	39.21	0.000636	
Kocaeli shock-2	41.177	0.000454	
Nepal shock -1	19.364	0.000221	
Nepal shock -2	53.543	0.000501	

Table.Results for 36 Storey Diagrid building with 6m spacing, , Case-2- Angles steeper towards the base

Earthquake	**Top Storey Displacement (mm)**	**Inter Storey Drift (unit less)**	**Fundamental Time Period (sec)**
EQX/EQY	77.359	0.000829	2.792
ELCentro	46.42	0.000727	
Kocaeli shock-1	32.67	0.000540	
Kocaeli shock-2	48.183	0.000638	
Nepal shock -1	23.928	0.000352	
Nepal shock -2	60.44	0.000686	

Table.Results for 36 Storey Diagrid building with 6m spacing, , Case-3- Angles steeper towards the top

Earthquake	**Top Storey Displacement (mm)**	**Inter Storey Drift (unit less)**	**Fundamental Time Period (sec)**
EQX/EQY	74.497	0.000808	2.533
ELCentro	52.058	0.00075	
Kocaeli shock-1	37.388	0.000599	
Kocaeli shock-2	37.92	0.000451	
Nepal shock -1	19.695	0.000274	
Nepal shock -2	56.657	0.000592	

Table.Results for 36 Storey Diagrid building with 9m spacing, Case-1- Uniform angle

Earthquake	Top Storey Displacement (mm)	Inter Storey Drift (unit less)	Fundamental Time Period (sec)
EQX/EQY	69.98	0.000763	2.66
ELCentro	54.58	0.000482	
Kocaeli shock-1	39.21	0.000531	
Kocaeli shock-2	41.177	0.000707	
Nepal shock -1	19.364	0.000799	
Nepal shock -2	53.543	0.000825	

Table.Results for 36 Storey Diagrid building with 9m spacing, , Case-2- Angles steeper towards the base

Earthquake	Top Storey Displacement (mm)	Inter Storey Drift (unit less)	Fundamental Time Period (sec)
EQX/EQY	81.84	0.000745	2.745
ELCentro	50.46	0.000582	
Kocaeli shock-1	59.97	0.000629	
Kocaeli shock-2	79.7	0.000885	
Nepal shock -1	91.85	0.000912	
Nepal shock -2	83.97	0.000806	

Table.Results for 36 Storey Diagrid building with 9m spacing, , Case-3- Angles steeper towards the top

Earthquake	Top Storey Displacement (mm)	Inter Storey Drift (unit less)	Fundamental Time Period (sec)
EQX/EQY	88.05	0.000864	2.711
ELCentro	58.54	0.000668	
Kocaeli shock-1	58.03	0.000609	
Kocaeli shock-2	86.91	0.000924	
Nepal shock -1	63.61	0.000649	
Nepal shock -2	86.27	0.000879	

2. CONCLUSIONS

Based on analysis results obtained in this study, the following conclusions are made:

- This study examined the influence of different configurations of Varying angle diagrids on the behavior of diagrid structures. It was found that, with the change in angle of diagrids the response of the structure to the external loads also changes.
- the Uniform angle diagrids shows better resistant to lateral loads when compared to the Varying angle diagrids.
- The Diagrids with 6m spacing reduces the magnitude of top storey displacement and inter-storey drifts as compared to the diagrids with 9m spacing.

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