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Dynamic Analysis of Diagrid Structural System for R.C. Building Structure

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Abstract: Present the major issue in tall building development is resistance by lateral load like earthquake and wind. The behavior of tall structure under the action of lateral load goes to laterally displacement, to insure these structure against these lateral load the specially arrangement are made in ordinary framed R.C. building which called structural form. there are different structural forms used in tall building such as shear wall structure, core structure, tube in tube structure, diagrid structure, outrigger structure etc. these works base on diagrid structures. It is formed as Lateral load resistance of the structure is provided by interior structural system or exterior structural system. Due to inclined columns lateral loads are resisted by axial action of the diagonal in diagrid structure compared to bending of vertical columns in conventional building. This paper also reviews the studies on the comparison of diagrids with regular configuration and diagrids with varying angles. In these study static and dynamic (response spectrum and time history both) are done in G+12 story and G+18 story building structure are done for model at different angle of diagonals. The static analysis, Response spectrum analysis and time history analysis are carried out in terms of story displacement, base shear, story drift and time period using ETABS software. Then comparative study is done between models of different angled diagrid building and results are presented.
Keywords: Structural form, Diagrid Structure, Displacement, Drift, PSA, PSV Base Shear, Time history, vase Acceleration, Base Velocity and Etabs etc.

I. INTRODUCTION

During the modern world, the development of tall buildings has been a product of close collaboration between the structural engineer and the architect. A most of tall buildings constructed during that period stand as a testament to such productive collaboration. The postmodern movement in early 1980s, however, witnessed a shift in the direction of development of tall buildings as architectural trends began to deliberately seek non-orthogonal treatments of architectural form. Newly emerging approach is in tall building design having been towards promoting architectural style. Cost of structure in relation to total construction cost 54 continues search for novel morphological schemes. This has manifested in a notable proliferation of architectural form typologies in which contemporary tall buildings are “emerging with an increasing degree of geometrical variation” and complexity.

The role of the new gene ration of generative tools, which ploy parametric and associative geometry modeling techniques, has been pivotal in driving such new design trends. Despite their powerful implications of on the “Structural form,” however, such approaches make no extension to in clued, among others, the structural performativity aspects along with other factors that directly influence the architectural form. In the context of current tall building design process, issues pertaining to structure are typically left to be dealt with after the articulation of the architectural form. This consequently requires that the form undergo extensive process of “rationalization” in or der to overcome its limitations regarding structure, material and constructability. While such an approach may enable a building stand up, it will not yield solutions that “perform fully in conceptual, formal, technical, financial and material sense,” particularly with reference to structure.

II. STRUCTURAL SYSTEM

The structural systems for high-rise buildings are constantly evolving and at no time can be described as a completed whole. Nevertheless, it is worthwhile to review existing systems while being aware the progress in systems development is ongoing. The author believes that a narrative of prevalent lateral load resisting systems would be of interest and value to practicing engineers and Architects as well as other tall building devotees. The role of steel members in earlier structures was principally to carry gravity loads. Gradually its function was enhanced to include wind and seismic resistance using systems ranging from modest portal frames to innovative systems such as outriggers, mega frames, and interior super-diagonals. Today there exists a myriad of lateral bracing systems that may be grouped into distinct categories, each with an applicable height range. However, selection of lateral load resisting system typically includes one or a combination of the following systems.

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A. Braced frame structure
B. Rigid frame structural system
C. wall frame system
D. shear walls system
E. Outtrigger structure system
F. Infilled frame structure system
G. Flat slab and flat plate structure system
H. Framed tube structure system
I. Trussed tube system
J. Diagrid System
K. Bundled tube structure system
L. Tube in a tube system
M. Coupled wall system
N. Hybrid structure system

III. DIAGRID SYSTEM

Unlike vertical columns of traditional structure, diagrid structural systems for tall buildings have special inclined columns. Due to the inclined columns, a diagrid structural system for tall buildings produces axial force along the column direction under horizontal load, which has the advantage of resisting horizontal wind load and seismic load and gives more freedom to architectural design, so a diagrid structural system for tall buildings becomes an effective new structure style for tall and super-tall buildings. Theories and tests regarding the diagrid structural system for tall buildings have been intensely researched. At present, studies for mechanical characteristics, joint form, theories, and tests have been systematized. The diagrid structural system for tall buildings and confirms that the structure has larger lateral stiffness and good seismic performance.

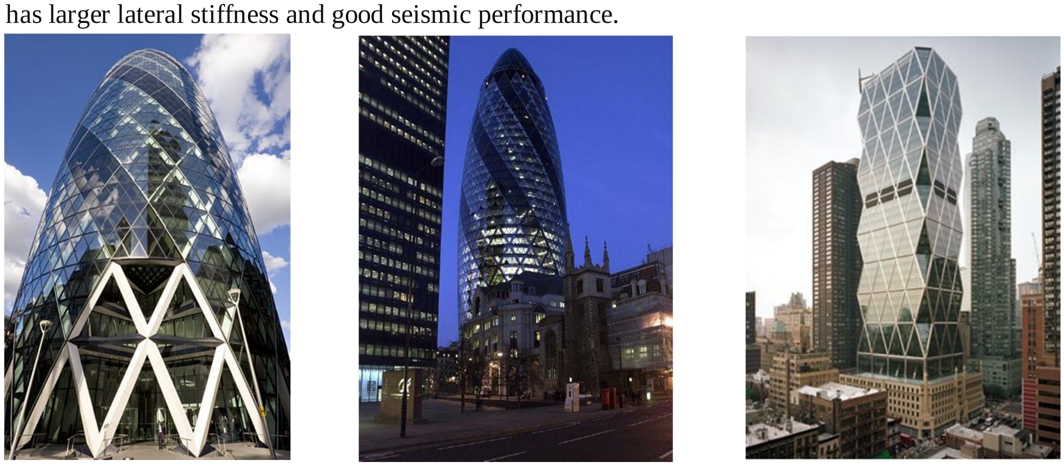

Figure 1 Example of diarid structral system

IV. MODELING AND ANALYSIS

In present work, the 3 D model of R.C.C. building of different symmetrical in plan area 1024 m^2 of G+12 and G+18 Storied of 3.3 m each are Modeled with 2 story diagrid (at angle 38.6^0), 3 story diagrid (at angle 50.2^0) and 4 story diagrid (at angle 58^0), as shown in figures. The linear Static, Response Spectrum and non linear time history analyses are done on these R.C.C. building models using IS 456:2000 and IS 1893:2016 with the help of ETABS Software.

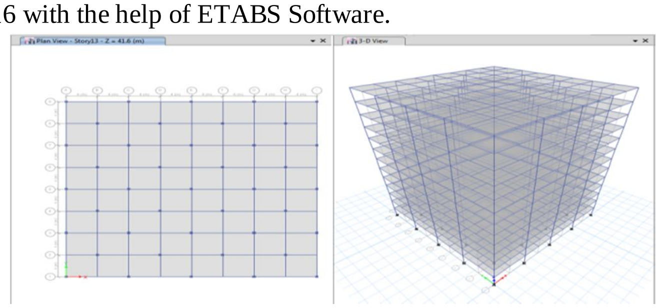

Figure 2 - Plan and 3D view of bare frame Building of G+12 stories building

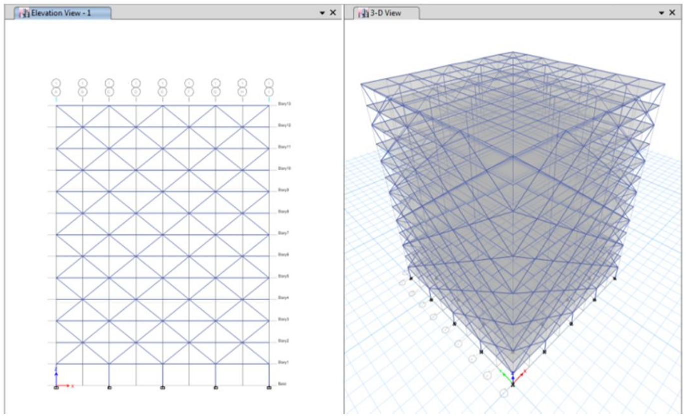

Figure 3 - 3D View and Elevation of 2 story diagrid structure of G+12 stories building

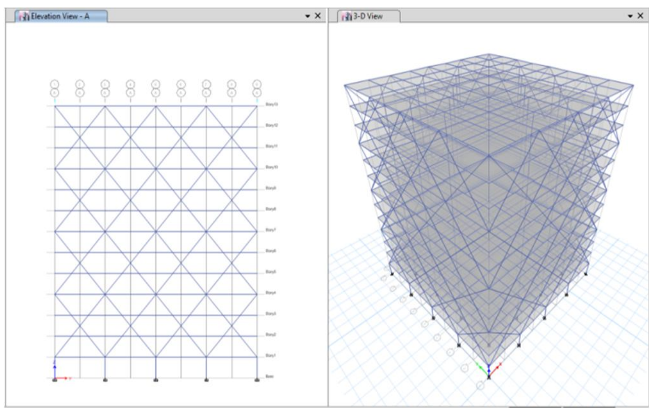

Figure 4 - View and Elevation of 3 story diagrid structure of G+12 stories building

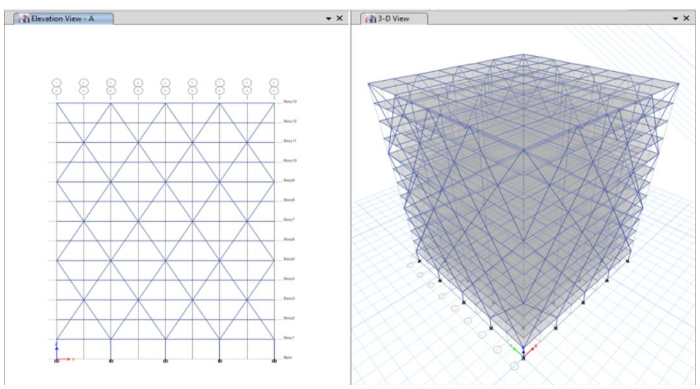

Figure 5 - 3D View and Elevation of 4 story diagrid structure of G+12 stories building

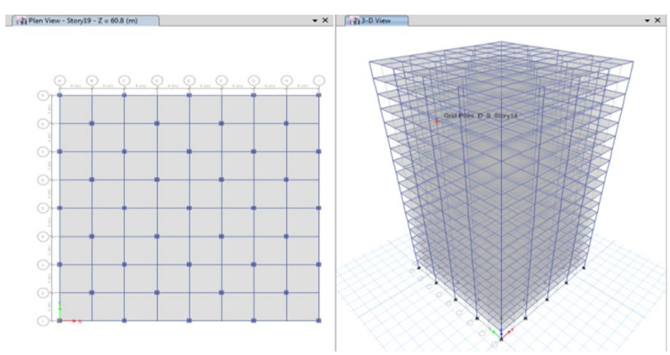

Figure 6 - Plan and 3D view of bare frame Building of G+12 stories building

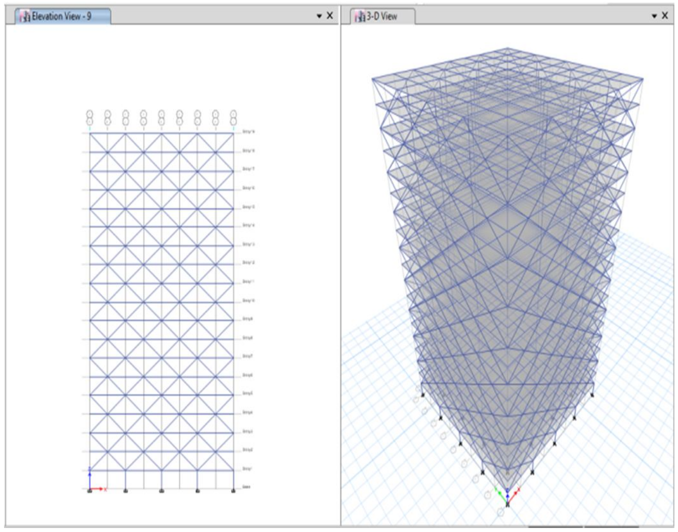

Figure 7 - 3D View and Elevation of 2 story diagrid structure of G+18 stories building

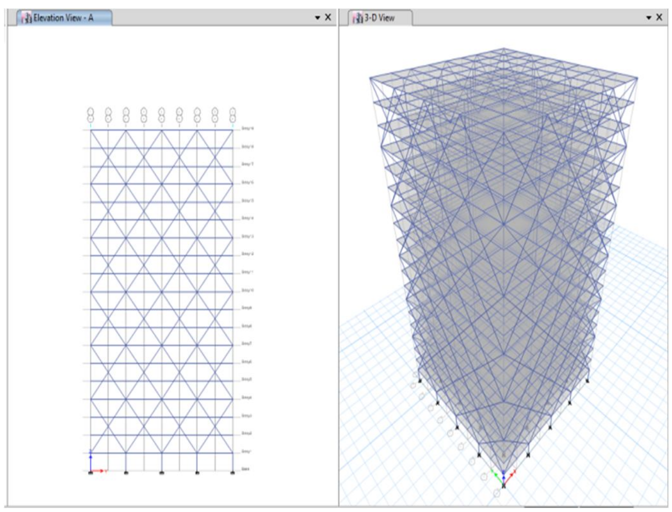

Figure 8 - View and Elevation of 3 story diagrid structure of G+18 stories building

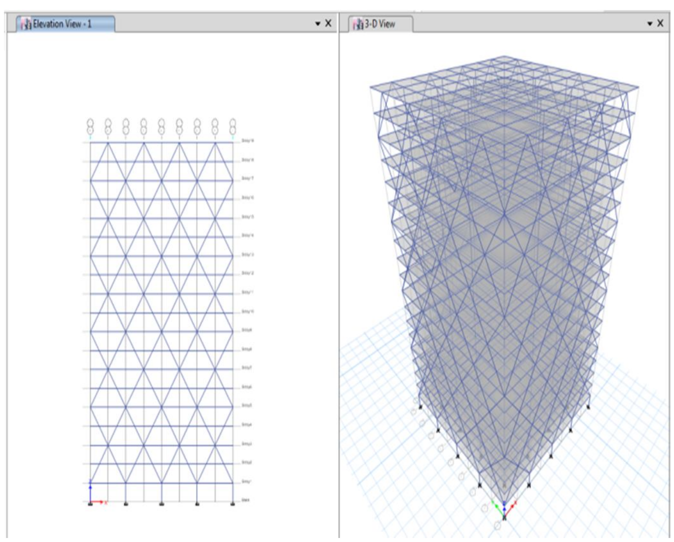

Figure 9 - 3D View and Elevation of 4 story diagrid structure of G+18 stories building

The general specification used in building for analysis shown in table 1.

Table1 Specification of Building

GENERAL PROPERTIES	
SIZE OF COLUMN	500mmx500mm, 600mmx600mm
SIZE OF BEAM	250mmx450mm
THICKNESS OF SLAB	125mm
MATERIAL PROPERTIES	
GRADE OF CONCRETE	$20N/MM^2$
GRADE OF STEEL	HYSD500
SOFTWARE USED	ETABS 2016
SEISMIC LOAD DETAIL	
SEISMIC ZONE	IV (0.24)
RRF	5
IMPORTANCE FACTOR	1
MASS SOURCE	DL+0.25LL
TIME HISTORY DETAIL	
Origin Time	14/12/2005 07:09:48
Lat.	29.88 N
Long.	77.901 E
Depth (Km)	25.7
Magnitude	5.2
Region	Roorkee -Uttarakhand

V. RESULT AND DISCUSSION

A. Displacement and Drift Ratio

Analysis carried out under the static and dynamic approach according to Indian standards. And results obtained displacement and drift due to static analysis, displacement and drift due to response spectrum analysis, displacement and drift obtained due to time history analysis are compared for both G+12 and G+18 stories R.C. building (having different 2 story diagrid model, 3story diagrid model and 3 story diagrid model) . And also discuss the PSA, PSV, base shear, base acceleration and base velocity under time history analysis.

The displacement due to linear static analysis is found to be reduced in 3 story diagrid model than two other 2 story diagrid and 4 story diagrid. Similar the maximum drift Ratio in static analysis is reduced to be found in 3 story diagrid model than two other 2 story diagrid amd 4 story diagrid model for both G+12 and G+18 story building model.

But in dynamic analysis of response spectrum maximum reduction in displacement and drift ratio are reduced in 3 story diagrid model for both G+12 stories and G+18 stories diagrid model. but in nonlinear dynamic analysis as time history analysis the maximum displacement and drift ratio are reduced to 4 story diagrid model. hence these results shows that higher angle of diagrid member is give better performance in dynamic analysis than static analysis as control to maximum displacement at the top of the building in G+18 stories building structure. The maximum value of displacement and drift in static analysis, response spectrum analysis and time history analysis are shown in table 2 and 3.

Table 2 Displacement in G+12 stories and G+18 stories model (in MM)

	Diagrid at 2 story (at 38.6^0)	Diagrid at 3 story (at 50.2^0)	Diagrid at 4 story (at 58^0)
For G+12 story model due to Static analysis	38.879	38.856	41.12
For G+18 story model due to Static analysis	79.219	73.121	74.54
For G+12 story model Due to response spectrum Analysis	56.089	53.007	53.613
For G+18 story model Due to response spectrum Analysis	54.335	52.342	54.815
For G+12 story model Due to time history analysis	26.241	23.865	25.147
For G+18 story model Due to time history analysis	59.841	51.363	48.346

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Table 3 Drift Ratio in G+12 stories and G+18 stories model (in MM/MM)

	Diagrid at 2 Story (at 38.6^0)	Diagrid at 3 story (at 50.2^0)	Diagrid at 4 story (at 58^0)
For G+12 story model due to Static analysis	0.002316	0.00226	0.002261
For G+18 story model due to Static analysis	0.001611	0.001629	0.001624
For G+12 story model Due to response spectrum Analysis	0.003921	0.003844	0.003942
For G+18 story model Due to response spectrum Analysis	0.001588	0.00154	0.001634
For G+12 story model Due to time history analysis	0.001899	0.001779	0.001665
For G+18 story model Due to time history analysis	0.001233	0.001347	0.001316

B. PSA and PSV due to time History Analysis

The maximum pseudo static acceleration (in g) and Pseudo static Velocity (in mm/sec) for 2 story diagrid, 3 story diagrid and 4 story diagrid with G+12 stories and G+18 stories building model are shown in the following figures . It explained that that increasing in height of building the angle of diagrid required increasing for making sustainable and stabling the medium rise building.

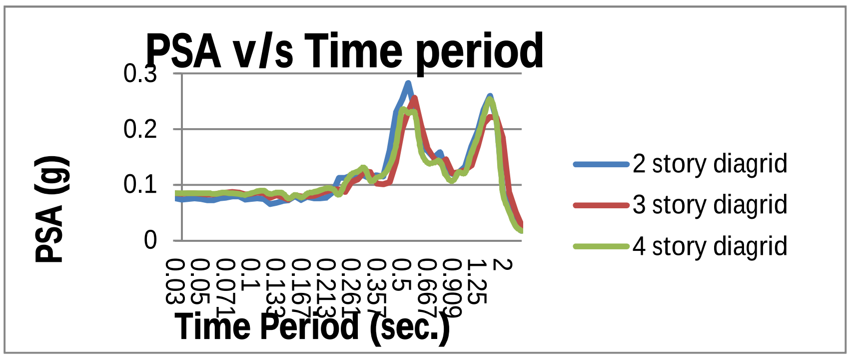

Figure 10 - PSA due to Time History analysis in G+12 storied Building

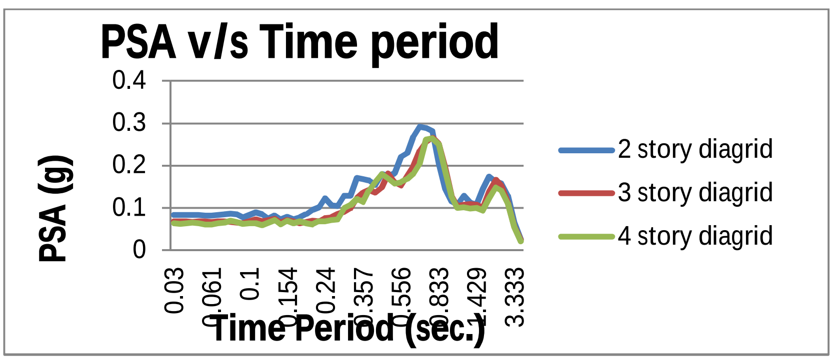

Figure 11 - PSA due to Time History analysis in G+18 storied Building

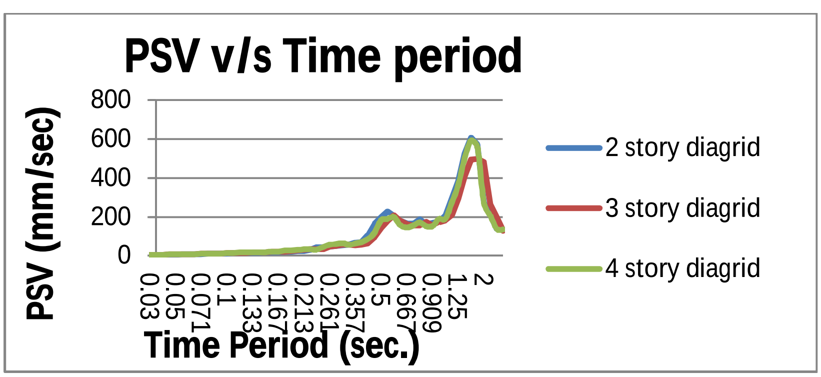

Figure 12 - PSV due to Time History analysis in G+12 storied Building

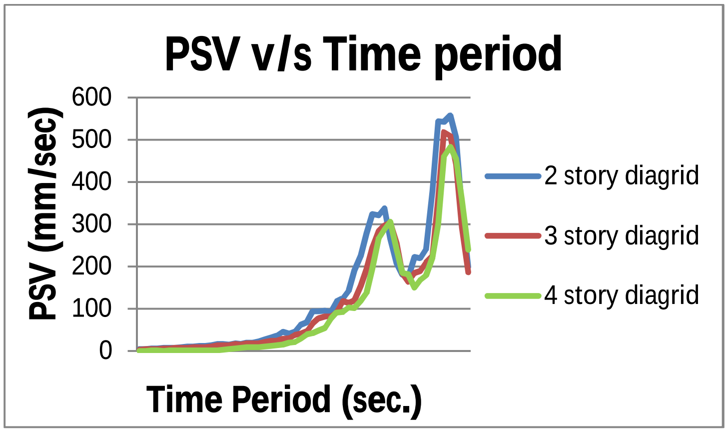

Figure 13 - PSV due to Time History analysis in G+18 storied Building

C. Base Shear Due to time History Analysis

The values of Base Shear in for for G+12 and G+18 stories building are compared in table 4 and.

Table 4 Maximum Base Shear due to Time History analysis

	Diagrid at 2 story (at 38.6^0)	Diagrid at 3 story (at 50.2^0)	Diagrid at 4 story (at 58^0)
For G+12 story model (in KN)	7355.1445	6985.8012	6799.6248
For G+18 story model (in KN)	8360.3085	8361.8616	8252.0272

D. Base Acceleration Due To Time History Analysis

The values of Base Acceleration in for different 2 story diagrid, 3 story diagrid and 4 story diagrid for G+12 and G+18 stories building are compared in table 5 and figures.

Table 5 Maximum Base Acceleration due to Time History analysis

	Diagrid at 2 Story (at 38.6^0)	Diagrid at 3 Story (at 50.2^0)	Diagrid at 4 story (at 58^0)
For G+12 story model (in mm/sec^2)	837.2	830.31	736.76
For G+18 story model (in mm/sec^2)	927.13	668.85	620.45

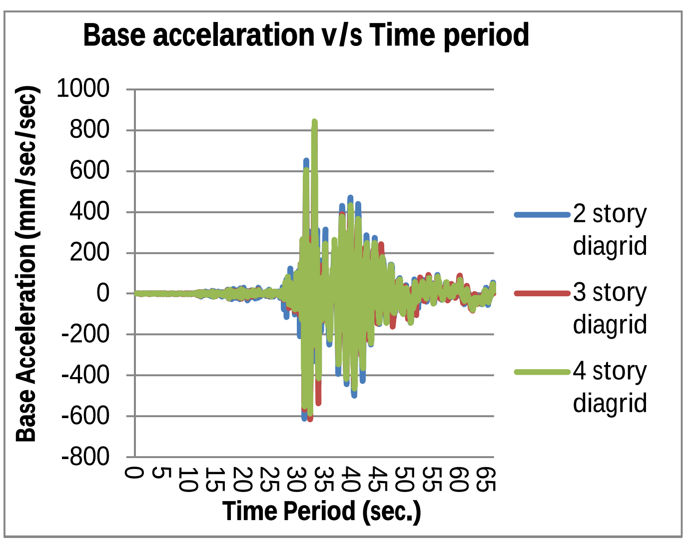

Figure 14 - Base Acceleration due to Time History analysis in G+12 storied Building

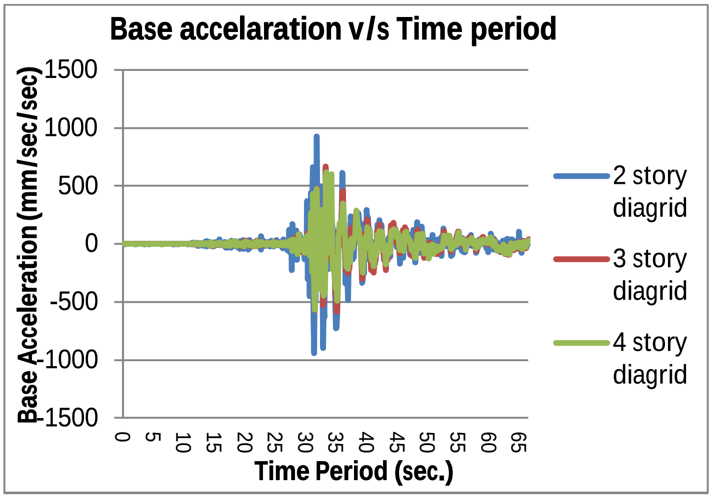

Figure 15 - Base Acceleration due to Time History analysis in G+18 storied Building

The maximum acceleration for 2 story diagrid, 3 story diagrid and 4 story diagrid of G+12 stories Building are 837.2 mm/s^2, 830.31 mm/s^2 and 736.76 mm/s^2 respectively. And the value of maximum acceleration for 2 story diagrid, 3 story diagrid and 4 story diagrid of G+12 stories Building are 927.13 mm/s^2, 668.85 mm/s^2 and 620.45 mm/s^2 respectively. It has been seen that the value of base acceleration increases by increasing the value of base shear as the lateral force included the acceleration at the base of structure.

VI. CONCLUSION

In this paper, comparative analysis and of G+12 and G+18 stories diagrid structural system building , Diagrid at 2 story diagrid (at angle 38.6^0), 3 story diagrid (at angle 50.2^0) and 4 story diagrid (at angle 58^0). ETABS 2016 software is used for modelling and analysis of structure. Analysis results like displacement at top of structure, story drift and story shear are presented here. Also design of both structures is done and optimum member inclination is decided to satisfy the safe design criteria. We conclude from the study that,

A. As the lateral loads are resisted by diagonal members, the top storey displacement is very much less in diagrid structure as compared to the simple frame building. And in static and dynamic analysis, the diagrid at angle 50.2^0 are giving best result.
B. The storey drift and storey shear is less for diagrid structural system.
C. Diagrid provide more resistance in the building which makes system more effective.
D. The design of both structures are done by using same member size but that member sizes are not satisfied to design criteria in case of simple frame structure and failure occurs with excessive top story displacement. So the higher sizes of members are selected to prevent the failure criteria.
E. Diagrid structure system provides more economy in terms of consumption of steel and concrete as compared to simple frame building.
F. Diagrid structural system provides more flexibility in planning interior space and façade of the building.

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