

Comparative Analysis of Conventional Steel Structure with Diagrid Structures of varied angles

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Abstract - A steel structure is viewed as a mix of various steel assistant parts called sub structures, which by and large joins weight and bowing segment which are relied upon to confine gravity and level burdens, and in addition give worthy solidness to general basic framework. Tall Structures are becoming a trend recently due to various factors such as shortage of land, increase in buiseness, financial development, mechanical progression, advancement in basic frameworks, feel for urban settlings and human desire to fabricate higher. As the tallness of the structure increases, the design criteria is governed by lateral forces like Earthquake forces and wind load that might act on the building during its service life. One of the effective way to counteract these lateral forces is by adopting a Diagrid Structural System which also sums up to the aesthetics of the building. Diagrids consists of inclined columns on the exterior. Due to this arrangement they act as axial members effectively withstanding the lateral forces. To know the desired angle of inclination of diagrids for structural efficiency, analysis of 50 storey steel building of regular floor plan 40mx40m and diagrids with various angles (30°, 45°, 55°, 65°) were analyzed using ETABS software and compared with conventional Steel Structure.

Key Words: Conventional Steel Structure, Diagrids, ETABS, Angle of Inclination, Lateral forces, Time History, Storey Displacement, Diagrid forces, Base Shear.

1. INTRODUCTION

A steel structure is viewed as a mix of various steel assistant parts called sub structures, which by and large joins weight and bowing segment which are relied upon to confine gravity and level burdens, and in addition give worthy solidness to general basic framework. Each steel helper part will bear on as an unprecedented individual from the entire structure, performing free major work adding to general robustness of the basic framework. . Steel structure has getting the opportunity to be obviously noticeable from past decades as a result of its consistency in its material and adaptable properties, and its high caliber to weight extent, and besides it is having high flexible nervousness contradicting limit, in this manner it can withstand broad distortion without incite fall of structure. Finally its straightforwardness of produce and fast constructability, made steel structures a basic building helper system. Tall

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2. DIAGRID

Diagrid is a particular form of space truss. It consists of perimeter grid made up of a series of triangulated truss system. Diagrid is formed by intersecting the diagonal and horizontal components.

2.1 General

Diagrids have developed as an engineering decision in the formation of contemporary structures. The diagrid structure comprises of modules which are precious stone fit as a fiddle and horizontal solidness is given more in diagrids than the other customary sort of structures. In the cutting edge world, diagrids are increasing greater ubiquity as a result of its basic adaptability and class in appearance. Basic designers and planners have now gained impressive ground in the patterns taking after diagrid structures.

2.2 Diagrid Structures

Diagrid came as an improvement of the Geodesic Dome created by Fuller in the late 40's including in triangular structures with inclining reinforce shafts. Frankly, the diagrid system is not another creation. An early instance of today's diagrid-like structure is the 13-story IBM Building in Pittsburg of 1963.

Some of the well-known Diagrid structures across the globe.

- (i) The Swiss Re in London,
- (ii) Hearst Tower in New York,
- (iii) Cyclone Tower in Asan (Korea),
- (iv) Capital Gate Tower in Abu Dhabi,
- (v) CCTV Headquarters, China.



(i)



(ii)



(iii)



(iv)

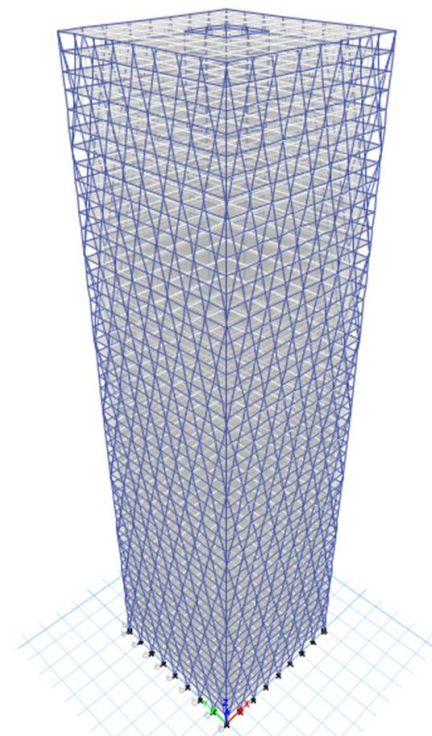
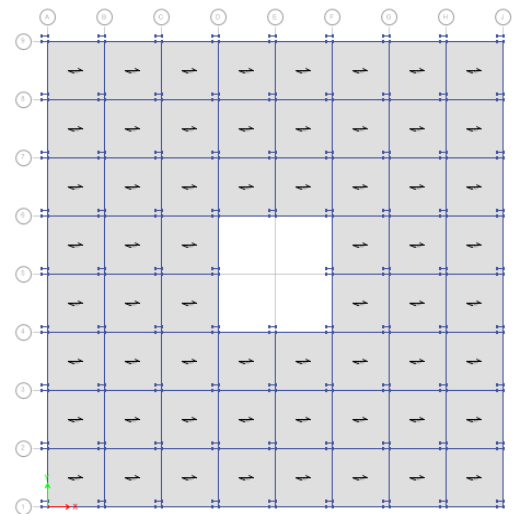


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3.1 Building data

Table: 1 building data

Description	value
Plan Configuration	40mx40m(square plan)
Total height of the building	150m
Height of each floor	3m
No. of Stories	50
Diagrid angle of inclination	30°, 45°, 55°, 65°.



3. MODELING

Modeling of steel moment resisting frame is done using ETABS Ver. 2015, which is 3D modeling and analysis software package.

3.2 Material Properties

Grade of Structural Steel – 380 grade

Grade of Concrete – M25 (Deck Slab)

3.3 Section Properties

Columns – Built up I sections (ISWB 600-2)

Beams – ISMB 450

– ISMB 600

Diagrids – Built up I sections (ISWB 600-2)

Deck Slab – 200mm

3.4 Loads

(a) Gravity load:

Live load – 4.0 KN/m²

Floors finish – 1.5 KN/m²

External Glazing – 2.0 KN/m

(b) Earth quake inputs as per IS 1893 (Part I):2002

Zone factor – II

Soil type – Soft and Medium

Important factor – 1.0

Response reduction factor – 5.0

Time Period – 3.643 seconds

(c) Dynamic Time history analysis

In the present study time history data of ELCENTRO is considered as per the following specifications.

Location: “Imperial Valley”

Date: 19th May 1940

Time: 4:39am

Station: “El Centro Array #9”

Direction: Horizontal, 180°

Units of acceleration: g= 9.81 m/s² (acceleration of gravity)

Number of time instants: 4,000

Sampling time: At= 0.01 s (f= 100 Hz)

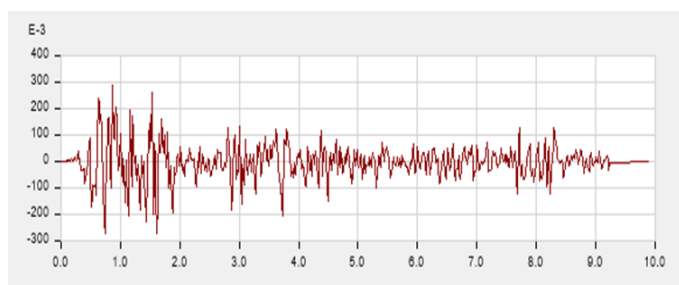


Fig: 1 Graph showing Time History Input – El-Centro

4. Result and Discussion

Analysis carried out using ETABS ver. 2015 and results of various parameters like Time period, Base Shear, Storey displacement, Storey drift, corner column forces and diagrid forces are obtained.

4.1 Time Period

Table: 2 Time period

Mode No.	Time Period (Seconds)				
	Steel MRF	Diagrid 30°	Diagrid 45°	Diagrid 55°	Diagrid 65°
1	7.72	6.36	5.20	4.79	4.87
2	7.67	6.28	5.20	4.78	4.87
3	6.74	1.11	1.27	1.49	2.16
4	2.51	1.11	1.14	1.49	2.14
5	2.50	0.87	1.14	1.49	2.14
6	2.23	0.68	1.01	1.49	2.12
7	1.43	0.67	1.01	1.44	1.84
8	1.42	0.67	1.01	1.16	1.50
9	1.32	0.66	1.01	1.16	1.48
10	1.00	0.46	0.53	0.65	1.48
11	0.99	0.46	0.53	0.64	1.46
12	0.92	0.40	0.43	0.64	1.37

From the modal analysis it observed that, steel moment resisting frame will have highest time period of 7.72 seconds compare to all other diagrid structures and minimum time period is found in diagrid of angle 55 degrees which is found to be 38%. And also it observed that, with the increase in diagrid angle, time period will decrease as shown in Table 2

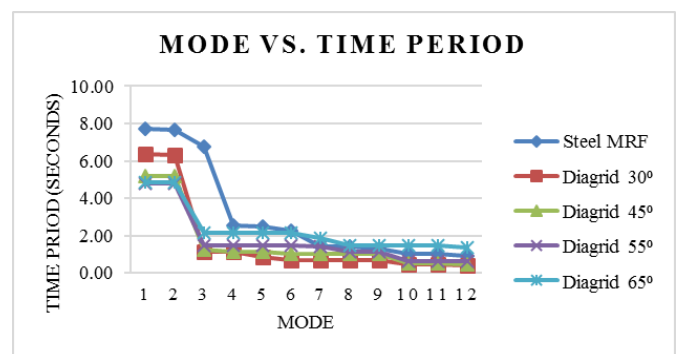


Fig: 2 Graph showing Mode v/s Time Period

4.2 Maximum Base shear

Table: 3 Base Shear

Base Shear (kN)				
Steel MRF	Diagrid 30°	Diagrid 45°	Diagrid 55°	Diagrid 65°
8043	8603	8096	8055	7924

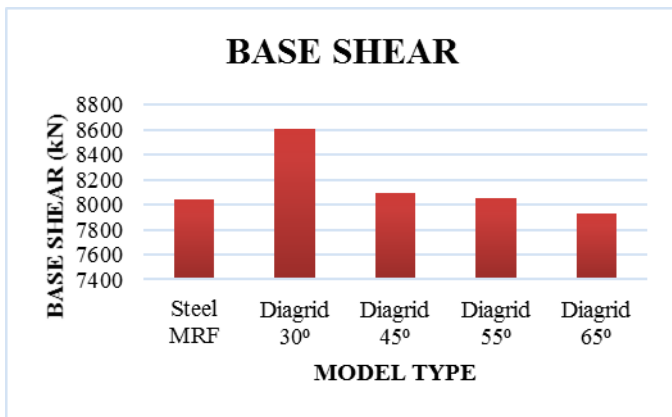


Fig: 3 Graph showing Maximum base shear

From the above base shear values and graphs, it is observed that change in the structural system has less effect on maximum base shear and has only 8.5% variation and diagrid with inclination of 30 degrees is having base shear maximum in comparison with all other diagrid structures.

4.3 Storey displacement

Table: 4 Storey v/s Storey displacement

Storey	SMRF	Diagrid 30°	Diagrid 45°	Diagrid 55°	Diagrid 65°
50	395.6	341.6	227.5	187	183.1
40	349.5	248.8	169.5	142	144.9
30	271.9	158.9	111.3	97.6	101.0
20	178.2	80.8	59.8	52.7	59.1
10	81.1	24.6	19.5	19.0	31.2
1	3.0	1.6	0.8	1.9	2.2
Base	0.0	0.0	0.0	0.0	0.0

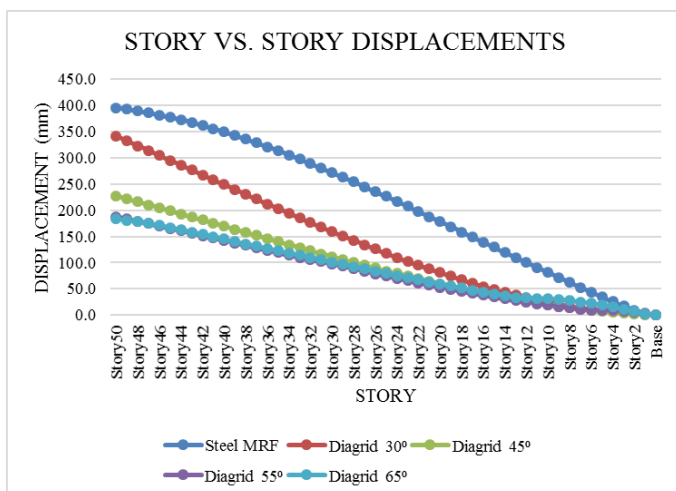


Fig: 4 Graph showing Storey v/s Displacement

It is observed that, change in diagrid angles will have major significance in resisting the later loads. From the results, maximum displacements is found to be 395.6 mm for regular steel moment resisting frame, and minimum of 183.1 mm for diagrid of 65 degree angle which is found to be 53.7% reduction in the displacements. Also, with the increase in the angle of inclination, displacements are reducing accordingly. And 55 and 65 degree angled diagrid show almost same displacement, except 65 degree angled diagrid will show little bit increase in displacements between story 4 and story 12.

4.4 Storey drift ratios

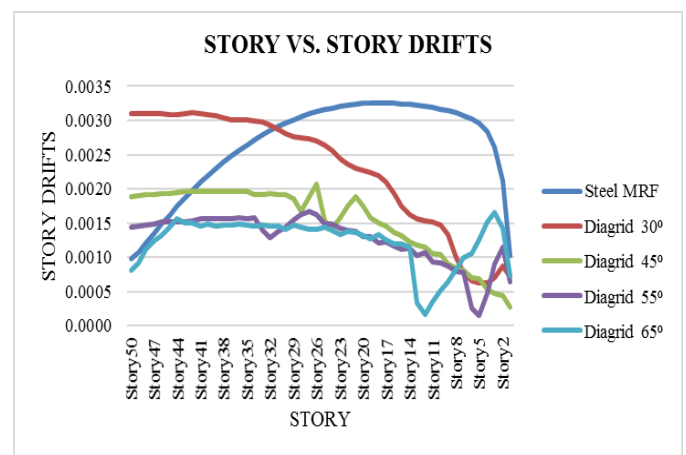


Fig: 5 Graph showing Storey v/s Storey drift

Diagrids shows an entire different pattern of story drift variation as shown, due to the change in the structural system, particularly due to the inclination of outer peripheral columns. Compare to all the structural systems, diagrid of angle 55 and 65 degrees show better resistance to later forces as shown in the Fig.12. Between story 2 and story 5, there is sharp increase in the story drift in 65 degree angled diagrid compare to all other angles, but as the story height increases, story drift remains constant and still further reduction is observed at the top floors between 47 to 50th floor.

4.5 Corner Column and Diagrid forces

4.5.1 Corner Column forces

Table: 5 Corner column force (KN)

Corner Column Forces - P (kN)				
Steel MRF	Diagrid 30°	Diagrid 45°	Diagrid 55°	Diagrid 65°
1871	7045	4637	3837	3360

Table: 6 Corner column moment (KN-m)

Corner Column Forces M (KN-m)				
Steel MRF	Diagrid 30°	Diagrid 45°	Diagrid 55°	Diagrid 65°
372	203	90	240	267

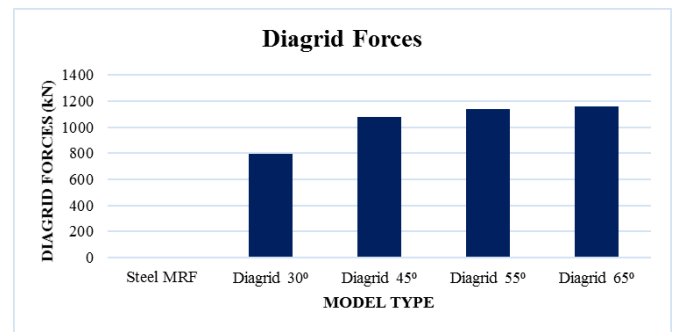


Fig: 8 Graph showing Diagrid forces

Diagrid force is found to be high in case of 65 degree angle diagrid structure, which is about 1156 kN which is 46% higher than diagrid 30 degree.

4.6 Dynamic Time History Analysis

Table: 8 Results of Time history analysis

Models	Base Force (kN)	Peak Displacement (mm)	Peak Acceleration (m/s ²)
SMRF Tube	6392	213	2.62
Diagrid 30°	17314	207	4.20
Diagrid 45°	15238	196	4.11
Diagrid 55°	13668	186	2.98
Diagrid 65°	15633	172	2.76

Corner Column Forces - P

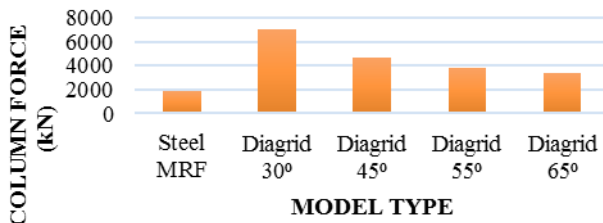


Fig: 6 Graph showing Corner Column forces

Corner Column Forces - M

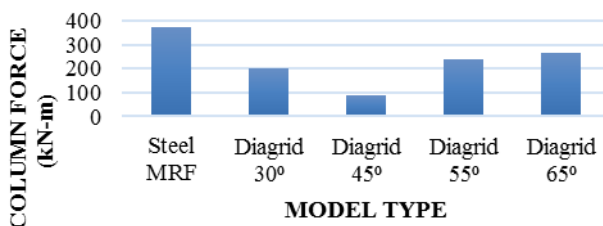


Fig: 7 Graph showing Corner Column Moment

From the above results it is observed that, columns of regular steel moment resisting frame experience less axial load compare to diagrid structural systems. And for 30 degree angle axial force is found to be more i.e., 7045 kN. And also with the increase in the angle of diagrids column forces is reducing and it has reduced up to 52% compared to 30 degree angled diagrid. And column moment forces is found to be less in 45 degree diagrid structural systems which is 90 kN-m and more in case of Steel moment resisting frame which is found to be 372 kN-m which is about 313% compared to diagrid structural systems.

4.5.2 Diagrid Forces

Table: 7 Diagrid forces

Diagrid Forces (kN)				
Steel MRF	Diagrid 30°	Diagrid 45°	Diagrid 55°	Diagrid 65°
0	794	1080	1141	1156

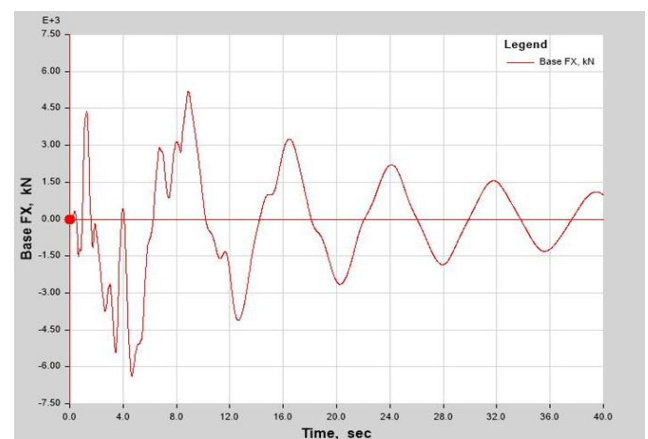


Fig: 9 Graph showing Typical Response of base forces

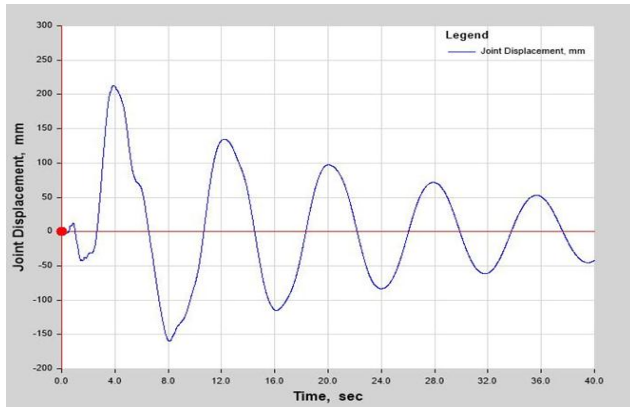


Fig: 10 Graph showing Typical Response of Peak Displacements

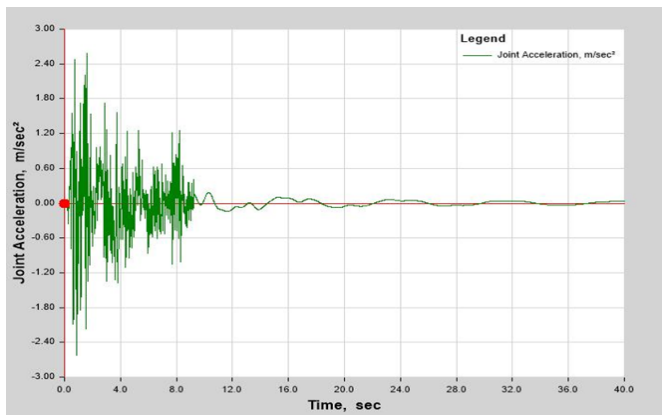


Fig: 11 Graph showing Typical response of Peak Acceleration

From the dynamic time history analysis, it is clear that, base force has increased considerably compared to steel moment resisting frame and is found to be 73%. And maximum base force is found to be in diagrid angle of 30 degree.

Peak displacement is found to maximum in case of steel moment resisting frame and minimum in case of diagrid structure of 65 degrees and is found to be 20% reduction.

Acceleration is found to be maximum in case of 30 and 45 degree angled diagrid structure.

5. CONCLUSIONS

- Reduction in time period is found in diagrid structural systems in comparison with the conventional steel moment resisting frame, which indicate that diagrid structural systems are stiffer than the regular steel moment resisting frame. The increase in stiffness of diagrid structure will limit the displacements and story drifts up to 54% less than that of the conventional steel structural systems.

- Diagrid structural systems has less effect on base shear and is found to be only 8.5%, but dynamic force has considerable effect on diagrid structural system. Hence dynamic effects are significant for diagrid structures.
- Diagrid structural systems are found to be efficient in resisting the lateral loads there by making the story drifts constant with the increase in height, unlike in regular steel moment resisting frame where story drifts will increase with the story height. And above out of all the diagrid structural systems diagrid with 65 degree is found to more efficient in resisting the later loads.
- From dynamic time history analysis results it can be concluded that diagrid structural systems with 65° diagonals is the optimum angle.

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