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Seismic Performance of Bracing, Diagrid and Outrigger System

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Abstract: ***In this paper bracing, diagrid and outrigger system have been analyzed for comparing the seismic performance of multistorey buildings. Bracing system is a very efficient system which can be used as a lateral load resisting system in concrete and steel buildings, in this system lateral loads are transferred through lateral bracing by undergoing in tension and compression .diagrid is another effective and efficient system that can be used as lateral load resisting system in steel and concrete tall buildings, in this system lateral loads are transferred by inclined members of the building. Another very effective system which commonly used for resisting lateral loads in concrete and steel high rise building is outrigger system, in this system lateral loads will be resisted by outrigger belt truss and core shear wall. Location and number of outrigger and type of bracing is very important which needs to be optimized in this system. In this paper comparison of bracing, diagrid and outrigger system have been studied on a 24 storey by using a standard package of ETABS 2017.***

Keywords : bracing, eccentric bracing, diagrid, diagrid in diagrid, outrigger, single outrigger, seismic analysis.

I. INTRODUCTION

Humans were interested in building tall structure from ancient times, but after the industrial revolution, this demand increased day by day because of rapid urbanization, people start moving from rural areas to cities for search of jobs and better life opportunities. Cities were overpopulated and needs for high rise building was growing and that's how the concept of vertical city came in to picture. High rise building is a relative term that defers from city to city and country to country, for a typical single-storey area a 10 storey building may appear tall but if we consider cities like Delhi 20 storey may be termed as tall building but if we talk about cities like New York and Dubai a 20 storey building may not be considered as tall building because there are much higher building than 20 storey buildings. but from structural point of view, we have a more specific definition of tall building, in buildings that lateral governs the building is called as tall building. In high rise building when height of the building increased lateral loads effect on the building also increases, to resist lateral loads there are so many effective systems to transfer the lateral load to the foundation safely.

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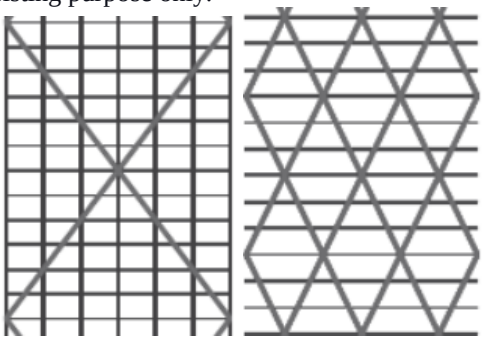
There are numbers of lateral load resisting system i.e. rigid frame system, core shear wall, bracing system, diagrid system, outrigger system, tabular system……

A. Bracing system:

To transfer lateral loads and dissipate energy in high rise buildings that have more than 35 to 40 number of stories rigid frame alone will not be enough because of large lateral drift. To control lateral drift and increase lateral strength, stiffness and ductility bracing system can be used. Bracing system transfers lateral loads by undergoing in tension and compression, and slenderness ratio of bracing has a crucial role on the performance of a structure. A slenderness ratio of 65-100 is desirable in order to control strength, stiffness and ductility of the bracing system. Bracing with very low slenderness ratio will attract seismic force and will cause reduction in ductility of the system, but at the same time bracing with a very high value of slenderness ratio will cause failure of bracing and worsen performance and efficiency of bracing system. There are mainly two types of bracing 1-Concentric bracing 2-Eccentric bracing, cross bracing, K bracing, V and inverted V bracing are concentric bracing while eccentric bracing does not have uniform geometry. Cross bracing is the simplest bracing and most commonly used type of bracing to transfer lateral loads by means of tension and compression and it can RCC buildings that have large columns. While providing K bracing care should be taken because it will increase shear in columns.

B. Diagrid:

Diagrid (Diagonal grid) structural system recently widely used as lateral load resisting system due to its aesthetic view and structural efficiency. The main difference between global bracing and diagrid system is that in the diagrid system all periphery vertical columns will be eliminated. Diagonal members in diagrid system will carry both gravity and lateral loads owing to their triangulated configuration, but diagonal members in the bracing system will be provided for lateral load resisting purpose only.



a)Diagrid **b)Bracing**

Diagrid can be a great replacement for a simple moment-resisting frame, especially when the building is located in high seismicity areas, it can be applied on the low rise as well as high rise buildings. Diagrid transforms all loads to axial force.

C. Outrigger system:

In case high rise building limitation of drift due to lateral loads is a big challenge. Outrigger system is a great technique to limit down the lateral drift due to lateral loads. This system consists of core shear wall and columns that will be connected with one, two or sometimes three-storey deep structural wall and vierendel truss. the working principle of this system to connect the core shear wall to the columns by structural wall and vierendel truss in order to reduce overturning moment. Outer columns will helps the core to reduce lateral displacement by means of tension and compression. Location, number and type of outrigger has a significant effect on effectiveness of the system which needs to be optimized. Core shear wall will help the building to increase strength while outrigger helps to increase its stiffness. Usage of outrigger increase stiffness of the building by 30-40 % as compares to core shear wall.

II. MODELLING AND ANALYSIS:

In this paper, a 24 story RCC building height of 84m and plan size of (40x40)m is used to compare bracing, diagrid and outrigger systems. The building is located at zone IV and according to IS 1893:2016 buildings in zone IV and V that have a height of more than 40m should be analyzed by dynamic analysis, which in this paper all models have a typical height of 84m that needs to be analyzed by dynamic method, linear static and response spectrum analysis are done on all the models. Loadings and seismic parameter are shown in table 1 and 2 respectively.

Table 1 loading

S.NO	Live load in KN/m^2	Imposed dead load in KN/m^2
1	3	1

Table 2 seismic parameters

S.NO	Importance factor I	Zone factor Z	Response reduction factor R	Type of soil	Damping ratio
1	1	0.24	5	II	5%

A. Modelling and analysis of bracing system:

A 24 storey building is modelled by using ETABS with a total height of 84m a plan size of (40x40)m. cross bracing, K bracing and eccentric bracing has been used to check the lateral load resisting of the building. Table 3 represents geometry of the building.

Table 3 geometry of the models

S.NO	Column size in mm	Beam size in mm	Bracing size in mm	Slab thickness in mm
1	700x700	450x450	450x450	200

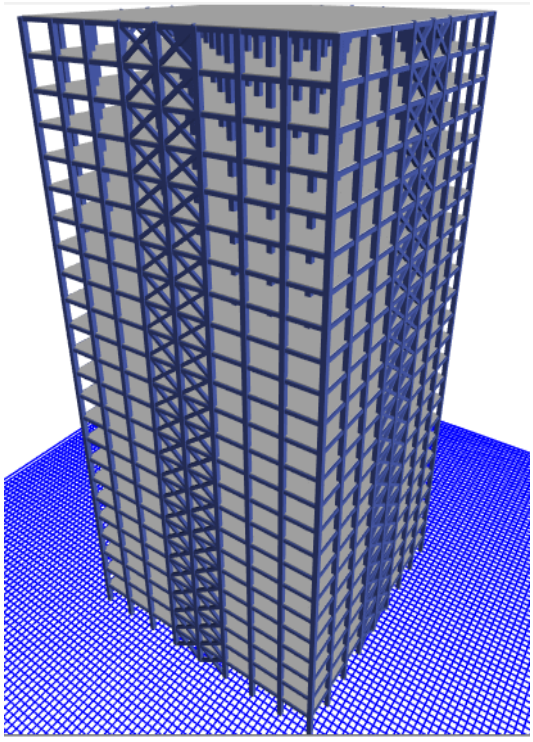


Fig:3D view of X-bracing

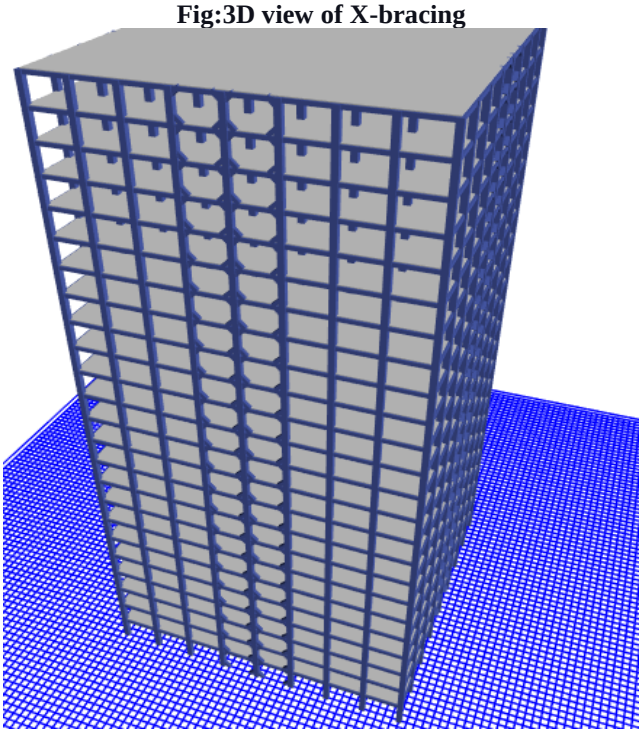


Fig:3D view of E-bracing

B. Modelling and analysis of diagrid system:

Same 24 storey has been modelled with a total height of 84 and plan area of (40x40)m. diagrid is used for lateral load resisting system with diagrid angle of 54 degree. Table 4 shows the geometry of the building

Table 4: geometry of diagrid models

S. NO	Column size in mm	Beam size in mm	Bracing size in mm	Slab thickness in mm	Angle degree
1	700x700	450x450	450x450	200	54

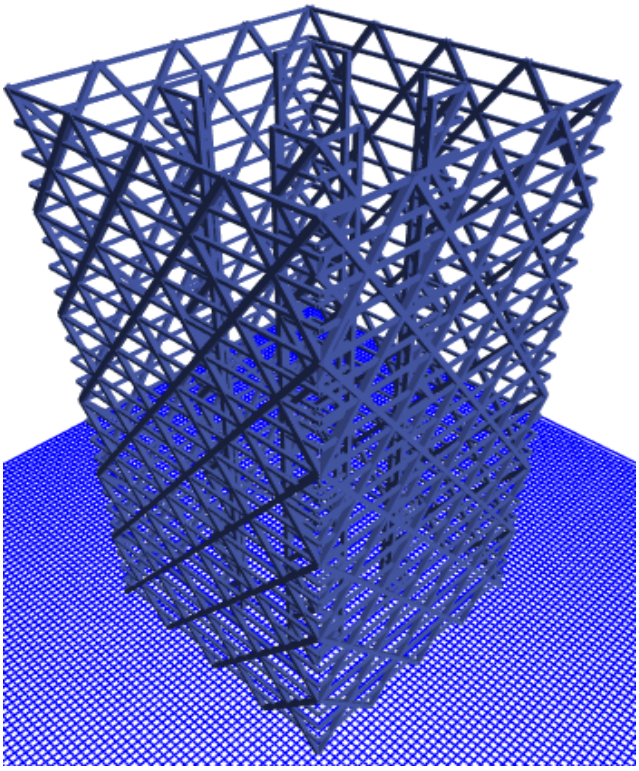


Fig:3D view of diagrid 2

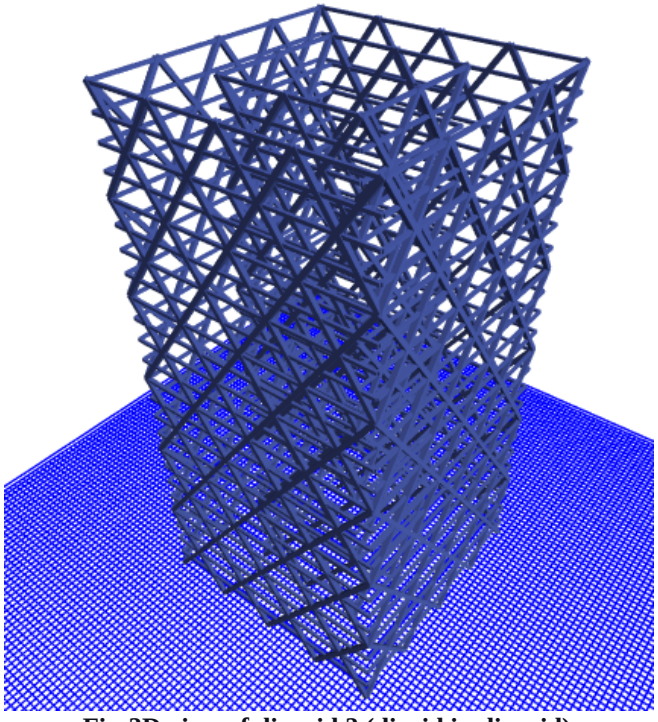


Fig:3D view of diagrid 3 (digrid in diagrid)

C. Modelling and analysis of outrigger system:

The same building with same geometrical properties have been used here, an outrigger of one storey deep at the top storey of the building have been provided and ETABS software has is used for modelling and analysis purpose.

Table 5: geometrical properties of outrigger

S. NO	Column size in mm	Beam size in mm	Bracing size in mm	Core shear wall & slab thickness in mm
1	700x700	450x450	450x450	200

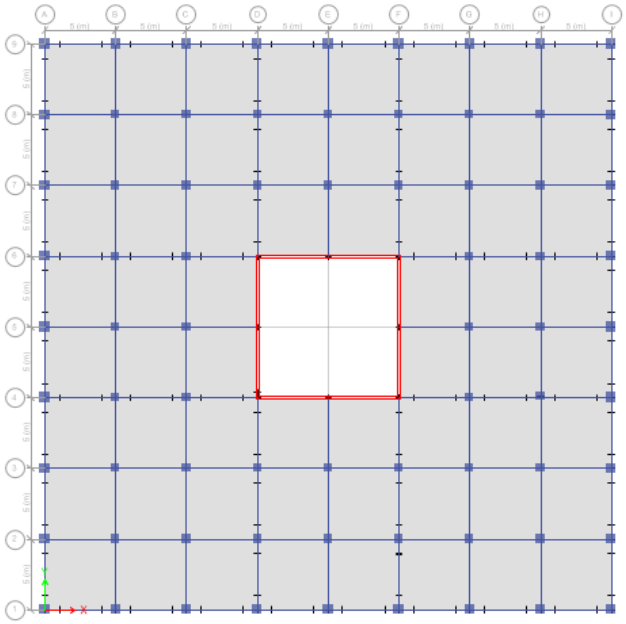


Fig: Plan view of outrigger

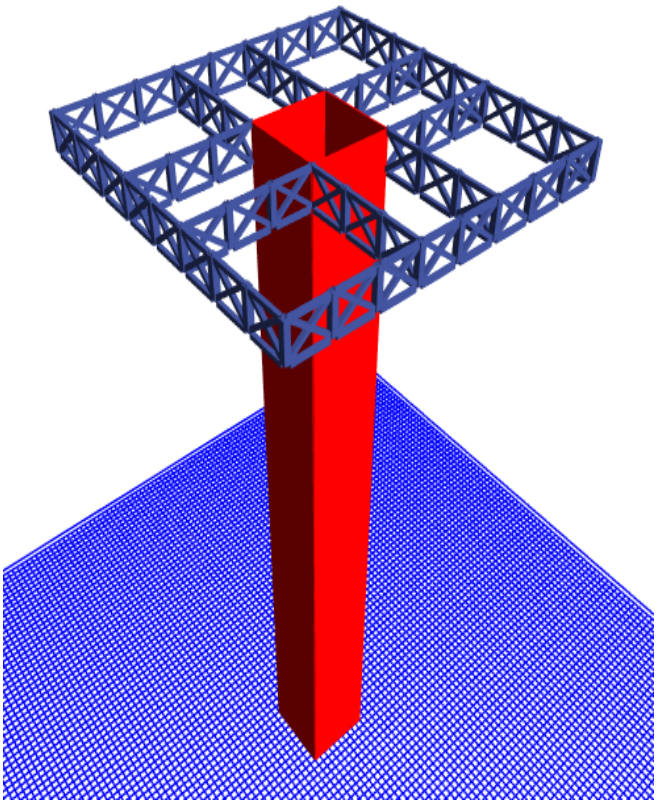


Fig: 3D view of outrigger with X-bracing

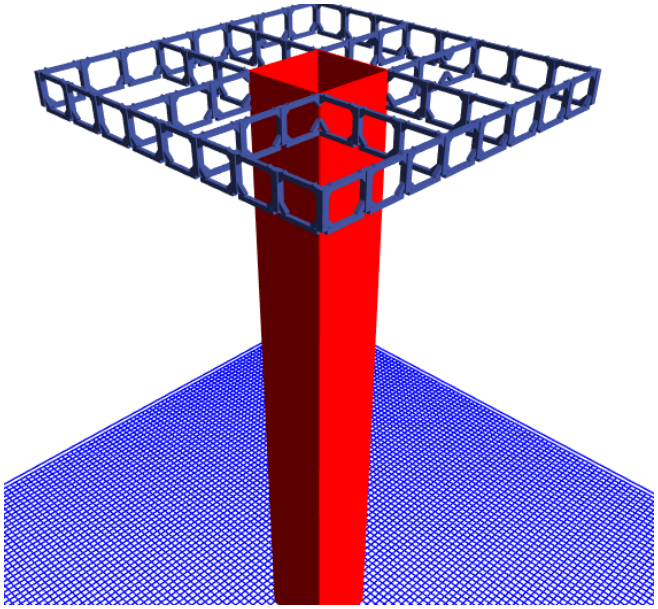
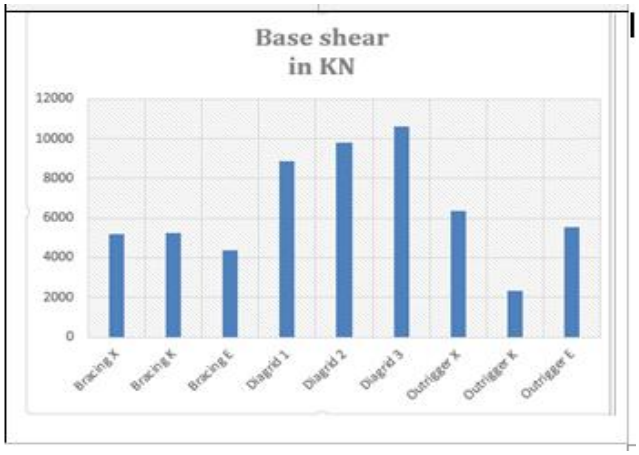


Fig: 3D view of outrigger with E-bracing

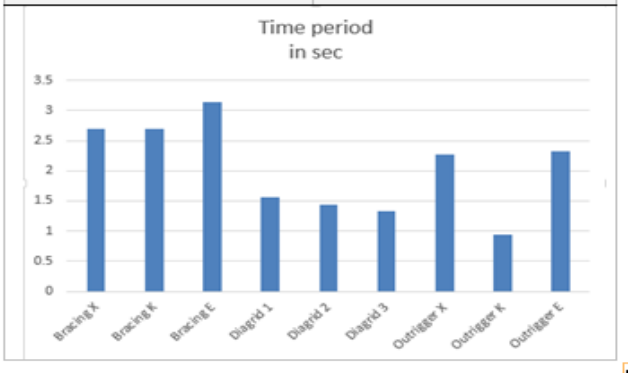
III. RESULT AND DISCUSSION

In this paper, all models have been analyzed by equivalent static and response spectrum methods. Base shear of response spectrum should be equal or more than 85% of static base shear. Max base shear, max lateral displacement and time period of all models have been shown in tables 6, 7 and 8 respectively. In bracing system X-bracing has Max base shear of 5165.265 KN, time period of 2.702 sec, Min lateral displacement of 28.121 mm and overturning moment of 214331.0327 KN-m. In diagrid system diagrid in diagrid (diagrid 3) has Max base shear of 10607.2211 KN, time period of 1.33 sec, Min lateral displacement of 15.841 mm and overturning moment of 399790.4833 KN-m, and outrigger system, outrigger with K-bracing has Max base shear of 2346.079 KN, time period of 0.933 sec, Min lateral displacement of 11.271 mm and overturning moment of 109700.8493 KN-m. Among these three lateral load resisting system bracing system is more flexible than diagrid and outrigger system that shows lesser lateral stiffness and more lateral displacement. Use of bracing system for super tall building is not desirable but for mid-rise building its performance is good.

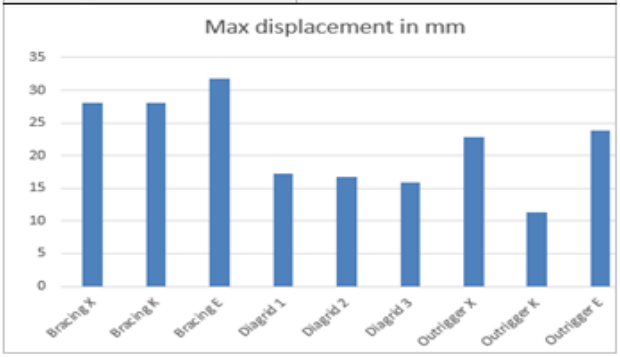
Base shear in KN	
Bracing X	5165.265
Bracing K	5263.6019
Bracing E	4376.7663
Diagrid 1	8863.8103
Diagrid 2	9786.0877
Diagrid 3	10607.2211
Outrigger X	6373.4788
Outrigger K	2346.079
Outrigger E	5565.8299



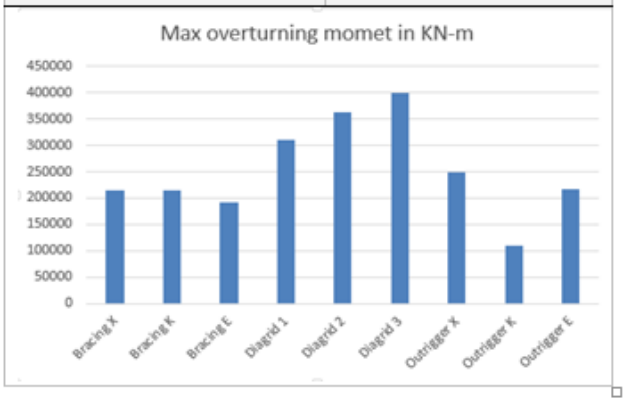
Time period in sec	
Bracing X	2.702
Bracing K	2.703
Bracing E	3.142
Diagrid 1	1.553
Diagrid 2	1.443
Diagrid 3	1.33
Outrigger X	2.272
Outrigger K	0.933
Outrigger E	2.326



Max displacement in KN-m	
Bracing X	28.121
Bracing K	28.129
Bracing E	31.708
Diagrid 1	17.195
Diagrid 2	16.753
Diagrid 3	15.841
Outrigger X	22.881
Outrigger K	11.271
Outrigger E	23.914



Max overturning moment in KN-m	
Bracing X	214331.0327
Bracing K	214416.1691
Bracing E	192293.4808
Diagrid 1	310487.2869
Diagrid 2	363448.7565
Diagrid 3	399790.4833
Outrigger X	248592.1559
Outrigger K	109700.8493
Outrigger E	216763.6207



IV. CONCLUSION

- In this paper three structural system have been compared to check their structural performance against seismic loads.
- In bracing system X-bracing shows better performance than the other two models but it has architectural disturbance, block views and give less space for the openings but E-bracing has an acceptable performance in all aspects that needs to be considered while designing a high rise building.
- In digrid system, diagrid in diagrid (digrid 3) has better performance than the other two models that it is showing more base shear and overturning moment, but showing reduction in case of time period and lateral displacement.
- In outrigger system, outrigger with K-bracing has very good performance, but as in high rise building engineers tend to have maximum usage of space, so outrigger with E-bracing will be a better option that it gives more space for openings and can be used as a floor.
- Among three systems that have been compared, diagrid system gives a fair result, as in high rise building using Max space of the building is an important factor that need to be considered while designing a building.
- In diagrid system, diagrid in diagrid (diagrid 3) has 15.841 mm lateral displacement that shows 43.7% reduction as compared to bracing system and 28.8% increase as compare to outrigger system with K-bracing.

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