iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** IX **Month of publication:** September 2022

DOI: https://doi.org/10.22214/ijraset.2022.46809

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue IX Sep 2022- Available at www.ijraset.com

Seismic Comparison of Diagrid and X-Bracing System in Highrise Building

Vishal Desai[1], V. M. Bogar[2], Mohammad Zunnoorain[3]
Applied Mechanics Department, Government College of Engineering, Karad
[1]M.tech Student, Government College of Engineering, Karad
[2] Asst. Professor Applied Mechanics Department, Government College of Engineering, Karad
[3]M.tech Student, Institute of Engineering and Technology, I.E.T-Lucknow

Abstract: The diagrid (diagonal grid) structural design is one of the fascinating structural design ideas for sturdy tall constructions. Diagrid, a new design style for tall, intricate structures, has emerged due to its aesthetic appeal and structural effectiveness. Diagrid's façade structural system resists both lateral loads and gravity loads by utilizing a small grid of diagonal components.

As it uses less structural steel than a conventional steel frame, making the structure more environmentally friendly. This study makes use of ETABS to assess tall structures built of Diagrid steel and tall structures using different bracing techniques. Being thin makes high-rise structures extremely vulnerable to lateral forces, thus they must be constructed to provide safety and comfort in accordance with user needs. In order to combat the lateral stresses that are most common in high-rise structures, diagrid and X-bracing systems have been created. In this study, the seismic behaviors of diagrid and X-braced systems are compared.

The E-tabs software is used to prepare two 36-floor models, one with a diagrid system and the other with an X-bracing system. Story drift, base shear, and member forces are compared while both models are investigated in various earthquake zones. The conclusion reached after looking at all of these variables is that the diagrid system performs better than the X-braced system.
Keywords: Diagrid Structural System, High rise buildings, Structural design.

I. INTRODUCTION

High-rise buildings are one of the enormous constructions we encounter in today's globe that would fascinate everyone. The construction of multi-story structures is expanding quickly over the world. Diagonal members are employed in diagrid structural systems to connect the beam and diaphragm, and these members transfer lateral loads and gravity loads. The diagrid method has gained enormous popularity in intricate buildings such curving form The use of diagonal elements is fast expanding as a result of the use of diagrid, which replaces traditional vertical columns.

To provide the structure greater optimization, several diagrid system characteristics must be determined, such as the ideal diagonal member angle.

Any high-rise building's diagrid system can be examined for a variety of factors, including the angles at which the diagonal elements are angled, a comparison of moment-resisting frame construction to conventional frame construction, and the placement of the building's shear walls at various locations to study the structure.

Additionally, a significant quantity of structural material is conserved and the project becomes more cost-effective by removing everything but the core columns from the design. In fact, the effectiveness of the diagonal members reduces the overall number of internal columns, giving the architect more room to create the objects. Architects and designersmuch prefer this strategy to a braced frame structure. A particular kind of space truss is called a diagrid. It is constructed up of a perimeter grid made of triangulated truss systems.

By crossing the diagonal and horizontal elements, a diagrid is created. The Swiss Re in London,Hearst Tower in New York, Cyclone Tower in Asan (Korea), Capital Gate Tower in Abu Dhabi, and Jinling Tower in China are some of the well-known diagrid structures in the world,as depicted in Fig 1. One example of using a diagrid structural system to sustain a difficult shape is the new Central China Television (CCTV) headquarters in Beijing[1].

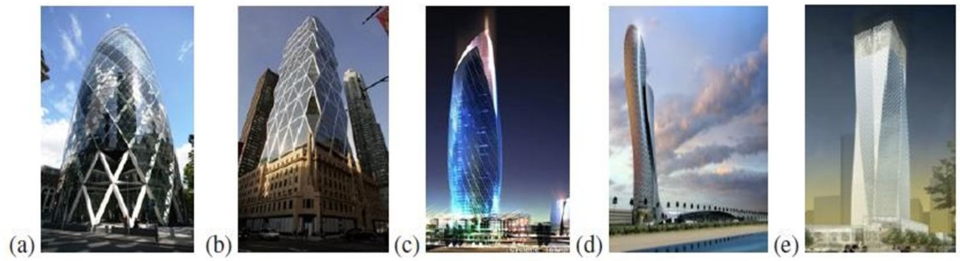

Fig. 1. Diagrid buildings (a) Swiss Re in London (b) Hearst Tower in New York (c) Cyclone Tower in Asan (Korea) (d) Capital Gate Tower in Abu Dhabi and (e) Jinling Tower in china.

Utilizing sustainable and effective structural techniques and designing freeform trademark structures are two current trends in the construction of tall and unique buildings. Both of those fashionable characteristics are present in Diagrid, a variant of the tubular constructions[2,3]. Diagrids are renowned for their versatility to produce free-form structures as well as for being an aesthetically beautiful and structurally effective system. Both lateral and gravitational loads can be supported by their inclined diagonal members[4-7]. The essential elements of a diagrid frame and its fundamental triangular element are shown in Figure 1.

Diagrids have been employed in a variety of iconic and free-form high-rise structures around the world, including the 595.7-meter Canton Tower, the 51-story Tornado Tower in Doha, Qatar, the 103-story Guangzhou International Finance Centre in Guangzhou, China, andthe 57-story The Bow in Calgary, Canada[8-10].

By supplying a response modification factor, R, to account for the nonlinear response of the structure during extreme events, design codes like ASCE710 permit elastic analysis forthe design of various structural systems[7].

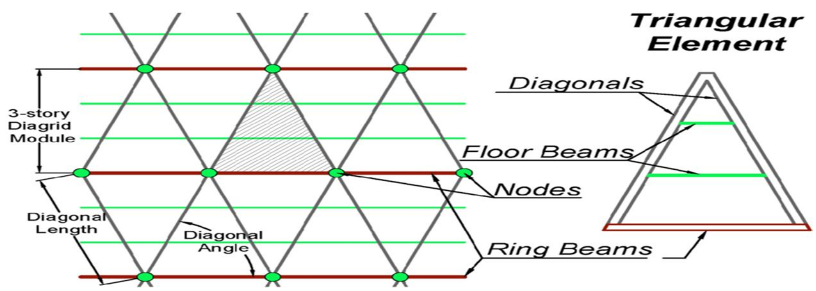

Fig 2 Main component of Diagrid elements and its

Triangulated elements.

Steel has become a popular building material and offers a variety of solutions that can make structures more comfortable, energy-efficient, and less expensive to operate.

In recent years, a number of environmentally friendly strategies that reduce the need for structural steel havebeen created.

Among these, the diagrid structural system is seen as a potentially effective solution for tall steel structures. Recently, a new design style for tall, complicated structures has evolved called"diagrid," which is a perimeter structural layout characterised by a small grid of diagonal components involved in both gravity and lateral load resistance.

II. ANALYSIS AND DESIGN

The 36-story structure has a plan dimension of 36-meter x 36-meter. The 3600 mm story height. Fig. 2 depicts the standard plan and elevation. A pair of braces is situated on the outside of diagrid structures. All along the height, the inclination angle is maintained constant. Along the perimeter, inclined columns are offered at six-meter intervals. The diagrid structures' internal frame is only intended to support gravity loads. The floor slab's intended dead load and live load are 3.75 kN/m^2 and 2.5 kN/m^2, respectively. According to IS:875 (III)-1987 (Gust factor technique), the dynamic along wind loading is calculated using a base wind speed of 30 m/sec and terrain category III.

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A. Model Description

S.No.	Structural System	Dimensions
1	No. of bays in X-Dir	13 No. @ 3.6m
2	No. of bays in Y-Dir	13 No. @ 3.6m
3	Length in X- Dir	36m
4	Length in Y- Dir	36m
5	Floor to floor Height	2.1x10^5 N/mm^2
6	Total Height of Building	129.6m
7	Type of Building	Commercial (G+35)

Fig 3 Description of building

S.No.	Material	Grade
1	Concrete (Slab)	M30
2	Steel section(I-Shape)	Steel structure
3	Rebar	HYSD-415
4	Density of Steel	7850 kg/m^3
5	Young Modulus E	2.1x10^5 N/mm^2
6	No of bays in Y-directions	80000N/mm^2
7	Poisson's Ratio	0.3

Fig 4 Material Properties

Table 1:- Size of all façade typical members and core members of Diagrid Building

Storey	Diagonal Columns	Interior Columns	Beams (same for all storey)
36 storey	375 mm Pipe sections with 12 mm thickness (from 19th to 36th storey) 450 mm Pipe sections with 25 mm thickness (from 1st to 18th storey)	1500 mm × 1500 mm	B1 and B3 = ISMB550, B2 = ISWB 600 with top and bottom cover plate of 220 × 50 mm

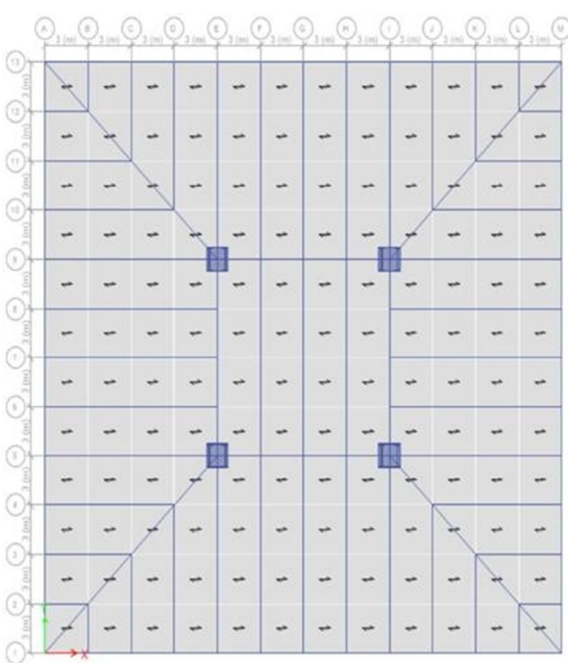


Fig 5 Typical floor Plan of Diagrid Steel Structure

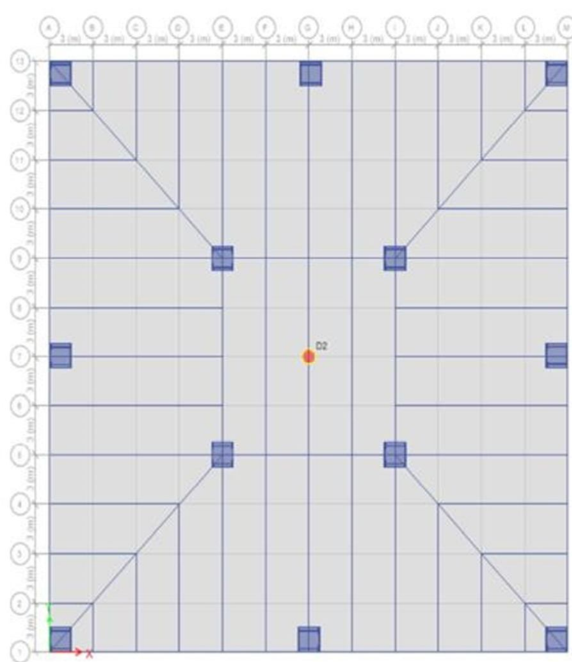


Fig 6 Typical floor plan of X-Bracing Steel Structure

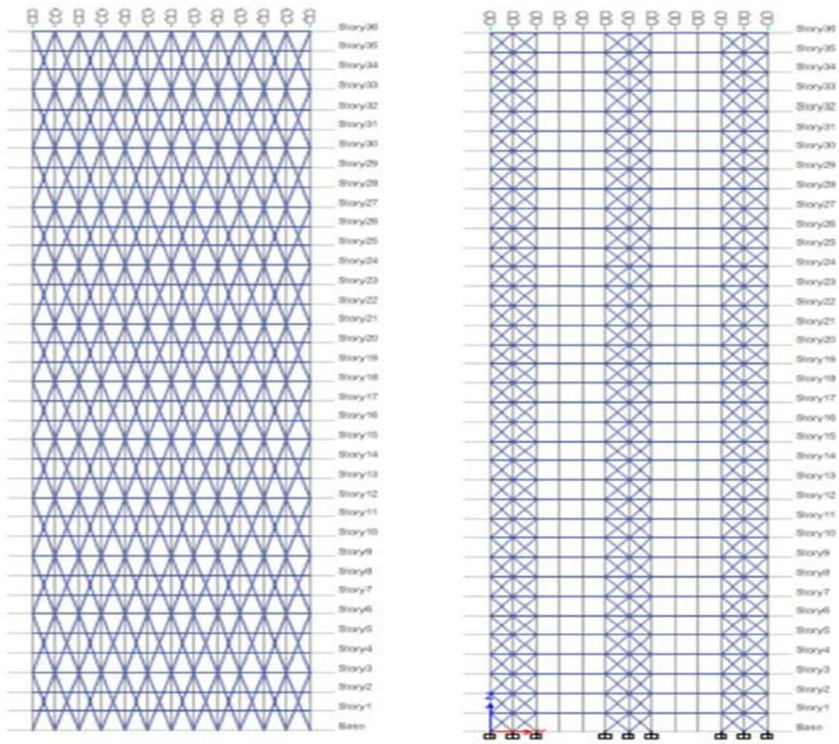
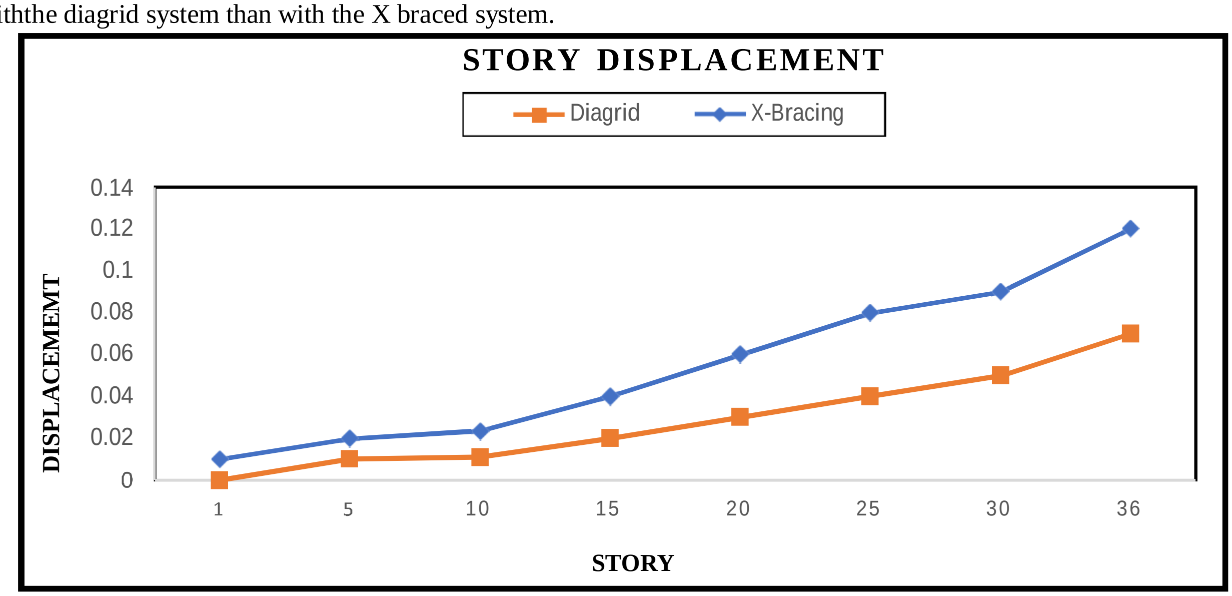


Fig 7 Elevation View of Diagrid and X-bracing Building

III. RESULTS AND DISCUSSION

A. Story Displacement

Graph the values of maximum displacement. As can be seen, maximum displacement values are lowest when the diagrid is spanning three levels and has an inclination angle of 74.47 Degree. Compared to Steel X-Bracing the result are less which shows that Diagrid building saves the consumption of steel in the building and make it sustainable structure. X-Bracing uses 50.17 degree of inclination of bracing. Measurements of storey displacement are made in relation to the structure's base. After examining the storey displacement graphs, it was found that the X-braced structure exhibits 682.35 percent greater displacement in the X direction and 672.76 percent more displacementin the Y direction than the diagrid structure. This demonstrates that the structure is firmer withthe diagrid system than with the X braced system.



STORY DRIFT

Fig 8 Comparative Story Displacement

Graph the values of story acceleration. As can be observed, story acceleration values are lowest when the diagrid is spanning three storeys and the angle of inclination is 74.47 Degree. As compared to inclination of bracing at 50.17 degree the drift in Diagrid building is comparativelyless , so building is more stiffer than X-Bracing during lateral loading.

The findings indicate that, in both the X and Y directions of response, the maximum drift in the X-braced structure is 647.96% greater than in the diagrid system. The maximum drift is shown in diagrid structures between the 18th and 22nd floor, and in X-braced structures it is seen between the 13th and 18th level. The more rigid foundation of the diagrid construction than the X-braced structure is the cause of the difference in maximum drift positions.

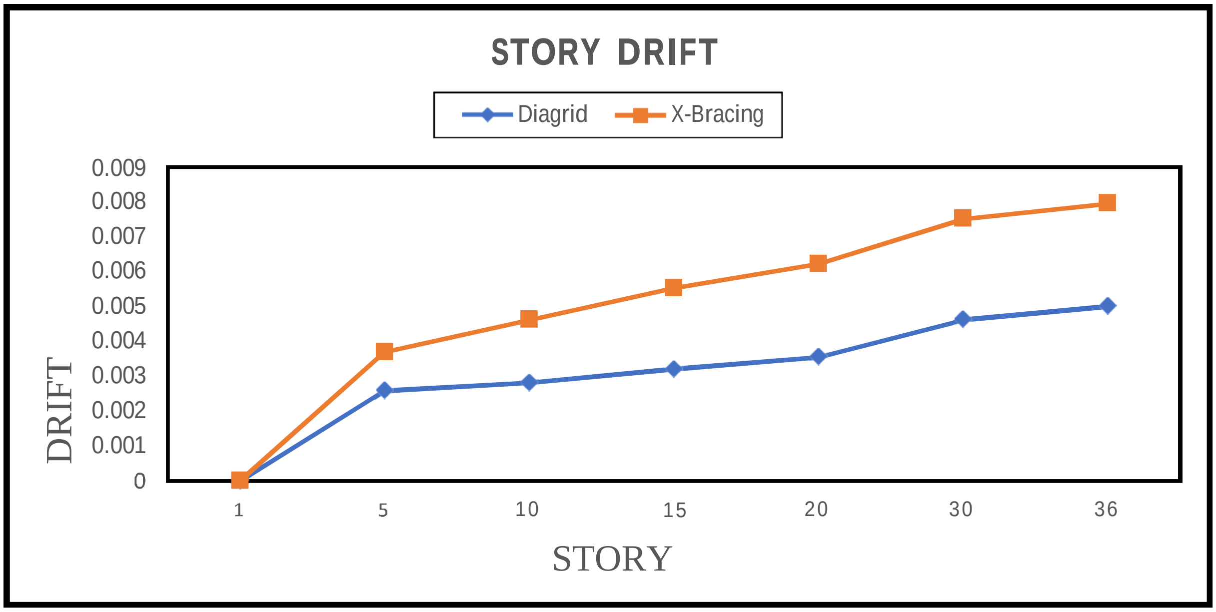


Fig 9 Comparative Story Drift

B. *Story Shear*

The maximum storey shear in diagrid structure occurs at 3rd storey while in X-bracing system it occurs at base. The maximum storey shear in diagrid structure is 27.18 and 27.48 percent more than bracing structure respectively. This change in location in maximum shear storey in diagrid structure is because the diagrid system joints are provided at every 3 floors. It shows that diagrid joints are subjected to more critical loads than X braced joints.

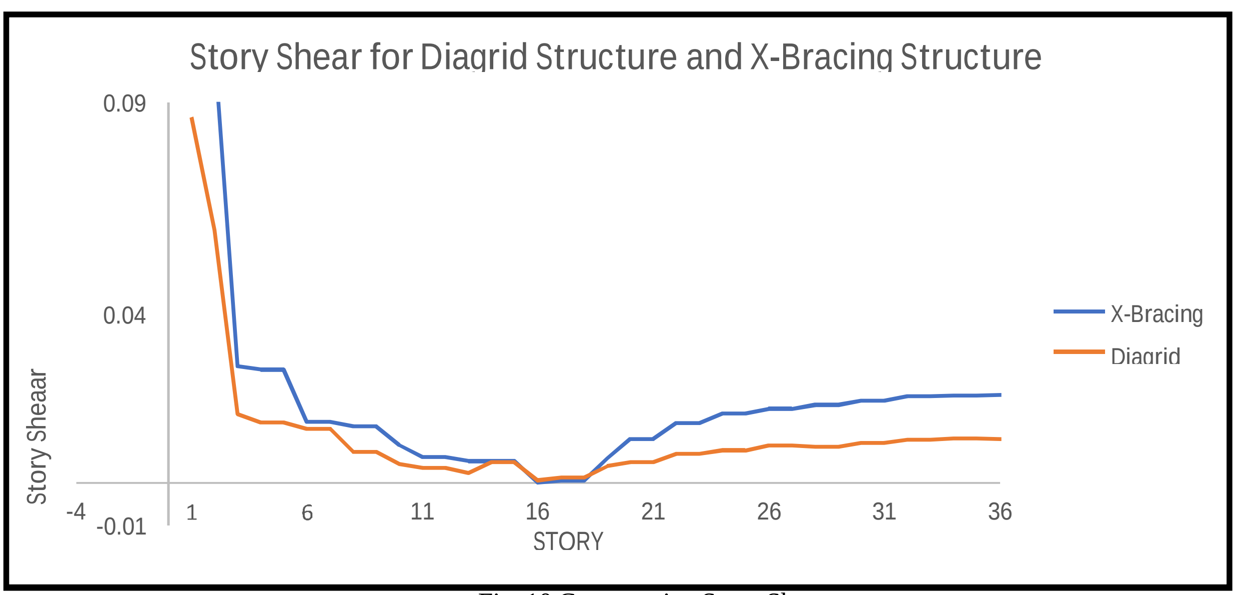


Fig 10 Comparative Story Shear

C. Maximum Combined Results

Table 1 : Maximum Values Of Combined Storey Plots In X-Direction

Criteria	Max. Displacement (mm)	Max. Drift (mm/mm)	Max. Shear (KN)	Overturning Moment (KN-m)
Diagrid	34	0.000369	5498.17	453712.44
X-bracing	266	0.00276	4003.27	374968.61
Percentage Difference	682.3529	647.9675	27.189	17.3554

Table 1 : Maximum Values Of Combined Storey Plots In Y-Direction

Criteria	Displacement (mm)	Drift (mm/mm)	Shear (KN)	Overturning Moment (KN-m)
Diagrid	34	0.000369	5503.88	454579.62
X-bracing	262.74	0.00276	3991	374353.28
Percentage Difference	672.7647	647.9675	27.4875	17.6485

D. Overturning Moment

Similar to storey shear, the overturning moment is also greatest in diagrid structures a reachesits highest value at diagrid joints. In the X and Y directions, respectively, the overturning moment in the diagrid system is 17.35 and 17.64 percent more than that of the X braced structure.

E. PSEUDO Spectral Accelerations

The pseudo spectral accelerations for a given time are significantly higher in the diagrid systemthan the X-bracing system, indicating the diagrid structure's stronger stiffness than the X- braced structure.

IV. CONCLUSION

It is evident from the information provided above that the diagrid method gives structures morerigidity than the X bracing system. As a result of its lower stiffness, the X-braced structure exhibits more storey displacement and drift, but this is still well below the maximum displacement limit outlined in IS 1893: 2016-Part 1 clause 7.11.1, which states that any building's maximum displacement must not exceed 0.004h, where h is the structure's height.

Diagrid structures are more likely to have plastic hinge creation at joints because they experience more shear and overturning forces there. Early plastic hinge creation might cause amechanism of collapse; therefore, joints must be built with greater care and with the appropriatefactor of safety.

This study presents a detailed analysis and design of a 36-story diagrid steel structure. A standard floor layout measuring 36 m 36 m is taken into account. The modelling and analysisof structures are done using ETABS software. IS 800:2007 is used to design all structural elements while taking into account all load scenarios. Additionally, diagrid system loaddistribution for 36multi-story building. The analysis shows that diagrid columns on theperiphery resist the majority of the lateral load, whereas gravity is the main source of resistance. Both the interior and peripheral diagonal columns support the load. Consequently, internal columns must be planned for merely a vertical load of the structure. The axial force inthe diagonal members on the outside of the structure resists the lateral and gravitational loads, which increases the efficiency of the system. Diagrid structural technology offers greater planning options for the building's interior and outside spaces.

So we can conclude from above analysis as per IS 1893 2016(PART 1) that X-Bracing is less efficient and uneconomical as compared to Diagrid Structures. Consumption of steel decreases in Diagrid structure which make it sustainable and eco-friendly. And these conceptscan be added to National Green Building Council of India, also.

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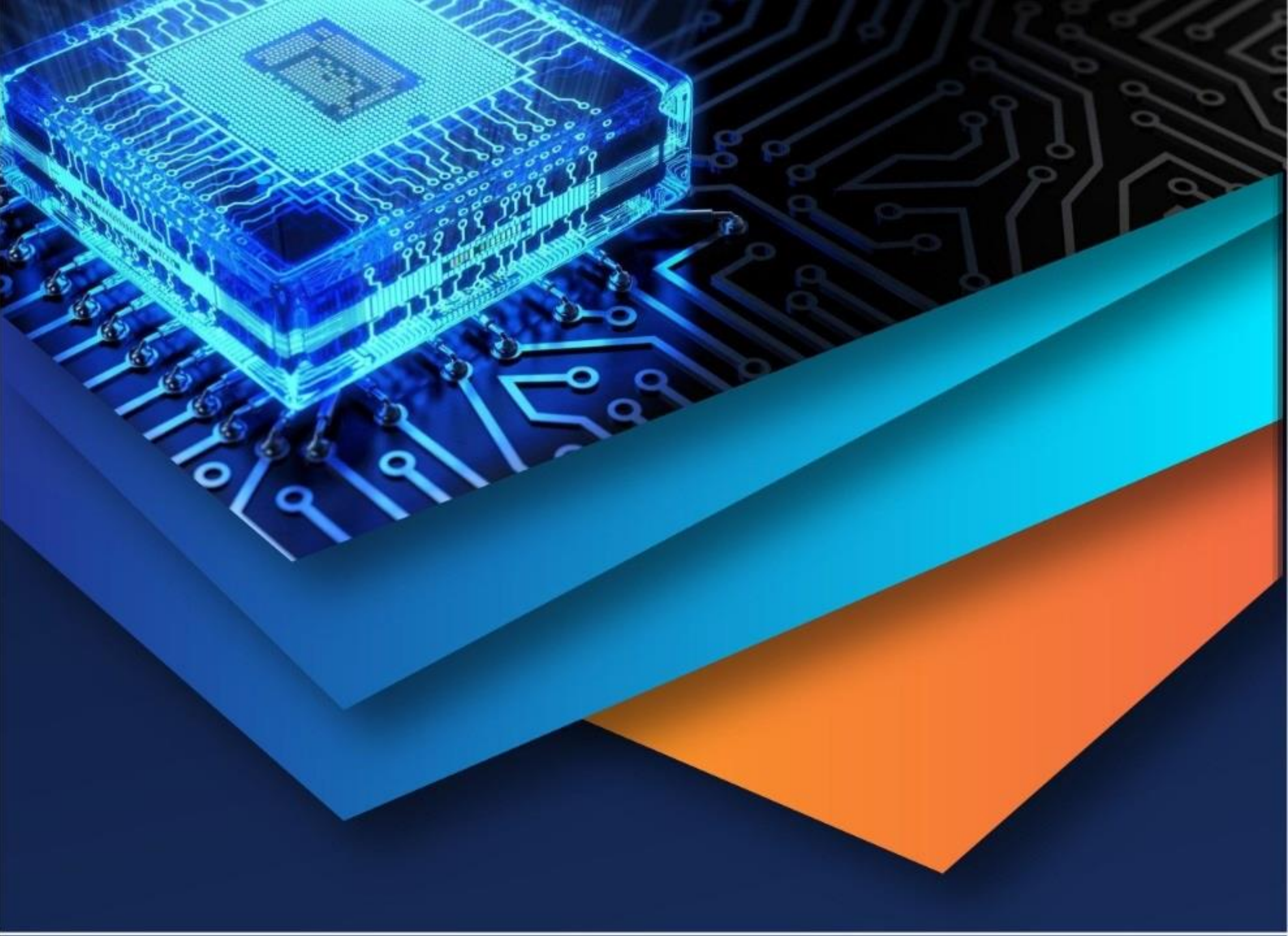

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