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Diagrid Based Multistorey Building Design and Durability Forecasting

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Abstract: The taller and higher structures results in the effects of lateral loading, lateral loads dominates when the height of building increases, lateral loads such as earthquake, wind causes the building larger displacement, to avoid larger displacement in high rise buildings lateral load resisting systems are deployed. Apart from other structural system, the diagrid and hexagrid system are adopted to improve structural performance of tall buildings. The various types of structural system in tall buildings have become obsolete and the new structural skeletons such as hexagrid and diagrid are being used.
Keywords: Diagrid building, conventional building, Tall Buildings, Storey Displacement, Diagrid Structures, Storey Displacement.

I. INTRODUCTION

Recent design trends have posed new challenges in the field of structural engineering. As the height of building increases the buildings become more susceptible to lateral loads as compared to gravity load and lateral load dominates over gravity loads and hence it becomes more important to design building considering lateral loads. To resists lateral loads there are various types of lateral load resisting system some of them are flat slab–beam system, flat slab–frame with shear walls, coupled shear walls, rigid frame, tube system with widely spaced columns, rigid frame with haunch girders, core-supported structures, shear wall– frame interaction, frame tube system, exterior diagonal tube, bundled tube, etc. In order to improve efficiency of the structural system the new structural system diagrid structural system and hexagrid structural system. Diagrid structural system is the large bracing system made of steel sections. In nature, bees have a fascinating, meticulous way of forming their beehives, which serve as their homes, their protection and their source of life. The beehive internal structure is a densely packed matrix of hexagonal cells called honeycomb. The bees use the cells to store food, and to house the breed. The hexagonal shape perfectly distributes and disperses the external man made or Environmental forces thus protecting its contents. Thus the literature related to diagrid as well as hexagrid structural system has been studied.

II. RESEARCH MOTIVATION

The structural system of a high-rise building is designed to cope with the vertical gravity loads and lateral loads caused by wind or seismic activity. The structural system consists only of the members designed to carry the loads; all other members are referred to as non-structural. The term structural system or structural frame in structural engineering refers to load-resisting sub-system of a structure. The structural system transfers loads through interconnected structural components or members. Diagrid structure consists of inclined columns on the exterior surface of the 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. Diagrid structures typically, don't need core because of lateral shear may be carried by the diagonals on the outer boundary of a building. The number of high-rise building is increasing day by day due to urban development and unavailability of land. As the height of the building increases, both lateral load and gravity load becomes important in the design. The structures are classified into interior structures and exterior structures based on the distribution of components of lateral load resisting elements. When major part of the lateral load resisting elements is located within the interior of the building, the system is termed as interior structures whereas if the lateral load resisting elements is located at the building perimeter, they are termed as exterior structures. Shear wall core, braced frame, outrigger structures constitute the interior system and framed tube, braced tube, diagrid constitute the exterior system.

III. LITERATURE REVIEW

ChengqingLiu, Separation of long-period components of ground motion and its impact on seismic response of long-period diagrid structures: The improved modified ensemble empirical mode decomposition (MEEMD) method is used to decompose the long-period ground motion, and the introduction of permutation entropy is used to eliminate the abnormal signal, which can avoid the phenomenon of mode aliasing in the traditional empirical mode decomposition method, so that the components of the long-period ground motion can be accurately separated.

Taking the separated and reconstructed ground motions as input action, the influence of long-period components on the seismic response of diagrid structure of high-rise building is studied. The results demonstrate that the MEEMD method can accurately extract long-period ground motion components from long-period ground motion. Long-period ground motion contains abundant short-term energy with low-frequency, which is the main reason for the large seismic response of long-period structure. The seismic response of diagrid structure is closely related to the natural period of the structure and the spectrum characteristics of the ground motion [1].

DengjiaFang, Mechanical characteristics and deformation calculation of steel diagrid structures in high-rise buildings: In order to propose a simple and practical methodology for calculating the deformation of diagrid structure with polygon plane in arbitrary direction, the diagrid structure is considered to be mainly composed of “element” by geometric method. The vertical stiffness and lateral stiffness of diagrid structure with arbitrary polygon plane under vertical load and horizontal load are derived respectively. The corresponding laboratory test and numerical simulation analysis are carried out through the scale models of steel diagrid structures. The analysis results show that the calculated results of each deformation equation are in good agreement with the test results and numerical simulation results. In addition, the influence of the parameters on the stiffness of the structure is revealed theoretically. The results demonstrate that when the diagonal angle is about 55°, the variation of the diagonal angle has the greatest effect on the vertical stiffness of the diagrid structure. Moreover, the vertical stiffness of steel diagrid structure is smaller than that of traditional structure, and the vertical displacement is obviously larger. It is necessary to limit the inter-story drift ratio of vertical modules. Furthermore, current paper theoretically explains that the more edges of diagrid structure, the greater the horizontal shear stiffness of the structure [2].

Kamil AshrafBhat, Analyzing different configurations of variable angle diagrid structures: Diagrid structures are popular among engineers and architects. The reason for this is its structural efficiency due to carrying both lateral loads and gravity loads and aesthetic attributes. Recent research has shown that using variable angle diagrids for a structure can be more efficient than using diagrid structures with constant angle of inclination. This paper provides an analysis of different configurations of the variable angle diagrid structures. For this purpose, the parameters of variable angle diagrid structures such as angle of inclination of diagrids and the ratio of heights for which angle of inclination of diagrids are varied to study its effect on the structure. Different patterns of variable angle diagrid structures are generated for a 60 storied building which are modelled and analysed in ETABS under gravity and wind loads. The optimum configuration is selected from these diagrid configurations based on the structural weights of diagrids and performances of the building [3].

PayamAshtari, Optimum geometrical pattern and design of real-size diagrid structures using accelerated fuzzy-genetic algorithm with bilinear membership function: Diagrids are the efficient systems of tube structures for tall buildings. One of the design considerations for these structures is the geometrical pattern of the system. In this paper, a new method of fuzzy-genetic algorithm based on bilinear membership functions is proposed with an improved crossover operator and penalty function. The method is applied on tall buildings with a diagrid system to find the optimum geometrical patterns and the overall structural weight. Various three-dimensional diagrid structures with 24, 36, 42, 56, and 60 stories and different slenderness ratios are analyzed under gravity and wind load. Then the effects of variation in the number of bays (4, 6, and 8) are investigated and compared with each other. The results show that by increasing the dimension of the structure, the structural weight is reduced up to 33% in some cases. However, the obtained angle of the diagrid members (range of 63 to 79 degrees) is increased by increasing the number of stories and the height of the structure. The optimum weight and geometrical pattern of the models is obtained and a formulation is extracted from the results regarding the optimum angle of a diagrid system. Considering GA, results show the merit of the accelerated fuzzy-genetic algorithm regarding the convergence and the avoidance of being trapped in local minimum [4].

QingxuanShi, Experimental investigation on the seismic performance of concrete-filled steel tubular joints in diagrid structures: Concrete-filled steel tubular (CFST) joints are widely used as a common joint form in diagrid structure systems. However, previous studies on CFST diagrid joints have mainly focused on the compressive bearing capacity, and they lack relevant experimental studies on the seismic performance of diagrid structure joints. In this paper, five CFST diagrid joints are tested under cycle loading to study the failure mode and hysteretic characteristics. In addition, the influence of the intersection angle, structural forms and the wall thickness of the steel tube on the seismic performance of the joints, such as the bearing capacity, ductility, and energy dissipation, are analysed. Three CFST joints are mainly damaged by shear cracking in the centre of the joints, and the other two specimens are damaged by buckling of the inclined column. Test results showed that the increase in the intersection angle reduces the bearing capacity of the specimen and changes the distribution of the main energy dissipation; the increase in the wall thickness of the steel tube can effectively improve the bearing capacity and energy dissipation capacity of the specimen. The joint reinforcing ring can effectively improve the ductility, energy consumption and other seismic performance of the joint.

In the CFST diagrid joints, the weak parts along the horizontal intersecting line of the joint and the intersection between the joint and inclined column need to be strengthened in the actual structure [5].

NehaTirkey, Analysis on the diagrid structure with the conventional building frame using ETABS: This article outlines the case study on diagonal perimeter often known as the diagrid structure using software ETABS (Extended Three Dimensional Analysis of Building System). The diagrid structure has emerged into an innovative method in the recent construction field and has led to the advancement of tall buildings and high rise structures not only in the engineering field but also in the architectural field. It has also made the structure stiffer and lighter when compared to the normal conventional buildings. The diagrid structure is designed, analyzed and is compared with the conventional building using ETABS software mainly focusing on seismic and wind analysis parameters. As per IS 456:2000 and the Linear Static Method all the structural members of the diagrid model are designed and IS 1893 (PART 1): 2002 is considered for load combination of seismic analysis [6].

SamanSadeghi, Improving the seismic performance of diagrid structures using buckling restrained braces: The seismic performance of diagrids equipped with buckling restrained braces (BRBs) is investigated. In that regard, the effects of BRBs on the seismic performance characteristics of diagrids such as response modification factor, R, overstrength factor, Ω_0, ductility ratio, μ, and median collapse capacity, S^CT, are evaluated. To this end, 6 three dimensional diagrid structures with various heights and diagonal angles are modeled using OpenSees program and are equipped with BRBs in a novel arrangement. Utilizing nonlinear static analysis, the seismic performance factors of models are evaluated. Subsequently, the median collapse capacity (S^CT) of the models are determined by performing nonlinear dynamic analyses. The results indicate that using BRBs improve the seismic performance of the considered models due to accumulation of plastic damages in BRBs and a better distribution of plastic hinges over those models. The nonlinear static analyses indicate that for the original diagrid models, the response modification factor, R, ranges from 1.7–2.5, while the ductility ratio, μ, varies between 1.2 and 2.5, depending on the diagonal angles. Also, the results show that the Ω_0 remains fairly constant. However, in BRB equipped diagrids, the range of *R* increases to 2.4–3.3, while the ductility ratio μ varies in the range 2.1–3.1. Similar to regular diagrids, Ω_0 remains constant for BRB equipped models. Furthermore, the output of the dynamic analyses indicates that the S^CT, which is a function of diagonal angles and generally increases by growing the diagonal angles, could rise up to 60% for diagrids equipped with BRB [7].

MahdiHeshmati, Seismic performance assessment of tubular diagrid structures with varying angles in tall steel buildings: Diagrid system has emerged as an innovative structural system with an aesthetic view in the design of tall buildings. In this study, seismic performance of 36-story diagrid structures with varying angles are evaluated using pushover and nonlinear time history analysis. Furthermore, in order to evaluate the effect of diagrid core on behavior of structures, interior gravity frames are replaced with diagrid frames. The results of pushover analyses demonstrate that diagrid core can enhance the hardening behavior of structures when the angles of perimeter panels are lower or equal than those of the core compared to the conventional diagrids. In addition, core diagrids provide safe margins between the damage states under lateral loading. Nonlinear time history analyses are then performed to assess inter story drift ratio, residual drift, energy dissipation and hinges distribution of structures. It is observed that most of the models perform well under rare ground motions and hinges are well spread throughout the height among different elements and diagrid structures are capable of undergoing large deformations under rare earthquakes Large portion of input energy are dissipated by diagonal members and as the slope of exterior diagonals exceed that of perimeter tube, diagrid core efficiently participates in dissipating energy [8].

MajidMoradi, Seismic fragility evaluation of a diagrid structure based on energy method: Diagrid structural systems have been brought into attention among architectures and engineers during recent years due to high structural efficiency and aesthetic potentials. Therefore, seismic behavior of diagrid structural systems under near and far-field earthquakes is investigated in this paper based on energy approach concepts in order to achieve a better understanding of their seismic behavior and the advantages of utilizing energy methods. For this aim, a 50-story building is modeled with a finite element method and its behavior is investigated through the Incremental Dynamic Analysis (IDA) method. Maximum story drifts, and plastic strain energy are studied as the engineering demand parameters (EDP). In addition, a fragility assessment method of the structure is presented with the aid of plastic strain energy and is compared to the fragility curves of maximum story drifts. This paper illustrates that the energy method can be applied to calculate the probability of the structure to exceed four performance levels including elastic, LS, CP and global instability. The results indicate that the fragility of the structure in far-field earthquakes is more than near-field ones in both maximum story drift and energy methods. Moreover, the fragility curves resulted from the energy method in LS and Instability levels have acceptable correspondence with the curves from the maximum story drift method, while the energy approach presents more conservative results in the CP level. It is demonstrated that the plastic strain energy can be considered as an appropriate parameter as EDP in the fragility evaluation of structures [9].

QingxuanShi, Simplified calculation of shear lag effect for high-rise diagrid tube structures: A high-rise diagrid tube structure is a new type of building structural system that can provide greater lateral stiffness. Simplified calculation methods for diagrid tube structures have been studied by scholars in recent years, but the shear lag effects in such structures have not been reviewed. The shear lag effect will affect the lateral stiffness and stress distribution of a tube structure, so it is necessary to propose a simplified calculation method that can consider the shear lag effect of diagrid tube structures. This paper adopts the principle of stiffness equivalence to equate a high-rise diagrid tube structure to an elastic orthotropic membrane, constructs the stress function considering the shear lag effect under the action of typical horizontal loads, and obtains the stress function through the principle of energy variation. A simplified calculation method is achieved; calculation formulas for the components internal forces and structural displacements are deduced and compared with a detailed finite element program calculation to verify the method. Further, through the simplified calculation method proposed in this paper, two key issues (angle optimization of diagonal columns and evaluation of the shear lag effect at any aspect ratio) are solved in the preliminary design of this kind of structure. Results of this paper can provide a theoretical reference for the preliminary design of a diagrid tube structure. Under the basic condition that only the aspect ratio of the structure is known, the optimal angle of diagonal column can be determined, and the shear lag effect of the diagrid structure can be quickly estimated by the proposed simplified method [10].

SamanSadeghi, Quantification of the seismic performance factors for steel diagrid structures: There are a number of studies on seismic performance of a diagrid structure indicating that it is an effective choice for constructing tall buildings. This research investigates the seismic behavior of diagrid structures and quantifies its seismic performance factors including the response modification coefficient (R-factor), the over-strength factor (Ω_0) and the displacement amplification factor (C_d) based on the FEMA P695 methodology. In that regard, a group of 3-D steel diagrid archetype models with different number of floors and various diagonal angles are designed using different R-factors. Then, in the first step, the over-strength factors of these models are determined by performing nonlinear static analyses. Then, utilizing the incremental dynamic analysis (IDA), the median collapse capacity and collapse margin ratio (CMR) of these models are calculated and their C_d factors are estimated using the computed R-factors. The obtained results indicate that the R-factor for steel diagrid systems depend on the diagonal angles. For diagrids with angles of 45°, 63.4° and 71.5°, amounts of R-factor were determined as 1.5, 2, and 3, respectively. Moreover, the pin and rigid types of end-connection of diagrid perimeter beams was found to have no effects on stiffness of the diagrid models. However, the IDA results indicate that the diagrids with pin-ended beams tolerate larger collapse displacements especially in shorter models. Furthermore, replacing the rigid-ended beams by pin-ended beams improves the seismic performance of diagrids, particularly for models with larger diagonal angles (63.4° and 71.5°). The OpenSees program was used for modeling and numerical analyses [11].

Giovanni MariaMontuori, Secondary bracing systems for diagrid structures in tall buildings: In this paper the authors define a framework for assessing the "local" structural issues in the design of diagrid tall buildings, and present a methodology for establishing the need for a specific secondary bracing system (SBS) as a function of the diagrid geometry. Further, design criteria for secondary bracing systems are worked out and applied to some 90 story building models, characterized by perimeter diagrid structures with different module height and diagonal cross sections. The outcomes of the proposed simplified procedures, both for assessing SBS necessity and for the consequent SBS member design, have been compared to the structural response of the diagrid building models, obtained without and with SBS, demonstrating both the accuracy of the proposed formulations and the primary importance of the discussed local questions. In fact, all analyzed diagrid models exhibited problems concerning stability of interior columns (i.e. multi-storey buckling modes) and/or local flexibility (excessive interstory drift); the above local problems are completely solved after the introduction of a SBS at the central core location, and, against a modest increase of structural weight (about 3%), any flexural engagements in the diagrid member is eliminated [12].

DomenicoScaramozzino, Selection of the optimal diagrid patterns in tall buildings within a multi-response framework: Application of the desirability function: Diagrids are efficient structural systems for tall building design and construction due to their high lateral stiffness. Their structural response can be optimized by changing the geometrical pattern of external diagonals. This has usually been carried out by looking for the diagonal pattern that employs the minimum amount of structural material, while complying with strength and stiffness requirements. However, other responses can be significant for the selection of the optimal pattern, such as the torsional flexibility and construction complexity of the building. In this work, the desirability function approach has been used for selecting the optimal diagonal pattern for diagrid tall buildings in a multi-response framework. The most desirable diagonal layout has been selected based on its overall desirability to minimize: (i) the wind-induced lateral displacement, (ii) the torsional rotation, (iii) the diagrid structural weight, and (iv) the construction complexity. The application of this methodology straightforwardly provides the optimal diagrid pattern considering the four responses simultaneously. The method has been applied initially to a limited set of uniform-angle patterns, and afterwards to a wider population of varying-angle geometries.

Four different floor plan shapes were also taken into account. The outcomes of the analysis revealed that the specific plan shape plays only a minor role in the definition of the optimal structure, whereas the diagonal layout affects greatly the efficiency of the solution. Uniform-angle diagrids are generally the most desirable, even for taller buildings, due to their higher performance in terms of torsional rigidity and construction complexity. Among these, the patterns in which the diagrid triangular module spans over two-three floors, corresponding to diagonal inclinations of about 55°–65°, have the highest desirability. Notably, because of the competition between the different responses, this optimal inclination is not found to increase as the building becomes taller [13].

KiranKamath, An analytical study on performance of a diagrid structure using nonlinear static pushover analysis: In this study, an attempt has been made to study the performance characteristics of diagrid structures using nonlinear static pushover analysis. The models studied are circular in plan with aspect ratio H/B (where H is total height and B is the base width of structure) varying from 2.67 to 4.26. The three different angles of external brace considered are 59°, 71° and 78° (Kim et al., 2010). The width of the base is kept constant at 12 m and height of the structure is varied accordingly. The nonlinear behaviour of the elements is modelled using plastic hinges based on moment–curvature relationship as described in FEMA 356 guidelines. Seismic response of structure in terms of base shear and roof displacement corresponding to performance point were evaluated using nonlinear static analysis and the results are compared. For 71° brace angle model base shear at performance shows an increase in all the aspect ratio considered in the study. The performance of the structure is influenced by brace angle and aspect ratio [14].

KyoungSun Moon, Diagrid Structures for Complex-Shaped Tall Buildings: Diagrid structures are prevalently used for today's tall buildings due to their structural efficiency and architectural aesthetic potentials. This paper studies structural performance of diagrid systems employed for complex-shaped tall buildings such as twisted, tilted and freeform towers. For each complex form category, tall buildings are designed with diagrid systems, and their structural efficiency is studied in conjunction with building forms. In order to investigate the impacts of variation of important geometric configurations of complex-shaped tall buildings, such as the rate of twisting and angle of tilting, parametric structural models are used for this study. Based on the study results, design considerations are discussed for the efficient use of diagrid structures for complex-shaped tall buildings [15].

IV. CONCLUSION

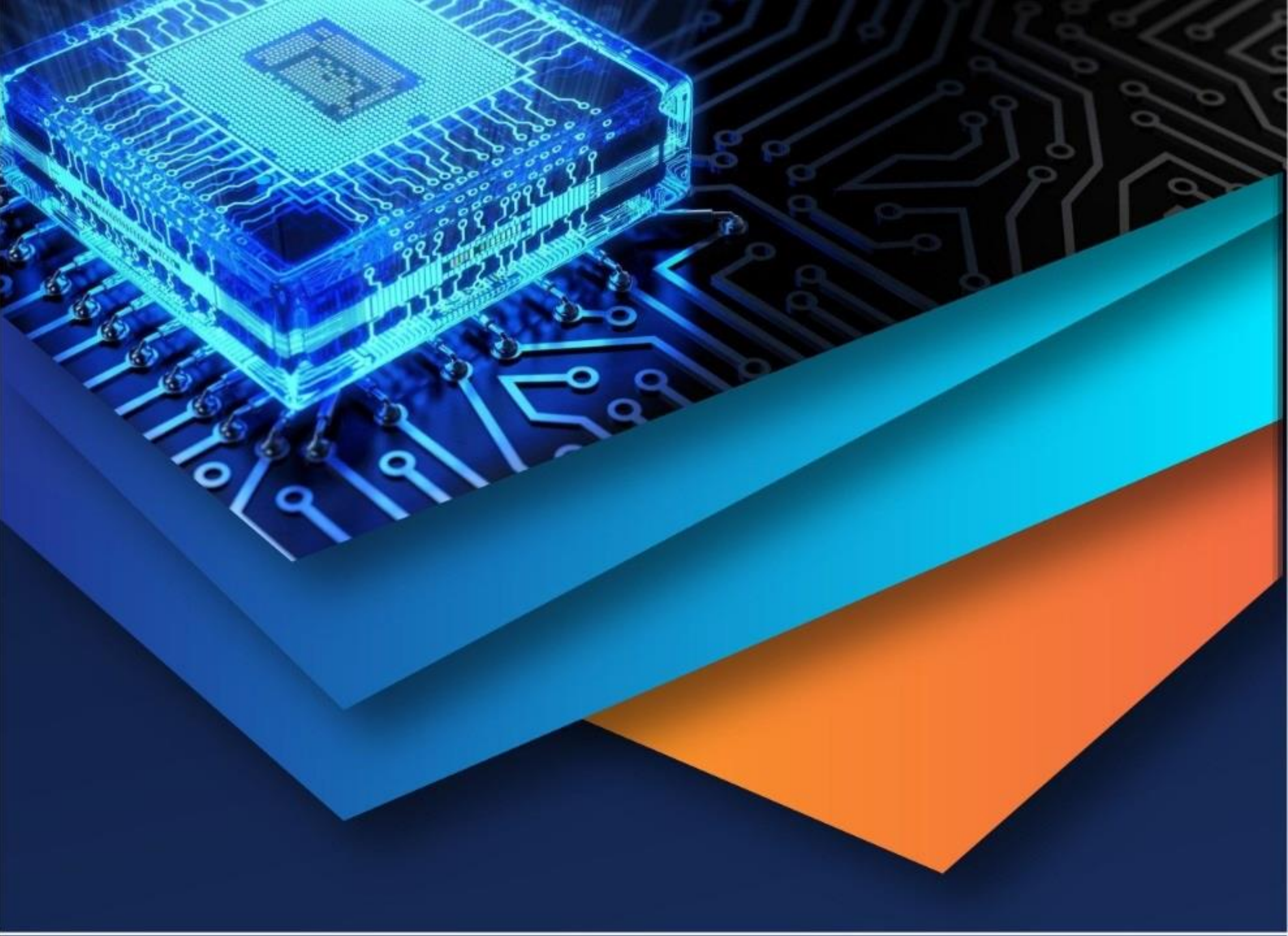
From the literatures reviewed it was revealed that:

1) Diagrid performs better across all the criterions of performance evaluation, such as efficiency, expressiveness and sustainability.
2) Diagrid structures have higher stiffness than other structures.
3) Diagrid structures have less deflection as compared to the conventional structures.
4) Weight of the structure gets reduced to a greater extent due to which structure has more resistance to lateral forces.
5) Displacement on each storey, storey drift and storey shear are observed to be less in diagrid structures as compared to conventional structures.
6) Diagrid structure gives more aesthetic look and gives more of interior space. Due to less number of columns, façade of the building can also be planned more efficiently.

REFERENCES

[1] ChengqingLiu, Separation of long-period components of ground motion and its impact on seismic response of long-period diagrid structures, Soil Dynamics and Earthquake Engineering, Volume 150, November 2021, 106942
[2] DengjiaFang, Mechanical characteristics and deformation calculation of steel diagrid structures in high-rise buildings, Journal of Building Engineering, Volume 42, October 2021, 103062.
[3] Kamil AshrafBhat, Analyzing different configurations of variable angle diagrid structures, Materials Today: Proceedings, Volume 42, Part 2, 2021, Pages 821-826.
[4] PayamAshtari, Optimum geometrical pattern and design of real-size diagrid structures using accelerated fuzzy-genetic algorithm with bilinear membership function, Applied Soft Computing, Volume 110, October 2021, 107646.
[5] QingxuanShi, Experimental investigation on the seismic performance of concrete-filled steel tubular joints in diagrid structures, Structures, Volume 31, June 2021, Pages 230-247.
[6] NehaTirkey, Analysis on the diagrid structure with the conventional building frame using ETABS, Materials Today: Proceedings, Volume 22, Part 3, 2020, Pages 514-518.
[7] SamanSadeghi, Improving the seismic performance of diagrid structures using buckling restrained braces, Journal of Constructional Steel Research, Volume 166, March 2020, 105905.
[8] MahdiHeshmati, Seismic performance assessment of tubular diagrid structures with varying angles in tall steel buildings, Structures, Volume 25, June 2020, Pages 113-126.

[9] MajidMoradi, Seismic fragility evaluation of a diagrid structure based on energy method, Journal of Constructional Steel Research, Volume 174, November 2020, 106311.
[10] QingxuanShi, Simplified calculation of shear lag effect for high-rise diagrid tube structures, Journal of Building Engineering, Volume 22, March 2019, Pages 486-495.
[11] SamanSadeghi, Quantification of the seismic performance factors for steel diagrid structures, Journal of Constructional Steel Research, Volume 146, July 2018, Pages 155-168.
[12] Giovanni MariaMontuori, Secondary bracing systems for diagrid structures in tall buildings, Engineering Structures, Volume 75, 15 September 2014, Pages 477-488.
[13] DomenicoScaramozzino, Selection of the optimal diagrid patterns in tall buildings within a multi-response framework: Application of the desirability function, Journal of Building Engineering, Volume 54, 15 August 2022, 104645.
[14] KiranKamath, An analytical study on performance of a diagrid structure using nonlinear static pushover analysis, Perspectives in Science, Volume 8, September 2016, Pages 90-92.
[15] KyoungSun Moon, Diagrid Structures for Complex-Shaped Tall Buildings, Procedia Engineering, Volume 14, 2011, Pages 1343-1350



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