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Diagrid Mono Column Structures with Different Geometry in Plan: A Review

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Abstract: ***Due to increasing urbanization and rapid infrastructural development, scarcity of land is a problem. Multi-story structures have been constructed to eliminate this problem. But for the requirement of large service spaces and good aesthetic appearances, the mono column structural system achieved popularity. Mono column structures are complicated since the mono column supports the whole structure and all other member acts as cantilevers. Mono column structures are vulnerable to seismic loads and adding a diagrid structural system on the periphery of the building improves seismic performances. This review paper aims to review the previous studies on mono column structure and diagrid structural system. It also focuses to review the performance of different plan geometry buildings.***
Keywords: Aesthetic, Cantilever, Diagrid Structural System, Mono Column Structure, Multi-Story Structure, Seismic Performance

I. INTRODUCTION

It is important to handle and accommodate the people in urban areas due to the population growth. Due to the rapid jump in land prices and scarcity of land, the trend is to build multi-story structures. But for the requirement of large service space and good architectural appearances, mono column structures achieved popularity. Structure supported only on a single column is known as mono column structure. Mono column structures are complicated since the mono column supports the whole structure and all other member acts as cantilevers. It requires less space for the foundation and so it provides more spaces for parking and other utilities. Eccentric loading causes structure to twist in any direction and causes failure. Mono column structures are vulnerable to seismic load [18]. Adding a diagrid structural system on the periphery of the building improves the seismic performance. Diagrid structure is an inclined column that replaces the conventional column. Diagrid structures are pin jointed elements that transfer the stress by axial action and it improves the seismic performance of the structure [12].

II. CANTILEVER STRUCTURE

Cantilever structures are structures with one end fixed and the other end free. Cantilever structure has low rigidity, and high deflection and is recommended for carrying low forces [1]. The cantilever structure is one of the important structures in engineering. Examples of cantilevers used in mechanical and aerospace models are fixed-wing of aircraft, helicopter fan blades, and solar arrays. But in civil engineering, these structures can be used in cantilever bridges and balconies. These structures should be flexible and should carry a high level of stress. Best cantilever beam designs should be based on maximum strength and long life span with minimum weight and cost-effective. Based on dynamic properties change such as stiffness lead to various mode shape, reduction in natural frequency, and an increase in damping [2].

Many architectural works are inspired by nature's designs. Trees are one of nature's examples. Trees can transfer loads efficiently. Standard triangle cantilever beams were the best design. If the projection remains the same method of tensile triangles cantilever beam can improve the cantilever design [3]. Long cantilevered structures like balconies in auditoriums, theatres, churches, and stadiums are subjected to excessive vibrations because of the movement of the crowd. The natural frequency reduces due to crowd movement vibration. Damping ratios increase for higher modes [4].

Overhangs form eccentricity on the building. When overhang length increases, eccentricities also increase. Overhangs must be limited to 1 m in length, wall construction elements that stand over overhangs increases eccentricity. Lightweight materials can be used on overhangs for minimum eccentricity [5].

When structural size increases, the failure pattern of RC cantilever beams of different structural sizes are similar. When structural size increases corresponding nominal shear strength and the safety reserve coefficient decrease. As structural size increases RC beam provides poor ductility and more energy the beam dissipates. The nominal shear strength of the RC cantilever beam decreases as structural size increases [6].

For a steel long cantilever structure, the top plate thickness of the box girder has little influence on torsional rigidity. The web plate and bottom contribute to the stiffness of the structure [7]. The natural frequency of cracked steel cantilever beams reduces when the crack is on the top and bottom edges of the beam, but a crack in the middle of the beam remains stable. Natural frequency changes slightly as the crack shifts from fixed to the free end of the cantilever beam. Mode shapes of a cracked cantilever beam depend on the depth and position of the crack [8].

A cantilever roof is generally more vulnerable to the wind because high suction loads act on the rooftop due to flow separation. The wind direction influences the distribution pattern and wind pressure value. The down-slopping roof is more appropriate since it reduces mean wind pressure, net lifting, and bending moment coefficient. Adding a vented leading edge slot reduces rooftop wind suction [9].

III. MONO COLUMN STRUCTURE

Building supported on a single column is called as mono column structure. It creates a good aesthetic appearance. The maximum shear force of seismic analysis is more than the maximum shear force obtained from the non-seismic analysis. The bending moment values obtained on the member increase about 91% in seismic analysis than the member with non-seismic loads. Seismic analysis displacement is more than the non-seismic analysis [18]. It concludes that single-column structure is 27.26% more costly when compared with multi-column structures and shear force and bending moment values in single-column buildings are much higher than that of multi-column buildings. Deflection for a single column in single-column buildings is lesser when compared to a column in a multi-column building. Support reactions in a single column in a single-column building are much higher than that of a support reaction for a column in a multi-column building.

Mono column structure is a tree-like structure that transfers the weight of the leaves and branches into the bark and distributes it into the soil by its root. A single column supports the whole structure and all other member acts as a cantilever. It is clear that from static and dynamic analysis, the story displacement, story drift, story shear, and overturning moment increase when we go for higher seismic zones. In all seismic zones, the mono column structure having a circular plan shape shows less displacement and story drift whereas the rectangular plan shape showed more story drift and story displacement. In all seismic zones of India, square shape plan configuration mono column structure showed minimum story shear, overturning moment, and story stiffness whereas triangular-shaped mono column structure showed higher story shear, overturning moment, and story stiffness.

Rectangular plan-shaped mono column structure showed more time period whereas circular-shaped mono column structure showed less time period. In all wind zones story shear, overturning moment and story stiffness are minima in square and circular shaped mono column structures. But in triangular-shaped structure story shear, story stiffness, and the overturning moment is higher. Rectangular shaped mono column structure should not be preferred in high seismic areas and high wind-prone areas since it showed large displacement. But circular, triangular, and hexagonal-shaped mono column structures showed better performance against seismic and wind loads [19].

IV. PLAN CONFIGURATION

The past earthquake damage assessments showed that the plan configuration of irregular buildings is prone to severe damage due to excessive torsional responses and stress concentration than the regular buildings. The plan configuration plays an important role in the seismic design of buildings. For example, L shaped building showed early collapse due to the presence of a re-entrant corner that causes stress concentration due to sudden change in stiffness and torsional response amplification [20].

The progressive collapse phenomenon is a new area of interest for many engineers. The disproportion between the initial and final damage is the main reason for the progressive collapse that can lead to the collapse of the entire structure. So it is important to prevent the expansion of initial damages by strengthening some load-bearing elements or by choosing a proper plan. Alternative Path Method(APM) is one of the common methods to examine building response to progressive collapse. It concluded that removing a corner column in the rectangular building showed serious effects including doubling the downward collapse rate and increasing the shear and axial loads in the column by 1.5 times compared with the square-shaped building [21].

Torsional deformation occurs due to plan asymmetry, which does not present in the corresponding symmetrical plan. Plan asymmetry also changes the lateral deformation. The effect of plan asymmetry on lateral and torsional deformation of the elastic system depends on the uncoupled lateral vibration period. Plan asymmetry affects the lateral deformation of the torsionally very stiff system negligibly. For inelastic systems, the increase in element deformation due to plan asymmetry is small. The element deformation in an asymmetric plan system is nearly similar to that of a symmetric plan system with increasing inelastic action [22].

From previous studies, unreinforced adobe or mud-brick structures showed severe damage by seismic load and caused a vast number of deaths. But some of the adobe structures performed well during past earthquakes. Most of these buildings were symmetrical-shaped structures that have a significant bearing on the performance during strong seismic events. By conducting tilt table testing, it was concluded that the seismic performance of the circular-shaped structure showed better performance than the square-shaped structure [23].

V. DIAGRID STRUCTURAL SYSTEM

Diagrid structures are diagonal elements often known as the diagonal perimeter. It is an innovative method used in tall buildings. It also gives a good architectural view. It made the structure stiffer and lighter compared to the conventional type of construction. It reduces the number of structural elements. It also reduces the possibility of failure when compared with conventional structures due to heavy vibration during an earthquake [10].

The diagrid structure provides structural efficiency as a result of triangular configuration. The gravity load and lateral load are resisted by triangulations. The diagrid member carries axial stresses that are tension or compression with no bending. These diagonal members can resist 42% of all lateral loads and they can resist about 21% of the total displacement due to all the loads. Story drift of diagrid structure can be reduced by 100% [11].

From earthquake and wind analysis of story drift, story displacement, and base shear, it is concluded that circular plan performs better than square and rectangular plan in braced tube structures. But square plan performs better than circular and rectangular plan in diagrid structure. Compared with the braced tube structure, the diagrid structure has the least story displacement and story drift values, and maximum shear values. So it is clear that the diagrid structure performs better than the braced tube structure [12].

In-cylinder type structure, the collapse margin ratio of vertical irregularity is larger than in other structures with vertical irregularity. The ground type structure that has the highest vertical irregularity with the longest natural period shows a smaller collapse margin. The structure that has a low center of the mass showed a larger collapse margin than that of the structure with a high center of mass. The collapse margin is slightly higher for convex structures compared with concave structures [13].

It shows that the use of variable angle diagrids can improve the efficiency and it can reduce the cost than the constant angle diagrids. Selecting a suitable angle configuration reduces the cost and material used for construction [14]. Diagrid structures are capable of undergoing large deformations during rare earthquakes. About a large portion of the input energy is carried by diagonal members. When the slope of exterior diagonals exceeds that of the perimeter tube, the diagrid core participates efficiently in dissipating energy [15].

Concrete Filled Steel Tubular (CFST) joints are widely adopted joint forms in diagrid structural systems. When the intersection angle increases the bearing capacity of the specimen reduces and changes the distribution of main energy dissipation. The bearing capacity and energy dissipation capacity of the specimen can be improved by increasing the wall thickness of the steel tube. It is important to strengthen the weak point of CFST diagrid joints along the horizontal intersecting line of the joint and the intersection between the joint and inclined column [16]. In the CFST diagrid structure, the joints are formed by intersecting four oblique CFST columns. From experimental and numerical analysis, it is clear that connecting separation angle plays an important role in failure modes and the numerical behavior of connection was similar to the behavior of the CFST short column [17].

VI. CONCLUSIONS

Mono column structures are tree like structure that the whole building is supported on single column. Since the whole structure is supported on single column all other members will act as cantilever. Eccentric loading can twist the building in any direction and causes failure. Mono column structure showed high deflection in members, high story displacement and high story drift. The maximum shear force and maximum bending moment in the members are more in seismic analysis than in the non-seismic analysis. Mono column structure are costlier than the conventional type of structure. These mono column structures are vulnerable to seismic loading. The plan configuration also plays an important role in the seismic performance of the building and it is proved that asymmetric plan shaped structure is prone to severe damage due to excessive torsional responses and stress concentration. Plan asymmetry also changes the lateral deformation in the structure. The studies showed that diagrid structural system improves the seismic performance of the structure and it provides good aesthetic appearance. It made the structure stiffer and lighter than the conventional type of structure. It reduces the number of structural elements and reduces the possibility of failure due to the lateral loading such as seismic load and wind load. The diagrid structure provides the efficiency due to its triangular configuration. Diagrid structural system decreases the story displacement, story drift and the base shear than the conventional structures.

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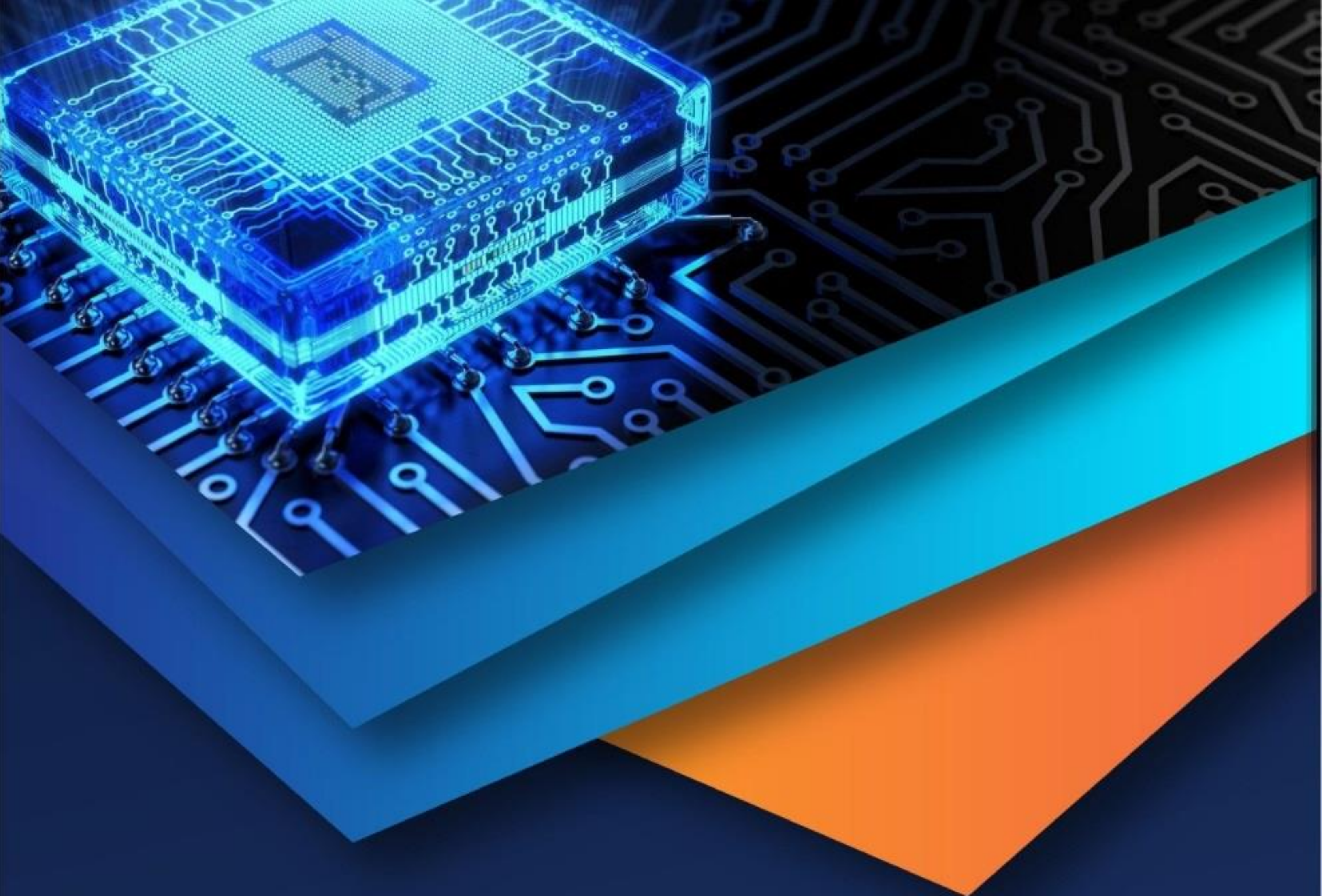

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