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Original Article

Seismic Evaluation of the Diagrid Structural System Configured Around the Perimeter Against a System of Structural Walls with Frames

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Abstract *- The objective of this research is to evaluate and compare the seismic performance of a perimeter-configuration Diagrid structural system against a conventional structural system consisting of concrete walls and frames, intended for common-use buildings with square and rectangular floor plans, located in the coastal city of Lima, Peru. Considering the high seismic hazard that characterizes the Peruvian coast, there is a need to analyze and propose more efficient structural systems that improve the response of buildings to seismic events. As a response to this problem, the implementation of the Diagrid structural system around the perimeter of the structures is proposed, due to its greater efficiency in resisting seismic forces. The Diagrid structural system was compared with conventional systems using linear dynamic seismic computational analysis to contrast seismic behavior, using the following indicators: fundamental vibration periods, lateral displacements, inter-story drifts, and internal forces. The results show that the Diagrid structural system, in the proposed configurations, presents better results in seismic analysis, registering a reduction of more than 30% in fundamental vibration periods, an approximate decrease of 50% in lateral displacements, and a 70% reduction in interstory drifts compared to conventional systems.*

Keywords *- Seismic performance, Diagrid, Perimeter structure, Reinforced concrete buildings, Structural optimization.*

1. Introduction

The high seismic hazard off the Pacific coast is one of the most significant threats to the structural safety of buildings. This is due to the intense tectonic activity associated with the Pacific Ring of Fire, where more than 90% of the world's earthquakes occur [1], reaching magnitudes of Mw 8.0 [2]. In this context, the Peruvian coast presents a high level of seismic hazard [3], leading experts to emphasize the need for adequate planning and the development of more efficient earthquake-resistant buildings [4], capable of preventing loss of life, ensuring the continuity of basic services, and minimizing structural damage [5].

Currently, the most used structural systems in large-scale projects are mainly based on dual systems and reinforced concrete frames because they are supported by the standards, their behavior under seismic loads is known, and the frame system offers greater architectural flexibility; however, it requires larger structural elements to withstand lateral loads, which increases costs and generates greater displacements during earthquakes [6]. On the other hand, the dual system improves the rigidity and seismic behavior of the building by combining frames and structural walls; however, it involves higher costs, greater design complexity, and restrictions on architectural layout [7].

Faced with seismic challenges and the need for more efficient systems in Peru, the Diagrid system stands out as an innovative solution developed in the late 19th century [8]. The Diagrid system is a system that we could call triangular because of the way its elements are connected, as shown in Figure 1 so this distribution allows buildings to resist gravitational and lateral loads through the axial action of their diagonal elements, reducing shear deformation and even decreasing the need for internal walls, furthermore, its optimized design reduces material consumption and improves lateral stiffness, making it especially suitable for tall buildings in areas of high seismicity [9] then although its application in the country has not traditionally been considered an ideal option, this research seeks to highlight the efficiency of this structural system in common or particularly important projects, with the aim of establishing its implementation as a standardized structural system.

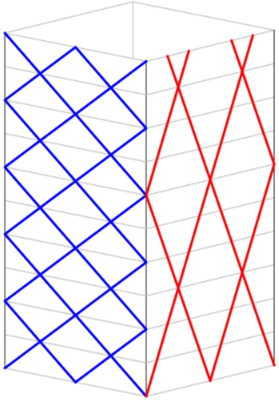

Fig. 1 Diagrid perimeter system

Therefore, in recent years several studies have been developed to evaluate the seismic performance of Diagrid systems compared to conventional structures, for example, researchers Quiroz et al. [9] conducted research to evaluate the seismic-resistant advantages of the Diagrid rigid grid system in buildings located in areas of high seismicity then they compared the seismic response of a 24-story, 114-meter-tall building structured with a traditional moment-resisting frame and bracing system with other similar buildings equipped with a perimeter Diagrid system and the results showed that, despite having lower levels of weight, stiffness, and lateral resistance, the Diagrid system exhibited better seismic performance under design excitation, resulting in only minor damage to a small proportion of its structural elements, furthermore, the authors concluded that the triangulated configuration of the system favors a more efficient transmission of lateral loads through predominantly axial stresses, contributing to the control of deformations and improving the overall performance of the structure.

Similarly, Maldonado [10] conducted a comparative analysis of the Diagrid structural system and a conventional moment- resisting frame system under seismic loading. The study employed modal dynamic analysis and response spectrum analysis on 12- and 24-story buildings. The study concluded that the Diagrid system exhibits superior structural performance, registering an approximate 22% reduction in primary vibration modes and reductions of between 59% and 30% in the torsional mode. This translates into greater structural stiffness and stability, promoting better architectural integration, optimizing space utilization, and improving the relationship between structural and architectural design.

Furthermore, Thasmitha and Sandeep [11] analyzed the seismic behavior of a reinforced concrete building with a Diagrid structural system and compared it with a conventional frame system, both of 12 floors and an area of 576 m2, using the ETABS software, from which they obtained results that show that the Diagrid system presents a reduction of 58.56% in the maximum displacements compared with the conventional frame model, as well as a reduction of 61.7% in the drift between floors and an improvement of 96.21% in lateral stiffness, which reflects a more efficient control of the lateral behavior of the structure and a greater capacity to resist seismic forces.

Similarly, Nayeemuddin's work [12] compared diagrid structures with conventional frames applied to a G+26 reinforced concrete structure located in a high seismicity zone, using linear analysis in ETABS to evaluate its structural performance and it demonstrates that diagrid structures distribute lateral loads more efficiently and offer greater lateral stiffness then to obtain a more optimal configuration, it is necessary to design the structure with an angle of 58°, since in this way we will obtain the best performance among the models, with a fundamental period of 2.886 s, a lateral displacement of 11,455 cm, a drift of 0.248 cm and a base shear of 12,079 kN, which demonstrates how a moderate angle maximizes seismic efficiency and overall, the work confirms that diagrid systems constitute a reliable and high-performance solution for earthquakes, outperforming conventional frames.

Despite the favorable results reported in previous research, most of these studies have been conducted on high-rise buildings or under seismic codes different from those in Peru, furthermore, there is limited evidence on the seismic behavior of perimeter diagrid systems in reinforced concrete buildings designed according to Peruvian seismic-resistant building codes, especially considering square and rectangular floor plans and similarly, no research has been identified that compares this system with the conventional structural systems widely used in Peru so this knowledge gap makes it difficult to accurately assess the efficiency and applicability of diagrid systems in Peru's context of high seismic risk.

In this context, the novelty of this research lies in the comparative evaluation of the seismic behavior of reinforced concrete buildings with perimeter diagrid systems and conventional structural systems, considering square and rectangular floor plans under conditions representative of the Peruvian context, to this end, a linear seismic analysis is applied to obtain a rapid and reliable evaluation of the structure's elastic behavior [13], using the fundamental period of vibration, lateral displacements, interstory drifts, and internal forces as indicators and based on the reviewed background information, it is hypothesized that buildings with perimeter Diagrid systems will exhibit better seismic performance than conventional structures, reflected in a reduction of lateral displacements, interstory drifts, and internal forces, as well as greater structural stiffness. It is expected that the results will contribute to generating technical evidence that allows for the assessment of the viability of the Diagrid system as an efficient alternative for the seismic-resistant design of buildings in Peru.

2. Materials and Methods

For the seismic analysis of a framed system with a perimeter diagrid structure compared to a framed system with structural walls, the coastal city of Lima was chosen as the study area. This is due to its location in a high seismic hazard zone and the frequent occurrence of earthquakes in the region [14]. These conditions are evident in Figure 2, which shows the concentration of seismic events along the country's coastal strip recorded in the first months of 2026 [15].

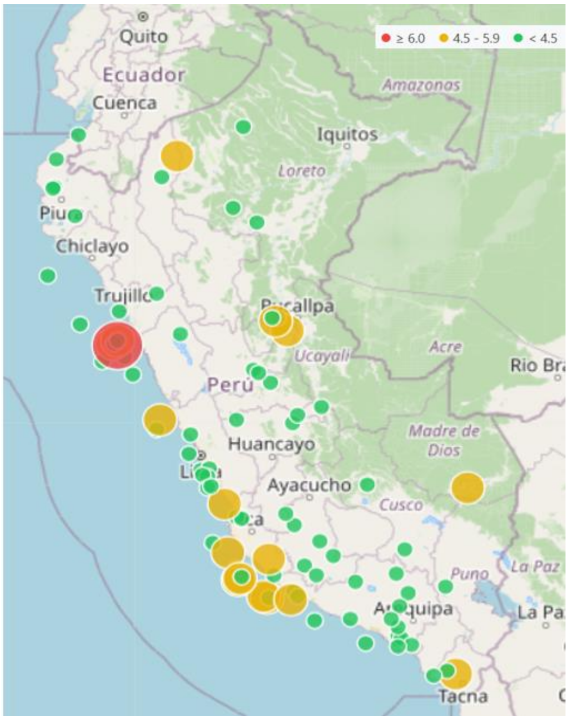

Fig. 2 Seismic activity in peru

2.1. Materials

2.1.1. Terrain Characteristics

For the development of this research, it is essential to understand the characteristics of the soil where the proposed building will be constructed. This knowledge will allow for the design of the foundation and, above all, the seismic analysis of the structure. Soil sampling for the study was carried out according to the Manual [16] and in compliance with Peruvian standard E 0.50 [17]. Two test pits were excavated to obtain representative samples. In both cases, the samples were taken manually to ensure they remained undisturbed.

To determine the soil profile type, a direct shear test was performed following the instructions in the Manual [16]. This procedure allowed us to know the characteristics and parameters of the two samples collected in the field, the results of which are presented in Tables 1 and 2, respectively.

Table 1. Properties of soil sample, C-1

Parameter	Symbol	Value
Angle of friction	φ	34°
Cohesion	C	0 kg/cm²
Specific weight	γ	19 kN/m³

Table 2. Properties of soil sample, C-2

Parameter	Symbol	Value
Angle of friction	φ	35°
Cohesion	C	0 kg/cm²
Specific weight	γ	19 kN/m³

Based on the properties obtained from the soil samples, the allowable bearing capacity was determined using the theory of Terzaghi & Peck [18], the results of which are summarized in Table 3. According to the Peruvian Standard E.030 [19], the terrain is classified as an intermediate soil, composed mainly of dense sands, firm silts, or compact clays

Table 3. Soil characteristics

Test pit	q all (kg/cm²)	Seismic profile type (E.030)
C-1	6.11	S2
C-2	6.95	S2

2.1.2. Characteristics of the Structure

The research was conducted in an area of 350 m², located in the capital city of Peru, considering two structural proposals: the first proposal with a square and symmetrical configuration, with dimensions of 18.7 × 18.7 meters, and the second proposal with a rectangular configuration, with dimensions of 25.0 × 14.0 meters. Both proposals correspond to the common use category, which applies to larger-scale buildings such as housing, offices, among others [19], corresponding to a 10-story building.

The conventional structures analyzed consist of structural walls and reinforced concrete frames, the most commonly used conventional structural systems in the country [20]. Figure 3 presents the first conventional structural system evaluated with a square floor plan configuration, while Figure 4 shows the second conventional structural configuration with a rectangular configuration; likewise, Table 4 details the dimensions, loads, and properties of the structural elements considered in both models.

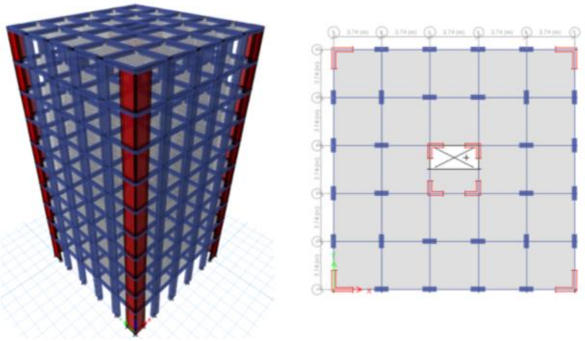

Fig. 3 Square-shaped framed structure with structural walls

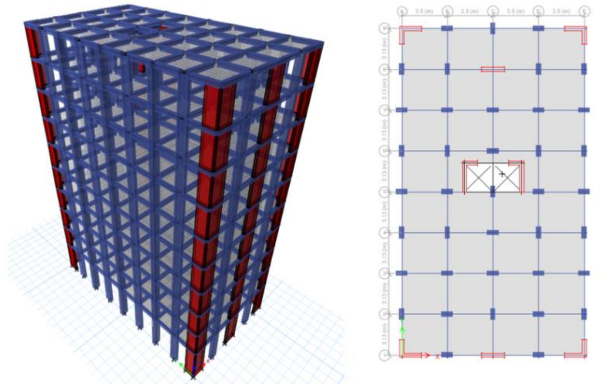

Fig. 4 Rectangular framed structure with structural walls

Table 4. Characteristics of conventional structures

	Square structure	Rectangular structure
Columns	0.40m x 1.10m	0.40 m x 0.90 m
	0.45m x 0.45m	0.40 m x 0.40 m
Beams	0.30m x 0.40m	0.30 m x 0.40 m
Plate	0.30m	0.30 m
Slab	0.20m	0.20 m
Dead load	0.30 ton/m2	0.30 ton/m2
Live load	0.30 ton/m2	0.30 ton/m2
Concrete strength (f´c)	280 kg/m2	280 kg/m2

The structural models with Diagrid perimeter systems proposed in this research are shown in Figures 5 and 6, corresponding to square and rectangular floor plan configurations, respectively.

The vertical and horizontal axes, as well as the project height, are maintained in the design to ensure a consistent comparison with conventional models; however, the perimeter structural walls are eliminated and replaced by the Diagrid system. Table 5 presents the dimensions, loads, and properties of the structural elements used in these models.

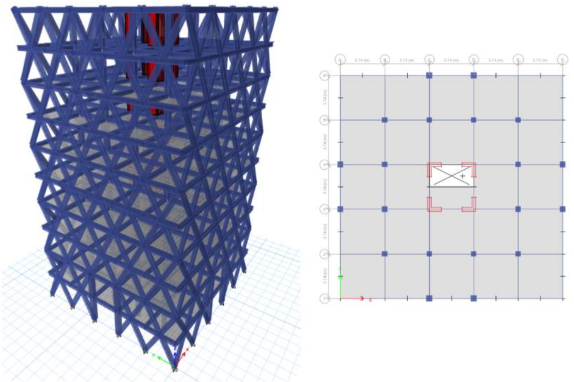

Fig. 5 Square-shaped structure with perimeter Diagrid system

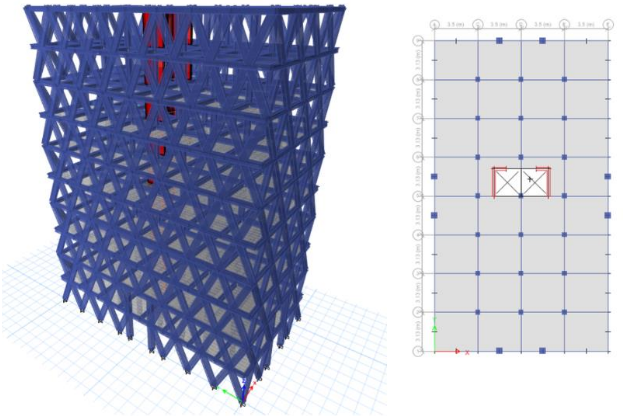

Fig. 6 Rectangular structure with perimeter Diagrid system

Table 5. Characteristics of structures with a perimeter Diagrid system

	Square structure	Rectangular structure
Columns	0.50m x 0.50m	0.50m x 0.50m
	0.45m x 0.45m	0.40m x 0.40m
Slanted columns	0.25m x 0.50m	0.30m x 0.60m
Beams	0.30m x 0.40m	0.30m x 0.40m
Plate	0.30m	0.30m
Slab	0.20m	0.20m
Dead load	0.30 ton/m2	0.30 ton/m2
Live load	0.30 ton/m2	0.30 ton/m2
Concrete strength (f´c)	280 kg/m2	280 kg/m2

2.1.3. Structural Modeling Tool

To evaluate the structural behavior of the conventional and proposed models under gravitational and higher-mode seismic loads, and to perform the corresponding verifications in accordance with the Peruvian standard E 0.30 [19], the ETABS software version 21.1.0 was used, which is a tool widely used internationally in the field of structural engineering, allows static and dynamic analysis in the linear range [21] and facilitates the acquisition of fundamental parameters for the evaluation of structural performance, such as the fundamental period of vibration, lateral displacements, drifts between floors and internal forces, which are essential indicators for the comparison and analysis of the models proposed in the study.

For the development of the research, three-dimensional models of the structural systems to be compared—a square structure and a rectangular structure—were created. Subsequently, in each configuration, the perimeter structural elements were replaced with a diagrid system to evaluate its influence on the structural response. The analysis was carried out using dynamic procedures, specifically modal spectral analysis and time-history analysis, which allowed for a comparison of the systems' performance under seismic loads and the identification of differences in their structural behavior.

2.2. Analysis Methodology

For the dynamic seismic analysis in the X–X and Y–Y directions, the parameters established in the Peruvian standard E.030 [19] were considered, which were defined according to the zoning criteria, site conditions, use category, and structural system, presented in Table 6.

The structural model was developed under assumptions of linear-elastic behavior, rigid diaphragms at each level, concentrated masses at the floors, and 5% structural damping, consistent with the modal spectral dynamic analysis used in the research. Furthermore, the model's reliability was assessed indirectly by comparing the fundamental periods with previous studies of similar structural systems, thus ensuring the consistency of the results obtained. The structural behavior was assessed using representative seismic performance indicators, such as the fundamental period of vibration, lateral displacements, interstory drifts, and internal forces. These indicators clearly identify the structure's dynamic response and allow for comparison of its behavior under seismic loads.

Table 6. Seismic parameters

Seismic Parameters - X-X, Y-Y Direction		
Zoning	zone	4
	Z	0.45
Site Parameters	Floor	S2
	S	1.05
	Tp (seg)	0.60
	TL (seg)	2.00
Use	Category	C
	U	1.00
Seismic Reduction Factor	Dual	
	Ro	7
	Ia	1.00
	Ip	1.00
	R	7.00

2.2.1. Fundamental Period of Vibration

According to the current standard, E.030 [19], the fundamental period of vibration is the time it takes a structure to complete one oscillation in its main mode when vibrating freely and is expressed in seconds and is directly related to the relationship between its mass and stiffness, which for regular buildings, the standard allows the use of approximate expressions based on the height or number of floors. Similarly, the American standard ASCE 7-16 [22] defines it as the period associated with the first natural mode of vibration in the considered direction, which must be obtained through structural analysis, and its importance in seismic analysis lies in the fact that, from this parameter, the spectral acceleration is determined and, consequently, the forces used to design the structure. In addition, it directly influences the estimation of displacements and drifts, which allows a clearer understanding of how the building responds to an earthquake.

2.2.2. Lateral Displacement

The National Building Code E.030 [19] defines lateral displacement as the horizontal movement of different levels of a building under seismic forces, a parameter that reflects the degree of deformation of the structural system, and its verification is carried out by monitoring the drift between floors, established as a fraction of the floor height, to ensure stable behavior and reduce the probability of damage to structural elements. Similarly, ASCE 7-16 [22] also recognizes it as an essential part of the structural response that must be evaluated in the analysis because the importance of this indicator lies in its ability to understand how the structure deforms, evaluate its stability, and verify that its behavior remains within levels compatible with safety and expected performance.

2.2.3. Interstory Drifts

Standard E.030 [19] defines the drift between floors as the relative horizontal displacement between two consecutive levels of a building subjected to seismic forces, and represents the angular distortion experienced by the structure, and is one of the most relevant criteria in earthquake-resistant design. For reinforced concrete buildings, the standard establishes a maximum allowable drift of 0.007 h, equivalent to 0.7% of the floor height, in order to limit the expected level of damage and ensure safe structural performance, for which the ASCE 7 standard [22] establishes allowable drift limits based on the risk category and the structural system, in order to ensure that buildings maintain adequate safety and functionality in the event of seismic activity.

2.2.4. Internal Forces

In the field of structural engineering, internal forces correspond to the actions generated within structural elements, such as axial forces, shear forces, and bending moments, as a consequence of the application of external loads. Indeed, the E.030 Standard [19] requires that internal forces and moments be obtained from seismic analysis for the dimensioning of structural elements, while ASCE 7-16 [22] establishes that the analysis must provide the internal actions derived from load combinations to verify the strength and stability of the system. Consequently, internal forces constitute an essential parameter for ensuring structural safety against gravitational and seismic actions.

2.2.5. Model Validation and Sensitivity Analysis

The numerical model developed in the ETABS software was indirectly validated by comparing it with analytical expressions and previous studies of reinforced concrete buildings with similar systems, including both Diagrid and wall systems with frames and likewise, the fundamental periods obtained were compared with approximate values established in the Peruvian seismic design code E0.30 [19] and ASCE 7-16 [22], showing agreement within acceptable ranges for linear dynamic analysis, thus ensuring the reliability of the model used. Additionally, a sensitivity analysis was performed considering the variation of key structural parameters, such as lateral stiffness distribution, mass participation, and the geometric configuration of the buildings, so this procedure allowed for the evaluation of the overall stability of the model under changes in its main behavioral conditions, ensuring the consistency of the comparative analysis between the structural systems evaluated.

3. Results and Discussion

The following presents the results obtained through dynamic seismic analysis, developed using computational analysis, which allow for the evaluation and comparison of the structural performance of the proposed configurations under seismic action.

3.1. Fundamental Period of Vibration

The vibration period results for conventional structures consisting of square and rectangular concrete frames and walls are shown in Tables 7 and 8, respectively. Tables 9 and 10 show the results obtained for the structures designed with the Diagrid system, also considering square and rectangular floor plan configurations, respectively. For the square and rectangular structure with the frame system complemented by structural walls, the fundamental vibration periods in the transverse directions range between 0.765s and 0.834s, while the torsional modes have periods of 0.597s and 0.608s. These values reflect an intermediate stiffness behavior, typical of dual systems, where the walls contribute to displacement control.

Table 7. Vibration period - Dual square system

Direction	Participatory Mass	Period (s)
X	0.7873	0.779
Y	0.7871	0.834
Torsional	0.7755	0.597

Table 8. Vibration period - Rectangular dual system

Direction	Participatory Mass	Period (s)
X	0.7211	0.787
Y	0.7596	0.765
Torsional	0.745	0.608

In contrast, structures with a perimeter Diagrid system show a significant reduction in vibration periods, reaching 40.1% in the X-X direction and 43.8% in the Y-Y direction and this is demonstrating a substantial increase in structural stiffness and reaffirming our hypothesis that the Diagrid system is better than the conventional one and that is because of diagonal elements, and the reason is that the diagonal elements optimize the transmission of axial forces and improve the control of deformation [23].

Table 9. Vibration period – Square perimeter Diagrid

Direction	Participatory Mass	Period (s)
X	0.7708	0.467
Y	0.7709	0.469
Torsional	0.8631	0.239

Table 10. Vibration period – Rectangular perimeter diagrid

Direction	Participatory Mass	Period (s)
X	0.8034	0.520
Y	0.7956	0.350
Torsional	0.8687	0.243

Furthermore, structures with a perimeter Diagrid system exhibit an approximate 60% reduction in the torsional period compared to frame structures with structural walls, demonstrating greater torsional stiffness. This behavior allows for better control of torsion, significantly reducing rotational deformation and improving the building's structural performance.

Table 11. Seismic lateral displacement, X-X

Displacement in the X-X direction				
Level	**Conventional square system (m)**	**Conventional rectangular system (m)**	**Square Diagrid System (m)**	**Rectangular Diagrid System (m)**
10	0.150	0.177	0.067	0.083
9	0.143	0.167	0.063	0.078
8	0.133	0.155	0.057	0.072
7	0.121	0.141	0.051	0.064
6	0.107	0.124	0.044	0.056
5	0.090	0.104	0.037	0.047
4	0.072	0.082	0.029	0.038
3	0.052	0.060	0.021	0.029
2	0.032	0.037	0.014	0.020
1	0.014	0.016	0.005	0.008

3.2. Lateral Displacement

We can observe the displacement results in Tables 11 and 12, according to the directions analyzed, that is, the X-X and Y-Y directions and when comparing structures with the same plan configuration in the X-X direction then the square Diagrid system shows an approximate reduction of 55% in the maximum lateral displacement compared to the conventional square system, and similarly, the rectangular Diagrid system shows an approximate decrease of 53% compared to the conventional rectangular structure and these results demonstrate a significant improvement in the lateral stiffness of the Diagrid system [24] compared to the conventional system.

In the Y-Y direction, the conventional square system registers a maximum displacement of 0.159 m, while the square Diagrid system reaches 0.068 m, representing an approximate reduction of 57%, furthermore, in the rectangular configuration, the conventional system presents 0.143 m compared to the 0.035 m of the Diagrid system, demonstrating a decrease of almost 75%. The Diagrid system shows significantly superior performance to the conventional system, achieving substantial reductions in displacement and, therefore, greater lateral stiffness.

Table 12. Seismic lateral displacement, Y-Y

Y-Y direction displacement				
Level	**Conventional square system (m)**	**Conventional rectangular system (m)**	**Square Diagrid System (m)**	**Rectangular Diagrid System (m)**
10	0.159	0.143	0.068	0.035
9	0.151	0.136	0.063	0.032
8	0.140	0.126	0.058	0.029
7	0.127	0.115	0.052	0.025
6	0.112	0.101	0.045	0.021
5	0.094	0.085	0.037	0.017
4	0.075	0.068	0.029	0.013
3	0.054	0.050	0.022	0.009
2	0.034	0.031	0.014	0.003
1	0.015	0.014	0.005	0.008

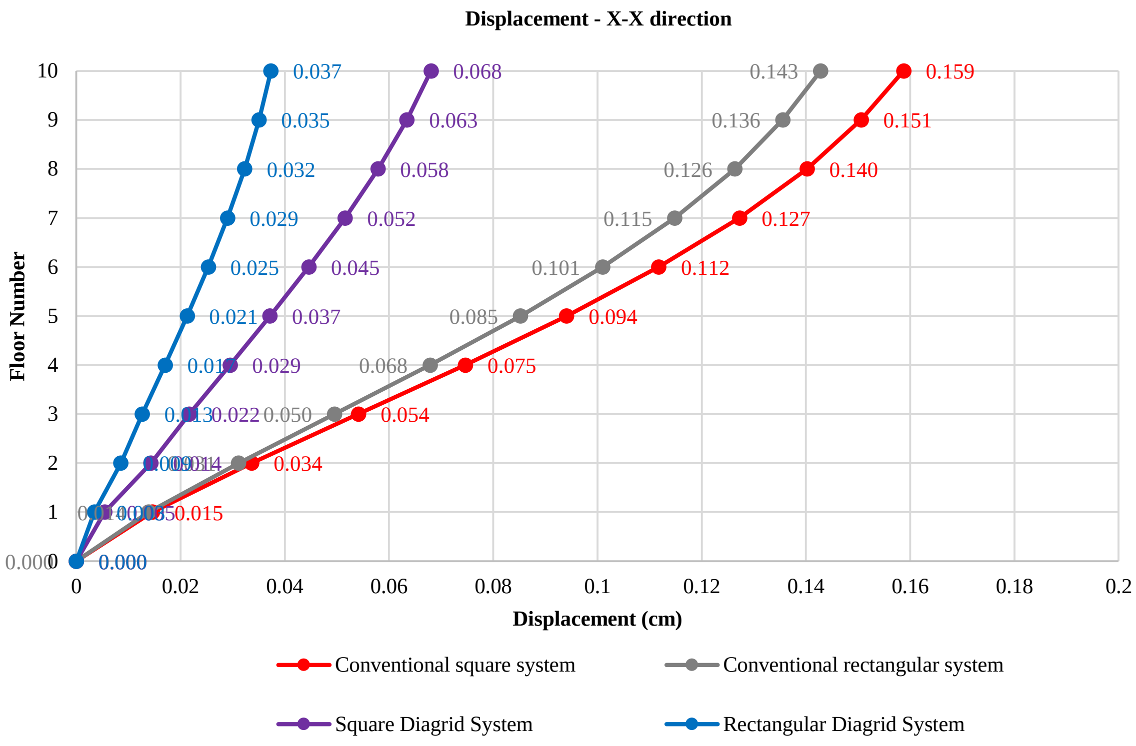

Fig. 7 Displacement of structures, X-X

Likewise, the lateral displacements obtained at each level of the structures are presented in Figure 7 for the X-X direction and in Figure 8 for the Y-Y direction. It is observed that conventional structural systems present the highest deformation values, reaching approximately 15 cm in the square configuration and 17 cm in the rectangular one, and for this reason we say that it is a deficient system and that it could be improved by implementing it with the Diagrid system and in contrast, Diagrid-type systems show a significant reduction in displacements, with values close to 6.7 cm in the square configuration and 8.3 cm in the rectangular one, representing a decrease of more than 50% compared to conventional systems. This improvement translates into greater control of structural drift and better performance under seismic and wind loads. We must mention and at the same time highlight that the Diagrid system with a square configuration presents the smallest lateral displacements, that is to say, within the Diagrid system, comparing the square and the rectangular, the square would be the best at controlling displacements and this also reflects that the square system has greater rigidity and this behavior is due to the symmetry of its structural elements, which allows for an adequate distribution of stiffness and mass in both main directions, thus improving the response to horizontal forces and reducing the probability of torsional effects; in conclusion, the square system optimizes structural performance.

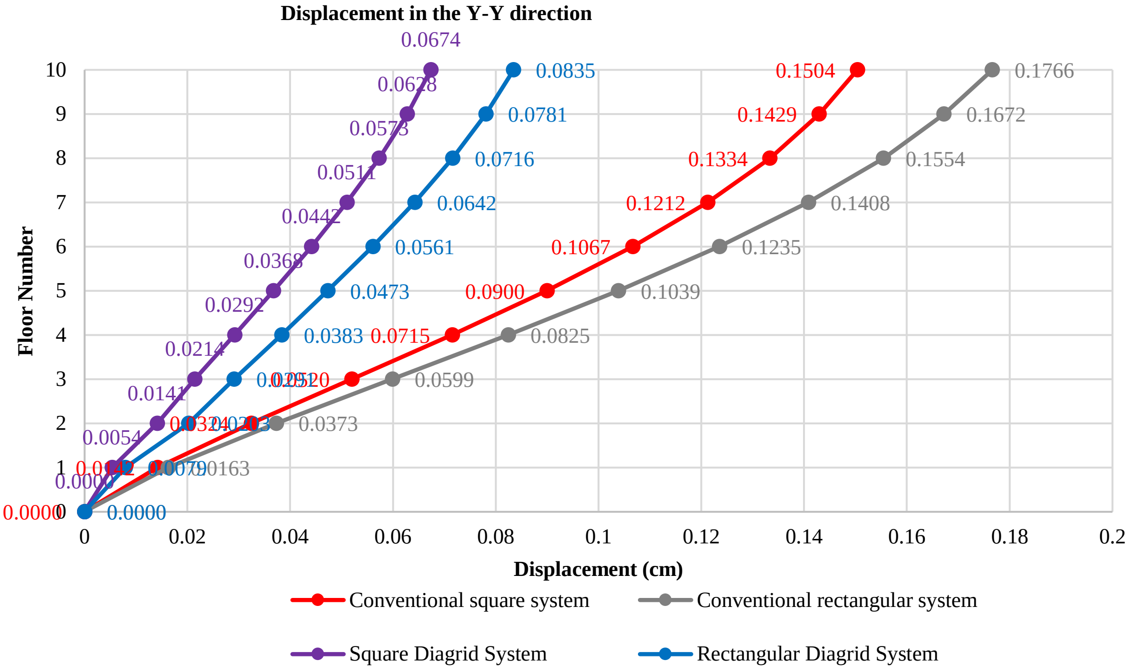

Fig. 8 Displacement of the structures, Y-Y

3.3. Interstory Drifts

The results of the drifts between floors of the compared structures are presented in Table 13 in the X-X direction and in Table 14 in the Y-Y direction, respectively to be analyzed and show that the highest drift values occur in the conventional structural systems, concentrated mainly between levels 3 and 6, where the most significant displacements are recorded in comparison with the proposed structures; however, the results comply with the limits established in Standard E.030 [21] for reinforced concrete buildings..

When comparing the structural systems, a clear difference is observed in their behavior under lateral loads, as the Diagrid system stands out for its superior performance, significantly reducing displacements compared to the conventional system, with reductions ranging between 40% and 70%, and these results reflect its greater efficiency in controlling lateral deformations.

Table 13. Inter-floor slab, X-X

Intermediate floor drift in the X–X direction				
Level	**Conventional square system (Δ%)**	**Conventional rectangular system (Δ%)**	**Square Diagrid System (Δ%)**	**Rectangular Diagrid System (Δ%)**
10	0.0022	0.0028	0.0013	0.0016
9	0.0028	0.0035	0.0016	0.0019
8	0.0036	0.0043	0.0018	0.0022
7	0.0043	0.0051	0.0020	0.0024
6	0.0049	0.0058	0.0022	0.0026
5	0.0054	0.0063	0.0022	0.0026
4	0.0057	0.0066	0.0023	0.0027
3	0.0058	0.0066	0.0021	0.0026
2	0.0054	0.0062	0.0026	0.0036
1	0.0029	0.0033	0.0016	0.0016

Table 14. Inter-story drift, Y-Y

Intermediate floor drift in the Y–Y direction				
Level	**Conventional square system (Δ%)**	**Conventional rectangular system (Δ%)**	**Square Diagrid System (Δ%)**	**Rectangular Diagrid System (Δ%)**
10	0.0024	0.0021	0.0014	0.0007
9	0.0030	0.0027	0.0016	0.0008
8	0.0038	0.0034	0.0019	0.0010
7	0.0046	0.0041	0.0020	0.0011
6	0.0052	0.0046	0.0022	0.0012
5	0.0057	0.0051	0.0022	0.0012
4	0.0060	0.0054	0.0023	0.0013
3	0.0060	0.0054	0.0022	0.0012
2	0.0056	0.0051	0.0026	0.0015
1	0.0030	0.0028	0.0016	0.0007

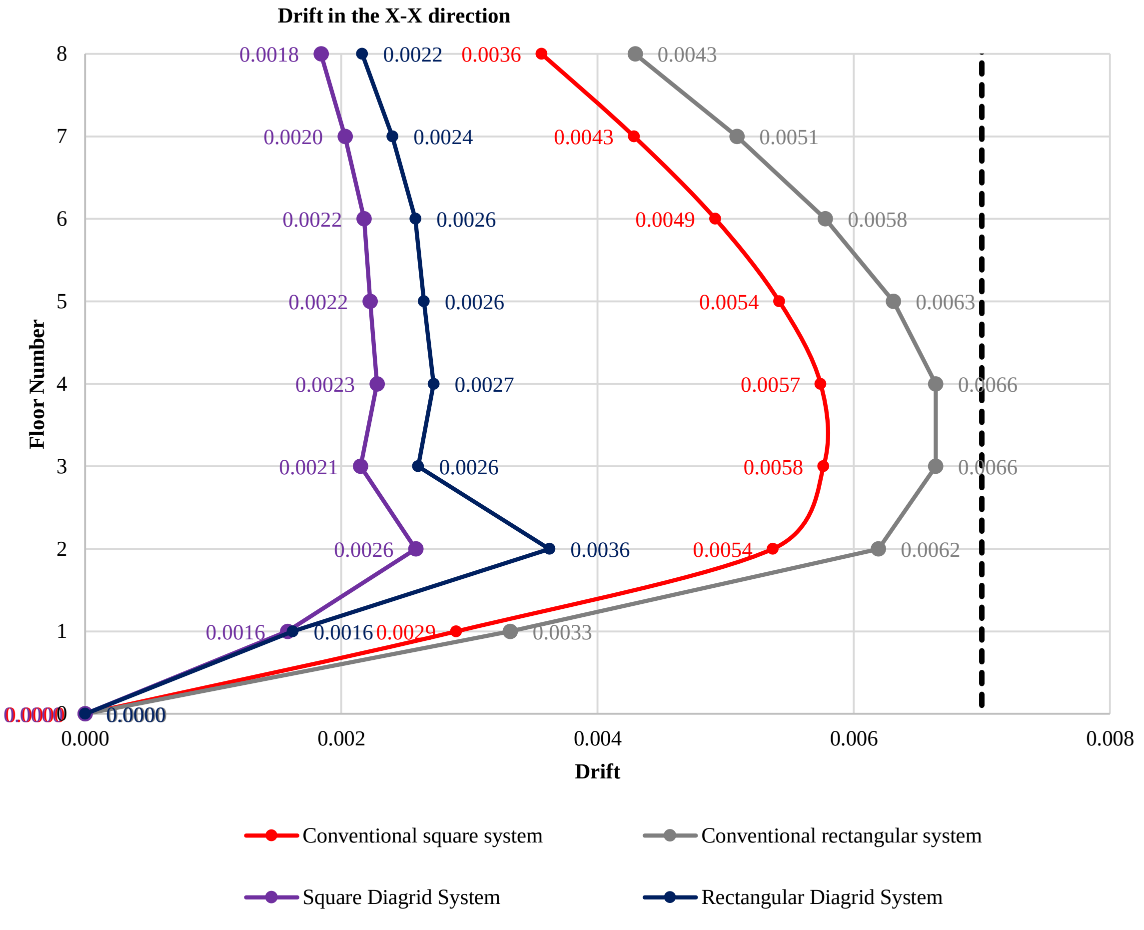

Fig. 9 Interstory drift of the structures, Y-Y

Figures 9 and 10 show the drifts developed along the structure in the X-X and Y-Y directions, and on this occasion we can also reinforce our hypothesis that the Diagrid system is the best because in its rectangular design it presents the lowest drift values of the study, especially in the Y-Y direction, which demonstrates its high efficiency in controlling lateral displacements then conversely, the square diagrid system produces remarkably symmetric results in both directions, reflecting a uniform distribution of stiffness, which is also favorable for the seismic behavior of the structure.

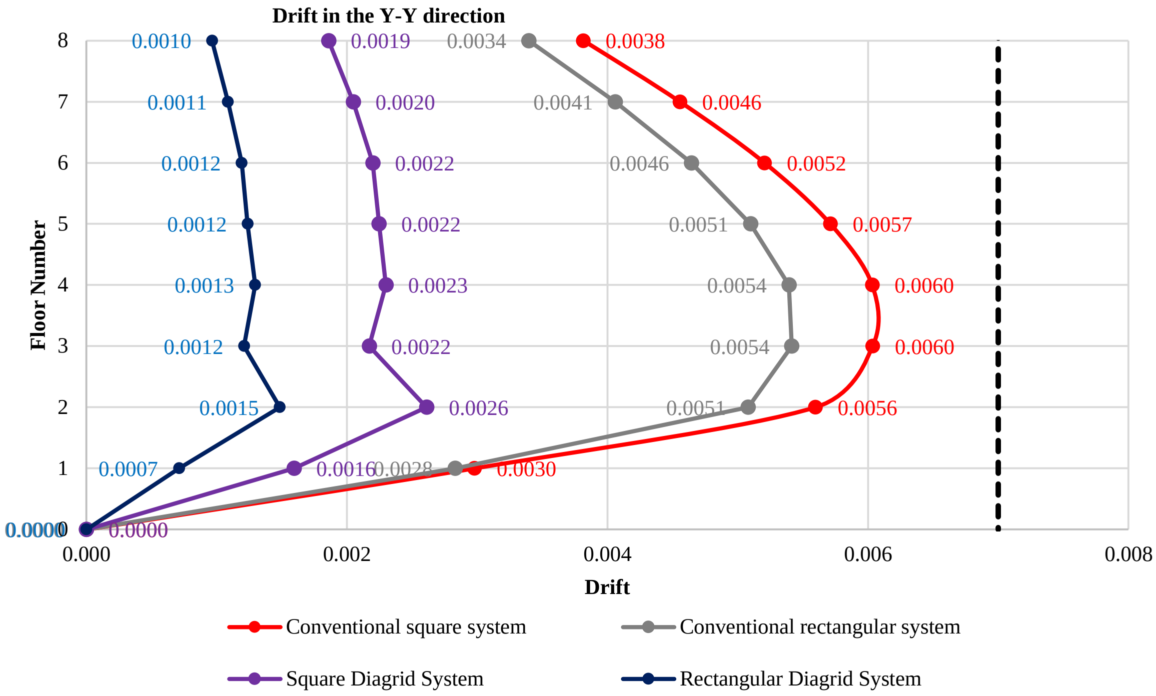

Fig. 10 Interstory drift of the structures, Y-Y

3.4. Internal Forces

The following figures present the maximum internal forces recorded at the first level of the conventional and proposed structures, in the X-X and Y-Y directions, and detail the corresponding shear forces, axial forces, and bending moments to clearly and accurately illustrate the observed structural behavior. The maximum shear forces corresponding to both directions are shown in Figures 11 and 12, where we can see that in the X-X direction, the maximum value is recorded in the conventional rectangular system, reaching 390.39 tons, while the conventional square configuration presents a slightly lower value, with a variation of approximately 4% and we can also see that, on the contrary, the structural models configured with a diagrid system show a substantial reduction of shear forces compared to conventional systems, and the reduction ranges between 72% and 78%, depending on the geometry analyzed.

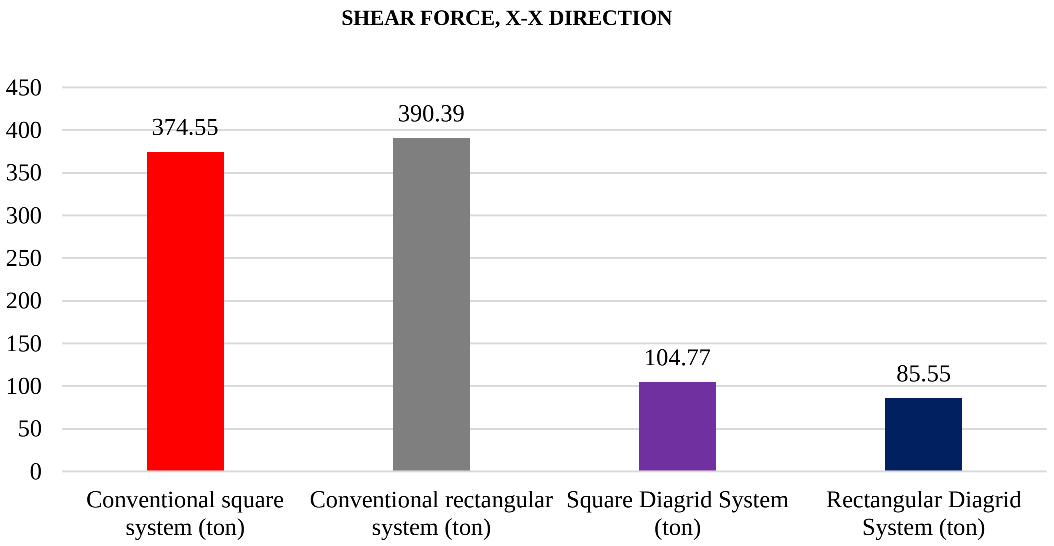

Fig. 11 Shear force in the X-X direction

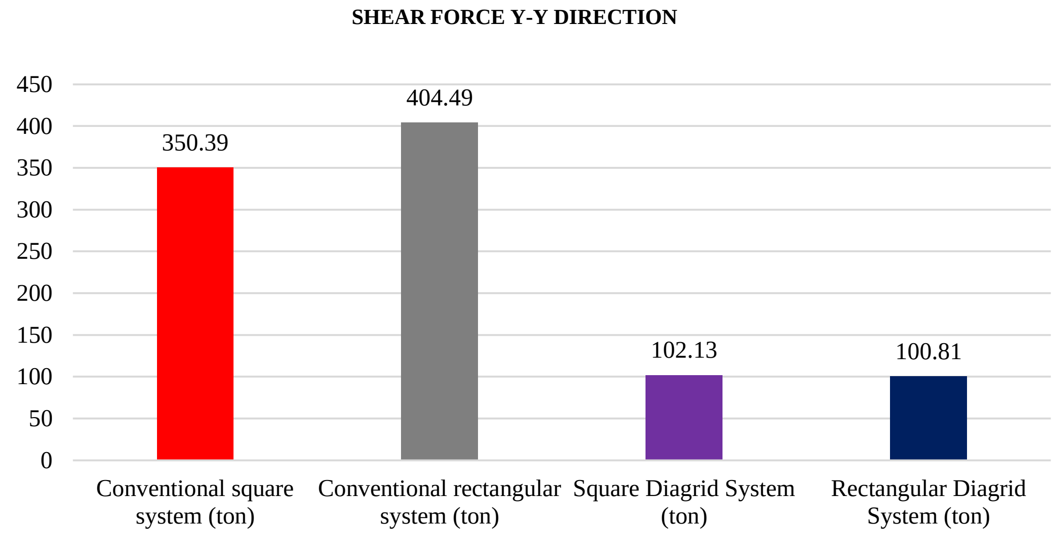

Fig. 12 Shear force in the Y-Y direction

With respect to the Y-Y direction as shown in Figure 12, the proposed systems with the perimeter Diagrid system maintain significantly lower shear levels than conventional systems, reaching maximum values of 103.13 tons.

The maximum axial forces obtained in the X-X and Y-Y directions in Figures 13 and 14 show very significant differences between the conventional system and the Diagrid system, as well as an appreciable influence of the plan geometry.

In the X-X direction, as shown in Figure 13, conventional systems reach maximum values of 1647.01 tons in the square configuration and 1936.69 tons in the rectangular configuration, representing an approximate 14% increase in the latter. This behavior reflects a slight influence of the plan geometry on the magnitude of axial forces in the traditional system. In contrast, Diagrid perimeter systems exhibit maximum values on the order of 712.27 tons.

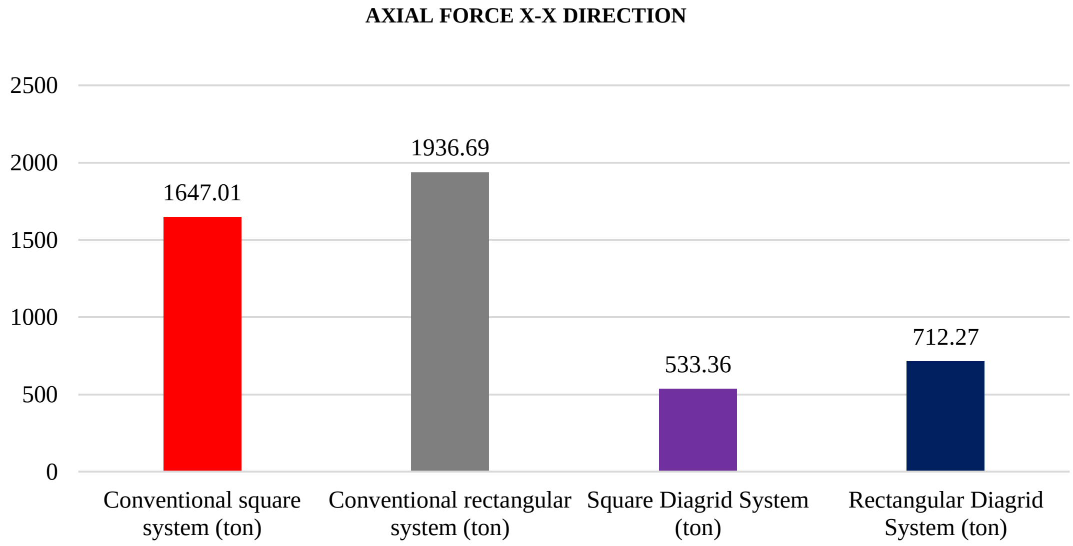

Fig. 13 Axial force in the X-X direction

Meanwhile, the Diagrid system in the Y-Y direction, as shown in Figure 14, registers values of 529.49 tons in the square configuration and 468.16 tons in the rectangular configuration, showing a minimal difference between the two geometries. When compared to the conventional system, approximate reductions of 66% are obtained in the square configuration and 73% in the rectangular configuration.

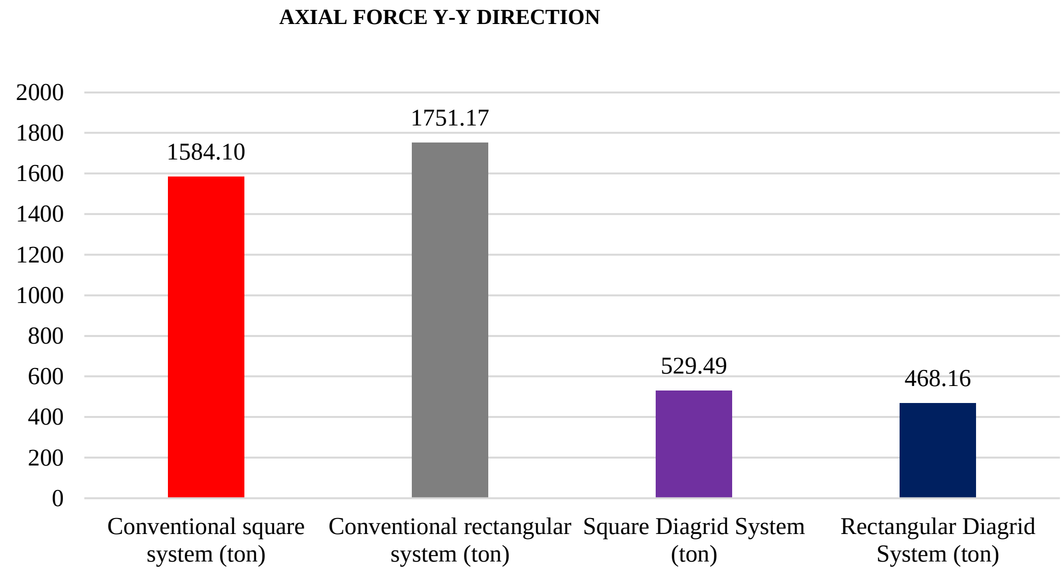

Fig. 14 Axial force in the X-X direction

Regarding the maximum bending moments at the first level, the results are shown in Figures 15 and 16, where even more pronounced differences between the evaluated structural systems are evident. In the X-X direction, the conventional system exhibits maximum bending moments of 438.05 tons in the square configuration and 813.72 tons in the rectangular configuration. Compared to the proposed Diagrid perimeter system, these figures are reduced by 93.7% in the square plan and by 97.7% in the rectangular plan.

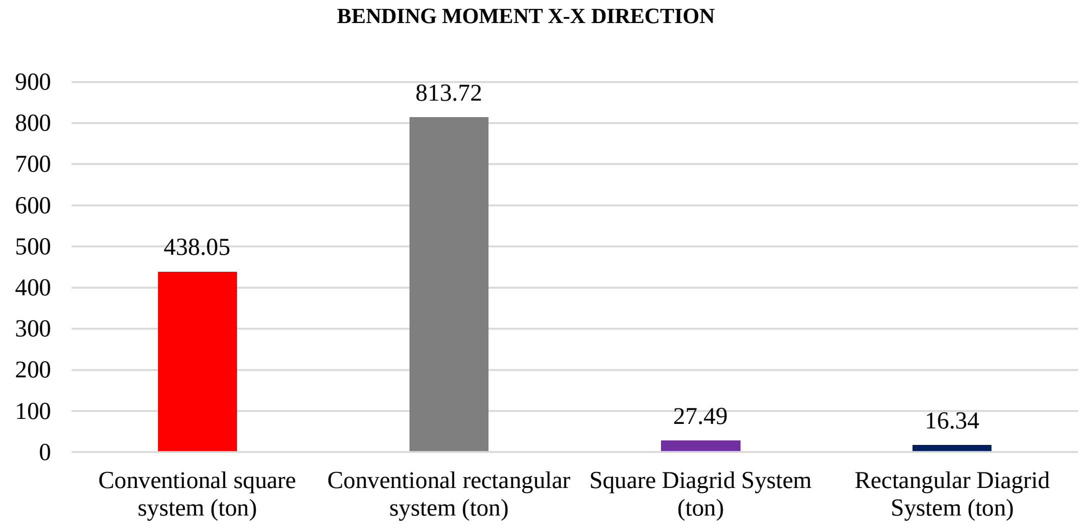

Fig. 15 Bending moments in the X-X direction

We can observe that on the Y-Y axis, the Diagrid perimeter system presents lower values, which reaffirms our hypothesis that the Diagrid system is better than the conventional one, since the values are reaching 32.81 tons in the square configuration and 14.08 tons in the rectangular one. These figures represent reductions of approximately 89% and 98%, respectively, compared to the conventional system. That is, if we were to replace the elements of the conventional system with elements of the Diagrid system, this would demonstrate a practically total elimination of the bending moment demand in this direction. And all this is possible thanks to the triangulated configuration, which achieves a more effective redistribution of lateral loads.

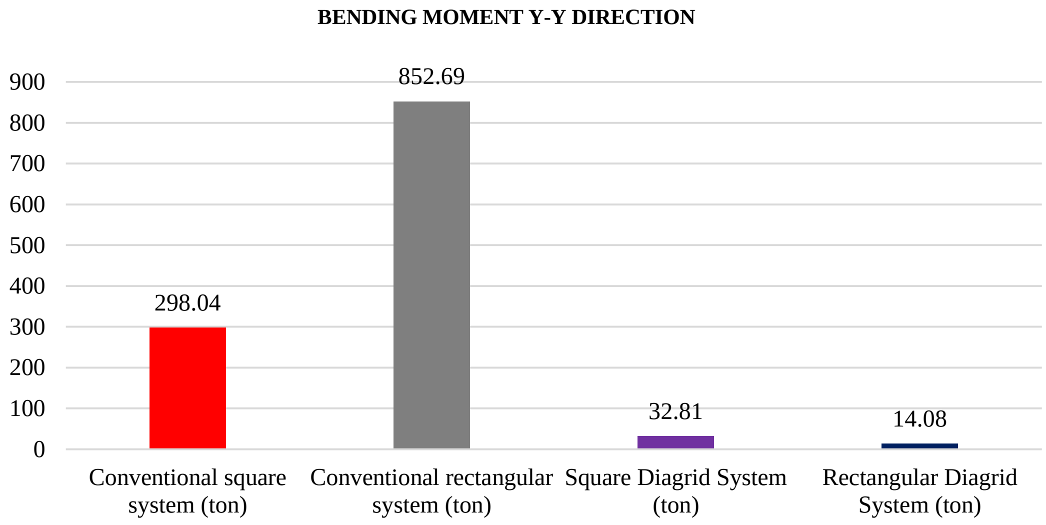

Fig. 16 Bending moments in the Y-Y direction

3.5. Discussion

The results obtained demonstrate that the perimeter Diagrid system exhibits a significant improvement in seismic performance compared to the conventional structural system, primarily reflected in the reduction of lateral displacements, interstory drifts, and internal forces and these findings are consistent with those reported by Maldonado [10], who identified a decrease in lateral deformations due to the greater efficiency of the Diagrid system under seismic loads so similarly, the results coincide with those obtained by Thasmitha and Sandeep [11], who attribute the improved structural behavior to the increased lateral stiffness provided by the triangular configuration of the system.

Furthermore, the reduction in the fundamental period observed in the Diagrid models confirms the increase in structural stiffness reported by previous research and in this regard, Quiroz et al. [9] concluded that Diagrid systems promote a more efficient transmission of lateral loads through predominantly axial stresses, improving the overall seismic performance of the structure so similarly, Nayeemuddin et al. [12] noted that the geometric configuration of the system contributes significantly to displacement control and optimization of seismic response and consequently, the results obtained in this research show a high degree of agreement with the evidence reported in the specialized literature and support the viability of the Diagrid system for buildings located in areas of high seismic hazard.

4. Conclusion

Through the evaluated indicators, we conclude that the linear dynamic seismic analysis of the Diagrid perimeter structural system, in its square and rectangular floor plan configurations, demonstrates a much more efficient structural performance compared to the conventional system composed of walls and structural frames because it shows greater rigidity, stability, and control of the seismic loads considered.

Regarding vibration periods, significant reductions are observed in the X-X and Y-Y directions. In the X-X direction, the maximum period of the conventional system reaches 0.787 s, while the Diagrid system reduces it to 0.520 s, representing a decrease of 33.93%, similarly, in the Y-Y direction, the maximum period decreases from 0.834 s to 0.469 s, equivalent to a reduction of 43.76% and the difference is even more pronounced in the torsional mode, where the maximum period of the conventional system, 0.608 s, is reduced to values between 0.239 s and 0.243 s in the Diagrid system, achieving reductions of almost 60%, which demonstrates a significant increase in stiffness.

Regarding lateral displacements, the differences are also clear: the conventional system reaches maximum displacements of 0.159 m in the square configuration and 0.177 m in the rectangular one, while the Diagrid system presents maximum values of 0.068 m and 0.083 m, respectively, which represents reductions of more than 50% and as for drift between floors, the Diagrid system shows reductions of around 60% compared to the conventional system, a result directly associated with its greater lateral stiffness and the efficiency of its perimeter triangulated configuration.

In terms of internal forces, the Diagrid system presents maximum shear force values of 104.77 tons and 100.81 tons, respectively, representing reductions of more than 70% compared to the conventional system, as for axial forces, maximum values of 533.36 tons and 712.27 tons are recorded, demonstrating an approximate decrease of 60% compared to conventional structures, however, the most significant difference is observed in bending moments: while the conventional system reaches values of up to 852.69 tons, the Diagrid system reduces this demand to approximately 14 tons, achieving remarkable reductions ranging from 89% to 98%.

In conclusion, we can affirm that the Diagrid perimeter system, in both square and rectangular configurations, exhibits significantly superior structural efficiency compared to conventional systems, and this is evidenced by the consistent reduction of internal forces and deformations, guaranteeing greater structural stability in the event of an earthquake. Within the Diagrid perimeter system, the square configuration displays more uniform and balanced behavior in both directions, while the rectangular configuration achieves the absolute minimum values in several comparisons, reflecting superior seismic performance. This improvement is primarily attributed to the perimeter structure's use of diagonal elements, which transform seismic forces into predominantly axial stresses and optimize stiffness distribution within the building.

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