

Comparative Analysis and Design of a High-Rise Building with Diagrid and Hexagrid Lateral Load Resisting Systems under Seismic and Wind Loads

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Abstract - As buildings grow taller the resistance to lateral load becomes the deciding factor in the structural design, more so than the gravity demand that governs ordinary low-rise frames. Wind and earthquake forces both produce large sway in slender towers, and the engineer has to pick a framing arrangement that keeps this sway within safe and serviceable limits. This paper reports a comparative study of two perimeter-active systems, the diagrid and the hexagrid, applied to the same forty-storey steel-concrete composite tower. Both skeletons were built in ETABS over an identical plan of 42.875 m by 25 m rising to 120 m, with the same composite columns, steel sections, material grades and loading, so that any difference in response can be traced only to the perimeter geometry. The structure was placed in Seismic Zone II and analysed by the equivalent static and response spectrum methods of IS 1893 (Part 1): 2016 for the seismic case and by the force coefficient and gust factor methods of IS 875 (Part 3): 2015 for the wind case. Fundamental period, base shear, storey displacement and inter-storey drift were the parameters compared. The hexagrid turned out to be the more flexible of the two, with a fundamental period of 3.23 s against 3.06 s for the diagrid, a top displacement higher by about 2.52 percent and a base shear higher by about 0.84 percent. The diagrid, being the stiffer system, held the drift down more tightly. An independent recalculation in Python, covering the code base shear, the empirical period and the drift checks, confirmed that the model output is consistent and code compliant. Taken together the results show that the hexagrid offers a more ductile and potentially more economical route for tall composite construction, while the diagrid retains an edge wherever tight drift control is the priority.

Keywords: Diagrid; Hexagrid; Composite column; Lateral load resisting system; Storey drift; Base shear; Gust factor; ETABS; High-rise design.

1. INTRODUCTION

Modern architecture keeps pushing buildings higher, and with every additional storey the structure becomes more sensitive to the forces of nature than a comparable low-rise frame would be. From the point of view of the designer, the resistance to lateral load, which comes mainly from wind and earthquakes, turns into a more critical concern than the capacity to carry gravity load. Wind grows stronger with height and can make a tall building sway or lose stability, while seismic ground motion produces larger displacements in taller structures. To keep these effects in check the engineer has to choose a lateral load resisting system that reduces sway and protects the integrity of the frame.

Among the systems that have appeared over the years, the perimeter-active skeletons known as the diagrid and the hexagrid, the latter sometimes called the beehive system, stand out as comparatively recent and efficient answers to this problem. The diagrid relies on a network of perimeter diagonals that provide both bending and shear rigidity through the axial action of their members. The hexagrid replaces the triangular module with a hexagonal one, placing a continuous pattern of hexagonal cells on the face of the building and offering advantages in ductility, force redistribution and architectural appearance. The present work takes both of these systems and applies them to the same forty-storey steel-concrete composite tower so that their behaviour can be set side by side under identical conditions.

1.1 Factors governing lateral load design

Three factors mainly decide how a tall building responds to lateral load. The first is the height-to-width ratio. With the bay size held constant, every extra storey calls for more steel in the columns and beams than the gravity load alone would require, because the slender form attracts a heavier lateral demand. The second is the set of forces and moments produced by the lateral load itself, which is normally caused by wind, although in some regions the earthquake force becomes the controlling action. The third, and arguably the most important for both economy and serviceability, is the sway under lateral load. Opinions differ on the exact limit that should be applied, but in every case the maximum sway has to be held within a reasonable bound so that the building remains comfortable to occupy and safe to use.

1.2 Lateral load resisting systems

The advance of analysis methods together with the arrival of high-strength materials has made it possible to build slender towers that are lighter than their predecessors yet still able to resist both gravity and lateral demand. The taller the building, the more important it becomes to select the right system. The family of lateral systems ranges from the rigid frame, which is efficient only up to about twenty storeys before column bending causes excessive drift, through the shear wall and the core-outrigger arrangement, to the tube systems that locate the resisting elements on the perimeter. The framed tube, the braced tube and the tube-in-tube all belong to this last group, and the diagrid and hexagrid are their more recent descendants. By concentrating the structural material at the outer face the perimeter systems engage the largest possible lever arm against overturning, which is the source of their efficiency.

1.3 Moment-resisting frames and the response reduction factor

IS 1893 (Part 1): 2016 separates steel and reinforced concrete moment frames into two classes according to the amount of ductile detailing provided, namely the ordinary moment-resisting frame and the special moment-resisting frame. The distinction matters here because the response reduction factor R , and therefore the design base shear, follows directly from it. An ordinary frame is detailed only for a limited level of inelastic ductility and is given a low value of R equal to 3, which means it must be designed for a larger share of the elastic earthquake force and tends to end up with heavier members. A special frame is detailed for ductility in line with IS 13920, follows the strong-column weak-beam philosophy and is given a higher R of 5, so it can be designed for a smaller fraction of the elastic force and stays lighter while keeping its safety margin through controlled plastic hinging. Both the diagrid and the hexagrid in this study are treated as special moment-resisting frames with R equal to 5, since the triangulated and hexagonal perimeter members supply the redundancy and the ductile load paths that justify this classification. The building sits in Seismic Zone II.

1.4 The composite column

A composite column is a compression member made either of a structural steel section encased in concrete or of a hollow steel section filled with concrete. In both forms the steel and the concrete act together through bond and friction and share the external load. The usual sequence in construction is for the bare steel section to carry the early erection loads, after which concrete is cast around or inside it. The combination lets each material work to its strength. The lighter, stronger steel allows smaller foundations, while the surrounding concrete limits lateral deflection, sway and buckling of the column. Composite frames of this kind, used together with composite decks and beams, make it both convenient and quick to erect very tall buildings, which is the reason composite columns were adopted throughout the present models.

1.5 Aim and objectives

The aim of the study is to carry out a thorough comparative analysis and structural design of a forty-storey high-rise building that uses diagrid and hexagrid lateral load resisting systems, so as to judge their relative efficiency against seismic and wind forces. The specific objectives that follow from this aim are listed below.

- To model a G+40 storey building with composite columns in ETABS, once with a diagrid configuration and once with a hexagrid configuration, keeping every other parameter the same.
- To evaluate the seismic and wind response of both systems in terms of storey displacement, storey drift, drift factor, base shear and gust effect.
- To design the structural members of both systems in accordance with the relevant Indian Standard codes.
- To compare the fundamental natural period, storey displacement, storey drift and base shear of the two systems and to comment on their material efficiency and economy.

1.6 Need for the study

As cities expand, the appetite for taller, safer and more efficient buildings keeps rising. Conventional systems tend to grow heavy and costly once the height becomes large, so there is a real need to compare the newer perimeter-active systems and to find out which of them offers better lateral stiffness and architectural flexibility for the towers being planned today. This study tries to answer that question for the diagrid and the hexagrid on a common footing.

2. REVIEW OF LITERATURE

The idea of moving the lateral resisting elements to the perimeter of a tall building goes back to the framed tube of Fazlur Khan and was refined through the braced tube and the bundled tube before the diagrid and the hexagrid appeared. A short survey of the work most relevant to the present comparison is given below.

Nejad introduced the beehive, or hexagrid, as a new structural system for tall buildings and demonstrated it on an eighty-storey model in ETABS, optimising the angle and topology of the hexagonal members. Mashhadiali and Kheyroddin then formalised the hexagrid in a sequence of papers, designing diagrid and hexagrid towers of thirty, fifty, seventy and ninety storeys on a strength and stiffness basis to resist wind. Their work found that the hexagrid carries a ductility and stiffness sensitivity roughly three times that of the diagrid and that it has the potential to push the height limit further, although the same sensitivity makes preliminary sizing harder. Montuori and co-workers studied the mechanical properties of hexagrids through a homogenisation approach and concluded that the best diagonal angle for both diagrids and horizontal hexagrids lies in the range of fifty to seventy degrees, with about sixty degrees being the most balanced choice, while the vertical hexagrid favours a lower forty to fifty degrees. They also noted that the hexagrid, being bending dominated, is inherently less stiff and therefore less weight efficient than the stretch-dominated diagrid.

Progressive collapse has been a recurring theme. Mashhadiali examined the collapse resistance of the hexagrid against that of the diagrid by removing structural elements in the storey above the ground and tracing the response through nonlinear static and dynamic analysis. The hexagrid redistributed load more smoothly after a member was lost, a result of the several alternative paths built into the hexagonal cell. Lee and Kim later proposed a stiffness-based preliminary design formula for hexagrid tubular buildings, analysing sixty-storey towers to extract size-pattern relationships of the kind Moon and colleagues had earlier established for diagrids.

On the diagrid side, the parametric study by Moon, Connor and Fernandez set the stiffness-based framework for steel diagrids and showed that the optimum diagonal inclination is close to sixty degrees for buildings in the forty to seventy storey range, where lateral stiffness governs. Jani and Patel analysed diagrid systems for high-rise steel buildings to Indian Standard codes and reported a steel saving of roughly fifteen to twenty percent over an equivalent moment-resisting frame, together with clear reductions in displacement, period and drift. Mugale and Londhe used response spectrum analysis in ETABS on buildings of several heights and found that diagrids reduce displacement and drift by margins in the range of twenty to forty percent relative to conventional frames.

Several studies have placed the two systems together with related geometries. Isaac and Ipe compared diagrid, hexagrid and octagrid systems under dynamic loading and reported that the hexagrid gave the best performance in displacement and base shear reduction, while a four-storey diagrid module with a diagonal angle near sixty-seven degrees came out as the most efficient diagrid arrangement. Deepika compared thirty-storey diagrid and hexagrid towers in ETABS and recorded a first-mode period of 3.268 s for the diagrid and 3.69 s for the hexagrid, a small difference that still shifts the two systems on the design spectrum. Mathews and co-workers studied different hexagrid patterns for a square plan and found that denser hexagrids and more regular hexagons perform better. A more recent comparative study on the architectural and structural performance of diagrid and hexagrid steel buildings found that both hexagrid configurations gave lower displacement and drift than the diagrid, with the larger module also consuming less steel per unit floor area.

The picture that emerges from this body of work is consistent. The hexagrid is the more flexible and more ductile system, with a longer period and a tendency toward larger displacement, while the diagrid is the stiffer system that controls drift more tightly and is usually the lighter of the two at moderate heights. The present study tests this picture on a single forty-storey composite tower analysed to Indian Standard codes.

3. METHODOLOGY

3.1 General approach

The comparison rests on three-dimensional finite element models of the two skeletons built in ETABS. The plan geometry, storey height, member sections, material grades and loading were kept identical for the diagrid and the hexagrid, which is what allows the difference in response to be attributed to the perimeter arrangement alone and nothing else. Both buildings were analysed for gravity, seismic and wind load to the relevant Indian Standard codes.

The seismic analysis used the equivalent static method and the response spectrum method of IS 1893 (Part 1): 2016 for a structure in Seismic Zone II, with both systems modelled as special moment-resisting frames. The wind analysis used the force coefficient method and the gust effect factor method of IS 875 (Part 3): 2015, because the height of the tower makes it sensitive to

the dynamic along-wind action of gusts. Composite columns and steel beams were designed to IS 800: 2007 and IS 11384: 1985, and the section was refined by trial and error until the most economical choice that still satisfied the deflection and load-moment criteria was reached. The two systems were then compared on fundamental period, storey displacement, storey drift, drift factor, base shear and seismic weight.

3.2 Equivalent static analysis

The equivalent static method, also called the seismic coefficient method, is the simplest of the procedures in IS 1893 (Part 1): 2016. It replaces the dynamic effect of an earthquake with a set of static lateral forces applied at the floor levels. The design base shear is found first from the seismic weight and the design horizontal seismic coefficient, the latter depending on the zone factor, the importance factor, the response reduction factor and the fundamental period. The base shear is then spread over the height in proportion to the product of each storey weight and the square of its height, so the upper floors attract a larger share. The method suits regular buildings whose response is governed by the first mode, and for the present tower it supplied the design base shear and the first estimate of the storey forces, which the response spectrum analysis later confirmed.

3.3 Building description

The building has an unsymmetrical plan of 42.875 m by 25 m and a uniform storey height of 3.0 m, giving a total height of 120 m over the forty-storey frame. Composite columns are placed at a spacing of 6.75 m along the horizontal axis and 5.0 m along the vertical axis. A preliminary linear analysis was run and sections were sized by trial. The first trial section was a 600 mm by 900 mm composite column embedded with an ISWB600 and an ISNB300 pipe acting as the perimeter brace element. This section satisfied the deflection criterion of IS 800: 2007 for both the diagrid and the hexagrid. Further trials were carried out with square sections of 1200, 1100, 1000 and 900 mm depth in the search for the most economical choice, and the 600 mm by 900 mm cross-section gave the best combination of economy and load-moment capacity for the G+40 frame. The loading was kept the same for the two buildings. Figures 1 to 3 show the plan, the column layout and the two three-dimensional models, and Tables 1 and 2 give the member sizes and the analysis data.

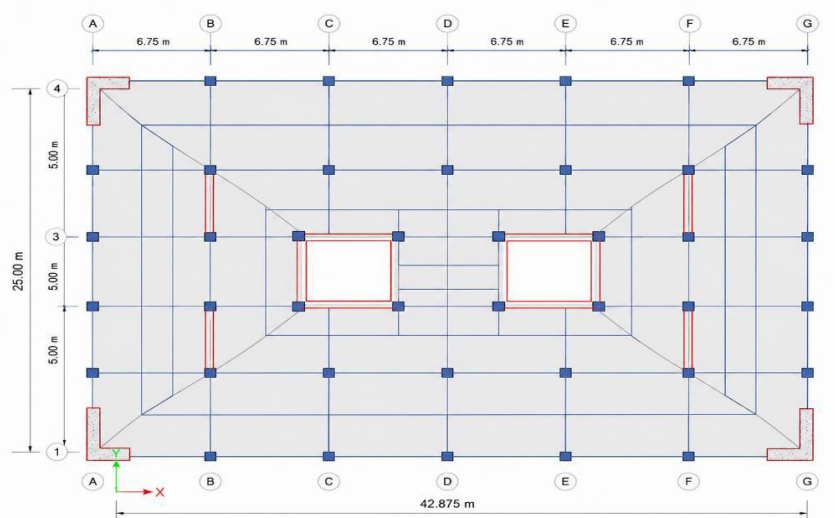


Figure 1. Plan view and column layout of the G+40 building (common to the diagrid and hexagrid models)

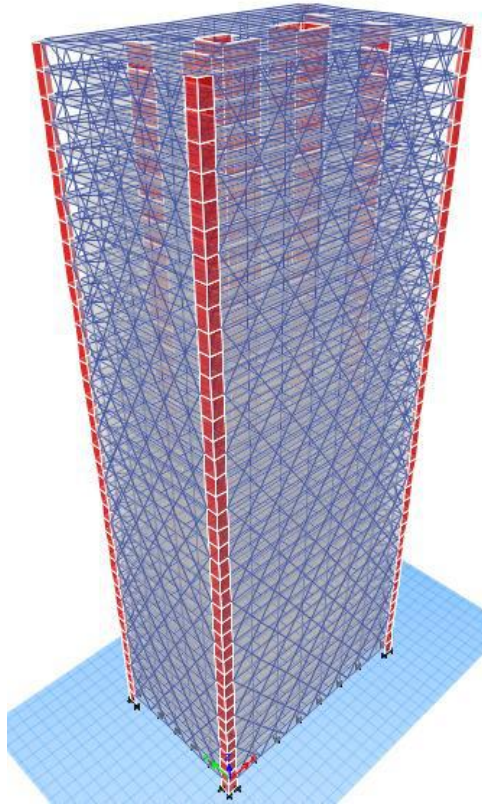


Figure 2. Three-dimensional ETABS model of the G+40 diagrid system

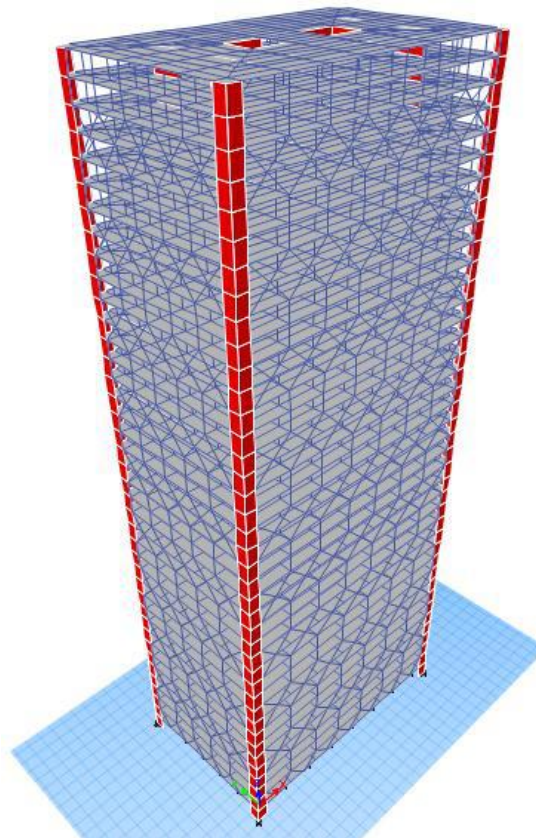


Figure 3. Three-dimensional ETABS model of the G+40 hexagrid system

Table 1. Structural member sizes for the G+40 building

Member	Diagrid system	Hexagrid system
Column	ISWB600	ISWB600
Composite column	600 mm x 900 mm concrete with ISWB600 steel	600 mm x 900 mm concrete with ISWB600 steel
Beam	ISWB600	ISWB600
Perimeter brace section	ISNB300H	ISNB300H
Slab / deck	200 mm deck slab	200 mm deck slab

Table 2. Data adopted for the analysis of both composite buildings

Particular	Diagrid	Hexagrid
Plan dimension	42.875 m x 25 m	42.875 m x 25 m
Total height	120 m	120 m
Storey height	3.0 m	3.0 m
Parapet height	1.0 m	1.0 m
Beam section	ISWB600	ISWB600
Perimeter section	ISNB300H	ISNB300H
Slab thickness	200 mm	200 mm
Wall thickness	230 mm	230 mm
Seismic zone	II	II
Importance factor I	1.0	1.0
Zone factor Z	0.10	0.10
Damping ratio	5 %	5 %
Floor finish	1.5 kN/m ²	1.5 kN/m ²
Live load (all floors)	2.0 kN/m ²	2.0 kN/m ²
Density of concrete	25 kN/m ³	25 kN/m ³
Density of brick	20 kN/m ³	20 kN/m ³
Grade of concrete	M40	M40
Grade of steel section	Fe345	Fe345
Soil condition	Medium soil	Medium soil

3.4 Gust factor method, IS 875 (Part 3): 2015

For a tall and wind-sensitive building, taken as one whose height is above about 50 m or whose height-to-least-width ratio is above 5, IS 875 (Part 3): 2015 requires the along-wind load to be found by the gust effect factor method rather than by the static method alone, because the fluctuating part of the wind adds a dynamic response. The along-wind load on a strip at height z is written as $F_z = C_f \times A_e \times p_d \times G$, in which C_f is the force coefficient, A_e the effective frontal area, p_d the design wind pressure at that height and G the gust effect factor. The gust factor itself combines a background component and a resonant component through the

roughness factor, the peak factor, the size reduction factor, the gust energy factor and the damping coefficient. Table 3 lists the gust-factor parameters used for the present Zone II site.

Table 3. Gust effect factor parameters, IS 875 (Part 3): 2015 (Zone II)

Parameter	Symbol	Value
Basic wind speed	Vb	39 m/s
Risk coefficient	k1	1.00
Terrain and height factor	k2	varies with z
Topography factor	k3	1.00
Importance factor (cyclonic)	k4	1.00
Peak factor	gv	3.0
Background factor	B	0.60
Damping coefficient (steel)	beta	0.016
Gust effect factor (computed)	G	approx. 2.0

3.5 Storey drift and drift factor

Storey drift is the lateral movement of one floor relative to the floor just below it. The drift factor, also called the drift ratio or inter-storey drift index, is the storey drift divided by the storey height, and this ratio is the quantity the codes actually limit. It is written as the difference between the displacements of two consecutive floors divided by the storey height. Under factored earthquake load IS 1893 (Part 1): 2016 limits the inter-storey drift to 0.004 times the storey height, that is h divided by 250, while IS 16700: 2017 limits the working wind drift to h divided by 500. Both limits were applied as serviceability checks in the present study.

3.6 Finite element modelling

The composite building was modelled in finite element software with every component that affects mass, strength, stiffness and deformability included, while non-structural elements that do not influence the behaviour in a meaningful way were left out. Beams and columns were modelled as two-noded frame elements with six degrees of freedom at each node, and the floor slab was taken as a rigid diaphragm and modelled with four-noded shell elements, again with six degrees of freedom per node, so that all the vertical resisting elements act together. The beam-to-column connections were treated as rigid and the supports were fixed against both translation and rotation. A displacement-controlled static analysis was preferred over a force-controlled one because it can be carried out up to a chosen displacement, here taken as four percent of the building height, at which the expected performance can be judged by comparing demand against capacity. The resulting three-dimensional models are the ones shown earlier in Figures 2 and 3.

4. RESULTS AND DISCUSSION

The two models were analysed for the parameters set out in the objectives, namely the modal time period, the storey displacement under seismic and wind load, the inter-storey drift, the base shear and the seismic weight. The findings are presented and discussed in turn below.

4.1 Modal time period

Figure 4 plots the time period against the mode number for the two systems. The hexagrid curve sits above the diagrid curve across the modes, which confirms that the hexagrid is the more flexible structure. The fundamental period comes out as 3.23 s for the hexagrid against 3.06 s for the diagrid. A longer period means the hexagrid oscillates back and forth more readily under lateral load, which is the expression of its greater ductility, and it also places the two systems at slightly different points on the design response spectrum.

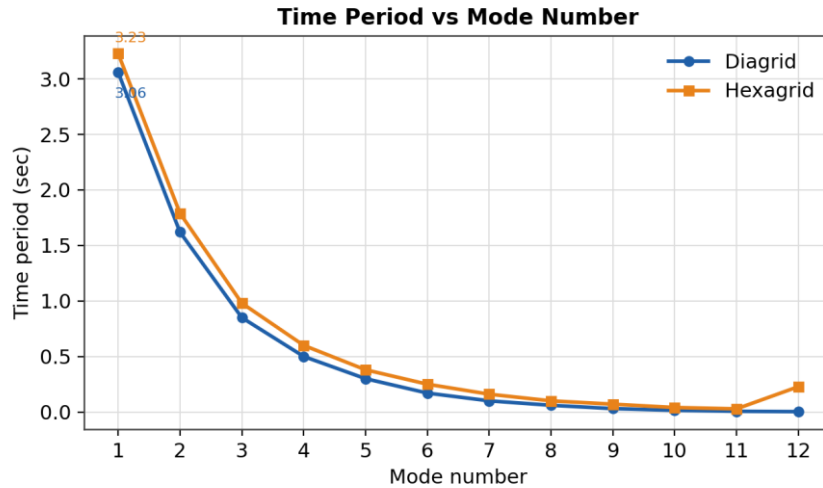


Figure 4. Comparison of modal time period (diagrid versus hexagrid)

4.2 Storey displacement under seismic load

Figure 5 sets the seismic storey displacements of the two systems side by side in the two principal directions, and Figure 6 compares the maximum top displacement. The hexagrid moves more at every level. Its peak top displacement reaches 34.49 mm against 33.64 mm for the diagrid, an increase of about 2.52 percent that again reflects the greater flexibility of the hexagonal arrangement. In the X direction the diagrid reaches 17.40 mm and the hexagrid 22.96 mm, while in the Y direction the diagrid reaches 25.62 mm and the hexagrid 29.34 mm. The higher value in the Y direction for both systems points to a lower lateral stiffness about that axis, which follows from the unsymmetrical plan. Both systems hold the displacement well within an acceptable range, and the diagrid keeps the marginally tighter control.

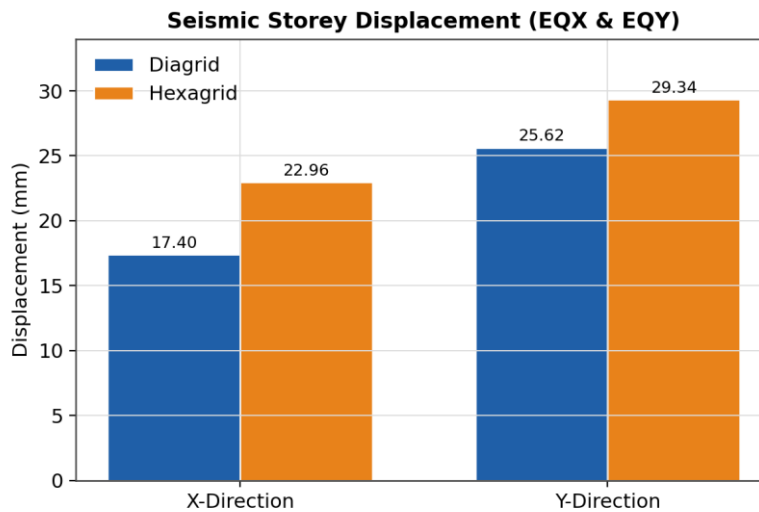


Figure 5. Seismic storey displacement in the X and Y directions

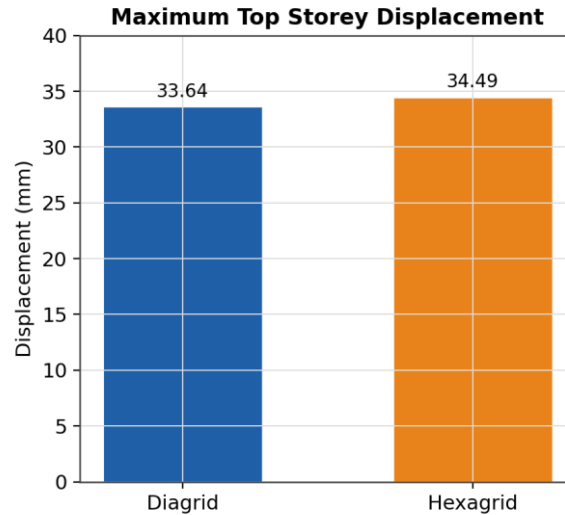


Figure 6. Maximum top storey displacement of the two systems

4.3 Storey displacement under wind load

The along-wind displacements are compared in Figure 7. Under wind the hexagrid again deflects more, peaking at 25.25 mm in the Y direction against 11.81 mm for the diagrid, while in the X direction the hexagrid reaches 18.77 mm and the diagrid 14.43 mm. The gap is wider here than under the seismic case, which shows that the diagrid offers the better wind-drift control. The gust effect factor came out close to 2.0 for both systems, and the wind drift factor stayed below 0.002 in every case, so both buildings remain safe against the wind serviceability limit.

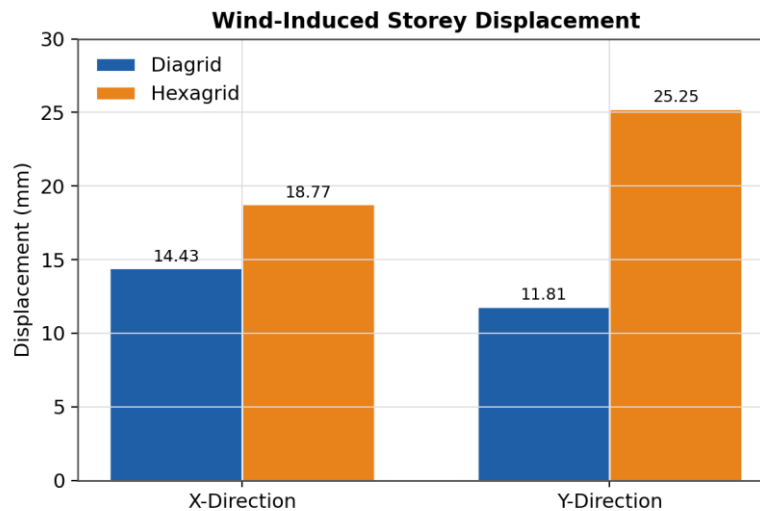


Figure 7. Wind-induced storey displacement in the X and Y directions

Table 4. Gust factor and wind-displacement comparison

Quantity	Diagrid	Hexagrid
Gust effect factor, G	approx. 2.0	approx. 2.0
Max wind displacement, X (mm)	14.43	18.77
Max wind displacement, Y (mm)	11.81	25.25
Wind drift factor (max)	< 0.002 (Safe)	< 0.002 (Safe)

4.4 Base shear

Base shear is the largest lateral force expected at the foundation from the seismic ground motion. Figure 8 compares the two systems. The hexagrid attracts a base shear of 3448.62 kN against 3419.36 kN for the diagrid in both principal directions, an increase of about 0.84 percent. The slightly higher base shear of the hexagrid means it draws a marginally larger lateral force, which is consistent with its greater seismic weight, and it indicates a somewhat higher resistance demand in the hexagrid configuration.

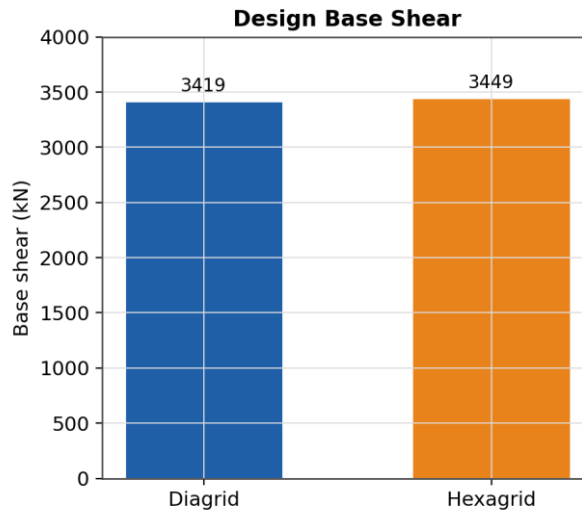


Figure 8. Design base shear of the two systems

4.5 Inter-storey drift

Inter-storey drift is the movement of one floor relative to the floor below, and the drift factor obtained by dividing it by the storey height is the quantity limited by the code. Table 5 lists the drift factors and Figure 9 compares them. For the diagrid the drift factor is 0.00018 in the X direction and 0.00028 in the Y direction, while for the hexagrid it is 0.00028 in the X direction and 0.00037 in the Y direction. The largest of these, the hexagrid value of 0.00037 in the Y direction, is far below the IS 1893 limit of 0.004, so both systems satisfy the drift criterion with a wide margin. The lower drift of the diagrid confirms that it is the stiffer of the two.

Table 5. Inter-storey drift and drift factor (storey height $h = 3000$ mm; permissible drift factor = 0.004)

Direction	Diagrid drift	Hexagrid drift	Diagrid factor	Hexagrid factor	Status
EQX	0.00018	0.00028	0.00018	0.00028	Safe
EQY	0.00028	0.00037	0.00028	0.00037	Safe

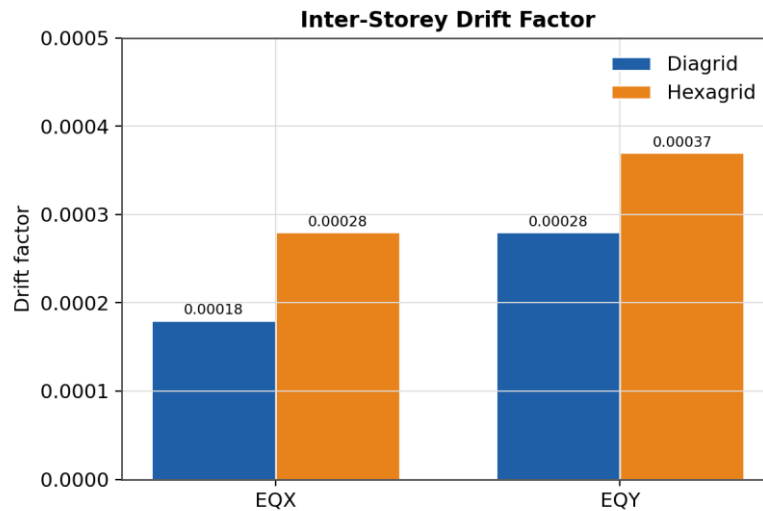


Figure 9. Inter-storey drift factor of the two systems against the IS 1893 limit

4.6 Seismic weight

The seismic weight of the two towers is almost the same, as Figure 10 shows. The hexagrid weighs 828387.93 kN against 821860.275 kN for the diagrid, a difference of less than one percent. Because the two models share the same plan, sections and material, this small difference comes only from the slightly different quantity of perimeter material in the two geometries, and it is the reason the base shear of the hexagrid is marginally higher.

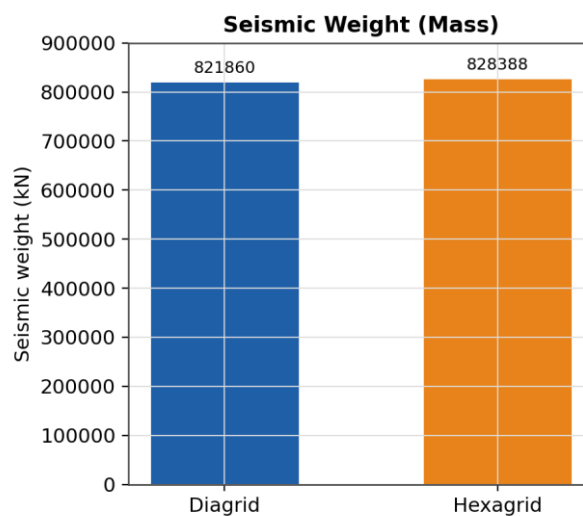


Figure 10. Seismic weight of the two systems

4.7 Independent validation in Python

To give the finite element output an independent check, the key design quantities were recomputed in Python rather than relying on ETABS alone. The reasoning is straightforward. ETABS solves the governing equations with its own solver, so a separate calculation built on the code provisions reaches the same quantities by a different route. Where the two agree the agreement supports the modelling assumptions, and where they diverge the difference flags the part of the model that needs a second look. The script reproduces the base shear, the empirical period and the drift checks for both models using the seismic weight, the modal period and the geometry already established in the analysis.

The base shear was recalculated from first principles by the equivalent static method of IS 1893 (Part 1): 2016. The design acceleration coefficient was read from the medium-soil spectrum, the design horizontal seismic coefficient was formed from the zone, importance and response reduction factors, and the base shear was taken as the product of that coefficient and the seismic weight. The recomputed base shear came out as 3652.7 kN for the diagrid and 3487.9 kN for the hexagrid, against the ETABS

values of 3419.36 kN and 3448.62 kN, which are deviations of 6.82 percent and 1.14 percent. Both differences lie inside the tolerance normally expected between a hand calculation and a full three-dimensional solver, so the seismic force in the model can be regarded as sound. Figure 11 shows the comparison.

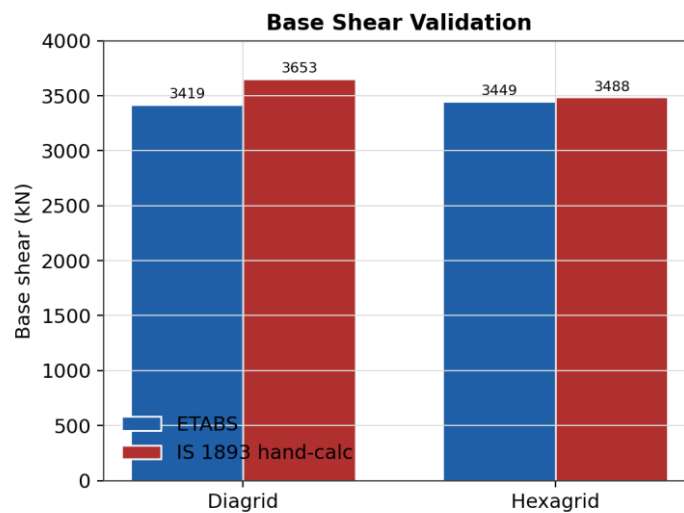


Figure 11. Base shear validation, ETABS against the IS 1893 hand calculation

The fundamental period was checked against the empirical expressions of Clause 7.6.2. The composite moment-frame expression returned about 2.90 s and the steel-frame expression returned 3.08 s, the latter falling very close to the diagrid modal period of 3.06 s and within roughly ten percent of the hexagrid value of 3.23 s. Since these formulae are calibrated for bare moment frames rather than perimeter tube systems the comparison is treated as indicative, and the closeness of the finite element periods to the steel-frame estimate is a reasonable outcome. Figure 12 sets the modal periods against the empirical estimate.

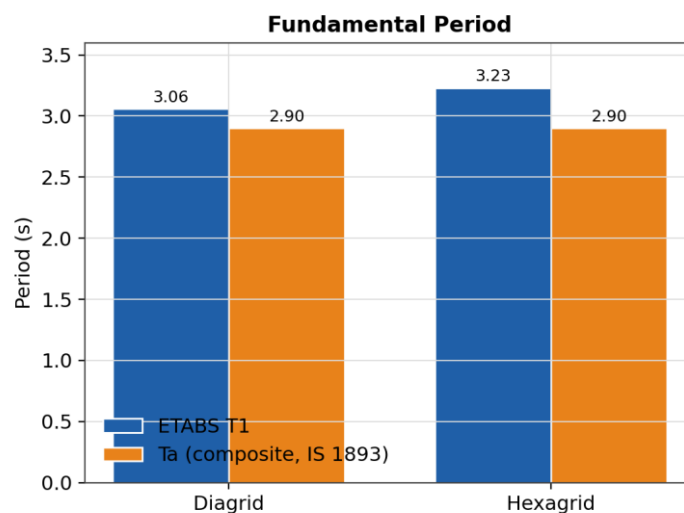


Figure 12. Fundamental period, ETABS modal period against the IS 1893 empirical estimate

The serviceability checks were then applied. The largest inter-storey drift factor, the hexagrid value of 0.00037 in the Y direction, sits far below the IS 1893 limit of 0.004, and the largest wind displacement of 25.25 mm stays well inside the IS 16700 working limit of H divided by 500, equal to 240 mm for this building. Every drift and displacement check returned a safe result for both systems, as Figure 13 shows.

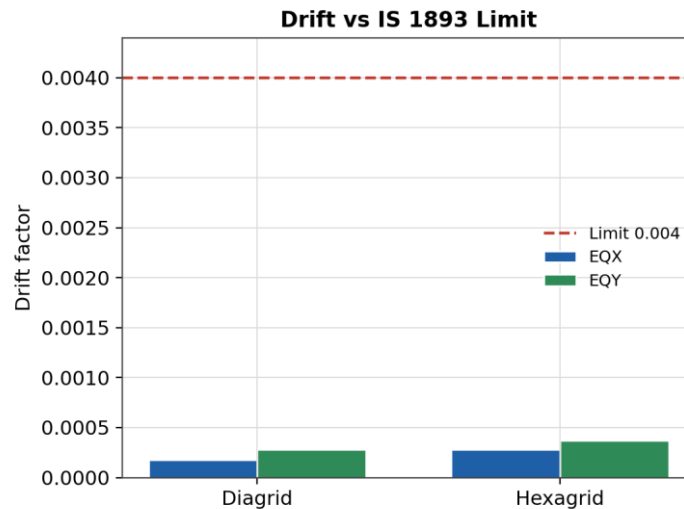


Figure 13. Inter-storey drift factor against the IS 1893 limit

A machine-learning surrogate was built as a final check on the shape of the displacement profile. A random forest regressor and a cubic polynomial were fitted to the storey displacement in the governing direction, and both reproduced the profile with a coefficient of determination near 0.9996 and a mean absolute error under 0.16 mm. The predicted roof displacement matched the finite element value to within 0.04 percent for each system, which shows that the response varies smoothly and monotonically with height in the manner of a combined flexural and shear cantilever. Figure 14 shows the fitted profiles. Taken together the four checks demonstrate that the ETABS results are internally consistent, code compliant and physically reasonable, and that the comparison between the two systems rests on a verified basis.

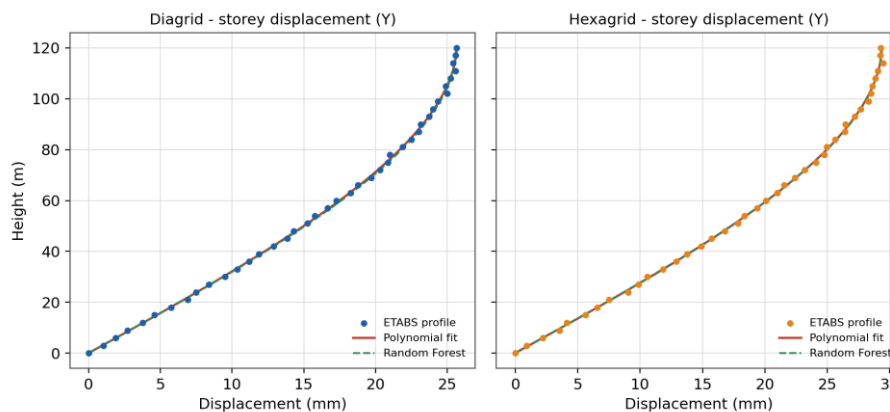


Figure 14. Machine-learning validation of the storey displacement profile (Y direction)

4.8 Summary of the comparison

Table 6 collects the principal results in one place. The pattern is clear and matches the trend reported in the literature. The hexagrid is the more flexible and more ductile system, with the longer period, the larger displacement and the slightly higher base shear, while the diagrid is the stiffer system that controls drift more tightly. The two carry almost the same weight.

Table 6. Summary of the seismic and wind response of the two systems

Parameter	Diagrid	Hexagrid	Remark
Fundamental period (s)	3.06	3.23	Hexagrid more flexible
Top displacement, seismic (mm)	33.64	34.49	+2.52 %

Parameter	Diagrid	Hexagrid	Remark
Max displacement X, seismic (mm)	17.40	22.96	Diagrid lower
Max displacement Y, seismic (mm)	25.62	29.34	Diagrid lower
Max wind displacement X (mm)	14.43	18.77	Diagrid lower
Max wind displacement Y (mm)	11.81	25.25	Diagrid lower
Base shear (kN)	3419.36	3448.62	+0.84 %
Drift factor EQX	0.00018	0.00028	Both safe
Drift factor EQY	0.00028	0.00037	Both safe
Seismic weight (kN)	821860.28	828387.93	Nearly equal

5. CONCLUSIONS

A forty-storey steel-concrete composite tower was analysed and designed with two perimeter-active systems, the diagrid and the hexagrid, on an identical plan, section and loading, and the response was compared for the seismic and wind cases to Indian Standard codes. The following conclusions can be drawn from the results.

1. The maximum top storey displacement of the hexagrid is about 2.52 percent higher than that of the diagrid, which shows that the hexagrid has the greater ductility of the two systems.
2. The base shear of the hexagrid is about 0.84 percent higher than that of the diagrid, so the resistance offered against the lateral force is marginally greater in the hexagrid configuration, in keeping with its slightly larger seismic weight.
3. The inter-storey drift of the diagrid is lower than that of the hexagrid in both directions, by roughly 35 percent in the X direction and a comparable margin in the Y direction, which confirms that the diagrid is the stiffer system and gives the tighter drift control. Both systems stay far below the IS 1893 limit of 0.004 and are therefore safe.
4. The hexagrid has the longer fundamental period, 3.23 s against 3.06 s, so it is more flexible and oscillates more readily under lateral load, while the diagrid keeps displacement and drift in check more effectively.
5. On balance the hexagrid offers a more ductile and potentially more economical option for tall composite construction, while the diagrid remains the better choice wherever tight control of lateral displacement and drift is the governing requirement. An independent Python recalculation of the base shear, the period and the drift confirmed that the comparison rests on a consistent and code-compliant analytical basis.

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