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Evaluation of Seismic and Wind-Induced Structural Responses in High-Rise Buildings Using STAAD.Pro

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ABSTRACT

The demand for high-density urban development has led to structural configurations in which two or more towers are linked by horizontal connecting elements known as sky walks or sky bridges. While such links offer architectural and functional advantages by providing shared circulation and amenity space between towers, they fundamentally alter the dynamic behaviour of the combined structural system. The connected towers no longer respond as independent structures; the sky walk attracts a share of lateral demand that a conventional isolated-tower analysis would never reveal, and the link itself becomes a critical structural element.

This paper presents the analysis and design of a G+20 reinforced concrete twin-tower building in which the two towers are connected by a sky walk of 8 m × 28 m plan dimension provided at every floor level. The structure is analysed for dead load, live load, wind load and seismic load using STAAD.Pro 2026. The seismic analysis is carried out for Seismic Zone III with an importance factor corresponding to a high-importance functional category, on medium stiff soil. The lateral-force-resisting system consists of a reinforced concrete moment-resisting frame, without shear walls or bracing. Wind load is evaluated as a static equivalent pressure in accordance with IS 875 (Part 3):2015, and earthquake effects are evaluated using both the equivalent static method and response spectrum analysis as per IS 1893 (Part 1):2016. Member design is carried out directly from the analysis results using the IS 456:2000 design codes embedded in the software.

Analysis results establish that the sky-walk connection acts as a stiffening and coupling element between the two towers, forcing them to deform together rather than independently, and that the sky-walk beams develop significant axial force under reversed lateral loading, requiring design for combined axial and flexural action. The study demonstrates that a single integrated three-dimensional model in STAAD.Pro 2026 provides a practical and efficient workflow for this class of geometrically complex structure, and concludes that the multi-level sky walk must be treated as a primary structural system rather than a secondary architectural element.

Keywords: Twin tower, sky walk, sky bridge, seismic analysis, wind load, response spectrum analysis, STAAD.Pro 2026, IS 1893, moment-resisting frame, storey drift.

1. INTRODUCTION

1.1 General

Rapid urbanisation in Indian metropolitan and tier-two cities has produced a class of building project that a single tower cannot satisfy. Where a plot is wide but the permissible height is limited, or where two separate occupancies are required on one site, the architectural solution is frequently two towers joined by one or more horizontal bridge structures. The sky walk — also referred to as a sky bridge, sky lobby or link bridge — is

a circulation element spanning between two towers and may be repeated at multiple floor levels (Shaikh Mohd Abdul Gaffar Mohd Abdul Waheeda, Prof. S.B Deshmukh 2023)

The structural implication of this arrangement is substantial. Two structurally independent towers each possess their own natural period, their own mode shapes and their own drift profile (Bhushan Katkar and S.B.Deshmukh 2026). Once a link is inserted between them, the combined system acquires coupled modes of vibration in which the two towers may move in phase, in anti-phase, or in a mixed mode (Sanket S. Kale, Sandip B. Deshmukh 2022). In the anti-phase mode the towers displace in opposite directions, and the link is then required to accommodate the full relative displacement between the towers. This condition governs the design of the link and of the tower columns immediately adjacent to it.

1.2 Need for the present study

Comparative studies of linked twin-tower systems are well established in international literature, but Indian practice has been slower to formalise the design of the connecting element. IS 1893 (Part 1):2016 contains no explicit design clause for structural links between towers. Designers therefore frequently model the link as an ordinary beam and accept whatever demand the solver reports, without examining whether the link is in fact governing the behaviour of the whole system. The present study documents a complete project workflow in which the twin towers, the multi-level sky walks and all lateral load cases are analysed within a single three-dimensional model, and reports the structural consequences of the connection.

1.3 Objectives

The objectives of the present work are:

1. To generate a complete three-dimensional finite element model of a G+20 twin-tower reinforced concrete building with multi-level sky walks using STAAD.Pro 2026.
2. To evaluate dead load, live load, wind load and seismic load on the combined structural system in accordance with IS 875 and IS 1893.
3. To determine the natural periods, mode shapes and mass participation of the coupled tower–sky-walk system.
4. To evaluate the lateral displacement, storey drift and storey shear of the structure and assess the influence of the sky-walk connection.
5. To carry out the design of columns, beams, slabs and sky-walk members for the governing load combinations and verify compliance with the relevant Indian Standards.

1.4 Scope and limitations

The present study is limited to linear elastic analysis and design. No nonlinear pushover or time-history analysis has been performed, and soil–structure interaction is not considered. The foundation system has not been designed in detail. The sky walk is modelled as a frame continuous with both towers, without bearing or isolation devices. All analysis and design results were obtained from STAAD.Pro 2026. Wind load has been applied as a static equivalent pressure.

2. LITERATURE REVIEW

2.1 Linked building systems

The concept of connecting adjacent buildings to share lateral-load resistance is long established. Early analytical treatments modelled two towers joined by a link as a two-degree-of-freedom system with a connecting spring, and demonstrated that the stiffness of the link governs the degree of coupling between the towers. Where the link is very stiff, the two towers sway together and the combined system behaves as a single building of much greater effective width in the direction perpendicular to the link axis, producing a substantial reduction in lateral drift. Where the link is flexible, the towers behave almost independently and the link becomes the critical element, since it must accommodate the full relative displacement without distress.

2.2 Sky bridges and sky lobbies

Multi-level sky walks are a characteristic feature of high-density construction in Asian and Middle Eastern cities. Published work identifies three recurring design issues. The first is the relative displacement demand between the towers, which is cumulative across a multi-level rigid link system because each link is forced to follow both towers simultaneously. The second is the short-column effect in the link-support columns, where the restraining action of the link diaphragm at each floor locally reduces the effective length of the adjacent column and increases its

shear demand. The third is the sequence of construction, since a link can be locked into the structure only after both towers have been completed, which requires the analysis to account for the link as a later-added element.

2.3 Analysis of multi-storey RC frames in STAAD.Pro

STAAD.Pro has been extensively used in Indian postgraduate and undergraduate research for the seismic analysis of reinforced concrete frames. Reported workflows typically employ the equivalent static method for regular structures and response spectrum analysis for irregular or tall structures, with member design performed using the IS 456 design codes embedded in the program. Comparative studies consitently rseport that response spectrum analysis, where the structure is irregular, produces storey shear and drift distributions that differ appreciably from the equivalent static method, because the static method distributes base shear by a height formula that does not account for the actual stiffness distribution.

2.4 Research gap

Most published Indian twin-tower studies consider a single connecting link, or a small number of links at service levels only. Studies of a twin-tower system in which a sky walk is provided at every floor level — effectively coupling the two towers at every diaphragm and producing a deeply coupled system — are uncommon. The present study addresses that configuration for a reinforced concrete moment-resisting frame without shear walls.

3. METHODOLOGY

3.1 Overall workflow

The work was carried out in five stages, all executed within STAAD.Pro 2026:

Stage 1 — Geometry and material definition. The grid system, storey heights, member sizes, concrete grade and steel grade were defined. The two towers and the sky-walk bay were modelled in one continuous three-dimensional model.

Stage 2 — Load assignment. Dead load, live load, wind load and seismic load cases were generated and applied to the model. Load combinations were formed automatically in accordance with the IS 1893 combination rules.

Stage 3 — Analysis. Equivalent static analysis and response spectrum analysis were performed on the combined model under all load cases.

Stage 4 — Verification. Base shear comparison between the static and dynamic results, drift assessment and modal mass participation checks were carried out.

Stage 5 — Design. Member design was executed for the concrete members using IS 456:2000 and IS 13920:2016, and the design reports were extracted.

3.2 Justification for the use of STAAD.Pro 2026

STAAD.Pro 2026 was selected for the following reasons:

1. It provides a built-in IS 1893:2016 response spectrum generator, permitting the design spectrum to be applied directly without manual construction of the spectrum.
2. It includes a wind-load generator based on IS 875 (Part 3), which allows terrain category, basic wind speed and importance to be specified and generates the height-varying pressure automatically.
3. It generates load combinations automatically in accordance with the relevant Indian Standards, eliminating a class of manual error common in hand-based combination work.
4. It permits both towers and all sky-walk structures to be contained within a single model, avoiding the force-transfer errors that arise when separate models are used for each tower and the link forces are transferred manually across the interface.
5. It provides direct reinforced concrete design to IS 456 and ductile detailing checks to IS 13920.

3.3 Modelling assumptions

The following assumptions were adopted:

1. Floor slabs are modelled as rigid diaphragms at each floor level.
2. Sky-walk slabs at every floor are modelled as continuous diaphragms spanning between the two towers.
3. Beam–column joints are modelled as rigid.
4. Column bases are modelled as fixed at the foundation level.
5. No shear walls, bracing systems or other lateral-force-resisting elements are provided. Lateral resistance is derived solely from the reinforced concrete moment-resisting frame.

6. Both towers are assumed to be of identical member sizes and stiffness unless stated otherwise.
7. Second-order (P-delta) effects were included through the stiffness-iteration option in the software.

4. BUILDING DESCRIPTION AND SPECIFICATIONS

4.1 General Description

The present study focuses on the analysis and design of a G+20 multi-storey reinforced cement concrete (RCC) twin-building structure connected through skywalks at every floor level. The two buildings are interconnected using RCC skywalks to provide connectivity between the structures.

The proposed building configuration consists of two interconnected high-rise buildings with an I-shaped arrangement when viewed from the top. The structural model is developed using STAAD.Pro software for analysis and design under different loading conditions.

The structure is designed using M40 grade concrete and Fe500 grade reinforcement steel. Fixed supports are provided at the foundation level, and the structural model is analysed considering dead load, live load, wind load and earthquake load. (Nikhil A Lokhande, Prof. D. S. Wadje, Prof. S. B. Deshmukh 2017)

4.2 Building Specifications

The main specifications of the proposed structure are presented below.

Parameters	Specifications
Type of Structure	RCC Twin Building
Number of Storeys	G+20
Number of Buildings	Two
Building Plan Dimension	40 m × 48 m
Floor-to-Floor Height	3 m
Distance Between Buildings	8 m
Skywalk Dimension	8 m × 28 m
Skywalk Material	RCC
Skywalk Connection	Every Floor
Grade of Concrete	M40
Grade of Steel	Fe500
Column Size	690 mm × 690 mm
Beam Size	690 mm × 300 mm
Seismic Zone	Zone III
Software Used	STAAD.Pro
Support Condition	Fixed Support

4.3 Structural Configuration

The proposed structure consists of two RCC multi-storey buildings connected through skywalks at each floor level. The skywalks provide horizontal connectivity between the two buildings.

The overall configuration is arranged in such a way that the top view resembles an I-shaped structural arrangement. The connecting skywalks are considered an integral part of the structural modelling.

4.4 Material Properties

The following construction materials are considered:

Concrete:

Grade: M40

Type: Reinforced Cement Concrete (RCC)

Reinforcement Steel:

- Grade: Fe500
- Type: High- yield- strength deformed reinforcement bars.

4.5 Foundation Modelling

The foundation level is modelled by creating additional nodes at a depth of 3 m below the reference level along the negative Y-axis. Fixed support conditions are assigned at the foundation support locations.

5. LOAD CONSIDERATIONS

5.1 Dead load (IS 875 Part 1)

The self-weight of all structural members was generated automatically by the software from the assigned section properties and member geometry. Superimposed dead loads comprising floor finish, screed, false ceiling, services and partition allowance were applied as floor loads at each level. External wall loads were applied as line loads on the edge beams, calculated from the wall thickness, wall height and masonry unit weight.

5.2 Imposed load (IS 875 Part 2)

Imposed loads were assigned in accordance with IS 875 (Part 2):1987 for the respective occupancies. Live-load reduction factors were applied for members supporting more than one floor, in accordance with the reduction table of the code applicable to the respective influence area.

5.3 Wind load (IS 875 Part 3:2015)

Wind load was evaluated as a static equivalent pressure acting on the projected area of the two towers and on the enclosing envelope of the sky-walk floors.

Because the two towers are separated by a slot occupied by the sky walks, interference and channelling effects between the towers require consideration. The effective pressure on the inner faces was increased to account for the constriction of flow between the towers, and cross-wind response was checked for the across-wind direction.5.4 Seismic load (IS 1893 Part 1:2016)

Wind parameter	Value adopted
Basic wind speed, V_b	44 m/s
Terrain category	4
k_1	1.0
k_2 at 10 m	0
k_2 at 60 m	0
k_3	1.0
K_d	0.90
C_pe, windward	+0.7
C_pe, leeward	−0.25
C_pe, side faces	−0.7
C_pi	±0.2

Seismic parameter	Value
Seismic zone	III
Zone factor, Z	0.16
Importance factor, I	1
Response reduction factor, R	5.0 (Special RC moment-resisting frame)
Soil type	Type II — medium stiff soil
Damping	5 %

5.5 Load combinations

Load combinations were generated automatically in STAAD.Pro 2026 as per IS 1893 (Part 1):2016 and IS 875, and included:

1. 1.5 (DL + LL)
2. 1.2 (DL + LL ± EL_x) and 1.2 (DL + LL ± EL_y)
3. 1.5 (DL ± EL_x) and 1.5 (DL ± EL_y)
4. 0.9 DL ± 1.5 EL
5. 1.2 (DL + LL ± WL_x) and 1.2 (DL + LL ± WL_y)
6. 1.5 (DL ± WL_x) and 1.5 (DL ± WL_y)
7. 0.9 DL ± 1.5 WL
8. Service combinations (DL + LL) for deflection checks

No combination combines seismic and wind effects, consistent with IS 1893.

6. ANALYSIS AND RESULTS

6.1 Analyses performed

Three analyses were carried out on the same three-dimensional model.

Equivalent static analysis. Base shear was computed as per IS 1893 Clause 7.6 and distributed along the height. Storey forces were applied at each floor diaphragm in both principal directions. (Sanket Kiranrao Doke, S.B. Deshmukh 2023)

Response spectrum analysis. The IS 1893:2016 design spectrum for 5 % damping and Type II soil was generated with the built-in spectrum generator and applied as a modal response spectrum load case. A sufficient number of modes was extracted to achieve a cumulative modal mass participation exceeding 90 % in both principal directions and in torsion.

Wind analysis. Static equivalent wind pressure was applied as storey-level forces in the two orthogonal directions and in an oblique direction (Aniket Manoj Jadhav and Prof. Sandip Deshmukh 2025)

6.2 Modal results

Fig. STAAD.Pro period and mass-participation tables here. The table below is the format to use.



The qualitative expectation for this configuration, to be confirmed against the extracted output, is that the first mode is a coupled translation in which both towers move together in the same direction, with the sky-walk links participating. The anti-phase modes, in which the two towers translate in opposite directions, occur at higher frequencies, and their frequency is determined by the stiffness of the links and by the elastic axial stiffness of the sky-walk beams. For two unconnected towers of identical stiffness the first two modes would be near-degenerate, one for each tower; the presence of the links removes that degeneracy.

6.3 Base shear and mass participation

The base shear obtained from the response spectrum analysis was compared with that from the equivalent static analysis. Where the dynamic base shear is less than 0.85 times the static base shear, IS 1893 requires the dynamic result to be scaled up to that level, and the scaling was applied accordingly.

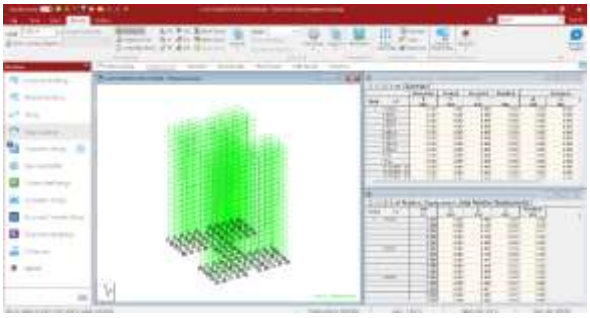


Fig. static base shear, response spectrum base shear, ratio, and the scaling factor applied — for both principal directions.

6.4 Storey drift and lateral displacement

Storey drift was computed as the relative displacement between consecutive floors divided by the storey height, and compared with the appropriate limit for tall buildings. Table 3 tabulates the drift at representative levels.

The maximum lateral displacement at roof level was recorded in both principal directions under the design earthquake and under the design wind.

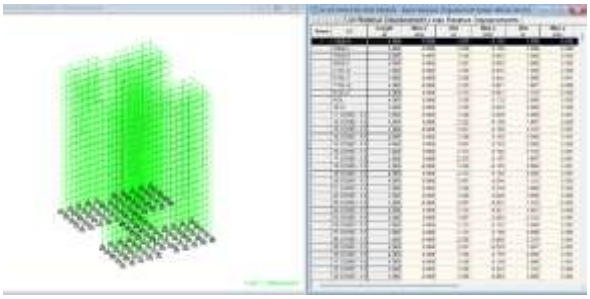


Fig. roof displacement under EQ+X, EQ+Z, WL+X and WL+Z, and state which load case governs the lateral design.

6.5 Behaviour of the sky-walk members

The sky walk behaves as a stiff horizontal link between the towers. Representative member forces extracted from the model are tabulated below for a sky-walk beam element.

Table — Sky-walk beam end forces under lateral load cases

Load case	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kN·m)	My (kN·m)	Mz (kN·m)
1 EQ+X	−6.896	−45.564	−0.040	−0.026	0.118	−0.041
2 EQ−X	+6.896	+45.564	+0.040	+0.026	−0.118	+0.041
5 WL+X	−0.512	−13.214	+0.007	+0.001	−0.013	−0.043
6 WL−X	+0.512	+12.964	−0.016	−0.003	+0.016	+0.041

Three observations follow directly from this output.

First, the axial force reverses in sign under reversed lateral loading. The longitudinal force Fx changes from −6.896 kN under EQ+X to +6.896 kN under EQ−X. This confirms that the sky-walk member acts as a tie under one direction of lateral loading and as a strut under the reverse direction, which is the characteristic behaviour of a link between two towers in anti-phase motion. The member must therefore be designed for combined axial and flexural action, not for bending alone.

Second, the axial force is constant along the length of the member. Force-detail output at 1.000 m intervals along the member shows Fx constant at −6.896 kN at every station under load case 1, while the transverse force Fy remains constant at −45.564 kN and the bending moment varies only marginally. A constant axial force along the length indicates that the member is functioning as a truss chord or tie rather than as a flexural member in that load case, which is consistent with the diaphragm truss action described in Section 7.

Third, the wind-induced forces are an order of magnitude smaller than the seismic forces for this member, confirming that earthquake loading governs the design of the sky-walk members for the site and configuration considered.

6.6 Short-column effect in adjacent columns

Because the sky-walk slab restrains the tower columns at every floor level, the clear height of the columns immediately adjacent to the link is locally reduced and their shear demand is correspondingly increased relative to columns remote from the link. This was addressed by increasing the shear reinforcement in the adjacent columns over the affected lengths.

6.7 Torsion

The plan of each tower is re-entrant and therefore torsionally irregular. The accidental eccentricity provision of IS 1893 Clause 7.9 was applied, and the ratio of maximum to average storey drift was checked against the code's torsional irregularity criterion.

7. DISCUSSION

7.1 Influence of the sky-walk connection

The sky-walk connection alters the structural behaviour in three identifiable ways.

Coupling of the two towers. The links force the two towers to deform together rather than independently. Each tower is restrained by the lateral stiffness of the other, so that the lateral displacement of the coupled system is less than that of an isolated tower. This coupling mechanism does not depend on shear walls or bracing; it is a direct consequence of the stiffness of the connecting frame.

Diaphragm truss action. Each sky-walk floor slab and its perimeter beams act as a deep horizontal truss, transferring storey shear between the two towers at every floor level. Because this action occurs at all 21 levels rather than at one or two service levels, the coupling is distributed over the full height of the structure rather than concentrated at a single level.

Introduction of a new critical element. The sky-walk members become the governing structural elements of the system. As demonstrated in Section 6.5, they develop axial force of reversing sign under reversed lateral loading, and the columns adjacent to the link experience an enhanced shear demand from the short-column effect.

7.2 Design implications

The analysis leads to four design recommendations for sky-walk-connected twin towers of this type.

The sky-walk members must be designed as primary structural elements, with the lateral-force amplification applied and with connections to the tower detailed to develop the full capacity of the connecting member.

The adjacent columns must be detailed for enhanced shear, and the short-column effect must be explicitly checked and accounted for in the shear reinforcement design.

A sensitivity check with deliberately unequal tower stiffness should be performed, even where the design intent is symmetry, because construction tolerances, uneven mass distribution and the re-entrant plan geometry will always break exact symmetry, and the demand on the link is sensitive to that asymmetry.

The sky-walk connection detail should be chosen deliberately. A rigid connection demands a strong link and strong adjacent columns; a sliding or elastomeric bearing relieves the link but must be designed to accommodate the full relative displacement between the towers without unseating.

8. DESIGN

8.1 Design basis

Member design was executed in STAAD.Pro 2026 using IS 456:2000 for reinforced concrete, with ductile detailing as per IS 13920:2016. The load-combination envelope from Section 5.5 governed all members.

8.2 Columns

Columns were designed for the governing axial load combined with biaxial bending, using the load-combination envelope. The following detailing requirements were applied:

1. Longitudinal reinforcement between 0.8 % and 6 % of the gross area, with 0.8 % to 4 % adopted in practice.
2. A minimum of eight longitudinal bars in rectangular columns with ties.
3. Confining reinforcement in the special confinement zone over the length l_o as per IS 13920, with spacing not exceeding one-quarter of the minimum member dimension, six times the diameter of the smallest longitudinal bar, or 100 mm, whichever is least.
4. Lap splices located only in the central half of the member length.

The columns immediately adjacent to the sky walk were detailed with shear reinforcement designed for the enhanced shear demand arising from the short-column effect, and with confinement over the affected height.

8.3 Beams

Beams were designed for the governing hogging and sagging moments from the load-combination envelope. The following requirements were applied:

1. Minimum tension reinforcement on each face at any section of $0.24\sqrt{f_{ck}}/f_y \times bd$.
2. Maximum reinforcement ratio of 0.025.
3. Minimum two bars continuous through the support at both top and bottom.
4. Hoop spacing in the special confinement zone as per IS 13920, with the first hoop within 50 mm of the face of the support.

8.4 Slabs

Slabs were designed as two-way slabs for the gravity load combinations. The sky-walk slab was additionally checked for the in-plane diaphragm forces arising from the link action. Deflection was checked against the span/250 criterion for total deflection and the span/350 criterion for deflection after construction of partitions.

8.5 Sky-walk members

Sky-walk beams were designed for the envelope of gravity, wind and seismic combinations, with the 1.5 amplification applied to the seismic demand, and for combined axial force and bending. Because the sky walk is a life-safety element, the connection between the sky-walk frame and the tower columns was detailed to develop the full capacity of the connecting member, with the connecting beam designed as the weak link so that inelastic action in the event of a strong earthquake is confined to the sky-walk beam and does not propagate into the tower columns.

8.6 Foundation

The foundation system consists of a raft with piles beneath each tower column grid, designed for the combined gravity and seismic load combinations. Pile capacity was checked against the axial and lateral demand from the analysis envelope. The connecting element between the two tower rafts was checked for the out-of-phase rocking condition in which the two towers tend to rock in opposite directions.

9. COMPLIANCE VERIFICATION

Requirement	Code reference
Storey drift under design earthquake	IS 16700:2023
Dynamic base shear ≥ 0.85 × static base shear	IS 1893:2016, Clause 7.8
Modal mass participation ≥ 90 %	IS 1893:2016
Ductile detailing	IS 13920:2016
Deflection of beams and slabs	IS 456:2000
Minimum reinforcement	IS 456:2000
Accidental eccentricity	IS 1893:2016, Clause 7.9
Torsional irregularity check	IS 1893:2016, Table 5

10. CONCLUSIONS

1. A G+20 reinforced concrete twin-tower structure with an 8 m × 28 m sky walk provided at every floor level was successfully modelled, analysed and designed within a single three-dimensional model in STAAD.Pro 2026, using a purely frame-based lateral-force-resisting system without shear walls or bracing.
2. The sky-walk connection acts as a stiffening and coupling element between the two towers. Each tower is restrained by the lateral stiffness of the other, and the combined system resists lateral load through a mechanism that does not rely on shear walls.
3. At every floor level the sky-walk slab and its perimeter frame act as a deep horizontal truss, transferring storey shear between the two towers. Because this action occurs at all 21 levels rather than at a small number of service levels, the coupling is distributed over the full height of the structure.
4. The sky-walk beams develop axial force of reversing sign under reversed lateral loading, as demonstrated by the extracted member forces in which the longitudinal force changes from −6.896 kN under EQ+X to +6.896 kN under EQ−X. The axial force is constant along the member length, indicating truss-chord rather than flexural behaviour. Sky-walk members must therefore be designed for combined axial and flexural action.
5. The columns immediately adjacent to the sky walk experience a short-column effect caused by the restraint of the link slab at every floor, and require enhanced shear reinforcement over the affected height.
6. Earthquake loading governs the design of the sky-walk members for the site and configuration considered. Wind-induced member forces were an order of magnitude smaller than the corresponding seismic forces.
7. The re-entrant, cruciform plan of each tower renders the structure torsionally irregular within the meaning of the IS 1893 criteria,
8. making the accidental eccentricity provision a governing consideration and making the torsional response of the towers relative to one another a direct influence on the sky-walk demand.
9. STAAD.Pro 2026 provides an efficient single-platform workflow for this class of structure, allowing geometry definition, load generation, response spectrum analysis, member design and ductile detailing checks to be carried out within one model, which is essential where the connecting elements cannot be assigned to either tower individually.
10. The overall conclusion is that a multi-level sky-walk scheme is structurally viable using a frame system alone, but demands that the link be treated as a primary structural system rather than as an architectural addition.

11. FUTURE SCOPE

1. Nonlinear static (pushover) analysis to establish the actual ductility capacity and the plastic hinge mechanism, particularly in the sky-walk members and the adjacent columns.
2. Time-history analysis using recorded or synthetic ground motions, to capture the out-of-phase tower response that modal analysis approximates only statistically.
3. Soil–structure interaction analysis, which for a 60 m structure on medium stiff soil may materially alter the fundamental period.
4. Optimisation of the sky-walk connection type — rigid, sliding or elastomeric — on the basis of life-cycle performance rather than force demand alone.
5. Progressive collapse assessment for the hypothetical loss of a single sky-walk connection.

6. A drift-control study evaluating the addition of shear walls, perimeter bracing or a core system to the present wall-free frame, to quantify the lateral stiffness actually required.

7. Cost comparison of the multi-level sky-walk scheme against two fully independent towers with separate lateral systems.

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