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September
2025

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Shounak Mitra, Head - Codes & Approvals (Fastening), Hilti India Pvt. Ltd.
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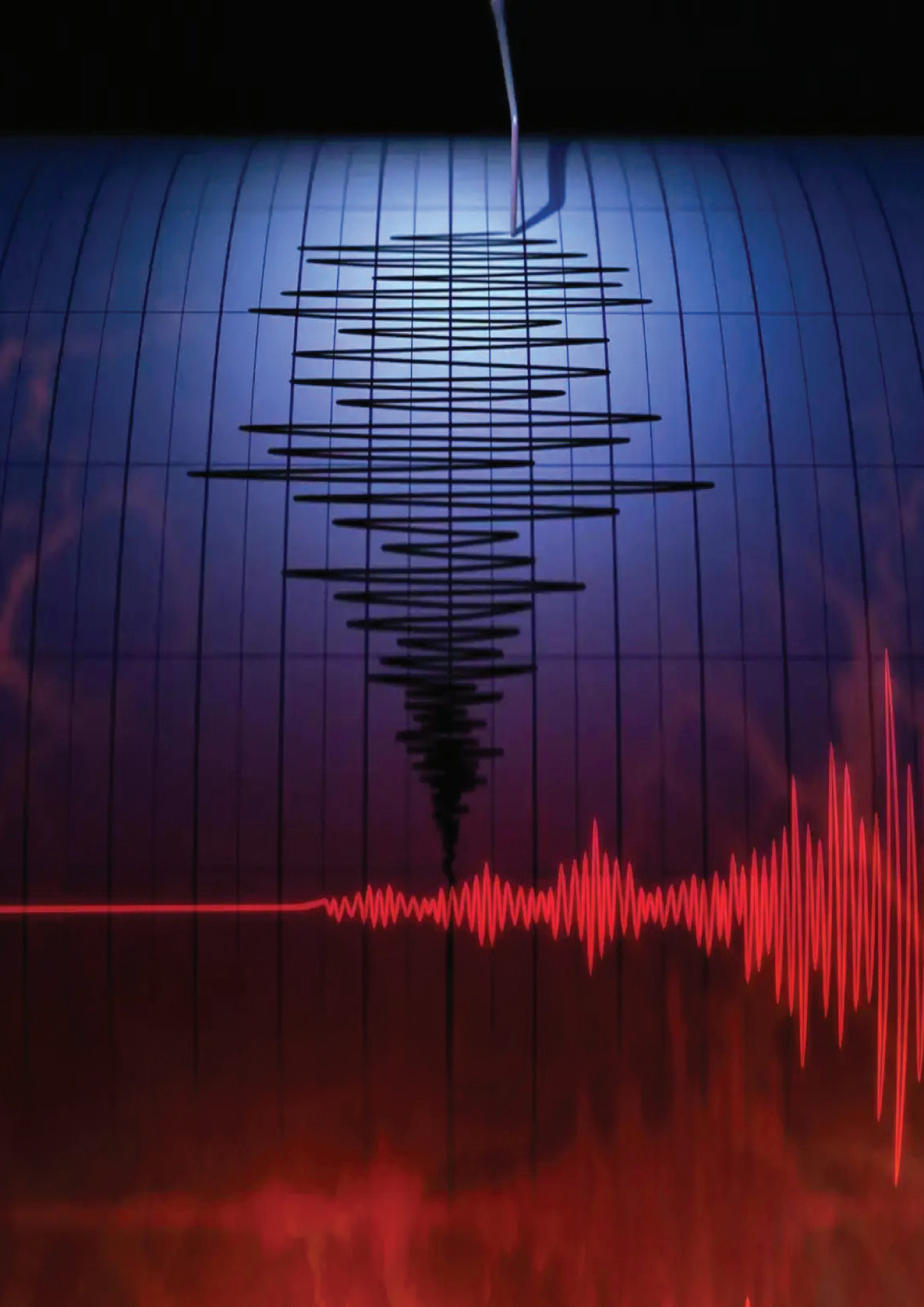

SEISMIC ACADEMY

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10:00 AM - 10:15 AM	**Welcome** Mr. Jayant Kumar General Manager & Managing Director, Hilti India
10:15 AM - 10:45 AM	**Key Note Lecture** TBC
10:45 AM - 11:15 AM	**Framework of Seismic Standards in India** Prof. Pradeep Kumar Ramancharla Director, CSIR – Central Building Research Institute
11:15 AM - 11:40 AM	**Risk Assessment & Retrofit of Towns** Dr. Ajay Chourasia Head of Structural Engineering, CSIR – Central Building Research Institute
11:40 AM - 12:00 PM	Tea Break
12:00 PM - 12:30 PM	**Global perspectives on Seismic Engineering** TBC
12:30 PM - 1:15 PM	Student Competition
1:15 PM - 2:15 PM	Lunch
2:15 PM - 2:35 PM	**Structural Strengthening - Case Study** Mr. Arunabho Bhattacharya Manager Design, CDC Technical Services (P) Ltd.
2:35 PM - 2:55 PM	**Structural Strengthening - Case Study** Dr. Rohit Yadav Founder & CEO, Texel Consulting Engineers
2:55 PM - 3:50 PM	**Panel Discussion** Mr. Aman Deep Garg, Managing Director, Creative Design Consultants & Engineers Pvt. Ltd. Mr. Pradeep Garg, Chief Engineer, CPWD Mr. Manish Jain, Chief Technical Lead, AECOM Dr. Vasant Matsagar, Head of Dept., Civil Engineering, IIT Delhi Dr. Shailesh Agrawal, Executive Director, BMTPC, MoHUA, Govt. of India Moderator - Dr. Harshavardhan Subbarao, Managing Director, Construma Consultants
3:50 PM - 4:00 PM	**Summary & Closing** Mr. Pulkit Kukreja Vice President - Engineering, Hilti India
4:00 PM - 5:00 PM	Tea and Departure

Structural Rehabilitation and Seismic-Safe Transformation of Shopping Complex: A Case Study in Functional Retrofitting

Aishwarya Gupta
Sr. Project Engineer
NVLN Constructions Pvt. Ltd.

Abstract

With the increasing demand for adaptive reuse of urban commercial buildings, structural rehabilitation has become a key strategy to extend the service life, improve the functionality, and ensure the safety of aging infrastructure. This paper presents a detailed case study on the structural rehabilitation and functional transformation of "Shopping Complex," a reinforced concrete (RC) framed multi-storey building located in a high-footfall commercial zone. The building, originally designed for general commercial use, underwent significant structural modifications to be repurposed as a modern shopping centre. The project involved a comprehensive set of interventions including floor saw slab cutting, anchorage installation, steel sections replacement, epoxy bonding, lift shaft creation, and corrosion protection through anti-corrosive coatings.

The transformation was carried out while considering updated live load requirements, seismic provisions, and the integration of modern circulation systems such as escalators and lifts. Techniques like surface preparation with Pneumatic breakers, steel-concrete composite slab design, structural welding, and epoxy bonding were applied to ensure safe and monolithic structural behaviour. Anti-corrosive treatments were applied to all exposed steel elements to enhance durability in an enclosed yet humid indoor environment.

This paper highlights the methodology, technical challenges, sequencing strategies, and key learnings derived from the project. The outcome not only improved vertical circulation and load-bearing capacity but also brought the structure in alignment with seismic safety guidelines. The case study exemplifies how detail-oriented engineering, interdisciplinary collaboration, and modern rehabilitation technologies can successfully transform aging RC structures into future-ready commercial assets.

Introduction

In recent years, the built environment has witnessed a paradigm shift from new construction to the strategic rehabilitation and adaptive reuse of existing structures. With over 70% of India's commercial buildings in metropolitan areas constructed before the early 2000s, there is an increasing push to upgrade outdated infrastructure to meet evolving performance, safety, and occupancy standards. According to a

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In recent years, the built environment has witnessed a paradigm shift from new construction to the strategic rehabilitation and adaptive reuse of existing structures.

report by the Confederation of Indian Industry (CII), the commercial real estate market is expected to grow at a CAGR of over 13% until 2030, with a significant portion driven by retrofitting and redevelopment rather than new builds. This trend is further accelerated by the challenges of land scarcity, regulatory hurdles for new construction, and growing awareness about sustainability and circular economy principles in the construction industry.

Retrofitting and rehabilitation of RC-framed buildings offer an opportunity to not only enhance structural integrity and seismic resistance but also to align aging structures with modern functional demands. Commercial complexes, in particular, face challenges such as increased live loads due to rising footfall, the need for energy-efficient layouts, and accessibility requirements such as escalators and lifts. Traditional office-style structures, when repurposed into multi-retail shopping centres, require extensive modification to accommodate vertical circulation, upgraded MEP systems, and public safety features. These changes must be executed while ensuring minimal disturbance to occupants and nearby structures.

This paper focuses on the rehabilitation of "Shopping Complex," an RC-framed commercial building consisting of two cellar levels, lower and upper ground floors, and eight upper storeys, originally used for mixed commercial purposes. With the client's vision to transform it into a high-traffic retail destination, extensive structural modifications were required. Key interventions included slab cutting to install escalators, reinforcement of floor systems to accommodate increased live loads, installation of goods and passenger lifts, and replacement of outdated steel elements with load-compliant Steel sections.

In addition to structural reconfiguration, the rehabilitation process also emphasized seismic safety, corrosion resistance, and long-term durability. Special attention was given to surface treatment, anchorage detailing, and composite action between new and existing structural elements. The entire execution was phased to allow partial functionality of the building during construction, thereby addressing the dual challenge of structural integrity and operational continuity.

"Retrofitting and rehabilitation of RC-framed buildings offer an opportunity to not only enhance structural integrity and seismic resistance but also to align aging structures with modern functional demands.

Through this case study, the paper aims to provide valuable insights into the technical, logistical, and interdisciplinary coordination involved in modern commercial retrofitting. It also highlights the growing importance of integrating structural rehabilitation techniques with lifecycle performance, safety codes, and urban redevelopment strategies.

Existing Conditions and Structural Overview

Shopping Complex is a reinforced concrete (RC) framed building with:

- **Cellar 1 and Cellar 2:** Initially used for parking and services.
- **Lower Ground to Upper Ground Floors:** Used for large retail outlets.
- **Ground to 8th Floors:** Mixed-use spaces including food courts, fashion stores, and cinema halls.

Though the primary frame was in stable condition, the internal configuration lacked modern circulation systems (like escalators and lifts) and was inadequate for updated loading and seismic requirements. The rehabilitation focused on:

- Removal of obsolete Steel sections and lift components.

- Reinforcement of slabs for escalators and lifts.
- Structural realignment using multiple steel sections.

Methodology and Execution

Slab Modification and Escalator Integration

- **Cutting Method:** Precision Diamond blade floor saw cutting was adopted for slab modification at escalator locations. This method minimized vibrations and protected surrounding structures.
- **Surface Preparation:** A Pneumatic breaker was used to prepare exposed concrete surfaces, ensuring proper mechanical bonding with new materials.
- **Reinforcement:** Steel sections were inserted where required and welded in-situ. Metal deck sheets and reinforcement were installed conforming to structural detailing before concreting.
- **Bonding Agents and Curing:** Epoxy bonding agents were applied at concrete–concrete interfaces, especially at cold joints, to ensure monolithic action. Curing was ensured using standard procedures to prevent shrinkage and improve strength.

Lift Shaft Rehabilitation and New Lift Installation

Separate lift systems for passengers and goods were constructed, requiring vertical and horizontal integration:

- **Marking and Anchoring:** Precise marking was done for the location of anchor bolts and MS base plates. Anchor bolts were installed using Hilti anchoring systems for precision and strength.
- **Decking and Reinforcement:** After placing the deck sheets over cut slabs, reinforcement bars were tied as per design loads.
- **Structural Steel Work:** For both passenger and goods lifts, vertical MS sections were aligned and welded in-situ with appropriate checks on plumb and alignment.
- **Protective Coating:** All sections and steel components were coated with anti-corrosive epoxy paint to increase lifespan and reduce maintenance in humid mall interiors.
- **Epoxy Bonding and Concrete Pouring:** Reinforced zones were bonded using epoxy-based coatings before concrete was poured to integrate the new and existing sections monolithically.

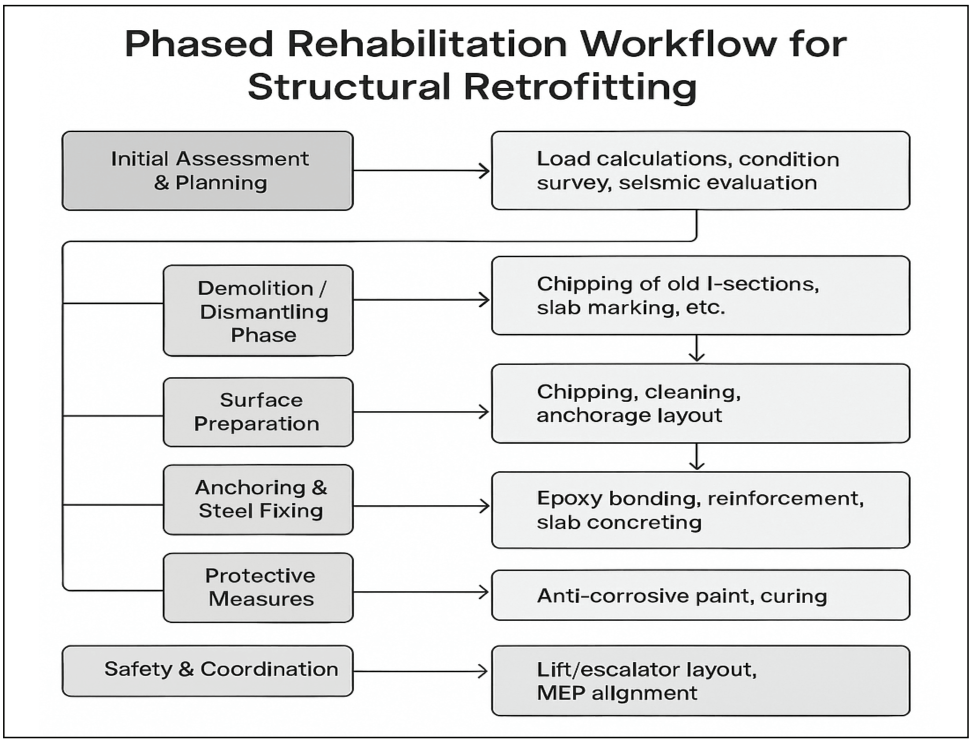

Fig. 1: Phased Rehabilitation Workflow for Structural Retrofitting

Removal and Replacement of Outdated Structural Components

- Existing Steel sections used in older infrastructure were dismantled carefully.
- Structural assessment was carried out to verify live load redistribution.
- New sections were introduced based on updated design load calculations, and welded to the existing frame using standard detailing for retrofitted joints.

Seismic Considerations

While this rehabilitation was not triggered by a seismic retrofit mandate, all modifications incorporated ductility-based detailing and anchorage as per IS 13920 and IS 1893 provisions for seismic zone II.

Project Outcome and Performance

- **Functional Optimization:** New escalators and lifts significantly improved vertical circulation. The repositioning of infrastructure opened up central corridors for footfall-based navigation.
- **Structural Integrity:** Post-rehabilitation audits confirmed that modified slabs and vertical components adhered to structural safety norms, including seismic considerations.
- **Durability:** Application of anti-corrosive coatings and epoxy bonding increased the projected lifespan of retrofitted members by minimizing corrosion and moisture ingress.
- **Client Satisfaction:** The rehabilitation successfully aligned with the client's commercial vision, enabling modern retail functionality without reconstruction.

Discussion and Key Learnings

The rehabilitation of Shopping Complex provided valuable insights into the practical challenges and technical nuances of transforming an existing RC-framed commercial structure into a modern shopping facility. One of the most critical learnings was the importance of precision in planning and execution when working within an operational or partially occupied building. The use of Diamond blade floor saw cutting instead of conventional methods significantly reduced vibration and damage to adjacent areas, allowing safe and clean modification of structural slabs for escalator integration and lift installations.

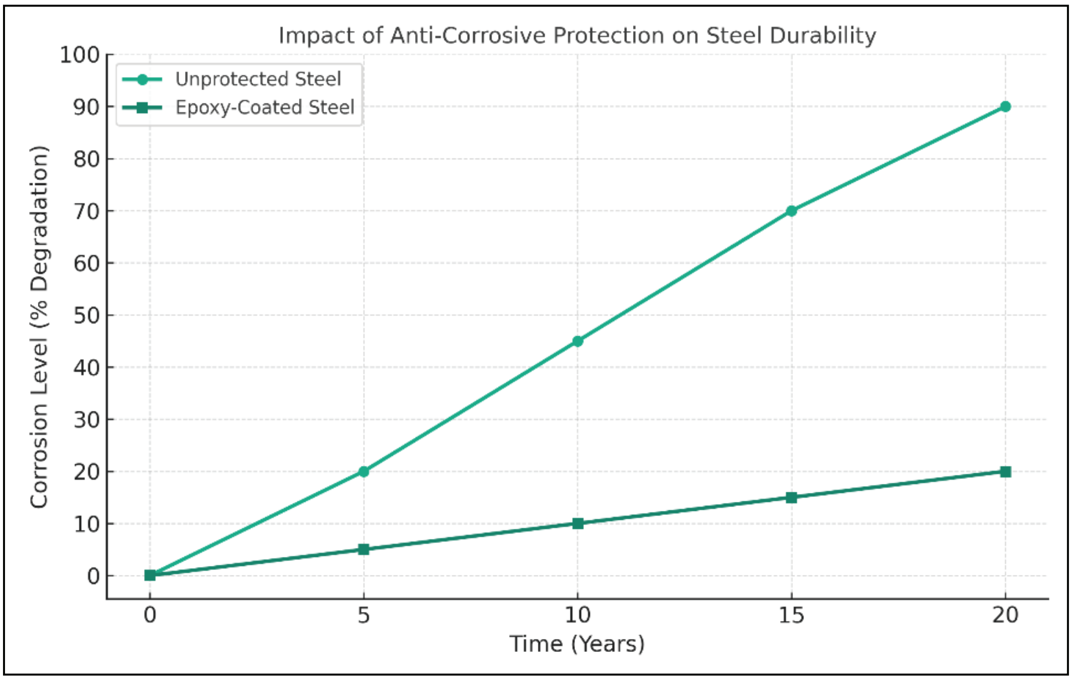

Fig. 2: Moisture/Corrosion Risk vs Protection Graph

Surface preparation using Pneumatic breakers ensured proper mechanical interlocking between old and new concrete layers, highlighting how vital it is to not compromise on surface treatment when dealing with bonding interfaces.

Another key takeaway was the efficient integration of structural steel and concrete to meet revised loading and usage demands. The use of Steel sections, placed and welded as per calculated requirements, combined with deck sheets and concrete infill, created a robust composite slab system. This approach ensured both structural rigidity and compatibility with existing floor levels and service layouts. The anchorage systems, including precision marking and placement of base plates and bolts, were executed using modern anchoring solutions that offered not only strength but also compliance with seismic detailing norms, as per IS 13920 and Hilti anchoring guidelines. These small yet critical details played a pivotal role in enhancing the overall safety and resilience of the modified zones.

Durability emerged as a major concern during execution, especially in steel-intensive components exposed to indoor humidity and potential water seepage. Anti-corrosive epoxy coatings applied to all exposed steel elements effectively mitigated corrosion risks. This measure also reflects a growing awareness that structural safety must be coupled with long-term material performance, especially in public-use buildings where maintenance access is often restricted post-commissioning. Moreover, the application of epoxy bonding agents at concrete interfaces proved essential in ensuring monolithic behaviour of old and new structural components, helping eliminate the risk of delamination and future crack propagation.

Project coordination and phased execution were equally significant learning aspects. Given the scale of intervention—ranging from slab alterations to lift shaft construction—each stage had to be precisely sequenced, with civil, structural, and MEP teams working in close coordination. Scaffolding, prop jacks, and safety barriers were deployed not just for

“Durability emerged as a major concern during execution, especially in steel-intensive components exposed to indoor humidity and potential water seepage.

structural support but to ensure the safety of workers and occupants. This reinforced the idea that in retrofit projects, construction management practices are just as critical as engineering design.

Finally, the experience underscored the essential role of multidisciplinary collaboration in successful retrofitting. The alignment between structural engineers, construction supervisors, architects, and service engineers ensured that interventions were functional, structurally sound, and architecturally coherent. This holistic integration allowed the transformation of Shopping Complex not merely as a structural upgrade, but as a complete functional evolution aligned with modern retail expectations. These learnings serve as a valuable reference for future retrofitting projects, especially those aimed at balancing occupancy continuity with structural renewal and seismic resilience.

Conclusion

The rehabilitation and transformation of Shopping Complex stand as a comprehensive example of how strategic retrofitting can breathe new life into aging commercial infrastructure. Through a blend of innovative construction techniques, precise structural detailing, and cross-disciplinary collaboration, the project successfully achieved its goal of converting an outdated RC-framed building into a modern, functional, and future-ready shopping center. The interventions addressed key challenges related to increased live load demands, circulation efficiency, vertical transport integration, and long-term durability—all while ensuring adherence to structural safety standards and serviceability criteria appropriate for its location in Seismic Zone II (Hyderabad, Telangana), which falls under a low seismic risk category.

One of the critical accomplishments of the project was the methodical execution of structural slab modifications using Diamond blade floor saw cutting, a technique that minimized vibration and preserved the integrity of surrounding elements. The installation of steel Steel sections, anchoring systems, deck sheets, and reinforcement bars formed the backbone of the structural strengthening effort. These were executed with care and precision, demonstrating how detailed engineering inputs and on-site supervision are pivotal in high-risk structural modifications.

Furthermore, the phased approach—allowing for operational continuity during execution—emphasizes the growing importance of construction management in retrofitting projects, especially in densely populated commercial environments. The use of scaffolding, prop jacks, and temporary supports ensured both worker and occupant safety while minimizing disruption. The incorporation of corrosion mitigation systems such as epoxy-based anti-corrosive paints and bonding agents provided additional resilience, extending the life cycle of structural steel elements and ensuring long-term serviceability.

The project also reinforces the importance of integrating modern building services—such as lifts and escalators—within existing structural grids. This required close alignment between structural engineers, MEP consultants, and architectural designers. The result was a seamless adaptation of new infrastructure into the old building fabric, aligning spatial layout with modern retail and fire safety norms.

At a broader level, this case study exemplifies the evolving role of rehabilitation in India's urban development landscape. With increasing emphasis on sustainability, land optimization, and seismic resilience, retrofitting is emerging as a mainstream alternative to demolition and reconstruction. The Shopping Complex project showcases how technically sound, economically viable, and environmentally responsible outcomes can be achieved through thoughtful planning and engineering-driven execution.

In conclusion, the rehabilitation of Shopping Complex is more than just a structural upgrade—it represents a strategic reimagining of space that combines safety, functionality, and commercial viability. The methodologies adopted and lessons learned can serve as a valuable reference for engineers, project managers, and policymakers involved in the future of structural retrofitting and commercial building transformation.

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Earthquake Resilient Sustainable Lightweight Steel Buildings

Dr. Arup Saha Chaudhuri
Professor
Civil Engineering Department
Techno Main Salt Lake
Kolkata, India

Abstract

Structural steel is a very ductile material with high strength carrying capacity, thus it is very useful to make earthquake resistant buildings. It is a homogeneous material also. The member sections and the structural systems can be made very efficient for economical design. As the steel is recyclable and reused it is a green material. The embodied energy for the efficiently designed steel structure is less than the RC structure. For sustainable green building steel is the best material nowadays.

Moreover, pre-engineered and pre-fabricated faster construction methodologies help the development work to complete within the stipulated time. In old days wooden buildings were made in highly earthquake prone areas for its low weight. With the recent advancement of steel industry if we can make these type of buildings using square hollow sections/ rectangular hollow sections, steel plated/wooden floors and puffed panel walling systems then it will be more strong and lightweight also. These types of buildings are green, sustainable and eco-friendly. In this paper one model building has been analyzed for seismic zone IV or wind speed 47 m/sec as per Indian Standard. Purpose of the building is residential or normal office type. It is found that wind forces developed in the structural members are greater than the seismic forces generated in the same. Because of low mass, seismic forces are not generated despite of heavy ground acceleration. Proper steel bracing systems are provided vertically and horizontally for stability of the structure. The production of new structural hollow members, chequered plates, puffed/sandwiched panels have created a new era in building industry making it more sustainable in all respect. Another way to design this type of building is to provide steel-concrete composite framing with eccentric bracing system. In this paper the usefulness of Eccentric Bracing Frame (EBF) in steel structure over Moment Resisting Frame (MRF) and Concentric Bracing Frame (CBF) is also shown. Stability of the steel structures against horizontal forces especially in seismic condition is efficiently possible by eccentric bracing systems with economic connection details. The EBF is pin – ended, but the beam – column joints are designed for pin ended or for full connectivity. The EBF has several desirable features for seismic resistance. In comparison with CBF system, EBF system can be designed for appropriate stiffness and drift control.

“

pre-engineered and pre-fabricated faster construction methodologies help the development work to complete within the stipulated time.

The link beam is designed to yield in shear or flexure prior to initiation of yielding or buckling of the bracing member in tension or compression. The behavior of a 2-D steel frame is observed under seismic loading condition in the present paper. With respect to time period of vibration and ratio of static base shear vs. dynamic base shear the ductility and brittleness of the frames are compared. It is observed that the EBF system is better than MRF system comparing the time period of vibration and base shear participation. The main beams and columns are made of wide flange rolled sections for economical lightweight design.

Introduction

The purpose of study is to understand the effect of earthquake on such building in highly seismic prone areas and the goal is to find ways and means to control seismic effects on those buildings. It will encourage construction of such buildings in highly seismic areas if not in large scale, at least in the construction of building marked as important building which needs to provide service to the population immediately after the event (earthquake) or building which cannot afford to be dysfunctional, such as railway stations, airports, telephone exchanges, bureaucratic offices, police stations, army headquarters etc. for any period of time. Schools and colleges should also come under this category because effect of earthquake in such buildings as would be revealed from the study is limited or even if there is limited effect, swift restoration is possible in such buildings. This is primary aspect. This should be encouraged in all parts of the country irrespective of seismic zone. The other aspect is to encourage buildings higher than 4-storeys in hilly areas of zone IV and all buildings in hilly areas of zone V as per Indian Standard to be steel buildings. In plain areas of zone V discretion should be used by local authorities primarily keeping in mind the height and volume of the building, the inclination should be to encourage steel buildings using low weight efficient sections like square and rectangular hollow sections SHS & RHS, wide flange beams and columns, light partition and flooring as suggested in the study.

“The purpose of study is to understand the effect of earthquake on such building in highly seismic prone areas and the goal is to find ways and means to control seismic effects on those buildings.

The purpose through this study is to encourage low weight construction. Heavy RCC design method is not suitable in highly earthquake prone areas. Thus the seismic forces shall be optimized to avoid impact and plastic deformations.

Background

The paper is built on the well known back ground of the damage that is caused by earthquake both in terms of life and property, which are visible losses. But for me more than the visible losses are the invisible traumas that people face during the earthquake and a certain period after the earthquake is more important. It is observed that people are staying nights after nights in playgrounds and open streets not knowing that open streets can be even more dangerous after earthquake. Frantic calls to experts and structural engineers are made to understand what to do and what not to do. The point that is missed is that not much can be done during those emergencies, and expert advices are not given due importance as emotions run high and hence more casualties. The point that is to be taken is that provisions should be made in advance such that the emergencies can be averted or at least minimized through good policy decisions. Good policy decisions can help minimize loss of life and property and more importantly the mental traumas that humanity suffers during and after the event. One such good policy that we can propose as structural engineer is the construction of steel buildings (as proposed in the paper) in highly seismic prone areas in such a way that it is least affected by earthquake. With this knowledge as back ground, our clear intent is to propose the design of a steel building with structural components (closed hollow steel sections SHS/RHS) and non-structural components (puff panels for walls and steel profiles as floor) such that seismic effect of the buildings can be eliminated or reduced to a great extent by reducing the seismic weight of the building, such that loss of life and property and more importantly mental trauma can be reduced. Another fruitful proposal is to make steel building frames with eccentric bracing systems, EBF. Here the floors could be steel-concrete composite slabs and steel beams and columns are made of wide flange rolled sections for optimization of mass in the building systems. But the problem is that, human memory is short and we tend to forget everything over a period of time. Responsible authorities should not miss the point.

Problems with Conventional Design

Basic problems with conventional RCC design are:

- Heavy weight of building and hence high seismic effect.
- Depleting natural resources in the form of fine and coarse aggregates (which are used as raw materials) thus weakening the earth and on the other hand, additional pressure in the form of heavy buildings are put on it.
- Resulting effects are frequent earthquakes, landslides and storm floods.
- High restoration time and cost of affected buildings and hence greater effect on economy.

It is to be noted that due to ease and low cost of construction, RCC building will continue to be used, but at least for selected purposes, buildings as proposed in the paper should be used. These will have desirable effects on sustainable economy of the country.

Earthquake – Weight Of Building – Ductility

It is a well known fact that seismic forces are reduced with reduction of weight of building. That ductile behavior of steel is effective in dissipating seismic forces during the period of motion and comes back to the original position most of the time without much damage. Even if there are damages, it is very limited and easily repairable. The paper uses these well known facts and advantages to design a building with steel sections in earthquake zone IV to reduce the effects of earthquake.

Bracings – Time Period – Displacement

The buildings proposed in this paper have been designed with all shear connections. Hence vertical bracings have been used. It has been observed during analysis that placing and quantum of bracings plays a key role in controlling the overall stiffness and hence the time period of the building. Higher quantum of bracings will increase the stiffness and also the earthquake forces which are not desirable. On the other hand inadequate bracings will increase displacement/drift of the building which a steel building will be efficient to resist because of ductility but will cause discomfort to inhabitants. Hence proper judgment is to be used to place bracings. It can vary with configuration of building. Proper review of analysis results will be required before proceeding with design. In the case of low weight building bracing system should not cause any adverse effect. Moreover, it will establish structural stability in the building skeleton frames and ease of connection details.

Design Of Steel Building Using SHS & RHS

- Materials used for columns, beams and bracings would be closed steel square/rectangular hollow sections of yield strength fy = 315 N / mm^2.
- Partition walls would be of low weight puff panels or glass as per architectural requirements.
- Flooring would be of stiffened steel plate of 6mm thickness/wooden with horizontal bracings.
- Response spectrum analysis has been done. Cross checked by p-delta analysis.
- Wind analysis has been performed. Basic wind speed assumed as 47m/sec.

- Following drawings are furnished to show the structural arrangement and achieved sections.
- Connections to be provided as per analysis assumptions.
- Ductile property of steel an advantage for earthquake resistant design has been acknowledged.
- Importance has been given to reduction of weight of building by using low weight structural and non structural materials.

Intent is to design a building in earthquake zone IV in such a way that it is least affected by earthquake.

Results

Results achieved justify the intent to a great extent and are summarized below:

Design results reveal that more than 90% of the members are critical in Dead load, Live load and Wind Load combinations.

Even the balance 5-10% of the members which show criticality to earthquake forces are very marginal.

Only those members (mainly columns) which are in proximity to the vertical bracings show criticality to earthquake forces which need slightly heavier sections.

Design of Steel Building Using EBF System

In the present problem, a (G+4) commercial building with long span grid frame is analyzed using STAAD Pro providing three types of connections i.e. eccentric bracing connection, moment connection and chevron bracing connection. Floor to floor height is considered 3m. (ground floor 2.5m) and column to column spacing is considered 9m. Columns and beams are made of steel beams and floors are made of concrete slab. The composite behavior of steel beam and concrete slab is considered in the analysis. Live load is considered 4 kN/m^2. The beam size, column size etc. are described for different frame as follows:

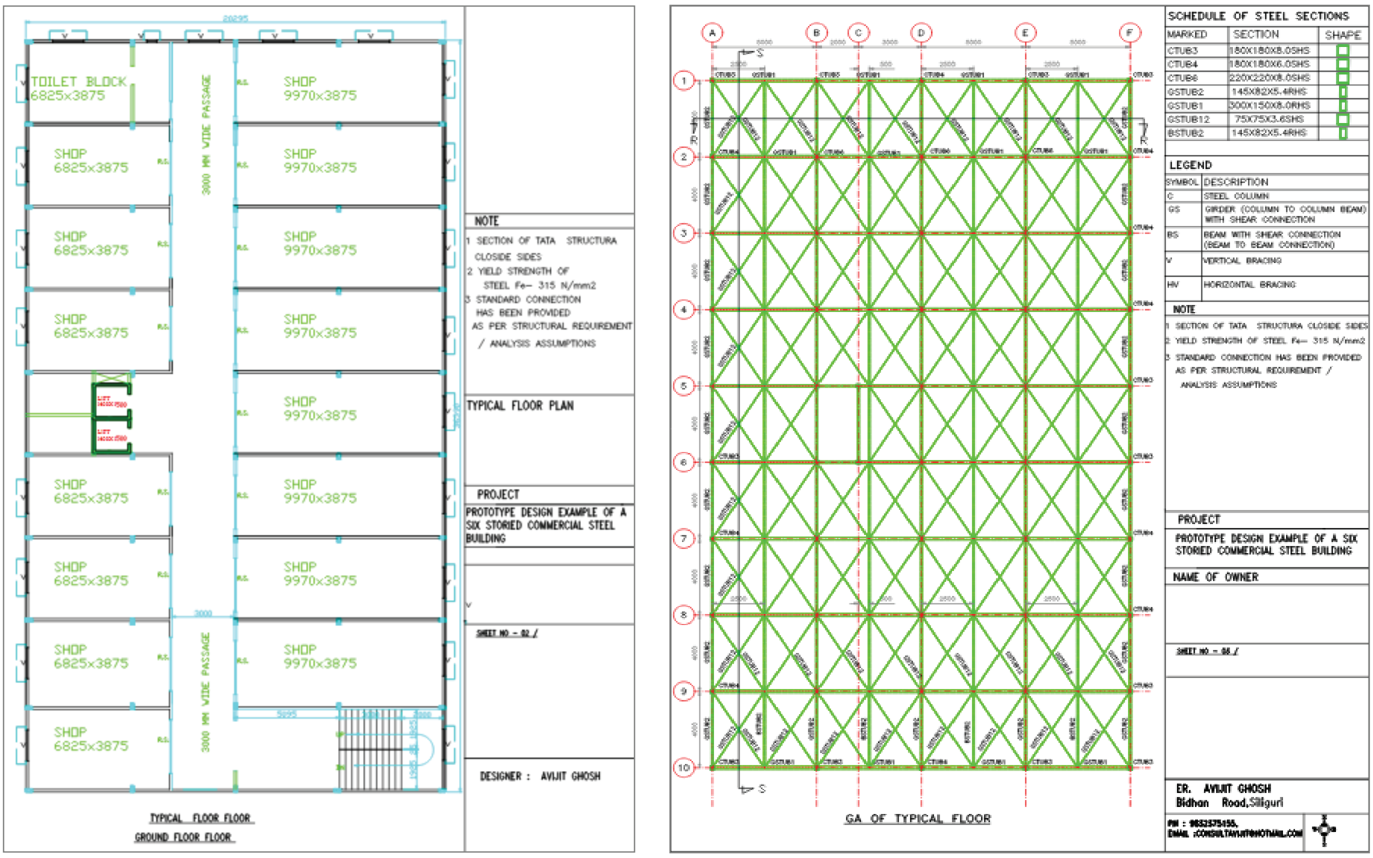


Fig. 1: Plan

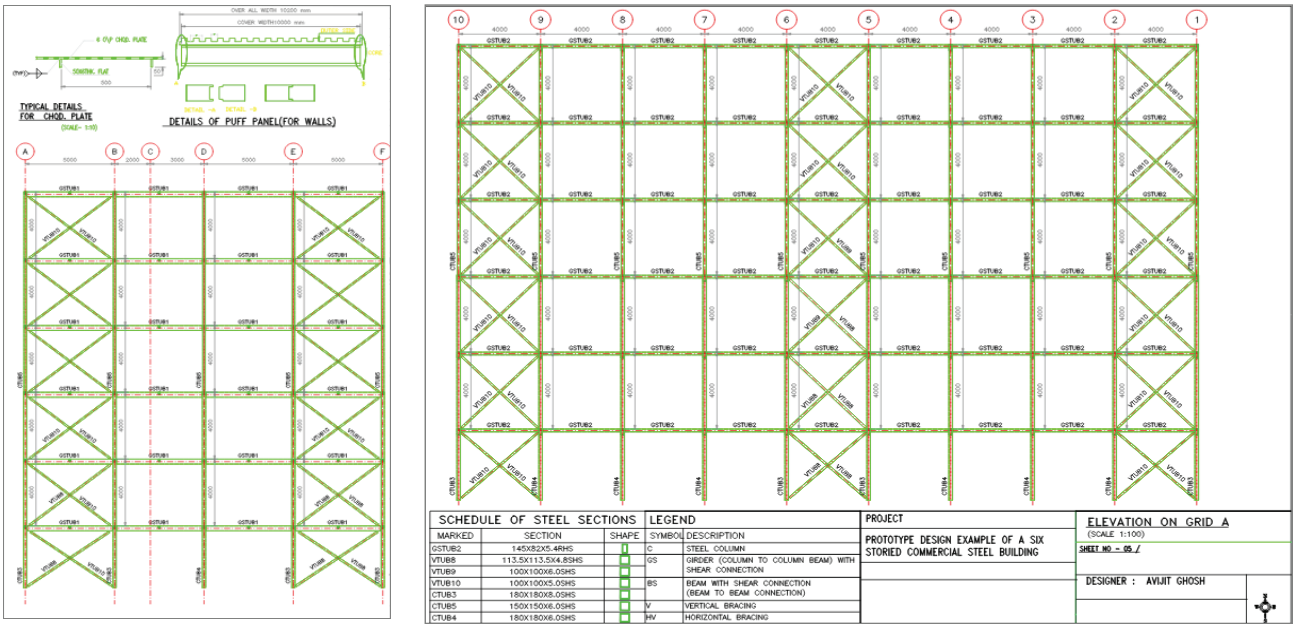


Fig. 2: Elevations

EBF

The bottom two stories of column are made of UC 305x305x118 + 2 WEB PL. 100x10 THK. Top portion of column is made of UC 305x305x97. Composite beams are made of UB 305x165x46 + 3000x200 THK slab connected with shear connection at end. Link beams are made of ISMB 300 (Grade Fe 540B) connected with moment connections at end. Bracing members are made of star angle 2-L 130x130x12. The frames are subjected to earthquake force of Zone IV of IS: 1893 – 2016. Response spectrum analysis is done for the frames (Figure 3).

MRF

The bottom two stories of column are made of 2-FLG. PL. 400x20 + 1-WEB PL. 660x16. Top portion of column is made of WPB 600x300x128.8. Composite beams are made of ISMB 300 + 3000x200 THK slab connected with moment connection at end. Similar response spectrum analysis is done for the frames (Figure 4).

CBF

The bottom two stories of column are made of UC 305x305x118 + 2 WEB PL. 100x10 THK. Top portion of column is made of UC 305x305x97. Composite beams are made of UB 305x165x46 + 3000x200 THK slab connected with shear connection at end. Bracing members are made of star angle 2-L150x150x12. The frame is subject to similar response spectrum analysis (Figure 5).

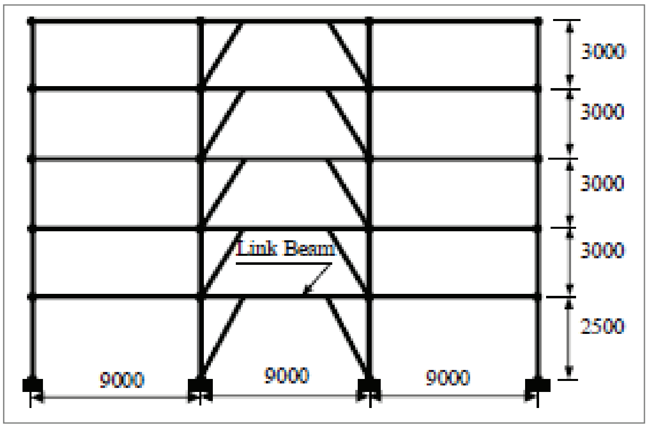


Fig. 3: Long Span Steel-Concrete Composite EBF Frame

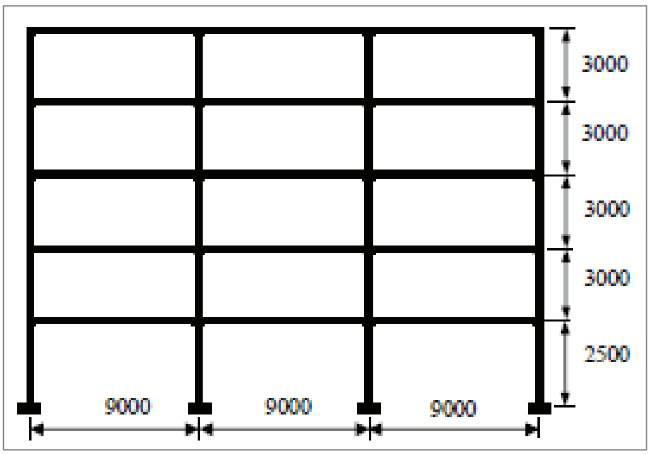


Fig. 4: Long Span Steel-Concrete Composite MRF Frame

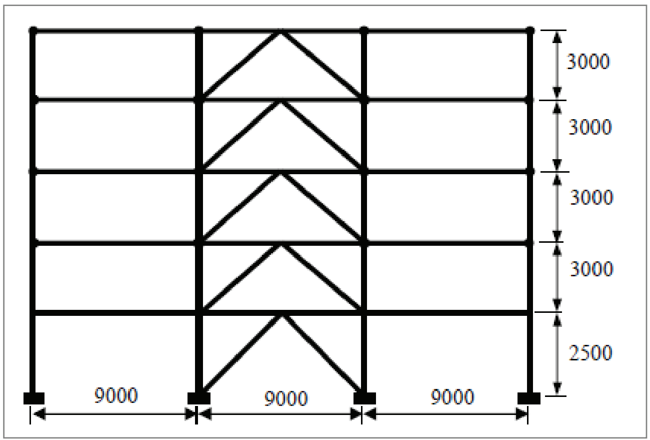


Fig. 5: Long Span Steel-Concrete Composite CBF Frame

Results

After analyzing the above three frames it is observed that during seismic load amplitude of vibration is maximum in EBF system thus the frequency is less than other two systems as shown in Table 1. Maintaining the limiting deflection criteria of code, the frequency in EBF system 0.685 Hz i.e. the time period of fundamental mode is 1.46 sec. The reserve strength compared to CBF of base shear participation in this case is 2.1. This frequency range is not falling with the acceleration amplification zone.

Results of MRF system are similar to that of EBF system. But the cost of connections is much greater than EBF system. The worst result came from CBF system. The frequency is 1.8 Hz. (nearer to 2 Hz.) which is falling in acceleration amplification zone. As the system is rigid the reserve strength in base shear participation is nil. So, EBF system should always be adopted because of its ductile behavior and reduced cost of connection.

Thus considering efficiency, the EBF system shall be applied in modern building systems. The IS: 1893-2016 code also says that response reduction factor (R) for EBF and MRF system is 5 and that for CBF system is 4. For the safety against collapse, the EBF system has more reserve strength and it will stand even experiencing a major earthquake force. The column sections in EBF system are designed for axial load only. Floor beams will have the composite action for the full length. These features give economy in steel quantity than MRF system. So EBF system is getting more popularity over MRF system and CBF systems nowadays.

Table 1: Study of Flexibility of EBF, MRF & CBF System

	STEEL FRAME		
	EBF	MRF	CBF
TIP DEFLECTION (mm) < H/200	64	55	13
FREQUENCY (Hz)	0.685	0.8	1.8
VB/vb	2.1	1.9	1.0

Conclusions

Findings encourage the initial assumption of steel buildings in highly seismic prone areas. Initial cost can be an issue compared to RCC building. Government initiative needs to be taken such that all important buildings such as railway stations, airports, bureaucratic offices, municipal offices, hospitals, telephone exchanges which are run by govt. should be steel buildings. Then it should be extended to all schools, colleges and other buildings which are marked important as per IS codes. Regulations should be in place to encourage such buildings in zone V and hilly areas in zone IV.

References

- IS: 800 (2007) – Indian standard for general construction of steel – code of practice
- IS: 1893 (2016) – Indian standard of criteria for earthquake resistant design of structures
- IS: 875 Part 3 (2015) – Indian standard for wind load
- A Saha Chaudhuri (2013), “Utility of Eccentric Bracing Frames in Seismic
- Resistant Sustainable Steel Buildings”, Proceedings of ISEUSAM 2012 AT IIEST, SHIBPUR, Springer India publication, pp 905-9011.
- A Saha Chaudhuri and A Ghosh (2021), “Buildings in Severe Earthquake Zones Made of Structural Steel Hollow and Plate Members”, Proceedings of 5th World Congress on Disaster Management at IIT Delhi, Routledge publication, pp 415-418.

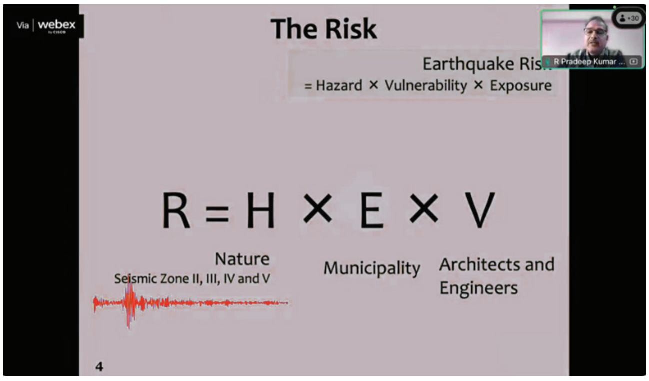
Understanding Earthquake Risk in India: Challenges and Opportunities | NIDM

With the ever increasing seismic activities across the country, it is extremely important that the right level of awareness is created among different stakeholders to ensure a safe built environment. The National Institute of Disaster Management (NIDM), Ministry of Home Affairs, Govt. of India, under the leadership of Shri Safi Ahsan Rizvi, Executive Director, aims to foster the much-needed capacity building in this regard through a series of webinars. This is organized in collaboration with the **Seismic Academy, an initiative by Hilti India Pvt. Ltd.** The first session of the series was held on 10th July 2025 on the topic **"Understanding Earthquake Risk in India: Challenges and Opportunities"** delivered by **Dr. Pradeep Kumar Ramancharla, Director, CSIR Central Building Research Institute (CBRI), Roorkee.**

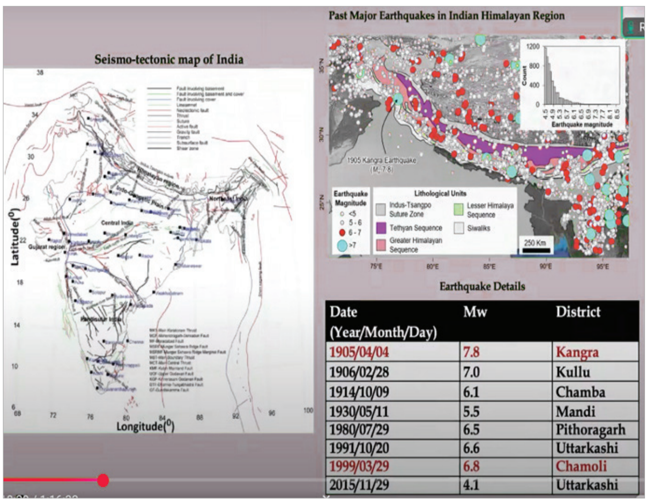
Dr. Amir Ali Khan, Head Resilient Infrastructure Division NIDM, and Mr. Shounak Mitra, Head-Codes & Approval, Hilti India Pvt. Ltd. set context of the session with the background of the recent tremor that was experienced in the northern part of the country, reminding us of the vulnerability of the country to seismic hazards. As per the Vulnerability Atlas of India, **nearly 60% of India's landmass is prone to moderate to high seismic activities,** underlining the urgency for structural resilience, urban risk reduction strategies, and community-level awareness. Statistical data reveals that over the last decade, the number of earthquakes of magnitude 4 or more which have occurred in and around India, would go as high as 20+ per month.

Dr. Pradeep started with the understanding of earthquake risk in India, challenges and opportunities.

Dr. Pradeep mentioned that risk has three important parameters - the **prevailing hazard,** the extent to which **infrastructure and people are exposed,** and the **vulnerability of the infrastructure** and finally, the way in which the risk is constituted or computed for mitigation. When it comes to hazard, it is in the form of ground shaking which is measured through the seismic zones Exposure is controlled by municipalities through factors such as floor space index (FSI) and land use regulations while vulnerability is influenced by the contributions of architects and structural engineers. Hazard is determined by nature. The hazard cannot be controlled; however, exposure and vulnerability are controllable parameters which enables us to be more prepared in the event of an earthquake.



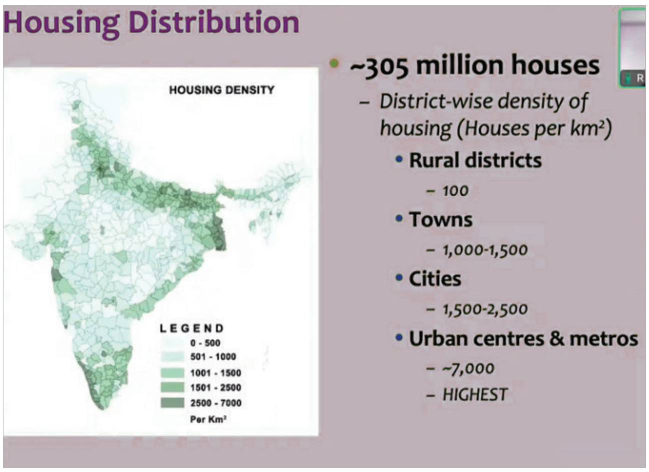
The seismotectonic map of India shows around 1,000 active faults. Generally, if an earthquake has occurred at least once in the last 10,000 years, it is considered as an active fault. Many of these earthquakes act as constant reminders to further work towards safety.



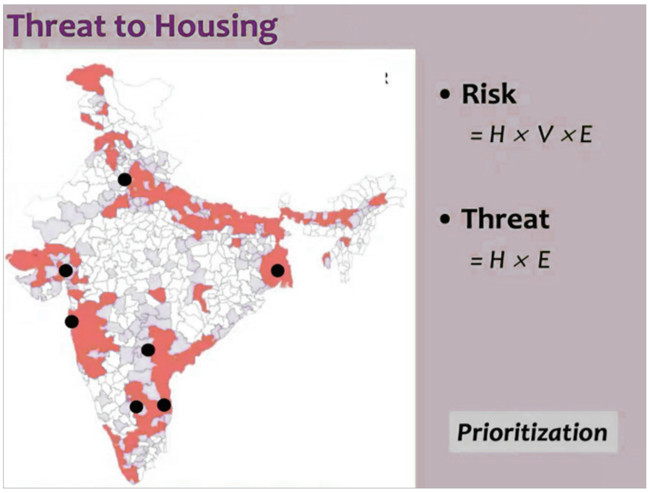
In particular, the Himalayan region has experienced numerous earthquakes, with magnitude ranging from 4 and going as high as almost 9.

Dr. Pradeep touch-based on the fact that after several refinements, the proposed draft of IS 1893 aims to replace the existing four seismic zones with five zones and increase the values of peak ground accelerations to enhance safety of buildings and built infrastructure. Seismic hazard assessment is the process of evaluating the design parameters of earthquake ground motion at a given site which include the amplitude, duration and frequency content. The hazard can be categorized as macro hazard, micro hazard and site specific seismic hazard. Macro hazard increases confidence of safety and examines the adequacy of design in next earthquake. Micro aims at risk assessment and disaster management, regulate land use planning and building design. Site specific seismic hazard assessment is required for design of special structures and tall buildings.

With a significant population in the country, the distribution of housing corresponds to the population concentration in different regions, which is categorized based on density — from small towns to metropolises and meg-policies. Accordingly, appropriate mitigation measures may be taken.

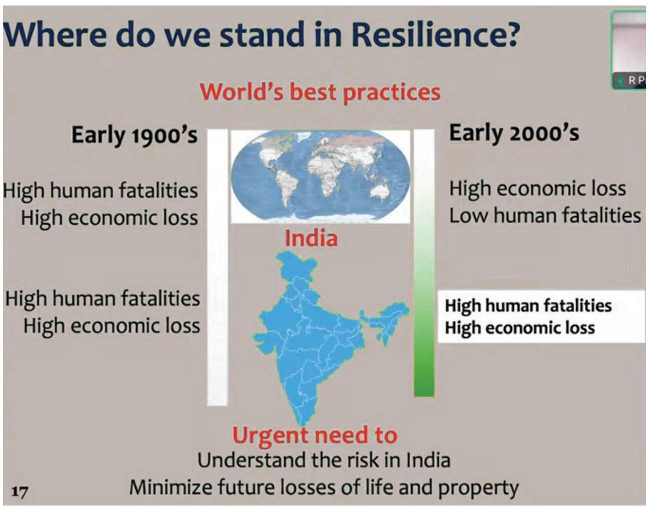


Risk is the combination of hazard, vulnerability, and exposure. Hazard and exposure together are referred to as threat.



For example, if an earthquake were to occur in a primary economic centers, the impact would be severe. Therefore, it is of paramount importance that before the next moderate earthquake strikes the said area, mitigation activities and measures are implemented. Speaking of the impact of earthquakes over the last two to three decades, there have been 50,000 lives lost in earthquakes, 5,00,000 buildings collapsed, one million severely damaged and collapsed and 5 million severely damaged,

Inspite of all the technological advancements which have happened in the field of engineering over the past decades, both high human fatalities and high economic losses still persist because of multiple reasons. There is an urgent need to better understand earthquake risk and take necessary steps to minimize future losses to life and property.



There are four major challenges which are observed on ground currently which can be broadly covered as follows:

- **Inadequate seismic instrumentation –** Lack of near-field recordings hampers the development of accurate ground response spectra, site specific design and seismic hazard maps. Without near-field ground motion records, the spectral data we use in IS 1893 (meant for seismic hazard assessment in plain areas) is also applied to hilly areas, which is a serious lacuna that needs to be addressed.
- **Non-compliance with building codes -** Despite the availability of adequate Indian standards (e.g., IS 1893, IS 4326, IS 13920, IS 13935, IS 15988), enforcement remains weak. Retrofitting of existing vulnerable structures is not proactive, particularly for hospitals and schools. In a small town, public buildings account for about 10–15% of the total numbers, while in large cities, the percentage is slightly lower (around 5–7%).
- **Low risk awareness and preparedness -** Public awareness campaigns and earthquake drills must be conducted. In terms of preparedness, technical education and skill upgradation among the public is extremely important. Disaster preparedness is not yet fully integrated into the curriculum of academic institutions and urban planning. The key requirements include sensitization, content preparation, creation of adequate facilities, media linkages, mass media campaigns, and awareness programs for policy makers.
- **Data gaps and research deficits –** There are limited site-specific micro zonation studies and these studies have often been conducted only to a certain level, with the end-user perspective still missing. In most cases, the results have not been translated into public use.

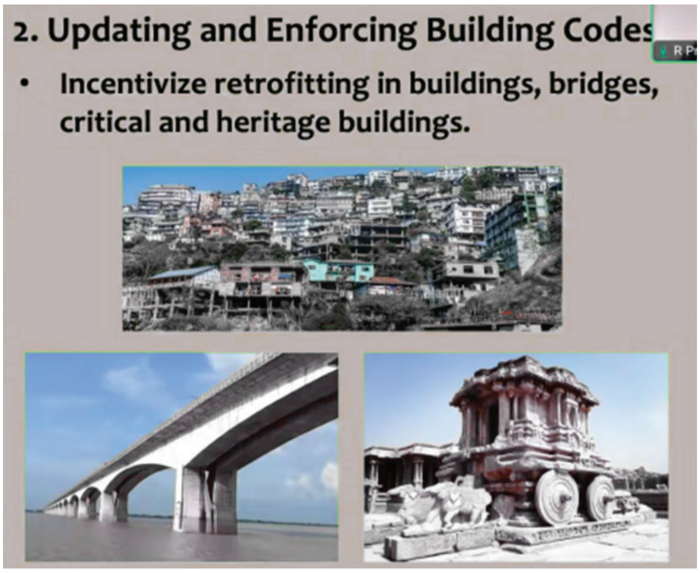
Dr. Pradeep explained the opportunities in terms of the following –

- Installation of SMS (Strong Motion Sensors)
- Updating and enforcing building codes
- Capacity building and funding engagement
- R&D and Innovation

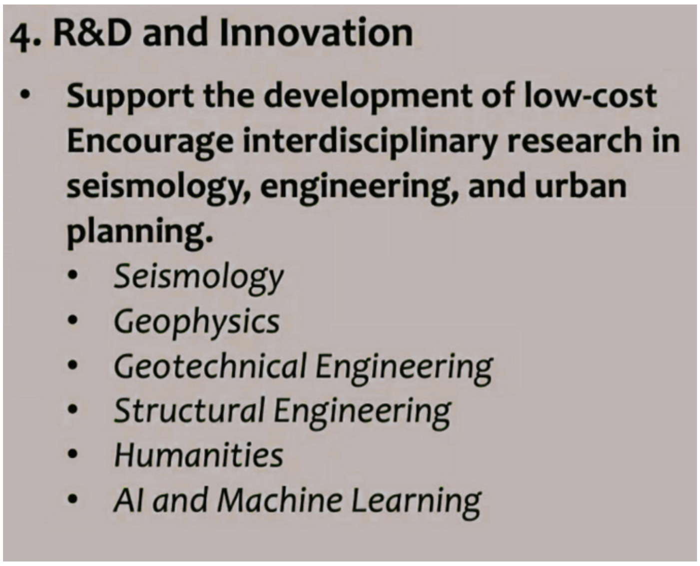

1. Strategic Installation of SMAs
• Prioritize the deployment of SMAs in the IHR and urban centers for better hazard modeling and real-time response.
• IS16700-Cl 11.1 recommends
• All tall buildings in seismic zone V
• Buildings Exceeding 150 m in Zone III, IV


2. Updating and Enforcing Building Codes
• Strengthen coordination between central and state governments for code compliance.
मानकः पथप्रदर्शकः
Bureau of Indian Standards


2. Updating and Enforcing Building Codes
• Introduce digital monitoring platforms for construction safety.
• Use of advanced technologies

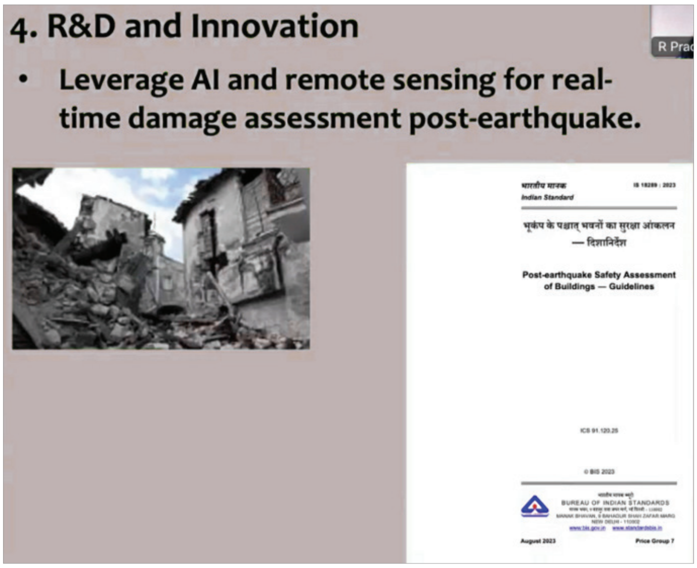

2. Updating and Enforcing Building Codes
• Incentivize retrofitting in buildings, bridges, critical and heritage buildings.


3. Capacity Building & Public Engagement
• Organize nation-wide seismic safety campaigns.
• Know what you'll face.
– Part of preparation is knowing exactly what kind of disasters you might face and
– knowing what to do in each situation.


4. R&D and Innovation
• Support the development of low-cost Encourage interdisciplinary research in seismology, engineering, and urban planning.
• Seismology
• Geophysics
• Geotechnical Engineering
• Structural Engineering
• Humanities
• AI and Machine Learning

He added that any new technology can be utilized to develop effective early warning systems. It is also important to encourage interdisciplinary activities—integrating seismology, geophysics, humanities, artificial intelligence and machine learning — to create innovative solutions.

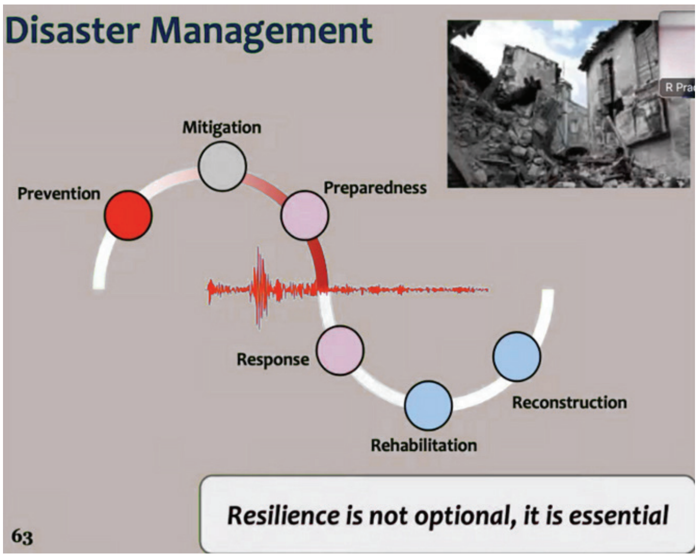
He touch-based on the recently published standard IS 18289 which introduces the concept of tagging of building during post-earthquake assessment surveys (e.g., Red Tag for buildings not safe for occupancy, Green Tag for buildings safe for occupancy, Yellow Tag where further inspection is needed and Black Tag where the building is extremely dangerous and must be demolished immediately)



Currently, this process is done manually and there is a scope for automation. Drone-based surveys can be used to quickly assess large numbers of buildings, significantly speeding up the process.

Dr. Pradeep introduced a Quick Guide to Retrofitting, which presents a quick, cost-effective, and scalable retrofitting technique, referred to as the Stable Technique. It is designed mainly for masonry buildings, but with slight modifications, can also be applied to RC buildings. The technique emphasizes the use of seismic bands to provide stability during earthquake shaking.

He summarized by mentioning that disaster management consists of six key components - prevention, mitigation, preparedness, response, recovery, and rehabilitation.

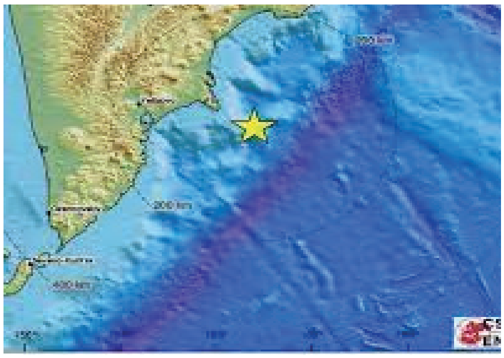


In the case of earthquakes, prevention is not possible. Therefore, the primary focus should be on mitigation, to reduce the potential damage and on preparedness for whatever residual risk remains. He added that resilience is not optional - it is an absolute necessity and urged to retrofit all the vulnerable structures to ensure they can withstand seismic events and protect lives.

The session ended with a Q&A, followed by vote of thanks.

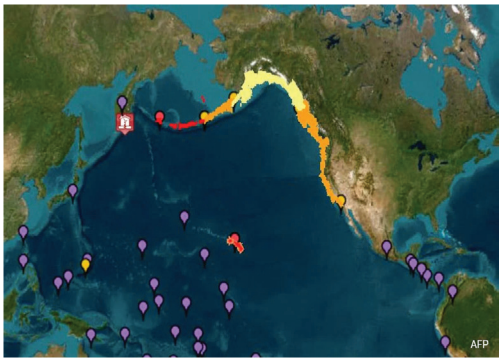
Global Earthquake Report

Russia



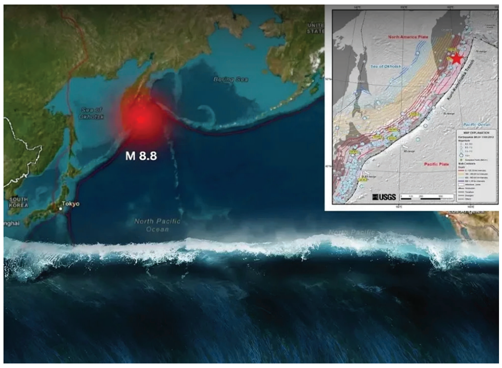
- Date: 20 July 2025
- Magnitude: ~ 7.4
- Epicenter: 144 km east of Petropavlovsk-Kamchatsky, depth ~20 km.
- Impacts: No major casualties or damage reported.

Russia (Kamchatka Peninsula)



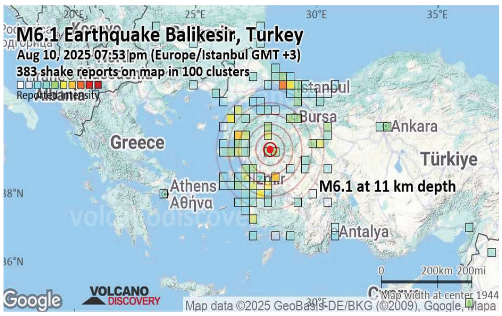
- Date: 29 July 2025
- Magnitude: ~ 8.8
- Epicenter: Off the eastern coast of the Kamchatka Peninsula, in the Kuril–Kamchatka Trench region, ~20–21 km depth; about 119 km east-southeast of Petropavlovsk-Kamchatsky.
- Impacts: Moderate damage in Kamchatka Krai and Sakhalin Oblast; injuries and one indirect death.

Russia (Kamchatka)



- Date: 29-30 July 2025
- Magnitude: ~ 8.8
- Epicenter: Offshore the eastern coast of Kamchatka Peninsula, Kuril–Kamchatka Trench; ~21 km depth.
- Impacts: One death (indirect), ~25 injuries.
  Tsunami warnings/advisories across Pacific, small tsunamis in nearby coastal areas.
  Significant aftershock activity; some damage in local areas, though due to remote region damage was limited.

Turkey

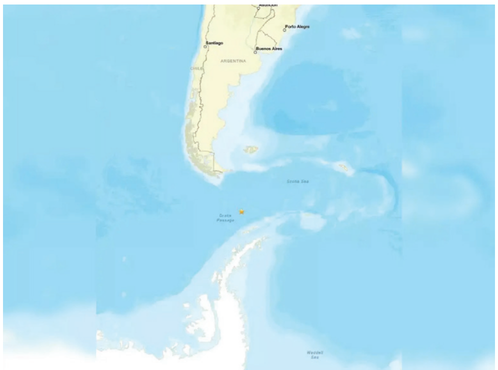


- Date: 10 August 2025
- Magnitude: ~ 6.1
- Epicenter: Sındırgı district, Balıkesir Province, western Turkey; south-southwest of Bigadiç.
- Impacts: 1 person dead, ~52 hospitalized.
  Many buildings damaged: a three-story apartment block collapsed; ~729 buildings severely damaged, plus dozens slightly damaged.
  Damage to mosques (73 affected), other public buildings; sinkhole in a rural area.

Indonesia (Sulawesi)

- Date: 17 August 2025
- Magnitude: ~ 5.8
- Epicenter: Central Sulawesi, ~12 km north-northwest of Poso; depth ~8 km.
- Impacts: 2 deaths, 44 injured.
  Church partly collapsed during service; damage to homes, schools, health post, villages.
  Minor tsunami triggered; disrupted daily life in affected areas.

(Southern Ocean / Antarctica region) Drake Passage, between Chile & Antarctica



- Date: 22 August 2025
- Magnitude: ~ 7.5
- Epicenter: Southern Drake Passage, ~710 km southeast of Ushuaia, Argentina; depth ~10.8 km.
- Impacts: No reports of human casualties or damage.

Afghanistan (Eastern provinces: Kunar, Nangarhar, Laghman, etc.)

- Date: 31 August 2025
- Magnitude: ~ 6.0
- Epicenter: Near Nurgal District, Kunar Province; ~8 km depth; shaking felt in multiple eastern provinces; also felt in nearby Pakistan and some northern India (Delhi etc.)
- Impacts: Over 2,200 deaths, thousands injured; many homes destroyed/damaged (5,230 homes destroyed in 49 villages; more villages unreachable).
  Severe damage to infrastructure: local health facilities overwhelmed; many villages remote with blocked roads; risk of exposure, lack of shelter, looming winter threats.

Afghanistan (aftershocks variant)

- Date: 4 September 2025
- Magnitude: ~ 6.2
- Epicenter: Southeastern Afghanistan, in or near Nangarhar Province (Shiwa district) close to the Pakistan border.
- Impacts: Significant damage especially in Kunar and Nangarhar provinces.
  Aftershocks further destroyed homes already weakened; many more people displaced.

The Awakening For A Safe Habitat

Let's Join Hands to Make Our Structures Safer and More Resilient

In an era marked by increasing structural failures, collapsing buildings, and deteriorating infrastructure, the safety of our built environment demands urgent attention. Recognizing this growing concern, Creative Design Consultants & Engineers Pvt Ltd. (CCEPL), under the visionary leadership of its Managing Director, Mr. Aman Deep, organized a landmark public awareness event titled "The Awakening for a Safe Habitat" on 12th July 2025 at Silver Spoons, Ghaziabad.

The event was a culmination of multiple objectives:

- To educate stakeholders on the importance of periodic structural inspections.
- To offer a common platform for dialogue among users, policymakers, consultants and contractors.
- To unveil "SAAR" – a dedicated wing of CCEPL focused on preserving the built environment.
- To celebrate the successful completion of the 12-week Skill Development and Training Program on Structural Audit of RCC Structures.

As India's urban footprint grows, the silent deterioration of buildings due to age, poor maintenance and lack of structural awareness poses a real threat. With many buildings designed decades ago under outdated codes, and having exceeded their service lives, the absence of periodic audits and professional evaluations has made them susceptible to failures. This event served as a wake-up call — not just for professionals, but for the society as a whole.

"SAAR" – Structural Audit, Assessment and Research

SAAR, publicly launched during the 12th July event, is a flagship initiative of CCEPL designed to address the deep-rooted issues plaguing structural safety. Its vision is grounded in the philosophy.

SAAR focuses on a 3-fold mission:

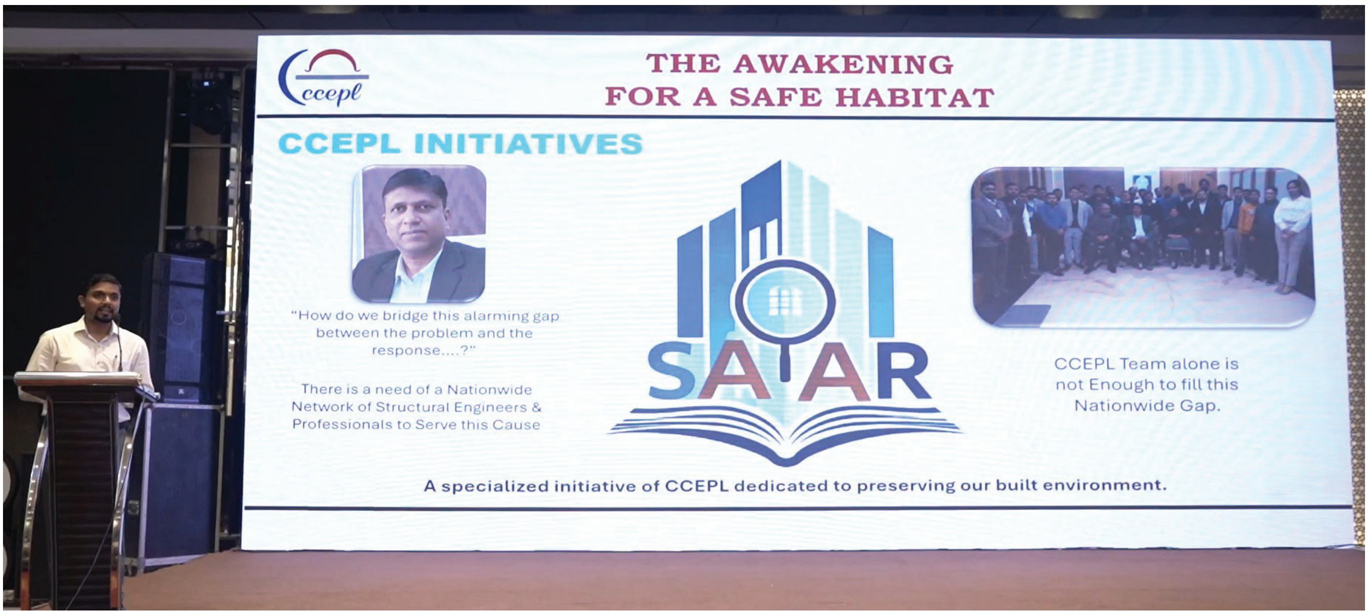
- **Awareness campaigns** for all the stakeholders including users, administrators, and policymakers.
- **Skill development** of engineers & professionals in Structural Audit & Assessment including repair techniques.
- **Applied research** in real-world retrofitting and monitoring of distressed structures.

In its very first initiative, SAAR launched a 12-Week Skill Development and Training Program on "Structural Audit of RCC Structures." This program aimed to build a nationwide cadre of engineers well-versed in evaluating, testing and recommending practical solutions for buildings in distress.

The 12-week program, led by senior experts and curated by Dr. Ankur Gupta, covered a range of essential subjects relevant to today's-built environment:

- Introduction to RCC Structures and Inspection Skills
- End-to-End Structural Audit Process
- Identification of Structural Challenges
- Waterproofing and Dampness Issues
- Corrosion Mechanisms and Mitigation
- Expansion Joints, Separation Joints, Construction and contraction joints behaviour in Structures
- Crack Classification and Assessment
- Non-Destructive and Minimal Invasive Testing
- Design Considerations in Rehabilitation
- Repair, Rehabilitation, and Retrofitting Strategies

Participants included practicing engineers, auditors, consultants, and government officials from across the country. The program emphasized not just academic learning, but practical, field-oriented training aligned with the latest BIS and International standards.



The 12th July 2025 Event: An Evening of Insight and Commitment

The program was formally opened by Er. Rhythm Garg, who introduced CCEPL's mission and vision. She highlighted the firm's commitment to strengthening the built environment through technically sound and sustainable engineering practices. CCEPL, she explained, is driven not by commercial interests alone, but by a vision to create a safer habitat through responsible consulting, training, and collaboration.

The technical tone of the event was set by Dr. Ankur Gupta, who shared the journey of launching SAAR and developing the 12-week training program. He emphasized the urgent need for a systemic approach to structural health, citing that our response to visible signs of distress such as cracks, corrosion, and water ingress has often been superficial. He stressed that every building, like a living being, ages and needs routine assessment and care. When we fail to understand "what to look for", "whom to connect with", and "how to respond", our built environment begins to collapse both physically and systematically.

The keynote address was delivered by Shri Sanjay Pant, Deputy Director General (Standardization), Bureau of Indian Standards, who emphasized the integration of sustainability principles in the audit, assessment, and retrofitting of structures.

The Guest of Honour, Prof. Bhattacharjee from IIT Delhi, shared real-life experiences from structural failures and audits he has conducted across India. He detailed how premature deterioration often stems from minor neglect and underlined the importance of building users and RWA members being technically informed and proactive.

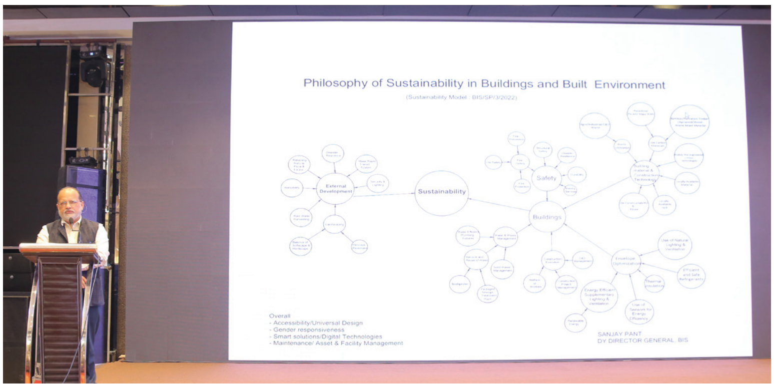
Insights from Mr. Aman Deep: From Practice to Policy

A highlight of the evening was the address by Mr. Aman Deep, Managing Director, CCEPL, who spoke not only as a practitioner but as a policy contributor. As a technical expert on multiple BIS committees, he has played a vital role in shaping several Indian Standards, including the National Building Code (NBC) and the upcoming standards on Structural Audit Services. He spoke about the significant strides made in code development and policy reforms, including the National Building code of India and BIS publication SP73, which now mandate structural audits for high-rise and special buildings after 10 years of occupancy, and every 5 years thereafter.

He presented multiple case studies, including recent failures due to water seepage, corrosion, unauthorized modifications and lack of audit mechanisms. Through detailed analysis, he highlighted that most collapses could have been prevented through simple, periodic interventions. He emphasized that structural audits are not just technical obligations but instruments for public safety, cost-effective maintenance and regulatory compliance.

Mr. Aman Deep also shared 5 Essential Points to Check Before Buying Any Property, a practical tool for property buyers to make informed decisions:

- Details of the structural consultant of the building project and the credibility of the consultant.



- Structural safety certificate issued by a competent structural engineer covering earthquake safety zone, height of the building, number of floors and compliance with the Indian National Building Code (not older than 5 years).
- Structural condition assessment report verifying that there is no dampness, structural cracks or corrosion in the reinforcement (steel).
- Structural drawings of the building covering the foundation, columns, beams, slabs, etc., for information on size and reinforcement details.
- No deviation from the structural design drawings in terms of size and location of columns/beams, and there should be no visible deflections, cracks, settlement, or seepage in the building.

These five points were widely appreciated by the attendees, particularly housing society representatives, and are now being circulated as a part of public awareness campaigns by CCEPL.

Panel Discussion and Collective Commitment

The event concluded with a dynamic panel discussion involving auditors, engineers, government officials, and policy influencers. The panel was formed with experts of mix domains – Shri Sanjiv Gupta, IAS (Former Secretary, Ministry of Home Affairs, Government of India), Shri Sanjay Pant (DDG,BIS), Shri P K Gupta (Former CMD, NBCC), Dr Shweta Goyal (Prof and Head, Civil Engg Department, Thapar Institute of Engineering and Technology), Prof. B. Bhattacharjee (former Prof IIT Delhi), Prof Vasant Matsagar (Head, Civil Engineering Department, IIT Delhi), Prof Chandan Ghosh (former Prof NIDM) which was moderated by Er Aman Deep (Managing Director, CCEPL). The discourse revolved around preventive maintenance strategies, the integration of structured audits into the approval processes, and ways to empower RWAs and local bodies.

All the stakeholders present unanimously advocated for the mandatory structural health assessment and monitoring of buildings, especially those that have outlived their original design life or show signs of distress.

Way Forward: A Movement for Structural Safety

The Awakening for a Safe Habitat was not merely an event it was the beginning of a movement. With SAAR, CCEPL is laying the foundation for a nationwide framework that connects expertise with execution, policy with practice, and awareness with action.

The event sent out a clear message: Safety is not an option it is a responsibility. Whether you are a builder, consultant, buyer, policymaker, or resident, the time to act is now.

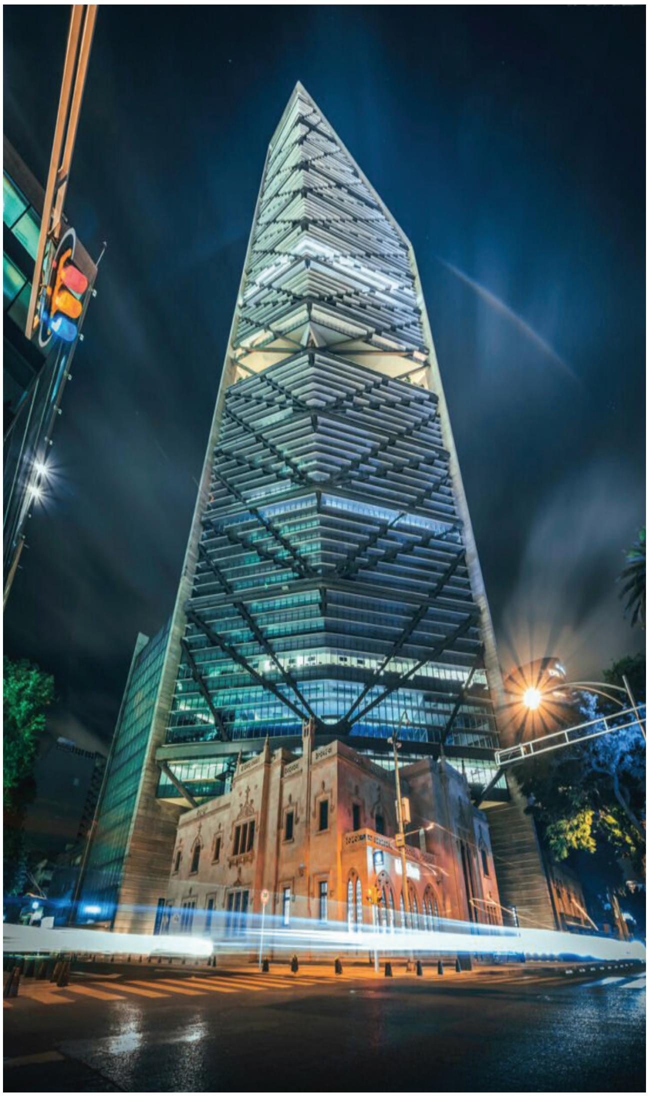
Torre Reforma

Combining a Striking Aesthetic and Earthquake Resistance

Mexico City sits on a plateau 2,240 meters above sea level, surrounded by mountains and volcanoes. This stunning location comes with challenges—frequent earthquakes that put every building to the test.

Amid this dramatic setting soars Torre Reforma, a 246-meter-tall, 57-story mixed-use tower that transformed the city's skyline and redefined shows how modern skyscrapers can excel in design, performance, and sustainability.

Conceived through a collaboration between Arup and L. Benjamin Romano Arquitectos, Torre Reforma's distinctive triangular profile is supported by a diagrid façade, interlocking shear walls, and deep-pile foundations—ensuring that its striking appearance is matched by uncompromising seismic safety.

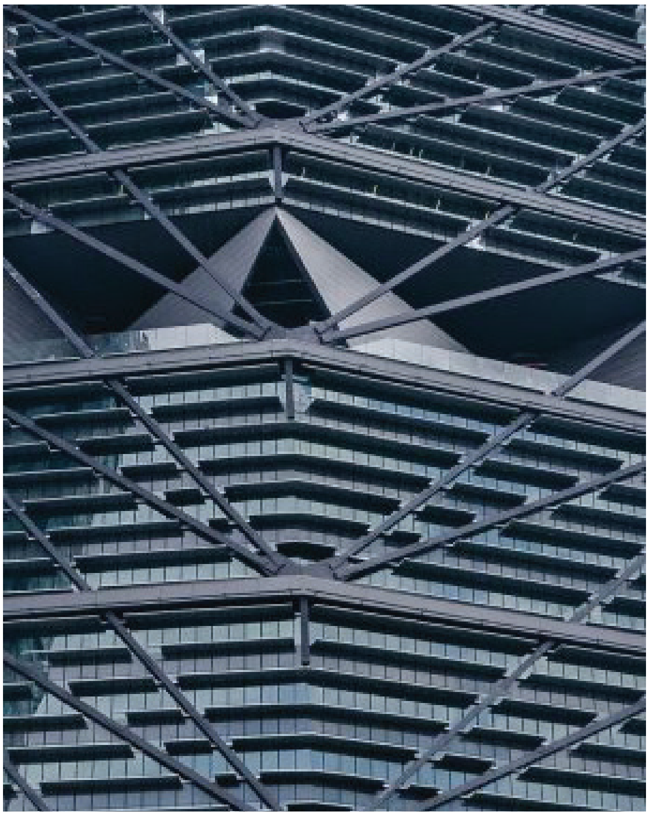


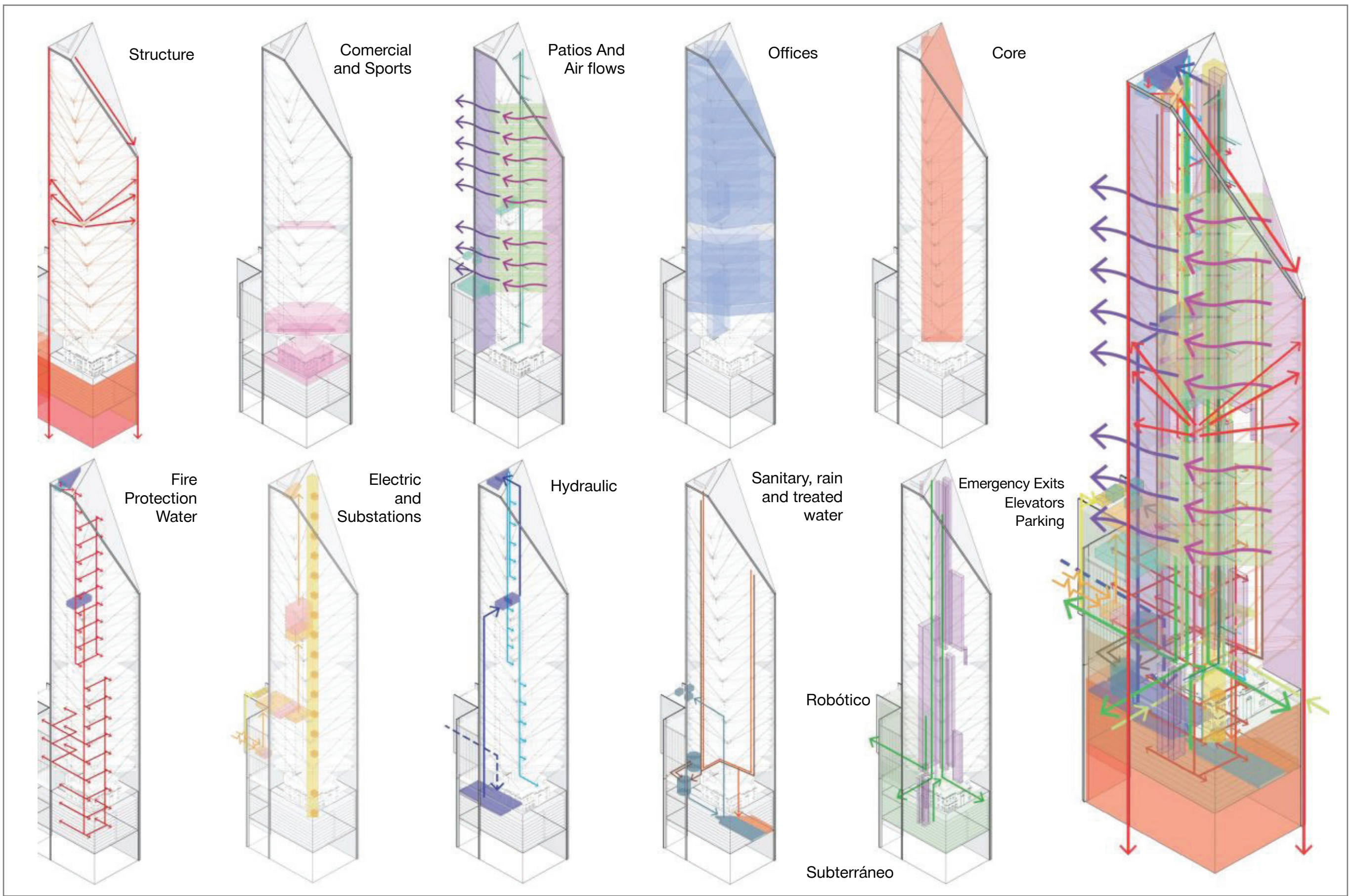
"Arup has been indispensable in helping to transform my architectural vision into an efficient and buildable structure," said Benjamin Romano, Principal of LBRA, in a press release. "They have provided innovative solutions to the complex seismic issues in Mexico City and have been instrumental in helping the bidding contractors understand that Torre Reforma is not more complex than standard vertical construction; it just applies traditional construction methods, that contractors are already familiar with, in a new and different way."

Torre Reforma's sharp, three-sided profile called for bespoke seismic solutions. On its upper floors, steel cross-bracing membranes tie the façades together, keeping the tower stable during tremors. The analysis undertaken to support the building's structural scheme utilized non-linear material behaviour to explicitly measure the dissipation of seismic energy. It confirmed that the structure would be undamaged during a service-level seismic event and that life safety would be preserved, even under the extreme case of maximum considered earthquake event (2475 year return period).

In a city famed for its seismic activity, Torre Reforma combines an interlocking concrete shell with a steel diagrid envelope, using performance-based seismic design to dampen vibrations and preserve structural integrity. A central core, tethered to the perimeter by steel outrigger trusses, resists both wind shear and seismic jolts. By placing that core near the building's center of gravity and reinforcing the southwest face with a fine steel-mesh of V-hangers, each floor plate gains extra stability under lateral loads. Meanwhile, massive reinforced-concrete shear walls, linked by slender coupling beams, flex and dissipate seismic energy.

In addition to its tectonics, the building's circulatory aspects were another area of focus. In conventional skyscrapers, vertical circulation is typically located in the central core of the building. However, with a triangular floor plan, the designers strayed away from using the central core. At Torre Reforma, the elevators and egress stairways are contained in the apex of the triangle. This, paired with the long-span pyramidal floor trusses that allow plumbing, electrical, and mechanical systems to be concealed within the structure, results in maximum ceiling heights and a column-free interior, facilitating unobstructed, dramatic views over adjacent Chapultepec Park and the city from every level. The triangular concrete walls act as both structural and





architectural elements, giving the tower its iconic "open book" silhouette.

Because of its triangular plan, the building has an inherent tendency to twist when subjected to lateral loads and wind, not to mention earthquake forces. Arup applied a comprehensive time-history analysis to establish the performance of the structure under extreme seismic conditions and engineered a solution that is both locally appropriate and consistent with international best-practice designs for tall buildings.

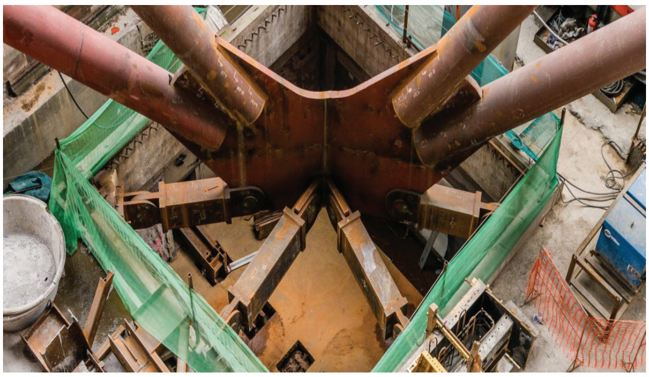
Additionally on the concrete faces, triple-height windows were installed every four floors allowing the walls bend under stress without breaking.

The solid concrete structural and architectural facades are influenced by Pre-Hispanic and colonial Mexican architecture, in which tectonic materials such as stones were predominant.

The exposed concrete walls of the tower are not just powerful symbols, they are the structure, architecture and construction process synthesized. They function both as a backbone and a supporting element, but also as dynamic elements that allow the building to move safely in an earthquake. These massive walls were inserted in the subsoil to a depth of 60 meters below grade to bedrock, giving the necessary stability to the building.

In summary, the seismic performance of the Terre Reforma may be attributed to the following features –

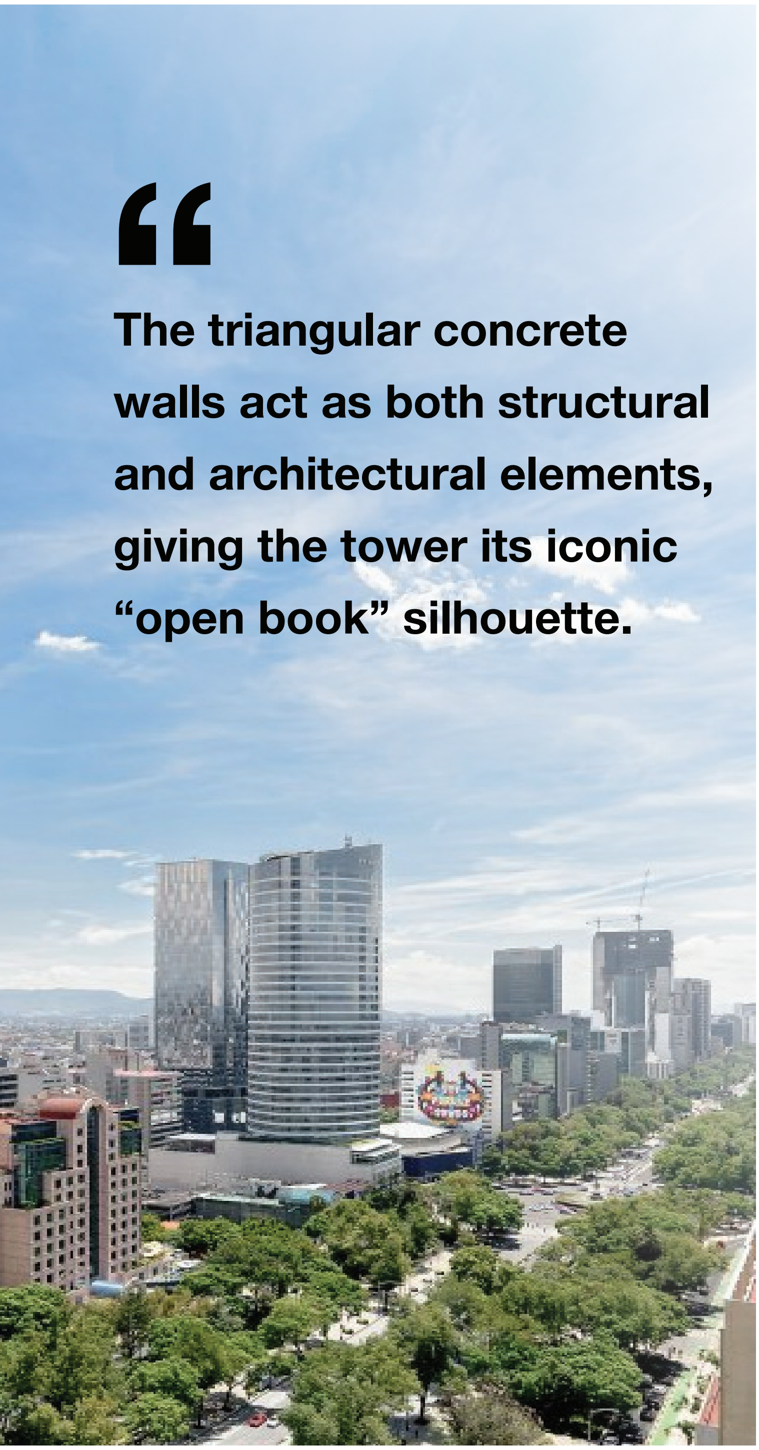
- **Performance-Based Seismic Design (PBSD) –** Designed using PBSD for centuries of seismic history to optimize the tower's stiffness and



energy dissipation rather than relying solely on prescriptive code requirements.

- **Massive Concrete Shear Walls –** The structure is anchored by two 57-meter-wide and 246-meter-tall exposed concrete walls on the north and east façades, providing exceptional lateral stiffness and seismic resistance

> **“The triangular concrete walls act as both structural and architectural elements, giving the tower its iconic “open book” silhouette.**



- **Structural Steel Diagrid –** On the southwest face, the diagrid provides extra lateral stiffness and allows for column-free interior spaces without compromising seismic resilience.
- **Energy-Dissipating Coupling Beams –** These beams connect the massive shear walls and are engineered to deform plastically, absorbing seismic energy and protecting the structural core
- **Triangular “Open Book” Geometry –** The building’s triangular footprint and asymmetrical form reduce torsional effects and distribute seismic forces more efficiently than rectangular towers
- **Crumple Zones in the Façade –** The façade includes engineered deformation zones that act like automotive crumple zones, absorbing shock and preventing damage to the main structure
- **Deep Foundation with Slurry Walls and Drilled Piers –** A network of caissons and piles anchors the tower into competent strata, reducing settlement and preventing overturning during major ground movements.

The system has already proven to be effective. During the 2017 Puebla Earthquake (Magnitude 7.1), the only damage the building faced were some harmless cracks in the concrete seams, which is a testament to the finest seismic engineering which went into the design of the building.

Torre Reforma is more than just a skyscraper—it is an example of structural innovation, proving that bold architecture and seismic safety can coexist. Its engineering solutions are now studied and emulated in other high-risk seismic zones around the world.

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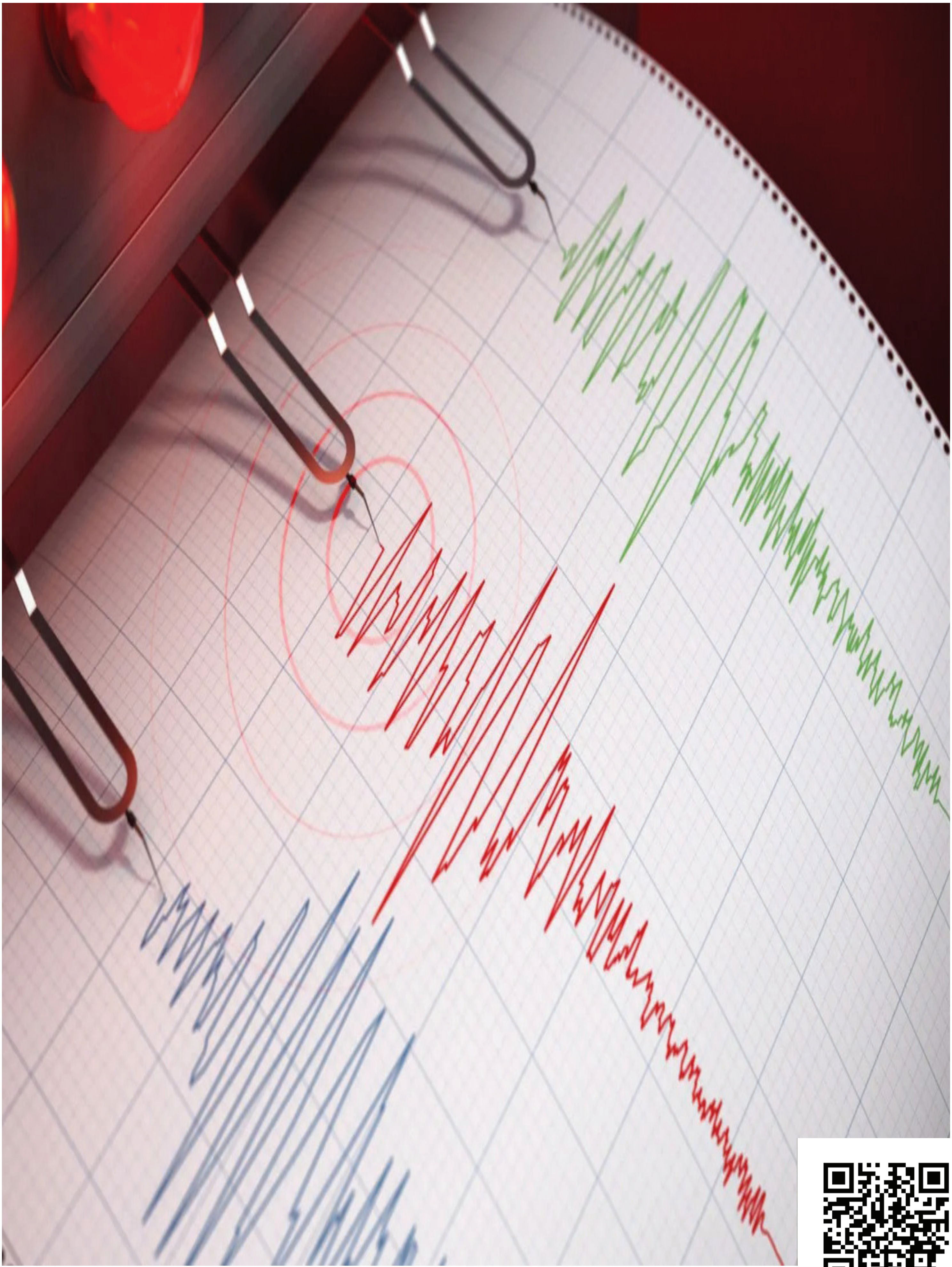

For further information, contact -
Shounak Mitra, Head - Codes & Approvals (Fastening), Hilti India Pvt. Ltd.
M: 9899732127 | E: support@theseismicacademy.com

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