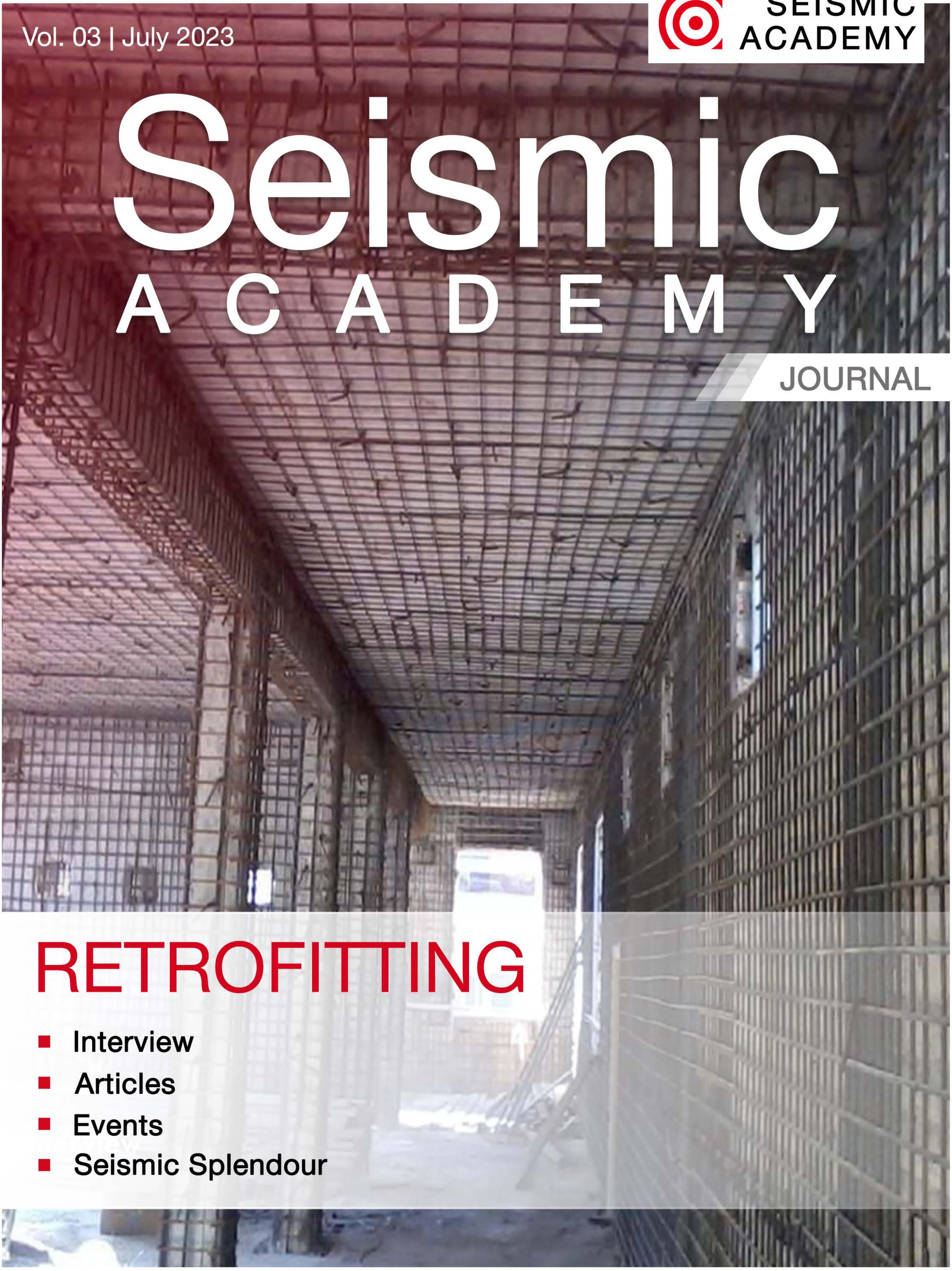
Vol. 03 | July 2023

SEISMIC ACADEMY

Seismic ACADEMY

JOURNAL



RETROFITTING

- Interview
- Articles
- Events
- Seismic Splendour

An Initiative by HILTI
Building Benchmarks for Industry and Academia

A CE&CR Production
unmatched coverage

Annual Conference 2023

SEISMIC RESILIENT INFRASTRUCTURE IN HEALTHCARE FACILITIES

Hospitals are at the core of any society's survival capacity as they provide timely healthcare services to the community. From regular check-ups to emergency care – they are indispensable and our biggest support in aiding our healthy existence. Therefore, during catastrophes like earthquakes, our healthcare infrastructure needs the best seismic resilience to save lives and ensure a safe-built environment. In a bid to ensure maximum disaster defence and continue to build the 'Safety Culture' in seismic designs, Seismic Academy Annual Conference is coming up on the 31st of August, 2023.

EVENT DETAILS -

- Venue - India Habitat Centre, New Delhi
- Date - 31st August '23
- Time - 09:00 -16:30 hrs (IST)
- To Register Scan the QR Code

SEISMIC ACADEMY

A forum for professionals, academicians, authorities and industry experts to interact and disseminate knowledge on various aspects of earthquake engineering with different stakeholders, with an intent to increase awareness and develop their expertise on the subject.

OUR VISION

To make seismic academy as one source of information and use it for promotion of all seismic initiatives in our country.

OUR ADVISORY BOARD

A **CE&CR** PRODUCTION

IN THIS ISSUE - Total No. of Pages: 44 (Including Cover)

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SEISMIC ACADEMY

FROM THE DESK OF ADVISORY BOARD

It's heartening to see that HILTI along with CE&CR have propagated activities of Seismic Academy which expected to immensely benefit the readers.

Indian history of known earthquakes is about 150 to 200 years old, even though, more earthquakes would have taken place in India, earlier, too. Development of seismometers and other equipment associated with measurement techniques have made it possible to measure such earthquakes and suitably design structures for the same. Philosophically, when a larger intensity / magnitude earthquake takes place at a location than the one depicted in the codes of practice, the earthquake zone of the location is upgraded.

It's good to know that lot many people that includes engineers and non-engineers have understood importance of earthquake engineering. Those times have gone when occurrence of an earthquake was a rare eventuality with the onset of frequent earthquakes, smaller or larger. Most of the times, earthquake causes larger scare than when it takes place. As far as awakening is concerned, in the commercial block of the 5 star hotel Radisson, Delhi, when Nokia wanted to acquire certain floors over 20 years ago, the client asked us (structural consultants) to give a certificate that the structure has been designed as per the prevailing codes of practice.

As a matter of information, IRC (Indian Roads Congress) has published IRC:SP:114 with several updated provisions regarding seismic design of bridges that include Capacity Design Concepts, Use of Seismic Isolators, Shock Transmission Units, etc. Similarly, BIS Code IS:1893 has brought in several updated seismic provisions which are in vogue.

Er. Vinay Gupta
Managing Director
Tandon Consultants Pvt. Ltd

"Philosophically, when a larger intensity / magnitude earthquake takes place at a location than the one depicted in the codes of practice, the earthquake zone of the location is upgraded."

TABLE OF CONTENTS

Dr. Bishwajit Bhattacharjee
Emeritus Professor
Indian Institute of Technology
Delhi

> **Truly engineered construction would reduce the fatality and damage to property.**

Seismic Academy: In the context of repeated earthquakes which we have experienced in the recent past in India, how relevant it is to adopt upgradation of existing buildings to enhance the performance level?

Dr. Bishwajit Bhattacharjee: Many of the damage to lives and properties during earthquake can be attributed to non-engineered construction and poor quality of (so-called) engineered construction. Truly engineered construction would reduce the fatality and damage to property.

Very important buildings which can lead to large scale fatality and damaging consequences only, i.e., limited cases, may be upgraded to a performance level at par with currently perceived risk.

Seismic Academy: While we speak about health monitoring of structures prior to suggesting any retrofit measure, how necessary is it to conduct a periodic audit of structures?

Dr. Bishwajit Bhattacharjee: Mass and stiffness of the structural member elements in buildings do not change significantly with time. Distress induced by deterioration due to material degradation leads to serviceability limit failure, and are so slow that safety limit failure to partial or full collapse can be easily avoided by paying heed to maintenance and repair needs. Hence, there is no need for periodic audit of structure in the context of seismic vulnerability. Health monitoring shall look into deterioration and not structural stiffness.

Seismic Academy: There are different retrofitting strategies which may be adopted – when do we happen to strike a fine balance between retrofit and demolition?

Dr. Bishwajit Bhattacharjee: Repair, rehabilitation and retrofitting are different things. Often retrofitting is done on structures where no damage or distress have been observed, but to satisfy the guidelines of currently acceptable practice adopted in the codes as per the changed risk perception, especially seismic risk perception because of uncertainty involved in dynamic load estimation. Since physics based models for prediction of likely dynamic forces are yet to be developed, the perceived risk tends to increase with time as and when new data on earthquake damages become available. Hence, the structure needs seismic retrofitting to the currently acceptable standard. Decision making on rehabilitation against demolition or retrofit against demolition can be based on financial criteria. The life cycle cost can be a criteria but estimating failure (or survival) probabilities for earthquakes of various magnitudes with different damage potential is a difficult task. The case is relatively simpler for rehabilitation of structures distressed due to deterioration. However, a simple financial criteria is given by the Federal Emergency Management Agency (FEMA) of the USA, known as the 50% rule. A facility is eligible for replacement when repair cost exceeds 50% of replacement cost.

Seismic Academy: Your recommendation for inspection, maintenance and retrofit of lifeline structures.

Dr. Bishwajit Bhattacharjee: An inspection schedule as per CEB [FIB (International Federation for Structural Concrete)] is given in the following table may be followed for periodic inspection for life line structure i.e., Class 1. This guideline relates to deterioration and shall be repaired/rehabilitated once the distress is identified. Preferably rehabilitation shall enhance the service life of elements to intended design life of structure. For safety against seismic load no periodic inspection is necessary.

Environment & Loading Conditions	Structure Classes					
	Class 1		Class 2		Class 3	
	Routine	Extended	Routine	Extended	Routine	Extended
Very Severe (Fatigue loading in aggressive env.)	2*	2	6*	6	10*	10
Severe	6*	6	10*	10	10	-
Normal	10*	10	10	-	Superficial	Superficial

Extended is with instruments between two routine inspections.

The seismic retrofit requirement is for only once, or at the most twice as codes do not change periodically. The retrofit may be taken up after assessment of seismic vulnerability.

Seismic Academy: There are several heritage structures. What is your recommendation to conserve their structural integrity?

Dr. Bishwajit Bhattacharjee: Conservation manual by Sir John Marshall, Archeological Survey of India can provide good guidelines. One can use the recommendations judiciously.

E-learning on the topic -

EVOLUTION OF EARTHQUAKE RESISTANT DESIGN

Earthquake is one of the most unpredictable hazards and the repercussions are devastating. We have seen loss of lives and assets and it is not easy to recover from the aftermath. The recent earthquake in Turkey has left us all in shock. The standards in our country have evolved over a period of time with due consideration to the changing seismic demand. This module is intended to create awareness on the evolution of earthquake resistant design of structures.

To start the course, click here -
https://theseismicacademy.com/e-learning-detail/evolution-of-earthquake-resistant-design

SEISMIC RETROFITTING OF MULTI-STOREY RCC BUILDING USING FLUID VISCOUS DAMPERS AND COMPARING THE RESULTS BEFORE AND AFTER THE RETROFITTING

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Techno Main Salt Lake
Techno India Group

Md. Toshif Alam
M.Tech (Structure)
Techno Main Salt Lake
Techno India Group

INTRODUCTION

Most of the buildings in India are normally constructed to resist static loads without considering exact seismic actions. However, this leads to deficiencies in the design of the structures. Typical deficiencies for the studied structure are the following:

- The boundary conditions of the supports. It is important to have proper supports, especially when considering seismic actions since a ductile behaviour of the structure is required.
- If the seismic zone changes for the particular area, the safety measure for the structure should immediately be taken into consideration.
- Even if the building is seismically designed, the data input and the factors considered for seismic designing are not taken into major consideration such as Response Reduction Factor.
- Irregularities in mass and stiffness. The choice of material and element types is important since they affect the weight and strength of the structure.
- Another type of irregularity is the geometry of the structure, the more complex the structure is the more irregularities it tends to get.
- Moreover, the combination of different types of elements and their distribution in the structure affect the overall stiffness and behaviour of the structure.

In our case, newly built 15 storey RCC framed building which has experienced a strong earthquake and due to which the building was undulating at a greater velocity, settled a fear among the tenants about the safety of the structure. After the earthquake the structure was carefully observed but no cracks or any sorts of damages to the frame members were found except to the wall on which hairline cracks were developed. But for the safety against the future earthquakes and most importantly safety of the structure, the building is to be retrofitted with Fluid Viscous Dampers. Here we will analyze the changes in the properties before and after retrofitting the structure with the damper. Though various past researchers worked on it but the retrofitting work using increased damping approach is still not tried yet which will retrofit the structure globally with joints safety also.

SEISMIC RETROFITTING TECHNIQUES

The Building Description

Addition of concrete shear walls, use of Steel Braced Frames, use of Moment Resisting Steel Frames, using Concrete Diaphragm walls, Jacketing columns, Beam Jacketing, Jacketing of Beam-Column joints, FRP composites, Dampers such as FVD, Electro-rheological and Magneto-rheological Dampers, Base Isolation, Mass Reduction, Strengthening of footings. Viscous damper functions on the principle of passive energy dissipation by adding damping of seismic forces in the structure. Previous study on response of structure to earthquakes provided with viscous damper shows that it can reduce storey drift, forces in members which lead to less damage to structure enabling it to resist large lateral forces. It is very important to safeguard the structures such as airports, fire department barracks, nuclear power plants, communication centers, hospitals, bus stops, institutions etc. from the earthquakes to reach higher level of safety. By the virtue of damping action of viscous dampers, it reduces forces in the members, enabling provision of smaller cross sections of structural members. This makes the structure safer against seismic action.

OUR CASE STUDY

MODELLING OF THE STRUCTURE

ETABS is a computer software package for analysis and design of civil structures. It offers an intuitive yet powerful user interface with many tools to aid in the quick and accurate construction of models, along with the sophisticated analytical techniques needed to do the most complex projects, so in the present study three dimensional analyses with the help of ETABS 18 is used for modelling and analysis of the structure. The work started with modelling and analysis of RCC building for two cases:

1. Analysis of the original building
2. Analysis of that building with effectively using Fluid Viscous Dampers

An existing 15 storey RCC building is modeled using ETABSs having the total building height of 46.1 m including the base and top floor. Concrete grade of M35 and Fe 500 grade steel were taken. Frame properties such as beams (450 mm x 250 mm) and columns (400 mm x 500 mm) are of these dimensions and slab thickness of 125 mm. The existing building was designed according to seismic zone II following the IS 1893 (2016): Part-1. Loads such as dead, live, seismic, wind and default load combinations were applied. Then the fluid viscous dampers of brand were fitted at the four corner sides of the building and also at the staircase side areas and analyzed.

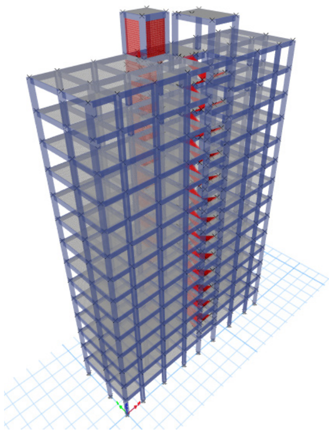

Fig. 1: Without Dampers 3D View

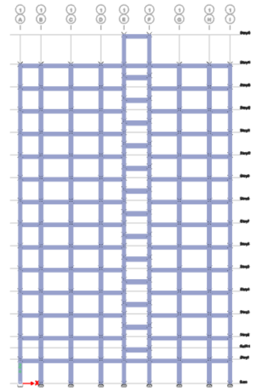

Fig. 2: Front Elevation View

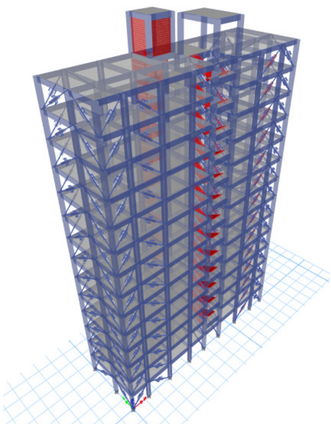

Fig. 3: With Dampers 3D View

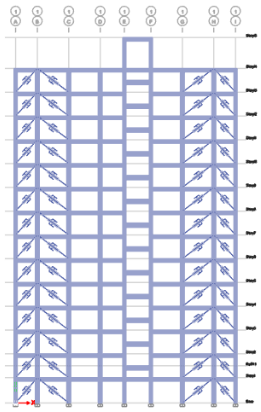

Fig. 4: Front Elevation View

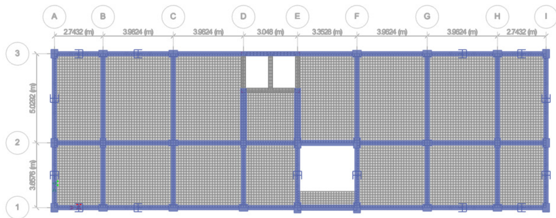

Fig. 5: Without Dampers Plan View

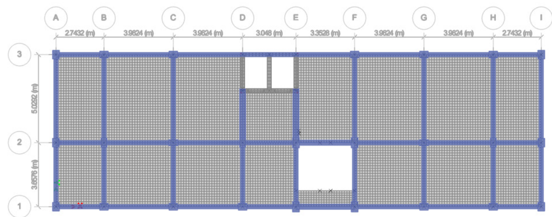

Fig. 6: With Dampers Plan View

RESULTS

All the results have been obtained after successfully completing the seismic analysis of the model, once before applying the seismic retrofitting and another after applying the seismic retrofitting. The aim of the project, as mentioned before, is to analyze only the global behaviour without taking into consideration the local behaviour of the model. Therefore, there will not be any

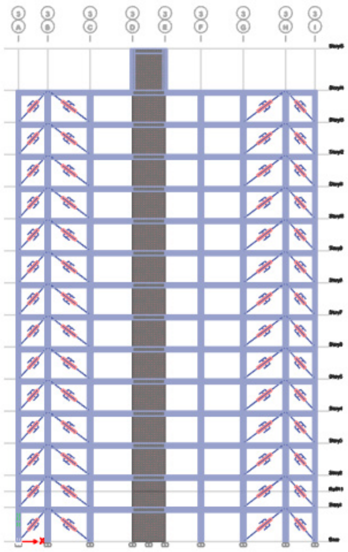

Fig. 7: With Dampers
Rear Elevation View

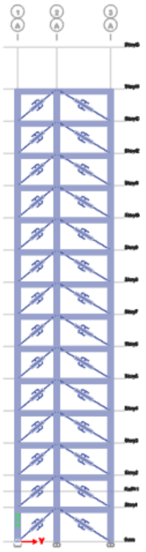

Fig. 8: With Dampers
Side View

analysis regarding the connections between the structural elements, material properties and steel design of the elements. Our goal is to strengthen the building under seismic vibration; hence, the main focus will be on the frequencies and the displacements of the structure before and after modifying the structure with a retrofitting method. Improving the frequencies and minimizing the displacements will give rise to a more stable structure.

Maximum Storey Displacement (mm)				
Load Case	Original		With Damper	
	Global x	Global y	Global x	Global y
Seismic X	162.66	46.51	70.28	3.02
Seismic Y	11.75	183.63	1.79	73.19

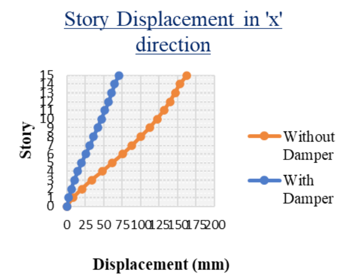

Fig. 9: Storey Displacements of Original and Retrofitted Building

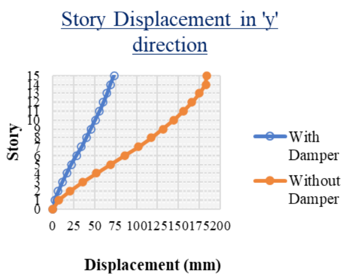

Fig. 10. Storey Displacements of Original and Retrofitted Building

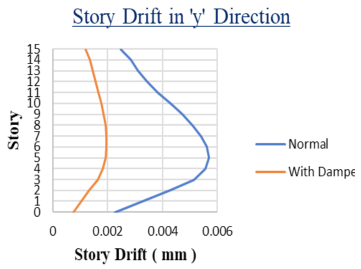

Fig. 11: Storey Displacements of Original and Retrofitted Building

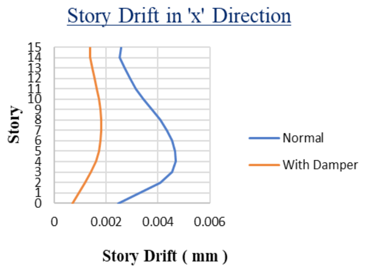

Fig. 12: Storey Drift of Original and Retrofitted Building

Modal Periods and Frequencies					
Case	Mode	Period	Period	Frequency	Frequency
		sec	sec	cyc / sec	cyc / sec
		Normal	With Damper	Normal	With Damper
Modal	1	1.95	1.065	0.513	0.939
Modal	2	1.742	1.02	0.574	0.98
Modal	3	1.487	0.662	0.672	1.51
Modal	4	0.63	0.3	1.586	3.335
Modal	5	0.486	0.282	2.058	3.548
Modal	6	0.399	0.208	2.507	4.803

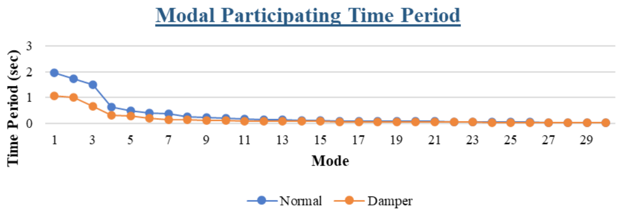

Fig. 13: Modal Periods

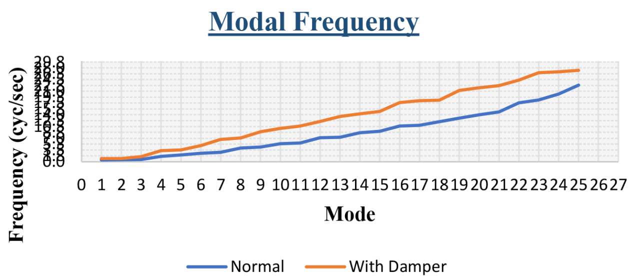

Fig. 14: Modal Frequencies

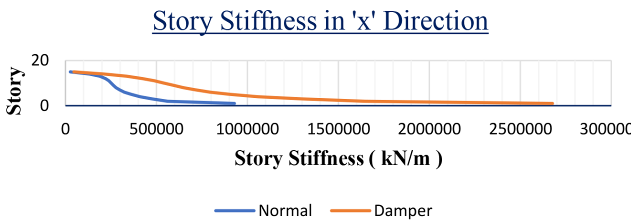

Fig. 15: Storey Stiffness in X Direction

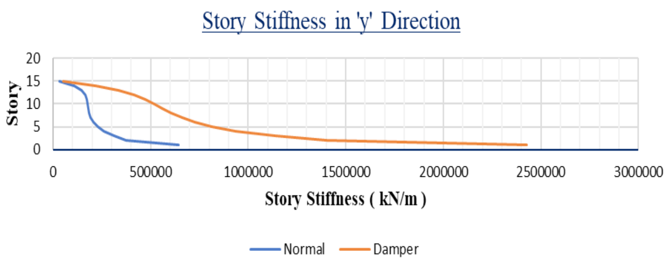

Fig. 16: Storey Stiffness in Y Direction

CONCLUSION

A general overview of the results showed that a better structural seismic performance of the model after the seismic retrofitting was accomplished and proves that the chosen structural methodology of this modification is a sufficient optimized design for this existing building.

Loading Case: Seismic Load along X Direction (Seismic X)											
Storey Number	Column Number	Critical Column Forces									
		Axial Force (kN)		Shear Force V2 (kN)		Shear Force V3 (kN)		Moment M2 (kN-m)		Moment M3 (kN-m)	
		Normal	Damper	Normal	Damper	Normal	Damper	Normal	Damper	Normal	Damper
1	C1	857.1	2239.5	58.33	14.46	60.1	6.95	156.9	14.41	145.87	40.19
	C3	900.01	2343.53	25.56	11.37	56.26	5.09	152.89	12.47	69.51	33.81
	C11	1106.66	353.23	85.17	28.07	5.43	2.62	21.4	5.19	169.77	58.18
	C12	2430.42	739.46	61.23	21.12	39.02	3.35	99.69	7.69	144.64	51.02
14	C1	25.56	1.14	10.74	1.69	16.43	0.4	23.53	1.05	16.49	3.16
	C3	14.16	0.65	21.44	0.43	15.68	2.09	22.13	3.01	29.05	1.49
	C11	212.26	111.07	25.15	24.35	60.98	40.37	82.25	55.14	33.9	35.19
	C12	49.97	22.77	52.9	45.71	5.18	1.86	8.93	4.85	67.33	59.1

Loading Case: Seismic Load along Y Direction (Seismic Y)											
Storey Number	Column Number	Critical Column Forces									
		Axial Force (kN)		Shear Force V2 (kN)		Shear Force V3 (kN)		Moment M2 (kN-m)		Moment M3 (kN-m)	
		Normal	Damper	Normal	Damper	Normal	Damper	Normal	Damper	Normal	Damper
1	C1	829.53	2518.87	10.36	1.3	12.73	14.42	65.98	51.51	24.09	2.83
	C3	479.04	2461.15	0.73	1.72	11.23	13.75	64.41	50.83	1.57	3.03
	C11	361.26	1229.48	6.38	2.15	95.21	44.33	248.81	111.9	15.47	3.84
	C12	1041.43	1641.52	10.01	1.83	74.4	31.51	242.01	99.6	19.28	2.58
14	C1	27.76	3.42	1.21	3.4	25.89	0.14	38.83	2.31	1.93	4.36
	C3	22.05	5.27	1.71	4.34	30.92	0.82	46.88	3.38	2.27	5.56
	C11	276.19	273.19	28.63	15.99	124.87	77.98	178.33	110.29	40.94	21.84
	C12	108.35	145.2	12.88	1.28	38.66	17.61	61.59	26.73	15.91	1.96

Loading Case: Seismic Load along X Direction (Seismic X)					
Storey Number	Beam Number	Critical Beam Forces			
		Shear Force (kN)		Moment (kN-m)	
		Normal	Damper	Normal	Damper
1	B31	166.58	54.27	147.2	49.47
	B26	100.53	18.82	101.47	19.22
	B19	100.09	18.53	101.38	18.95
	B34	93	27.42	67.46	22.28
14	B47	90.68	49.44	85.97	46.14
	B32	71.71	40.74	56.29	39.87
	B29	67.54	36.41	50.27	33.39
	B33	64.02	23.92	40	14.31

Loading Case: Seismic Load along Y Direction (Seismic Y)					
Storey Number	Beam Number	Critical Beam Forces			
		Shear Force (kN)		Moment (kN-m)	
		Normal	Damper	Normal	Damper
1	B46	107.17	65.8	14.17	75.65
	B47	106.37	63.37	94.34	61.13
	B15	90.25	25.96	82.32	22.36
	B13	78.72	23.89	72.27	22.1
14	B47	279.88	185.31	105.99	68.51
	B47	129.63	71.98	82.6	81.98
	B12	63.26	34.36	51.04	27.87
	B7	60.71	27.2	36.36	12.23

More detailed, applying FVD as bracing, improved the structure's characteristics such as:

- Storey Displacement got reduced by almost 60%
- Storey Drift also got reduced
- The Frequency of the structure also got improved
- The Stiffness also got improved
- Column Shear Force and Moment got reduced (design will be governed by the axial force mainly)
- Beam Shear Force and Moment got reduced

The stiffness was mainly enhanced by the added FVD at two sides of staircase along transverse direction, which increased the frequency remarkably. Moreover, the structure became more ductile primarily because of the FVD applied; hence, an improved capability to undergo plastic deformation before fracture is achieved. After performing the seismic retrofitting, the strength of the structure was developed. Since our research is regarding an existing structure, all the existing conditions and properties must be maintained as much as possible the same, such as support types, connections between the structural elements, sizes of each structural element, soil type and so forth. The reason is to adjust to the current situation and achieve more realistic results. In conclusion, we maintained as much possible as all the properties and conditions of the structure; therefore, the obtained results are reasonable and realistic. However, another conclusion is that we should not have enormous expectations on the level of strengthening improvements of the structure against seismic hazards since, the present conditions limit the analysis. This research study provides gaining more knowledge concerning the global strengthening of existing structures under seismic vibrations.

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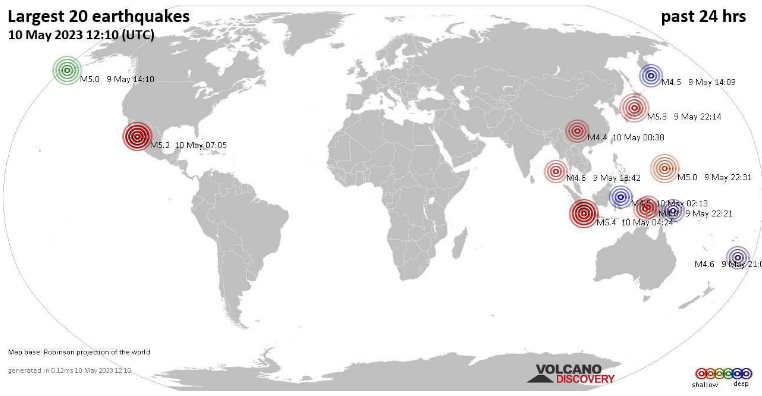
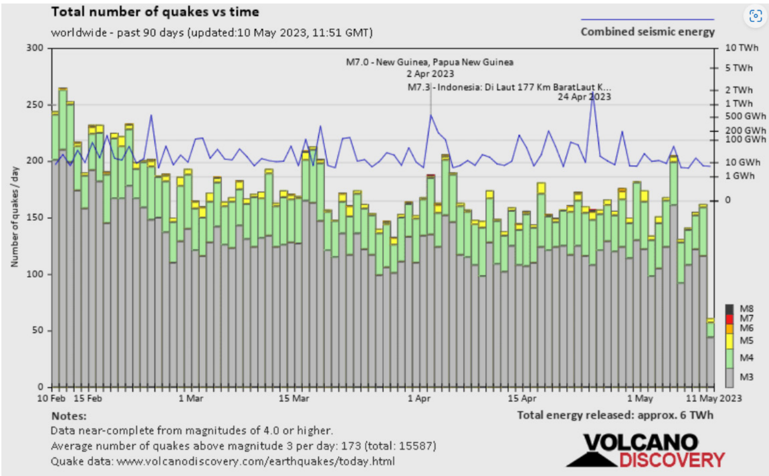
https://www.youtube.com/watch?v=TCa-9SYYPIU

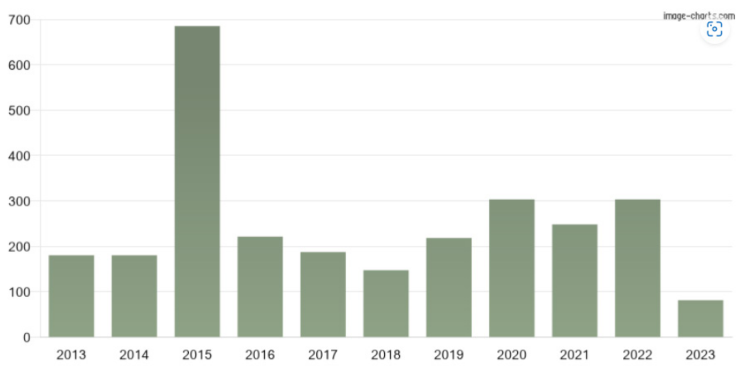
SEISMIC RETROFITTING OF BUILDINGS





Several structures around the country have been designed based on the earlier prevailing codes of practice, which have undergone major revisions over the years. Also, many of them have undergone damage and deterioration due to multiple reasons during the service life which include (but not limited to) change in building usage leading to different load requirement (or enhanced load acting on the structure), construction or design defects, updation of the design standards, seismic events, fire incidents, corrosion ageing of the structure, and lack of inspection and maintenance. One of the primary reasons which cause extensive damage to the structure is the occurrence of earthquake events.

The recent earthquakes across the globe and the extensive devastation caused by them have left everyone in shock. Number of moderate to high intensity tremors have also been experienced in different parts of our country over the last 6 to 8 months. They are one of the most unpredictable hazards.



Yearly Earthquakes within 300 kilometers (186 mi) of India with a magnitude of 4 or above.

In India, the landmass has become more and more prone to earthquakes. A total of 2,699 earthquakes with a magnitude of 4 or above have struck within 300 km (186 mi) of India in the past 10 years. This comes down to a yearly average of 269 earthquakes per year or 22 per month.

In wake of this increasing seismic activity, evaluating the adequacy of our existing infrastructure and retrofitting them to meet the seismic demands is of paramount importance. A proactive approach to improve the building performance to withstand the estimated seismic forces can help to minimize the loss to mankind and the society which is suffered in the event of an earthquake. With this endeavor, National Institute of Disaster Management (NIDM), Ministry of Home Affairs, Govt. of India together with Seismic Academy organized a webinar on “Seismic Retrofitting of Structures” on 12th May, 2023. This was attended by more than 170 enthusiastic participants. The panel was graced by Shri Rajesh Ratnoo, Executive Director, National Institute of Disaster Management (NIDM); Prof. Chandan Ghosh, Head – Resilient Infrastructure Division, National Institute of Disaster Management (NIDM) as the Patron and Guide, respectively.

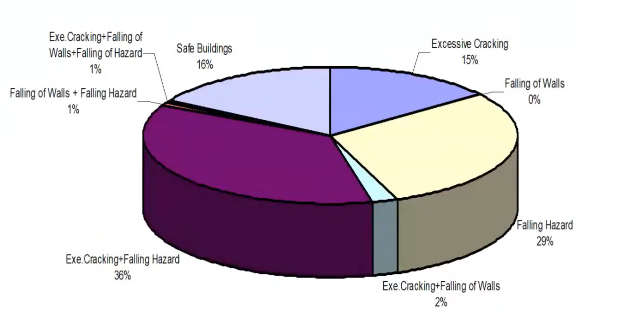
The esteemed Speakers for the Webinar were Prof. (Dr.) Ajay Chourasia, Chief Scientist and Head of Structural Engineering and 3D Concrete Printing Group, CSIR-CBRI, Roorkee; Dr. Hemant Kumar Vinayak, Associate Professor, Dept. of Rural Development, NITTTR, Chandigarh and Mr. Shounak Mitra, Head – Codes & Approval, Hilti India Pvt. Ltd., Delhi. Ms. Avipsha Mohanty, a young professional at Resilient Infrastructure Division, National Institute of Disaster Management (NIDM) acted as the moderator.

The webinar aimed to serve as an opportunity for professionals and academicians to learn and understand the significance of seismic retrofitting to improve building performance and create resilient infrastructure.

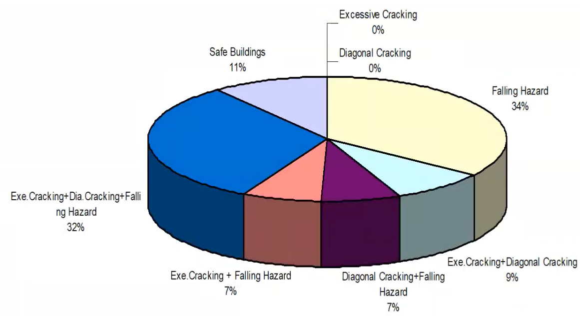
Dr. Chandan Ghosh set the stage by emphasizing the need to create awareness on this pertinent topic and encouraged dissemination of knowledge at all levels. He mentioned that with the current seismic vulnerability, it is important to understand and analyze the structural performance, diagnose the existing condition of the structure, and provide an acceptable and implementable solution.

Dr. Ajay Chourasia in his introduction to the presentation on “Seismic Risk Reduction for India – Retrofit of Masonry and RC Buildings” highlighted that the general expectation from one and all is that our habitat should be safe, sustainable, comfortable, economical and socially acceptable. We are moving towards the concept of smart cities where we have uninterrupted lifeline services, education, governance, etc. In the process we forget that in case of any natural hazard like earthquake, the building structure together with its utilities, undergoes the highest level of damage. Hence, we need to be adequately prepared for earthquakes, which can be of low frequency in terms of return period but have high impact in terms of the damage it causes.

He took reference to all the recent earthquakes like Gujarat earthquake, Nepal earthquake and the recent Turkey earthquake, all of which have caused extensive damage to both masonry and RC buildings – both new construction as well as heritage structures. The failure could be attributed to inadequate



Masonry



RCC

connections, inadequate seating and anchorage of roof panels, lack of floor-diaphragm effects, etc. He mentioned that after the Jabalpur earthquake, there was post-earthquake damage assessment conducted wherein it was concluded that almost 85% of the existing buildings were vulnerable to seismic activity. The analysis was carried out for masonry buildings as well as for RCC buildings.

He mentioned that as a general practice it has been observed the essence of the topic is lost and the reaction to it diminishes with passage of time. This was nicely captured in a tabular form.

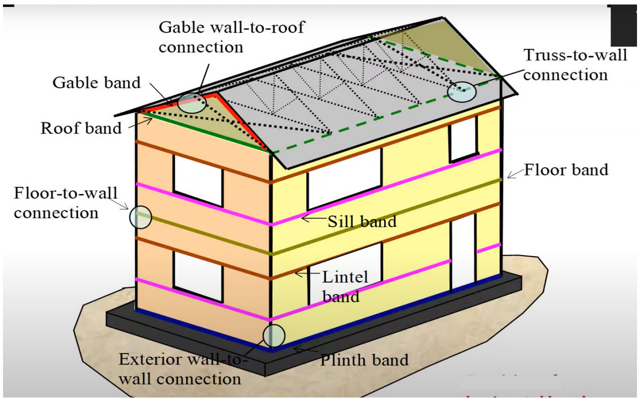
Stage	Time	Event	Reaction	
			Positive	Negative
1	0 -1 min	Major EQ		Panic
2	1 min to 1 week	Aftershocks	Rescue and Servival	Fear
3	1 week to 1 month	Diminishing Aftershocks	Short Term Repairs	Allocation of blame to builders, designers, officials etc.
4	1 month to 1 year		Long term repairs, action for higher standards	
5	1 year to 10 years			Diminishing Interest
6	10 years to next EQ			Reluctance to meet costs of seismic provisions etc, Increasing non-compliance with regulations
7	The next EQ	Major EQ	Repeat Stages 1-7	

Dr. Chourasia re-emphasized that 59% of the land in India, with a population of almost 78%, is susceptible to seismic events

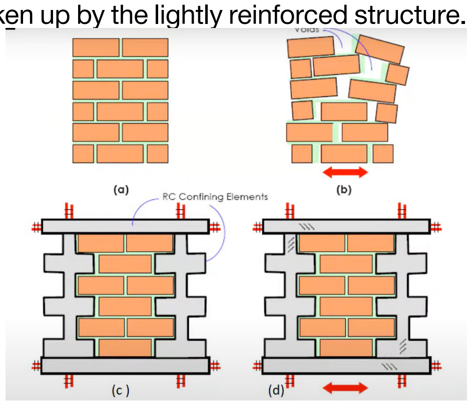
and it is high time that we are adequately prepared to minimize the loss in future events. Among the major challenges which came up in his discussion, techno-legal regime was one, wherein we need to create a sense of urgency among the municipal bodies to be able to regularly monitor the health of the structures in their purview and undertake proper remedial measures to maintain the health of the structure, as and when needed. This would also call for capacity building among the engineers.
He enumerated the reasons for collapse and damage as mainly three –

1. Unregulated development of built environment
2. Individual houses are largely self-built
3. Lack of awareness of earthquake standards for design and construction

Further in his presentation, he deliberated on masonry structures and the basic requirements to ensure safety. He highlighted on the requirement of horizontal band and vertical reinforcement in masonry construction to minimize damage due to deformability. Confined masonry is another technique which can ensure seismic resistance. However, majority of the structures on ground are found to be non-compliant. To understand in detail the performance of masonry structures, CBRI undertook full scale investigation for evaluation of performance of masonry structures – unreinforced, reinforced and confined. There has been significant difference in the overall performance which has been observed for confined masonry both from load capacity as well as deformation criteria. For an unreinforced masonry construction subjected to ground shaking, the block work is most likely to bulge out. On the contrary, if it is confined by means of lightly reinforced concrete element, the block work is not likely to collapse miserably, rather the lateral force will be taken up by the lightly reinforced structure.

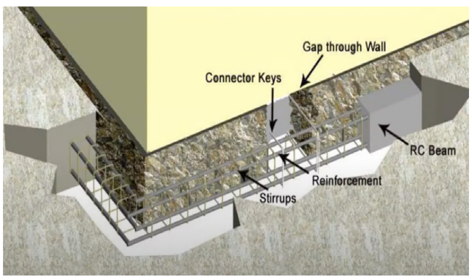


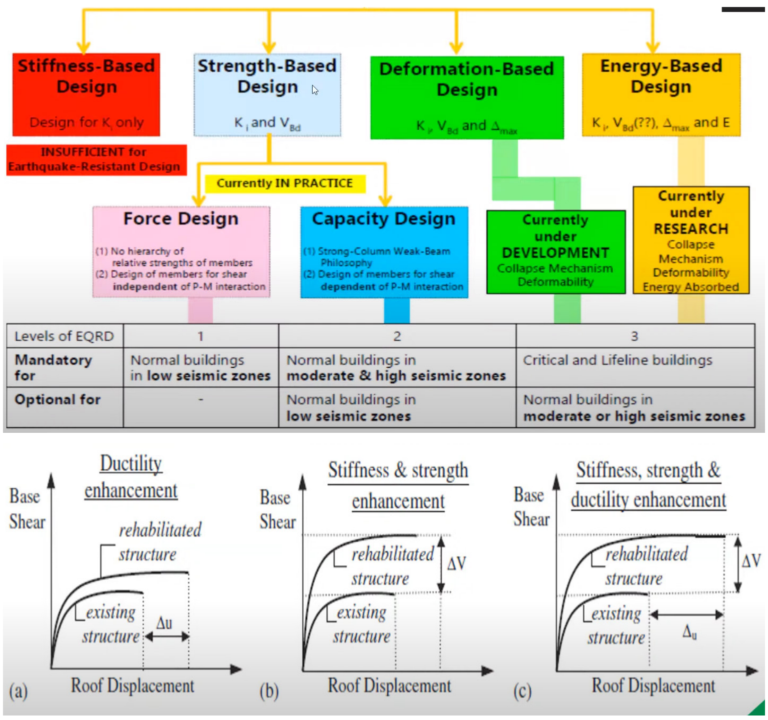
Dr. Chourasia also touched based upon alternate techniques like use of welded wire mesh, chicken mesh, nylon mesh to strengthen the masonry walls. With the use of these arrangements, it is possible to achieve full wall meshing or undertake split bandage, based on requirement. However, these are clearly not to be adopted on prescriptive basis, but reference to relevant standard like IS 1905 to be made to ensure absolute conformity.



Strengthening of foundations of existing structures is another critical aspect, which includes restriction of drainage system, geotechnical investigation and eventually section enlargement. Reinforcements to be provided adequately and the detailing should be such that the structures are able to behave in unison. He took reference of IS 17848:2022 for design of confined masonry.

In the next segment, he extended his lecture to the design of RC structures wherein he mentioned that the earthquake resistant design approaches have evolved from stiffness based design to the current practice of strength based design and we are gradually shifting toward deformation based and energy based concepts. The current strength based design philosophy follows the seven virtues of earthquake resistant design namely, configuration, stiffness, strength, ductility, deformability, desirable collapse mechanism and energy dissipation capacity.

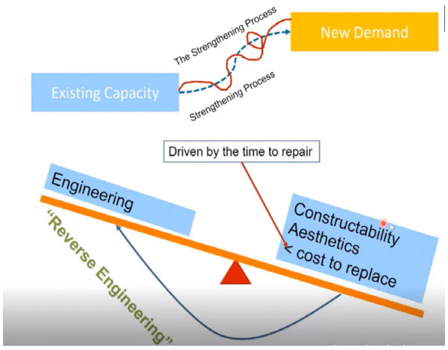




Retrofitting of existing RC structures is a complex process since there is a constraint of parameters like geometry, material, load, etc. The correct retrofitting strategy to be adopted is based on the desired requirement of ductility enhancement or strength enhancement or a combination of both.

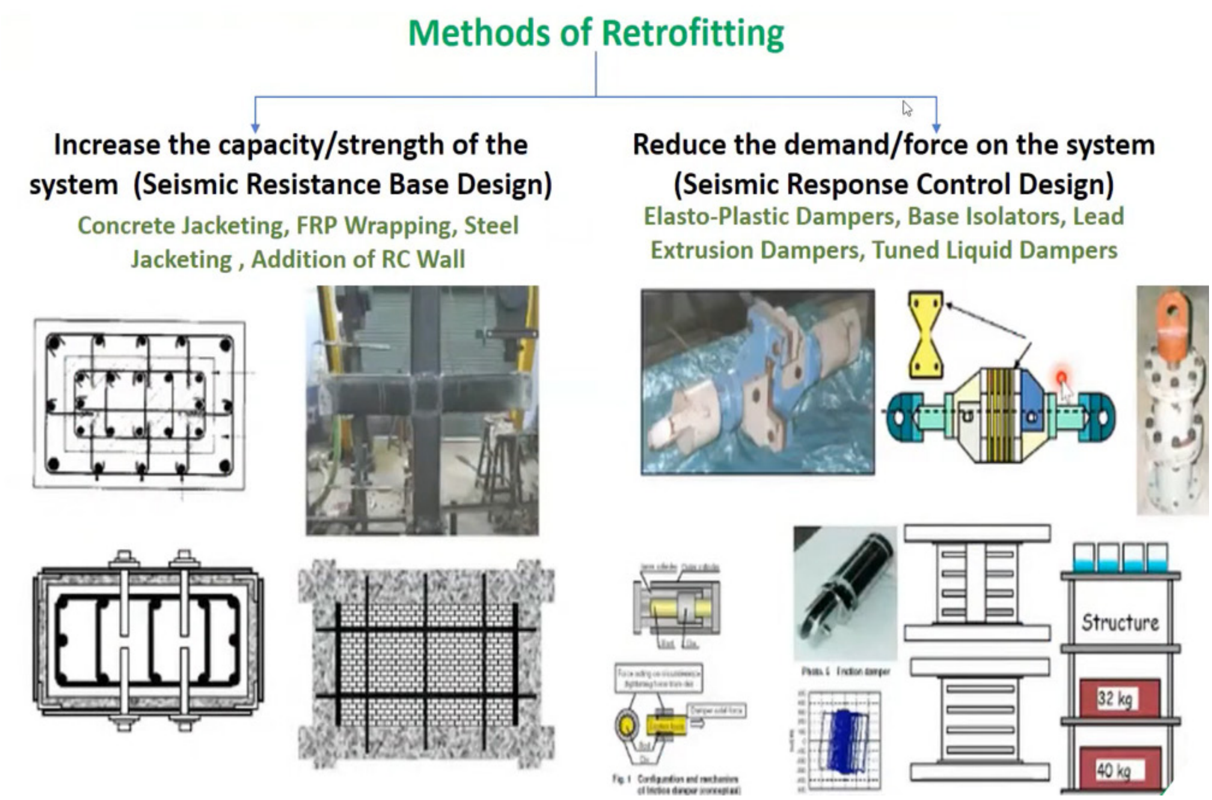
Adoption of a retrofitting strategy is also governed by the demand and reverse engineering is performed to make an assessment of the time and cost to restore.

He touched based upon the different retrofitting techniques – both global and local level strengthening which are commonly adopted along with few case studies.



In conclusion, Dr. Chourasia mentioned that there are robust codal provisions in India and we are working towards further development but there is a need for adoption and enforcement. There is a requirement to create local think tanks for implementation of the right practices and create accountability. We also need to in education and capacity building among all stakeholders and encourage community participation.

Dr. Hemant Kumar Vinayak in his deliberation highlighted on the different references from Hamirpur during his project under



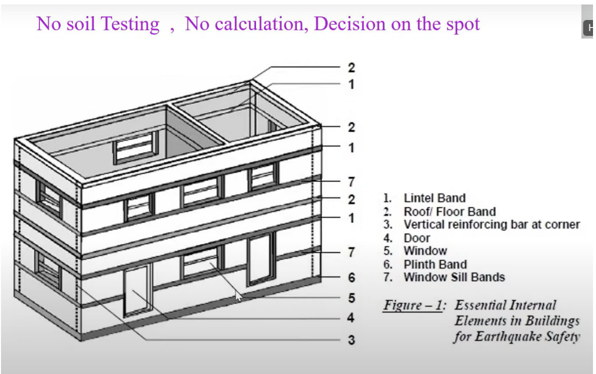


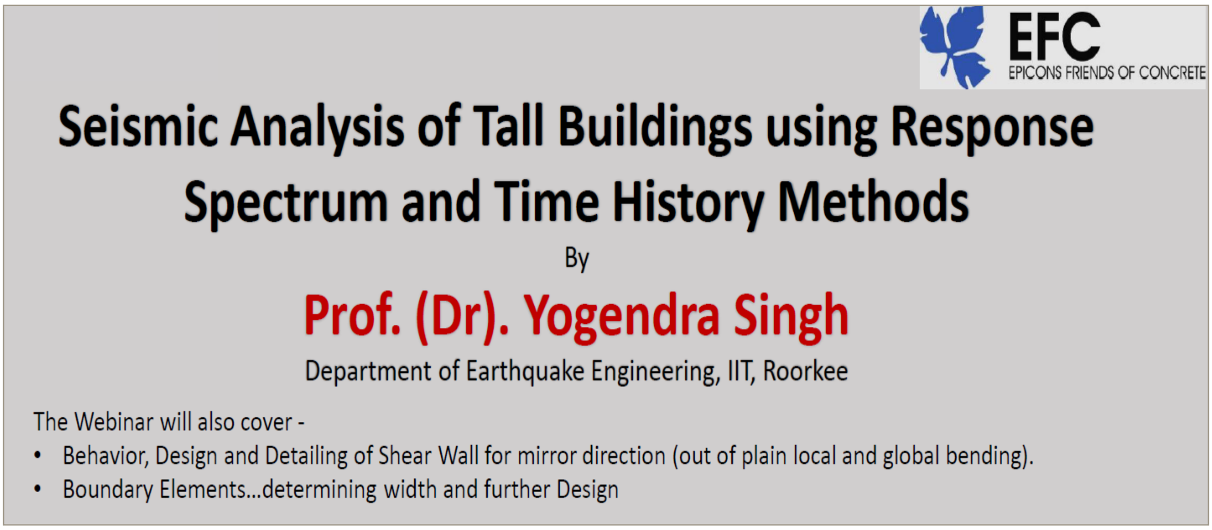
Figure – 1: Essential Internal Elements in Buildings for Earthquake Safety

Himachal Pradesh State Disaster Management in 2012. As a general observation, it was found out that initially the level of construction was below par and with no monitoring. He added that subsequently with regular monitoring and with effort form the local administrator, definite improvement was achieved in the overall construction quality. Drawing reference to Dr. Chourasia's session, he re-emphasized the need for proper detailing in masonry structures and made reference to IS 4326.

In addition to meeting the seismic requirement, he brought up several other factors which may lead to building damage like reinforcement corrosion, differential settlement, water seepage, dampness, improper workmanship. He illustrated with many examples of damage from his experience. Design and construction of row housing is another challenge and can lead to short to long terms defects. While every structure indicates early signs of distress, they are many a time not duly considered, mainly because of ignorance.

Dr. Vinayak, in his concluding remarks, also emphasized on capacity building at every level and cited ignorance/improper knowledge as the prime cause for structural deficiency and collapse.

Dr. Chandan Ghosh concluded the session by appreciating Seismic Academy for taking up this initiative and being an enabler to spread the knowledge. He urged the learned engineering community to come forward and meaningfully contribute to make construction safer.



Webinar on "Seismic Analysis of Tall Buildings using Response Spectrum and Time History Methods" organized by Epicons Friends of Concrete (EFC) was held on Saturday, 29th April '23 from 03:00 pm to 06:30 pm.

The Webinar also covered -

- Behavior, Design and Detailing of Shear Wall for Mirror Direction (Out of Plain Local and Global Bending).
- Boundary Elements

Speaker - **Prof. (Dr.) Yogendra Singh**, Department of Earthquake Engineering, IIT, Roorkee

Webinar Convener: Mr. Jayant Kulkarni

Moderators: Mr. Anand Kulkarni, Mr. Arvind Parulekar, Mr. R. D. Deshpande

To know more, click - https://www.theseismicacademy.com/e-learning-detail/evolution-of-earth-quake-resistant-design

PERFORMANCE OF LEAD-RUBBER BASE ISOLATED BUILDING STRUCTURE IN HIGH SEISMIC PRONE REGION

Om Gomase
Dy. General Manager (Design)
Epicon Consultant Pvt. Ltd.

INTRODUCTION

Seismic isolation mitigates earthquake induced responses based on the concept of reducing the seismic demand by shifting the primary period of the structure rather than increasing the earthquake resistance capacity of structure. [1] The isolation technique can be adopted to improve the seismic performance of strategically important buildings such as schools, hospital, industrial structures, government office buildings etc. The goal is to simultaneously reduce inter-storey drifts and floor accelerations to limit or avoid damage, not only to the structure but also to its foundation, in a cost-effective manner. The main feature of the base-isolation technology is that it introduces between superstructure and its foundation a properly chosen flexible layer in order to shift the natural period of structure away from the dominant period of earthquake ground motion and thus to avoid the destructive effects given by the system resonance. [2-3] Based on the content of control to be achieved over the seismic response, the choice of the isolation system varies and thereupon its design is done to suit the requirements of use of the structure.

In seismically base-isolated systems, the superstructure is decoupled from the earthquake ground motion by introducing a flexible interface between the foundation and the base of the structure. Thereby, the isolation system shifts the fundamental time period of the structure to a large and dissipates the energy in damping, limiting the amount of force that can be transferred to the superstructure such that inter-storey drift and floor acceleration and reduce drastically. It is very essential to understand the various characteristics affecting the response of fixed and base-isolated structure when used for seismic protection of the structures. Moreover, the performance of base isolated structure also reportedly depends on superstructure stiffness, damping and flexibility of the isolation system. [4-5] The intense research activity in the field of seismic isolation has led to the development of a variety of base isolation system, which have been tested and implemented in many countries with very encouraging result. Various types of isolation system enormously and effectively implemented all over the world for seismic protection, where elastomeric rubber bearing, lead-rubber bearing and sliding bearing are most widely used. Thus, in this paper parametric characteristics have been evaluated for lead rubber bearing for different time period, bearing damping and its performance on building structural response. The bilinear model, used to express the relation between the shear force and the lateral displacement, can be defined by three parameters: initial stiffness, post-yield stiffness, and characteristic strength. The characteristic strength, Q, is usually utilized to estimate the stability of hysteretic behavior when the bearing experiences many loading cycles. For this study 10 storey RCC hospital

> **“It is very essential to understand the various characteristics affecting the response of fixed and base-isolated structure.”**

building taken and modeled in ETABS program for the region IV, as per Indian code and site soil condition. The model has been analyzed by non-linear time history analysis have been performed on the set of different mathematical models, with time period T=2, 2.5, 3, 3.5 sec & bearing damping value, ξ=0.10, 0.15, 0.20, 0.25, 0.30. The spectral matching procedure for real accelerograms is summarized and applied to a target earthquake response spectrum given in IS: 1893-2016, for type-I site soil. Matching technique in based on scaling of selected time history in time domain. The specific objectives of this study are: (i) to investigate the effects of increase of initial stiffness on structural response, (ii) to analyze the effect of isolation period on structural response and, (iii) to investigate the effects of characteristic strength ratio of isolator on structural response.

1. To evaluate the parameters of lead rubber isolator as per the variation of effective time of isolation and damping of the isolator.
2. To study the parametric analysis and compare the seismic response of fixed base with base isolated building.
3. To evaluate the building floor spectra.

MATHEMATIC FORMULATION

The Building Description

For comparative parametric analysis typical floor plan and elevation of RCC building, with 2 basements + ground floor + 10 storeys above ground level is considered as shown in Fig. 1 and Fig. 2. The building comprises with four bays in X-direction, having 8 m each length, whereas, five bays in Y-direction, having 5 m for middle and 4 m for both external ends. The dimension of building at ground floor and basement is 40x31 m.

> **The spectral matching procedure for real accelerograms is summarized and applied to a target earthquake response spectrum given in IS: 1893-2016, for type-I site soil.**

The heights of basement floors are 3.6 m and 3.5 m for typical floors. Total height of building from Ground floor is 35 m. Concrete grade taken as M30 for beam and floor element, whereas for column M50 grade is used. Structural member sizing considered as mentioned as below:

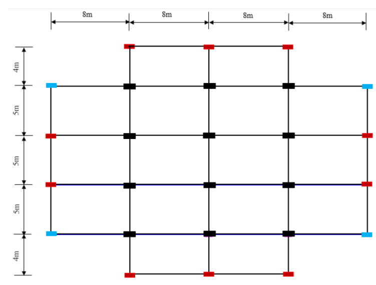


Fig 1. Typical Floor Plan

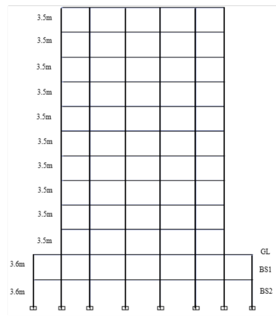


Fig 2. Longitudinal Section

Column	
Group-1	C 600x800 mm
Group-2	C 350x800 mm
Group-3	C 350x600 mm
Beam	B 300x700 mm
Slab	175 mm

Table 1: Structural Elements

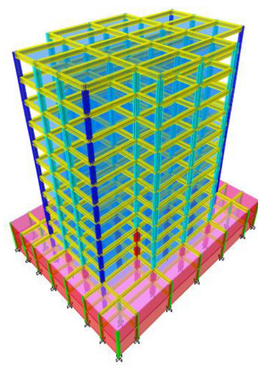


Fig 3. ETABS analysis model

Sample Earthquake used in the Analysis and Scaling

In this study, ground motion record has been selected from PEER Strong Ground Motion Database. [6] The Details of earthquake record as mentioned in Table 2.

Location	Imperial Valley-02
Date	19-May-40
Magnitude (M)	6.95
Station	El-centro Array #9
Closes to fault Rupture (km)	6.09
PGA (g)	0.28
PGV (cm/sec)	30.95
PGD (cm)	8.76

Table 2: Time History Record

In order to obtain a design earthquake compatible with the local seismicity, an earthquake signal treatment was performed consisting baseline correction, filtering and spectral matching in time domain, using computational program SeismoMatch - 2018. [7] The objective of

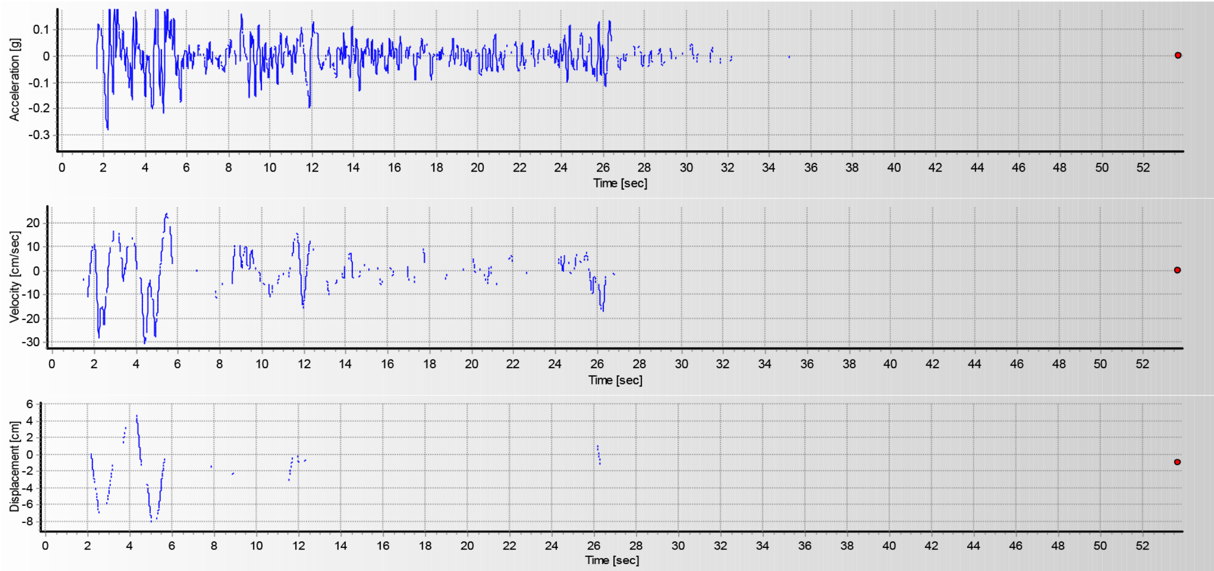


Fig 4. Imperial Valley-02-Time History Plot for Acceleration, Velocity and Displacement.

the spectral matching is to correct the actual acceleration record, compatible of standard target response spectrum properties as per IS1893-2016, for hard soil. [8] The principal goal of scaling accelerograms records is to obtain a design acceleration time history that will have a response spectrum as close as desired to the predetermined codal target spectrum. After matching the time history data is examined to ensure that the acceleration, velocity and displacement time histories should be reasonably close to the target codal spectrum.

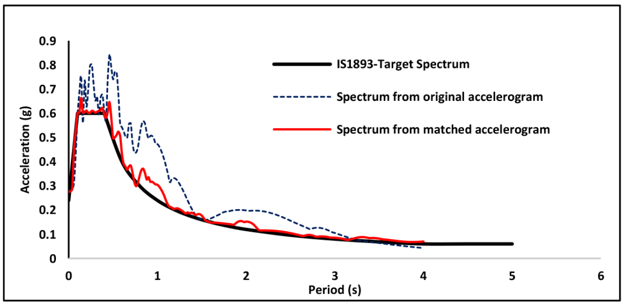


Fig 5: Scaled Spectra compatible to IS1893:2016

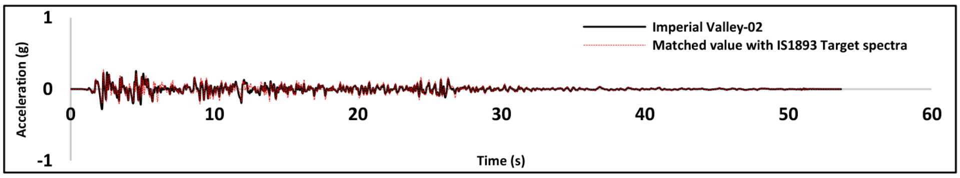


Fig 6: Scaled Time History compatible to IS1893:2016

basement floors and dissipate earthquake shocks. Lead-rubber bearing were first introduced and used in New Zealand in late 1970s.[9] Since then, lead-rubber bearings were widely used all around the world for effective seismic isolation including USA and Japan. The lead-rubber bearing is similar to the elastomeric rubber bearing from construction perspective, except the additional lead-plug in central part of bearing. The lead plug has a property to deform plastically under shear deformation, thereof enhancing the energy dissipation compatibility in comparison to elastomeric bearing.

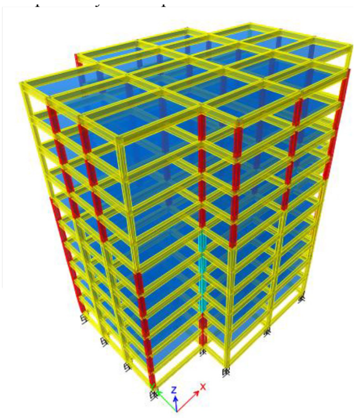


Fig 7: Building 3D model with base isolator

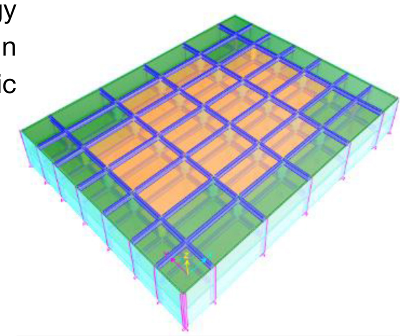


Fig 8: Building podium substructure

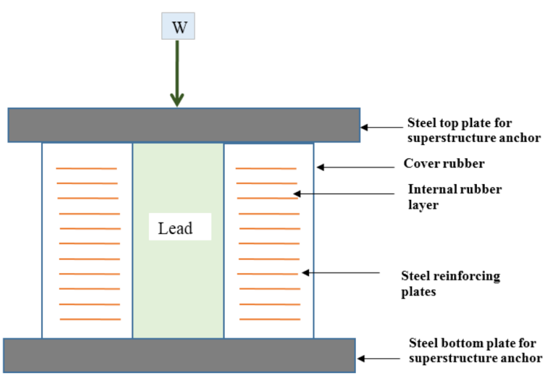
Design of Isolator

Analysis model developed, analyzed and maximum vertical load on each column have been carried out. The lead-rubber isolator has been designed to mount at ground floor to decouple the superstructure from

In practice lead-rubber isolator characterized and modeled by bilinear behavior with force-deformation relationship. This relationship, termed the hysteresis loop, defines the average stiffness at a specified displacement (Effective stiffness)

Accelerogram	Original Accelerogram	Matched Accelerogram
Max Acceleration (g)	0.280	0.276
ax. Velocity (cm/sec)	30.939	20.867
Max Displacement (cm)	86.6	83.9

Table 3: Ground Motion Parameter



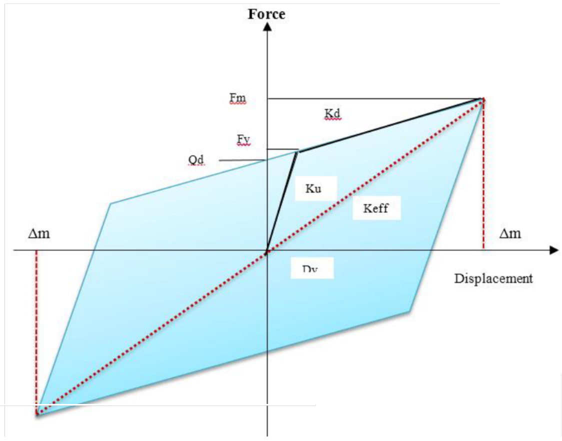


Fig 9: Bilinear Force-Deformation relationship of lead-rubber isolator.

and hysteretic damping provided by the system. A typical hysteresis for a lead rubber bearing is shown in Fig. 9. For design and analysis this shape represented as bilinear behavior mainly based on three parameters initial/elastic stiffness (K_u), post yield stiffness (K_d) and zero-displacement force intercept (Q_d). The characteristic strength of lead rubber bearing is controlled by the yield strength of the lead in shear, ϭy, and the cross-sectional area of the lead-plug, AL as:

$$Q_d = 6_L A_L \quad (1)$$

Post yield stiffness, K_d, is equal to the shear stiffness of the elastomeric bearing alone:

$$K_d = \frac{G_y A_r}{T_r} \quad (2)$$

The shear modulus G_y=0.35 MPa, for a high damping rubber bearing is a function of shear ϒ. The unloading elastic stiffness for lead-rubber bearing is defined as:

$$K_u = 6.5K_r\left(1 + \frac{12A_{pl}}{A_r}\right) \quad (3)$$

The second-slope stiffness, K_d, is the stiffness of elastomeric component of the bearing which can be calculated by the equation:

$$K_{eff} = \frac{Q_d}{\Delta} + K_d \quad (4)$$

The isolator displacement can be calculated from the effective period, equivalent viscous damping and spectral acceleration as:

$$D_D = \left(\frac{g}{4\pi^2}\right)\frac{C_v}{B}\,T \quad (5)$$

Where,

$C_v = \frac{S_a}{g}$ Spectral acceleration value for T = 1sec

T = Target design period of isolated building

B = Damping coefficient corresponding to the effective damping ratio. The relation between B and ξ expressed in here. [10]

$$\frac{1}{B} = 0.25(1 - In\ \xi) \quad (5a)$$

Effective damping ξeff is given by

$$\xi_{eff} = \frac{1}{4\pi}\frac{E_D}{E_{so}} \quad (6)$$

Where, E_{so} = Energy stored

$$E_{so} = \frac{1}{2}K_{eff}\,D^2 \quad (6a)$$

As we put eq. (6a) in eq (6) it becomes

$$E_D = 2\pi\xi_{eff}K_{eff}D^2 \quad (7)$$

E_D = Energy dissipated in one cycle which is equal to the area of the hysteresis loop.

For dynamic analysis code permits, furthermore reduction of target displacement which can be expressed as:

$$D'_D = \frac{D}{\sqrt{1 + \left(\frac{T}{T_M}\right)^2}} \quad (8)$$

Numerical Study

Mathematical Modeling of Building –

In this paper, mathematical models were defined for fixed base building and base isolated with lead rubber bearing. Building models were analyzed with scaled actual time history analysis building was analyzed. Analysis details of the building as shown in table: [11]

Description		Remark
No storey	10 storey+2 basement	
Type	RCC	Use as-Hospital building
Analysis used	Time history analysis	EQ-Imperial Valley-02
Scale History	Target response spectrum for hard soil	Code-IS1893-2016
Response reduction factor	4	
Seismic Zone Zone Factor	IV 0.24	Zone classified as per-IS1893-2016
Soil type	Hard	Type-I-IS1893-2016
Time Period	Tx = 0.60 S=sec.	Used formula as per-IS1893-2016
	Ty = 0.72 sec	

Table 4: Building Analysis Details

Seismic Isolation System –

In this study, dynamic building analysis has been performed by ETABS (Nonlinear version 16.2.0). Dynamic axial loads under each column at calculated for calculating parametric mechanical properties of lead-rubber bearing. As the structure got decoupled from the basement podium and mounted isolator at ground level. Nonlinear dynamic history analysis has been performed, to give a more accurate picture of the contribution of the base isolation system to the total seismic forces that are developed at the superstructure during a seismic excitation. It must be noted here that the response of the superstructure is elastic, while the response of the seismic isolation bearings is inelastic.

- Specification of Target Displacement - The target displacement of an isolator calculated from the expression given in Eq. 5. Design deflection governed by spectral 5% damped acceleration, Sd1 and time period, T, shown in Fig. 10.

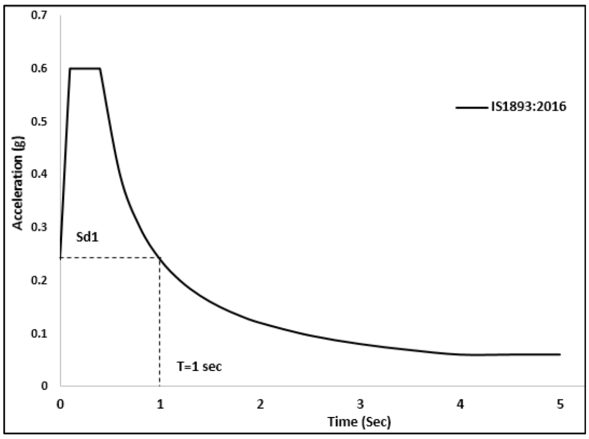


Fig.10-Codal horizontal response spectra for hard soil.

- Parametric Study for Mechanical Properties of LRB - In this paper, iterative LRB properties have been evaluate for different vertical loading on the column. As per the maximum vertical seismic loads on each column three column grouping are made for the building shown in Table 1. For these column groups, different LRB properties have been worked out to make economical design and thereby reduce the cost of the isolation. Parametric study carried out for target time period Tb=2.0, 2.5, 3.0 and 3 sec. corresponding effective damping, ξb=0.10, 0.15, 0.20, 0.25, 0.30. For each loading group, parametric iteration of LRB properties have been evaluated which are mentioned in table 5.

RESULT AND DISCUSSION

Comparison between Design and Time History Analysis Procedure

To investigate the effectiveness of base isolated building, time history analysis has been perform on both the model. The isolator performance parameters are the shear force coefficient, C, (the maximum isolator force normalized by the weight of structure) and the isolator displacement, DD. The ratios of the displacements and shear coefficient from the time history analysis to the values predicted by the design procedure are plotted in Table 6. In this study all twenty cases analyzed to work out the optimum case in each assumed time period.

Comparison between LRB and Fixed Structure

Table 6 shows the performance result of all LRB parameter for Tb=2.0, 2.5, 3, 3.5 sec.

with respect to the LRB damping 0.10, 0.15, 0.20, 0.25, 0.30. All four LRB system time history analysis, optimum performance of isolator have been worked out for these damping values.

11Sr no	Tb Sec	ξeff	S_{d1}	B	D_D (m)	$D_{D'}$ (m)	Dy (mm)	K_U (kN/mm)	K_{eff} (kN/mm)	K_V (kN/mm)	Q_D (kN)	Fy (kN)
1	2	0.1	0.24	1.21	0.099	0.094	5.57	6.45	0.863	1301	30.79	35.92
2	2	0.15	0.24	1.38	0.086	0.083	7.52	5.9	0.845	1067	38.23	44.4
3	2	0.2	0.24	1.53	0.078	0.074	8.52	5.47	0.828	880	40.21	46.67
4	2	0.25	0.24	1.67	0.071	0.068	12.13	5.73	1.167	874	60.34	69.48
5	2	0.3	0.24	1.814	0.066	0.063	15.77	6.02	1.594	867	83.1	94.92
6	2.5	0.1	0.24	1.21	0.123	0.12	5.67	6.33	0.754	1309	30.79	35.92
7	2.5	0.15	0.24	1.21	0.108	0.105	7.52	5.9	0.749	1067	38.23	44.4
8	2.5	0.2	0.24	1.53	0.097	0.095	10.62	6.16	0.977	1061	40.21	46.67
9	2.5	0.25	0.24	1.67	0.089	0.087	14.56	6.52	1.329	1052	60.34	69.48
10	2.5	0.3	0.24	1.814	0.082	0.08	15.77	6.02	1.313	867	83.1	94.92
11	3	0.1	0.24	1.21	0.148	0.145	5.67	6.33	0.71	1309	30.79	35.87
12	3	0.15	0.24	1.38	0.13	0.127	8.53	6.6	0.876	1302	48.66	56.28
13	3	0.2	0.24	1.53	0.117	0.115	10.62	6.16	0.873	1061	56.71	65.38
14	3	0.25	0.24	1.67	0.107	0.105	13.95	6.46	1.126	1053	78.82	90.16
15	3	0.3	0.24	1.814	0.099	0.097	15.77	6.02	1.131	867	83.1	94.92
16	3.5	0.1	0.24	1.21	0.173	0.17	5.67	6.33	0.679	1309	30.79	35.87
17	3.5	0.15	0.24	1.38	0.151	0.149	7.52	5.9	0.641	1067	38.23	44.4
18	3.5	0.2	0.24	1.53	0.136	0.134	10.62	6.16	0.803	1061	56.71	65.38
19	3.5	0.25	0.24	1.67	0.125	0.123	13.95	6.46	1.016	1053	78.82	90.16
20	3.5	0.3	0.24	1.814	0.155	0.113	15.77	6.02	1.01	867	83.1	94.92

Table 5: Parametric Properties of LRB for Group 1 Column Loading

							Design Procedure			Time History Analysis			
No	System	Seismic Weight (W)	Qd (kN)	Variation	Tb (Sec)	ξeff	DD	Vs=K.Δ	C=Vs/W	DD	BS	C=BS/W	Accel
1	LRB	75399	30.79	0.04	2	0.10	94	832.2	0.011	69	1298	0.017	0.830
		75399	38.23	0.05	2	0.15	83	734.8	0.010	72	1310	0.017	0.940
		75399	40.21	0.05	2	0.20	74	655.1	0.009	82	983	0.013	0.750
		75399	60.34	0.08	2	0.25	68	602.0	0.008	87	786	0.010	0.720
		75399	83.1	0.11	2	0.30	63	557.7	0.007	85	764	0.010	0.680
2	LRB	75399	30.79	0.04	2.5	0.10	120	679.2	0.009	62	1686	0.022	1.100
		75399	38.23	0.05	2.5	0.15	105	594.3	0.008	64	1686	0.019	1.030
		75399	40.21	0.05	2.5	0.20	95	1273.5	0.017	73	1012	0.013	0.870
		75399	60.34	0.08	2.5	0.25	87	492.4	0.007	82	830	0.011	0.740
		75399	83.1	0.11	2.5	0.30	80	452.8	0.006	88	726	0.010	0.690
3	LRB	75399	30.79	0.04	3.0	0.10	145	517.7	0.007	67	1329	0.018	1.050
		75399	48.66	0.06	3.0	0.15	127	453.4	0.006	65	1329	0.017	1.020
		75399	56.71	0.08	3.0	0.20	115	410.6	0.005	76	894	0.012	0.840
		75399	78.82	0.10	3.0	0.25	105	374.9	0.005	75	825	0.011	0.770
		75399	83.1	0.11	3.0	0.30	97	346.3	0.005	88	698	0.009	0.690
4	LRB	75399	24.15	30.79	3.5	0.10	170	491.3	0.007	62	1435	0.019	1.120
		75399	30.79	38.23	3.5	0.15	149	430.6	0.006	65	1220	0.016	1.030
		75399	35.34	56.71	3.5	0.20	134	387.3	0.005	71	977	0.013	0.900
		75399	50.89	78.82	3.5	0.25	123	355.5	0.005	84	716	0.009	0.730
		75399	69.27	83.10	3.5	0.30	113	326.6	0.004	88	679	0.009	0.690

Table 6: LRB Isolation System Performance

Sr. No	Tb (Sec)	ξ	BI		Fixed	
			Db (mm)	Ac (m/sec²)	Db (mm)	Ac (m/sec²)
1	3.5	10	62	1.12		
2	2.5	15	64	1.03		
3	2.5	20	73	0.87	5.7	2.48
4	2	25	87	0.72		
5	2	30	65	0.68		

Table 6: LRB Isolation System Performance

Floor Spectra Plot Variation

Response spectrum is the curve showing the maximum response versus the structural frequency relationship. [11] A study of floor response spectra for a base-isolated multi-storey structure under seismic ground excitations is carried out. All the LRB systems studied in Table 6 have been considered An El-Centro earthquake accelerogram is used to evaluate the floor response spectra. The characteristics of the spectra generated by different base isolation systems are studied, and the variation of all twenty LRB System plotted on a single graph. [13] The results are compared with those for the fixed-base structure. Fig.11 shows the plotting of floor acceleration spectra at top floor of the building. All optimum design cases are shown in dark line. For all the cases (ξ=0.10, Tb= 3.5 S, ξ=0.15, Tb=2.5 S, ξ=0.20, Tb= 2.5 S, ξ=0.25, Tb=2.0 S ξ=0.30, Tb= 2.0 S) maximum peak ordinate occur at the time period of 0.8 sec. and gradually lower down further.

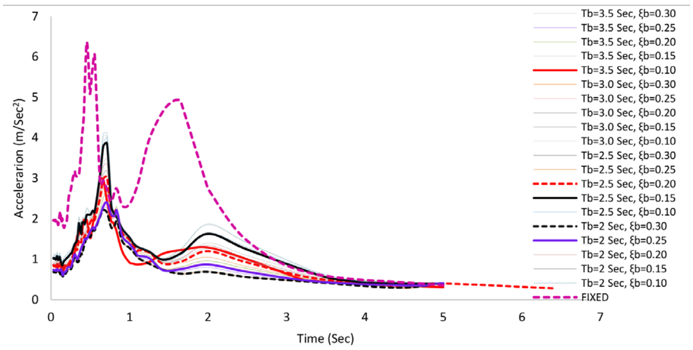


Fig.11-Floor acceleration response spectra at top floor

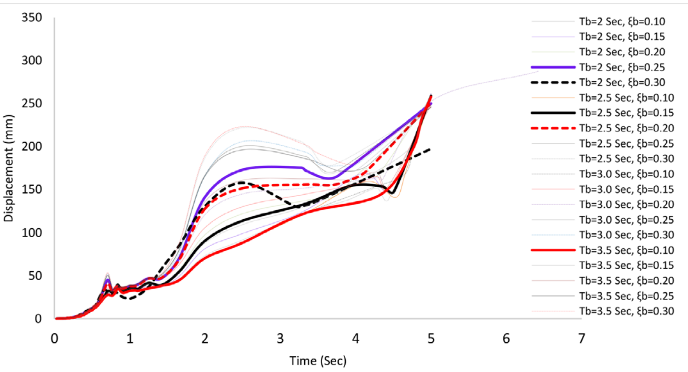


Fig.12-Displacement spectra at ground floor (Top of LRB)

Similarly, Fig.12 shows the floor displacement spectra at ground floor (top of the isolator & column interface). Displacement spectra depict the LRB performance for all studied systems. From all the cases studied system ξ=0.25, Tb= 2.0 S and ξ=0.30, Tb= 2.0 S evaluate the better response than other governing optimum cases of LRB performance.

Floor Time History Plot

In time history analysis of building lead rubber bearings designed are linked at bottom of the respective column at ground level to ensure all the properties of spring. Table 6 shows the performance of all the LRB system considered in this study. The time history for base shear of the BI building (ξ = 0.30, Tb = 2.0 sec.) and fixed building comparisons are illustrated in Fig. 13. The maximum base shear in fixed building occurs 4900 kN at T-4.9 sec. and for base isolated building, the base shear reduces 1140 kN drastically.

Similarly, Fig. 14 dipict floor acceleration time history for fixed and base isolated building at the top level of the building. The maximum top floor acceleration in fixed building occur 2.48 m/sec^2 and for base isolated building, the base shear reduces 0.68 m/sec^2.

Displacement and Acceleration Plot

In base isolation technique of building, seismic forces are dissipated by flexible bearing with high damping material. Fig. 15 shows storey forces variation for both fixed and BI building structure. In fixed structure dynamic forces absorbed by the structural itself caused heavy forces and moments induced in structural element. Fig. 15(a) shows the 67 mm base displacement at ground level (Top of LRB interface). Fig. 15(b) shows the maximum storey acceleration comparison for both the systems. Thus, acceleration of BI building successively lowered in each storey of the building in compare to the fixed structure, due to flexibility

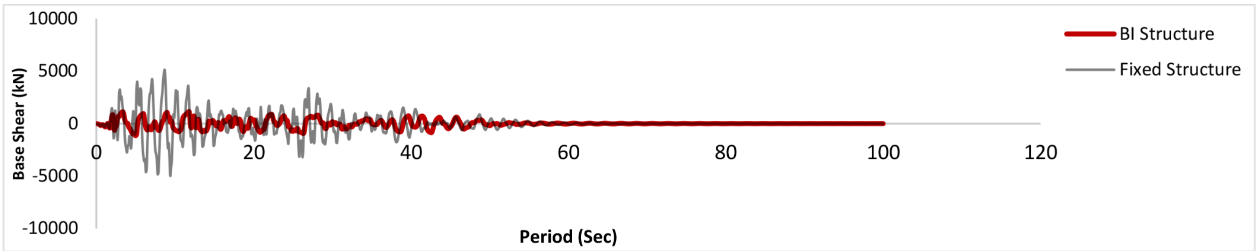


Fig.13-Plots the time history at ground floor (Top of LRB)

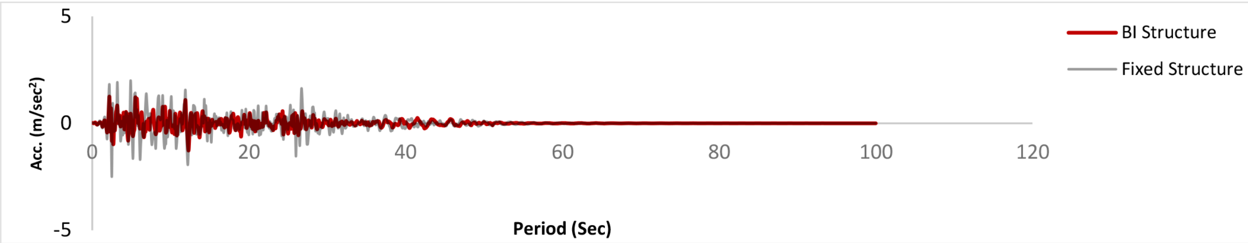
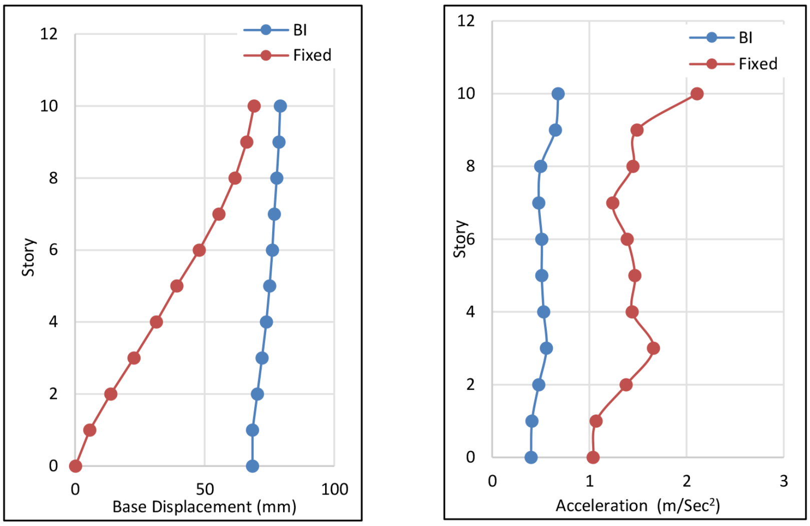


Fig.14- Plots the time history at top floor



(a) (b)

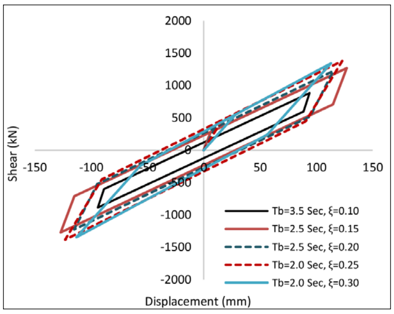
Fig.15- Story plot for Fixed and BI base (a) Displacement & (b) Acceleration

dissipation of earthquake forces at the base of the building.

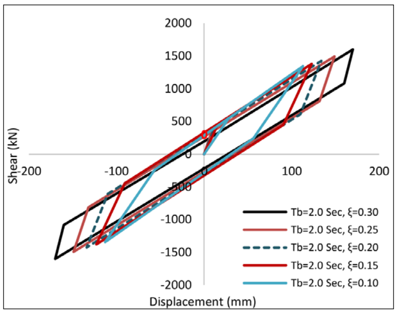
Force-deformation of LRB

Lead rubber bearings constructed of high damping rubber, have a nonlinear force deflection relationship. This relationship, termed the hysteresis loop, defines the effective stiffness (average stiffness at specified displacements) and the hysteretic damping provided by the system. [12] Fig. 16(a) depicts the bi-linear hysteresis curve for each optimum case shown in Table 6. Each case shows different shear resisted by the bearing with corresponding to the bearing displacement. Maximum force resisted by the case 1. Tb = 2.0 Sec, ξ = 0.25 and lower force dissipated by the case 2. Tb = 3.5 Sec, ξ = 0.10.

Fig. 16(b) depicts the cases for Tb = 2.0 Sec. with ξ = 0.10, 0.15, 0.20, 0.25, 0.30. As the damping of the bearing increases, the displacement of the bearing gets increased and vice versa. Fig. 16(c) depicts the actual hysteresis of optimum isolator.



a)



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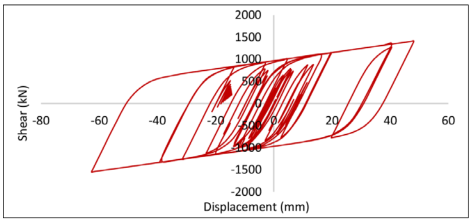

c)

Fig.16- Hysteresis curve
(a) Optimum cases as per Table VI,
(b) Optimum design case ξ=0.30 & Tb=2.0 sec.
(c) Time history analysis - case ξ=0.30 & Tb=2.0 sec.

CONCLUSION

The analysis of fixed base and LRB base isolated 3D ten storey RCC building have been performed in this paper. An exhaustive study has been performed on the performance of base isolated structures.

The behavior of building structure resting on LRB isolator is compared with fixed base structure under maximum capable earthquake. A complete list of performance of isolator is presented in Table 6. Seismic base isolation can reduce the seismic effects and therefore floor accelerations, inter-storey drifts, and base shear by lengthening the natural period of vibration of a structure via use of rubber isolation pads between the columns and the foundation. However, in case the deformation capacity of the isolators exceeded, isolators may rupture or buckle.

Therefore, it is vitally important to accurately estimate the peak base displacements in case of major earthquakes, particularly if the base isolated building is likely to be struck by near-fault earthquakes. Near-fault earthquakes may contain long-period velocity pulses which may coincide with the period of the base isolated structures. In such a case, the isolators may deform excessively.

The analysis comparison revels that base isolated structure reduces response performance considerably in compare to the fixed structure which impart a vital role in reducing the sizing of structural members and amount of designed steel requirement as well. Top floor acceleration and displacement floor spectra have been developed to study the exact earthquake response and finding out the optimum design parametric properties of LRB and corresponding cost comparison in case of Indian site area in highly seismic zone IV. According to analysis study, conclusions are as follows:

1. Increase of time period of building – As result of the increased flexibility of the system, natural period of the structure increased from T = 0.6 sec. to T = 4.2 sec, distancing natural period of the system from the predominant periods of the expected earthquake actions.
2. Reduction of base-shear – Reduction of the base-shear force is evident in the model with implemented seismic isolation. For the optimum case of LRB isolator, the base-shear force under the El-Centro earthquake excitation has been reduced 3.2 times in compare to fixed base structure.
3. Increase of displacements – Increased flexibility of the system led to increase of the total displacements due to the elasticity of the existing isolation. Displacements of the system are concentrated at the isolation top plan level. Total displacement at isolation top level is 68 mm under the El-Centro earthquake excitation.
4. Optimum LRB system – After analyzing all cases of different Tb and ξ values of the isolator system optimum design cases found as a) ξ = 10, Tb = 3.5 S, b) ξ = 15, Tb = 2.5 S, c) ξ = 20, Tb = 2.5 S, d) ξ = 25, Tb = 2 S, e) ξ = 30, Tb = 2.0 S.
5. Reduction of storey acceleration – Due to increased flexibility and damping of isolator, it predominantly dissipates most of the earthquake energy. Analysis has been shown significant reduction of floor acceleration. For fixed structure top floor acceleration under earthquake excitation has found 2.48 m/sec^2, where as in base isolated structure for same floor it is found 0.68 m/sec^2.

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Indian Association of Structural Engineers

Join The Panel Discussion On

Draft Code IS 1893 (Part 1) General Provisions

June 17, 2023 (Saturday) at 4:30-6:30 PM (IST)

Lead Speaker

C. V. R. Murty
IIT, Madras

Panelists

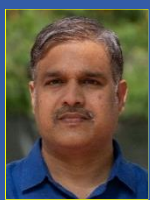
Rupen Goswami
IIT Madras

Alpa Sheth
VMS Consultants Pvt Ltd.

Praveen Khandelwal
NTPC

Moderators

Alok Bhowmick
Past President, IAStructE



R. Pradeep Kumar
President, IAStructE

S. T. G . Raghukanth
IIT Madras

I. D. Gupta
Former Director, CWPRS, Pune

D. Srinagesh
Prof of Practice, IIT Madras

About The Panel Discussion

With rapid strides in earthquake engineering in the last several decades, the seismic codes world over are becoming increasingly sophisticated. Indian seismic codes are no exception. The first Indian seismic code (IS 1893) was published in 1962 and it has since been revised in 1966, 1970, 1975, 1984, 2002 and 2016. The code is once again revised and the revised draft is currently in wide circulation for comments from wider community. The Part-1 of current code is split into two parts in revised version. Part-1 containing general provisions (applicable to all structures) and Part-2 specific provisions for buildings has been published.

This time, the revision of the seismic code is a quantum jump and brings in many significant changes, introducing many advances that have occurred in the knowledge related to earthquake-resistant design of structures over the last 20 years, since its publication in 2002. Some of these new developments have been incorporated in the 2016 version of the code, while many others have been left out so that the implementation of the code does not become too tedious for Indian professional engineers.

IAStructE is happy to organise a panel discussion on the Draft IS 1893, in two sessions, where the code makers and experts, who piloted this revision, will look at the process of development of the draft code IS 1893 (Part-1) and IS:1893 (Part-2). In the first panel discussion on 17th June 2023, the eminent panellists will discuss the main changes that are proposed in Part-1 of the revised code. This will be followed by an interactive session where participants can directly ask questions to the esteemed panellists and clear their doubts.

ABOUT IAStructE

Indian Association of Structural Engineers (IAStructE) is a national apex body of structural engineers established two decades ago with the objective to cater to the overall professional needs of structural engineers.

DRAFT CODE IS 1893 (PART 1) GENERAL PROVISIONS

With rapid strides in earthquake engineering in the last several decades, the seismic codes across the world are becoming increasingly sophisticated and the Indian seismic codes are no exceptions. The first Indian seismic code (IS 1893) was published in 1962 and it has since been revised in 1966, 1970, 1975, 1984, 2002 and 2016, and now the code is once again revised. This time, the revision of the seismic code is a quantum jump and brings in many significant changes, introducing many advances that have occurred in the knowledge related to the earthquake-resistant design of structures over the last 20 years. In order to discuss the developments, IAStructE has organized a panel discussion on IS 1893 (Part 1) on 17th June, 2023 where experts who contributed for the development of the code participated in the discussion.

Prof. R. Pradeep Kumar, President IAStructE and Mr. Alok Bhowmick, Past President IAStructE welcomed the esteemed speaker and eminent panelists to the deliberation on the proposed revision of IS 1893. Mr. Bhowmick highlighted that the proposed revision of the standard is a quantum jump and captures many significant changes. The intent of the workshop was to provide better insight into the proposed changes to the structural engineers and also invite their valued suggestions to make the standard more comprehensive

Mr. S. Arun Kumar, Head – Civil Engineering Department (CED), Bureau of Indian Standards (BIS) excellently set the stage for the session and spoke about the massive exercise that was taken up by the national standards' body for the revision of the standard. He mentioned that the promotion of safety is one of the key objectives of standardization and in line with the objective, standards are reviewed and updated to imbibe the practice and define clear provisions, thereby providing a framework for future technological development. IS 1893 has seen multiple revisions since its inception in 1962. In this revision, the standard is developed in 2 parts – the first part deals with the general provisions and the second part highlights the design requirement.

He added that in 2010, the Government of India published its first probabilistic seismic hazard map of the nation. Over the years, other countries have codified them in way of their national standards. Hence, the CED-39 committee, which is responsible for the development of earthquake-related standards in the country, decided to include the PSH map of India in the current revision of the standard. During the development of this standard, extensive research work was taken up at IIT Madras under the patronage of the National Disaster Management Authority (NDMA). The PSH map and the rationale have been very explicitly spelt out in the standard and pave the way for any future research work and development.

Prof. C.V.R. Murty, Chairman of the CED39 Committee, started his talk by mentioning that the focus of IS 1893 is earthquake hazard and hence the implications can also be traced to the upcoming revisions of IS 13920 and IS 13935. The mandate from BIS is to undertake comprehensive harmonization of all standards related to earthquake safety and hence all parts pertaining to the dominant set consisting of IS 1893, IS 13920 and IS 13935 will be sequentially taken up for publication.

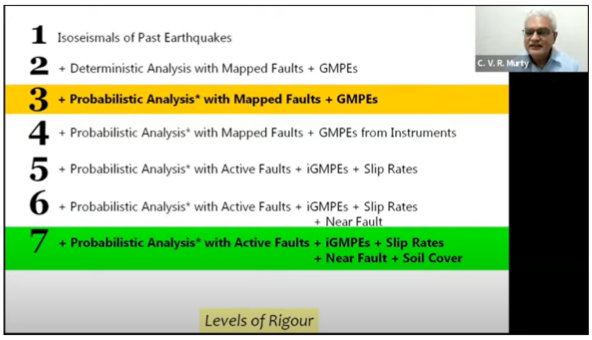
Prof. Rupen Goswami, IIT Madras reinforced the same message in his lecture. Prof. Murty mentioned that the motivation for this revision came from the past earthquakes and the loss of life which occurred due to them. As per statistical analysis, about 50,000 lives have been lost in India in the last 35 years due to earthquakes. Both Prof. Murty and Dr. D. Srinagesh, IIT Madras took reference of the 1967 Koyna earthquake, 1993 Killari earthquake and 1997 Jabalpur earthquake which have been shown to spring surprises and cause extensive damage.

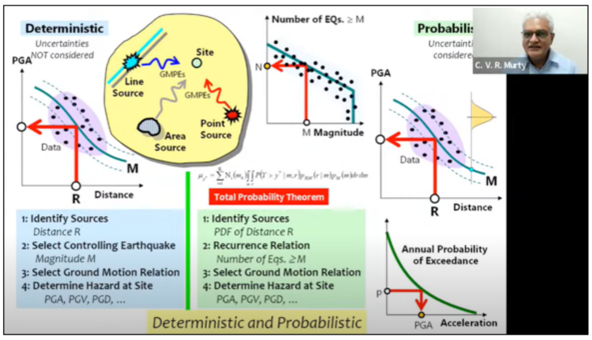
Prof. Murty added that the earthquake zoning of the country has undergone an evolution from 1962 when there were 7 zones, which then got modified to 5 in 1984 and further compressed to 4 in 2002. All the earlier versions were motivated by the MSK intensity that was experienced by different parts of the country and then isoseismal was used as the basis for zonation. He identified three gaps in the current framework –

1. Insufficient data on the past earthquakes
2. Underestimated earthquake hazard in the part
3. Insufficient instrument to record strong ground motion in future earthquakes

Dr. I.D. Gupta, former Director, CWPRS Pune, also mentioned that the zone boundaries in all previous maps were demarcated from a limited number of observations and zone factors were decided based on engineering judgement, rather than ground motion analysis. Such maps were qualitative and subjective in nature, without explicit use of the source.

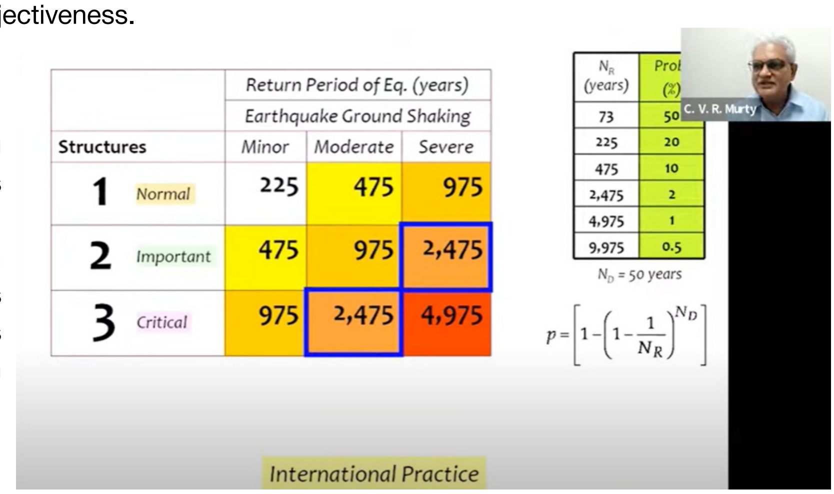
Looking at the earthquake hazard assessment levels, Prof. Murty mentioned that the current proposal is to include both probabilistic and deterministic assessment as the baseline. The way forward is to include the ground motion derived from instruments, capture active faults, and understand the slip rates and near-fault effects, which have become prominent in recent times





Dr. I.D. Gupta added that the need to refine the standard arose since the state-of-the-art methodology had been established as the PSH approach in the late 1990s in the United States. A probabilistic map of India was published in 1999 under GSHAP and the same is now being realized in practice. PSHA is a fully quantitative approach based on sound mathematical principles and models developed using available data, with minimal subjectiveness.

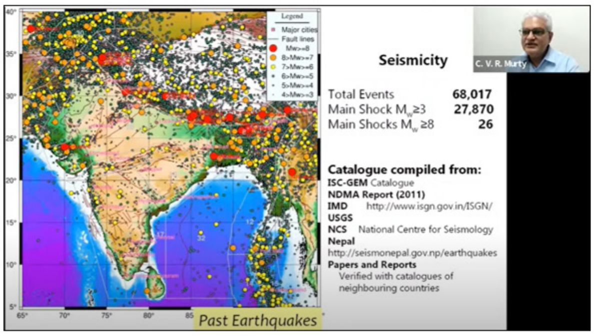
The PSHA estimates the ground motion at a place which has a 2% probability of exceedance during its design life (considered as 50 years). Looking at international practices, a significant decision was that severe earthquakes which are used as a basis for design have been taken corresponding to a return period of 2,475 years.

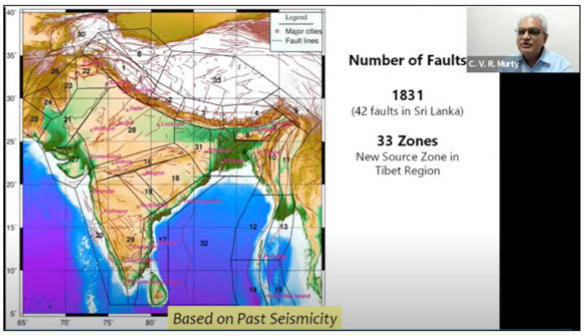


The PSHA method performs this by modelling possible seismic sources and defining an earthquake occurrence model for each source. Thus, the first step in carrying out the PSHA was to identify the seismic sources. Based on the past occurrence of earthquakes from different sources, a catalogue was prepared. Prof. Murty and Dr. I.D. Gupta touched base upon the observation that more than 27,000 earthquakes of magnitude 3 or more have hit the landmass of India with 26 events having a magnitude of more than 8. The Shillong earthquake, the Kangra earthquake, the earthquake at the Bihar-Nepal border and also the one in Arunachal Pradesh formed the basis for deciding the zones. The landmass has been divided into 3 regions – the Himalayan segment, the Indo-Gangetic segment, and the continental base for prediction of ground motion. India and its neighbouring landmass have been divided into 33 seismogenic source zones. For each of these sources, the relevant parameters have been extracted and used as a basis for quantitative assessment.

For probabilistic hazard assessment, peak ground acceleration, peak ground velocity, peak ground displacement and corresponding contours were considered.

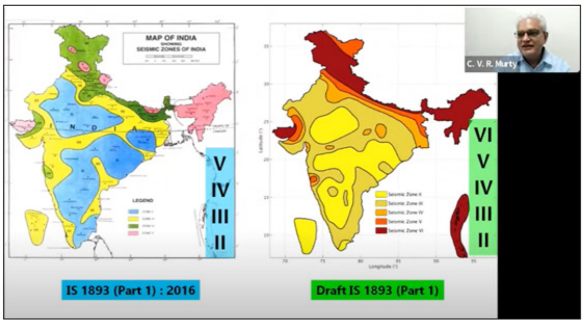
An earthquake recurrence model was developed for each zone and this resulted in improved hazard distribution as compared to previous practice.

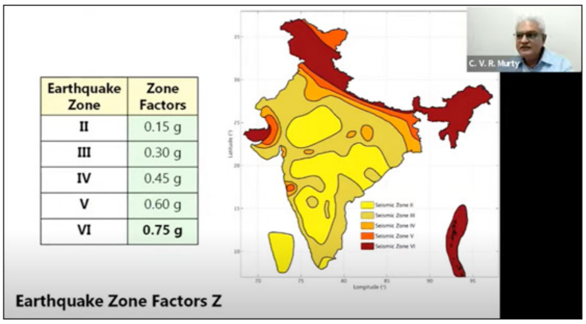




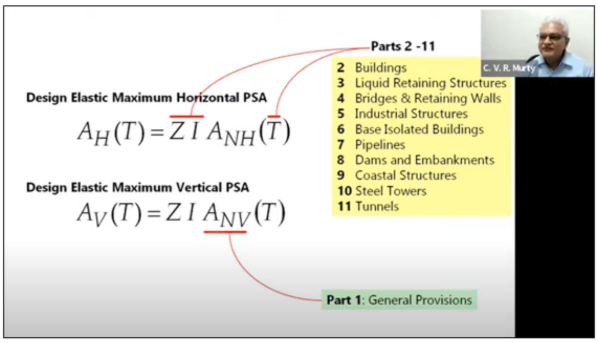
Prof. Murty added that considering earthquake as a natural phenomenon and uncertainty of its place of occurrence, the approach of taking median value as the base has been adopted and a return period of 2,475 years forms the reference. Background seismicity has been considered for all 33 regions and results were validated basis input received on different ground motion prediction equations (GMPE).

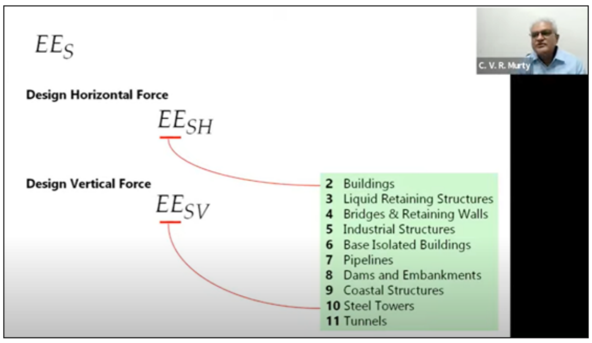
The seismic zone map of India that was derived was superimposed on the seismicity of the country and found to be fairly consistent with earlier events and also with the fault lines. As per the new standard, there are 5 seismic zones – Zone II to Zone VI with the PGA values ranging from 0.15g to 0.75g at increments of 0.15g.





The design elastic maximum pseudo spectral acceleration (PSA) is a function of the zone factor, importance factor of the structure and the normalized spectral shape. The design force is calculated by dividing the PSA by the response reduction factor.

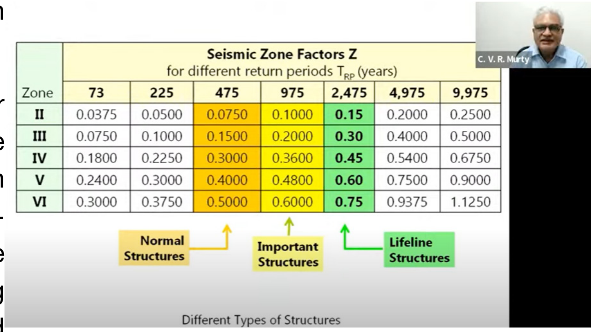




Prof. Murty added that certain modifications have been made in the load combinations to be considered for both strength and serviceability criteria. Another welcome addition is the inclusion of safety factor for soil design under earthquake shaking for different types of structures. Another significant addition is the soil structure interaction in the design provision.

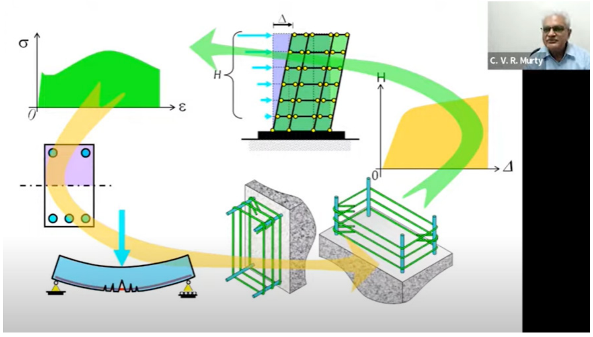
Another important aspect which has been addressed in the modification of the standard is the closed loop design process which highlights the likely behaviour of a structure and the estimation of damage location.

This will form the basis of earthquake retrofit which will be addressed in the revision of IS 13935.

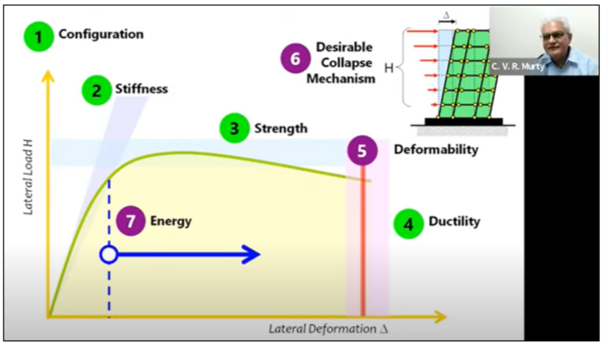


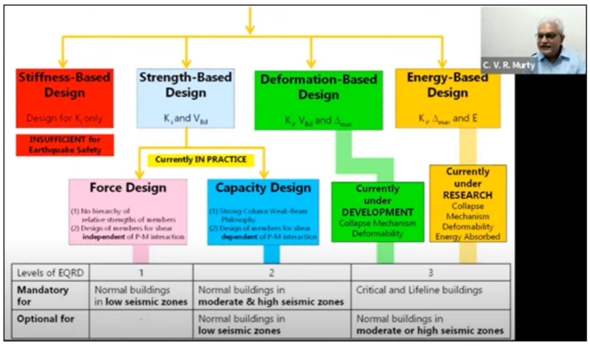
Zone	73	225	475	975	2,475	4,975	9,975
II	0.0375	0.0500	0.0750	0.1000	0.15	0.2000	0.2500
III	0.0750	0.1000	0.1500	0.2000	0.30	0.4000	0.5000
IV	0.1800	0.2250	0.3000	0.3600	0.45	0.5400	0.6750
V	0.2400	0.3000	0.4000	0.4800	0.60	0.7500	0.9000
VI	0.3000	0.3750	0.5000	0.6000	0.75	0.9375	1.1250

Earthquake-resistant design has progressed over the years and from strength-based design, we transitioned to capacity design in the last revision of the standard. In the current draft, a deformation-based design has been introduced for the purpose of retrofitting. There is a graded use of it, depending on the normal buildings, important buildings, and critical buildings. Earlier the design philosophy was based on 4 virtues – configuration, stiffness, strength, and ductility. Ductility was never quantified but assumed to be achieved if the prescribed detailing was followed. In the current standard, the aim is to estimate the deformation and establish that the demand is less than the capacity, implying the structure will not collapse (at least for critical structures). Revised clauses, addressing the requirement of liquefaction of soil have also been presented.



The last important addition is the concept to protect the architectural elements and utilities in the building to protect life and assets.





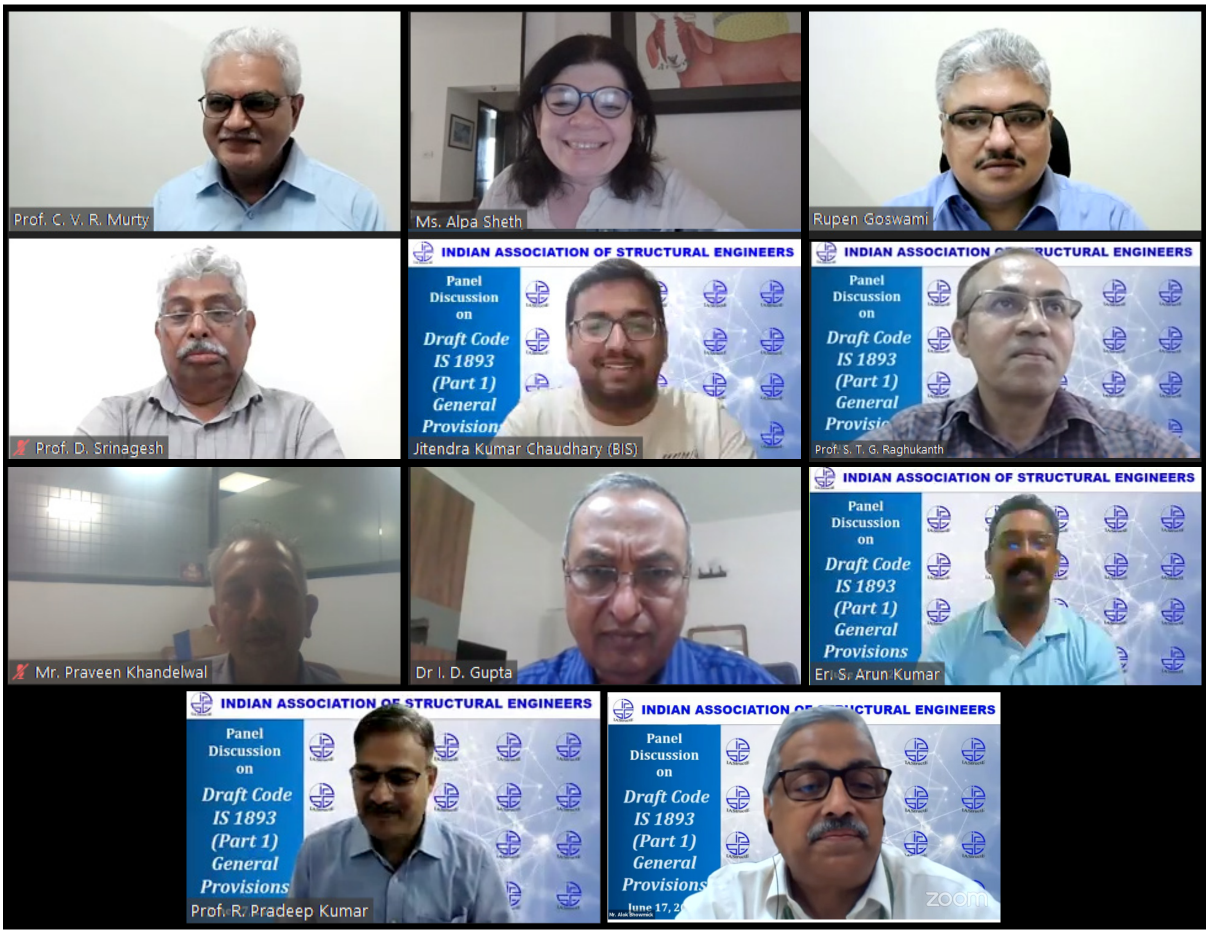
Prof. Raghukanth, IIT Madras mentioned that lot of advancement has happened in the subject of seismology and hazard analysis. Some of the earthquakes recorded ground motion as high as 1.0g in the epicentral region and very close to the faults. The recent Turkey earthquake also demonstrated the same. With extensive research going into the subject, much clarity has been built around the topic and all this information has been pulled up to refine the standard with a more consistent approach.

Prof. Rupen Goswami added that it is not recommended to compare zone factors with previous editions of the standard, since they are not based on the same philosophy. Also, it is evident that there will be an increase in the design forces in certain cases, but this should be a reason to panic. He encouraged that with the proposed design standard, there is much more rationale being built into the approach and is optimistic that engineers will come out more confident with their designs.

Mr. Praveen Khandelwal, NTPC appreciated the great initiative to put all information related to earthquake engineering in one place and this will help the stakeholders by and large. The code is a visionary approach towards defining the limit state and is very structured. He highlighted that where the zone factor is not changing, the increase in seismic force is not extensive. Even though the zone factor is increased, the factored load will increment will compensate for the same, owing to the revised load combination. In industrial structures, where the civil cost is comparatively less, the cost implication for a change of code is minimal and does not alter the economics drastically. For buildings where the civil cost is on the higher side, a change of seismic zone for a specific area may lead to an increase in the project cost.

Ms. Alpa Sheth, VMS Consultants Pvt. Ltd. appreciated the concern of practising engineers about the design process and the cost implication the revised standard would have. She encouraged the adoption of the new standard with thorough understanding. She added that the past is not necessarily an indication of the future and if we have not seen earthquakes in the past, it is all the more concerning, since there is more stress concentration built at the fault.

The discussion was followed by a panel discussion where panelists addressed the questions raised by the participants. Mr. Jitendra Chaudhary, Member Secretary – CED 39, BIS gave closing remarks. Finally, Prof. Pradeep proposed a vote of thanks and requested all the participants to register for the second-panel discussion which is scheduled on 1st July, 2023 focusing on IS 1893 (Part 2): Buildings.



4,700 EARTHQUAKES OVER 72 HOURS!

Spreads Concern of Impending Volcanic Eruption in Iceland

The area surrounding Reykjavik – capital city of Iceland has experienced an extraordinary number of earthquakes in the past 72 hours, raising concerns of an imminent volcanic eruption, as per the Icelandic Meteorological Office (IMO).

As per a report by news agency AFP, approximately 4,700 earthquakes have been recorded beneath Mount Fagradalsfjall located on the Reykjanes Peninsula. And the largest earthquakes have been felt in the Southwest part of Iceland. This region has witnessed two eruptions in the past two years.

Iceland is Europe's largest and most active volcanic region. It is situated on the Mid-Atlantic Ridge, a geological feature separating the Eurasian and North American tectonic plates.

Indian Association of Structural Engineers | **Bureau of Indian Standards**

Jointly organizing the Panel Discussion On

Draft IS Code 1893 (Part 2) Buildings

July 1, 2023 (Saturday), 4:30-6:30 PM (IST)

Lead Speaker

Rupen Goswami
IIT Madras

Panelists

C. V. R. Murty
IIT Madras

Ravi Sinha
IIT Bombay

Arun Kumar S.
BIS

Alpa Sheth
VMS Consultants Pvt Ltd.

Praveen Khandelwal
NTPC

Jitendra K. Chaudhary
BIS

Moderators

Sangeeta Wij
Vice President (North), IAStructE

R. Pradeep Kumar
President, IAStructE

About The Panel Discussion

With rapid strides in earthquake engineering in the last several decades, the seismic codes world over are becoming increasingly sophisticated. Indian seismic codes are no exception. The first Indian seismic code (IS 1893) was published in 1962 and it has since been revised in 1966, 1970, 1975, 1984, 2002 and 2016. The code is once again revised and the revised draft is currently in wide circulation for comments from wider community. The Part-1 of current code is split into two parts in revised version. Part-1 containing general provisions (applicable to all structures) and Part-2 specific provisions for buildings has been published.

This time, the revision of the seismic code is a quantum jump and brings in many significant changes, introducing many advances that have occurred in the knowledge related to earthquake-resistant design of structures over the last 20 years, since its publication in 2002. Some of these new developments have been incorporated in the 2016 version of the code, while many others have been left out so that the implementation of the code does not become too tedious for Indian professional engineers.

The panel discussion on IS 1893 Part 1 General Provisions was organized on June 17, 2023. IAStructE & BIS are now happy to organise a panel discussion on the Draft code IS 1893 Part 2 Buildings, where the code makers and experts, who piloted this revision, will look at the process of development of the draft code. In the panel discussion, the eminent panellists will discuss the main changes that are proposed in Part-1 of the revised code. This will be followed by an interactive session where participants can directly ask questions to the esteemed panellists and clear their doubts.

DRAFT IS CODE 1893 (PART 2) BUILDINGS

In continuation to the discussion on 17th June, another panel discussion was organized by IS 1893 (Part 2) on 1st July, 2023 delivered by experts in the code committee.

Professor R. Pradeep Kumar, President, IAStructE and Ms. Sangeeta Wij, Member, IAStructE extended a warm welcome to the esteemed speaker, eminent panelists and to all the participants. Prof. Pradeep Kumar set the stage by summarizing three prominent reasons which have led the standardization body to take up this extensive exercise –

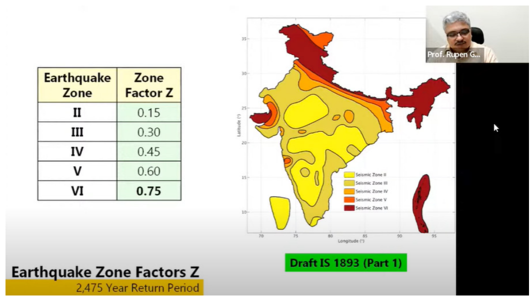
1. In urban areas, there is the prominence of open-ground storey structures and adoption of construction practices which do not meet the requirements of the code;
2. In rural areas, buildings are largely self-built and lack the compliance;
3. Lack of awareness about the right construction practices and specifications.

Ms. Sangeeta Wij broadly highlighted the changes in the standard which include the method of analysis, categorization of buildings, detail on structural systems to be adopted for RCC, steel, masonry buildings, provision of torsional flexibility etc. These are welcome additions which have been formulated based on intense deliberations and she encouraged fellow engineers to follow the guidelines diligently.

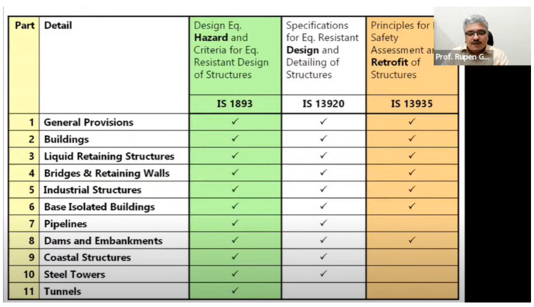
Mr. S. Arun Kumar, Head of Civil Engineering Department (CED), Bureau of Indian Standards (BIS) encouraged the practicing engineers to review the standard for the significant changes which have been made in this refined version.

Prof. Ravi Sinha, IIT Bombay, in his deliberation, highlighted the fact mentioning that changes in standards and construction practices happen because of perceived shortcomings in the existing practice. He touched base on the critical fact that India has more number of people living in high earthquake hazard zone which means more people are at risk of loss of life. Drawing reference from the Turkey earthquake, he mentioned that the magnitude of the earthquake which was experienced was similar to what is considered for design in seismic Zone V. We have been fortunate to have not experienced major catastrophes due to earthquakes in India in the recent past, however, this also means that we learn from real earthquakes in other parts of the country and be better prepared. Life safety is never negotiable and compliance with codes during design and construction ensures that occupants within the building do not lose their life in a codal level earthquake.

Prof. Rupen Goswami, IIT Madras started his session by highlighting the changes which have been made for the seismic zones based on the revised seismic hazard map and for a return period of 2,475 years.



The earthquake standards in the country are being segmented in line with the larger harmonization vision of BIS. Part 2 of IS 1893 talks about all buildings in general, followed by masonry, concrete and steel buildings in the subsequent sections of the document. There are future provisions to include timber, adobe and steel-concrete composite buildings as part of the code.



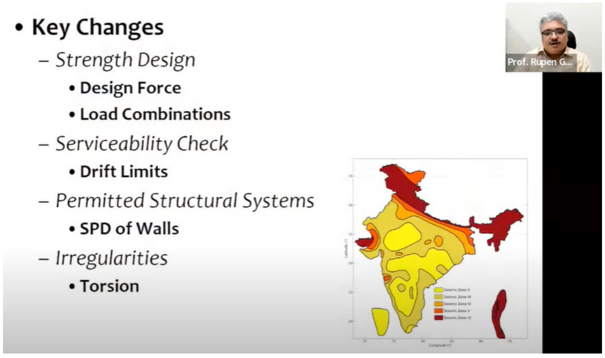
Part	Detail	Design Eq. **Hazard** and Criteria for Eq. Resistant Design of Structures	Specifications for Eq. Resistant **Design** and Detailing of Structures	Principles for Safety Assessment a **Retrofit** of Structures
		IS 1893	IS 13920	IS 13935
1	General Provisions	✓	✓	✓
2	Buildings	✓	✓	✓
3	Liquid Retaining Structures	✓	✓	✓
4	Bridges & Retaining Walls	✓	✓	✓
5	Industrial Structures	✓	✓	✓
6	Base Isolated Buildings	✓	✓	✓
7	Pipelines	✓	✓	
8	Dams and Embankments	✓	✓	✓
9	Coastal Structures	✓	✓	
10	Steel Towers	✓	✓	
11	Tunnels	✓		

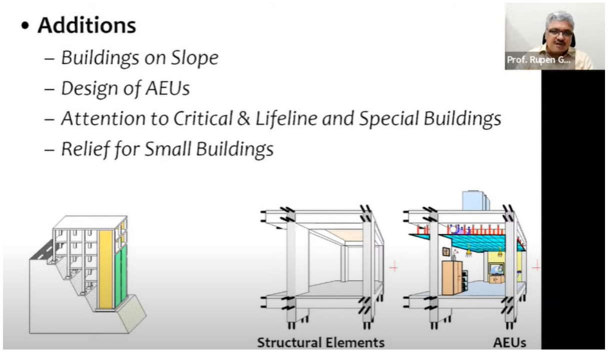
He summarized the key changes in the revised standard, with changes in strength design consideration being the most important. Graded approach for serviceability criteria, permitted structural systems (SPD of walls), and guidelines for torsional irregularities being other major changes.

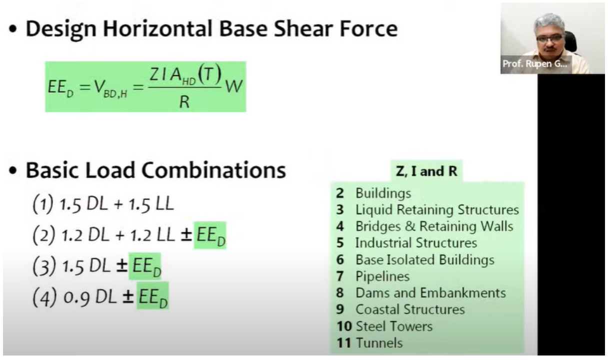
He touched upon the additions which have been made in the standard. With the extensive development of construction in the North-East and in the Himalayan regions, it was perceived as extremely critical to address the safety requirement in those areas. Design on non-structural components has come under the purview of the standard. Attention has been given to critical and lifeline structures. While all these may call for an advanced level of detailing to be carried out, relaxation has been given to small and regular buildings

Regarding the strength design, a couple of major changes have been observed in terms of the factors. Based on a more robust and scientific analysis, the estimate of "Z" has been made more rational. Also, the factor on earthquake load has been modified to 1 against an enhancement by 50% as per the current practice.

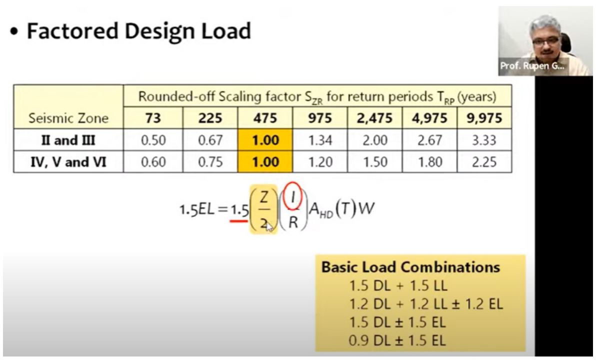
The hazard analysis has been carried out in accordance with international practices and values have been modified to obtain "Z" values for other return periods. The proposal is to consider a return period of 475 years for normal structures, 975 years for important buildings and 2,475 years for lifeline structures. This is the general framework under which IS 1893 is going to operate. Currently, the "Z" value is determined irrespective of the type of building, however going forward, it can be chosen appropriately.

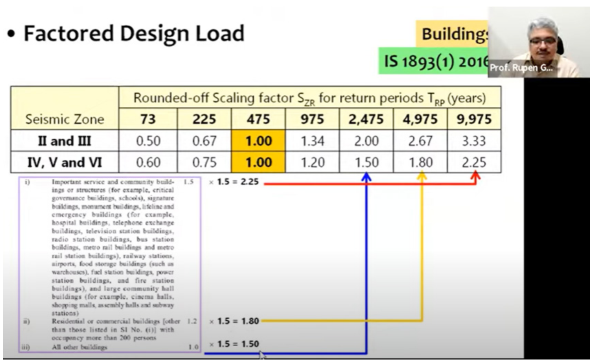


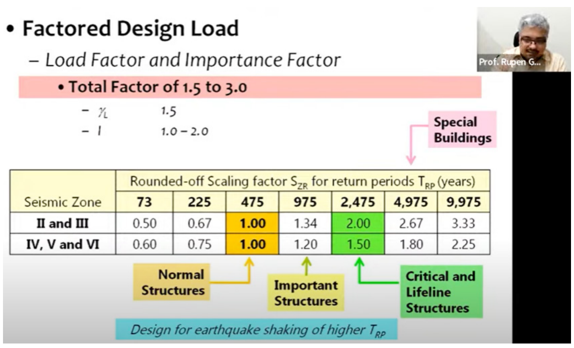


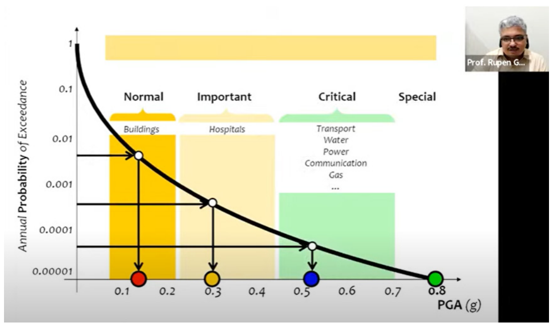


Prof. Goswami further explained the impact of all the influencing factors on the design force for strength design, with sample calculation for the current scenario vis-à-vis the proposed change for normal buildings. This goes well with the general idea.





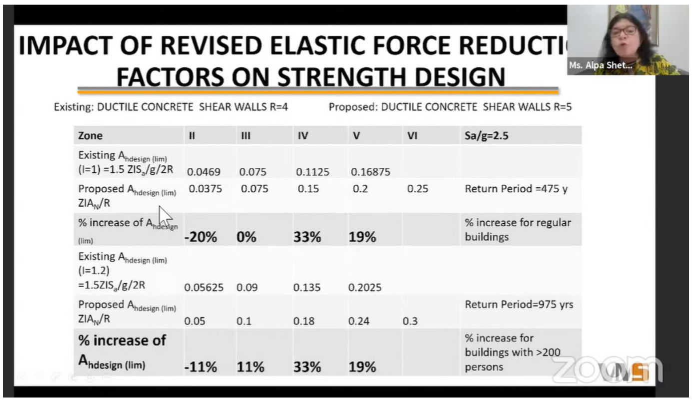


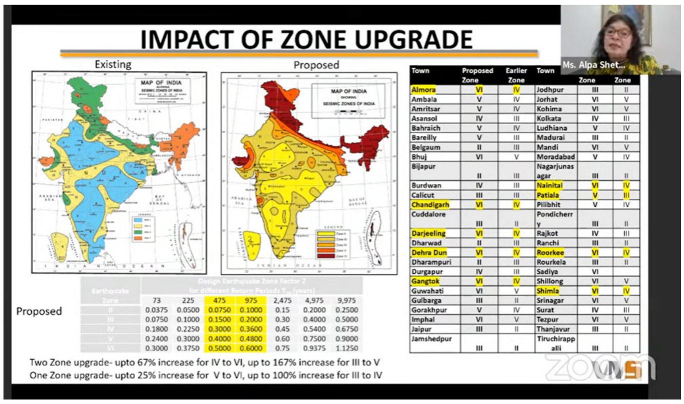


The return period relates to the annual probability of exceedance. For normal buildings, with a design life of 50 years, the probability of exceedance is taken as 10% as per global practice. For important structures, the probability is 5% and for critical structures, it is 2%. For a critical building, there is a higher return period, which indicates a bigger event. This essentially translates to a larger intensity of shaking which can be correlated to higher peak ground acceleration and therefore a higher zone factor.

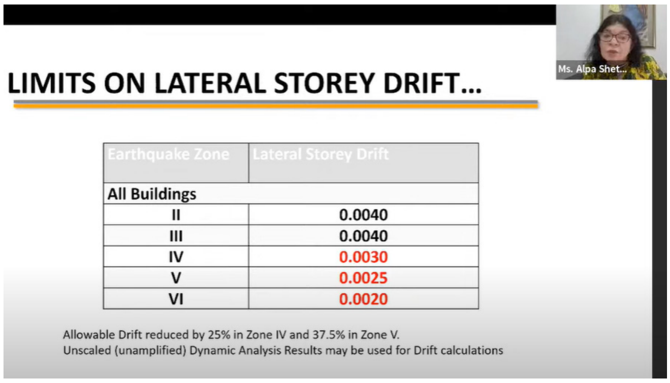
Prof. Goswami shared a comparison of current practices against changes for different scenarios. From his analysis, it was understood that for no change of zone, the increase in horizontal force will range between 25-50% for normal buildings. However, for a change of zone by +1 or +2 levels, amplifications will be higher. A similar analysis was made for important and critical structures.

Ms. Alpa Sheth, VMS Consultants Pvt. Ltd. reinforced the understanding of the topic. She captured the places which would experience the upgradation of the seismic zone due to the revision of the standard. She also highlighted the impact of revised elastic force reduction factors on strength design with elaborate examples.



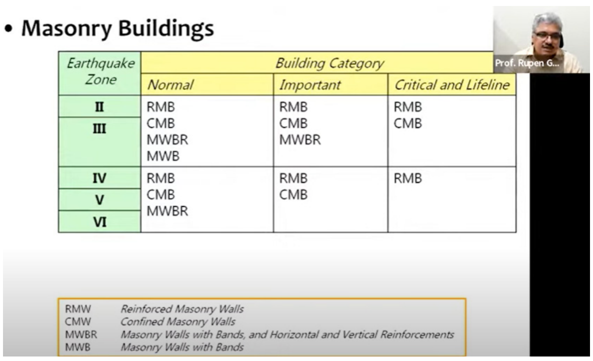


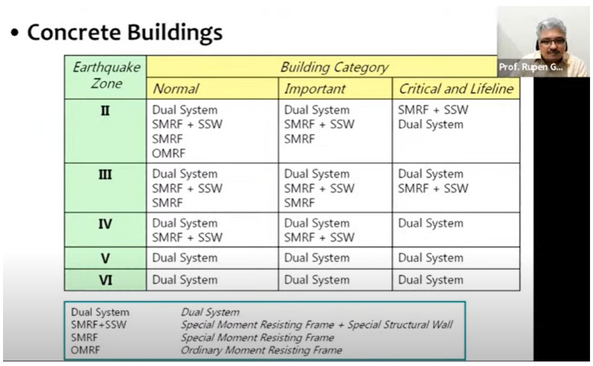
In the serviceability criteria, Prof. Goswami deliberated that for the allowable damage to structures, a graded approach has been adopted with respect to drift limitation. Ms. Alpa Sheth added that the allowable drift has been reduced by 25% for Zone IV and by 37.5% for Zone V.

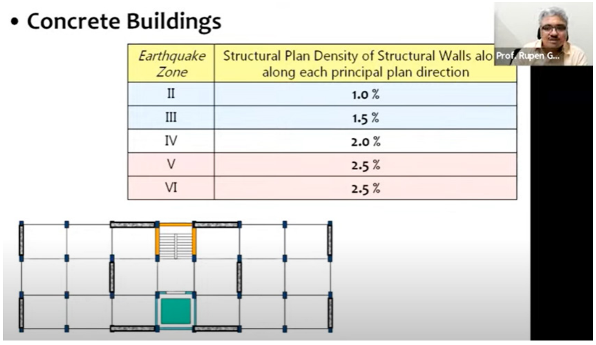


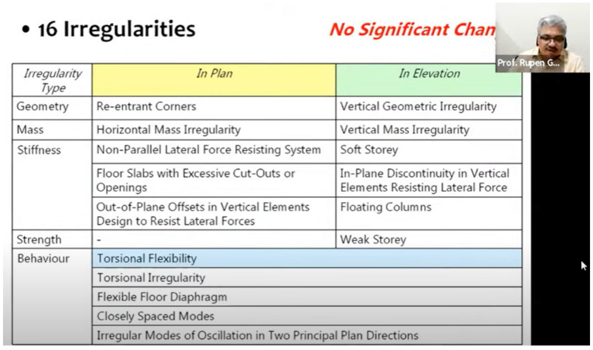
Regarding the structural systems, Prof. Goswami added that depending on the type of structure, lateral load-resisting elements have been prioritized for different zones and building categories. For masonry construction, the primary recommendation is to adopt reinforced masonry or confined masonry, followed by other systems. For reinforced concrete buildings, in high seismic zone, robust lateral systems are recommended and hence the dual system is the preferred approach. A similar provision has been given for steel buildings.

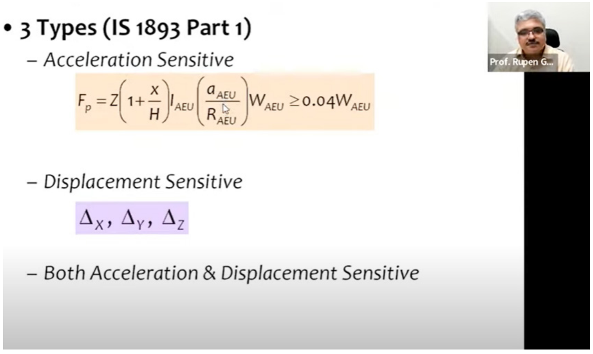
For concrete buildings, another welcome change is the prescription of the structural planned density of walls. In the current practice, a fixed value of 2% is considered in each plan direction.











However, going forward, a graded approach has been adopted, in line with the basic consideration and other design provisions. Another important aspect is building irregularity, which plays a vital role in the seismic behaviour of a structure. No major changes have been made in this regard, except that the provision has been more explicit in the new standard.

An additional requirement of torsional flexibility has been taken into consideration in the proposed revision to factor in the effect of torsional irregularities.

Addition of provision for buildings in slope and inclusion of seismic design for non-structural elements are among the major changes in the proposed revision.

Mr. Praveen Khandelwal, NTPC, touched base on the cost implication which this revision might have on the overall project cost. He mentioned that there is always the total cost and then the civil cost. In projects, where the cost due to civil work is less (e.g. industrial structures), the impact on the overall cost due to revision of the standard will not be large enough to disturb the techno-economic feasibility of the projects. Even for buildings, where the proportion of civil work is comparatively high, the difference may still be anticipated in the reasonable range of 15-20% of the overall project cost. Hence, it is more appropriate to pay due diligence to the adoption of the right design principles.

While answering a few of the questions raised by the participants, Prof C. V. R. Murty mentioned that surprise earthquakes in high seismic zones are of minor consequence while the surprises in low seismic zones are having very high consequence and this has been demonstrated by historical evidence.

When asked whether seismic design is important for a wind sensitive structure, he clarified that even if for a structure, the design wind load is more onerous than the design seismic load, still ductile design and detailing for seismic need to be followed, since design philosophy for earthquake assumes that structure will undergo inelastic deformation, unlike the wind load design philosophy. He added that even within a category of structure, if one wants to distinguish between them, there is an option to marginally enhance the force level, keeping in mind that we don't jump onto the next return period Z-values. And that is the essence of importance factor in the overall consideration as per the revised draft.

The code committee is still open to suggestions from the industry for further refinements and improvements in this regard. Regarding the consideration of architectural elements in a building, he added that any component that is not involved in the load transfer mechanism will be considered as a non-structural element and the relevant clauses will be applicable.

The discussion was followed by a panel discussion where panelists addressed the questions raised by the participants. Mr. Jitendra Chaudhary, Member Secretary – CED 39, BIS gave closing remarks and a vote of thanks.

A SEISMIC RESISTANT STRUCTURE – PHILIPPINE ARENA MIRRORS ENDURANCE

The archipelagic nation of 7,641 islands, Philippines has diverse ecologies to cater to the world. Among the nature's bounty, it also houses some of its equally stunning infrastructure; solidifying a unique balance between the two: nature and human creation. The Philippine Arena boasts to be one of the notable structures of the country.

Keeping in mind the extreme high-winds speed, torrential rains and severe earthquakes, the largest indoor entertainment venue in the world is designed to shelter up to 55,000 spectators and 5,000 performers against these elements. The Phillipine Arena is inspired by the traditional Filipino Nipa Hut and the indigenous Narra tree and is a symbol of endurance, strength and indomitable spirit of the Filipino people.

Being situated in the Pacific 'Ring of Fire', the area is distraught with frequent volcanic eruptions and earthquakes of magnitude as high as 8 or more. The Arena is located just 24 km away from the West Valley Fault, a long active fault line that runs through Metro Manila and some provinces in Luzon. This highly engineered structure acts as a respite for the people of the island nation for being one of the best earthquake resistant design.

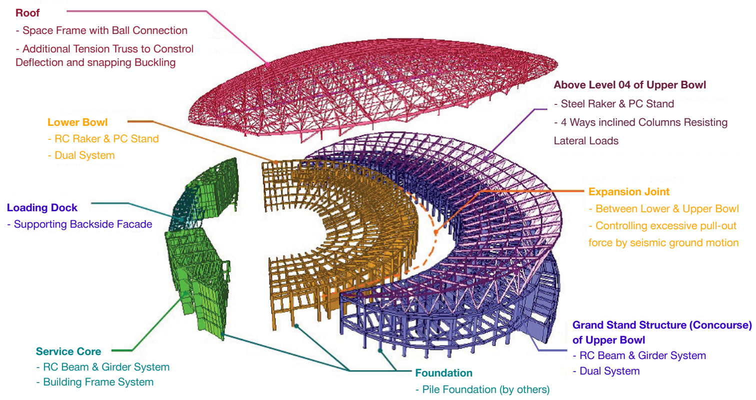
The domed roof structure which is also the largest non-column area in the world, measured to be around 227 m × 179 m is located in Barangay Duhat, Bocaue, Bulacan, which is north-west side of Manila, capital of Philippines. The arena has total floor area of 99.000 sq. m and it took more than two-year time of labor to build the structure, containing 9,000 tons of steel work. The roof was made as a separate unit to reduce burden on the arena with extra load. The arena is 65 m in height, or about 15 storeys high and founded on pile construction. About a third of the dead load of the building was designed for earthquake loads.

> **“About a third of the dead load of the building was designed for earthquake loads.”**

The building was also divided into multiple structures to strengthen the arena's earthquake resistance. It is one of the center piece of the many centennial projects of the Iglesia Ni Cristo (INC) for their centennial celebration on 27th July, 2014.

Populous Architects followed an extensive search throughout Asia to find the most suitable construction company. Buro Happold from Hong Kong was entrusted with the structural and MEP for the project.

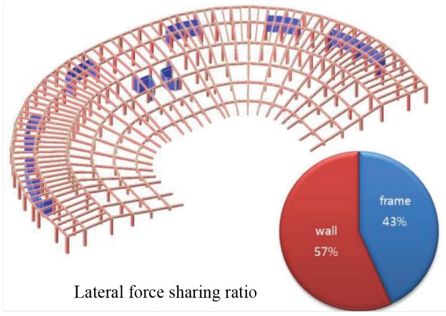
Philippine Arena is divided into four major parts – the roof, upper bowl, lower bowl and service core with loading dock. The roof and the upper bowl are steel structures while the lower bowl and service core are made of reinforced concrete.



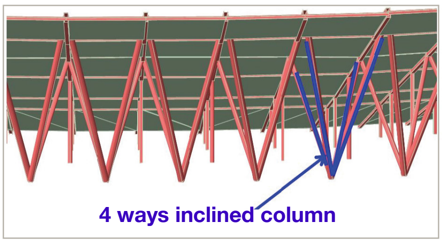
Seismic Design

The structural member designs were mainly governed by seismic force. For this reason, it was very important to select proper seismic force resisting system from the onset. Analysis of the structure required a seismic demand corresponding to more than 40%, for the frame and more than 50% for the shear wall.

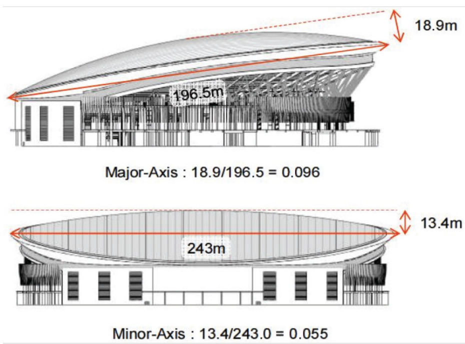
A dual system was selected for lower bowl which meant that 25% of lateral load would be resisted by frames without shear walls and hence, adequate reinforcement was provided in column and girder to ensure ductile behavior of the frame. Precast stand was planned for diaphragm action of bowl structure.



Lateral force sharing ratio of lower bowl.



Columns of upper bowl



Overall geometry of roof structure

The shape of structure indicated enough stiffness to exhibit behavior in seismic activity. Push over analysis was performed to estimate the seismic resistance of the structure, which clarified that columns, rakers and girders of upper bowl remained in the elastic range in case of earthquake. The structural elements were designed with amplified seismic force by over strength factor of 2.8 to be safe at the force level with elastic response.

The seismic behavior of a spatial structure is different from that of general structure since in spatial structure, horizontal seismic force happens to cause vertical vibration which has a significant effect on the overall structure. Hence, static and dynamic analysis (response spectrum analysis and linear time history analysis) were conducted for seismic load. The earthquake wave of linear time history analysis was made by extracting the three artificial seismic loads, using response spectrum of MCE (maximum considered earthquake) level. These earthquakes were scaled down to 2/3 and applied to the structural DBE (design based earthquake) level. When ground acceleration passes the structures, response acceleration may be reduced or amplified according to dynamic characteristics of each structure. Hence, five points of the roof supports were selected from different sub-structure (three points from upper bowl, two points from service core). Then, response acceleration was compared with ground acceleration. As Philippine Arena had short period, the response acceleration was greater than two to four times than ground acceleration itself.

Buro Happold's innovative response to this challenge was to design a foundation and base that is independent from the rest of the arena structure, isolating the building at ground-level to reduce acceleration of forces. The structure and the base are joined by lead bearings, allowing the base to move with the violent quake tremors while the structure remains stable. This incredible piece of engineering has ensured the Philippine Arena is amongst the top five most earthquake resistant structures in the world.

In this case, lead rubber bearing (LRB) was applied as a base isolation system owing its high energy dissipation ability. The lead core inside of the LRB provides the specific behavior which has different stiffness as external force reaches to designated value. From the characteristic of the LRB, displacement caused by normal use can be absorbed while lead core remains in elastic range and against severe lateral loads, it can provide high energy absorption capacity. To confirm effectiveness of the LRB, response acceleration and member forces were compared between two cases, with and without LRB. When the isolators were installed, the response acceleration and member forces were reduced significantly. Thus, the structural design progressed including stiffness of isolators. Moreover, by employing a seismic joint system, the building has strong durability and the ability to withstand earthquakes up to a magnitude of 7.0-7.5.

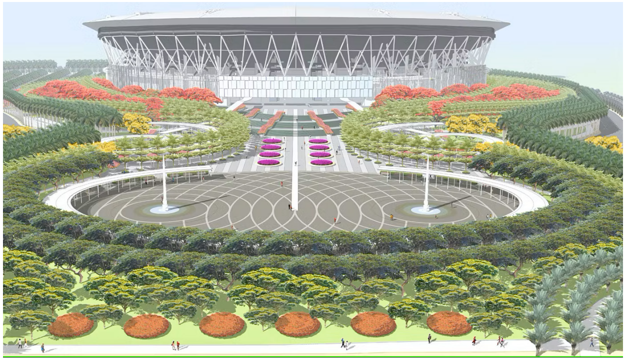
As the 10,000 ton dome structure is one of the greatest load, the Arena was constructed with thick core shear walls using 1,127 tons of steel and 541 major concrete columns. The load support system of the entire structure consists of 55,000 cubic meters of concrete and around 8,000 tons of reinforced steel bars.

Other significant features of the structure, which make it an engineering splendor include:

1. **The Large Dome** – It was designed with utmost safety while creating the most beautiful angles and curves. The arena withstands external forces of heat and wind due to such intricate engineering. The exterior design maximizes aesthetics while the interior of the 4 storey building offers a lavish space for cultural events.
2. **Space Frame** – The Philippine Arena built with the space frame construction method divided the dome ceiling frame into 46 blocks and enabled assembly on the ground prior to installation. This reduced the weight on the steel frames and minimized internal columns to minimize seat loss and dead angles. Not only did this reduce the risk of fall accidents but this also brought down the overall construction time since it was able to avoid the time-consuming welding work at height.
3. **Roof Surface without Connecting Joints** – The surface of the world's largest dome is free from connecting joints and covered with extruded sheets. This technology absorbs thermal expansion caused by higher temperatures and provided much needed relief in the tropic climate of the Philippines.

4. **Sandwich Plate System (SPS)** – Use of lightweight construction materials, specially the ones normally reserved for ships, were used to complete the upper seating area of the Arena. This enabled increased precision and reduced the construction period.

Structure	One of the 5 major earthquake resistant structures consisting of a roof structure, upper bowl, lower bowl and service core with loading dock.
Roof and Upper Bowl	Steel System
Lower Bowl and Service Core	Reinforced Concrete System
Construction Period	2011-2014
Architectural Firm	Populous
Structural Engineer	Buro Happold (Hong Kong)
Main Contractor	Hanwha Engineering and Construction Corp.
Cost	US$ 213 Million



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Research Initiative

SEISMIC PERFORMANCE ASSESSMENT OF NON-STRUCTURAL ELEMENTS IN A BUILDING

The recent earthquakes in India and across the globe have again reminded us about the most unpredictable behavior of the hazard. Over the last 10 years, there has been more than 2500 moderate to severe earthquakes which have been experienced within a distance of 300 km of India (source: earthquakelist.org). As per the Vulnerability Atlas of India, 59% of the land is prone is earthquake hazard and almost 11% is susceptible to severe earthquakes. While the standards for design of earthquake resistant structures have evolved over period of time creating robust guidelines, the same was not observed for non-structural elements (NSE) within a building.

It is important to understand that NSE constitute a major compnent of any builing project. Their contribution to the overall project cost is to the tune of almost 75 to 80% for specific categories of buildings. Failure of non-structural elements have several repercussions. They lead to loss of life, extensive repair cost, create obstacles in the escape routes and jeopardize the safe evacuation of the people and also render the building like hospitals, airports, data centers, etc. non-functional.

The existing Standards in India lacked adequate assessment criteria until the release of National Building Code 2016. Emphasis on the structural stability of non-structural elements is a welcome addition. IS 16700-2017 resonates the requirement. A research project was taken up between **Hilti India Pvt. Ltd. and Earthquake Engineering Department, Indian Institute of Technology (IIT) Roorkee** on “Seismic Performance Assessment of Non-Structural Elements in a Building”.

To know more, click here -

https://theseismicacademy.com/research-initiative-detail/seismic-performance-assessment-of-non-structural-elements-in-a-building

Training Program on

URBAN RISK MITIGATION – FOCUS ON SEISMIC & FIRE SAFETY

8th – 10th August ‘23
(Tuesday – Thursday)

Organised by

In Collaboration with

In India, we live in a seismically active zone. The Vulnerability Atlas released by the GoI mentions that the Indian Subcontinent is among the world’s most disaster-prone areas. Almost 59% of the country is vulnerable to earthquake with 10.9% being liable to severe earthquakes (intensity MSK IX or more). These incidents have resulted in loss of life as well causing severe damage to the built infrastructure, highlighting the fact that built environment is fragile and need adequate attention. This emphasizes on the need for taking principal initiatives by concerned authorities and departments, compliance of municipal byelaws and enforcement thereof in India.

A fire can happen at any time at any place. The recent major fires that occurred in various parts of country during the last few months reinforce the view that a fire can happen at any place. We can expect a fire at any structure, irrespective of its occupancy status – residential, commercial, industrial, hospitals, theaters, malls and so on. Therefore, any structure or building should be erected only after meeting the basic infrastructure needed to protect them from fire. Fire and life safety deals with safeguarding the occupants and assets of an establishment from harm, prevention of property loss by fire and related hazards.

Both of these hazardous phenomena create the need for active crisis management and mitigation strategies which has led to the ideation of a distinctive training program by **National Institute of Disaster Management** (NIDM) on “URBAN RISK MITIGATION – FOCUS ON SEISMIC & FIRE SAFETY” in collaboration with **Bureau of Indian Standards** (BIS), **Building Material & Technology Promotion Council** (BMTPC), **Delhi Disaster Management Authority** (DDMA), **Indian Society for Technical Education** (ISTE), Seismic Academy & Firestop Academy initiatives by **Hilti India Pvt. Ltd**. The aim of the training program is to sensitize the professionals about the safety standards which need to be adhered to during design and construction. It aims to bring together civil and structural engineers, higher degree research students, faculty members and government agencies on seismic design standards, seismic safety of non-structural elements & structural retrofit to ensure safety of connections during earthquake. At the same time, the program intends to provide insights on various aspects of active & passive fire protection that enables to save lives, protect assets and enhance building performance.

The DAY 1 of the dedicated training program will focus on **"Seismic Design of Structures"** with special lecture on **"Standard Perspective on Seismic, Seismic Design of Buildings"** by Mr. Jitendra Kumar Chaudhary, Assistant Director (Civil Engg.), BIS; **"Seismic Consideration for Critical & Lifeline Structures"** by Ms. Sangeeta Wij, Managing Partner, SD Engineering Consultants; **"Perspective of Disaster Management Team for Earthquake Hazards (Case Study of Turkey) - Learnings & Recommendations"** by Shri Mohsen Shahedi, Deputy Inspector General, (Ops/Trg./PRO), NDRF and **"Seismic Design of Non-Structural Elements"** by Mr. Shounak Mitra, Head - Codes & Approval, Hilti India Pvt. Ltd.

DAY 2 will focus on **"Structural Health Monitoring & Retrofitting of Structures"** with lectures on **"Identification of Buildings at Risk due to Frequent Earthquakes & Retrofitting of Building – Case Studies"** by Dr. Pratima Rani Bose, Head - Structure Design, DDF Consultants Pvt. Ltd.; **"Retrofitting of Structures (Bridges & Other Infrastructure) – Case Studies"** by Mr. Vinay Gupta, Managing Director, Tandon Consultants Pvt. Ltd.; **"Health Monitoring and Audit of Structures"** by Dr. Naveet Kaur, Senior Scientist - Bridge Engineering & Structures, CSIR-CRRI and **"Emerging Construction Practices"** by BMTPC.

Finally on DAY 3, **"Fire Safety in Buildings"** will be the focal point of the training program with lectures on **"Recent Fire Accidents & Key Takeaway: Role of Different Stakeholders & Understanding of NBC Part 4 (Fire & Life Safety)"** by Dr. K.C. Wadhwa, Chairperson - Fire Fighting Sectional Committee, BIS; **"Understanding of Fire Safety Standards Developed in India"** by Mr. Rajesh Choudhary, Assistant Director (Civil Engg.), BIS and **"Minimizing Damage through Passive Fire Protection of through Penetration & Joint Systems"** by Mr. Shounak Mitra, Head - Codes & Approval, Hilti India Pvt. Ltd.

The program will have dedicated sessions on practical demonstration and panel discussion to foster exchange of techincal ideas.

Interested participants may reach out to the following nodal contacts:

- **Dr. Garima Aggarwal** — Email: garima.nidm@nic.in
  (Senior ConsultantResilient Infrastructure Division)
- **Mr. Shreyash Dwivedi** — Email: shreyash.nidm@nic.in
  (Junior Consultant, Resilient Infrastructure Division) — Phone No. +91- 83688 75235
- **Mr. Shounak Mitra** — Email: shounak.mitra@hilti.com
  (Head – Codes & Approval (Fastening) at Hilti India Pvt. Ltd.) — Phone No. +91- 78271 40423

URBAN RISK MITIGATION – FOCUS ON SEISMIC & FIRE SAFETY
Venue: NIDM Campus, Sector 29, Rohini, Delhi
Date: 8th – 10th August '23 (Tuesday – Thursday)

SPEAKERS

Prof. (Dr.) Ajay Chourasia
Chief Scientist and Head of Structural Engg. & 3D Concrete Printing Group CSIR-CBRI, Roorkee

Mr. Shounak Mitra
Head – Codes & Approval (Fastening)
Hilti India Pvt. Ltd.

To know more, click - https://theseismicacademy.com/webinar-detail/seismic-resilient-infrastructure-in-hilly-regions

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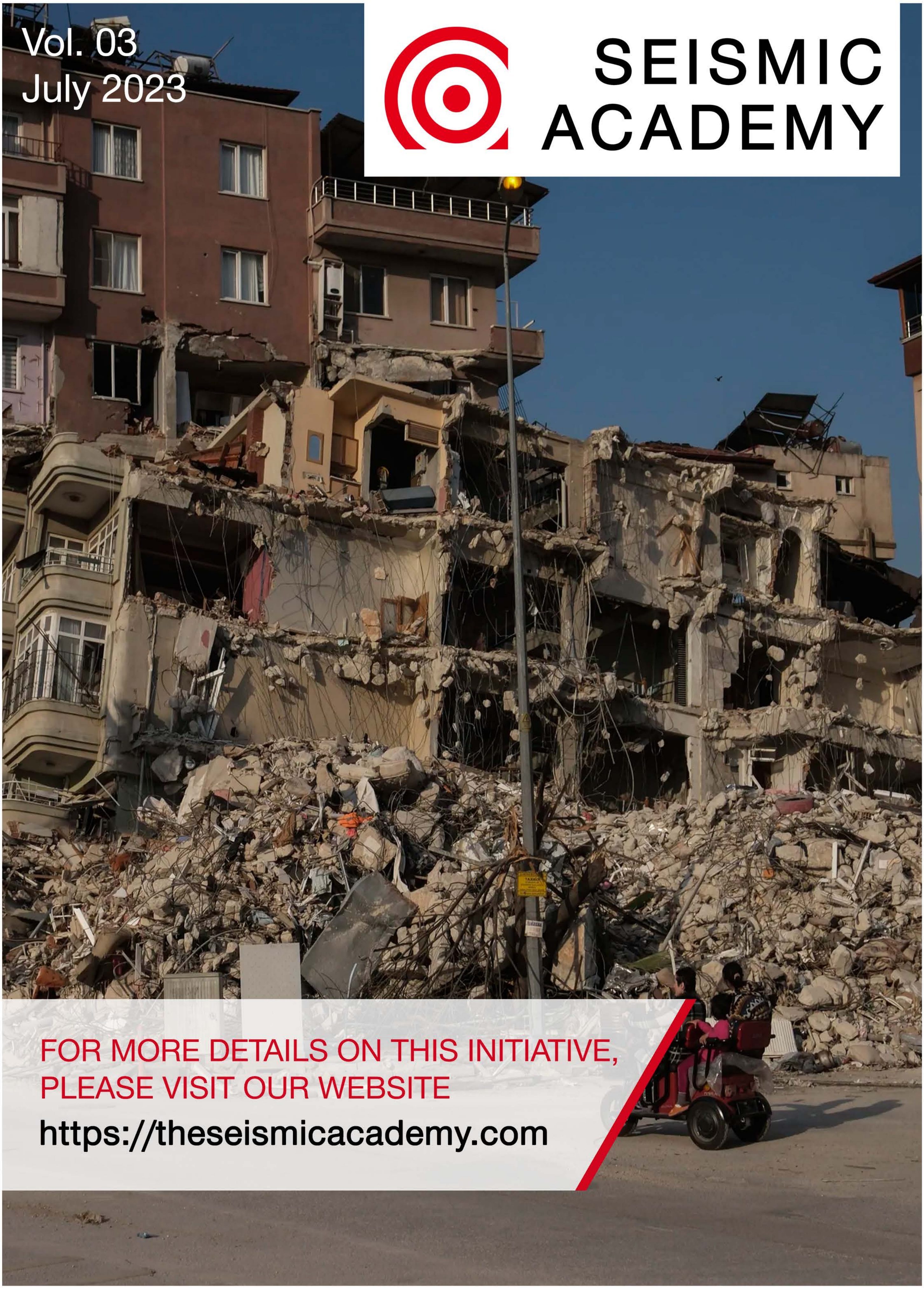
SEISMIC ACADEMY



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