https://theseismicacademy.com/webinar-detail/emerging-technologies-for-earthquake-resilience

WEBINAR ON EMERGING TECHNOLOGIES ON EARTHQUAKE RESILIENCE

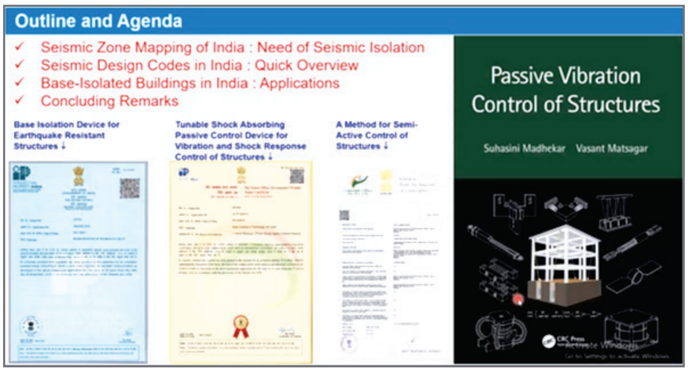
Growing concerns about seismic events in our country has enforced structural engineers and architects to embrace the hazardous effect of ground motion in design. Over a period, extensive research work on the topic and subsequent evolution of Indian Standards have led to a lot of sensitization on the topic among different stakeholders in the construction fraternity. With increase in the seismic activities across the country, it is important to adopt proactive mitigation measures to minimize the loss of life and damage to assets caused by it. Developing and implementing high-level seismic design strategies is a significant step in this regard. In the last decades, countries with advanced seismic protection technologies have significantly reduced losses due to seismic damage in structures through developing and implementing such strategies, including seismic isolation and vibration control (dampers) designs. Adoption of these technologies ensure the continuous operation of the structure even in the aftermath of a strong seismic event. And to effectively understand, adopt and implement them, it is important to impart the right knowhow on this topic.

With this endeavor, Seismic Academy, an initiative by Hilti, organized a webinar on "Emerging Technologies on Earthquake Resilience" on 14th June 2024. Dr. Vasant Matsagar, Head, Department of Civil Engineering, Indian Institute of Technology (IIT) Delhi and Dr. Yogendra Singh, Professor, Department of Earthquake Engineering, Indian Institute of Technology (IIT) Roorkee shared their expertise with the participants on the use of base isolation and seismic dampers respectively, for seismic resilient structures.

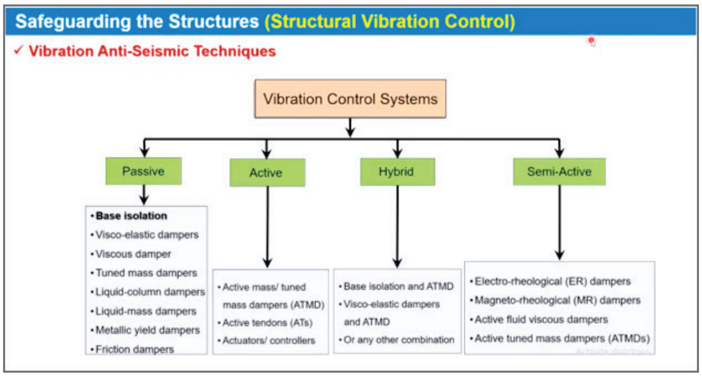
Shounak Mitra, Head – Codes & Approval, Hilti India Pvt. Ltd. and the moderator for the session, set a context by introducing Seismic Academy and the different initiatives under its aegis to the participants.

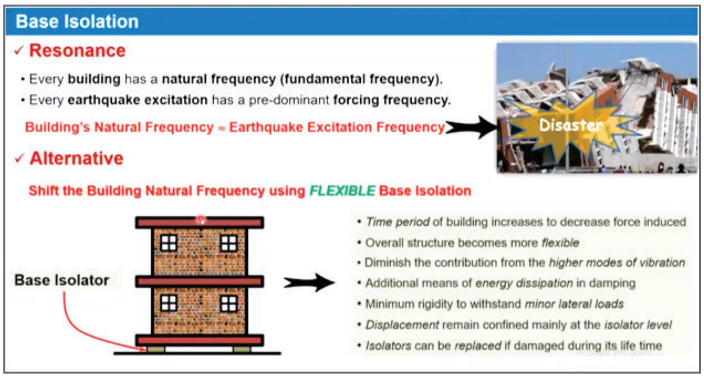
Dr. Vasant Matsagar started with the overview of the agenda wherein he looked to give some tenets of base isolation system and how it is being implemented, particularly in the Indian context and what has been the latest developments. He looked to outline his lecture around the need for base isolation, how code developments have happened over the years both in India as well as worldwide, specific examples of structure where these are implemented and the way forward.

There are enough reference material on the subject and the encouragement to participants is to appropriately refer to them. A very comprehensive book on "Passive Vibration Control of Structures" by Suhasini Madhekar and Vasant Matsagar is also available for the construction professions.

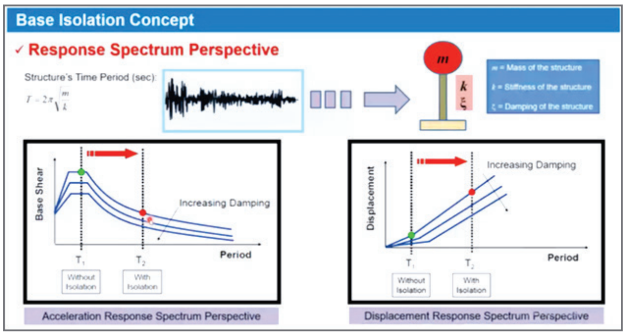


Dr. Matsagar started with the different types of structural vibration control devices which can be categorized as passive, semi-active, active and hybrid systems and the focus for the session was to deliberate on the base isolation which is a type of passive control devices. A base isolation, by definition, is used to render flexibility to the structure which in turn enhances its time period, thereby allowing more displacements. With the incorporation of base isolation system below the structure, the structure is isolated from the shaking ground and resonance is conveniently avoided. In addition, there is significant amount of energy dissipation which happens through damping. As a result, there is significant amount of reduction is the response of the superstructure in terms of acceleration. As compared to conventional structures which require strengthening against earthquake, this can completely be avoided for base isolated structures.



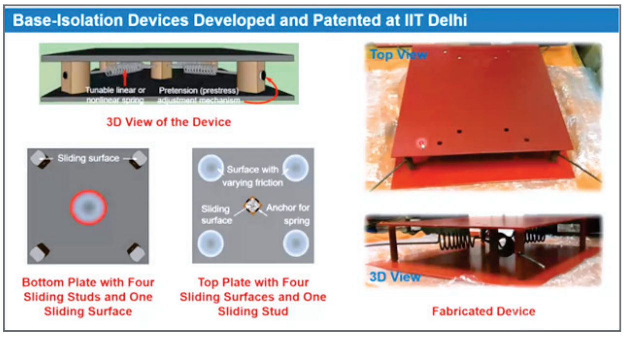


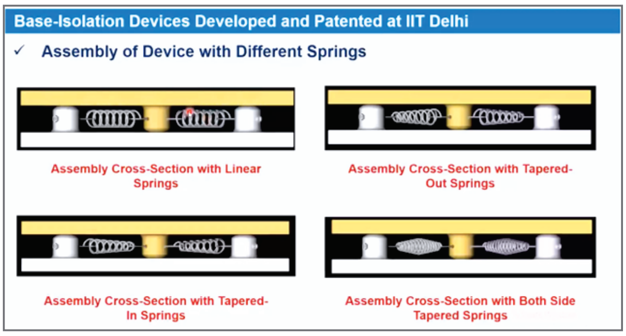
He explained the behavior in further detail through the response spectrum analysis and emphasized that a significant reduction to the tune of 50% in spectral acceleration can be achieved through base isolation and in such cases, the design will be governed more by other load combinations rather than earthquake. However, he also mentioned that enhanced flexibility brings with it increased displacement. To control the excessive displacement, dampers are provided. As compared to conventional structures, the damping in base isolated structures can be as high as 10-15% depending on the material being used. This synergy enables us to control the acceleration response on one hand and the displacement of the structure on the other hand.

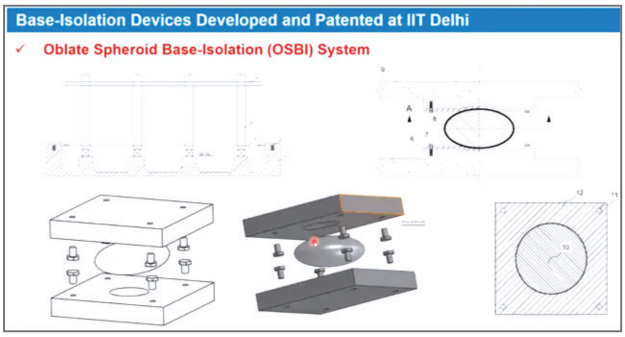


Dr. Matsagar briefly introduced to the different types of base isolators which are commonly in practice in the industry and their common areas of application. While every type of isolator has it own advantages, a base isolated structure is generally provided with more than one type of isolation system which helps to overall economize the application cost.

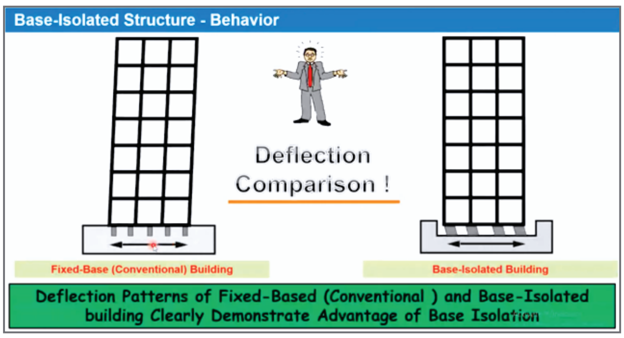
He highlighted on the different research work which is being carried out at IIT Delhi on this subject. One such innovation is the development of patented isolation technique through which it would be possible to control multi directional earthquake excitation in horizontal plane by using different kind of restoring springs. This technology is now being used for certain industrial equipment and finds use in case of lightweight structures. The same has been investigated through a shake table test and it has been observed that the floor acceleration could be reduced by as high as 35% as compared to a fixed-base structure.

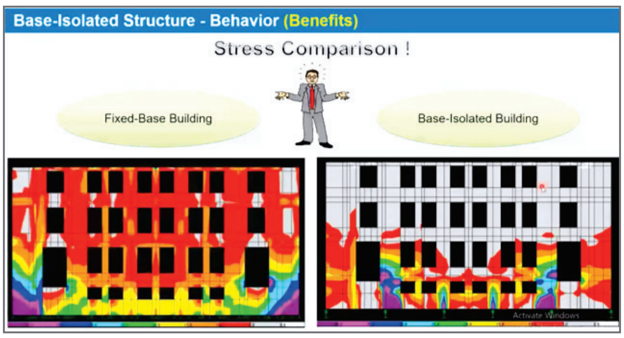






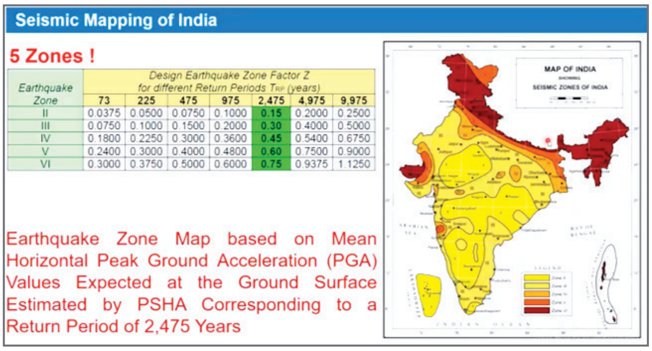
Dr. Matsagar added that because of the introduction of the isolation system at the base, significant amount of stress is reduced in the super structure in both the directions.



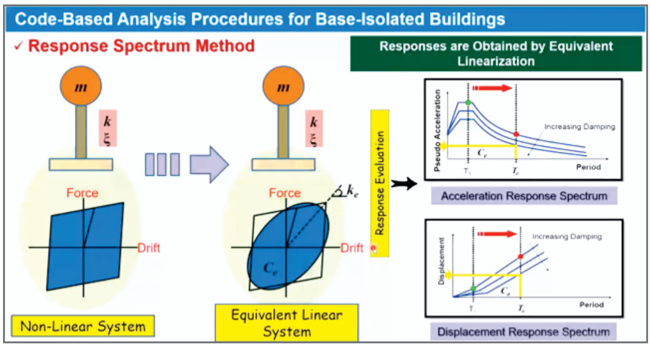


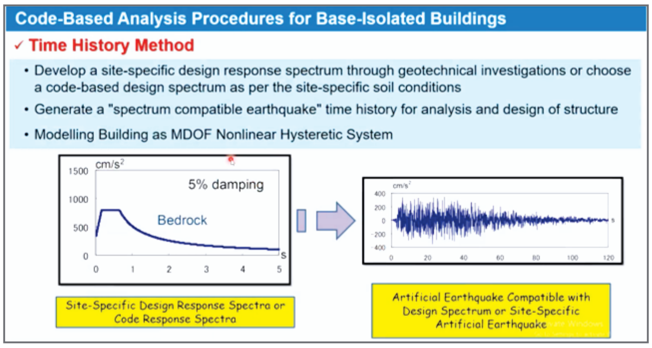
He touch based upon the different seismic zones of the country as per IS 1893 and emphasized that in higher seismic zones, lifeline structures like healthcare facilities need to be functional during as well as after an earthquake and base isolation provides an excellent alternative for the purpose over conventional approaches. Reference was also made to the proposed revision of IS 1893.

Earlier, international standards were commonly referred to in this regard. However, Bureau of Indian Standards (BIS) under the Civil Engineering Committee (CED) 39 has formulated IS 1893 part 6 in 2022 which gives clear guidelines on Base Isolated Buildings under Criteria for Earthquake Resistant Design of Structures.

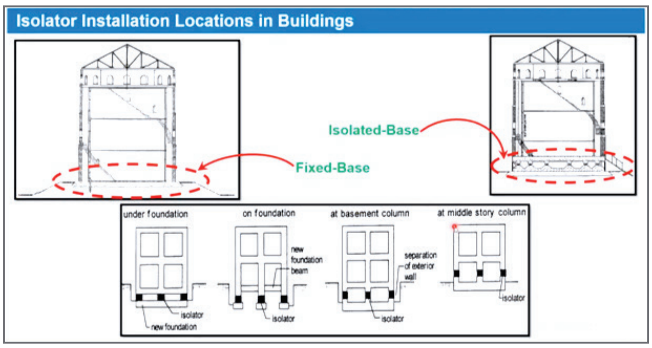


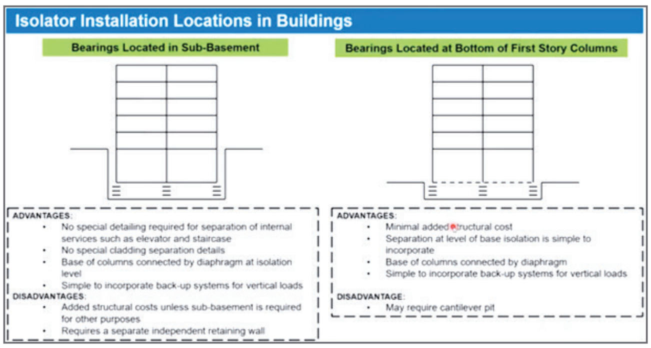
The code typically talks about different approaches for analysis and design of base isolated structures, and they are divided into dynamic analysis (response spectrum analysis and time history analysis) and equivalent lateral force analysis. For all seismic designs, however, it is important to perform a static analysis to establish a minimum level of design displacement and forces.

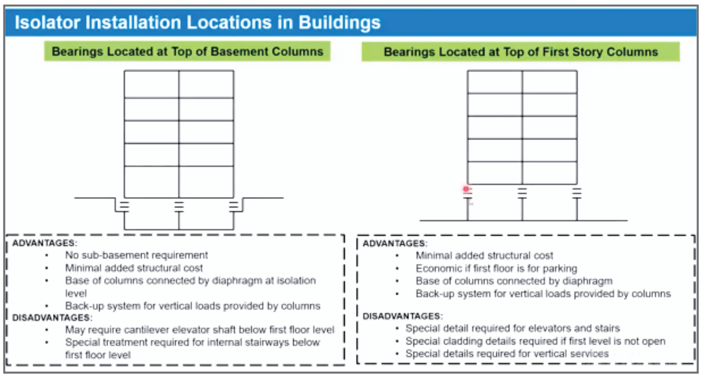


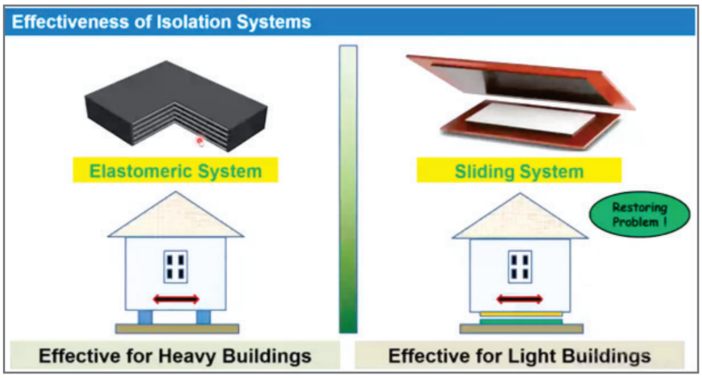


It is very important to address the fact that what are the appropriate locations for providing the base isolation systems in a structure and the Indian Standard does cover this aspect in detail. There are different alternatives as to where they should be provided – in the sub-basement, at the top of the basement columns, at the bottom of the ground floor columns or even in the superstructure. All these locations have their advantages and disadvantages, and the selection is done based on the engineering judgement of the structural engineer. However, a gap has to be essentially maintained from the adjacent structure to ensure effective isolation. Even the choice of the system is an important factor governing the overall performance.

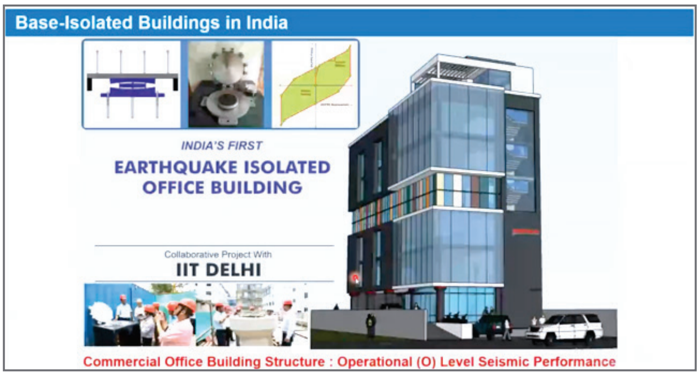




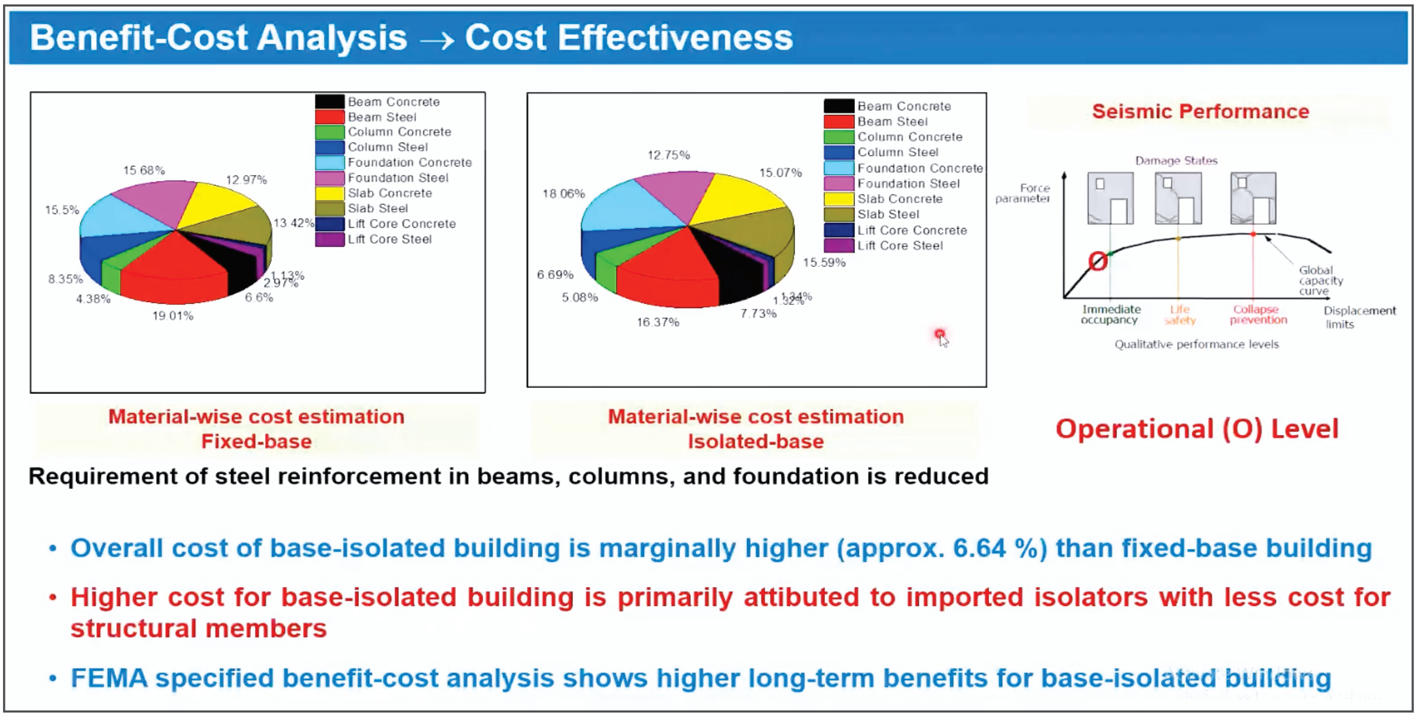




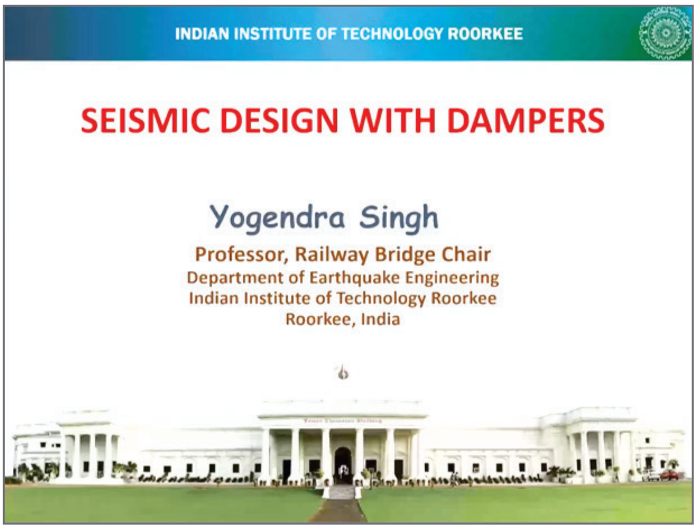
The technology can in fact be extended to the retrofitting of existing structures. However, overall, the application of base isolated structures in India is still limited as compared to other seismically active countries over the globe. He shared some case studies of base isolated structures in India which have been already executed.

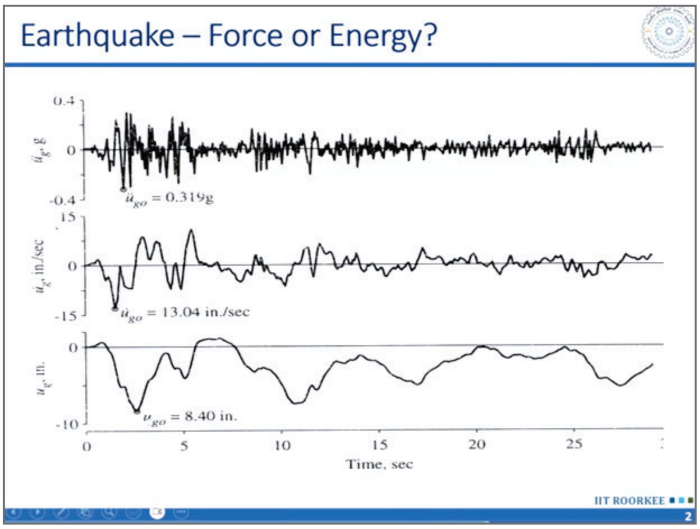


Dr. Matsagar in his concluding remarks also addressed the apprehension of different stakeholders about the enhanced expenses which might be incurred due to implementation of base isolation system within a building. A comparative analysis carried out to indicates a difference of around 6 to 7 percent in the overall cost as compared to conventional structures. At the same time, his recommendation was that if the isolated systems can be indigenously made, the cost can be further optimized.



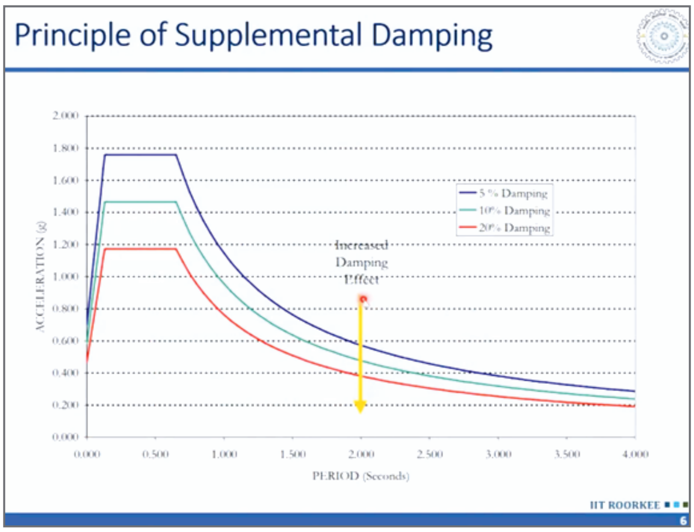
Dr. Yogendra Singh in his deliberation focused on the use of seismic dampers in structures. He mentioned that irrespective of the type of seismic performance enhancement measures being adopted, one has to take into consideration the characteristics of ground motion. The acceleration causes an inertia force which causes damage to the structure. The force also depends on the natural time period of the structure and through base isolation, this is adjusted to minimize the effect of earthquake on a structure. There can also be another dimension to this analysis. The acceleration due to earthquake changes its direction very rapidly which imparts an energy to the structure. The structure needs to dissipate this energy at the same rate at which it is received. This dissipation can happen only through damage. While base isolation detunes the structure, thereby reducing the energy imparted to it and as a result causing lesser damage, another way of enhancing the performance is to provide supplemental devices to dissipate the energy. This means that the structure as a whole will be required to dissipate lesser energy, resulting in lesser damage to the structure.

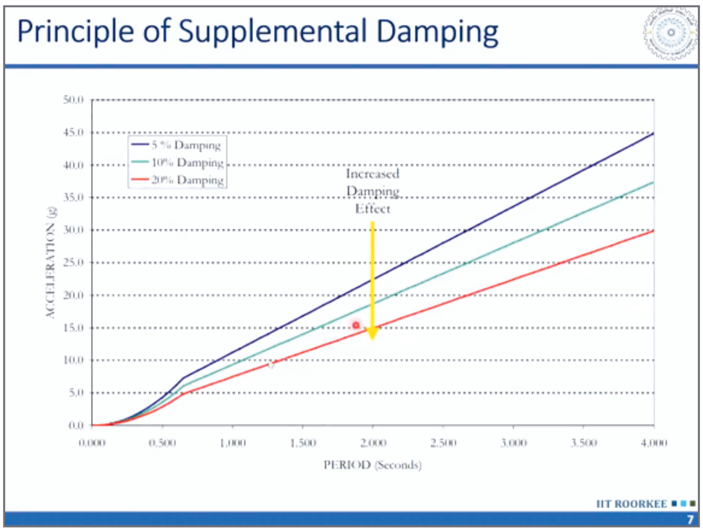




In case of supplemental energy dissipation, it is acting like an added damping and hence at any given period, with increase in damping, the response spectrum and therefore the forces on the structure will reduce. Similar effect can be observed on the displacement as well. Consequently, the inter storey drift also reduces.

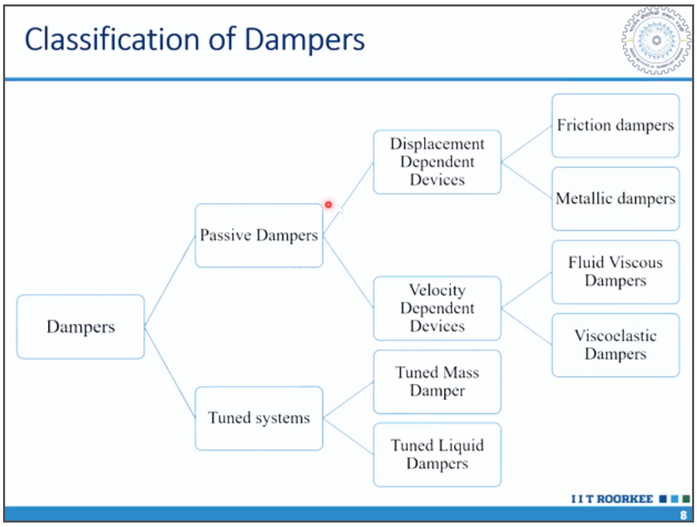
Acceleration at the different floor levels are also reduced and this has significant impact on the behavior non-structural components. Non-structural components are of two types – acceleration sensitive e.g., equipment capped at the floor and displacement sensitive which depend on the drift. Thus they are adequately safeguarded in the event of an earthquake by the provision of dampers.

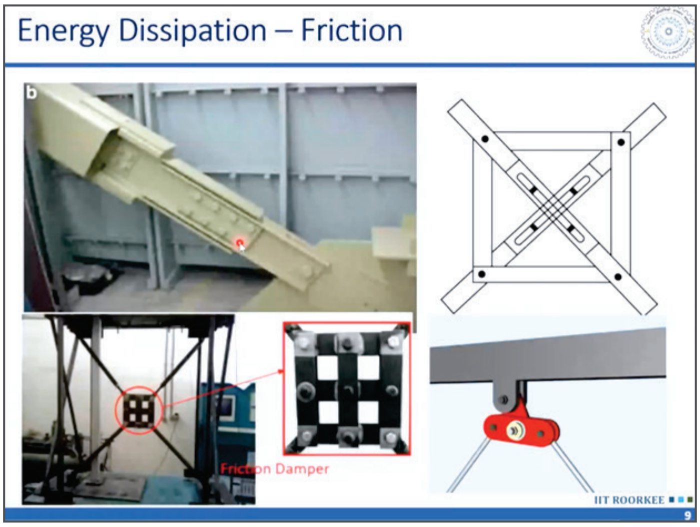


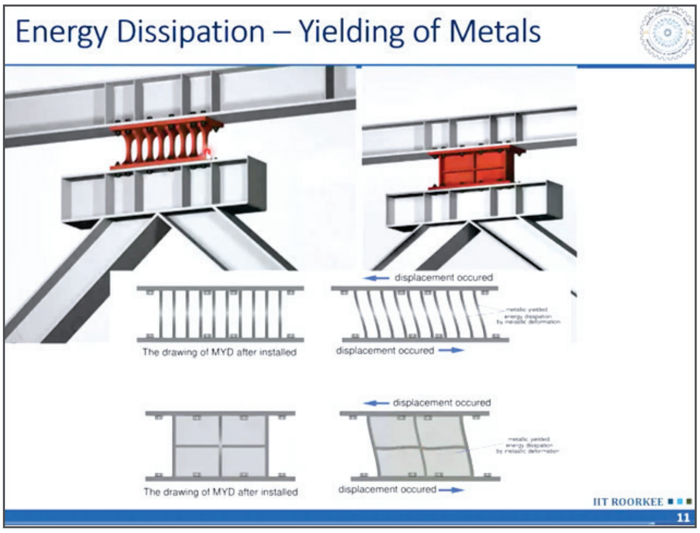


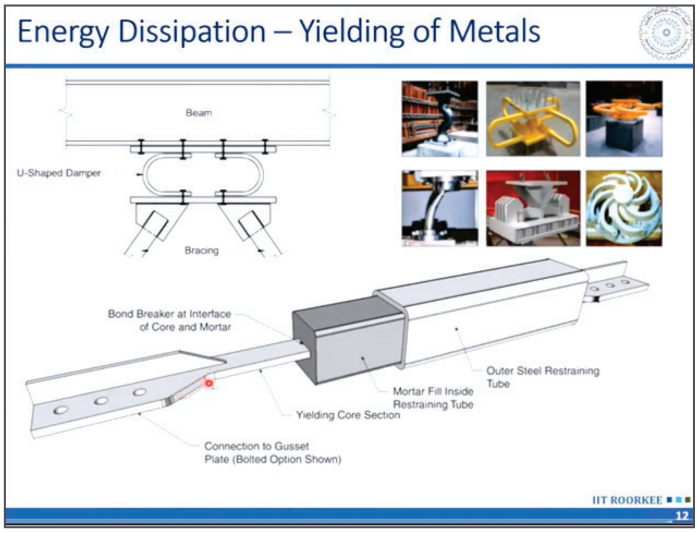
Commonly used dampers are passive dampers and tuned systems. In passive system, the energy is dissipated through friction, yielding or viscosity of the material. Passive dampers can be classified based on the energy dissipation mechanism i.e., either through displacement or through velocity. Displacement dependent devices can be friction dampers or metallic dampers, while velocity dependent devices can be fluid viscous dampers or viscoelastic dampers. Tuned systems can be tuned mass dampers or tuned liquid dampers.

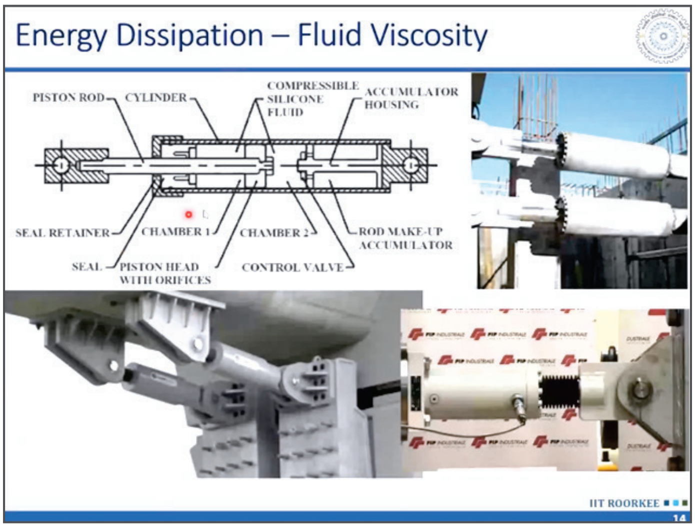
Dr. Singh further elaborated on each type of damper with their individual working principle.

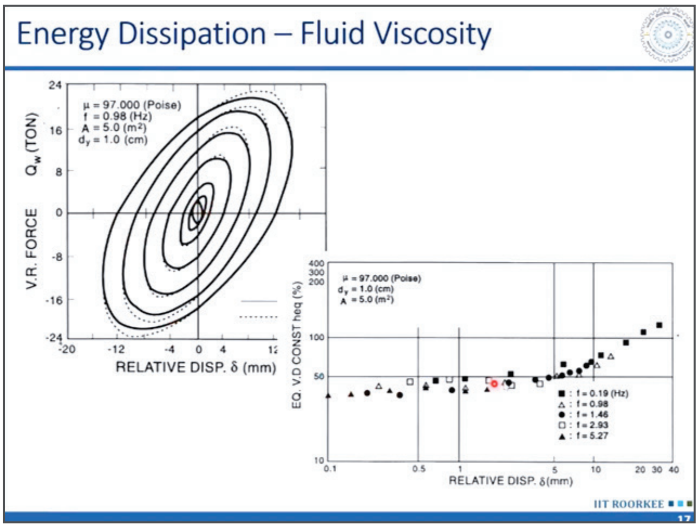






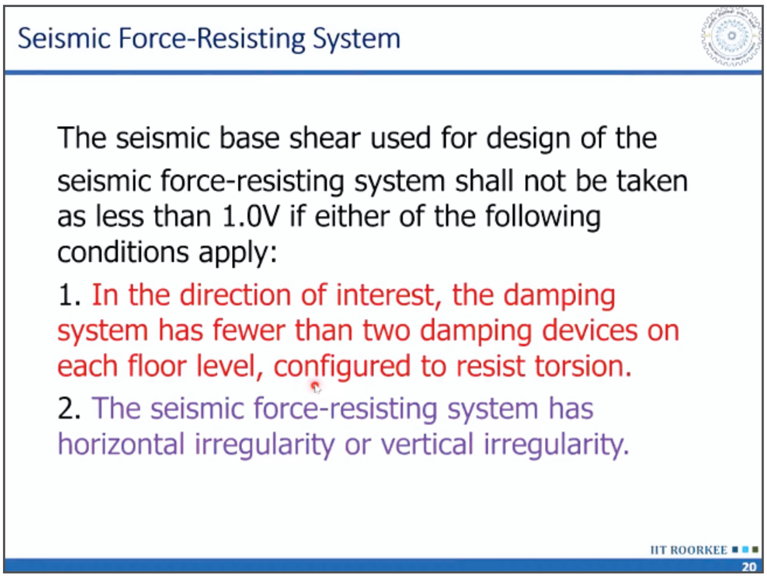


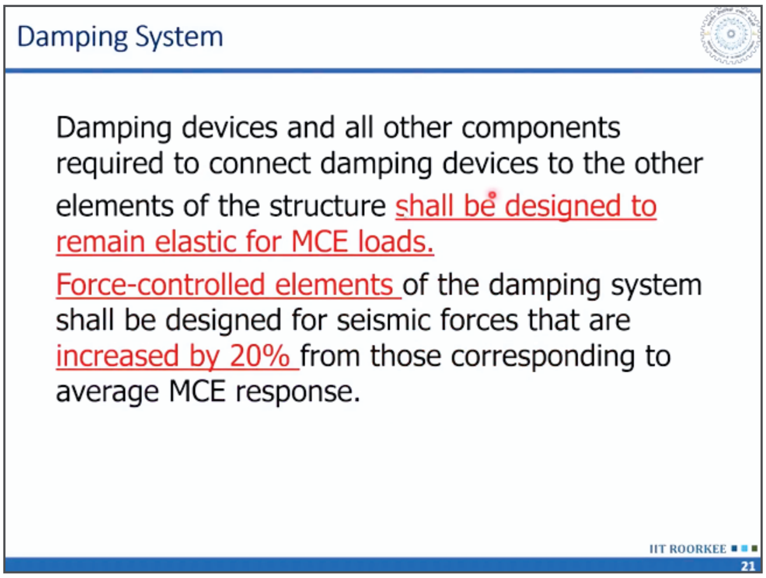




In absence of national standard on seismic dampers, ASCE-7 and ASCE-41 provide detailed guideline for the design of damping devices. He emphasized here that the use of these technologies is not intended towards economizing the overall cost of execution of the structure but to achieve enhanced performance in the event of earthquake. Specifically for lifeline structures like hospitals which require to be operational throughout, these devices provide the best design option.

The fundamental design philosophy is that during design basis earthquake (DBE), the structure should remain elastic and under maximum considered earthquake (MCE), there should be limited yielding so that there is no visible damage, and it continues to perform even under MCE. There are certain considerations and restrictions in terms of considering the seismic base shear, which need to be strictly adhered to.





When the devices are designed to remain elastic under MCE loads, one must consider the low cycle and large displacement degradation caused by seismic loads, high cycle and small displacement degradation caused by thermal, wind and other cyclic loads as well as forces and displacements caused by gravity loads. A common apprehension with friction based devices is that with time these may get corroded or be subject to abrasion over period of time. As a result, there can be adhesion between the metal elements and the devices may not effectively function in the event of an earthquake. So, the device should be adequately designed and protected against corrosion. In addition, the effect of other factors temperature, humidity, moisture, radiation, etc. should also be taken into consideration.

Additionally, if four or less energy dissipation devices are provided in any storey of a building in either principal direction or less than two devices are located on each side of the center of stiffness of any storey in either principal direction, all the devices should be designed to sustain displacement equal to 1.3 times the maximum calculated displacement under MCE. A velocity-dependent device should be capable of sustaining force and displacement associated with a velocity equal to 1.3 times the maximum calculated velocity under MCE.

Dr. Singh summarized his session with a case study on the use of seismic dampers in a typical building.

The deliberations were followed by Q&A and ended with a vote of thanks.