JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Base Isolation System

[1]prof. Ravi Gupta, [2]Khan Aftab, [3]Ansari Rehmat Ali,[4]Ifran Shaikh, [5]Wasim Shaikh,
[1]professor, [2]student, [3]Student,[4]student, [5]Student
[1]Civil Engineering,
[1]Rizvi College Engineering, Mumbai, India

Abstract : The research presented herein investigates the ability of an Adaptive seismic isolation system to protect structures subjected To a variety of earthquake ground motions. Seismic isolation Enables reduction in earthquake forces by lengthening period of Vibration of the structure. An base isolation system must satisfy Four basic criteria of effectiveness, in particular, acceleration Response, shear and overturning moments are reduced by a factor Of four to eight for buildings mounted on isolators.
IndexTerms **- base Isolation, seismic, isolated structure, retrofitting, perception, earthquake engineering.**

I. INTRODUCTION

1. OVERVIEW

A common perception on how to resist an earthquake force is by strengthening the structure. The traditional engineering design strategy based on increasing the design capacity and stiffness to accommodate foreseeable lateral forces may not be the most efficient solution. The problem with the latter is that all seismic forces from the foundation will be absorbed by the superstructure. The base isolation technique is exactly the opposite of traditional engineering design strategy.

Base isolation is a system that protects a building from the damaging effects of a seismic movement. If the structure separates from the ground during an earthquake, the ground is moving but the structure is still dormant. However, this scenario is not realistic. The current technology that is active and expanding is the introduction of a low lateral stiffness support that isolates the structure from the ground movement. This technology was introduced as early as the 1900's; however, not until the 1970's did it evolve into the practical strategy for seismic-resistant design.

2. PRINCIPLE AND CONCEPTS

The objective of base isolation system is to decouple the structure from the ground. It lowers the effect of ground motion transmitted to the structure. When the ground moves, a perfectly rigid structure will have a total displacement equal to ground displacement, relative displacement equal to zero, and period equal to zero. Thus, a perfectly laterally flexible structure will have a total displacement equal to zero, relative displacement equal to ground displacement, and the period would be infinite.

Structures are neither perfectly rigid nor perfectly laterally flexible, and therefore the response of the structure lies in between the two extremes. Lengthening the fundamental period of the structure reduces the pseudo acceleration and the seismic forces induced in the structure. However, it increases the displacement of the structure, but mostly concentrated in the base isolation system as shown in Figure 1.1. In addition, the added damping by the isolation system allows the seismic energy inputted to be absorbed by the isolation system thereby reducing the energy transmitted to the structure. Finally, the torsional effects due to eccentricities can be reduced by coinciding the center of stiffness of the base isolation system with the center of mass of the superstructure.

In contrast, in Figure 1.2, the conventional structure has distributed displacement along its entire height. In addition, seismic energy and forces are entirely absorbed by the structure, thereby increasing the vulnerability of the whole structure.

FIG . 1.1: DISPLACEMENT OF BASED ISOLATED STRUCTURE (DIS)

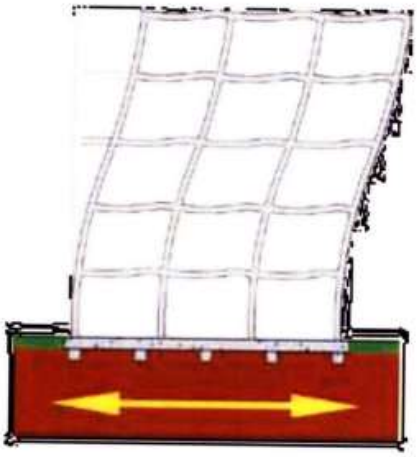


FIG . 1.2: DISPLACEMENT OF FIXED BASE STRUCTURE (DIS)

3. APPLICATION OF BASE ISOLATION

Structures that are midrise in height are the best candidates for base isolation technology. Base isolation design provides a good substitute for fixed based design in locations where very strong seismic activities are likely. The initial cost of base isolation might be higher compared with a fixed based. However, after a seismic event, the cost of repairing a structure plus the loss in opportunity might be considerably higher.

Most of base isolated structures in the west coast of United States are hospitals. These facilities must be in operation after a seismic event. The world's first base isolated structure in the United States is the University of Southern California Hospital, see Figure 1.3. It remained operational after experiencing the Northridge earthquake in 1994 .

FIG . 1.3: USC UNIVERSITY HOSPITAL

Other structures that can benefit from base isolation design in the long term are the manufacturing facilities (i.e. semiconductors) that need to be in operation after a seismic event; otherwise economic loss is at stake. 1.3.

In addition, historic structures have benefitted from base isolation technology through retrofitting. Figure 1.4 shows the installation of base isolators by jacking the columns of San Francisco City Hall.

FIG . 1.4: BASE ISOLATION RETROFITTING OF SAN FRANCISCO CITY HALL

4. Example of Application of the Base Isolatiobearings

The 300 bed Bhuj Hospital that claimed 176 lives when it collapsed during the major January 2001 Gujarat Earthquake is studied. This was the first new building in India to be fitted with earthquake – resistant NZ developed base isolation technology. Eventually, 280 lead rubber bearings were installed in the structure. The hospitals base isolation design and bearings have been provided with the assistance Earthquake Engineering NZ members.

With the assistance of the New Zealand Government and support of the Earthquake Engineering NZ cluster we were able to identify the reconstruction of the Bhuj hospital as a suitable project for New Zealand's earthquake engineering assistance. They recommended that the replacement hospital be fitted with New Zealand developed base isolation lead rubber bearings. This robust technology is well-suited to construction styles in India. The New Zealand Government contributed $ 150,000 to the cost of the project base-isolation feasibility study and design work as part of the initial disaster recovery stage. The Indian Prime Minister's Relief Fund funded the hospital construction, including the cost of the Robinson Seismic Ltd bearings.

Fig. 2 Lead Rubber Bearing designed by Bill Robinson

Fellow cluster members Holmes Consulting Group and Dunning Thornton Consultants, with the bearings manufactured and supplied by Robinson Seismic Ltd undertook the specialist computer-based earthquakeresistant base-isolation building design work in Wellington. Cluster member Bill Robinson invented the lead rubber bearing technology.

The Creative Capital Cluster of the achievement of rebuilding the new Bhuj hospital within two years of the earthquake by India's leading architects, engineers and construction firm working with the assistance of New Zealand's specialist earthquake engineering expertise. Architect Uday Pattanayak of EFN Ribeiro Associates, New Delhi, and Structural Engineer Kamal Sabharwal, has led the Indian design team for the hospital. The construction company was India's largest, Larsen & Toubro. New Bhuj Hospital completed with Earthquake Engineering NZ technology is reputed to be able tostand a force of 10 tremor on the Richter scale.

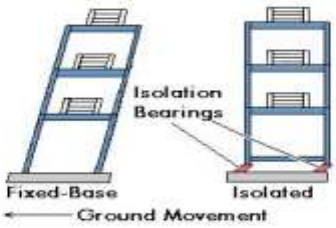


Fig. 3 Seismic behavior of building mounted without and with isolator.

5. COPE OF THE PROJECT

- There is a very wide scope for the technique of base isolation. In the near future, there will be a wide possibility of earthquakes because of the undesirable changes in the surroundings. Base Isolation technique of earthquake resistance will prove immensely fruitful in such conditions.
- The biggest advantage is that there will be no need of reconstruction of a structure to install the base isolation devices as it can be done through the technique of retrofitting.
- A huge loss of life and property can be avoided by the use of base isolation devices.
- Use of Base Isolation in high rise buildings, statues and bridges will almost nullify the tremors of earthquake, protecting it from considerable damage to life and property.
- We believe that it is vital that important buildings like hospitals, rescue centers, government buildings, nuclear power plants etc. are seismically isolated so they remain fully functional during and immediately following earthquakes.
- The design of base isolation devices for Kelkar Museum, Pune needed expensive test methods like NDT (Nondestructive testing) and hence is not included in the scope of project. However, it can be included in the further study and can be applied to the best of its use.

II. OBJECTIVE

1. IMPORTANCE OF BASE ISOLATION SYSYTEM

Base isolation is one of the most powerful tools of earthquake engineering pertaining to the passive structural vibration control technologies. The isolation can be obtained by the use of various techniques like rubber bearings, friction bearings, ball bearings, spring systems and other means. It is meant to enable a building or non-building structure to survive a potentially devastating seismic impact through a proper initial design or subsequent modifications. In some cases, application of base isolation can raise both a structure's seismic performance and its seismic sustainability considerably. Contrary to popular belief base isolation does not make a building earthquake proof.

Base isolation system consists of isolation units with or without isolation components, where:

- Isolation units are the basic elements of a base isolation system which are intended to provide the aforementioned decoupling effect to a building or non-building structure.
- Isolation components are the connections between isolation units and their parts having no decoupling effect of their own.
- Isolation units could consist of shear or sliding units.

This technology can be used for both new structural design[9] and seismic retrofit. In process of seismic retrofit, some of the most prominent U.S. monuments, e.g. Pasadena City Hall, San Francisco City Hall, Salt Lake City and County Building or LA City Hall were mounted on base isolation systems. It required creating rigidity diaphragms and moats around the buildings, as well as making provisions against overturning and P-Delta Effect.

Base isolation is also used on a smaller scale—sometimes down to a single room in a building. Isolated raised-floor systems are used to safeguard essential equipment against earthquakes. The technique has been incorporated to protect statues and other works of art—see, for instance, Rodin's Gates of Hell at the National Museum of Western Art in Tokyo's Ueno Park.

Base isolation units consist of Linear-motion bearings, that allow the building to move, oil dampers that absorb the forces generated by the movement of the building, and laminated rubber bearings that allow the building to return to its original position when the earthquake has ended.

2. UNDAMENTALS OF BASE ISOLATION SYSYTEM

A base isolation system must satisfy four basic criteria of effectiveness:

- It should lower horizontal acceleration response of the building under givenseismic load.
- A predominantly translational behavior of the building.
- No amplification of the vertical motion with respect to the ground motion.
- A satisfactory accommodation to the large displacement that can take place.

The first criterion is obvious. Low acceleration response leads to reduced shears and overturning moments and consequently to minimum damage. The structural materials work essentially in the elastic range and always remain capable of withstanding successive shocks.

The second criterion excludes rotational motions about the principal horizontal axis of the building. The whole building then moves like a quasi-rigid body with three main consequences: firstly, drift between stories is reduced, resulting in little or no non-structural damage, secondly, the base rocking is strongly decreased which entails a lesser risk of large irregular settling in the foundation soil and lastly no significant coupling exists between the vertical and horizontal motions which enables a substantial simplification of the design.

The third criterion aims to prevent the vertical amplification which can result from the practical dispositions employed to satisfy the criteria a) and b). Considering that buildings are constructed to withstand high vertical forces, the third criterion is a minimum isolation requirement permitting vertical seismic forces to be transmitted through the structure without attenuation or amplification.

The fourth criterion concerns the building stability under large displacements that can occur during strong earthquakes. Stability is obviously a basic parameter when designing any earthquake resistant system.

3. PRACTICAL IMPLEMENTATION OF EFFECTIVE BASE ISOLATION SYSYTEM

The most practical method of implementing a really effective base isolation system is to mount the building in energy absorption devices called isolators that are located between the first floor and the basement or between the first floor and the ground floor level, if no basement exists.

Isolators consist of laminated layers of rubber and steel plates strongly bonded together during the rubber vulcanizing process (Fig. 1). Their main feature is a relatively high stiffness in the vertical direction and around the two principal horizontal axes and a low stiffness in the horizontal plane and around the vertical axis. Lateral stiffness of isolators is currently five hundred times less than the vertical one and one hundred times less than the horizontal stiffness of the first storey concrete column; the structure of the isolators permits the separate control of horizontal and vertical stiffness. Isolators have a quasilinear behavior upto 10% compressive strain ratio and upto 100% shear strain ratio. Thanks to special chemical composition, the rubber employed is efficiently protected against air oxygen and the steel plates are covered with highly resistant paints. Thus the isolators have a life expectancy at least as long as that of the building that they protect. Finally, in spite of the fact that isolators are strongly attached to the structure, provisions are made to change them if necessary, without excessive work.

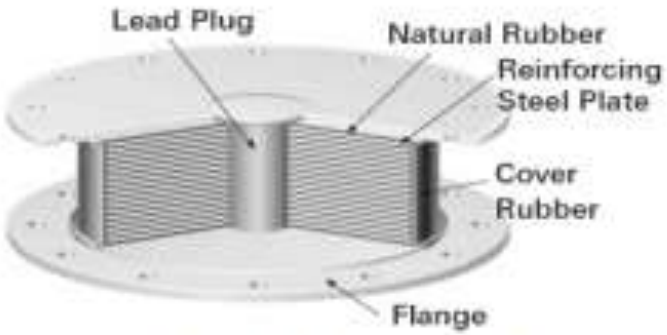


Fig. 1 Lead Rubber Bearing

III. LITERATURE REVIEW

1. PAPER I

SEISMIC ISOLATION RETROFIT IN JAPAN

SUMMARY

Seismic isolation technology is very effective to retrofit existing buildings while they are in service. In Japan, more than 17 existing buildings has been executed or under planning of retrofit work up to the end of March 1999. Those buildings are historical buildings including temples, government buildings, school buildings and so on. Among them, two middle-rise reinforced concrete buildings are reported in this paper as the first completion of retrofit by seismic isolation method in Japan. These buildings are used as the personnel-training center of Taisei Corporation that is one of the leading construction companies in Japan. One is a 16 storied building, where 22 columns on the 8th story were cut at their mid-height and LRB's (lead rubber bearings) were installed. Retrofit isolation at this height must be the first in the world. Due to the reduction of seismic force by isolation, strengthening of the structure above isolators has come to be unnecessary and that of the structure below isolators also has been mitigated. Elevator, staircase, piping and walls on the isolation floor are schemed so as to follow the large story drift in case of earthquakes. The other building is 7 storied and supported on piles, where base isolation method was adopted. After cutting off the head of piles, rubber and sliding

isolators were installed in parallel. This hybrid isolation system is called "TASS (Taisei Shake Suppression) system" and of high performance. Strengthening of the super structure has come to be unnecessary.

INTRODUCTION

In the 1995 Hanshin-Awaji Great Earthquake Disaster severe damage concentrated on buildings designed by old code which was effective before 1981. To prevent the recurrence of such kind of damage on existing buildings, "Law on the Promotion of Seismic Repair of Buildings" was enforced on December 25th 1995. Owners of disqualified existing buildings over a certain scale are encouraged to do the seismic diagnosis and repair.

There are several conventional methods of strengthening existing buildings; addition of reinforced concrete shear walls or steel bracing, thickening existing walls, shear reinforcement of columns by jacketing reinforced concrete, steel plate or carbon fiber sheet. These methods are effective to increase strength and stiffness of buildings. However their construction is mostly done inside the building, which burdens the users or residents of the buildings inconvenience to some extent.

To avoid such disturbance on daily life, exterior strengthening method or seismic isolation retrofit are preferred these days. Construction work can be done outside the building or in limited area, which enables the undisturbed or less disturbed usage of the buildings.

OUTLINE OF THE RETROFIT BUILDINGS

The two retrofit buildings are used as the personnel-training center of Taisei Corporation. The site is located in the central part of Japan on the Pacific coast, where earthquakes of Richter magnitude 7 to 8 are worried to occur in the near future. Layout of buildings is shown in Figure 1. Main building is a 16 storied steel encased reinforced concrete building with 7 and 2 storied reinforced concrete portion, whose height is 49m. It is built on direct foundation whose level is partially varied along slope of the ground. East building is a 7 storied reinforced concrete building supported on reinforced concrete piles of 30cm diameter and 6m length. The total floor area is 15,658 . They were built in 1964 and more than 30 years have passed since then. Whole view of the buildings is shown in Figure 2.

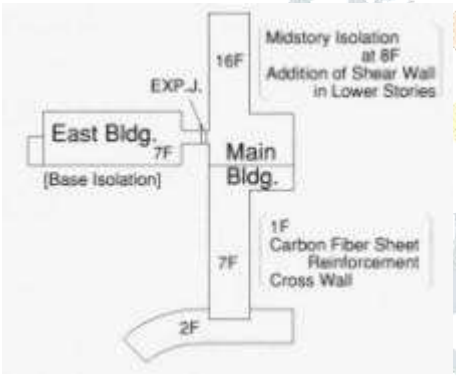


Figure 1 Layout of buildings

Figure 2 Whole view

Diagnosis was conducted along the standard published by Japan Building Disaster Prevention Association. The results revealed that the earthquake resistant capability of these buildings was "doubtful". Most of the stories was estimated to have around or less than half of the required seismic index for structures.

SEISMIC ISOLATION RETROFIT AT MID - STORY

Installation of Isolators

Mid-story isolation at the 8th floor was chosen for the main building, as it is partially underground from the 7th floor below. It is difficult to put isolators below the existing foundation stepwise along slope. Mid-height portion of all twenty-two columns of the 8th floor was cut off to install a lead rubber bearing (LRB). Longitudinal section of the main building is shown in Figure 3. Among 22 units of isolator, 4 units are 80cm in diameter and 18 units are 70cm, whose layout in plan is shown in Figure 4.

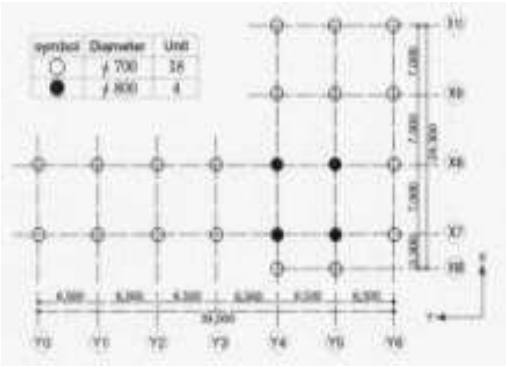


Figure 4 Layout of isolators (Main Bldg.)

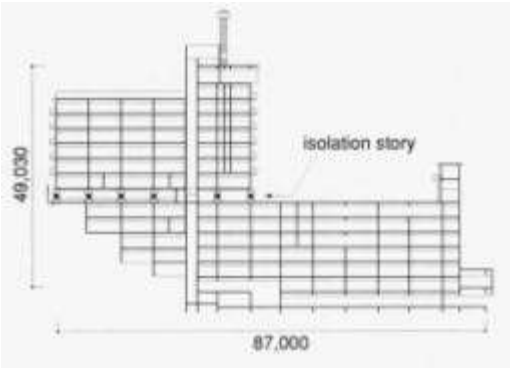


Figure 3 Section of Main Bldg.

Response characteristics

By changing an old building to a seismically isolated structure, the fundamental period in X direction has been elongated from 0.40sec to 1.18sec in small amplitude and 3.00sec in 100% shear deformation of isolators. In Y direction 0.45sec has been changed to 1.19sec and 2.96sec respectively depending on the amplitude.

Two levels of input earthquake motion were considered; level-1 and level-2. Their maximum velocities were 25cm/sec for level-1 and 50cm/sec for level-2. Three kinds of typical observed earthquake record were used for both levels as well as the synthetic motion taking the probable seismic source around the site into consideration for level-2.

By the preliminary linear response analysis maximum acceleration and shear force of the upper structure above isolators are reduced to 1/5~1/10 of the elastic response of the existing structure (Figure 5). Nonlinear response analysis was done by the 3D model as shown in Figure 6. As seen in Figure 7, no strengthening is necessary in the upper structure. In the lower structure seismic loads are also reduced by large amount. However, to prevent the torsional motion parallel to the slope and to enhance the stability of the lower structure, reinforced concrete shear walls were added in some stories. Also columns on the 1st floor were jacketed by carbon fiber sheet and also strengthened by putting precast concrete cross wall between columns.

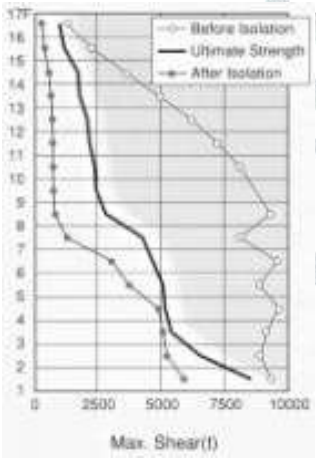


Figure 5 Response reduction.

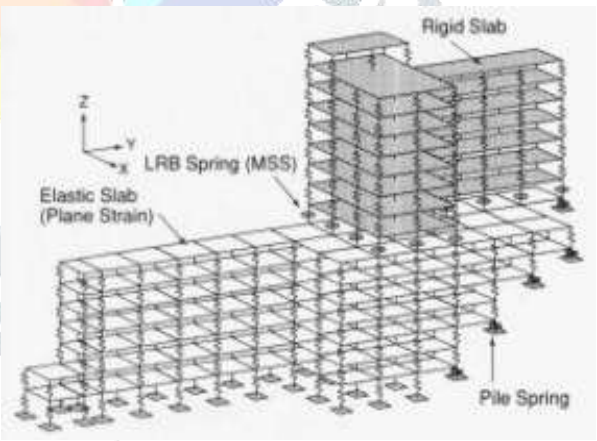


Figure 6 3D model of main bldg.

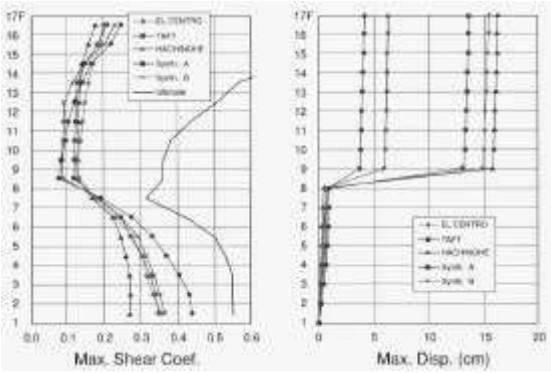


Figure 7 Response of main bldg. (X direction, Y4 axis)

Reform Work

Non-jack method was adopted to support 6,500tf upper structure during cutting and reform 22 columns. As shown in Figure 8 the reform work was done.

It was designed so as to maintain the safety of the building during the reform procedure even in case of earthquake. Due to the transition of vertical load from column to tube and from tube to isolator, about 1mm and 3mm settlement occurred respectively. No harmful differential settlement or cracking of concrete members was observed. Prior to the execution of the work, full-scale model test was done to assure the safety and workability of the method.

Figure 9 is the photos of actual work. As jacks and laborious temporary works were not necessary, the work site was very neat and reliable. Owing to the well-schemed method, the construction time was quite short. The total time was 9 months from August 1996 to April 1997.

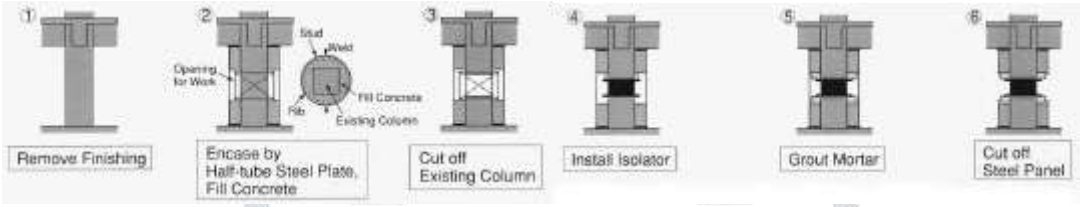


Figure 8 Reform process of mid-story isolation

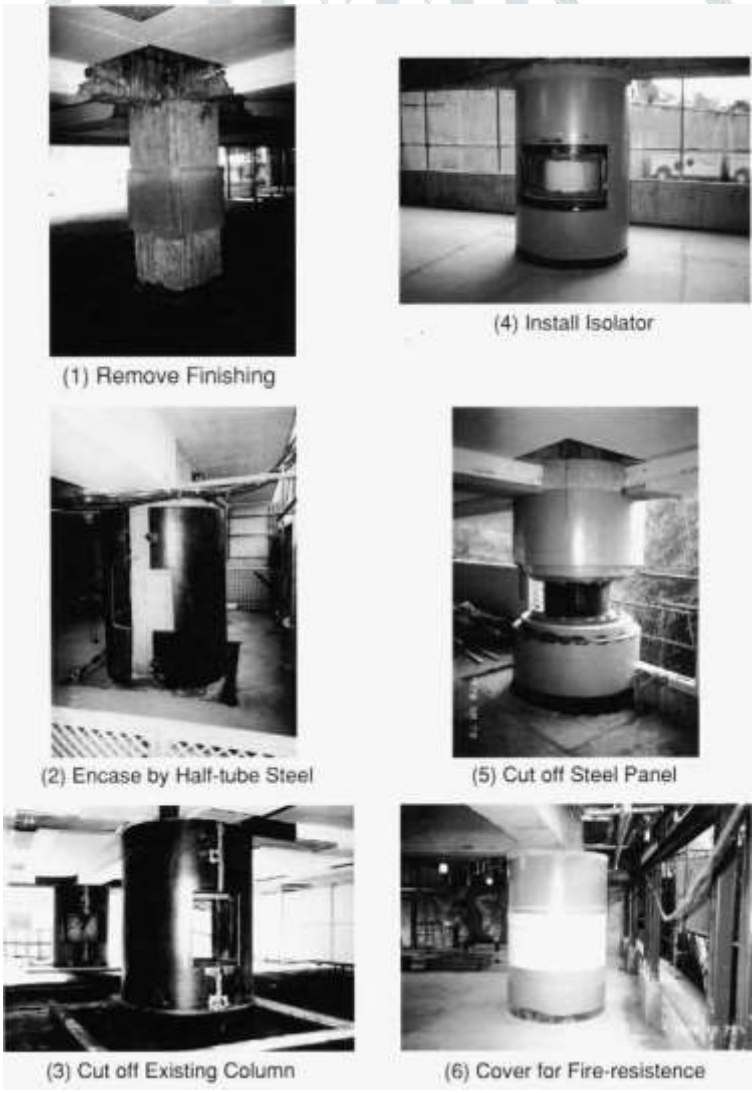


Figure 9 Reform work of mid-story isolation

Hybrid Isolation System

Base isolation was adopted for the east building which is supported by piles on flat ground. Piles were cut at their head to install rubber and sliding isolators. Figure 13 is the longitudinal section of the east building. Figure 14 is the layout of isolators; 7 units of sliders and 13 units of rubber bearings. In this case "Hybrid TASS system" was used, which is the combination of rubber bearings and sliding bearings in parallel. This system is superior to the conventional rubber bearing system, as more elongation of equivalent natural period and more absorption of response energy can be realized.

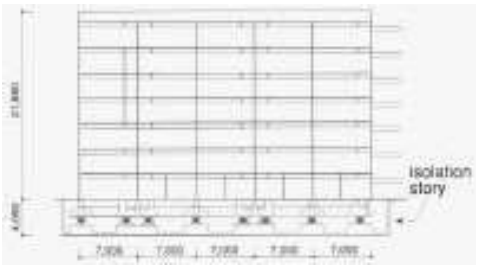


Figure 13 Section of east bldg

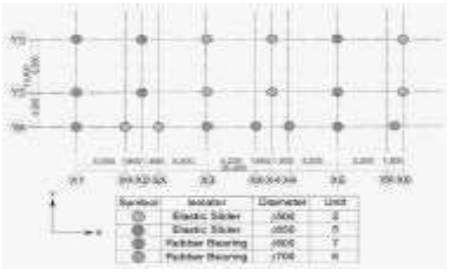


Figure 14 Layout of isolators

Response Characteristics

The fundamental period in X direction has been changed from 0.51sec to 1.43sec before sliding and 4.07sec after sliding. That in Y direction has become from 0.24sec to 1.38sec before sliding and 4.05sec after sliding. Nonlinear response analysis was conducted, whose results are shown in Figure 15 in terms of maximum shear coefficient and displacement. As the seismic response is reduced enough by the rubber-slider hybrid isolation system of high performance, strengthening of the upper structure is not necessary.

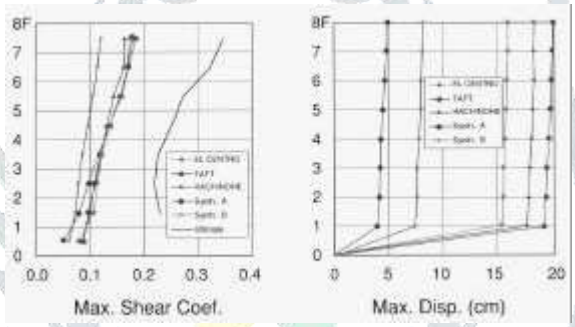


Figure 15 Maximum response of east bldg.

Reform Work

Figures 16 and 17 show the work procedure of base isolation retrofit. As there is an open courtyard in front of the building and also the 1st floor level of the east building is elevated as high as the 2nd floor level of the main building, excavation was done laterally from the front side more easily. The maximum relative displacement between the upper structure and ground was calculated to be 11cm for level-1 earthquakes and 19cm for level-2 ones. Piping which connects outside and inside of the building was so schemed as to be able to follow up to 40cm displacement by using flexible metal or rubber joints.

Figure 16 Reform process of base isolation retrofit

Figure 17 Reform work of base isolation retrofit

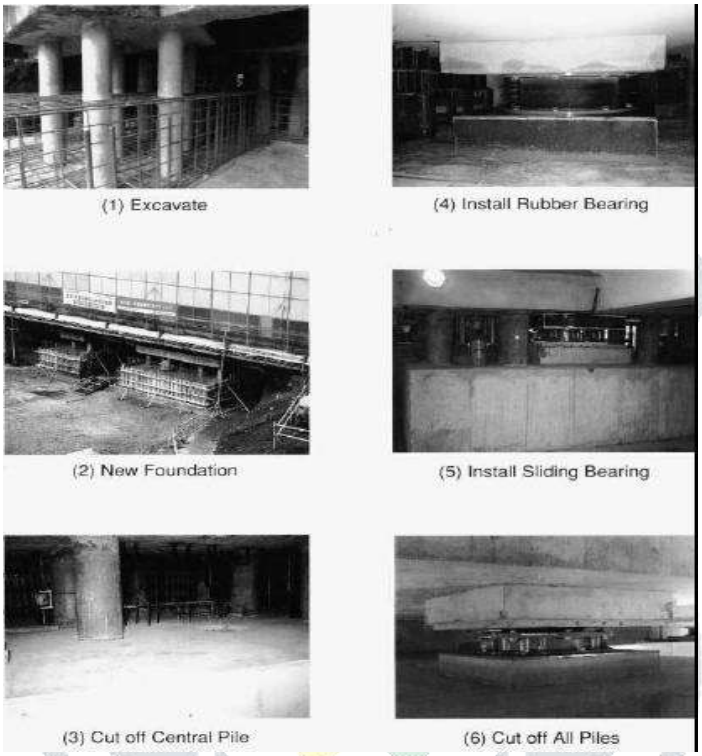
PROJECTS OF SEISMIC ISOLATION RETROFIT IN JAPAN

Until the end of March 1999, seventeen seismic isolation retrofit projects have passed the check of the committee of Building Center of Japan, most of them have been completed or under construction. They are historical buildings including temples, government offices, school buildings and so on as shown in Table 1.

Figure 18 is the government office of Toshima-Ward of Tokyo. It is now under construction of seismic isolation retrofit putting rubber and sliding isolators below the existing foundation. The building is used as usual by officials and citizens even during the construction work.

Figure 19 is the school building of Nihon University, where mid-story isolation is applied at the top of the columns of basement floor. Also in this case the building is used for research and education uninterrupted during construction work.

In both cases isolation retrofit was adopted through assessing its superiority to other counter measures like conventional strengthening method on the point of cost-performance and uninterrupted use of the buildings during construction work.



CONCLUSIONS

Seismic isolation retrofit in base or mid-story has advantages over the conventional strengthening method as follows.

- It is effective for reform buildings while they are in use as usual, because the work area can be limited or outside of the building.
- Construction cost is cheaper than the conventional strengthening method in the case of middle-rise buildings; e.g. around 10 storied or more. Taking temporary move to other place during construction work inside the building into consideration, and also from the view point of life cycle cost reflecting the seismic performance, cost benefit increases.
- Seismic performance is excellent not only to secure structural safety but also for the preservation of function and properties.
- Scarce deformation of the isolated structure is suitable to keep structural integrity even in case of reinforced concrete, whereas conventional method or response control method are difficult to avoid some degree of damage.

On the contrary attention should be paid on the following items due to the large displacement as much as scores of centimeter during severe earthquakes.

- Clearance to the neighboring structure requires around 40cm.
- In the case of base isolation the distance to the border of site requires 1~2m excluding work space, as there should be dry area and retaining wall.
- In the case of mid-story isolation, repair and space are necessary for piping, staircase, elevator and escalator to follow the large displacement of the isolation story.
- The retrofit work herein described was done safely and reliably almost without jacks and temporary support.
- Noise was also measured at various points during construction work to choose suitable method and device.
- These experiences can be reflected on the future project of this type.

PAPER II

BASE ISOLATION OF EXISTING STRUCTURE BY RETROFITTING

ABSTRACT

The Raja Dinkar Kelkar Museum is an important historic monument of the city of Pune in the western state of Maharashtra. The Kelkar Museum constructed in the 1910's is considered a cultural heritage building. The building framing is comprised of unreinforced masonry (URM) bearing wall system with stone masonry foundations. Seismic isolation provides the optimum retrofit solution because: a) the reduced seismic demand would protect vulnerable structural and nonstructural components, and b) the selected retrofit would eliminate the need for alterations above grade and preserve the historical features of the building. Analysis showed that the base isolation by retrofit was effective and the existing members would be able to resist the reduced seismic forces without the need for upgrade.

INTRODUCTION

RAJA DINKAR KELKAR MUSEUM

Raja Dinkar Kelkar Museum is situated in the western region of Maharashtra at a distance of about 140km from the epicenter of the 1967 Koynanagar earthquake occurred near Koynanagar Maharashtra, India On11 December. The magnitude 6.6 shock hit with a maximum Mercalli intensity of VIII. It occurred near the site of Koyna dam, raising questions about induced seismicity, and claimed at least 177 lives and injured over 2,200.

The Raja Dinkar Kelkar Museum in Pune, Maharashtra, India. It contains the collection of Dr. Dinkar G. Kelkar (1896–1990), dedicated to the memory of his only son, Raja. The three-storey building houses various s sculptures dating back to the 14th century. There are also ornaments made of ivory, silver and gold, musical instruments (a particularly fine collection), war weapons and vessels. The collection was started around 1920 and by 1960 it contained around 15,000 objects.

The museum was established in 1962, and Dr. Kelkar donated his collection to the Government of Maharashtra in 1975. The museum now holds over 20,000 objects of which 2,500 are on display. These consist of mainly Indian decorative items from everyday life and other art objects, mostly from the 18th and 19th centuries. The museum's collection depicts the skills of the Indian artists of the time. The Mastani Mahal no longer exists in Pune. However, history has it that it was beautiful palace. The best part of it is that a section of it still lives-not at its original locations but at the Raja Dinkar Kelkar Museum in Pune.

EARTHQUAKE

Pune, formerly known as Poona is the eighth largest metropolis and the second largest in the state of Maharashtra after Mumbai. The city is an academic, administrative and industrial centre situated 560 meters above sea level on the Deccan plateau at the confluence of the Mula and Mutha rivers.
As per the 2010 census of India, the population of the Pune urban area is around 5,518,688. Pune is emerging as a Information Technology hub, presence of automobile and manufacturing companies resulted to rank as the eight largest metropolitan economy and the sixth highest per capita income in the country. Pune has a mixed type of building stock from modern steel structures to old historic buildings. The city core areas are densely populated with a mix of various building types. Pune lies very close to the seismically active zone around Koyna Dam, about 100 km (62 mi) south of the city, and has been rated in Zone 4. Pune has experienced some moderate-intensity and many low-intensity earthquakes in its history. Earthquakes felt in Pune with a magnitude of more than 3.0.

DATE	MAGNITUDE	EPICENTER
MAY 17, 2004	3.2	KATRAJ REGION, PUNE, MAHARAHSTRA
JULY 30, 2008	4.2	KOYNA DAM, KOYNA NAGAR, MAHARASHTRA
APRIL 14, 2012	4.9	SATARA DISTRICT, MAHARASHTRA

DAMAGE

More than 80% of the houses were damaged in Koyna Nagar Township, but it did not cause any major damage to the dam except some cracks which were quickly repaired. There have been several earthquakes of smaller magnitude there since 1967. The deadly earthquake caused a 10–15 cm (3.9–5.9 in) fissure in the ground which spread over a length of 25 kilometers (16 mi). Some geologists believe that the earthquake was due to reservoir-triggered seismic activity.

Earthquake of 3.6 magnitude jolts koyna region in Maharashtra, Pune. An earthquake measuring 3.6 on the Richer scale jointed areas near the koyna dam in Maharashtra, according to the Indian Metrological Department (IMD).

Pune lies in earthquake zone III which is likely to face an earthquake of moderate magnitude. During the koyna, tragedy tremors of around 3.6 magnitude were felt in Pune. This gives us a wide possibility that the tremors can escalated to a higher magnitude in due course of time.

BASE ISOLATION

Base isolation is a relatively recent development in seismic design. The principal is to insert a discontinuity at the base of the structure that has relatively low resistance to shear. As earthquake motions are transmitted upward from the ground, the effect of the soft discontinuity will be to increase the natural period of the structure and to absorb energy by shear deformation. In general, this will reduce magnitude of the response of the structure to earthquake shaking, particularly if the structure is founded on The base isolation technique is a seismic design approach in which, due to the insertion of a flexible layer between the foundation and the superstructure, the fundamental frequency of the system decreases to a value lower than the predominant energy containing frequencies of earthquake ground motion. In addition, the damping capacities provided by the isolation systems help dissipate the energy imparted during seismic activities.

Types of Base Isolators

Lead Rubber Bearings: Lead rubber bearing (LRB) are the laminated rubber bearing containing one or more lead plugs to deform in shear. The lead in the bearing deforms physically at a flow stress of 10 MPa, providing the bearing with bilinear response. For that reason the lead must fit tightly in the elastomeric bearing, and this is achieved by making the lead plug slightly larger than the hole and applying force at the time of inserting it in the hole.

High Density Rubber Bearings: High density rubber bearing (HDRB) is another type of elastomeric bearing which consist of thin layers of high damping rubber and steel plates in alternate layers. Like LRB this type of bearing does not contain lead at the center of bearing. The rubber used is either natural rubber or synthetic rubber which provide a sufficient amount of damping.

Friction Pendulum System: The friction pendulum system (FPS) is a sliding type isolation system and consists of a spherical stainless steel surface and an articulated slider, covered by Teflon based composite material. It works on the principal of simple pendulum. Friction Pendulum bearings are seismic isolators that are installed between a structure and its foundation to protect the supported structure from earthquake ground shaking.

LEAD RUBBER ISOLATION BEARING

The earthquake is a disruptive disturbance that cause shaking of surface of the earth due to undergoes moment along a fault plane or from volcanic activity is called Earthquake. Earthquake resistant structure is structure designed to withstand earthquakes. While no structure can be entirely immune to damage from earthquakes. Base isolation is a most effective method for earthquake resisting structure. “Earthquake doesn’t kill folks, folded building do.” The Indian landmass contains a history of devastating earthquakes. The most recent version of unstable seismic zoning map of India given within the earthquake resistant design code of India [IS 1893 (Part1) two002] divides India into four unstable zones (Zone 2, 3, 4 and 5), with Zone five expects the best level of seismicity whereas Zone two is related to very cheap level. every zone indicates the results of Associatein Nursing earthquake at a selected place supported the observations of the affected areas and may even be delineated employing a descriptive scale like changed Mercalli intensity scale or the Medvedev-Sponheuer-Karnik (MSK) scale. The MSK intensity generally related to the varied unstable zones is VI (or less), VII, VIII and IX (and above) for Zones two, 3, 4 and 5, severally, like most thought-about Earthquake (MCE). Zone 5, that is mentioned because the terribly High injury Risk Zone within the IS code, assigns zone

issue of zero.36 toit, that is indicative of effective (zero period) peak horizontal ground accelerations of zero.36 g (36% of gravity) which will be generated throughout MCE level earthquake during this zone. The state of Kashmir, the western and central Himalayas, the NorthEast Indian region and also the Ran of tannic acid fall during this zone.

EXPERIMENTAL ANALYSIS OF KELKAR MUSEUM BY E-TAB SOFTWARE

Fig No.1 Storey Data

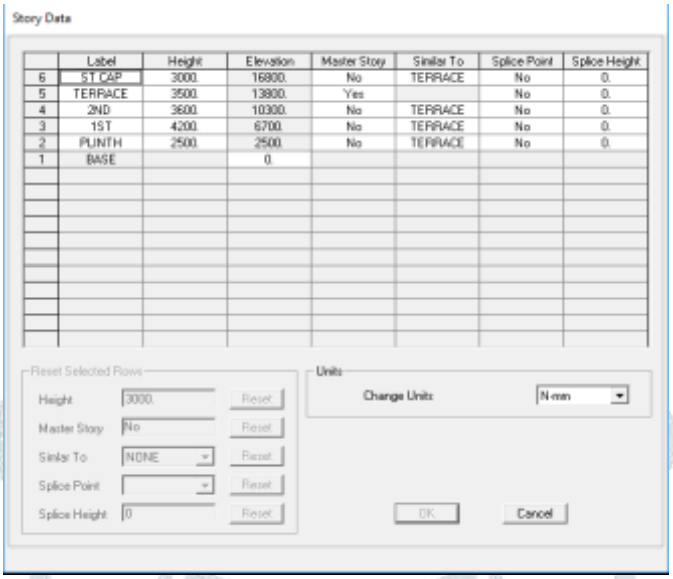


Fig.2 material properties of structure for beam and slab.

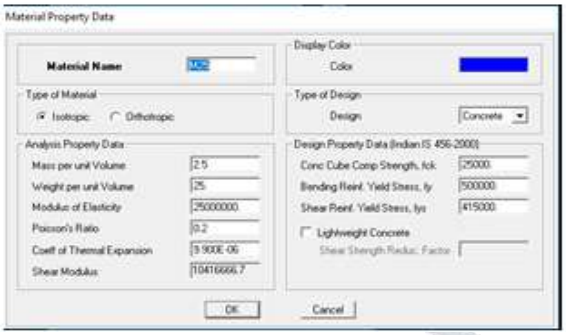


Fig.3. material properties of structure for column.

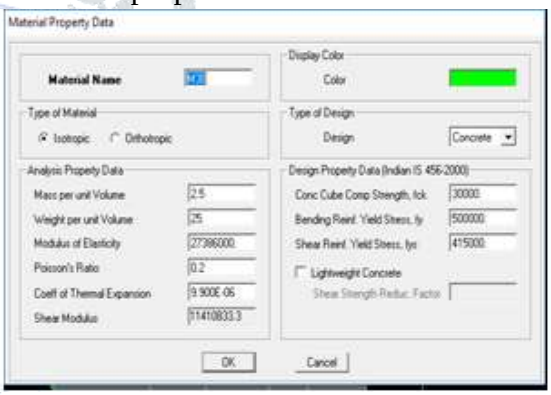


Fig No.4 3D View Of Structure

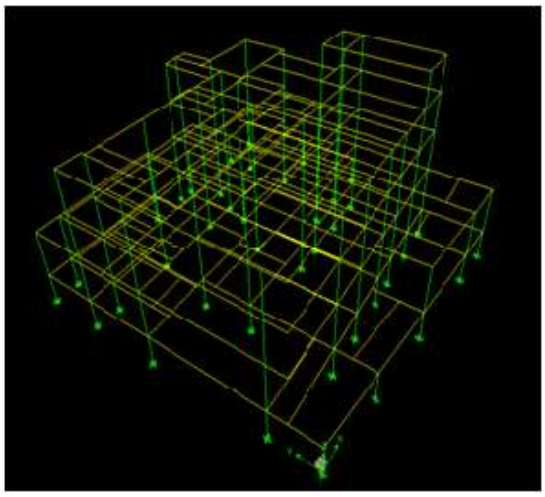


Fig No.7 First Floor Live Load

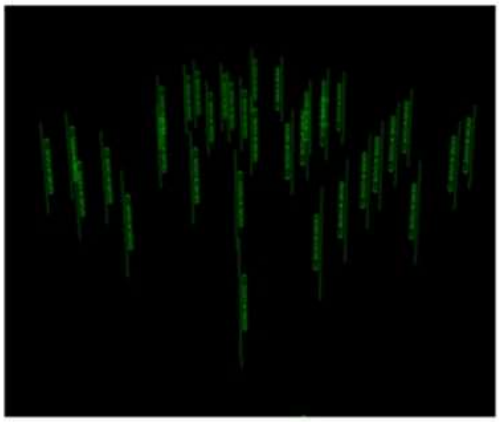


Fig No.5 Columns Sizes

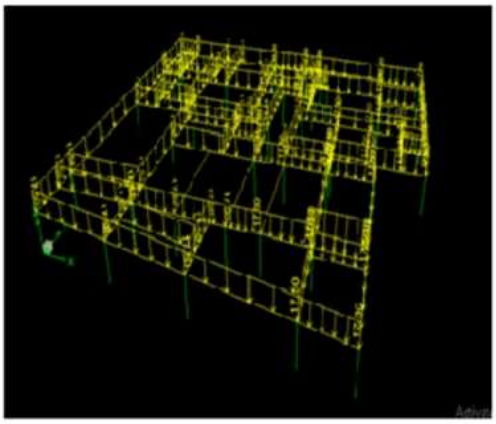


Fig No.8 Plinth Wall Load

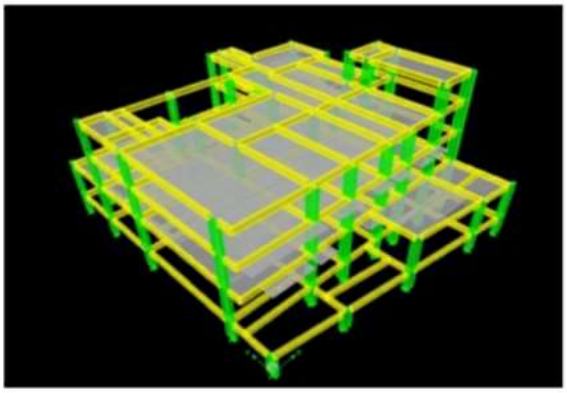


Fig No.6 3D View Of Structure

No.9 First Floor Live Load

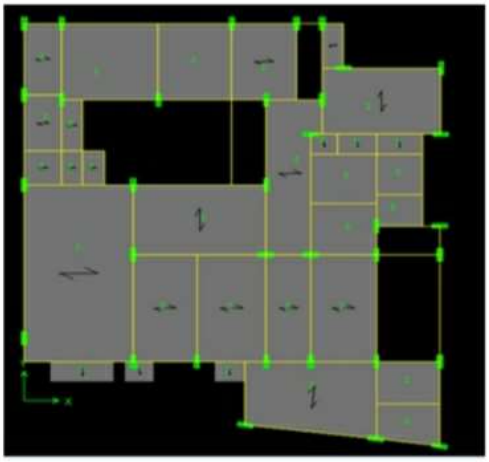


Fig No.10 First Floor Of Super Dead Load

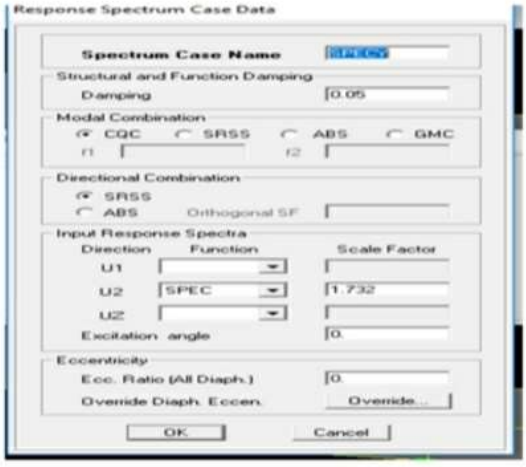


Fig No.11 Response Reduction Factor In Y Direction

SEISMIC RETROFIT TECHNIQUE

Retrofitting means providing something with a component not fitted during manufacture or adding something that it did not have when first constructed. The retrofitting technique using base isolation has great potential for rehabilitation of ordinary civil structures such as apartment blocks and critical facilities such as schools, hospitals. It is well known that the isolated building involves deformation only in the isolation system, the building being to all intents and purpose rigid. The higher modes do not participate in the motion so that the high energy in the ground motion at these higher frequencies cannot be transmitted into the building.

CONCLUSION

- The E-TAB software has been used to calculate live load, dead load, earthquake load, shear force and bending moment for Kelkar Museum, Pune.
- The successful study of base isolation concludes that Kelkar Museum can be retrofitted with base isolation devices which would prove essential in terms of saving life, valuables, property and also increase its life span.
- The Cost Benefit Ratio of Kelkar Museum proves that its financial aspect has been studied and successfully applied for two cases for the structure. It also proves that base isolation is necessary for a heritage structure which is old in order to saves additional cost, damages, deaths and injuries during an earthquake.
- A detailed report is submitted to the PMC so that the Corporation can successfully use this technique for other structures in the city.
- With the help of the demo model, we can conclude that a base isolated structure can survive an earthquake and faces slight to no damage as compared to a non-base isolated structure.

IV. MATERIALS AND METHODOLOGY

1. MAJOR TYPES OF ISOLATORS

- Elastomeric bearings

Elastomeric bearings have been used widely in bridges as bearing pads between the girder and the supporting structure for many years. Elastomeric bearings have multiple layers of steel shims and rubber laminated together under high pressure and heat in a mold. Steel shims prevent lateral bulging of the rubber when axially loaded. They do not resist shear forces and do not prevent the horizontal deformation of the layered rubbers. Therefore, steel shims increase the vertical stiffness of isolators but do not increase the lateral stiffness of elastomeric bearings.

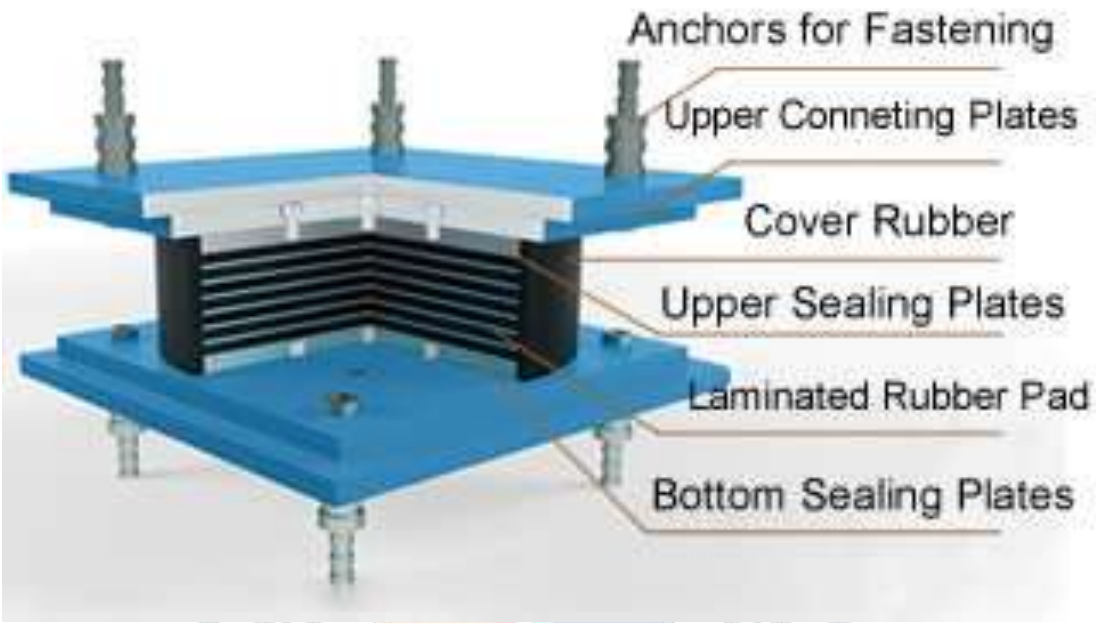
Figure 2.1 shows elastomeric bearings subjected to dynamic shear test. The uneven surface of the elastomeric bearings shown is due to its steel shims. Generally, elastomeric bearings have low critical damping resistance, approximately 2% to 3% of critical viscous damping; and have minimal resistance under service loads. Therefore elastomeric bearings need to be improved. The result is a high damping elastomeric bearings and the lead rubber bearings.

Fig.1 Elastomeric Bearings under Shear Test. (Maurer Söhne)

- High Damping Rubber Bearings (HDRBs)

As an alternative to elastomeric bearings, high damping rubber bearings provide critical damping from 10% to 20% at 100% shear strains. The construction methodology is the same with elastomeric bearings; however, the damping is increased by adding carbon block and other fillers. In addition, it has an adequate resistance to service loads.

The damping characteristic is in between hysteretic and viscous. The energy dissipation is linear and quadratic for hysteretic and viscous, respectively. The energy absorption capability help reduced the earthquake energy transmitted to the superstructure.
The load capacity of HDRB can be computed using the same method as elastomeric bearings. The damping value can be computed using the equivalent damping ratios for specific elastomeric compounds.



- Lead Rubber Bearings (LRBs)

Lead rubber bearings are elastomeric bearings that contain one or more lead plugs inserted into their preformed holes. The lead provides significant stiffness under service loads and low lateral loads as compare to the elastomeric bearings. Figure 2.2 shows the alternating sheet of steel shims and rubbers circumscribing a lead core. In addition, the lead serves as energy dissipation mechanism under severe lateral loads.

During high lateral loads, the lead yields and the lateral stiffness of the LRB is significantly reduced. This increases the duration of the period of the structure and thereby serves the purpose of base isolation system. The bearing is cycled into a hysteretic damping as it absorbs the energy. LRB has a range of damping from 15% to 30% which is a function of displacement.

The LRB are the most common base isolator used for isolating midrise buildings. It is usually designed and optimized according to a specific performance based target design. It combines the stiffness needed for service loads and low lateral loads while providing the flexibility and damping needed for high lateral loads. A wide array of damping and stiffness is possible through the use of LRB. As for the case of HDRB design, the formulas of elastomeric bearings are suitable for the design of LRB.

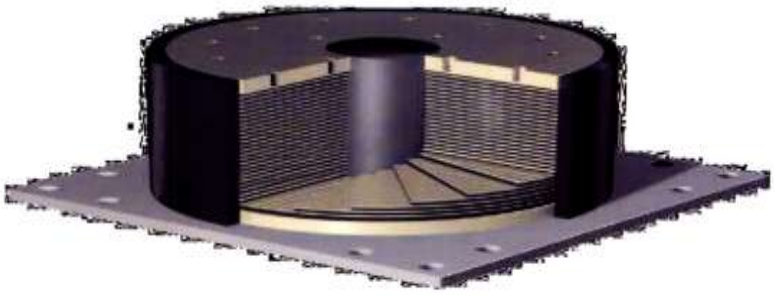


Figure 2-2: Lead Rubber Bearing with Layers of Rubber and Steel; and a Lead Core. (DIS)

- Flat Sliding Bearings

Flat sliding bearings consist of PTFE (Teflon) disc that slides on a stainless steel plate. They provide a perfectly plastic hysteresis shape, and adequate stiffness under service loads with high damping properties. In addition, the coefficient of friction is a function of both pressure and velocity of sliding. It provides the resistance under service loads. However, it must be combined with other bearings (i.e. HDRBs, LRBs) because it has no capability to return to its initial position.

Figure 2.3 shows an assembly of flat sliding bearing, which has the stainless steel plate supporting the circular disc. There is no other part in the assembly that shows that it has the capability to return to its initial position. A modified version of flat sliding bearing that has self restoring force is the friction pendulum bearings.

Figure 2-3: Assembly of Flat Sliding Bearing. (Maurer Söhne)

- Friction Pendulum Bearings

The friction pendulum bearings have the same properties as the flat sliding bearings. However, the sliding surface is concave in shape rather than flat as shown in Figure 2.4. The hemisphere at the center of the concave surface is the pendulum slider. The spherical concave surface provides a restoring force to the pendulum slider to return to its initial position.

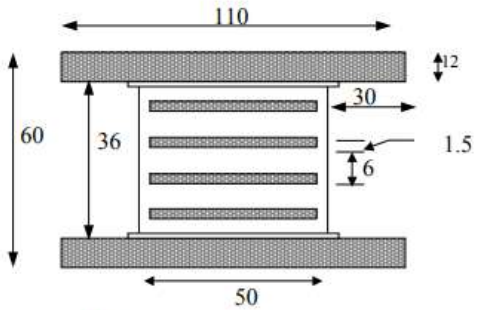
Varying the radius of the concave surface varies the stiffness of the friction pendulum bearings. In addition, once the coefficient of friction is overcome the lateral movement of the mass is accompanied by a vertical movement of the mass because of the curved shape of the slider. As for the case of LRB, the friction pendulum bearings have a wide array of damping and stiffness design capabilities.

Figure 2-4: Friction Pendulum Bearing Assembly. (EPS)

2. DESIGN OF LRB SYSTEM FOR LABORATORY TESTING

The isolator system designed for the present study is shown in the Fig 1. The important points considered while designing the LRB system are given below

- The Height to width ratio of the LRB system ≤1
- Rubber thickness between two plates < 2 cms.
- Frequency of isolator considering structure as rigid ≈ 0.5 Hz. (Due to limitation in testing it is considered approximately 5 Hz.)
- Maximum vertical load to be supported ≈ 100 kg. (Limitation due to testing facility). The various properties of the isolator are listed in table1. The properties are calculated according to formulation given in Appendix A. This test LRB's are manufactured and tested on one story frame as shown in Fig.2 .The frequency of superstructure without isolator was 20 Hz which came down to 6.59 Hz after introducing LRB isolation. The sine loading of 0.2g amplitude is applied on the model. The acceleration experienced has come down from 5.8g to 0.2g because of LRB. This shows the effectiveness of the isolator.



All dimensions are in mm.

Fig 1. Laminated Rubber Bearing (Test Model)

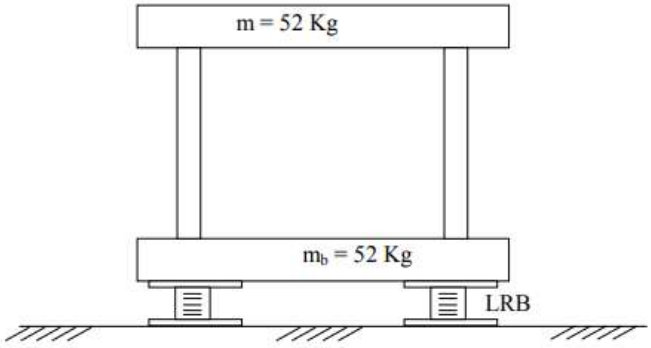


Fig 2. One story Steel frame supported on LRB system

Table 1. Properties of Isolator For Laboratory Testing

Horizontal frequency	6.26 Hz
Vertical frequency	24.80 Hz
Rocking frequency	618.67 Hz
Torsional frequency	6.2 Hz
Horizontal stiffness	40.02 kgf/cms
Vertical stiffness	618.67 kgf/cms

ANALYTICAL STUDIES

A Finite element model of the laminated rubber bearing system is prepared as shown in Fig 3. The Steel plate is modeled as linear system while the rubber layers are modeled as non-linear elements. Model consists of eight-nodded plain strain element. The Mooney Rivlin model is used to model the rubber behavior. The details of Mooney Rivlin model and various constants are given in Appendix B

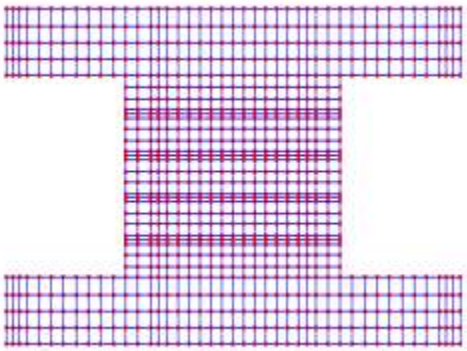


Fig 3. Finite element model of LRB test model

Deflected shape of LRB is shown in Fig 4. The Horizontal load deflection curve of the LRB is obtained which is compared with the test data as shown in Fig 5 and 6. The testing has shown a 5% damping of the isolator (Ref 11).

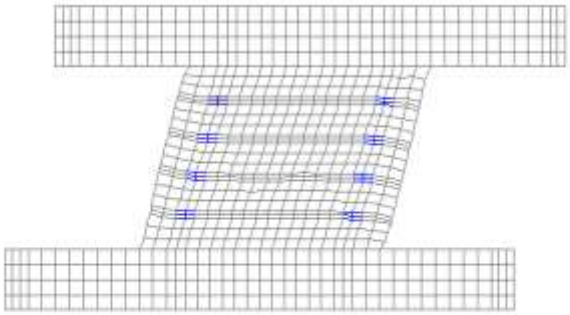


Fig 4 . Deflected shape of LRB Test Model under vertical and Horizontal Load

In Finite Element analysis rubber is generally described as hyper elastic material; this means that there is a strain energy density function, which when differentiated with respect to a strain measure yields the

corresponding stress measure. The mechanical response of a material is defined by giving the required parameters in the chosen strain.

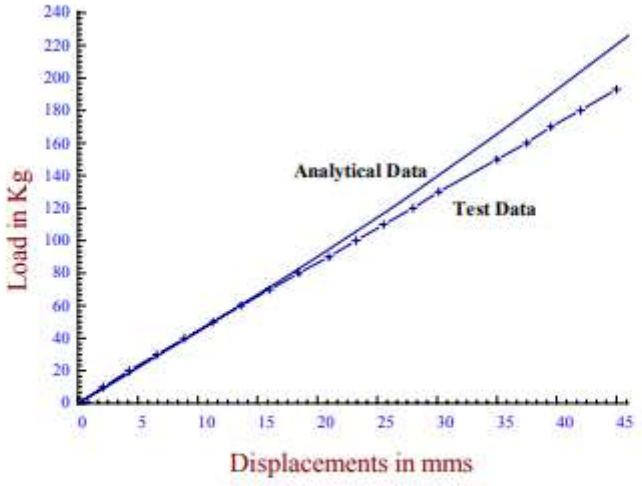


Fig 5. Comparison of analytical and experimental deformation of LRB (Test Model)

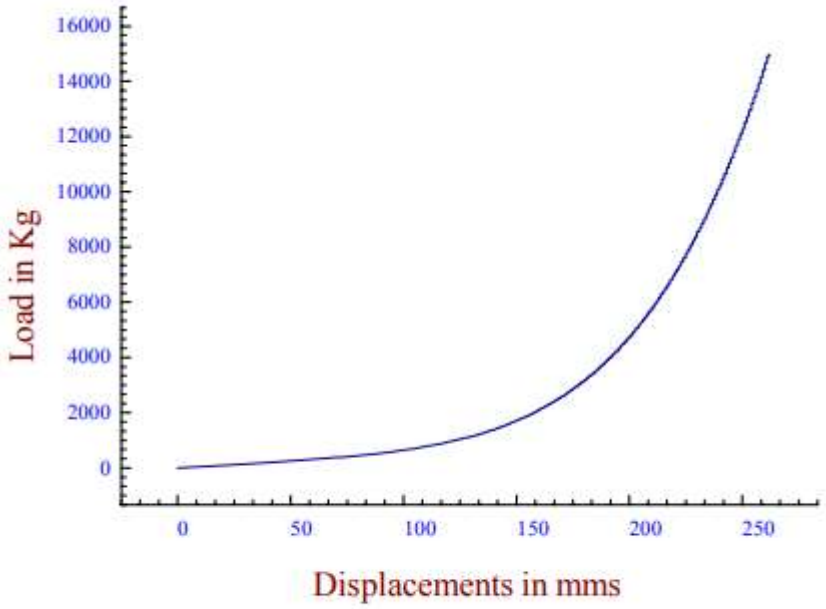


Fig 6. Load deformation behavior of LRB (test model) under horizontal and vertical load obtained analytically

3. STEPS FOR INSTALLATION OF BASE ISOLATION BY RETROFITTING

STEP 1: Take an existing building and excavate around its foundation.

STEP 2: Remove the ground level slab and drive Soles piles in the ground. Note that use of piles depends upon the characteristics of soil. Now prepare a first mat foundation slab and place it above the piles. It would not be linked to the building and piles.

STEP 3: Prepare second mat foundation slab and place it over the first mat foundation slab in such a way that it is connected to the building. Make holes in the second mat foundation slab for provision of installation of hydraulic jacks.

STEP 4: Place the hydraulic jacks in the holes made at equal distances in the second foundation slab.

STEP 5: The hydraulic jacks are mechanically operated in such a way that pressure is exerted on the lower mat foundation slab by means of the hydraulic jacks and the upper mat foundation slab is lifted, thus lifting the entire building.

STEP 6: Now place the base isolators in the space between the first and the second mat foundation slab. Note that the base isolators are placed as per the design given by the experts.

STEP 7: Remove the hydraulic jacks from its holes. The existing building is now equipped with the base isolation device.

STEP 8: Construct a retaining wall around the excavated foundation area to prevent surrounding soil from entering.

STEP 9: Construct a manhole in the upper foundation slab to allow inspection and maintenance of the base isolators.

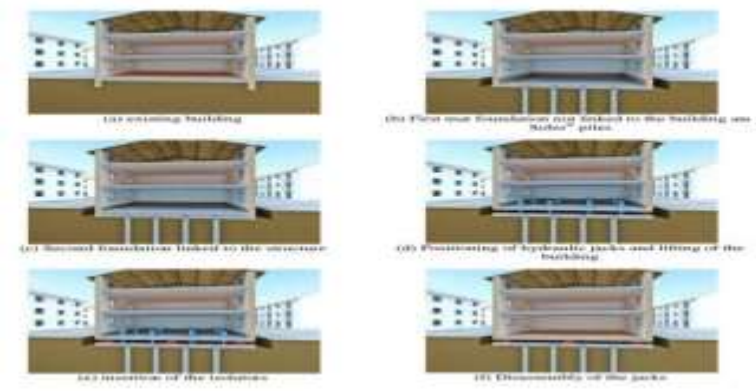
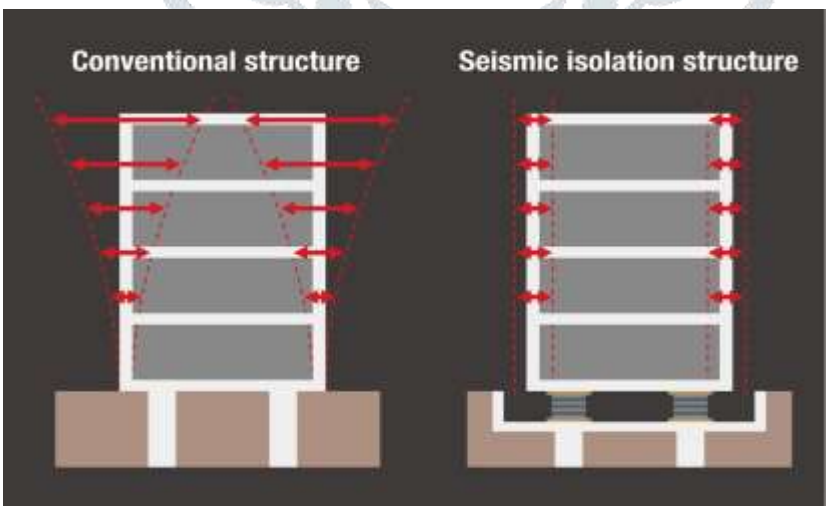


Fig.1 Steps for installation

4. COST FOR BASE ISOLATION (US CASE STUDY)

For one thing, base isolation is more expensive than conventional engineering methods. Hamburger estimated that a base isolation system may cost roughly $30-50 per square foot, or between $600,000 and $1,000,000 for a five-story building. That adds about 5% to 10% to a building's total construction costs, Hamburger said, though he estimated that a developer could save 20% in repair costs if an earthquake were to strike.



In the event motion an earthquake, base-isolated buildings won't necessarily be the only ones that save lives. "Whether we isolate buildings or not, we believe that we design them to be very safe in earthquakes," Hamburger told Business Insider. "The risk of serious injury in a modern building designed for earthquake resistance is very low."

But the cost of structural damage — multiple buildings out of operation for months after an earthquake — could constitute a major disaster for a city, Hamburger said.

In 2015, the US Geological Survey put the likelihood of "The Big One," a magnitude 8.0 earthquake located along the San Andreas Fault, occurring in the next 30 years at 7%. The agency estimated that there was a 72% chance that the San Francisco Bay Area would see at least one earthquake of a magnitude of 6.7 or greater by 2043, and a 60% chance that Los Angeles would witness the same scenario. That prediction almost came true on July 5, with the 7.1 magnitude quake striking about 125 miles northeast of LA.

COST BENEFIT RATIO

There is a widely held misconception that seismic isolation is expensive. When viewed against the savings it can in some cases result in a slightly lower construction cost overall.
E.g. Union House built in Auckland in 1983 with base isolation produced an estimated 7% cost saving in the total construction cost of $6.6m which included a construction time saving of 3 months due to the structural form requiring less seismic force, ductility demands and structural deformations. As a general rule, the inclusion of all aspects of seismic isolation in a new structure will add no more than 3% to total construction cost and considerably less when assessed against the benefits of isolation.

CASE 1:

Cost Benefit Ratio involving cost of construction and materials.
Following are the various parameters involved in the base isolation system for Kelkar Museum along with their approximate costs:- -
Plot area of Kelkar museum = 8550 sq.ft
Plinth area of Kelkar museum =4627.37 sq.ft
Ground floor area = 3971.12 sq.ft -First floor area= 4288.62 sq.ft
Second floor area = 2587.50 sq.ft
Total built up area = 10847.24sq.ft
Lead Rubber Bearings:
The cost of the base isolation device is taken to be 3%-5% of the total cost of construction of Kelkar Museum.
Cost of 1 lead rubber bearing isolator = Rs 25000 to Rs 30000
No. of Columns = 35 nos.
Cost of lead rubber bearings for 35 columns = Rs 875000

Hydraulic Jacks:

Lifting with hydraulic jack = Rs 200/sq.ft
Cost of hydraulic jack x plinth area = Rs 25474

Excavation:

Take quantity and cost of excavation as lumpsum.
Assume excavation cost {manual} = Rs 10/sq.ft
Depth of excavation = 6 ft
Total area of excavation in sq.ft= 27764.22 sq.ft
Total cost of excavation = Rs 277642.2

Materials:

Concrete:
M25 grade concrete will be sufficient for this particular type of building.
Capacity of 1 RMC mixer =6 cubic meter
Cost of 6 cubic meter concrete = Rs 24000
Total cost of concrete = 6 4 24000 = Rs 576000
Steel:
Grade of steel FE415 is suitable
Cost of 1 metric tonne steel = Rs 32000
Plinth beam:
Cost of construction of plinth beam including material, labour, casting, shuttering etc = Rs 70000 for 4627.37 sq.ft
Retaining wall:
For construction of retaining wall in RMC up to 2 meter height = Rs 155/sq.ft
Cost for construction of retaining wall = RS 717242.35
Total cost of Base Isolation with Retrofitting =RS 3473358.55
Cost Benefit ratio
Cost of construction for 10847.24 sq.ft {according to today's market value}
= Rs 17355584
Total amount saved = Cost of construction - Cost of retrofitting = Rs 13882225.45
{Benefit} Therefore Cost Benefit Ratio = Benefit/ Cost of retrofitting
= 13882225.45/347335
= 3.996

CASE 2:

No. of visitors at the museum daily = 367 persons
Compensation for 20% people resulting in death = 20% of 367 2000
= Rs 14680000
Compensation for 30% people resulting in severe injury = 30% of 367 x 50000
= Rs 5505000
Compensation for 30% people resulting in moderate injury = 30% of 367 x 25000
= Rs 2752500 Compensation for 20% people resulting in light injury = 20% of 367 x 10000
= Rs 734000
Total compensation = Rs 23671500
Cost of retrofitting = Rs 3473358.5
Cost benefit ratio = total compensation/cost of retrofitting = 23671500/3473358.5
= 6.815

V. CONCLUSION

Base isolation seems to be a very promising seismic technology to use for all types of structures. However, it is not; base isolation is recommended only for midrise structure (i.e. less than 20 story high) or structures with a height to width ratio that is less than two to one. This is because the base isolation is designed to resist lateral shear forces and not to carry moments. In addition, base isolation is recommended for rigid structures that can act as a single degree of freedom. Otherwise, the framing system will act as multiple single degrees of freedom with different frequencies. In this case, the building will collapse.

If a Base Isolation System satisfies the four basic requirements, it can solve a great variety of earthquake protection problems with greatly increased security and at generally cheaper costs than classical strengthening techniques. A full protection may be obtained when it is required, due to the fact that the isolators and the structural materials of the building mounted on isolators work in the elastic range only.

VI. REFFERENCES

IJISET | International Journal of Innovative Science, Engineering and Technology
https://theconstructor.org/earthquake/what-base-isolation-system-building-construction/36142/
Ballantyne, B.F., Seismic Isolation of Bridges, M.Eng. Thesis submitted to the Department of Civil and Environmental Engineering, MIT, 2000.
Chopra, A.K., Dynamics of Structures: Theory and Application to Earthquake, 3rd ed., Prentice Hall, New Jersey, 2007, Chapter 20.
Computer and Structures, Inc., CSI Analysis Reference Manual, Berkeley CA, 2007.
Connor, J.J., Introduction to Structural Motion Control, 1st ed., Prentice Hall, New
Jersey, 2003, Chapter 5.
Kelly, J.M., Earthquake Resistant Design with Rubber, 2 nd ed., Springer-Verlag, London 1996.
Komodromos, P., Application of Seismic Isolation as a Performance Based Earthquake Resistant Design Method, S.M. Thesis submitted to the Department of Civil and Environmental Engineering, MIT, 1995.
Lapointe, E. M., An Investigation of the Principles and Practices of Seismic Isolation in Bridge Structures, M.Eng. Thesis submitted to the Department of Civil and Environmental Engineering, MIT, 1999.
DOUGLAS WAY, KAI-CHEN TU and FARZAD NAEIM, "Implementation of a hybrid Base Isolation system with breaking features", Proceedings of the 11th World Conference on Earthquake Engineering, Paper no. 93.
P. P. ROSSI, P. LENZA and M. PAGANO, "Base Isolation Strategy for Framed Buildings", Proceedings of the 11th World Conference on Earthquake Engineering, Paper no. 1345.
Michael D SYMANS, Glenn J MADDEN and Nat WONGPRASERT, "Experimental Study of an adaptive Base isolation System for Buildings", Proceedings of the 12th World Conference on Earthquake Engineering, 2000, Paper no. 1965.