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Base Isolation of Existing Structure by Retrofitting

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***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.

Table 1: Past Earthquakes in Pune Region

DATE	MAGNITUDE	EPICENTER
May17,2004	3.2	Katraj Region, Pune, Maharashtra
July 30, 2008	4.2	Koyna Dam, Koyna Nagar, Maharashtra
April14,2012	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.

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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 North-East Indian region and also the Ran of tannic acid fall during this zone.

EXPERIMENTAL ANALYSIS OF KELKAR MUSEUM BY E-TAB SOFTWARE

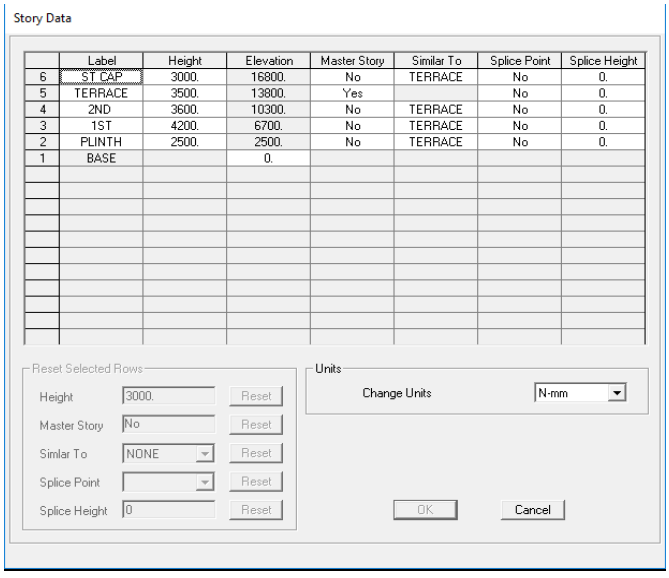

Fig No.1 Storey Data

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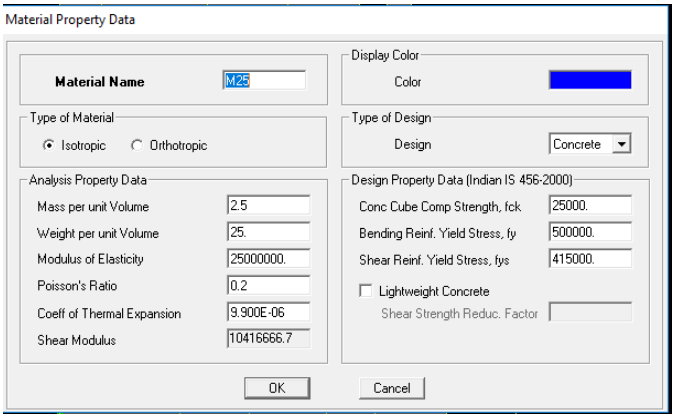

Fig No.2 Material properties of Structure For Beam And Slab

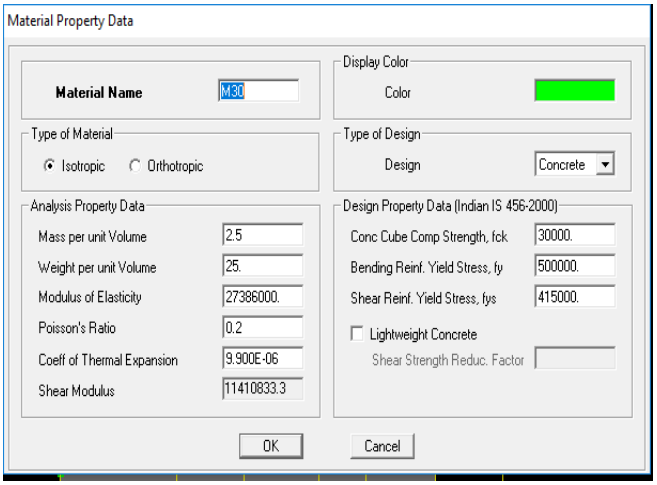

Fig No.3 Material Properties Of Structure For Column

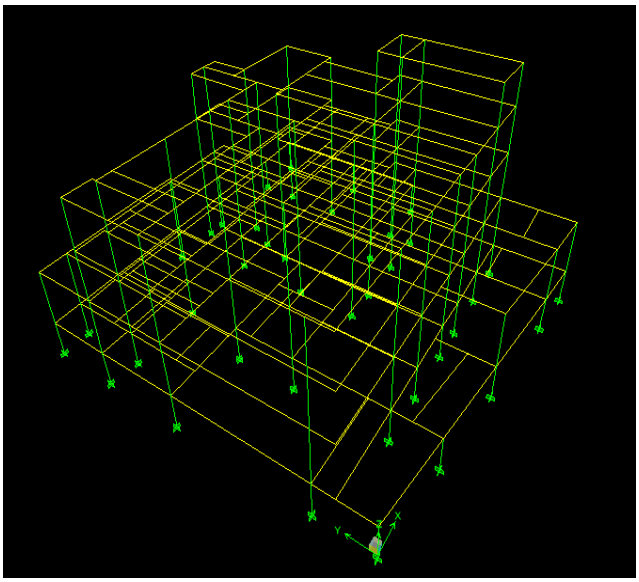

Fig No.4 3D View Of Structure

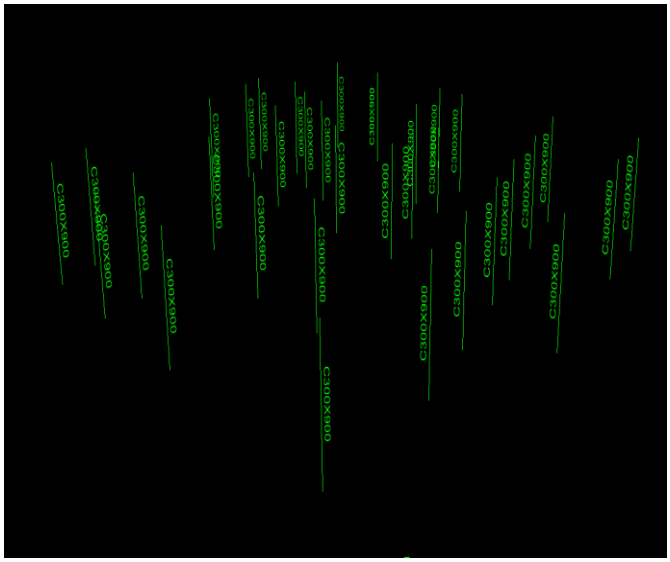

Fig No.5 Columns Sizes

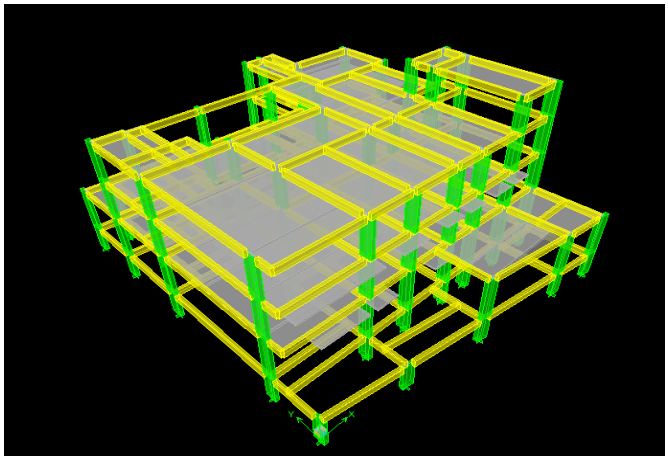

Fig No.6 3D View Of Structure

Fig No.7 First Floor Live Load

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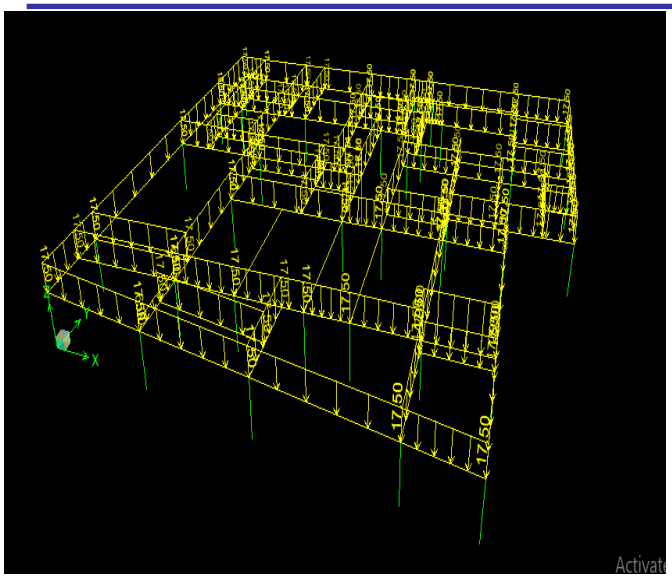

Fig No.8 Plinth Wall Load

No.9 First Floor Live Load

Fig No.10 First Floor Of Super Dead Load

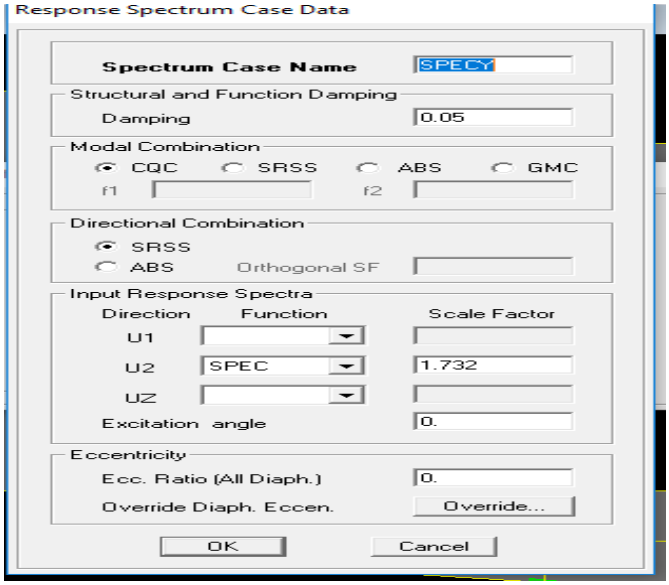

Fig No.11 Response Reduction Factor In Y Direction

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.

STEP FOR INSTALLATION OF BASE ISOLATION BY RETRROFITING

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.

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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.

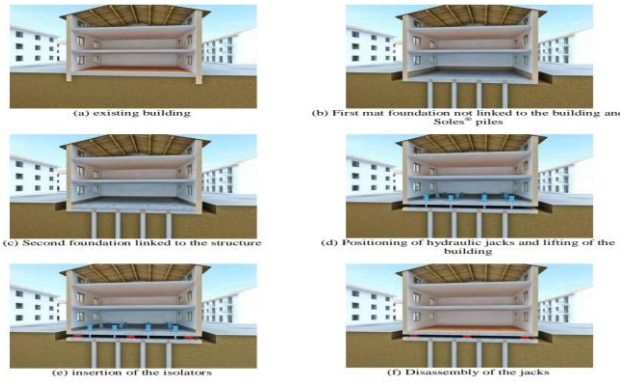

Fig No.12 STEPS FOR INSTALLATION

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 A:

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 367x50000
=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

FUTURE SCOPE

[1] There is a very wide scope for the technique of base isolation. In the near future, there will be a wide possibility of

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earthquakes because of the undesirable changes in the surroundings. Base Isolation technique of earthquake resistance will prove immensely fruitful in such conditions.

[2] 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.

[3] A huge loss of life and property can be avoided by the use of base isolation devices.

[4] 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.

[5] 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.

[6] The design of base isolation devices for Kelkar Museum, Pune needed expensive test methods like NDT (Non-destructive 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.

CONCLUSION

[1] The E-TAB software has been used to calculate live load, dead load, earthquake load, shear force and bending moment for Kelkar Museum, Pune.

[2] 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.

[3] 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.

[4] A detailed report is submitted to the PMC so that the Corporation can successfully use this technique for other structures in the city.

[5] 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.

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