Smart Earthquake Resistant of RCC Building Structure

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Abstract— Simulation of collapse procedure of a scaled reinforced concrete structure is carried out and compared with the results obtained by spring base isolator experiments. The experiment was performed using RC building model and analyzes the time of cracking under Magnified excitation. The experiment was performed using three storied RC building. Springs-with-damper base isolator installed under a three-storey building. It is a base isolation device approximately similar to Lead Rubber Bearing. This experiment is totally based on frequency ranges. In this experiment we compare our structure from different frequencies of an earthquake and analyze the results i.e. in which frequency, cracking starts in RCC building structure.

Key words: Spring Base Isolator, Earthquake Resistant Structure

I. INTRODUCTION

HE sudden tremors or shaking of the earth crust is called an earthquake. When a part of the earth's surface move forward and backward or up and down the earth's surface quakes, this is called an earthquake. The earth crust is made up of different parts of various sizes. They are called tectonic plates. Most of the earthquakes in the world are caused by the movements of the plates [4].

Earthquake resistant techniques are Base Isolation, Energy Dissipation Device and Spring Base Isolator. For the protection of building from different magnitude of an earthquake we use spring base isolation technique [4].

Base Isolation is made up of lead rubber bearing pad, which is flexible in nature. So it introduces flexibility to the structures. Building is rested on flexible pads. When earthquake strike the building it does not moves and it is suitable for hard soil only.

Energy dissipation device are used in place of structural element such as diagonal braces. When seismic energy is transmitted through them, dampers absorb part of it and damp the motion of the building. It acts like hydraulic shock absorb in the car.

Generally Spring Base Isolator is a base isolation device which is used for conservation of various building and non-building structures adjacent to potentially harm lateral impacts of strong earthquakes.

Springs with damper base isolator installed beneath a three storey town house. It is a base isolation device approximately equal to Lead Rubber Bearing.

One of two three storey townhouses like this, which was well instrumented for the recording of both vertical and horizontal accelerations on their floors and the ground, has survived a flinched shaking during an earthquake.

II. PRELIMINARIES

A. Base Isolation Description

Base isolation device for large structures have been in use for many years, with some base isolators dating back to the early 1900's. Base isolation bearings for an isolated structure install between the structure and its foundation. The isolation bearings permit relative transverse motion among the structure and the ground while providing rigid support in the vertical direction. The flexibility among the structure and the ground reduces structural response under seismic shaking.

There are three main types of base isolation systems currently in use; flat plate sliding bearings, friction pendulum bearings, and elastomeric bearings. These three types of base isolators are shown in Figures 1, 2 and 3 along with their force/stroke characteristics. All three types of isolators are effective, yet each one has inhibition. Their main inhibition is that none of these isolators can consistently provide the high degree of energy dissipation needed in several current applications. Moreover, when these three types of isolators are designed for maximum energy dissipation, their action typically imply sudden changes in force level, which tends to excite higher structural modes. In addition, the friction essential in sliding element bearings could create significant residual displacement after an earthquake [5].

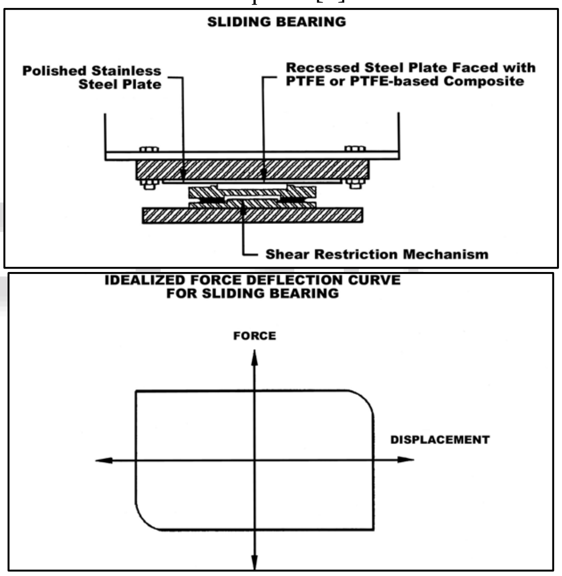

Fig. 1: Typical Sliding Plate Bearing. [5]

The main disadvantages of the sliding plate bearing system are the lack of centering action, and the lack of damping. Variations in friction due to temperature changes and long term environmental subjection are also concerns. Since the friction force depends on the vertical loading, accurate and predictable analysis results may be difficult to achieve. Also, sliding plate bearings have a limited history in building projects, particularly in this country.

While it is possible to provide energy dissipation in the sliding plate bearing by using a high friction material for the bearing pad, the resulting hysteresis causes abrupt changes in the forces applied to the isolated structure whenever the velocity changes direction. This in turn tends to excite the higher modes of the structure, with adverse effects.

Typical friction values for sliding plate bearings range from a low of .04 to a high of .15. The higher the friction the more energy dissipation, so the lower the displacement under earthquake shaking. However, higher friction increases the excitation of higher modes in the isolated structure, and also increases the likelihood of high residual displacement. This dilemma can be completely eliminated by adding fluid viscous dampers in series with the sliding plate bearings. As described elsewhere in this paper, the viscous damping provided by fluid viscous devices smoothly varies with velocity, and minimally excites the higher modes of a structure. Moreover the amount of damping available is much higher than the equivalent of a frictional coefficient of 0.15.

It is also possible through the addition of hybrid fluid damper elements (described earlier) to provide centering action for the sliding plate bearings. This particular kind of element has a very strong centering action, strong enough to return the isolated structure to its original position after an earthquake. The centering action of the hybrid damper can be designed to overcome the friction of the sliding plate bearing and provide near-exact re-entering.

B. Friction Pendulum Base Isolator

The friction pendulum base isolator is shown in Figure 6 along with its characteristic force displacement loop. Note that this type of isolator has a centering action, caused by the horizontal component of reaction in the dish to the vertical gravity force. This horizontal component increases with travel away from center, providing the same effect as a linear spring.

There is also energy dissipation, due to the friction between the spherical pad and the dish surface. This friction can range from .04 to .15, just like in the flat plate sliding bearing.

The lower the friction the better the centering action of the friction pendulum isolator. However, higher friction is desirable to increase energy dissipation, which reduces dynamic displacement under earthquake shaking. But higher friction increases the tendency to excite higher modes in the isolated structure due to the abrupt change in loading as the velocity reverses direction. The design of any friction pendulum base isolation system is always a compromise between the need for low friction to minimize residual offset and higher mode excitation, and the need for high friction to minimize dynamic displacement [5].

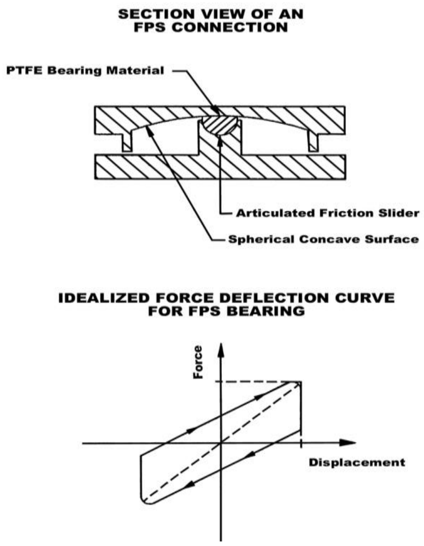

Fig. 2: Friction Pendulum Base Isolator [6]

C. Elastomeric Pad Base Isolators

Elastomeric base isolation bearings have been in use for at least the past 30 years, and originated in New Zealand. As shown in Figure 7, they consist of a large number of thin layers or "pancakes" of rubber interspersed with metal plates. The entire sandwich of rubber disks and metal plates is bonded together.

When correctly manufactured, this type of bearing can support lateral motions up to twice the height of the bearing. Actual design displacements will vary depending upon the vertical load on the bearing and the end attachment details.

Until recently elastomeric base isolators were made from natural rubber or similar low damping elastomeric material. This material is very reliable, and has a long and successful history. As it has very little damping, relative displacement under earthquake input can be high. When used for structures subjected to the Loma Prieta or the Northridge earthquake within approximately five miles of the epicenter, the displacement for low damping rubber base isolators can exceed the capacity of most practical bearings. Under these conditions the displacement of structures supported on low damping elastomeric bearings can be as high as +/- four feet.

As more accurate estimates of earthquake shaking have become available, it has become clear that some form of damping is needed to limit displacements to values that can be handled by the elastomeric bearings. This has led to the development over the last ten years or so of "huge damping" elastomeric pad bearings, which have typical damping values in the range of 15% of critical. Lead-Rubber bearings, patented by DIS, also provide high damping. In these bearings a lead core is installed inside of low damping or natural rubber to provide hysteretic damping which can be as high as 30% of critical.

It should be understood that the type of damping essential in all elastomeric bearings is not viscous damping, but is instead the hysteretic damping produced by differential spring rate.

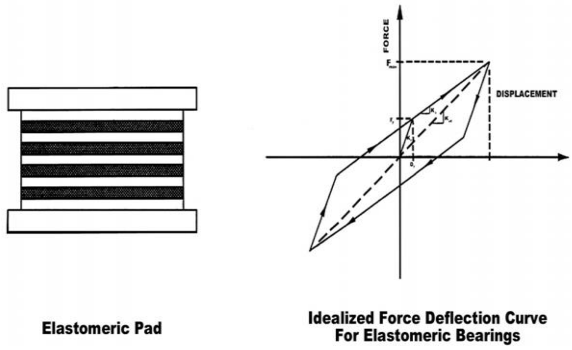

Fig. 3: Elastomeric Base Isolation Bearings [7]

The shear spring rate for a high damping elastomeric pad is high until it reaches it's prearranged "yield point," as given in Figure 3. This bi-linear behavior is a function of the particular type of elastomeric material or the yielding of the lead core, and does not indicate degradation of the material at deflections apart from the prearranged "yield point." The area enclosed by the force deflection curve as the isolator travels away from center and then back is the amount of energy dissipation per half cycle. Depending upon the type of the bearing, there may be a fairly sudden change in force level whenever the displacement changes direction, which may tend to excite the higher modes in the isolated structure. The likelihood for this happening is not as high in elastomeric bearings as it is in friction type bearings [6].

D. Energy Dissipation Device

1) Viscous Damper Description

The viscous damper for structures externally resembles the shock absorber on an automobile, but operates at an enough higher output. Base isolation dampers are much larger than automotive dampers, and are created of stainless steel and other intensely durable materials as required to furnish an activity of at least 40 years. The damping fluid is silicone oil, which is dormant, non-flammable, non-toxic, and stable for acutely long periods of time. The seals in the viscous damper are an exclude high technology design based on aerospace fluid elements, and provide totally exposure free service. This design has been confirming through rigorous testing and has been in use for past 40 years.

The damping action is given by the flow of fluid across the piston head. The piston head is made with a deliberate clearance beneath the inside of the cylinder and the outside of the head, which forms an annular orifice. The fluid flows over this orifice at huge speed as the damper strokes.

The shape of the piston head determines the damping characteristics [7].

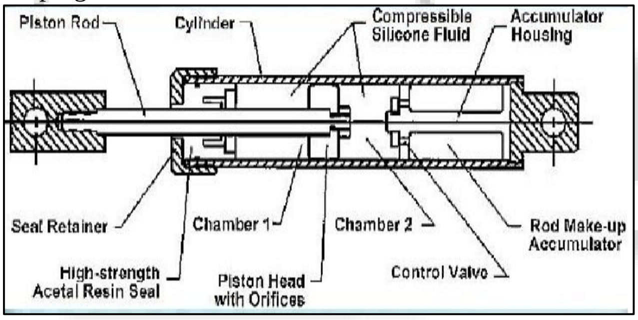

Fig. 4 Viscous Damper [8]

2) Hybrid Fluid Viscous Damper with Restoring Force

The hybrid fluid viscous damper force with restoring force uses the same viscous damping action as the basic damper mentioned in the previous section, with the addition of compression spring force and a mechanical cage and yoke mechanism to provide attracting action in both the tension and compression directions, while also adding bi-directional damping.

The main element of the hybrid damper is the fluidic shock cartridge, shown in Figure 5A. This element is similar to a hydraulic cylinder with no ports. As there is no way for the fluid to bring out, fluid pressure builds rapidly when the piston rod pushes towards the cylinder. This causes a strong spring action.

During compression of the damper, fluid must flow around the piston head at high velocity, similar to the damper just described. This causes a strong damping action in addition to the spring action.

This same kind of damping action occurs during extension. During compression the damping action adds to the spring force. During extension it subtracts from the spring force, forming a hysteresis loop. Figures 5B, 5C and 5D show how structural elements are added to the fluidic shock cartridge to form the complete tension/compression liquid spring damper.

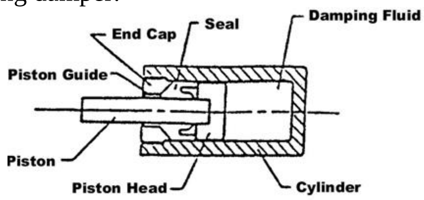

Fig. 5A: Fluidic Shock Absorber [9]

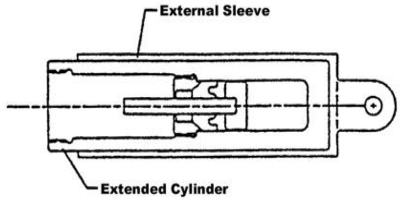

Fig. 5B: Tension Compression Isolation Design [10]

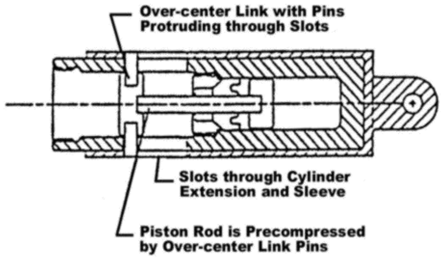

Fig. 5C: Add Over-Center Link, Slots, Precompression [11]

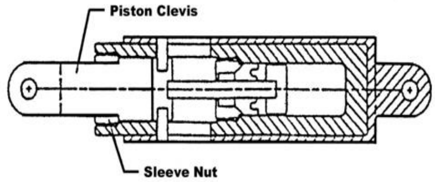

Fig. 5D: Add Piston Clevis / Sleeve Nut [12]

The end result is the force/stroke characteristic shown in Figure 6B. Here are the important elements of this characteristic

- There is a strong centering action. The element acts just like a rigid beam until its preload is exceeded.
- There is a strong spring action. When moved slowly, the element behaves just like a powerful preloaded spring that wants to return the structure to its neutral position.
- There is a high damping, enough to absorb significant amounts of earthquake energy.
- The action is the same in both the tension and the compression directions.

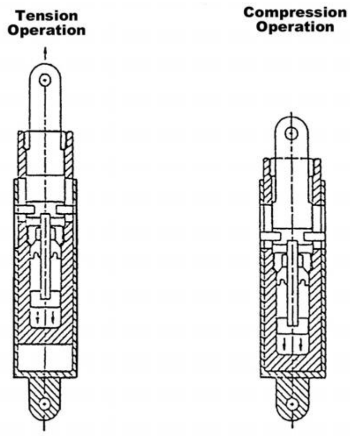

Fig. 6A: Tension and Compression operation [13]

The hybrid fluid viscous damper with restoring force can provide maximum force up to 2,000 Kips. Its spring rate, preload, damping constant and damping exponent can be adjusted to optimize performance in a particular structure. When a system of hybrid fluid dampers is added to a set of flat sliding plate bearings, the resulting isolation system performs extremely well and often costs less than other isolation systems to do the same job [8].

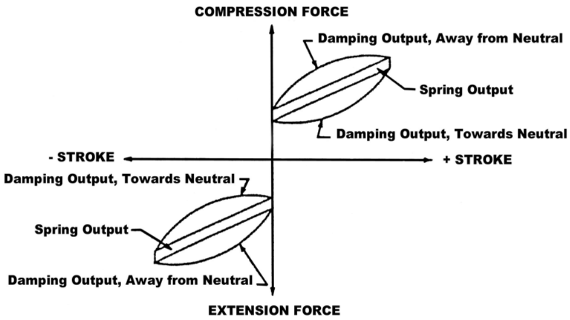

Fig. 6B: Operational Output [14]

E. Spring Base Isolation Description

Spring Base Isolator is a base isolation device which is used for conservation of various building and non-building structures adjacent to potentially harm lateral impacts of strong earthquakes.

Springs with damper base isolator installed beneath a three storey town house. It is a base isolation device approximately equal to Lead Rubber Bearing.

One of two three storey townhouses like this, which was well instrumented for the recording of both vertical and horizontal accelerations on their floors and the ground, has survived a flinched shaking during an earthquake.

Spring base isolator structure generally works:-

– When earthquake strikes the building it does not moves
– Building is rested on springs (Spring Isolator)
– Helps to avoid cracking
– It is suitable for hard soils only

Fig. 7: Spring Base Isolator [17]

Fig. 8: Prototype Model of RCC Building

F. Outline of Experiment

Simulation of cracking process of RC structure is carried out and compared with the results obtained by spring base isolator structure experiment [1]. The experiment was performed using three storied RC building. Springs-with-damper base isolator installed under a three-storey building. It is a base isolation device approximately similar to Lead Rubber Bearing [3].

This experiment is totally based on frequency ranges. In this experiment we compare our structure from different frequencies of an earthquake and analyze the results i.e. in which frequency, cracking starts in RCC building structure.

This study will focus particularly on earthquake building design and smart technology process in INDIA [4]. Interviews with experts in this field show that there is scope to look at better individual structures, but also the whole infrastructure of cities. Furthermore, consideration has been given to how smart process could be developed to reduce localized destruction [5]. Exploration into the adaptation of this smart technology will hint whether structural stability and mortalities could be drastically reduced [6].

G. Concepts

1) When the quake comes the system dissipates energy in the building cores and exteriors [9].
2) The frames are free to rock up and down within fittings fixed at their bases [10].

III. METHODOLOGY

A. Installation process of spring base isolator structure by a section plan

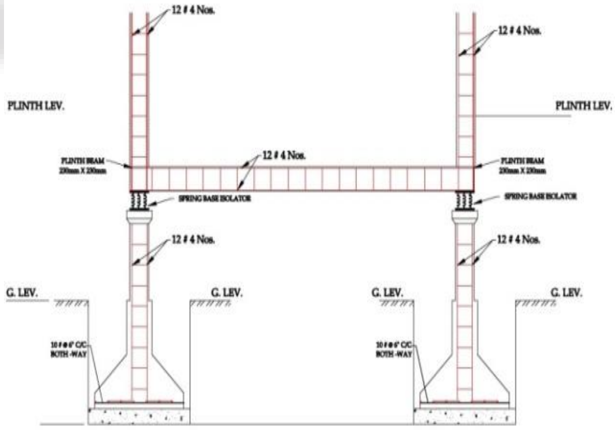

Fig. 9: Section plan (Spring Base isolator Structure)

Fig. 9, represents a section plan in a proper scaled proportion i.e. Proto type scale model:

– 1:10H
– 1:10V

Here, G.LEV. Is denoted as Ground level, # represent diameter of reinforcement bar and @ represents center to center spacing of the diameter bar [2].

IV. ANALYSIS AND RESULTS

A. Setup, Installation and Results

1) Setup:

A shaking table is a setup which is generally used for the shaking of RCC building model.

2) Installation:

A shaking table is made up of wooden ply, tire and motor, which is of 14000 RPM and 145 watt power.

3) Analysis:

In this section numerical analysis of the model under shaking table excitations is performed and the results are introduced. The shaking table is moving with different frequencies i.e. 10Hz, 25Hz and 40 Hz. The structural element consists of a prototype reinforced concrete model structure. Simulation cases, summarized in Table 1, are performed with considerations of different parameters. Structural behaviour is studied from three different viewpoints. First, start the shaking table with the minimum frequency range i.e. 10 Hz and we analyzes that our prototype structure is safe, there is no cracking. Second, increase the frequency ranges i.e. 25 Hz and 40Hz we analyzing the same result. But if the frequency is greater than 40 Hz the selected result are introduced:

B. Cracking Analysis under Expand Excitation

1) Failure starts by excessively high cracking and move forward by yield and cut of reinforcement at base columns and beams [17].
2) Collision of the failed beams with other structural members during collapse causes intense damage for the lower floors [18].
3) Even though columns and beams of lower floors suffer absolute damage, the upper floor suffers almost no damage but they moved together in the rigid body motion and rotate around the failed structural element till they collide with the ground [19].

C. Analysis Stages of RCC Building Model

Frequency	Result
10 Hz	Safe
25 Hz	Safe
40 Hz	Safe

Table 1: Model stages

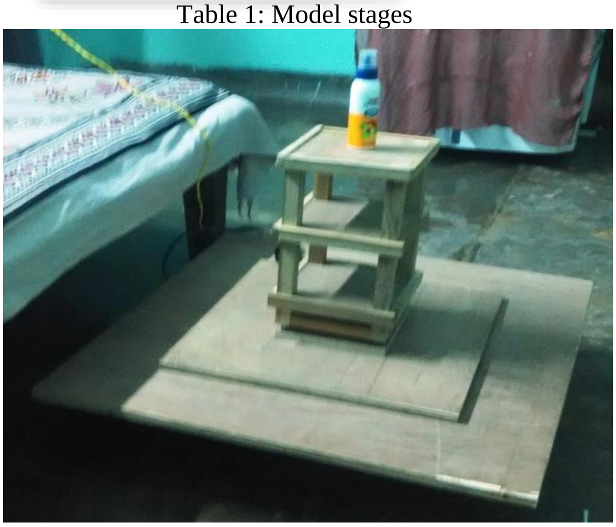

Fig. 10: Shake Table

This figure represents a Shaking table which is shaking with different frequencies i.e. 10 Hz, 20 Hz and 40 Hz. It is made up of ply wood, tire and motor. Motor is of 145 watt and 1400 RPM.

Fig. 8: Prototype Model of Reinforced Concrete Structure

This figure represents a prototype model of reinforced concrete structure which is made up of reinforced bar and concrete.

V. Units

Here

- # represent diameter of reinforcement bar
- @ represents center to center spacing of the diameter bar,
- Hz represents frequency of the shaking table which is shaking and
- M represents the unit of meter.

VI. Helpful Hints

A. Figures, Table and Notations

1) Figures

- Figure 1 represents Typical Sliding Plate Bearing
- Figure 2 represents friction pendulum base isolator
- Figure 3 elastomeric base isolation bearing
- Figure 4 Viscous damper
- Figure 5A Fluidic Shock Absorber
- Figure 5B Tension Compression Isolation Design
- Figure 5C Add Over-Center Link, Slots, Precompression
- Figure 5D Add Piston Clevis / Sleeve Nut
- Figure 6A Tension and Compression operation
- Figure 6B Operational Output
- Figure 7 Spring base isolator
- Figure 8 RCC building model
- Figure 9 Section plan of spring base isolator structure
- Figure 10 Shake table

2) Table

- Table 1Analysis stages of RCC building model

3) Notations

- H represents Horizontal
- V represents vertical
- G. LEV. Represents ground level
- Nos. represents number of bars

VII. Conclusion

1) In the construction of a building, particularly against earthquakes, there are many aspects to consider. Most of them are included in the design, one of the most important parts, such as the regular shape, appropriate structure, the calculation of high rigidity and good stability; other with the choice of site for the building, as floor firm and good foundation; other with the choice of materials, as lightweight or the materials to

dissipate energy; and finally with the execution of the work, as quality of construction or set of finishes and installations.

2) Taking into deliberation all these tips and they are carried out well, the likelihood that the building in question hold increases, always depending on the scale of the earthquake that always can surprise us and not pleasantly [20].
3) Stiffening element of the set, reducing the lateral displacements. It is important to have the cores or minimizing the eccentricity in order to avoid torsion in the overall structure [21-22-23].

VIII. Future Scope of Study

For collapse/ cracking mechanism of structures, additional effects like:

- Buckling of reinforcement bars
- Spalling of concrete cover

Are needed to be modelled which are not taken into account in this analysis.

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