SEISMIC ANALYSIS OF KINEMATIC BEARINGS USING VOIDED BIAXIAL SLAB

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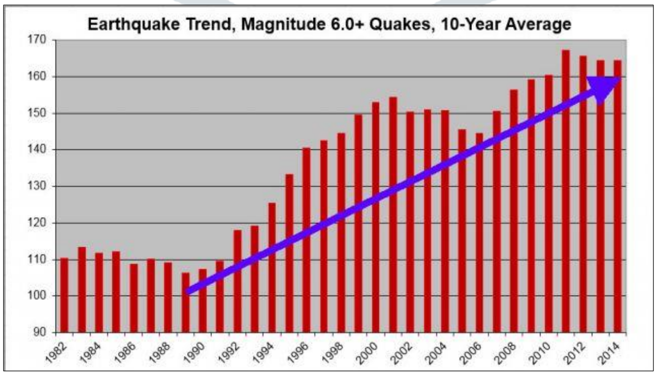
Abstract

The basic intention of seismic protection systems is to decouple the building structure from the damaging components of the earthquake input motion, that is, to prevent the superstructure of the building from absorbing the earthquake energy. This paper reviews the experimental study and model simulation of kinematic bearings with use of voided biaxial slab system (uboot technology). Shaking table test was done. from moderate to severe vibrations and effects like gyro, acceleration, drift, maximum displacement was derived. The aim is to build such type of structure which provides maximum stability and minimum damage to building components during seismic action, also to make structure economical and environmentally sustainable in seismic zones

Keywords- seismic waves, polypropylene, rubber Bearings, voided slab.

1. INTRODUCTION

Earthquake is amongst the catastrophic natural calamities where an abrupt movement or tremor is initiated under earth's causing major damage to mankind. Although a great deal of research has been carried out regarding seismic isolation, there is a lack of proper research on its behavior and implementing technique in low to medium seismic region. From past earthquakes, it is demonstrated that a significant number of structure are absolutely/somewhat harmed because of earthquake and now-a-days it has turned out to be important to decide seismic reactions over such structures. Hence there is a need to build structures that can withstand these seismic attacks and palliate its effect. To thwart the structural damage there are two major methods adopted.



Source- USGS (United States Geological Survey

Fig. 1

They are broadly classified as use of damping devices and base isolation method. However, installing damping devices can be mere exorbitance as it has high maintenance cost and complex structure. The later one i.e. base isolation is thus preferred. Base isolation systems are again sub divided into elastomeric bearing systems and sliding systems. Use of sliding system can be challenging as it possesses the risk of displacing the complete structure after reaching its threshold. Elastomeric bearing systems are thin layers of natural or synthetic rubber bounded in between steel plates. Elastomeric bearing systems have kinematic system as an important type. Kinematic bearing base isolation system is groups of vertical floating piles connected through rigid massless caps and subjected to vertically propagating harmonic *S*-waves.

Thus it is advantageous above all the type. However the structure is still bulky, this can be overcome by using voided biaxial slabs. Voided biaxial slabs are reinforced concrete slabs in which voids reduce the amount of concrete and steel by placing different type of formworks or materials. Various kind of voided biaxial slab available are bubble deck system, cobix , air-deck, uboot baton. Uboot is preferred as it is lightweight and decreases the cost of production drastically. Uboot Beton is a recycled polypropylene formwork designed to create bidirectional lightened slabs and slabs of reinforced concrete. It has advantages like increased number of floor, reduced slab thickness, no beams between pillars and most importantly reduction in overall load of the structure weighing on the pillar and foundation. Thus, making it an infallible and depended structure.

2. LITERATURE REVIEW

Shuiqiang Qin et al. stated that the time history analysis done shows that short period isolated structure has more efficiency as compared to long period isolation under the action 8 degree earthquake. A frame type prototype of an office building was analyzed. Two model simulations were generated on SATWE software- 1) Seismic isolated model 2) Non-isolated seismic model. Rationality and wind bearing capacity of isolated layer was done by Time history analysis & Mode decomposition reaction spectrum method. This experiment was simulated considering earthquake resistance criteria. The tensile stress of bearing was under maximum limit and it was observed that isolated layer has sufficient stability & safety. The main deformation of base isolation layer is at isolated layer and the isolation effect is commendable. IT can be observed that high raise structure has tensile strength due to bearing. The results obtained are reliable as even after making the structure more complicated. The consumable design was obtained by adding gravity loading which leads to increase in overall economy of structure.

Swapnil Ambasta et al. analyzed two structures of G + 6 rigid jointed plane on ETABS. Namely, fixed base and base isolated structure using lead rubber bearings. The peak value of acceleration, velocity and displacement was obtained by using response spectrum method. It was observed that the variation in maximum displacement of storeys in Base Isolated Model was very low compared to fixed Base model. Also, drift of storey was reduced by 60% and shear of storey was reduced by 47%. Use of lead rubber bearings had increased structural stability and made the structure economical.

Saifee Bhagat self-weight reduction, stiffness reduction factor and punching shear were derived for different cases of voided flat slabs by using cobiax technology. By finding moment of Inertia solid and flat slab relation between slab thickness, stiffness modification factor & percentage weight savings was obtained. The bending moment value is less than 0.2, so the voided slab can be design as solid flat slab. Self-weight is reduced by 32% and by results of punching shear the solid portion around the column adequate to take applied shear stress. Saifee Bhagat et al. derived self-weight reduction, stiffness reduction factor and punching shear for different cases of voided flat slabs by using cobiax technology. By finding moment of Inertia of solid and flat slab, the relation between slab thickness, stiffness modification factor & percentage of weight savings was obtained. It was found that the bending moment value was less than 0.2, so the voided slab could be design as solid flat slab. Self-weight of the slab was reduced by 32% resulting in reduced dead weight. Results of punching shear exhibits that the solid portion around the column was adequate to take applied shear stress.

Juozas Valivonis et al. stated that the flexural capacity and the stiffened Monolithic Biaxial hollow slab was found by simulation of numerical model using DIANA software of the hollow close square cross section. Plastic inserts were placed in slabs to monitor crack formation and to display character of fracture. The concrete slab was hardened under real conditions and two points loading was applied. It was observed that concrete input was reduced by 20%-40% compared to similar solid slab of similar cross section. There was also decrease in cement input which resulted indirect reduction in CO_2 released in atmosphere. Plastic inserts can be produced from plastic waste thus contributing to environmental protection.

3. COMPONENTS

3.1. <u>Motor</u>: A DC Motor of **600** RPM if 12 V is used to vibrate the table.

3.2. <u>Rack</u> <u>&</u> <u>Pinion</u>- Rack of 200 mm and pinion of 50 mm diameter mechanism is used.

3.3. <u>Electronic</u> <u>circuit</u>- A Electronic Circuit is used to increase and decrease the speed with Frequency range 1-5 hertz and frequency control of +/- 5%

3.4. Shaft – Shaft of 40 mm is connected to pinion gear by mechanical bushing

3.5. Base ply- - It is a ply of 20 mm thickness It is the main part on which the sub base ply rests

3.6. Caster wheels- Wheels were attached to sub base ply for its lateral movement.

3.7. Sub base ply- It is a ply of 18 mm thickness on which the model rests.

3.8. Nut- Bolts - Nut-Bolts are used to connect racks to sub base ply .bearings, building.

3.9. Rubber pads- Rubber pads of 10 mm thickness were used to level the base ply.

3.10. Glass tanks- Glass tanks of 150mmx150mm were used on intermediate floors for observation of wave movement through water.

3.11. Bearings- Kinematic bearings of Mild steel were used in proposed structure.

3.12. Arduino: The Arduino Mega 2560, a microcontroller board based on the ATmega2560 is used to connect all the sensors and display readings on the serial monitor.

3.13. Photo transistor sensor: Phototransistor sensor is used to measure distance. The voltage drop over the phototransistor will be proportional to the intensity of the IR light it picks up which is proportional to the distance the emitter and detector are from the reflecting surface

3.14. MPU-6050 3-Axis Accelerometer and Gyro Sensor:

3.14.1. **3-Axis Gyroscope:** The MPU6050 consists of 3-axis Gyroscope with Micro Electro Mechanical System (MEMS) technology. It is used to detect rotational velocity along the X, Y, Z axes.

3.14.2. **3-Axis Accelerometer:** The MPU6050 consist 3-axis Accelerometer with Micro Electro Mechanical (MEMs) technology. It used to detect angle of tilt or inclination along the X, Y and Z axes.

4. DESIGN OF BUILDING

4.1. Column

- Size of Column :- 50mm x 50 mm
- Square column is being used. (No of columns - 8)
- Height of column :- 900mm

4.2. Slab

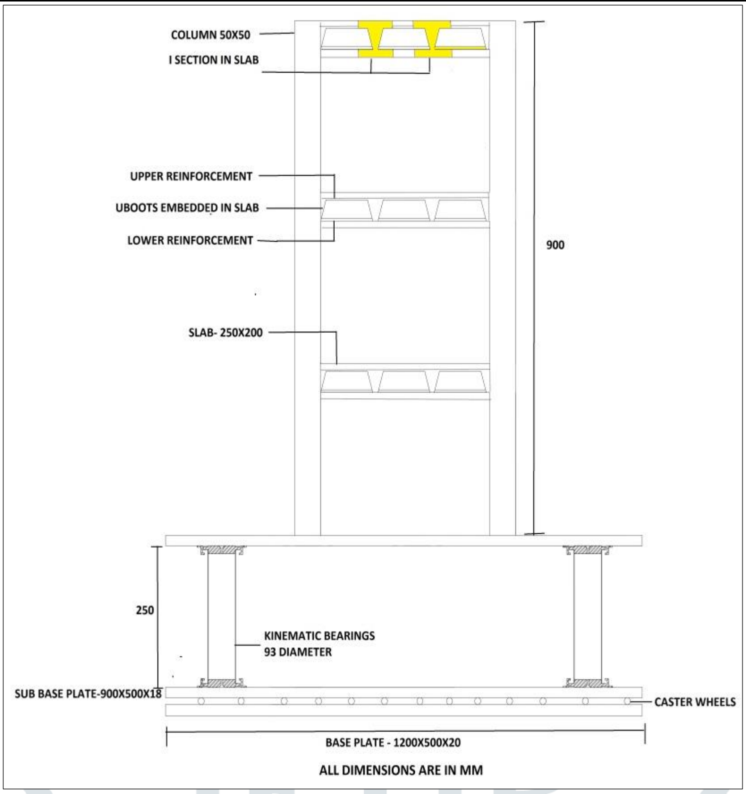
- Dimension of slab :- 250 x 200 mm
- Thickness of slab:- 5 mm conventional structure
- Thickness of slab :- 50 mm proposed structure

4.3. Beam - side view 250mmx20mmx50mm conventional structure front view 200mmx20mmx50mm conventional structure No beams - Proposed structure

4.4. Base plate - 1200mm x 500mm x 20 mm

4.5. Sub base plate – 900 mm x 500 mm x 18mm

4.6. Bearings - 93mm diameter and 250mm height outer to outer.



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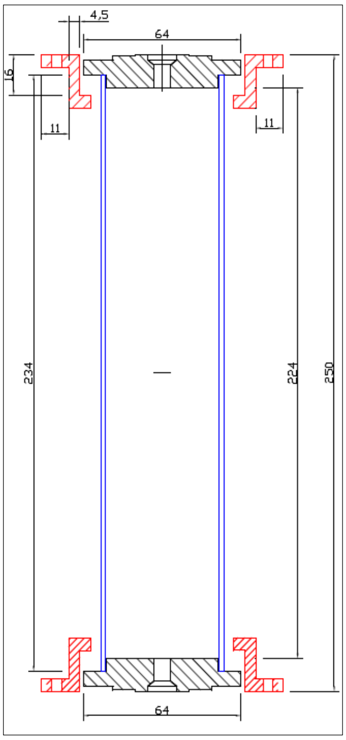

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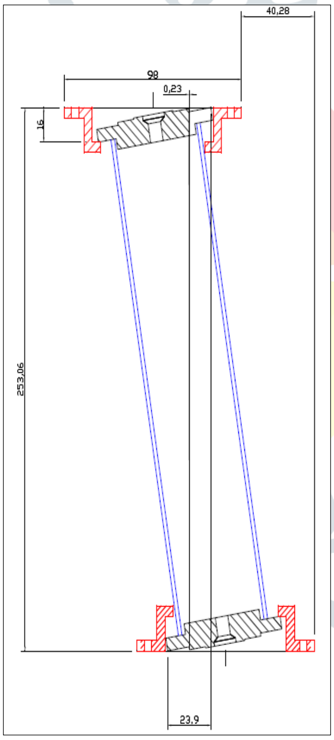

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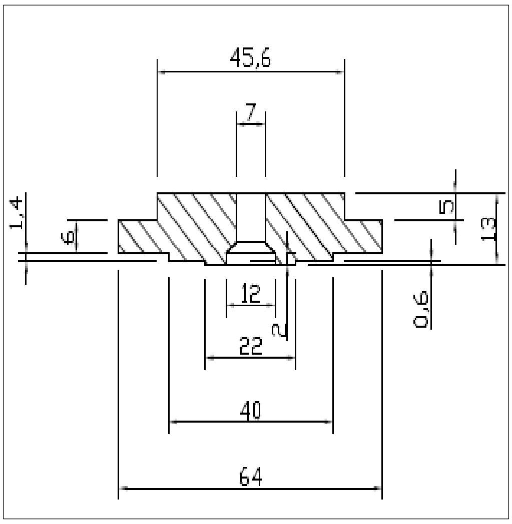

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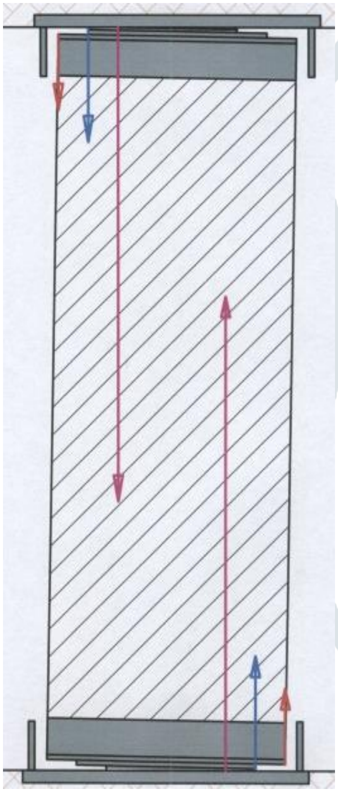

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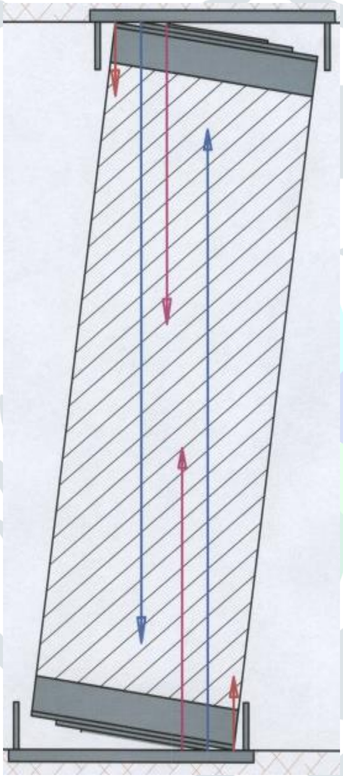

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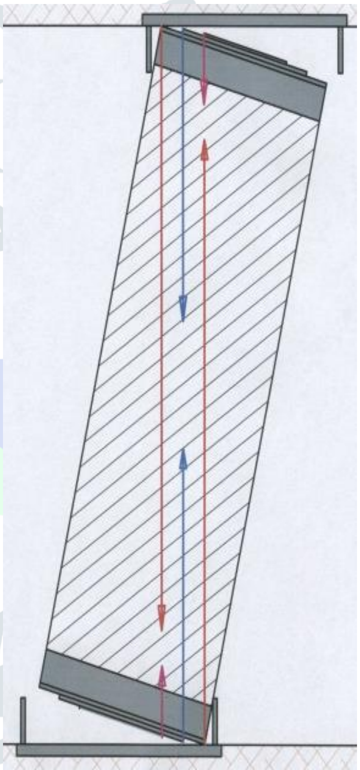


Fig.12

5 WORKING

5.1. A rack and pinion mechanism converts the rotational motion of pinion gear in to linear motion.

5.2. When a certain frequency is set the motor starts rotating resulting in linear motion of rack which is connected to the sub base ply and vibration motion is created.

5.3. Amplitude of 3 cm is provided and caster wheels provide smooth movement of sub base ply.

5.4. Kinematic Bearings has special hinges at top and bottom which restricts the lateral displacement to a required value and allows building to make a significant move.

5.5. This bearing is in flexible to resist any radial lateral movement.

5.6. As the vibration starts the bottom section of the bearings results in force in direction of the force applied by rack and pinion mechanism and at top section of bearing force in opposite direction is generated.

5.7. There is a restoring torque at the initial stage before vibration, but as the vibration or lateral movement is generated the Couple moment is created in bearing.

5.8. This couple moments are equal in magnitude but has different line of action so as they produce an angular acceleration to the rigid body at right angles to plane of couples.

5.9. It creates a rotation movement without producing translation movement providing stability to the superstructure.

5.10. The hinges are so designed that the center of mass is maintained during vibrations.

5.11. Once the vibrations are stopped the bearing comes back to its initial position and restoring torque is again created.

5.12. The amplitude is 3 cm but can be extended to 6 cm but If the amplitude is smaller, then the oscillation frequency is greater and if the amplitude is larger, then the oscillation frequency is smaller, thus in order to increase the oscillation frequency we have reduce the amplitude to 3 cm to check the maximum efficiency of bearing.

5.13. The Uboot system used in the slabs eliminates the beam and makes the structure act as monolithic resulting in lower seismic mass and providing high rigidity.

6. Sensors are than installed at various levels on both the structures.

6.1. Gyro Effect: -

The torsion is faced by any humongous structure due to uneven as the lateral force on it is uneven. Gyro meter can be used to measure this torsion at the top of the structure. The in x, y, and z directions are measured by the gyro sensor. Thus the measure of angle of torsion can be obtained.

6.2. Acc vs Freq: -

Frequency is provided at the bottom of the shaking table. The frequency is gradually increased ranging from 0 to 60 Hz and acceleration of the structures are measured by the accelerometer and the values are displayed on the Arduino serial monitor and later graph is plotted for both the structure.

6.3. Acc vs Time: -

Acceleration of the structure is measured by setting up accelerometer at the top of the structure. The acceleration of each of the structure is plotted against the time.

6.4. Floor vs Displacement: -

Photo transistor sensor is places at each floor of the structures to measure the displacement of each floor w.r.t. ground.

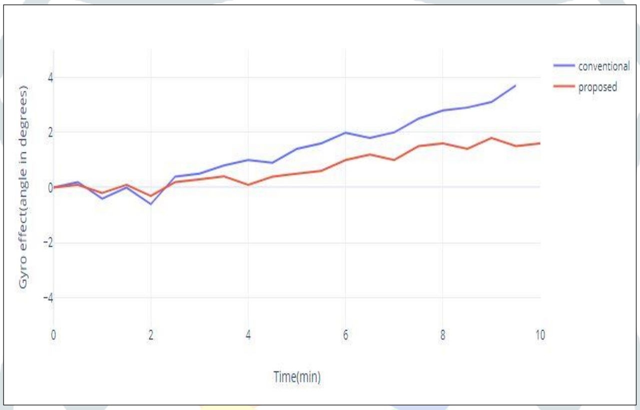
6.5. Floor vs Drift: -

Photo transistor sensor is places at each floor of the structures to measure the drift of each floor w.r.t. preceding floor.

7. RESULT & ANALYSIS

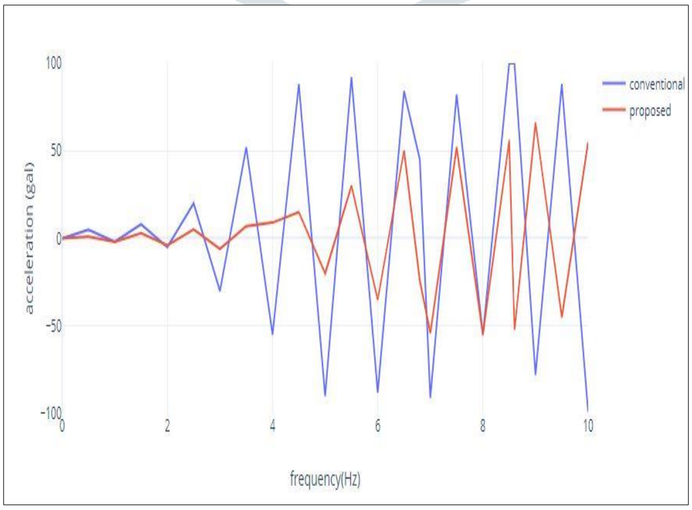
7.1. Gyro Effect:

Torsion is caused during earthquake mainly due to non-symmetric mass distribution. In torsion force of inertia acts through the center of mass and the resistive force acts through the center of rigidity. Thus gyro effect can be majorly seen during an earthquake which becomes an important parameter to be analyzed. Thus gyro sensor was used to measure the deflection in angle from the initial position. It could be observed that the conventional structure would give a deflection of 4 degrees while the proposed structure would show merely of 2 degrees.



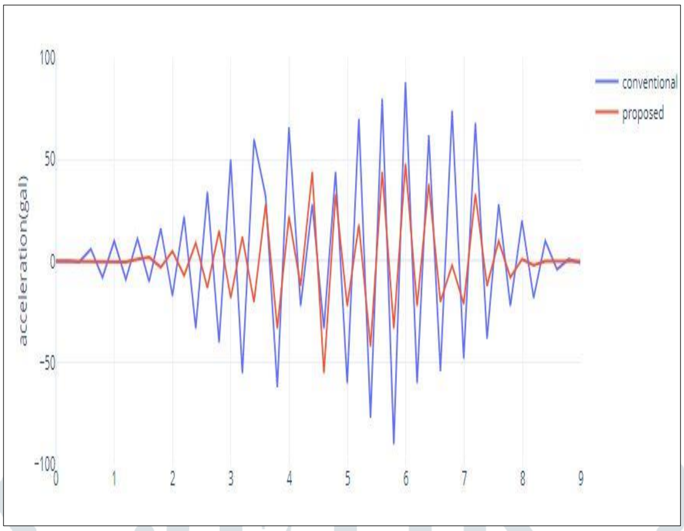
7.2. Acc vs Freq:

The acceleration records are useful for the prediction of the behaviors in building structures during earthquakes. The structure tends to accelerate depending on the intensity of the generated wave that replicates the seismic wave. The acceleration tends to aggravate on elevating the frequency that is provided through the circuit. It can be interpreted that acceleration for the conventional structure ranged from 0 to 100 m/s while the proposed structure could want it to the range of 0 to 50 m/s



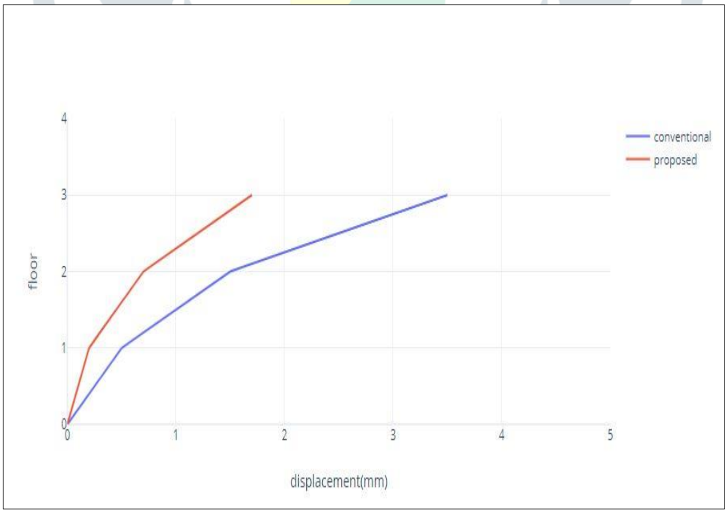
7.3. Acc vs Time

The earthquake wave was simulated by shaking table method to analyze the effect of acceleration along with the time. Acceleration time graph for a fixed frequency range was plotted. It could be clearly observed that the proposed structure remained stable at the beginning of the time stamp whereas the conventional structure had already started shaking. The acceleration of the system has reduced to half. Thus making the structure more sustainable.



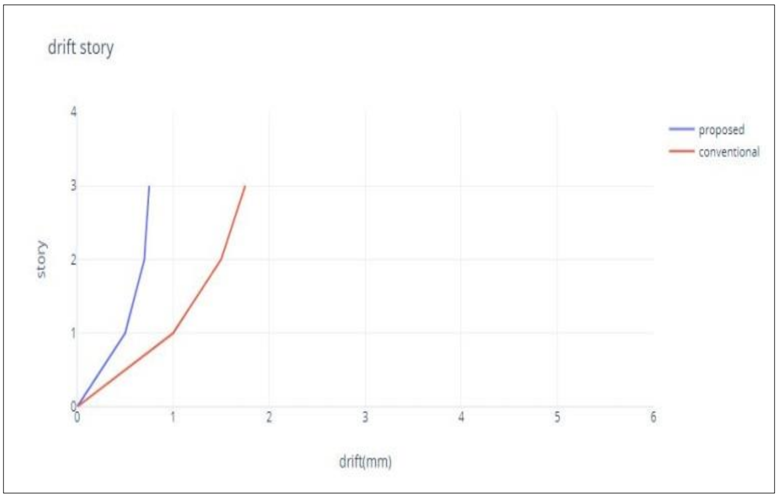
7.4. Floor vs displacement

There is a modicum displacement of each storey with respect to the ground when an earthquake hits the surface. As the floor ascends the cumulative displacement can be experimentally observed. For the purpose photo- transistor sensors were placed which could give the displacement at each floor and total displacement was found. It could be observed that displacement was low at the bottom of the structure. However, as the floor increased, the conventional structure showed the displacement as high as 3.5 mm for 3rd floor whereas the proposed structure decreased it to 1.7 mm which is almost halved.



7.5. Floor vs drift :

As the earthquake strikes the surface the bottom most floor of the structure is extensively affected. The drift of each floor is measured and analyzed. It can be found that the drift is of very little for proposed structure as compared to that of the conventional structure when a graph is plotted of storey against drift. It also could be observed that the drift is maximum at lower flours as compared to higher floors for both the structure.



8. CONCLUSION

The experimental analysis demonstrated that kinematic bearings base isolation system when integrated with voided biaxial slabs (U-boot) enhances the structural stability and provides high axial stiffness and low lateral stiffness to the structure to withstand turbulent action seismic waves. The kinematic bearing is a technique developed to test its ability to act in case a quake is struck to a structure. The results obtained turns out to be compelling when combined with voided biaxial slab system. The bearing develops coupling moment to induce torsional response and reduces the translational response at the center of mass of the structure.

After amalgamation of both the techniques the result obtained articulated the decrease of displacement, drift, acceleration and torsion. U-boot systems placed in the slab have lower stiffness than that of solid flat plate slabs. The load carrying capacity is increased by 10-20% and thus resulting in construction of more number of floors in seismic zones. It eliminates resonance phenomena in building and the building becomes ready in 15-20 seconds, and also retains its capability to resist earthquake of same intensity.

The system works as a monolithic structure due to installation of u-boots in the slab. This also plays a major role while considering wind effect acting on the structure. The bearing that are used inexpensive and easy to manufacture thus reducing the cost of production. The optimal height of kinematic bearing can range from 2.5 up to 6 meters. This makes the foundation space to be used more efficiently and also provide better parking space compared to other systems.

The use of voided slab system eliminates the use of beam in a structure thus resulting in reduction of heavy concrete and steel affecting its overall economy. It also provides flexible design thus, these systems can be adapted to irregular and curved plan layouts, longer spans and fewer supports, uniform and continuous distribution of forces.1 kg of recycled plastic can replace up to 100 kg of concrete. Reducing material consumption quickens the construction time thus reducing the overall cost.

9. ACKNOWLEDGEMENT

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