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MODIFIED DAMPERS FOR EARTHQUAKE RESISTANT BUILDING

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Abstract— **Earthquake cause severe damages to large-scale infrastructures. Structures are designed to resist dynamic forces through a combination of strength, deformability and energy absorption. Three control systems are used in earthquake resistant buildings. The Fluid Viscous Damper is an equipment protecting structure from damage in earthquake or strong wind. It comes under Semi-Active control systems when a control valve is provided. Viscous dampers distributed throughout an otherwise conventional structure can achieve damping at significantly lower cost. This project describes the fluid viscous damper used in the construction of earthquake resistant buildings. It also shows the design of modified fluid viscous damper by replacing the fluid used in fluid viscous damper with glycerol. A model of this damper and its alignment in the building is shown. It's performance is compared with a building without the presence of damper using shaking table.**

Index Terms **— Fluid viscous damper, Shake-table equipment, Glycerol.**

I. INTRODUCTION

Earthquake cause severe damage to infrastructures. Structures are designed to resist dynamic forces through a combination of strength, deformability and energy absorption. These structures may deform well beyond the elastic limit in case of a severe earthquake. It shows that structure designed with these methods are sometimes vulnerable to strong earthquake motions. In order to avoid such critical damages, structural engineers are working to figure out different types of structural systems that are robust and can withstand strong motions. Alternatively, some types of structural protective systems may be implemented to mitigate the damaging effects of these dynamic forces. These systems work by absorbing or reflecting a portion of the input energy that would otherwise be transmitted to the structure itself.

Structural control techniques are believed to be one of the promising technologies for earthquake resistance design. The concept of structural control is to absorb vibration energy of the structure by introducing supplemental devices.

Different types of structural control have been developed and a possible classification is done by their dissipative nature.

Structural control systems can be classified as passive, active, semi-active and hybrid.

A passive control device is a device that develops forces at the location of the device by utilizing the motion of the structure. Through the forces developed, a passive control device reduces the energy dissipation demand on the structure by absorbing some of the input energy. Thus, a passive control device cannot add energy to the structural system. Furthermore, a passive control device does not require an external power supply. Examples of passive devices include base isolation, tuned mass dampers (TMD), tuned liquid dampers (TLD), metallic yield dampers, viscous fluid dampers and friction dampers.

The active control systems are the opposite side of passive systems, because they can provide additional energy to the controlled structure and opposite to that delivered by the dynamic loading. Active control devices require considerable amount of external power to operate actuators that supply a control force to the structure. An active control strategy can measure and estimate the response over the entire structure to determine appropriate control forces. As a result, active control strategies are more complex than passive strategies, requiring sensors and evaluator/controller equipment. Cost and maintenance of such systems are also significantly higher than that of passive devices. Examples among active control devices include active tuned mass damper, active tuned liquid column damper and active variable stiffness damper.

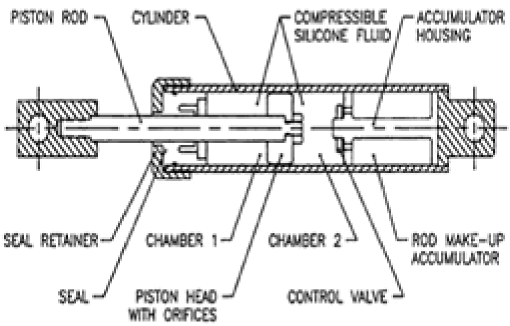
Semi-active damper control devices combine the positive aspects of passive and active control devices. Like passive control devices, semi-active devices generate forces as a result of the motion of the structure and cannot add energy to the structural system. However, like an active control device, feedback measurements of the excitation and/or structural system are used by a controller to generate an appropriate signal for the semi-active device. In addition, only a small external power source is required for operation of a semi-active control device. Examples of semi-active devices include variable orifice dampers, variable friction dampers, variable stiffness damper, and controllable fluid dampers, MR dampers, piezoelectric friction dampers.

II. FLUID VISCOUS DAMPER

Fluid viscous damping is a way to add energy dissipation to the lateral system of a building structure. A fluid viscous damper dissipates energy by pushing fluid through an orifice, producing a damping pressure which creates a force. These damping forces are 90 degrees out of phase with displacement driven forces in the structure. This means that the damping force does not significantly increase the seismic loads for a comparable degree of structural deformation.

The addition of fluid viscous dampers to a structure can provide damping as high as 30% of critical, and sometimes even more. The addition of fluid dampers to a structure can reduce horizontal floor accelerations and lateral deformations by 50% and sometimes more.

The fluid viscous damper for structures, is similar in action to the shock absorber on an automobile, but operates at a much higher force level. Structural dampers are significantly larger than automotive dampers, and are constructed of stainless steel and other extremely durable materials as required to furnish a life of at least 40 years. The damping fluid is silicone oil, which is inert, non-flammable, non-toxic, and stable for extremely long periods of time. The seals in the fluid viscous dampers provide totally leak free service.



A. COMPONENTS OF THE FLUID VISCOUS DAMPER:

The typical FVD mainly consists of following components
Piston rod: The piston rod is manufactured using high alloy

stainless steel and is designed to resist the stiffness during compression buckling and must not bend or break under the high loads.

Cylinder: The cylinder contains working fluid and they are designed in such a manner to resist or withstand the high pressure loading during the operations of damper. The cylinders are made from seamless steel tube machined from steel bars.

Fluid: The working fluid in the FVD must be fire resistant, non-toxic and thermally stable and doesn't change its properties with age

Seal: The seal must provide a minimum working life of 35 years without any replacement. In most cases the dampers sit for larger periods without any use therefore the seal must not exhibit long term sticking or allow any fluid leakage. The common polymers used nowadays are Teflon, stabilized nylon and members of acetyl resin family.

Piston head: The piston head is usually made from different materials than the cylinder to provide thermal compensation. It is joined to the piston rod and also separates the cylinder into two different pressure chambers. The space between the outer diameter of the piston and the inner diameter of the cylinder creates the orifice.

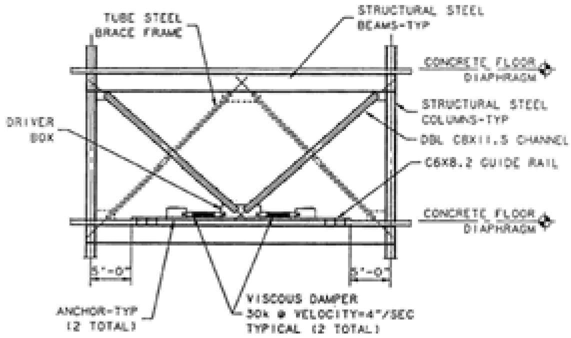
Accumulator: The typical FVD as shown in figure uses an internal accumulator to do any sort of variation in volume whenever the rod strokes.

III. WORKING OF FLUID VISCOUS DAMPER

The damping action is provided by the flow of fluid across the piston head. The piston head is made with a clearance between the inside of the cylinder and the outside of the piston head, which forms an annular orifice. The fluid flows through this orifice at high speed as the damper strokes. The shape of the piston head determines the damping characteristics.

When the fluid viscous damper strokes in compression, fluid flows from chamber 2 to chamber1. When the fluid viscous damper strokes in tension, fluid flows from chamber 1 to chamber 2. The high pressure drop across the annular orifice produces a pressure differential across the piston head, which creates the damping force.

Spherical bearings at each end of the fluid viscous damper permit the damper to angulated relative to the structure without binding. These bearings permit rotation in every direction, which prevents binding in the fluid viscous damper. In some cases there is enough flexibility in the structure to make it possible to solidly mount the dampers, in which case the spherical bearings are either not needed, or may be used at one end only.



IV. COMPARSION AMONG CONTROL SYSTEMS

Among active, passive and semi-active control system semi active control system is very much preferable because it requires partial power consumptions and generates some energy internally. Visco elastic dampers are more preferable because these are economical, highly, reliable and resist the building against dynamic loads like earthquake loads and wind loads

V. REPLACEMENT OF FLUID IN FLUID VISCOUS DAMPER

Generally silicone fluid is used in fluid viscous dampers as damping fluid. Silicone fluid can be obtained with a wide range of viscosities and do not change their viscosity with respect to the temperature as much as petroleum based oils. Standard viscosity silicone fluids range in viscosity from 50cst to 1000cst

Here in the project we are trying to replace the silicone fluid with glycerine /glycerol.

GLYCEROL:

- Glycerol is a colorless, odorless, viscous liquid
- Formula C3H8O3
- Density 1.26 g/cm3
- IUPAC ID: propane-1o2o3-triol
- Boling point: 290o C
- Melting point: 17.8o C
- Kinematic viscosity: 1127Cst at 293k

The main criteria for these fluids is that they have high viscosity which is the main characteristic required for damping fluid. So we have replaced the silicone fluid with glycerine and its performance is checked by installing it in a building model.

VI. TESTING

The performance of the damper can be checked using the shake table equipment.

SHAKE TABLE:

The shake table is an equipment to stimulate the condition of the earthquake, with known frequency and amplitude of vibrations. It consists of four major units. Drive unit, eccentric cam unit, shake table and control unit.

The shaking table is having a platform over which rotary table is mounted and this table can be rotated in 360 degrees with respect to the fixed bottom circular plate.

The control unit of the shake table is having variable frequency with additional safety of MCB and ON/OFF indicators. The driving unit is having motor which is connected to eccentric cam unit through the coupling, the inner cam is connected to the motor shaft, and over which flywheel is mounted. A flywheel is having radial scale to adjust the amplitude. The outer cam is supported in the bearings in the bearing block.

SPECIFICATIONS OF HORIZONTAL SHAKE TABLE:

SPECIFICATIONS:

Motion horizontal load capacity 30kg

Operating frequency 0.25 hz least count 0.5hz

FREQUENCY CONTROL+/-5% AMPLITUDE 0-10 mm

TABLE SIZE 400*400 mm ROTATING TABLE DIAMETER 190 mm

The chart mentioned in the next page gives the theoretical values of amplitude v/s frequency since the shake table is made of different components and each will be having the different natural and resonant frequencies at some frequencies there is a chance of observation of high vibrations.

TABLE-1: AMPLITUDE V/S FREQUENCY TABLE FOR SHAKE TABLE

AMPLITUDE (mm)	FREQUENCY (Hz)
1	25
2	16.5
3	12.5
4	10.50
5	9
6	8
7	7.25
8	6.75
9	6.10
10	5.75

VII. OPERATION PROCEDURE ADJUSTING AMPLITUDE:

• Loose the grub screw on the outer cam with the Allen key.

• Put the Allen key in the grub screw which is marked with red color.

• Rotate the flywheel in anticlockwise direction by holding the Allen key till the Allen key touches plate of the connecting rod, which is marked with red color.

• Loosen the red colored grub screw without disturbing the amplitude the position of the Allen key.

• Rotate the flywheel in anticlockwise direction to adjust the amplitude with the help of the red pointer.

• Keep the fly wheel at any desired amplitude with respect to the pointer, list us say “5” and tighten the red colored grub screw without disturbing the Allen key position and then tighten another grub screw which is placed opposite to red color grub screw.

• Now tighten properly both grub screws to the maximum possible.

A. FIXING THE EXPERIMENT MODELS:

• Now place the experimental models on the rotating table (use array of tapped holes) and tighten the mounting bolts of the model.

• Now loosen all the six nuts on the circular rotating table with the help of spanner, and with the help of the handles rotate the table in desired angles with reference to the fixed bottom plate and angular scale, and tighten all six nuts properly.

B. RUNNING THE MACHINE:

• Now insert the three pin plugs in to 230 volts mains supply.

• Switch on the mains.

- Observe the frequency verses amplitude chart on the panel carefully.
- Switch on the "MAINS MCB" (indicator will glow)
- Press the "RUN/START" (green) button on the control panel, a small red indicator inside the drive will glow, and the display will show "0.00".
- To increase the frequency press "increase button" (blue color) in steps, depending on the amplitude as per no 1 set the frequency with the help of th chart on the panel.
- Wait for stabilization of speed for about 20 seconds.
- Now take the experimental readings.
- Once experimental is over press the "RESET" button (yellow) on control panel which will bring the frequency to zero.
- Put off the MCB.

C. BUILDING WITH DAMPERS:

- The model of the building is made using steel.
- The dimensions of the model of the building is 31 cm-length, width-14.5 cm, height of each storey is 29.5cm.
- The thickness of the column is 2mm.
- Width of column is 2.4mm.
- Thickness of slab is 3mm.
- The weight of the building fixed with dampers used is 6.98kg.
- The maximum weight which the equipment can bear is 30kg.
- The amplitude which has been set while performing the experiment is 3mm.
- According to the table given by the equipment manufacturers the maximum frequency that can be applied is 12.5Hz.
- The building used for experiment is g+1 building.

D. TESTING THE PERFORMANCE OF THE DAMPERS:

- Switch on the main switch and make the wiring arrangements.
- After switching on the equipment initially calibration is to be done. Frequency is to be increased with 0.5Hz variation.
- Results of variation is amplitude at different frequencies are noted.
- Graphs with RMS amplitude and time will be displaced in the system connected to the shake table. These graphs will be given for each storey.
- Scale for this graph is time-1000millisec and amplitude-autoscale.
- The results from this experiment are to be substituted in the suitable equations and damping ratio is to be found.

E. TESTING THE BUILDING MODEL WITH DAMPERS:

- The mentioned procedure is followed after fitting the building installed with dampers diagonally.
- The results of the displacement of each channel at different frequencies will be obtained after the completion of the testing.
- By analyzing these results we can arrive at our conclusions.

F. TESTING THE BUILDING WITHOUT DAMPERS:

- The mentioned procedure is followed after fitting the building model to the shake table equipment.
- The results of the displacement of each channel at different frequencies will be obtained after the completion of the testing.

VIII. NATURAL FREQUENCY OF THE BUILDING TWO DEGREE OF FREEDOM SYSTEM

Formulation of equation of motion for mass m1

$$m_1 x_1 + kx_1 - k(x_2 - x_1) = 0$$

formulation of equation of motion for mass m2

$$m2x2 + k(x2 - x1) = 0$$

Combining both equations in vector form, the required equation motion for undamped free vibration is.

The natural frequency and mode shape for different modes can be given by

$$\omega_{12} = 0.5[((k11/m1)+(k22/m2)) \pm \sqrt{[\left(\frac{k11}{m1} - \frac{k22}{m2}\right)^2 + \left(\frac{4k1k2}{m*m}\right)}$$

Putting k11=2k, k12=-k, k22=k and $m_1=m_2=m$ in the above equation.

$$\omega^2 = 0.5[((2k/m)+(k/m)) \pm \sqrt{[\left(\frac{2k}{m} - \frac{k}{m}\right)^2 + \left(\frac{4(-k)(-k)}{m*m}\right)}]]$$

$$\omega_1^2 = 0.382\ k/m$$

$$\omega_2^2 = 2.618(k/m)$$

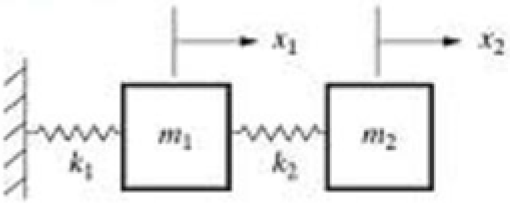
Lowest natural frequency will be the fundamental frequency that is ω will be the fundamental frequency For the building model k = (4*12EI/L3)

E =2*105N/mm2

I =(24^3*2)/12

m =1.18kg

ω=5.289 rad/sec



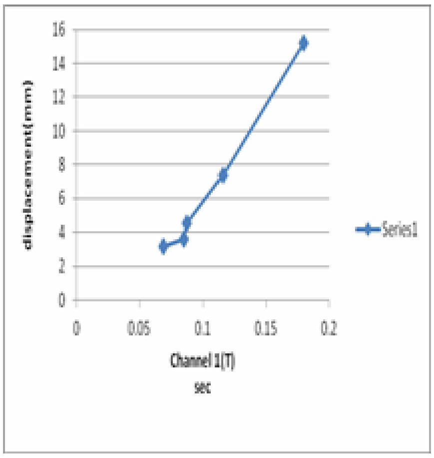
IX. RESULTS WITH DAMPERS:

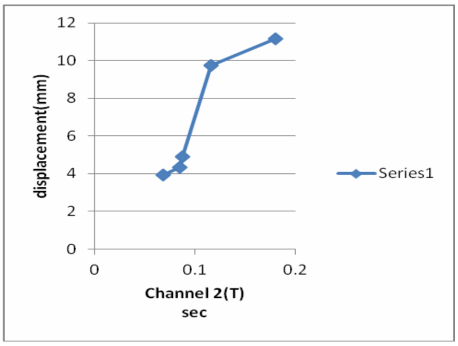
TABLE-2: TABLE FOR TIME PERIOD AND DISPLACEMENT

R/sec radian/sec t time period
C channel
Disp displacement

FREQUENCY	R/SEC	T	C-1DISP	C-2DISP	C-3DISP
0.0492187	0.30390934	3.2352677	860426	0	0
0.885938	5.5636906	0.179736	15.2176	11.1601	11.926
1.37813	8.6546564	0.1155447	7.3771	9.7418	10.5418
1.82109	11.436445	0.0874398	4.5618	4.8966	5.8956
1.87031	11.745547	0.085138	3.5941	4.3542	5.5661
2.31328	14.527398	0.0688354	3.1613	3.9472	4.8299

GRAPHS





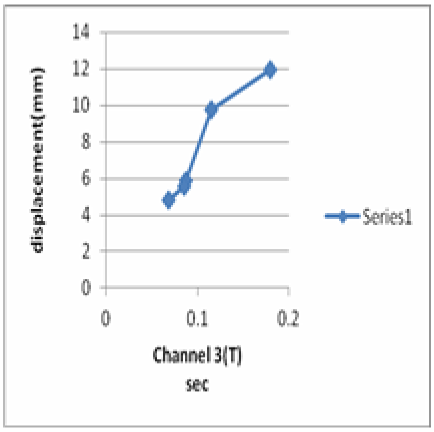
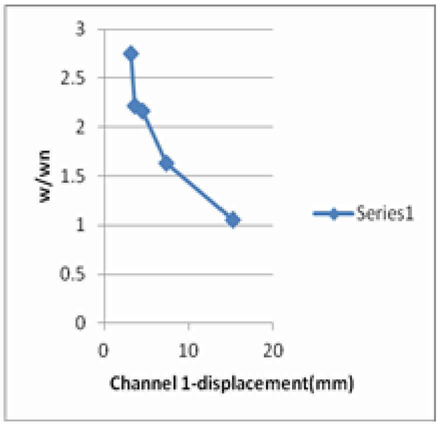
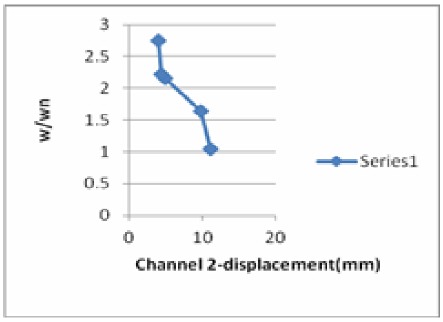


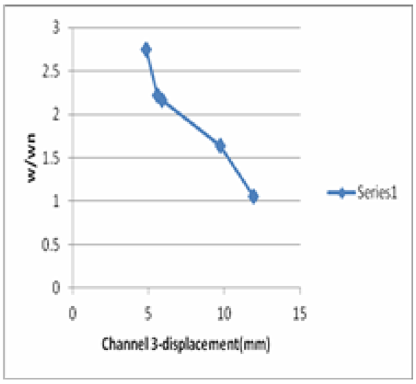
TABLE-3: TABLE FOR DISPLACEMENT AND ω/ω_n

CHANNEL-1 DISP	CHANNEL-2 DISP	CHANNEL-3 DISP	ω/ω_n
860426	0	0	0.0584298
15.2176	11.1601	11.926	1.0517374
7.3771	9.7418	9.7256	1.6360409
4.5618	4.8966	5.8956	2.1618989
3.5941	4.3542	5.5661	2.2203302
3.1613	3.9472	4.8299	2.7462002

GRAPHS



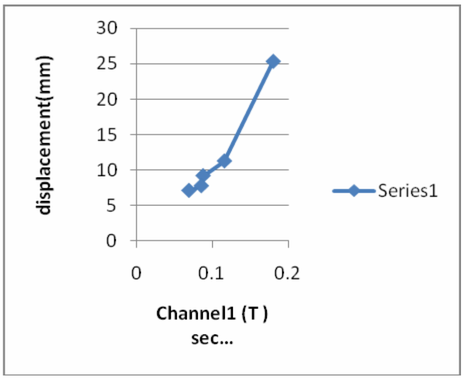


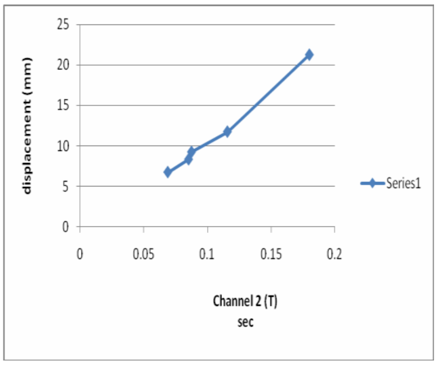


WITHOUT DAMPERS:

TABLE-4: TABLE FOR TIME PERIOD AND DISPLACEMENT

FREQUENCY	R/SEC	T	C-1 DISP	C-2 DISP	C-3 DISP
0.0492187	0.30390934	3.2352677	16435.1	0	0
0.885938	5.5636906	0.1797368	25.3628	21.2261	21.5543
1.37813	8.6546564	0.1155447	11.2724	11.7147	13.8727
1.82109	11.436445	0.0874398	9.20575	9.20575	11.549
1.87031	11.745547	0.0851387	7.76806	8.2885	8.2885
2.31328	14.527398	0.0688354	7.11183	6.70878	7.94961





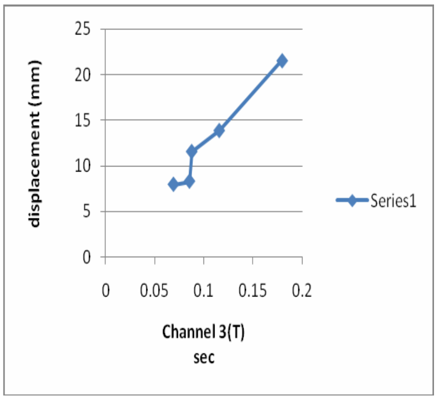


TABLE-5:TABLE FOR DISPLACEMENT AND ω/ω_n

CHANNEL-1 DISP	CHANNEL-2 DISP	CHANNEL-3 DISP	ω/ω_n
860426	0	0	0.0584298
15.2176	11.1601	11.926	1.0517374
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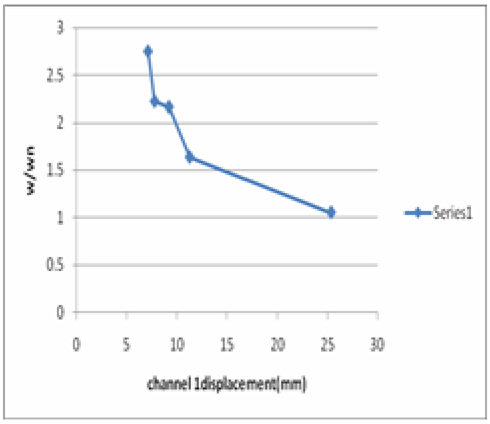

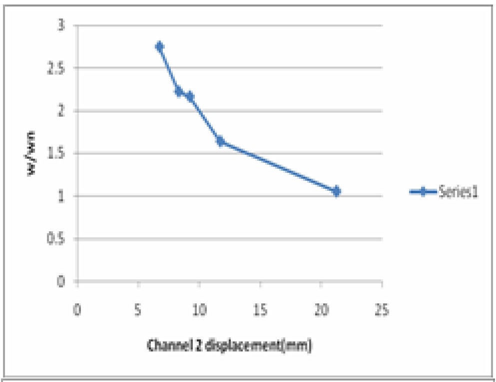

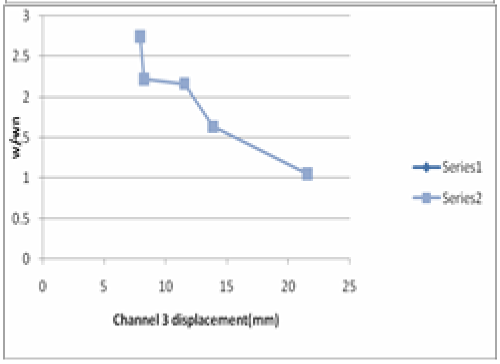

CONCLUSION

- By the installation of dampers in the building the building acquires the resistance to the structure.
- Based on the results obtained from testing of building installed with damper and without dampers it is known that the displacement of the building decreases with the installation of the buildings.
- The replacement of fluid in the damper with glycerol is known to be effective based on the results obtained. Hence glycerol can also be used as a fluid in fluid viscous damper.

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