A Study of Damping Systems on RCC Structures Subjected To Specified Ground Motion

Pawan R. Birewar[1], Dr. Hanmant R. Magar Patil[2]
[1, 2] Civil Engineering Department
[1, 2] Maharashtra Institute Of Tech, Pune

Abstract- *Now-a-days several techniques are available to minimize the vibration of the structure, out of the several techniques available for vibration con-trol, however concept of using NSD (Negative Stiffness Damper)is a newer one. This study was made to study the effectiveness of using NSD for controlling vibration of structure with compari-son of other damping systems. At first a numeri-cal algorithm was developed to investigate the response of a shear building fitted with a NSD. Then FEA was developed to investigate the re-sponse of a 2D frame model fitted with a TMD. A total of three loading conditions were applied at the base of the structure. First one was a Earth-quake loading, the second one was corresponding to compatible time history as per spectra of IS-1894 (Part -1):2002 for 5% damping at rocky soil with (PGA = 1g) and the third one was 1940 El Centro Earthquake record with (PGA = 0.313g).*

Keywords- RCC, Damping, TMD, Staad-Pro

I. INTRODUCTION

1. Introduction

Vibration control is having its roots pri-marily in aerospace related problems such as track-ing and pointing, and in flexible space structures, the technology quickly moved into civil engineering and infrastructure-related issues, such as the pro-tection of buildings and bridges from extreme loads of earthquakes and winds.

The number of tall buildings being built is increasing day by day. Today we cannot have ac-count of number of low-rise or medium rise and high rise buildings existing in the world. Mostly these structures are having low natural damping. So increasing damping capacity of a structural system, or considering the need for other mechani-cal means to increase the damping capacity of a building, has become increasingly common in the new generation of tall and super tall buildings. But, it should be made a rou-tine design practice to design the damping capacity into a structural system while designing the structural sys-tem.

The control of structural vibrations pro-duced by earthquake or wind can be done by vari-ous means such as modifying rigidities, masses, damping, or shape, and by providing passive or active counter forces. To date, some methods of structural control have been used successfully and newly proposed methods offer the possibility of extending applica-tions and improving efficiency.

The selection of a particular type of vibra-tion control device is governed by a number of factors which include efficiency, compactness and weight, capital cost, operating cost, maintenance requirements and safety.

2. Scope of the Work

- From the previous studies, it is understood that commonly used seismic protection strategies are to make a structure ductile which reduces shear force and accelera-tion but simultaneously increase inelastic excursions other is damper and base isola-tion device which reduces inter storey drift but leads to contribute to acceleration and base shear. To overcome this an adap-tive passive device to reduce simultane-ously the deformations/ accelerations and base shear of the structure is used.
- In the present work, an attempt is made to study and verify code provisions associat-ed, with damping and stiffness with par-ticular reference to NSD.
- Effects on seismic response parameters of structures such as time period, understory displacement, acceleration etc are studied before and after the introduction of NSD.
- By varying number and position of NSD within a building frame effects are stud-ied.

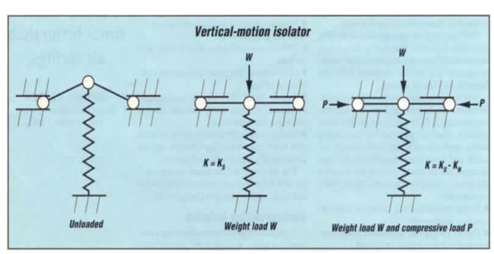

Figure 1. Negative Stiffness Mechanism by D. Platus

The objectives of present work are,

1. The existing analysis of NSD used for chevron bracing is applied to various multi-story frames and the results are verified with those available in literature.
2. Dynamic analysis is done to let all relevant pa-rameters like time period, base shear, drift and mode participation.
3. Effects of Damping on structure is studied to verify IS code provisions.

II. DAMPING SYSTEMS IN RCC

1. Passive Energy Dissipation:

All vibrating structures dissipate energy due to internal stressing, rubbing, cracking, plastic deformations, and so on; the larger the energy dis-sipation capacity the smaller the amplitudes of vibration. Some structures have very low damping of the order of 1% of critical damping and conse-quently experience large amplitudes of vibration even for moderately strong earthquakes. Methods of increasing the energy dissipation capacity are very effective in reducing the amplitudes of vibra-tion. Many different methods of increasing damp-ing have been utilized and many others have been proposed.

Passive energy dissipation systems utilizes a number of materials and devices for enhancing damping, stiffness and strength, and can be used both for natural hazard mitigation and for rehabili-tation of aging or damaged structures. In recent years, efforts have been undertaken to develop the concept of energy dissipation or supplemental damping into a workable technology and a number of these devices have been installed in structures throughout the world (Soong and Constantinou 1994; Soong and Dargush 1997). In general, they are characterized by the capability to enhance en-ergy dissipation in the structural systems in which they are installed. This may be achieved either by conversion of kinetic energy to heat, or by transfer-ring of energy among vibrating modes. The first method includes devices that operate on principles such as frictional sliding, yielding of metals, phase transformation in metals, deformation of visco-elastic solids or fluids, and fluid orificing. The later method includes supplemental oscillators, which act as dynamic vibration absorbers.

2. Types of Passive Control Devices

Metallic Yield Dampers

One of the effective mechanisms availa-ble for the dissipation of energy, input to a struc-ture from an earthquake is through inelastic de-formation of metals. The idea of using metallic energy dissipators within a structure to absorb a large portion of the seismic energy began with the conceptual and experimental work of Kelly et al. (1972) and Skinner et al. (1975).

Several of the devices considered include torsional beams, flexural beams, and V-strip ener-gy dissipaters. Many of these devices use mild steel plates with triangular or hourglass shapes so that yielding is spread almost uniformly throughout the material. A typical X-shaped plate damper or add-ed damping and stiffness (ADAS) device is shown in Fig.

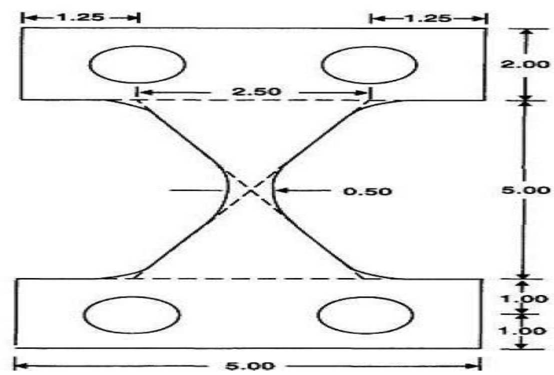

Figure 2. X-shaped ADAS device

Friction Dampers

Friction provides another excellent mech-anism for energy dissipation, and has been used for many years in automotive brakes to dissipate ki-netic energy of motion. In the development of fric-tion dampers, it is important to minimize stick-slip phenomena to avoid introducing high frequency excitation. Furthermore, compatible materials must be employed to maintain a consistent coefficient of friction over the intended life of the device. The Pall device is one of the damper elements utilizing the friction principle, which can be installed in a structure in an X-braced frame as illustrated in the figure (Palland Marsh 1982)

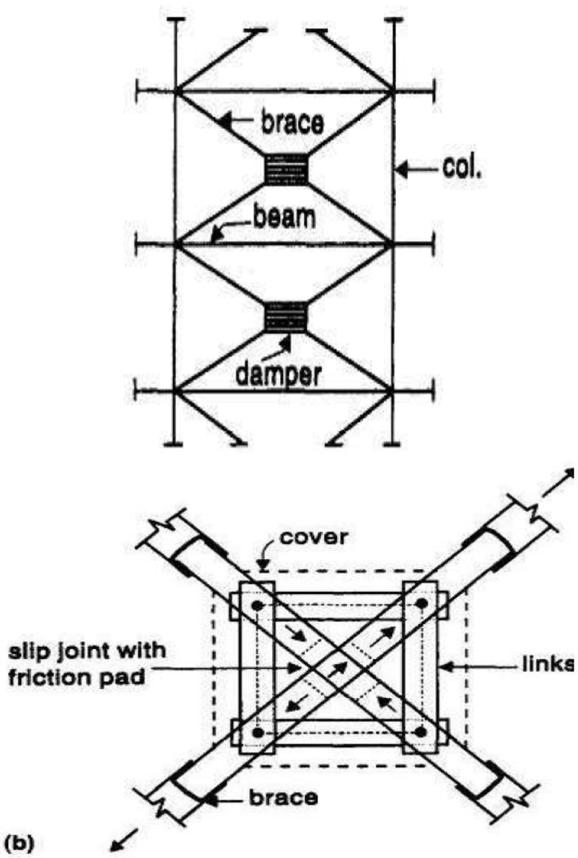

Figure 3. Pall Friction Damper

Viscoelastic Dampers

The metallic and frictional devices de-scribed are primarily intended for seismic applica-tion. But, viscoelastic dampers find application in both wind and seismic application.

Their application in civil engineering struc-tures began in 1969 when approximately 10,000 viscoelastic dampers were installed in each of the twin towers of the World Trade Center in New York to reduce wind-induced vibrations. Further studies on the dynamic response of viscoelastic dampers have been carried out, and the results show that they can also be effectively used in reducing struc-tural response due to large range of intensity levels of earthquake. Viscoelastic materials used in civil engineering structure are typical copolymers or glassy substances. A typical viscoelastic damper, developed by the 3M Company Inc., is shown in Fig. It consists of viscoelastic lay-ers bonded with steel plates.

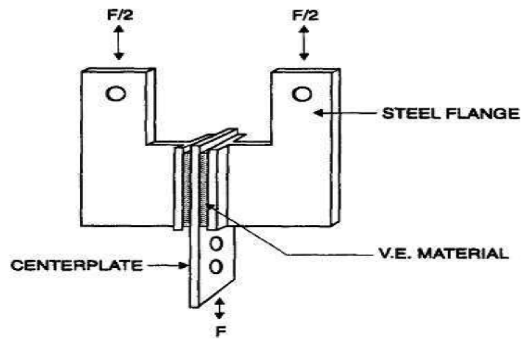

Figure 4. Viscoelastic damper

Viscous Fluid Dampers

Fluids can also be used to dissipate energy and numerous device configurations and materials have been proposed. Viscous fluid dampers, are widely used in aerospace and military applications, and have recently been adapted for structural ap-plications (Constantinouet al.1993). Characteristics of these devices which are of primary interest in structural applications, are the linear viscous re-sponse achieved over a broad frequency range, insensitivity to temperature, and compactness in comparison to stroke and output force. The vis-cous nature of the device is obtained through the use of specially configured orifices, and is respon-sible for generating damper forces that are out of phase with displacement. A viscous fluid damper generally consists of a piston in the damper hous-ing filled with a compound of silicone or oil (Makris and Constantinou 1990; Constantinou and Sy-mans1992).A typical damper of this type is shown in Fig.

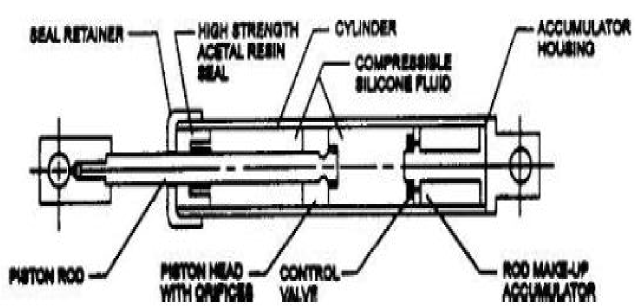

Figure 5. Taylor device fluid damper

Tuned liquid damper

A properly designed partially filled water tank can be utilized as a vibration absorber to re-duce the dynamic motion of a structure and is re-ferred to as a tuned liquid damper (TLD). Tuned liquid damper (TLD) and tuned liquid column damper (TLCD) impart indirect damping to the system and thus improve structural performance (Kareem 1994). A TLD absorbs structural energy by means of viscous actions of the fluid and wave breaking.

Tuned liquid column dampers (TLCDs) are a special type of tuned liquid damper (TLD) that rely on the motion of the liquid column in a U-shaped tube to counter act the action of external forces acting on the structure. The inherent damp-ing is introduced in the oscillating.

The performance of a single-degree-of-freedom structure with a TLD subjected to sinusoi-dal excitations was investigated by Sun(1991), along with its application to the suppression of wind induced vibration by Wakahara et al. (1989). Welt and Modi (1989) were one of the first to sug-gest the usage of a TLD in buildings to reduce overall response during strong wind or earthquakes.

Tuned Mass Dampers

The concept of the tuned mass damper (TMD) dates back to the 1940s (Den Hartog 1947). It consists of a secondary mass with properly tuned spring and damping elements, providing a frequen-cy-dependent hysteresis that increases damping in the primary structure. The success of such a system in reducing wind-excited structural vibrations is now well established. Recently, numerical and ex-perimental studies have been carried out on the effectiveness of TMDs in reducing seismic response of structures (for instance, Villaverde(1994))

3. Classification of Control Methods

Active Control

An active control system is one in which an external power source the control actuators are used that apply forces to the structure in a prescribed manner. These forces can be used to both add or dissipate energy from the structure. In an active feedback control system, the signals sent to the control actuators are a function of the response of the system measured with physical sensors (optical, mechanical, electrical, chemical, and so on).

Passive Control

A passive control system does not require an external power source. Passive control devices impart forces that are developed in response to the motion of the structure. Total energy (structure plus passive device) cannot increase, hence inherently stable.

Hybrid Control

The term "hybrid control" implies the combined use of active and passive control sys-tems. For example, a structure equipped with dis-tributed viscoelastic damping supplemented with an a
ctive mass damper near the top of the struc-ture, or a base isolated structure with actuators actively controlled to enhance performance.

Semi-active Control

Semi-active control systems are a class of active control systems for which the external ener-gy requirements are less than typical active control systems. Typically, semi-active control devices do not add mechanical energy to the structural system (including the structure and the control actuators), therefore bounded-input bounded-output stability is guaranteed. Semi-active control devices are of-ten viewed as controllable passive devices.

III. METHODOLOGY

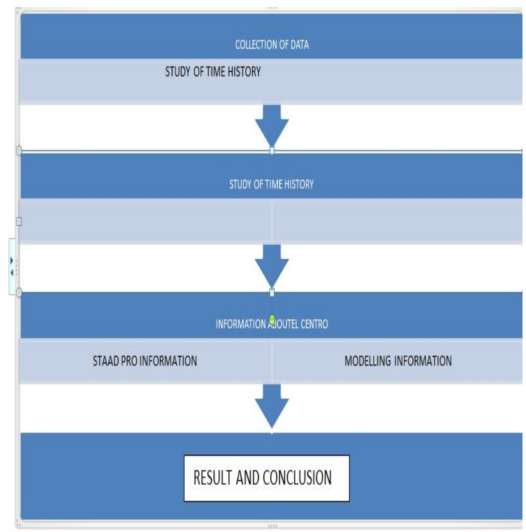

Figure 6.

Buildings are subjected to ground motions. The ground motion has dynamic characteristics, which are peak ground acceleration (PGA), peak ground velocity (PGV), peak ground displacement (PGD), frequency content, and duration. These dynamic characteristics play predominant rule in studying the behavior of RC buildings under seismic loads. The structure stability depends on the structure slenderness, as well as the ground motion ampli-tude, frequency and duration. [23] Based on the frequency content, which is the ratio of PGA/PGV the ground motion records are classified into three categories [38]:

1) High-frequency content PGA/PGV > 1.2
2) Intermediate-frequency content 0.8< PGA/PGV< 1.2

3) Low-frequency content PGA/PGV < 0.8

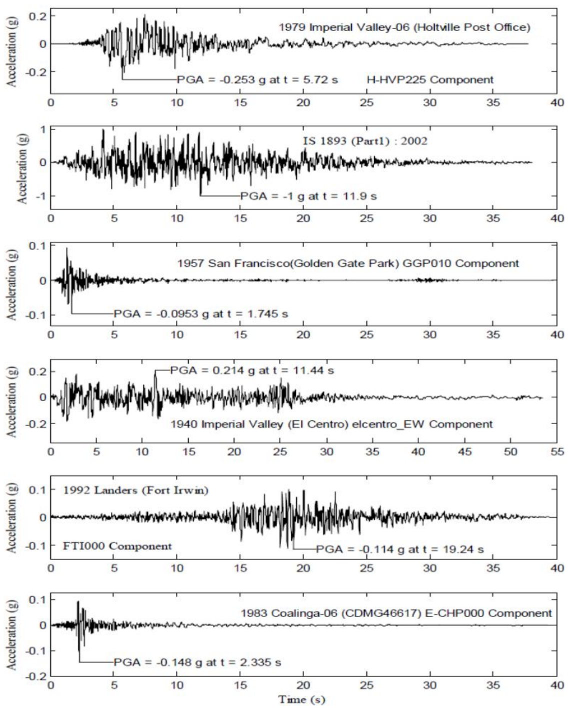

Figure 7.

IV. PROBLEM STATEMENTS

Design of frame structure in soft-ware(STAAD.PRO).
The following data are taken for analysis of the frame:

1) Grade of concrete M30
2) Grade of steel Fe415
3) Type of the structure Multi- storey rigid jointed plane frame.
4) Size of columns 0.230 m × 0.450m
5) Size of beams 0.230 m × 0.450m
6) Depth of slab 0.150 mm
7) Modulus of elasticity 200×10³ N/m²
8)Earthquake zone III& V
9)Time History Load-El-centro

1. Frame Structure Without Damper

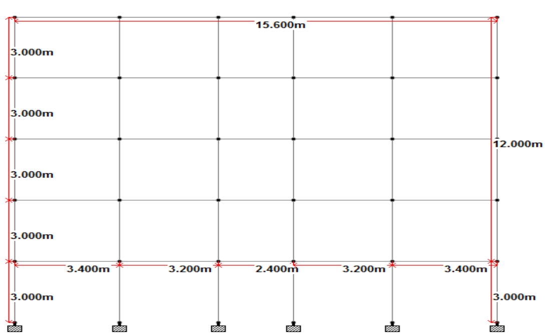

Figure 8.

2. Frame Structure WithBase Isolation

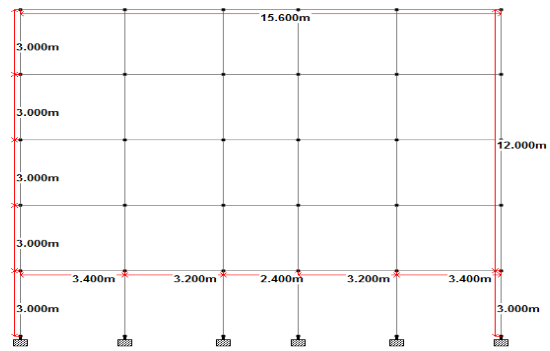

Figure 9.

3. Frame Structure with Negative Stiffness Damper

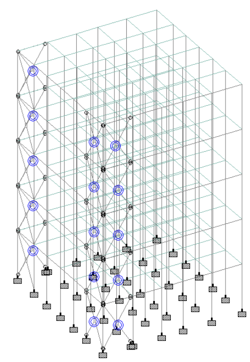

Figure 10.

V. RESULTS AND DISCUSSION

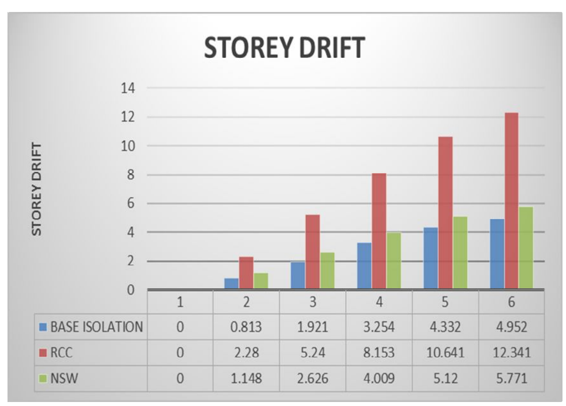

Figure 11.

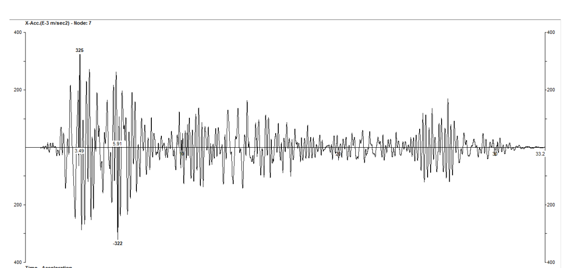

Figure 12.

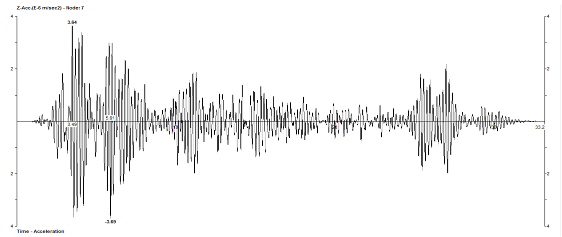

Figure 13.

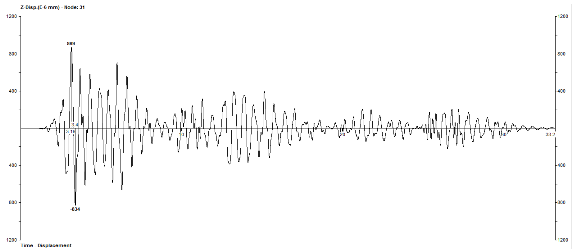

Figure 14.

VI. CONCLUSION

In the present study finite element modelling of RCC structurewith NSD , Base Isolationis proposed using STAAD-Pro and it is concluded that

- The use of base isolation in RCC reduces the longitunal deformation by 9%.
- However Maximum moments, shear force, bending moment does not change significantly the difference is observed up to 4-5% only.
- By graph no.2 it is concluded storey drift of all floors is 25-30% less in base isolator RCC as compared to RCC without base isolator.
- From storey drift graph it can be conclud-ed that storey drift is minimum for base isolation than other damping systems

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