

# Some Experimental Investigations for the Development of Integrated Model of a Structure with the Controllable Fluid Damper

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**Abstract-** This paper presents a brief overview of research being conducted in the area of Seismic Hazards Mitigation. The focus of the study has been on the development of integrated model of a structure with controllable fluid damper. The damper is used with the objective of reducing the dynamic wave propagation potential in the structure upon the structural excitation. Before its employability to serve the intended purpose, system identification and model validation are pre-requisites for optimal functioning of the damper. A phenomenological model of the controllable fluid damper-Magnet orheological damper is used along with other smart materials in the experiments conducted under controlled conditions. The experimental results are used to verify the integrated system model. The experimental results obtained indicate that high performance can be attained with controllable fluid damper to meet the requirements associated with seismic response reduction in civil engineering structures.

**KEY WORDS-** SYSTEM IDENTIFICATION, CONTROLLABLE FLUID DAMPER, SEISMIC HAZARDS MITIGATION.

## I. INTRODUCTION

Structural control systems fall into four basic categories;- passive, active, hybrid and Semi-active. Passive control systems have the limitations of not being able to adapt to structural changes and to varying usage and loading conditions. Active control systems operate by using external energy supplied by actuators to impart forces on the structures. The appropriate control action is determined based on measurements of the structural responses. A hybrid control system employs a combination of two or more passive or active devices. Because multiple control devices are operating, hybrid control systems can alleviate some of the restrictions and limitations that exist when each system is acting alone. Semi-active control device is one that cannot increase the mechanical energy into the controlled system, but has the properties, which can be dynamically varied to optimally reduce the responses of a structural system. Therefore, in contrast to the other structural control systems, semi-active control devices do not have the potential to destabilize the structural system, in the bounded input/bounded output sense.

### A. Semi-active structural control Systems

These systems perform significantly better than passive devices and have the potential to achieve, or even surpass, the performance of fully active systems, thus allowing for the possibility of effective response reduction during a wide array

of dynamic loading conditions. Of the conventional semi-active devices like variable fluid orifice dampers, controllable friction devices and variable stiffness devices, controllable fluid dampers are more reliable.

### B. Controllable-Fluid Dampers

The essential characteristic of controllable fluids is their ability to reversibly change from a free-flowing, linear viscous fluid to a semi-solid with a controllable yield strength in milliseconds when exposed to an electric (ER Damper) or magnetic (MR Damper) field. This theological metamorphism of these type fluids, acknowledging the receipt of dynamic waves to it, exploits its adoptability to mitigate the effects of natural hazards on the structures. MR Damper is used in these investigations. This is an approach, wherein the measured input/output data from the system is directly employed to consider a mathematical model that replicates the observed behavior. This is normally done either by Time domain approach or by the Frequency domain approach. Time domain approach is preferred where limited measurement time is available and the system is with more nonlinearity. Frequency domain approach is employed when the system is linear, time invariant and significant noise is present in the measurement. In this study, for the development of integrated model of a structure with the controllable fluid damper, Frequency domain approach of system identification is adopted, as the structure itself is assumed to remain in the linear region. System identification block diagram of the primary structure is as shown in Fig.1.

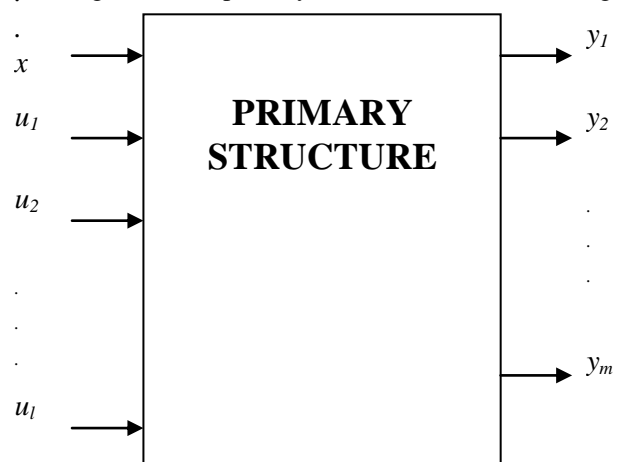


Fig.1. System identification block diagram of the primary structure

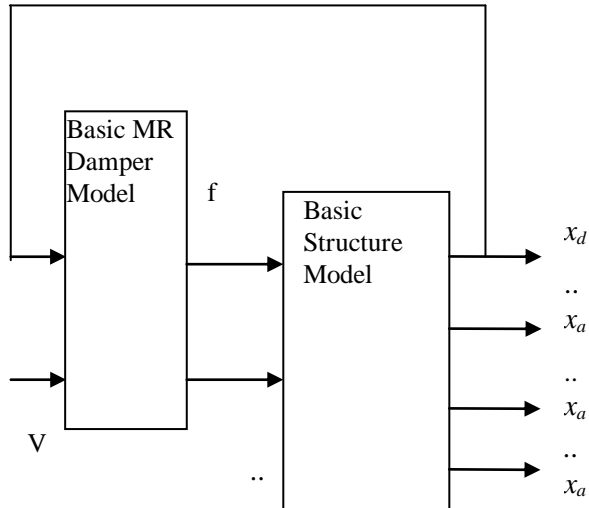


Fig. 2. Block Diagram of the Integrated Structural System

**C. Frequency domain approach**

The methodology adopted in the present investigations, under this approach envisage

- i) Experimental determination of Transfer functions
- ii) Mathematical modeling of the transfer function and
- iii) State space realization.

**D. Inputs/outputs of the system**

The two inputs are ground excitation  $\dot{x}_g$  and the applied control force  $f$ . The four measured system outputs include the displacement  $x_d$  of the structure at the attachment point of the MR Damper, and the absolute accelerations,  $x_{a1}, x_{a2}, x_{a3}$ , of the three floors of the test structure i.e,  $y = (x_{a1}, x_{a2}, x_{a3})$ . Thus, a 4x2 transfer function matrix is identified to describe the characteristics of the system.

**II. EXPERIMENTAL PROGRAMME**

The experimental setup includes a three storeyed steel structure (designed with its specifications as shown in Table-1) is employed with two Magnet orheological dampers- one installed between the ground floor and first floor and another between the first floor and second floor. Uni-axial accelerometers (Bruel & Kjare make) are used at each floor to measure the absolute accelerations. Force transducers are used in series with the dampers to measure the damping force and LVDT's are used to measure the displacements of the different floors of the model and to measure the displacement of the damper. The experimental setup is as shown in figure.4. The transfer functions from ground acceleration to each of the measured responses were determined by exciting the structure with band-limited ground acceleration (0-50Hz). A series of tests were conducted to measure the response of the system with the dampers in place. Base of the structure was excited and a command voltage applied to damper (0 V to 50V). The force

generated in the damper, absolute accelerations of the floors of structure, damper displacement and relative displacement of the structure at the three floors are measured. The behavior of developed integrated model response is examined, by conducting tests with broadband excitation (0-20Hz) with rms ground accelerations of 0.20g.

**III. DISCUSSIONS ON RESULTS**

$$C_1 \dot{y} = \alpha z + k_u(x_d - y) + C_0(\dot{x}_d - \dot{y}) \tag{1}$$

$$\dot{y} = 1/(c_0 + c_1 + c_2)(\alpha z + c_0 \dot{x}_d + k_0(x_d - y)) \tag{2}$$

and the total force,

$$f = c_1 y_1 + k_1(x_d - x_0) \tag{3}$$

Figures a-f (graph obtained from Dynamic signal analyzer) show the representative magnitude for the experimentally determined transfer functions obtained using 12 averages. The three distinct, damped peaks 21.5, 84,168 Hz correspond to the first three modes of the structural system. The errors near the peaks in the transfer functions from the control force to the structural responses are due to the effect of control structure interaction. Six poles were necessary to model the input/output behavior of each transfer function in the frequency range of interest, to have 12 poles of the controlled system. A least-square output-error method with a non-linear optimization was employed to obtain 8-model parameter to model the damper. Optimization was done using MATLAB and optimized parameters were determined to fit the generalized model of Damper to experimental data.

**IV. CONCLUSION**

The integrated system model is obtained by connecting the basic models of the controllable fluid damper and structure.

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APPENDIX

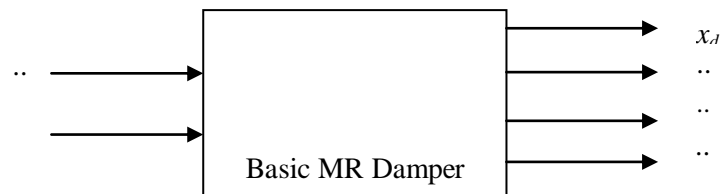


Fig.3. Block Diagram of the basic MR damper model

TABLE.1. SPECIFICATIONS OF THE MODEL STRUCTURE

Number of bays	01	Number of columns	12
Number of floors	03	Weight of each floor	80

Fig. 4 Experimental Setup of a three storeyed steel structure

Fig .5(a) Control force to III floor Accelerations, 5(b) Control force to II floor acceleration,5(c) Control force to I floor acceleration,5(d) Ground acceleration to I floor acceleration,5(e) Ground acceleration to II floor acceleration,5(f) Ground acceleration to III floor acceleration

