MCEER RESEARCH TASK STATEMENT

Thrust Area 2

Budget: Yr 8 Assigned
Project Number: 8.2.3

Task Title: Modeling Visco-elastic Composite Panels and Impact on Floor Velocities and Accelerations

Investigator/
Institution: Amjad Aref*/ University at Buffalo
Andrei Reinhorn/ University at Buffalo
Gary Dargush/ University at Buffalo

* indicates task leader

Statement of Project Goals: (Conceptually describe what the work is intended to accomplish, in 100 words or less. Do not provide detailed description here.)

The objectives of this task are: (a) Implementation of constitutive relations and special finite elements in existing computational platforms to model the visco-elastic composite panels within 2-D and 3-D models. (b) Using the derived computational tools, perform structural simulations of the demonstration projects that utilize the visco-elastic composite panels to assess their impact on floor accelerations and velocities. The assessment of the floor response is particularly driven by the limits set for the motion-sensitive equipment and non-structural components.

Problem Description and Research Approach of Proposed Work for Year 8: (Detailed description of research to be conducted and methodology to be used.)

Figure: ABAQUS 2-D FE model of viscoelastic composite panel and the associated kinematics of deformation
The Research Approach:

To successfully address the modeling issues of the visco-elastic composite panels, we need to derive, implement, and validate: (1) constitutive relations and special finite elements (FE) that can be used within a 2-D and 3-D finite element model or a structural analysis program. Under the category of finite element programs, we are using ABAQUS because this software allows for user-defined subroutines to be compiled with the computer program thereby the required computational tools (constitutive models and special elements) can be implemented. However, under the category of structural analysis programs, we identified SAP, IDARC, and DRAIN-2D as potential platforms to implement material models and new special finite elements.

(2) The implementation of computational tools will allow us to perform structural simulations of the composite panels when used for retrofitting the demonstration projects (emergency critical facilities).

There are two fundamental questions that any researcher dealing with supplementary damping technologies is trying to answer, and in our case they are: (1) what is the number and capacity of the visco-elastic composite panels? And (2) what is the optimum distribution that leads to significant reduction of floor accelerations, velocities, or other performance measures?

While the derivation and implementation of constitutive models and special finite elements are inherently basic research tasks, our primary pursuit will be to utilize the computational tools to study the impact of the developed visco-elastic composite panels on reducing the floor displacements, velocities and acceleration of the demonstration projects. Hence, the final outcome is geared toward fulfilling the MCEER’s goal of enhancing the seismic resilience of communities by improving the seismic response of emergency critical facilities.

Assessment of State-of-the-Art: (Describe other relevant work being conducted within and outside of MCEER, and how this project is different.)

The structural simulations of visco-elastic composite panels within existing general-purpose finite element software is a major challenge that requires, implementation of either new elements or user defined subroutines to define the visco-elastic material properties. As part of other related research dealing with modeling composite bridges, the principal investigator has been engaged in the development of user-defined subroutines to simulate the nonlinear behavior of such structures. Thus, applicable models can be used or modified to model the visco-elastic composite panels.

Progress to date: (If applicable, a short description of achievements in previous years. Clearly distinguish progress achieved in the past year, i.e., accomplishments from April 1, 2003, to March 31, 2004.)

The 2-D FE simulations of one of the critical facilities are done. A finite element model (ABAQUS) similar to the one shown in figure 1. is used to assess the response of the structure with various configurations and arrangements of visco-elastic composite panels within each floor.
**Role of Proposed Task in Support of Strategic Plan:** (Describe how the effort will make a unique, useable contribution to the MCEER strategic plan.)

This research task supports the MCEER strategic plan by developing a set of visco-elastic composite panels that will be ready for implementation in emergency critical facilities to enhance the seismic resilience. The visco-elastic composite panels devised in this task complement and play an integral part of the collective effort undertaken by Thrust Area 2 researchers who are developing other kinds of seismic retrofitting technologies. In particular this task contributes to the “Response Modification block” of the flow chart that describes the envisioned integration scheme of thrust area 2. Along with the development of composite systems for enhancing the seismic response of critical facilities, the computational tools that can be used by engineers to design the composite panels will be shared and disseminated through MCEER’s Users Networks. Such tools include: (i) simplified analysis and design procedures (developed in year 6), (ii) rigorous computational tools (2D FE models) that we are developing in year 7, (iii) and the material models and special elements that are under development partly in year 7 and to be continued in year 8.

**Task Integration:** (Describe how the work performed interfaces with other tasks and researchers funded by MCEER.)

The integration of this task with other tasks entail the following:

1. Research in composite panels produced three distinct conceptual designs. The distribution of the various panel designs within a structure can be integrated in the evolutionary optimization framework that Dr. Dargush is working on, whereby the optimum number and distribution of panels can be determined to produce an optimum seismic retrofitting strategy. The objective function can be tailored to produce the optimum design with respect to performance measures related to the structural system, however, upon identification of performance levels of critical non-structural components, optimum solutions can be similarly investigated.

2. The conceptual composite panels under investigation in this task can be combined with other researchers’ proposed systems to produce hybrid energy dissipation strategies. Since the ultimate goal in Thrust Area 2 is to improve the seismic resiliency of emergency critical facilities, interaction with other researchers in this area will be an important positive factor to achieve the desired goal by creating a spectrum of robust hybrid retrofit strategies that can be used.

3. In the development of constitutive models and special FE elements, we will collaborate with Dr. Reinhorn to implement elements or material models in IDARC. Moreover, in our effort to implement visco-elastic constitutive models in ABAQUS, we will also collaborate with Dr. Dargush.

4. The data and computer subroutines produced in this task will be disseminated through MCEER’s Users Networks. In preparing the data and electronic files for dissemination we will interact with Dr. Reinhorn.

**Possible Technical Challenges:**

- Numerical simulations of the steel frame with visco-elastic panels that contain both the 3M visco-elastic materials and polymeric honeycomb cannot be represented by 3-D finite
element models because of the lack of constitutive relations that describe the volumetric behavior of this material combination. Therefore, calibration of constitutive models will be needed to successfully implement a user-defined subroutine that describes the visco-elastic model in 3-D finite element commercial software.

- A second challenge pertains to the modeling of contact behavior of the panels with the surrounding frame. When the visco-elastic composite panel comes in contact with the surrounding frame at high lateral drift levels, the friction induced at the interface contributes to the energy dissipation. Therefore, consideration of the contact behavior in the numerical simulations is another challenge that we have to address.

- A third challenge is related to the numerical stability of the finite elements and the material models that we are planning to derive and implement in FE software, and in structural analysis programs.

### Anticipated Outcomes and deliverables:
*Also indicate those of particular benefit to IAB members and other end users.*

1) Three conceptual energy dissipating visco-elastic composite panels.
2) Simplified analysis and design procedures for the visco-elastic composite panels tailored for use by practicing engineers.
3) Constitutive relations for visco-elastic material and special elements implementation in commercial FE software through user defined subroutines.
4) Dissemination of findings in archival journals, technical reports, and conferences. Two MCEER technical reports are in progress, two refereed journal papers have been published, and two manuscripts are in review (The Contributions to MCEER Objectives form contains the citations of published papers).

### Potential end-users beyond academic community: (IAB members and others.)

1) Results of using high performance visco-elastic composite panels, after they have been tested in the laboratory and numerical simulations validate their effectiveness in a structural system can be used in the demonstration project.
2) The simplified analysis and design procedures are readily available for engineers. However, computational tools related to constitutive models and special finite elements will be made available to researchers and engineers upon completion.
3) The research on composite panels has been partially supported by a composite manufacturer (ANCOR Industrial Plastics, Inc.), and a supplier of visco-elastic material (Sumitomo 3M LTD., Japan).

### Educational outcomes and deliverables, and intended audience:
The findings of the research dealing with analysis and design procedures have been used in a graduate course at UB (CIE528 composite structures). Integration of the findings of this research in a graduate course will facilitate and promote the use of such systems, thus, accelerating the transfer of research into industrial applications.
**Project Schedule and Expected Milestones for the Project:** *(Milestones and estimated time of achievement; e.g. Fall, Spring, Summer.)*

**Fall:** derivation and implementation of FE models of the composite panels to be used in SAP or IDARC. Simulation of the critical facilities with visco-elastic composite panels using 3D FE models.

**Spring and Summer:** Verification of the FE models and simulations of the critical facilities using 3D SAP or IDARC models will be carried out, and results will be compared to those obtained from ABAQUS analyses.

**Team Members:** *(If known, provide names of team members associated with project including project leader, other faculty and their departments, undergraduate students, graduate students, postdoctoral students, industrial participants.)*

Amjad Aref*, Principal Investigator, Associate Professor, Department of Civil, Structural, and Environmental Engineering (CSEE), University at Buffalo.

Andrei Reinhorn, Professor, CSEE, University at Buffalo.

Gary Dargush, Professor, CSEE, University at Buffalo.

WooYoung Jung, Ph.D. candidate, CSEE, University at Buffalo.

Justin Jecewicz, M.S. candidate, CSEE, University at Buffalo.

**Possible Direction of Work in Subsequent Years:**

In the subsequent years, once all computational tools have been derived, implemented, and validated, the work will continue to focus on ways to improve and modify the response of critical facilities.

In particular, the research in this task is well positioned to tie-in with the possible research task that will deal with limits on non-structural components and motion sensitive equipment. The collaboration is envisioned to be in the form of additional simulations to fine tune the distribution and number of visco-elastic composite panels such that floors response (velocities and accelerations) remain below the limits for the motion sensitive equipment.