MCEER RESEARCH TASK STATEMENT

Thrust Area 2                  Budget:                   Yr 8 Assigned
                             Project Number:  8.2.4

Task Title: Emergency Care Facility Evaluation through Integration of Nonstructural and Structural Response Data

Investigator/  Andrew Whittaker*
Institution:   University at Buffalo
* indicates task leader

Statement of Project Goals:

The following items are the goals of this Year 8 project. These tasks will be executed in close coordination and collaboration with Professor Filiatrault.

1. Continue to collect and synthesize non-structural-component and -content fragility data for emergency care facilities from MCEER, USC-FEMA, and other sources to populate the MCEER non-structural component/content database.

2. Analyze, design and construct a multi-story test platform suitable for evaluating the seismic vulnerability of generic hospital-type contents.

3. Evaluate the utility of published analytical fragility formulations for generic free-standing non-structural contents. Collect data to facilitate the development of improved formulations.

4. Develop inexpensive protective hardware and tethers for non-structural contents to reduce content vulnerability. (The utility of this hardware and tethers will be evaluated in Year 9 via earthquake simulator testing.)

A separate networking subtask will be submitted. The networking subtask statement describes the proposed databases and the associated fragility-based computational tool that will be made available to the MCEER Users Network.

Problem Description and Research Approach of Proposed Work for Year 8:

Each of the four goals listed above is discussed in turn below.

Nonstructural components and contents represent more than 90% of the initial investment in emergency care facilities, as indicated in the figure to the left from Miranda. Robust characterization of the vulnerability of key non-structural components and contents is needed to judge the likelihood of loss of operation and financial loss in emergency care facilities following earthquake shaking. A fragility-based approach is being used by MCEER for this purpose. Fragility data for the key components and contents will be assembled where available from MCEER (see right), USC-FEMA, and other sources. This information will be used to populate the MCEER non-structural component/content database. The database will be made
Analytical formulations for the fragility assessment of free-standing non-structural components/contents have been published in the past 18 months by Professors Soong and Makris. These important formulations require experimental substantiation before they can be used widely to judge the fragility of nonstructural components and contents. Working in conjunction with Professor Filiatrault, a single-story test platform will be analyzed, design and constructed for installation on the 2 earthquake simulators in the new NEES laboratory at UB. The frame will be designed to remain elastic (as would be the expectation in an emergency care facility) for maximum shaking; moment-frame and braced-frame variants will be considered.

Following construction of the test fixture, sample generic contents (represented by blocks of differing geometries and mass distributions) will be installed on surfaces similar to those used in emergency care facilities for vulnerability assessment by earthquake simulator testing. Simple studies to characterize the interface friction properties will be conducted prior to simulator testing. Earthquake histories for testing will be developed in Year 7 in coordination with Professor Filiatrault. Predicted and measured fragility data will be compared.

Techniques and hardware have been developed to protect nonstructural components from the effects of earthquake shaking. These techniques and hardware will be extended toward the end of Year 8 to generic building contents with the objective of assessing their utility in Year 9 via earthquake simulator testing. Coordination and collaboration is expected with Professor Constantinou on this topic. Professor Soong will be asked to review the proposed technologies and hardware.

To maximize the benefit of the work conducted by individual MCEER investigators and to best serve the stated need for program integration, a database of information and knowledge related to emergency-care-facilities, mathematical models (on a variety of platforms), and non-structural fragilities will be expanded in close consultation with Professor Reinhorn and other MCEER Thrust Area 2 researchers. The databases and the evaluation tools will be developed, published, and distributed through the MCEER Users Network as part of a separate networking task.

Assessment of State-of-the-Art:
Research work on nonstructural components is being conducted in the PEER program, with important contributions from Professors Miranda, Hutchinson, Makris and others. Of particular relevance to this work are the recent studies of Makris at Berkeley involving earthquake-simulator testing of three slender laboratory contents. The proposed work will build on but not duplicate the study of Makris and investigate generic (hospital-type) blocks of different dimensions and mass distributions to those tested previously, for the purpose of judging the utility of existing fragility formulations for generic building contents, including the formulations of Soong, Lopez-Garcia and Makris.

Progress to date:
Three demonstration hospital structures have been designed and data are now available at the MCEER website. Included in the materials at the web site are (a) an 80-page report describing the analysis and design of the three separate buildings (WC70, WC60, and EC70), (b) the SAP2000NL input files that can be used for the analysis of the three buildings, and (c) drawings...
of the three buildings in AutoCAD. All of these files can be downloaded. (2002)

IDARC models of the hospital building have been prepared with explicit modeling of all gravity- and lateral-load-resisting components. Revisions to IDARC to incorporate semi-rigid connections have been implemented. Analysis results based on different modeling assumptions have been published showing the effect of structural-component modeling assumptions on demands on non-structural components. (2003)

A M.S. thesis on the fragility of suspended ceiling systems was published. (2003)

Two papers on nonstructural components in building structures were published at the ATC-29-2 meeting. (2003)

An MCEER report and a journal paper on the fragility of suspended ceiling systems were prepared. The MCEER report will be published in Q1 2004.

A M.S. thesis on the vulnerability of nonstructural components in fixed-base and base-isolated versions of the MCEER demonstration hospital is being prepared. Analysis of the building is being performed using OpenSees and IDARC.

An MCEER report related to the vulnerability of the MCEER demonstration hospital and nonstructural components in the building is being prepared. New mathematical models of the building in the OpenSees and IDARC environments are being used to update the earlier assessments.

Role of Proposed Task in Support of Strategic Plan:
The proposed work in Year 8 has been coordinated with the leader of Thrust Area 2, Professor Filiatrault. The work supports the MCEER strategic plan and will operate at all three levels of the MCEER 3-plane chart, namely, (1) to develop valid and applicable scientific knowledge based on fundamental research, (2) to integrate fundamental knowledge into testable technologies and tools, and (3) to evaluate the efficacy of the knowledge, technologies, and tools using the MCEER demonstration hospital.

Task Integration:
This experimental task and the companion work proposed by Professor Filiatrault will serve to both deliver important fragility data and integrate and evaluate many of the computational and analytical tasks in Thrust Area 2, by permitting the experimental verification of results derived by analysis and numerical simulation.

Possible Technical Challenges:
None anticipated at this time.
<table>
<thead>
<tr>
<th>Anticipated Outcomes and deliverables:</th>
<th>Potential end-users beyond academic community:</th>
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<tbody>
<tr>
<td>Sample fragility data (<em>IAB and design professionals</em>).</td>
<td>Design professional community and facility administrators for use in performance-based earthquake engineering of hospitals.</td>
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<tr>
<td>Integrated fragility framework for performance-based earthquake engineering (<em>IAB, ATC-58 project</em>)</td>
<td>The ATC-58 project: a national FEMA-funded effort to develop guidelines for performance-based earthquake engineering. The PI is a leading player in this endeavor.</td>
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<tr>
<td>Matlab files for the analytical development of fragility curves for selected non-structural components.</td>
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<tr>
<td>Databases (<em>IAB and design professionals</em>)</td>
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**Educational outcomes and deliverables, and intended audience:**

Information/deliverables to be included in the UB graduate class in earthquake engineering (CIE 619). Intended academic audience is graduate students.

Other impacted groups will include (a) the design professional community, and (b) members of the ATC-58 SPP and NPP teams.

**Project Schedule and Expected Milestones for the Project:**

*Year 8, Q1*: Analyze and design the multi-story test frame (with Professor Filiatrault)

*Year 8, Q2*: Construct the test fixture

*Year 8, Q3*: Install the test fixture on the simulators and conduct dynamic testing

*Year 8, Q4*: Earthquake simulator testing of selected generic contents

*Year 8, Q4*: Identify and document appropriate protective technologies and tethers for generic contents.

**Team Members:**

Michael Astrella, a PhD candidate at UB.

Professor Andre Filiatrault, University at Buffalo, + 1 post-doctoral associate

Professor Michael Constantinou, University at Buffalo, + 1 graduate student

Professor Andrei Reinhorn, University at Buffalo, + 1 graduate student

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

Continued earthquake-simulator testing in Year 9 including a study of restrained and protected/damped blocks and contents.

Preparation of MCEER technical reports and journal papers

Development of tools and information to address ATC-58 team input.

Continued population of the non-structural component/content fragility database