2009 BFRL Project Description

Project Title: Fire Performance of Load Bearing Wall Elements

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BFRL Program: Reduced Risk of Fire Spread in Buildings Program

Objective: Provide the technical basis for an accurate measurement methodology to investigate the performance/failure of a load bearing steel stud gypsum board wall assembly under real fire and furnace exposures; collect data necessary to guide and validate FDS sub-models to predict failure.

Problem:

What is the problem? Standard fire resistance testing of load bearing steel stud gypsum board wall assemblies provides a relative indicator of resistance on a scale that is arbitrary but has proven valuable over time. While standard fire resistance has reduced the number of fires that have resulted in loss of life, the inability of the fire resistance rating to act as an absolute predictor of performance in an actual fire was recognized from the beginning. Standard fire resistance tests are conducted under furnace conditions and furnace data is of limited use to validate computational models that could be used to predict the performance and failure of these assemblies under arbitrary fire loadings. Specifically, realistic fires do not heat assemblies uniformly or in a continuous manner, and real fires move causing the assembly to cool will still in the presence of smoke and flames. There is no documented understanding of the performance and failure of load bearing steel stud gypsum board wall assemblies under realistic fire conditions; this greatly hampers the application of performance-based design approaches[1,2,3]. Industry is calling for performance based design approaches to stimulate innovation for new fire resistance design of gypsum wall elements[4]. Data and sub-model implementation in BFRL's Fire Dynamics Simulator (FDS) of gypsum assembly failure will enable performance based design and afford the ability to quantify how fire spreads from one compartment to another. To

[1] C.Beyler *et al*., Fire Resistance Testing for Performance-based Fire Design of Buildings. Final Report. NIST-GCR 07-910, 2007.
[2] W. Grosshandler (editor), Fire Resistance Determination and Performance Prediction Research Needs Workshop: Proceedings, NISTIR 6890, 2002.
[3] Making the Nation Safe From Fire, A Path Forward in Research, National Research Council, The National Academies Press, Washington, DC, 2003.

be able to model the behavior of load bearing steel stud gypsum board wall assemblies, thermophysical property data as well as mechanical property data are needed as a function of temperature. For common construction materials as gypsum board[4], thermophysical/mechanical property data is either not available as a function of temperature or large uncertainties exist in regard to the quality of the data reported. Load bearing steel stud gypsum assemblies are an ideal assembly to investigate as these are very common and can be found in commercial low-rise construction, such as hotels, offices, and clinics.

Why is it hard to solve? Without physical knowledge of actual failure mechanisms, it is impossible to predict the time to failure of a load bearing steel stud gypsum board wall assembly under fire exposures using current methods. Such information is critical to determine safe egress times from buildings and provide guidance to firefighters entering a building. Quantifying the performance/failure of a load bearing steel stud gypsum board wall assembly under real fire/furnace exposures is difficult since the measurement science to quantify failure under real fires requires unique experimental facilities and unique expertise to conduct full scale fire testing in a safe manner (described below as part of this project). In addition, thermophysical property data as well as mechanical property data are needed as a function of temperature for gypsum board; new experimental methods are required for these measurements.

How is it solved today, and by whom? Universities and research laboratories are investigating specific components necessary to predict the performance and failure of load bearing steel stud gypsum board wall assemblies in fires, such as mechanical property determination for gypsum board, but an approach that includes testing to understand failure mechanisms in real fires and furnaces in conjunction with thermophysical property/mechanical property databases for common construction materials does not exist.

Why NIST? Developing measurement science to understand performance and failure of load bearing steel stud gypsum board wall assemblies is consistent with BRFL's core competency of fire protection and fire spread within buildings and communities. The proposed team has the requisite expertise to tackle this important problem. The methodology developed by this project will benefit public safety by enabling risk informed building design. Such an advance would empower the use of prescriptive requirements while contributing to the emerging discipline of performance-based design.

Approach:

What is the new technical idea? The new technical ideas are divided into two main focus areas: full scale and reduced scale experiments. The failure point of interest is when the load bearing steel stud gypsum board wall assembly can no longer serve as a fire barrier. Using full scale experiments that will make use of loaded assemblies, the proposed effort will (1) conduct experiments of load bearing steel stud gypsum board wall assemblies in the BFRL-NIST Large Fire Laboratory (LFL) under different fire loadings in order to compare the performance and failure mechanisms to the uniform furnace exposure, and (2) obtain performance and failure

[4] P.Shipp, ASTM E05 Chairman and ISO Convenor, ISO TC92/SC2/WG1, Support Letter to Dr. Manzello of BFRL-NIST

mechanisms of a load bearing steel stud gypsum board wall assemblies under furnace conditions at The Center for Better Living (CBL) in Japan, across North America as part of the North American Fire Testing Laboratories (NAFTL) Consortium, and potentially at SP in Sweden and BRANZ in New Zealand (see below). Reduced scale experiments are a necessary step to provide thermophysical property data as a function of temperature as well as mechanical property data as a function of temperature. Unique measurement capabilities must be developed at BFRL-NIST to determine thermophysical property and mechanical property information as function of temperature; the proposed effort seeks to develop these methodologies for gypsum board. An example of unique measurement science methods developed in support of this project includes non-intrusive image analysis to quantify linear contraction of gypsum board at fire temperatures. Collaborative efforts are also going to be explored at NRC-C for mechanical property data for gypsum board as a function of temperature.

Why can we succeed now? This project is unique in that the full scale experiments performed under furnace exposures are being conducted across North America under the auspices of the North America Fire Testing Laboratories (NAFTL) consortium. These experiments continue the successful NAFTL collaboration completed this past FY. As part of the FY07 effort, experiments were conducted by NAFTL members for non-load bearing steel stud gypsum board wall assemblies to ascertain furnace proficiency; this project designed, coordinated, and monitored these experiments across nine different NAFTL members' (see NIST IR 7471 in recent results). Current NAFTL testing will focus on load bearing steel stud gypsum wall assemblies; the assemblies will be loaded. In addition to NAFTL participation, Manzello has received a fellowship from Japan Society for the Promotion of Science (JSPS). In support of this project, full scale furnace testing will be conducted at The Center for Better Living (CBL) using a unique, fully programmable furnace while Manzello resides in Japan. Finally, the BFRL-NIST LFL will be used to conduct full scale real fire exposures. The compilation of all these full scale testing capabilities in support of this effort is unprecedented.

What is the research plan?

Full Scale Experiments Across North America, Japan, and at NIST

For the proposed experiments to be conducted at BFRL-NIST, a load bearing 3 m by 3 m wall, with steel studs and Type X gypsum board construction to yield a nominal 2 hr fire resistance rating will be used for the testing. NIST intends to construct a compartment and the load bearing steel stud wall assembly will be installed as one of the side walls. These experiments will use both commercially available Type X gypsum board as well as special NAFTL Type X gypsum board. The BFRL-NIST compartment fire experiments will be conducted based on experience gained from a scoping test planned as part of this project in FY08. The nature and application of the loading to be applied will be based on input from structural engineering experts (Dr. John Gross of BFRL-NIST will provide input); the use of hydraulic jacks for load application is under consideration. For the proposed work at CBL while Manzello is in Japan, a total of four experiments are proposed in Japan; for a fixed load, one experiment will be performed under the ASTM E119 time-temperature curve and one experiment will be performed under the more severe ASTM E1529 time-temperature curve. The experiments will then be repeated but with a different applied load. The experiments will be conducted until a significant amount of material fallout is observed on the unexposed face. Similar to the NIST experiment, the proposed tests at

the CBL will make use of commercially available Type X gypsum board to compare the failure mechanisms with respect to the special NAFTL Type X gypsum board. The special NAFTL Type X gypsum board was purchased by the individual laboratories in a single lot from the manufacturer since it was desired to have as little variation as possible in the material used as part of the NAFTL testing. The results will be used to create an experimental database of load bearing steel stud wall assembly performance under different, uniform furnaces exposures, and different applied loads.

The proposed results will be compared to failure mechanisms observed by NAFTL members across North America (using same assembly design) as well as failure mechanisms recorded for load bearing steel stud gypsum board wall assemblies at BFRL-NIST under different real, fire loadings. For clarity, the NAFTL tests will be conducted under a fixed load using an ASTM E119 exposure. Finally, a roadmap for collaboration with SP in Sweden and BRANZ in New Zealand will also be developed; SP and BRANZ have expressed interest in joining the furnace testing as part of this project.

Reduced Scale Experiments at NIST

Property determination is one important aspect of the data collection needed to be able to model the performance/failure of such assemblies; the results presented are part of a NIST effort to quantify gypsum board properties for various gypsum board types. The basic premise is to generate a database of these properties using a suite of in house metrology methods. This methodology will afford a uniform and consistent database for the needed properties necessary to model gypsum board assembly performance under a fire load. The time dependant properties of interest include the thermal conductivity, specific heat, mass loss, linear contraction for gypsum, and bending strength. For linear contraction measurements, new measurement methods will be developed based on non-intrusive image analysis. For thermal conductivity as a function of temperature, new measurement methods developed within BFRL (Mr. Dale P. Bentz) for fire resistive materials (FRMs) will be applied to gypsum board; application of these techniques will enhance understanding of gypsum dehydrations reactions on thermal conductivity determination.

Recent Results:

Output:

Manzello, S.L., Park, S.., Mizukami, T., Bentz, D., "Measurement of Thermal Properties of Gypsum Board at Elevated Temperatures," *Proceedings of the 5th Int'l Conference Structures in Fire*, 656-665, Singapore, 2008.

Manzello, S.L., Grosshandler, W.L., Mizukami, T, "Furnace Testing of Full-Scale Gypsum Steel Stud Non-Load Bearing Wall Assemblies: Results of Multi-Laboratory Testing in Canada, Japan, and USA," *Proceedings of the 5th Int'l Conference Structures in Fire*, 687-698, Singapore, 2008.

Manzello, S.L., Gann, R.G., Kukuck, S., Lenhert, D., "The Influence of Gypsum Board Type (Xor C) on Real Fire Performance of Partition Assemblies," *Fire and Materials* 31:425-442, 2007.

Grosshandler, W.L., Manzello, S.L., Maranghides, A., Mizukami, "Analysis of Inter Laboratory Testing of Non-loadbearing Gypsum/Steel-Stud Wall Assemblies," NISTIR 7471, 2007.

Manzello, S.L., Gann, R.G., Kukuck, S.R., Prasad, K., and Jones, W.W., "Performance of Non Load Bearing Steel Stud Gypsum Board Wall Assembly: Experiments and Modeling," *Fire and Materials*, 31:297-310 (2007).

Manzello, S.L., Gann, R.G., Kukuck, S.R., Prasad, K., and Jones, W.W., "Fire performance of a Non-Load Bearing Glass Wall Assembly," *Fire Technology*," 43:77-89 (2007).

Co-hosted NIST/NRC Workshop on Characterization of Gypsum Wallboard at High Temperatures, NIST, Gaithersburg, MD September 26-27, 2007.

Outcomes:

- Unique experimental methods developed, including non-intrusive image analysis to quantify linear contraction of gypsum board at fire temperatures; controlled loading of a gypsum wall with fire exposure..

- Formal collaboration established between BFRL-NIST and CBL in Japan (July 2008).

Standards and Codes: We will work with manufacturers, professional societies such as SFPE, and standard bodies to integrate the results of this project into practice. ISO TC92 SC2, which maintains ISO 834, is currently examining the extent to which ISO standards for fire resistance can be adapted to provide information for fire safety engineering. ASTM E5, which maintains ASTM E119, is undertaking a similar effort for its standards.