Research in Progress

Advanced Housing Research Center
Forest Products Laboratory
Madison, Wisconsin

Phase I: Higher Order Theories for Analysis of Structural Insulated Panels

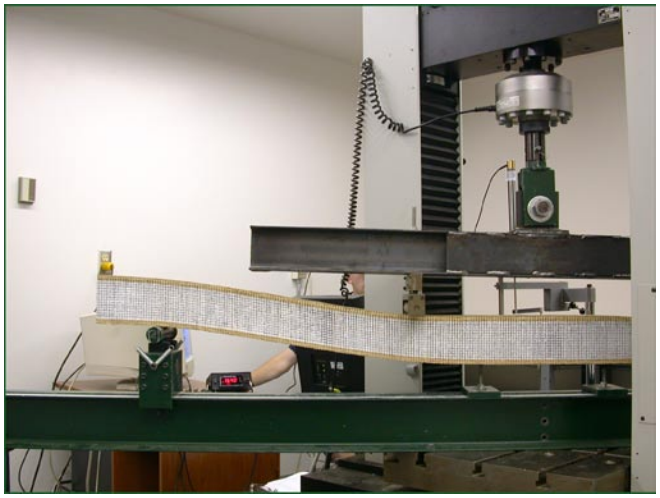

Figure 1. Testing of a SIP in flexure.

A structural insulated panel (SIP) is an engineered composite product composed of an insulating foam core sandwiched between two face sheathings (skins). The core provides the insulation and rigidity; the face materials provide durability and strength. Panels with expanded polystyrene (EPS) core and oriented strandboard (OSB) skins are the most popular in residential applications for load-bearing walls, floor panels, and roof panels. SIPs are finding increasing popularity as an alternative to the conventional framing system in construction because of their energy efficiency, ease and speed of construction, cost effectiveness, and interest in utilizing small-diameter logs.

Background

National and local building codes recognize SIPs as a proprietary engineered building component. Like any other proprietary building product, the recognition and approval process (Acceptance Criteria AC04) requires extensive testing followed by ongoing quality control. Acceptance Criteria AC04 requires at least three replicas of full-size panels to be tested for intended applications. Testing large panels is expensive and time consuming. Instead of full-scale testing of all different sizes of panels, AC04 also permits the use of rational modeling based on properties derived from panel component tests followed by limited confirmatory tests on full-size panels. Manufacturers have been reluctant to pursue modeling techniques due to lack of reliable rational models and uncertainty that the models will be accepted by code agencies. Although it is expensive and time consuming, they find it easier and safer to go with the full test program of AC04. Basic research is essential to develop rational analytical models to accurately predict the mechanical response of SIPs.

Composite and sandwich panels have long been used in the automotive and aircraft industries. These industries have successfully used finite element and other numerical models to solve these complex engineering problems. However, very limited attempts have been made to apply numerical techniques to predict the response of SIPs in the construction industry. The basis of this approach is to predict the global behavior of the SIP based on the behavior of the constituent material.

A rational model that accurately predicts the performance of a panel is likely to minimize full-scale tests of panels for code acceptance. A modeling tool would also allow the behavior of panels to be investigated under different load combinations.

Objective

The objectives of the project are to

- investigate finite element models to predict the behavior of structural insulated panels with OSB skins and EPS cores subjected to transverse loads and
- develop simplified design equations based on component material properties of the panel.

Approach

The scope of the overall project will be limited to SIPs with oriented strandboard skins and EPS cores. Flexural testing of the panels was limited to 4-in. by 2-, 4-, 6-, and 8-ft beams from one manufacturer.

Modeling of SIPs can be accomplished in four steps:

1. Establish mechanical properties of the panel components—OSB sheathing and EPS core
2. Develop a finite element model that adequately represents the response of the constituent materials (EPS and OSB)
3. Verify the response of the model with test data
4. Evaluate the sensitivity of the model for different load combinations and variations in material properties, then develop simplified design equations to predict deflections and strengths of a panel with known material properties of the components

Expected Outcomes

Analytical models are likely to enhance flexibility and innovations in the SIP industry. Because a rational model will minimize full-scale tests of panels, time required in the panel development process will likely be reduced. Modeling techniques will reduce the cost of panels, making them more competitive with conventional framing systems.

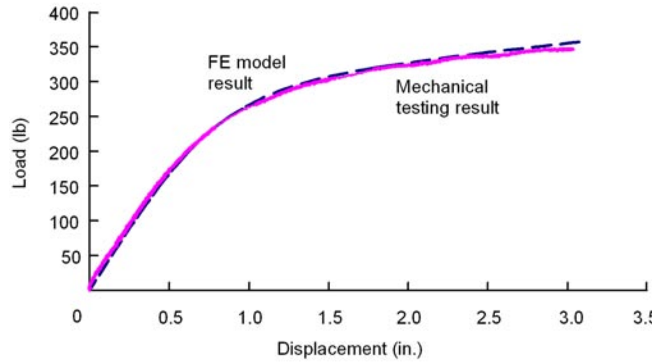

Figure 2. Flexural testing with finite element model results for an 8-ft-long beam with 6-ft span.

Timeline

The experimental procedures have been completed (Figure 1), and the mechanical behaviors of the core and sheathing have been modeled. These models have been incorporated into a finite element analysis, and the results have compared very well (Figure 2). Task 4 remains to be undertaken to develop the simplified design equations for SIPs. The parametric study and development of simplified design equations will be completed by March 2005.

Cooperators

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