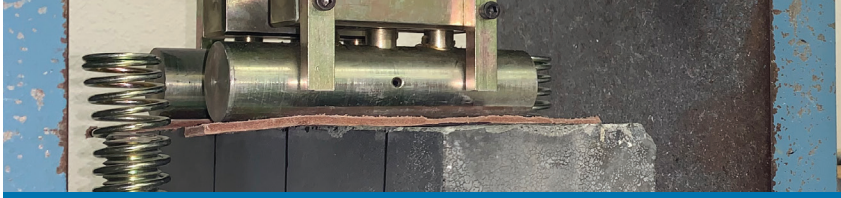


PCI-funded research on insulated wall panels shows their strength

Andrew Osborn

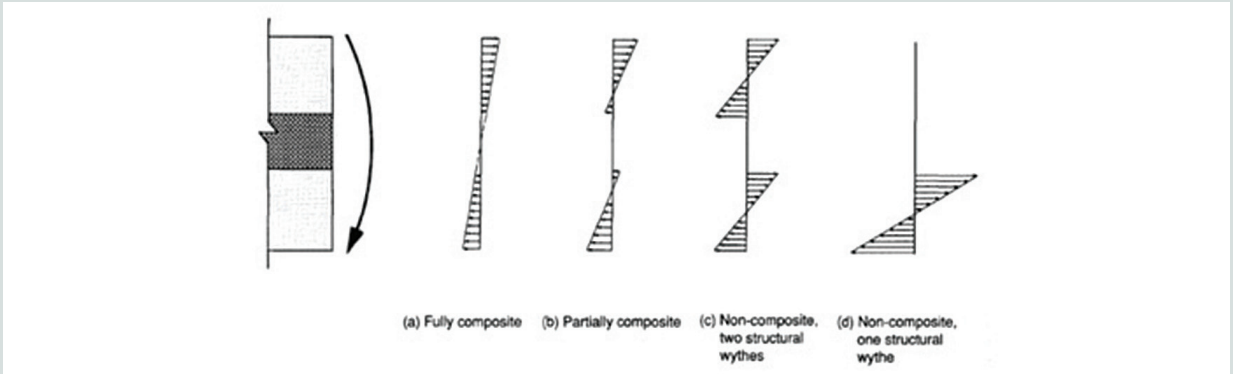
The theme of this issue of the *PCI Journal* is "Slabs, Panels, and Hollow-core." Numerous research and development projects have investigated various aspects of these three component types, and this Research Corner focuses on precast concrete insulated wall panels, which are sometimes called sandwich panels.

A precast insulated wall panel has rigid insulation sandwiched between inner and outer wythes of concrete. The main purpose of the insulation is to reduce heat (in other words, energy) loss through the panel, but the insulation also provides sound attenuation and impact energy absorption. Connections between the individual concrete wythes are necessary to tie the panel together. Connections may comprise solid zones of concrete or distributed or individual ties fabricated from metal, rigid polymer composite, or carbon-fiber materials. The greatest degree of composite behavior is achieved by using solid zones of concrete to connect the wythes, but this results in the poorest thermal performance.

The concrete wythes may be reinforced with non-prestressed steel reinforcing bars or mesh, fiber-reinforced-polymer bars or mesh, or may be prestressed with prestressing strands. Both concrete wythes may be designed as structural, in which case the mechanical ties are intended to provide some degree of composite behavior and the two wythes act as a system to resist external lateral and gravity loads. Sometimes just the inner wythe is structural and the outer wythe primarily provides weather protection and impact resistance. In this case the mechanical ties transfer wind forces from the outer wythe to the inner wythe.

There have been many PCI-funded projects that investigated precast concrete insulated wall panels, but three key aspects prevail:

- their composite structural behavior



Degrees of composite behavior. Source: Olsen et al. (2019).

- their thermal performance
- their resistance to blast loads

Studies funded by PCI have also examined panel response to seismic loads, impacts, and differential volume change.

Several researchers[1–3] have studied the degree of composite behavior afforded by different types of wythe connectors. Some composite behavior is achieved through the rigid insulation alone. Full composite behavior means that bending from an out-of-plane load will generate a uniform strain profile with compression in one wythe and tension the other wythe. Noncomposite behavior means that each wythe resists a portion of the out-of-plane load independently, with each wythe undergoing compression on one face and equal tension on the opposite face. Partially composite panels fall between a fully composite and noncomposite panel. The figure from Olsen et al.[3] illustrates varying degrees of composite behavior.

Lee and Pessiki[4,5] studied the heat transfer properties of the insulated wall panels through testing and analysis and found that connections between wythes serve as thermal conduits. The total thermal performance of a panel was found to be analogous to the resistance of an electric circuit with two resistors in parallel, namely that the inverse of total resistance.

$$A_{total}/R_{total} = A_{insulation}/R_{insulation} + A_{connection}/R_{connection}$$

where

A_{total} = total face area of panel
R_{total} = total effective R-value
$A_{insulation}$ = total face area of the insulation
$R_{insulation}$ = R-value of the insulation
$A_{connection}$ = total face area of the solid zones
$R_{connection}$ = R-value of the solid zones

Hence, solid concrete areas tend to degrade the thermal performance disproportionate to their relative size. As a result of this research, panel design standards encouraged minimal ties between wythes to achieve the maximum energy benefit. One consequence of this is a reduced composite interaction between wythes. One research project[4] studied triple-wythe panels with two layers of insulation and offset concrete wythe between layers in order to maximize both energy performance and structural behavior benefits.

Recently, several research projects[6–8] have focused on the blast resistance of precast concrete insulated wall panels. Panels were erected in frames and subjected to impulsive loads generated by explosives at varying standoff distances. Precast concrete panels with suitable connections and ties have demonstrated excellent blast resistance. Mander et al.[7] and Alawad et al.[8] summarize the results of past PCI funded research and provide design guidelines.

Research implemented in practice has demonstrated that insulated wall panels provide an excellent building enclosure system. They can be designed to be energy efficient while at the same time providing strength to resist environmental and human-generated loads. Guidelines for the use of insulated wall panels can be found in "State of the Art of Precast/Prestressed Concrete Wall Panels, Second Edition"[9,10] with updated information related to blast-resistant design in Mander et al.[7] and Alawad et al.[8]

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