White Paper WP002

Demystifying R-Values

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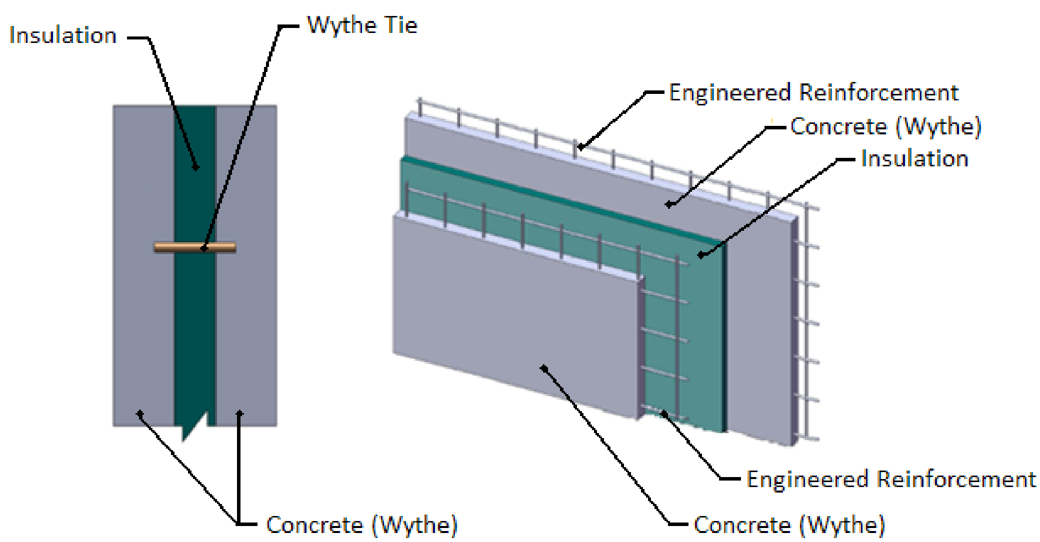
EnCon produces four types of insulated precast concrete products: Insulated Wall Panels, Styrocore Insulated Wall Panels, and AltusGroup™ CarbonCast® Architectural Spandrels and Insulated Wall Panels. This paper will describe the difference in Steady State R-Values and other terms that are loosely used in the industry, "Mass Enhanced R-Value" and "Effective R-Value".

Insulated Precast Panels

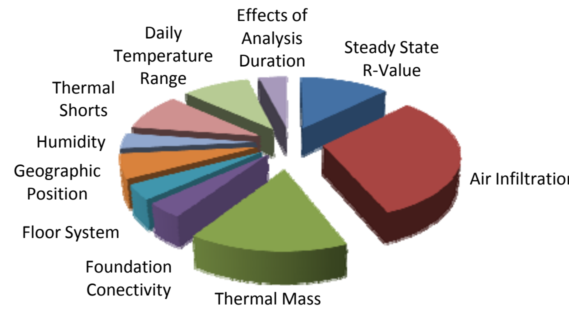
The following image depicts a typical precast insulated wall panel. A portion of the concrete or thermal mass is in contact with the interior space giving it the greatest thermal advantage over other building systems[1].



The inner and outer concrete thicknesses are called *Wythes*, and they are connected together with Wythe Ties. These ties can be steel, carbon fiber or for the purposes of this paper, solid zones of concrete. It is the intent of most designers to minimize these ties to prevent thermal shorts or thermal bridging. A thermal bridge creates a direct path for the transfer of heat and reduces the effect of the insulation within the wall system. Carbon fiber solutions have a superior advantage as they can be designed to develop composite action between the wythes of concrete while nearly eliminating the thermal short.

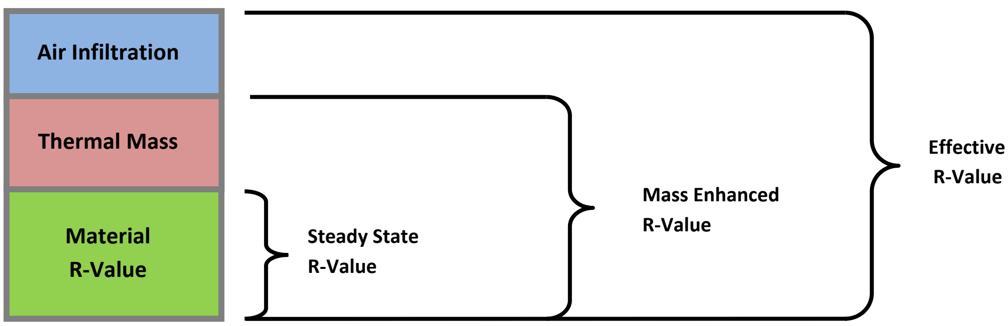
R-Values

R-Value, *Thermal Resistance*, is one measurement of the thermal performance of a system. The following chart depicts the many of the factors that impact the thermal performance of a structure.



There are two types of R-Values discussed in the construction industry, Steady State R-Values and Effective R-Values. The Steady State R-Value is based on the measured resistances of the construction materials that comprise the system for a given assembly of materials.

Although there are a number of factors that influence R-Value, the Effective R-Value is primarily a combination of Steady State R-Value, Thermal Mass, and Air Infiltration.



Thermal Mass, Mass Enhanced, or Mass Effect?

Mass Enhanced R-Values account for the material's ability to absorb, store, and release heat as needed. This phenomenon reduces temperature fluctuations within an occupied environment. The more thermal mass a structure has in direct contact with the interior space the greater the impact created by the thermal mass[2]. In addition, geographic climate plays a significant role in the affect of this thermal mass; in a given day structures in regions with small temperature variations will receive less of an impact than those structures in climates with larger temperature variations.

Air Infiltration

Air infiltration can account for as much as 20% to 40% of a structure's heat load requirement. Minimizing this leakage can dramatically improve the performance of the mechanical systems. When sizing mechanical equipment, the potential for air infiltration should be recognized in areas such as the position of dock doors, the quantity of man-doors, as well as the envelope detailing.

Potential Comparison Methods

At the writing of this report there are no standard methods of calculating Effective R-Values. At a minimum one could interpret the ***Table B-17, Building Envelope Requirements[3]***, and use the maximum required U-Value, *Coefficient of Heat Transmission*, $\left(U = \frac{1}{R}\right)$ as the basis for a mass effect multiplier. However, it would only be a basis of comparison for a Mass Wall system and Non-Mass Wall system. (Table B-17 is for the Denver, Colorado vicinity; there are tables for other geographic regions.)

Using ***Table B-17***, assuming that steel-framed structures are the least thermally efficient due to thermal shorts in the steel stud framing.

$$U_{\text{Mass Wall Structure}} = 0.123$$

$$U_{\text{Steel Frame Structure}} = 0.084$$

$$\text{Mass Wall Benefit (MWB)} = \frac{U_{\text{Mass Wall Structure}}}{U_{\text{Steel Frame Structure}}} = \frac{0.123}{0.084} = 1.46$$

Another method is the development of a multiplier for mass wall systems, Dynamic Benefit for Massive Systems, (DBMS)[2]. This multiplier relates the Steady State R-Values to Effective R-Values using a standardized lightweight wood frame structure as a base line. The standardized home is modeled with each wall system in order to determine the total building energy load for a given duration and climate. The Steady State R-Value of the exterior wall system of the standardized lightweight wood framed home is then manipulated until the energy loads are the same as the mass wall system in question. The ratio of the Steady State R-Value of the modified wood structure to the Steady State R-Value of the mass wall system is equal to the DBMS. One benefit of this approach is that it allows for the evaluation of similar mass wall construction techniques, wall assemblies of sandwiched insulation, and wall assemblies of sandwiched concrete. Results for the Denver area shown below for an averaged DBMS multiplier:

Wall System	**Material Order**	**DBMS***
Precast Insulated Wall Panel	Concrete – Insulation – Concrete	1.87
Generic Mass Wall	Insulation – Concrete – Insulation	1.50

* Results are from an average over 6 samples, 3 sample points for R-17.2 test and 3 sample points for the R-13.0 tests

It is interesting to note that the lower bound of values found in this report[2] are of the same magnitude as those using the proposed Mass Wall Benefit value developed from U-Values found in ASHRAE 90.1 Table B-17.

What Designers Should Compare

Whenever one system or method is compared to another it is important to make sure the comparison is of sound judgment and of equal benefit. The industry standard for thermal performance comparison should be a comparison of Steady State R-Values. Comparing terms that relate constructability or results of non-standardized calculation methods create unequal comparisons. ASHRAE 90.1[3] defines a method of calculating R-Values for assemblages of mixed materials, and many methods have been developed and tested that comply with this code requirement. Although the standard recognizes thermal effect in its definition of ***Mass Wall***[3], it provides little to no guidance on the creation of comparative calculation techniques. It has been shown that there is a significant advantage when using a mass wall construction method and that precast panels of Concrete–Insulation–Concrete can enhance performance.

EnCon's Insulated Precast Concrete Products are available in numerous shapes, sizes, and architectural finishes with a variety of reinforcing techniques. The method used to calculate the Steady State R-Value of the assembly follows the "Characteristic Section Method".[4] This method is an excellent predictor of R-Values with variations in material thickness, solid zones, or thermal shorts. It has been adopted by the PCI Handbook[5] as the preferred method of calculating R-Values for complex assemblies.

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Includes subsidiary companies and insulated precast products manufactured by
EnCon Utah, EnCon Washington, EnCon Colorado, Stresscon Corporation, Atlanta Structural

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1. J. Kosny, T. Petrie, D. Gawin, P. Childs, A. Desjarlais, and J. Christian, "Thermal Mass – Energy Savings Potential in Residential Buildings", Buildings Technology Center, Oak Ridge National Labs, updated 2001

2. Dr. J. Kosny, Dr. E. Kossecka, A. Desjarlais, and J. Christian, "Dynamic Thermal Performance and Energy Benefits of Using Massive Walls in Residential Buildings", Oak Ridge National Labs and Polish Academy of Sciences, updated 2001

3. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., ASHRAE Standard 90.1 (IP Edition), New York, 2001

4. You-Joung Lee, Stephen Pessiki, "Development of the Characteristic Section Method to Estimate Thermal R-Values for Precast Concrete Sandwich Wall Panels", ATLSS Report No. 03-06, Pennsylvania, 2003

5. Precast Prestressed Concrete Institute, PCI Design Handbook 6th Edition, Illinois, 2004

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