National Bureau Of Standards Tests Confirm Energy-Conserving "Thermal Mass Effect" For Heavy (Log) Walls In Residential Construction

Summary of Test Findings

A study was conducted by the National Bureau of Standards (NBS) for the Department of Housing and Urban Development (HUD) and the Department of Energy (DOE) to determine the effects of thermal mass (the bulk of solid wood log walls, or brick and block walls) on a building's energy consumption. For the test, six 20'x20' test buildings were built on the grounds of the National Bureau of Standards, 20 miles north of Washington, DC, in the fall of 1980. Each structure was identical except for construction of its exterior walls. The buildings were maintained at the same temperature levels throughout the 28-week test period between 1981 and 1982. NBS technicians precisely recorded energy consumption of each structure during this entire period.

Test Results

- During the three-week spring heating period, the log building used 46% less heating energy than the insulated wood frame building.

- During the eleven-week summer cooling period, the log building used 24% less cooling energy than the insulated wood frame building.

- During the fourteen-week winter heating period, the log building and the insulated wood frame building used virtually the same amounts of heating energy.

The National Bureau of Standards technicians conducting the test calculated the R-value of the log building, which was constructed with a 7" solid square log, at a nominal R-10. It rates the insulated wood frame building, with its 2'x4' wall and 3-1/2" of fiberglass insulation, at a nominal R-12, thus giving the wood frame structure a 17% higher R-value. Yet during the entire 28 week, three season test cycle, both buildings used virtually identical amounts of energy. This led the National Bureau of Standards to conclude that the thermal mass of log

walls is an energy-conserving feature in residential construction.

NBS Tests Confirm Energy-Conserving "Thermal Mass Effect" of Log Walls

Full Report

In the first extensive field testing of its kind, researchers at the Commerce Department's National Bureau of Standards (NBS) have confirmed that walls of heavyweight construction (such as those built with solid wood logs, concrete block or brick) exhibit an energy conserving "mass effect" in residential buildings during the summer and the intermediate heating season representative of fall or spring in a moderate climate. However, no mass effect was observed during the winter heating season.

According to NBS researchers, these extensive field tests should help resolve a controversy over whether residences having heavyweight walls consume less energy for space heating and cooling than buildings having lightweight walls of equivalent thermal resistance.

The National Bureau of Standards research team found that the heavyweight walls (including building number 5, the log structure) "did exhibit a thermal mass effect and thus save significant amounts of energy both in the summer cooling season and the intermediate heating season representative of fall or spring in this (Washington, DC) area."

The Use of R-Values

Most state and local building codes require specific "R-Values," or thermal resistance values, for the walls, ceilings, and floors of houses. The R-Values in these codes vary with geographical location and climate considerations. The Building Systems Councils' technical staff and other industry professionals have often challenged the exclusive reliance on R-Values alone to rate the energy efficiency of a wall's building materials while ignoring the thermal mass effect inherent in heavyweight (log) walls. R-Values are recognized by most professionals to be a reliable indication of the thermal performance of a material--under conditions of constant interior and exterior temperatures. The Building Systems Councils' technical staff argues that these are not the conditions that exist in the "real world," where outdoor temperatures vary widely during a typical day-night cycle. To

obtain a true rating of building's thermal efficiency in these conditions, building codes must also consider the "mass effect" of heavyweight (log) walls.

What Is "Mass Effect"?

According to NBS researchers, "the mass effect relates to the phenomenon in which heat transfer through the walls of a building is delayed by the high heat (retention) capacity of the wall mass. Consequently, the demand for heating or cooling energy to maintain indoor temperature may, under some circumstances, be pushed back until a time when wall heat transfer and equipment operating conditions are most favorable." This heat retention phenomenon is also referred to as "thermal capacitance" or time lag--the resistance of a material (such as solid wood walls) over time to allow a change in temperature to go from one side to the other.

How Mass Saves Energy

NBS researchers explained the energy saving effect of mass during the summer cooling season this way: "In an insulated wood frame building, which is considered to have low mass, the maximum wall heat gain rate during this season is operating most often and working the hardest. In a heavy walled building (such as the log building), however, the heat transfer lag means the maximum wall heat gain rate general during the cool night period when the cooling plant is operating least often or not at all. Consequently, the cooling energy requirement is reduced."

The NBS test showed that the log structure performed better than the insulated wood building in the intermediate heating season and the summer cooling season; however, there was no appreciable difference during the winter heating season. During the winter heating season, no effect of mass was noted since all insulated buildings and the log building required comparable amounts of heating energy each hour to maintain their predetermined indoor temperatures.

Test Limitations

As with all such test procedures, these tests have their own limitations, according to NBS, and therefore these factors should be considered in using the results. The structures had no partition walls or furniture; items which would tend to give the wood frame structures some of the mass effect. Also, the buildings were closed at all times, and the buildings were constructed to maximize the mass effect

attributable to the walls.

- Also, the results are very climate dependent, and results relate to the moderate climate found in the Washington, DC, area.

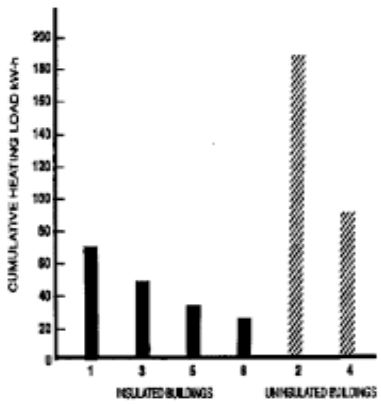
Future Tests

Future tests to be carried out on the six buildings will address some of these limitations by installing partition walls and opening windows when appropriate. Moreover, a recently developed NBS computer model that predicts the energy consumption for multi-room structures will be validated and subsequently used to extend the NBS test results to other locations and climates around the country.

Conclusion

The Building Systems Councils is gratified that its long struggle to gain recognition for the importance of "thermal-mass" has been confirmed by these tests and that the energy efficiency of log homes has been proven. The Council is presently participating in a similar testing program being conducted by the Oak Ridge National Testing Laboratory in Albuquerque, New Mexico, and hopes to add the results of those tests to this material in an effort to gain acceptance of "thermal mass effect" in building codes throughout the country. We further await the results of future tests to be performed by the NBS at this test site and the results of the NBS computer-modeling program.

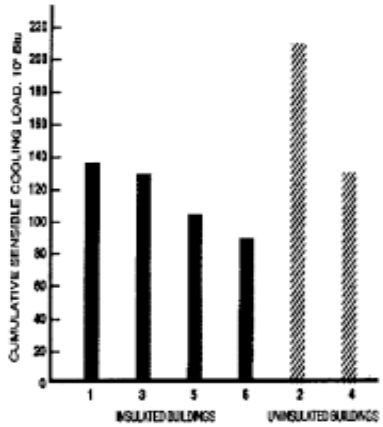
A-Intermediate Heating



During this 3-week intermediate (spring/fall) heating season, the log building #5 used 46% less heating energy than the insulated wood frame building #1.

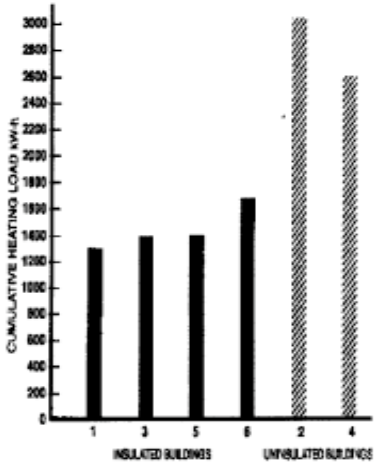
Note: See back page for construction details of these six buildings.

B-Summer Cooling



During this 11-week summer cooling season, the log building #5 used 24% less cooling energy than the insulated wood frame building #1.

C-Winter Heating



During this 14-week winter heating season, the R-10 rated log building #5 used almost the same amount of heating energy as building #1, the insulated wood frame with its R-12 walls, and building #3, the insulated masonry building with its R-14 walls.

Technical Information

Description of Test Buildings

Six 20' wide and 20' long one room test buildings with a 7-1/2" high ceiling were constructed outdoors at the National Bureau of Standards facility located in Gaithersburg, Maryland (20 miles north of Washington, DC).

Construction Details of Walls

Building #1

An insulated wood frame home, nominal R-12 (without mass) with 5/8" exterior wood siding, 2x4" stud wall, 3-1/2" fiberglass insulation, plastic vapor barrier, and 1/2" gypsum drywall.

Building #2

An un-insulated wood frame home, nominal R-4 (without mass) with same detail as above, but without the fiberglass insulation.

Building #3

An insulated masonry home, nominal R-14 (with exterior mass) with 4" brick, 4" block, 2" polystyrene insulation, plastic vapor barrier, furring strips and 1/2" gypsum drywall.

Building #4

An un-insulated masonry home, nominal R-5 (with exterior mass) with 8" block, furring strips, vapor barrier, 1/2" gypsum drywall, and no polystyrene insulation.

Building #5

A log home, nominal R-10 (with inherent mass) with 7" solid square wood logs with tongue and groove mating system, no additional insulation, no vapor barrier, and no interior drywall.

Building #6

An insulated masonry home, nominal R-12 (with interior mass) with 4" brick, 3-1/2" loose fill perlite insulation, 8" block and 1/2" interior plaster walls.

Interior/Exterior Surfaces

Interior surfaces were painted off-white. Exterior surfaces of buildings 1,2 and 4 were painted approximately the same color as the exterior face brick of buildings 3 and 6.

Windows
Four double-hung, insulating glass (double pane) windows, with exterior storm windows, two in south facing wall, two in north facing wall. Total window area was 43.8 sq. ft. or 11% floor area.

Doors
One insulated metal door on east wall. Total door area was 19.5 sq. ft.

Ceiling & Roof System
Each test building contained a pitched roof with an attic space ventilated with soffit and gable vents. The ventilation opening was consistent with the HUD Minimum Property Standards. Eleven inches of fiberglass blanket insulation (R-34) was installed over the ceiling of each test building.

Floor System
The edges of the Concrete slab-on-grade floors were insulated with 1" thick polystyrene insulation at both the inner and outer surfaces of the footing.

Heating/Cooling Equipment
Each test building was equipped with a centrally located 4.1 kW electric forced air heating plant equipped with a 13,000 Btu/h split vapor-compression air conditioning system.

Technical Report Available

A complete technical presentation of this study was prepared by D.M. Burch, W.E. Remmert, D.F. Krintz, and C.S. Barnes of the National Bureau of Standards, Washington, DC, in June, 1982, and is entitled "A Field Study of the Effect on Wall Mass on the Heating and Cooling Loads of Residential Buildings." This study was presented before the "Thermal Mass Effects in Buildings" seminar held in Knoxville, Tennessee, on June 2-3, 1982, Oakridge National Laboratory, Oakridge, Tennessee.

Copies of this report and other studies are available by writing to: US Department of Commerce, National Bureau of Standards, Center for Building Technology, Building 226, Room B114, Gaithersburg, MD 20899.

BSC's Participation

The log building used by the National Bureau of Standards for this energy conservation study was donated and erected by members of the Log Home Council. Since the inception of the Log Homes Council in 1977, well over a quarter of a million dollars have been spent on research and testing projects related to the log home industry.

Members of the Council have voluntarily contributed tens of thousands of hours of their time to accomplish these tasks for the benefit of the industry and the builders and owners of log homes. On January 1, 1982, the Log Homes Council affiliated with the National Association of Home Builders as part of the Building Systems Councils. In July 1985, the Council membership expanded due to a merger with the North American Log Builders Association. All members of the Council are also individual members of the National Association of Home Builders and through their dues support the many worthwhile activities of the NAHB. The Log Homes Council is a non-profit, voluntary membership organization representing some sixty manufacturers of log homes.

A research report published by the Log Homes Council of the National Association of Home Builders, 1201 15th Street, NW, Washington, DC 20005 -- (800) 368-5242 ext. 576
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