17 THE POWERHOUSE HOME

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SUMMARY: For more than 100 years, builders throughout the United States have built homes using standard 2 x 4 wood construction; today more than 90% of homes built in North America feature this type of building. Recognizing the need for change, the need to significantly reduce a home's energy usage, enhance its design, improve comfort and focus on environmental issues, the concept for the PowerHouse Home was born. Created by VGI Design, an architectural and engineering firm based in Des Moines, Iowa, the innovative floor plan and design of the home prove that there are ways to make work and life safer, healthier and more comfortable. Built by Alliant Energy-Interstate Power and Light Company and the Des Moines based firm Zero Net, the PowerHouse Home uses a revolutionary new home building technology and features the latest in energy efficient building techniques, materials and appliances. Approximately 60 to 70% more energy efficient than a traditionally built home of the same size, the walls and roof are composed of expanded polystyrene panels bonded with premix GRC on both interior and exterior surfaces. The home is situated on a 1.5 acre lot in Newton, Iowa and offers 1,880 square feet of living area on the main level and 1,150 square feet in the walkout lower level.
KEYWORDS: Energy usage, GRC, polystyrene panels, premix GRC.

INTRODUCTION

This paper presents an innovative application of GFRC. We felt this special application of GFRC could address the global issue of energy efficiency while at the same time enhancing our living environment. We hope you are interested in what we show you today and we are available at the end of the presentation to answer all questions.

Figure 1

Condition
Over 90% of the North American housing market utilizes 2 × 4 (2in × 4in) wood framing for the building envelope. Up to 53% of the energy consumed is the result of loss through the building envelope.

Objective
Plan a home that utilizes traditional materials in a non-traditional manner to provide living and work spaces that provide levels of performance that heretofore had not been affordable; allow the owner more flexibility in choice of energy sources; develop a building system that offers a broad range of design options for multiple building types.

Performance
An effective building envelope is the primary determinant in allowing each component of the entire facility to achieve its maximum effectiveness. Our composite panel will:

- resist air, water, dust, noise and odor infiltration;
- resist snow, wind and earthquake loads;
- resist thermal transfer;
- provide uniform comfort at each level or room;
- allow high levels of natural lighting;
- be low maintenance;
- allow variation in design/character;
- not preclude the use of traditional interior systems.

Innovation
The integrated composite wall and roof system is an innovative design.

Building envelope construction
The exterior walls and roof are composite panels using conventional expanded polystyrene (EPS) as the core and a GFRC 'skin' on the interior and exterior surfaces. Walls are 8in thick and roofs are 12in thick. Because EPS can be cut to any shape and concrete can be applied to any shape, certain improvements in the building envelope can be achieved that were not possible with traditional methods. The roof/fascia/soffit assembly is fabricated as a single component. Windows and doors are adhered to the through-wall concrete skin with full-bed adhesives to resist infiltration. The panels are anchored to a composite wood post-and-beam frame and panel joints can either be expressed or concealed (exterior finish system). The result is a unified building envelope.

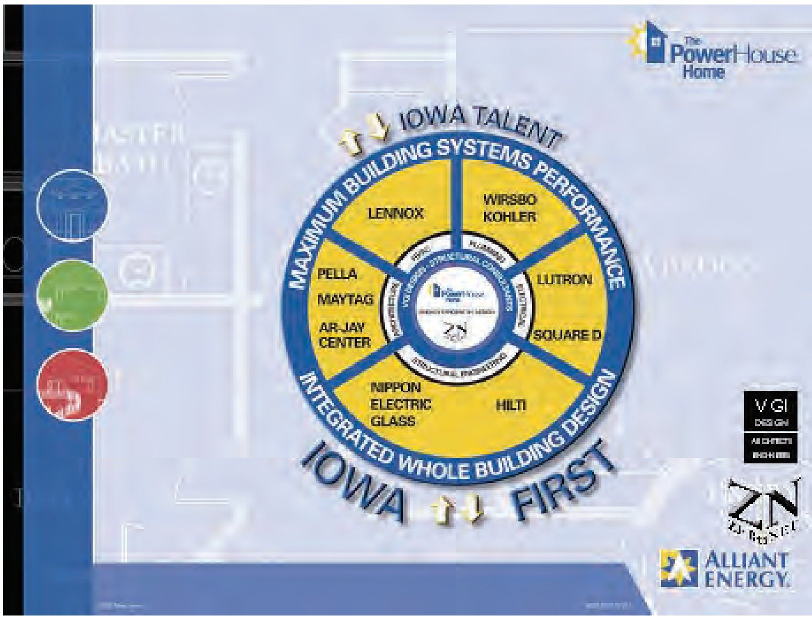

Figure 2

Not too many people, companies or other entities have addressed the complete redesign of a home building envelope.

It takes many like-minded people to accomplish the goal . . . all working together with forward vision.

This is why you do not see innovation in this important area. It is a fragmented industry.

Figure 3

The home specification is as follows:

- lower level is 1100 sq ft finished, 800 sq ft unfinished;
- upper level is 1900 sq ft finished;
- four-zone air conditioning;
- each room has in-floor radiant heat;
- 8-foot exterior doors;
- large triple pane, double low emissivity internally shaded windows
- design is orientation-independent
- it demonstrates that innovative geometric shapes can be accomplished.

Figure 4

The intention is to build a premium home that looks like any other but with a radical new design and materials:

- the exterior can have cultured stone, etc . . . applied to it;
- no soffit vents or roof vents are necessary; the attic is in conditioned space;
- it is an area of extreme interest for building researchers.

Figure 5

The design offers an innovative re-use of traditional materials:

- it requires advanced solid modeling, detailing, foam cutting and GFRC application techniques;
- it allows building system integration;
- erection of precast panels drastically reduces labour and number of trades;
- significant improvements cannot be made with traditional materials and building methods.

Figure 6

The initial prototype had no framing, roof joists, nails screws or drywall.

The PowerHouse Home had a pole barn type structure to hold up the roof. The next generation design will not have the wood framing and will be replaced with cast-in-place concrete.

Lower level walls consisted of ICF (insulated concrete forms) and structural GFRC insulated panels containing reinforcing bars.

Upper level wall panels were composite and not structural.

Figure 7

The envelope must be all encompassing, unified and sealed to make a significant difference.

Construction of the roof was not easy.

We had to invent a process as we were building but it proved satisfactory.

Figure 8

This shows more innovative building pieces including the turret section in foam and GFRC with complicated geometry.

Roof detailing was difficult because of thickness issues, as a result of major differences between roof parts built with plywood compared with composite.

Figure 9

This illustrates all stages of construction and components involved, notably roof panels, underlayment and roof tiles, which were fixed with a nail-less technique. The edges were completed with GFRC trim boards and components received a final cosmetic finish in desired colors.

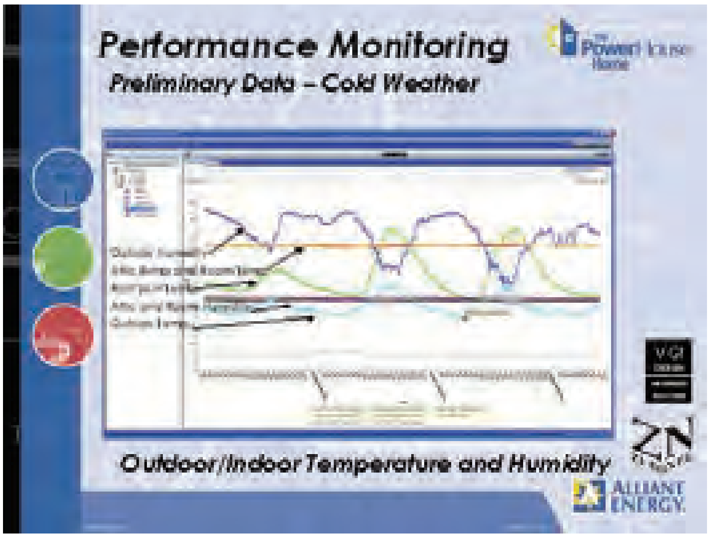

Figure 10

This graph shows some key features of home performance.

While outside temperature varies between 23°F and 40°F, there is virtually no change in inside temperature, attic temperature or space temperature.

Similarly while outside humidity varies greatly there is virtually no change in the attic or space.

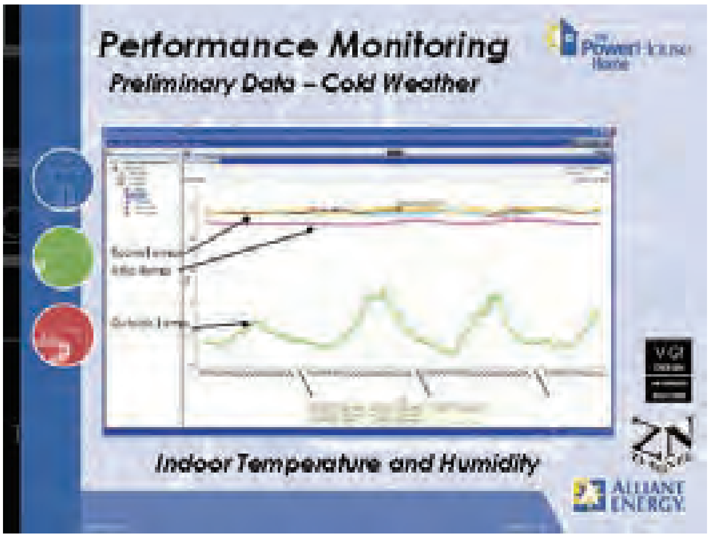

Figure 11

Further aspects of home performance are shown in this graph.

Individual space temperature graphs are superimposed on top of each other showing little variation of temperature gradients from room to room or level to level. This is extremely important to older people who are more sensitive to temperature.

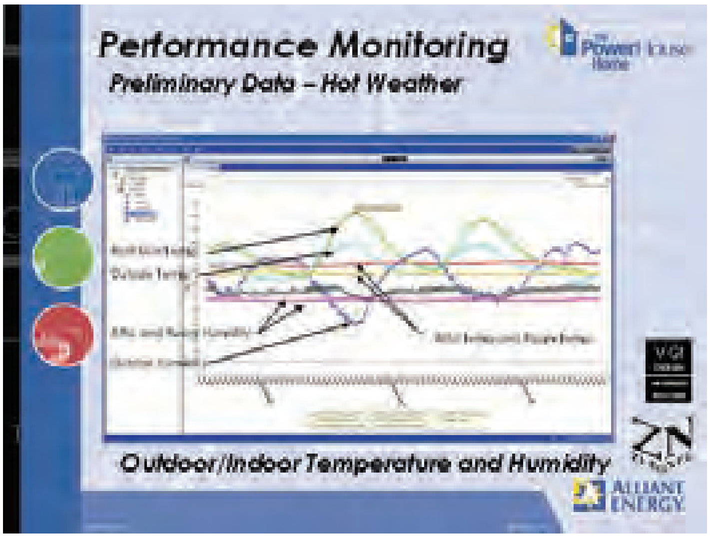

Figure 12

This graph illustrates that under an outside temperature variation between 65°F and 95°F there is virtually no change in inside temperature, attic temperature or space temperature.

Again, with outside humidity varying considerably there is only a small change in the space humidity and virtually no change in the attic humidity.

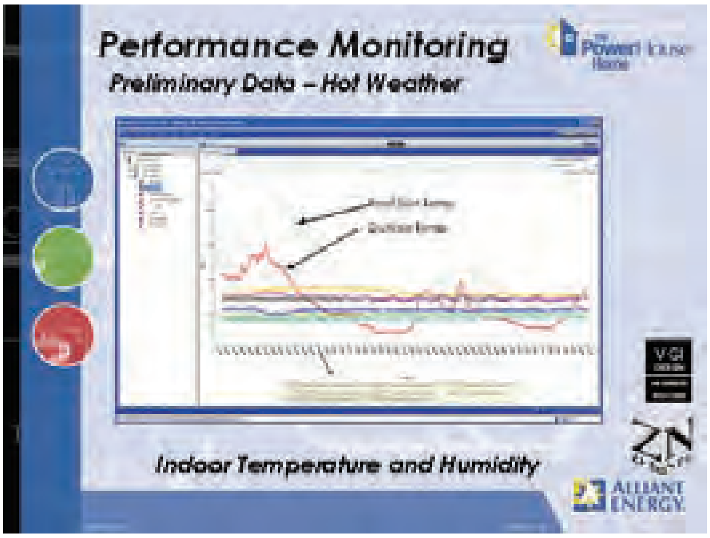

Figure 13

In conditions of high heat on the roof skin, high ambient air temperature and relative humidity, stable inside temperatures are still maintained.

Figure 14

This picture and those following illustrate the nature and degree of heat loss in a conventional 2 × 4 construction building. Black colors are cold temperatures and show extreme heat loss. There is significant heat loss where the two corners meet and the wall meets the roof.

The framing and headers around the windows are nearly all made from wood which does not provide any insulation.

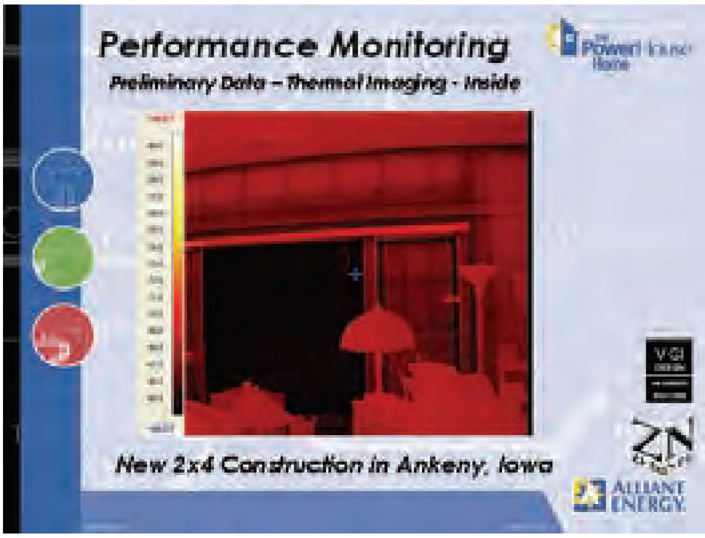

Figure 15

In this further view, as before, black colors signify cold temperatures and show extreme heat loss.

The significant heat loss is again visible where the wall meets the roof.

On close examination even the drywall screws are visible as cold spots.

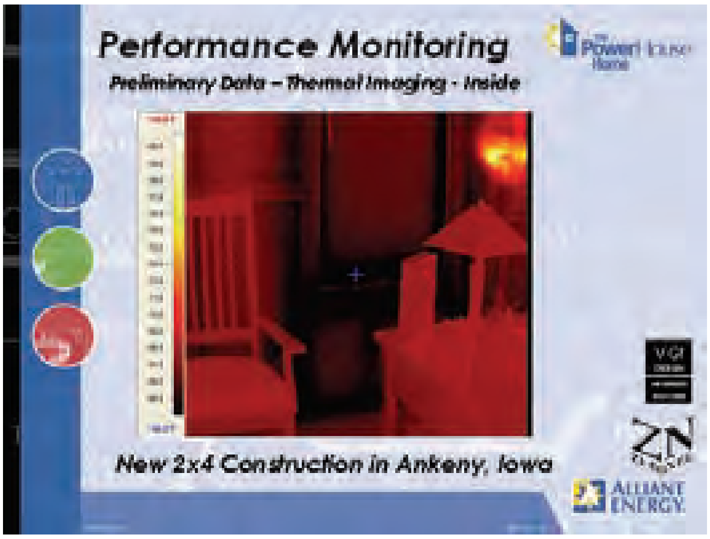

Figure 16

Again, the black colors are cold temperatures and show extreme heat loss.

There is significant heat loss around and below the windows and in this view significant loss at floors.

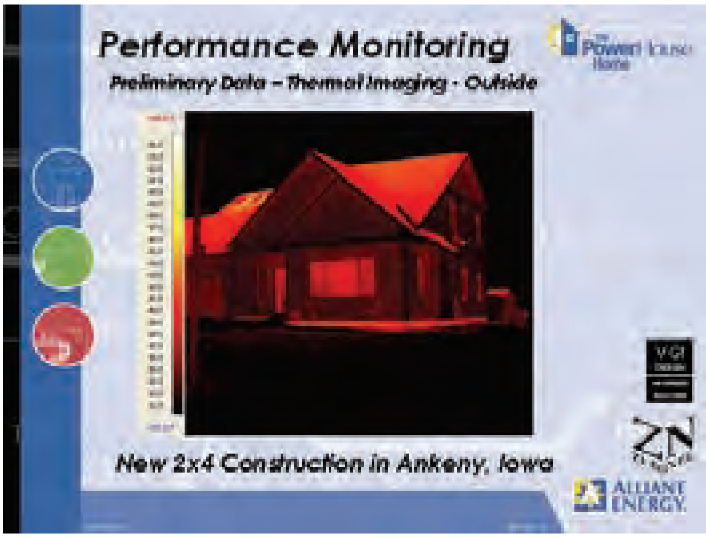

Figure 17

An alternative way of seeing the problem is from the outside looking in:

- this shows the opposite of colors inside;
- bright orange colors show extreme heat loss at the roof and foundation wall, and even more heat loss at the sky lights;
- on close examination the wood studs can be detected.

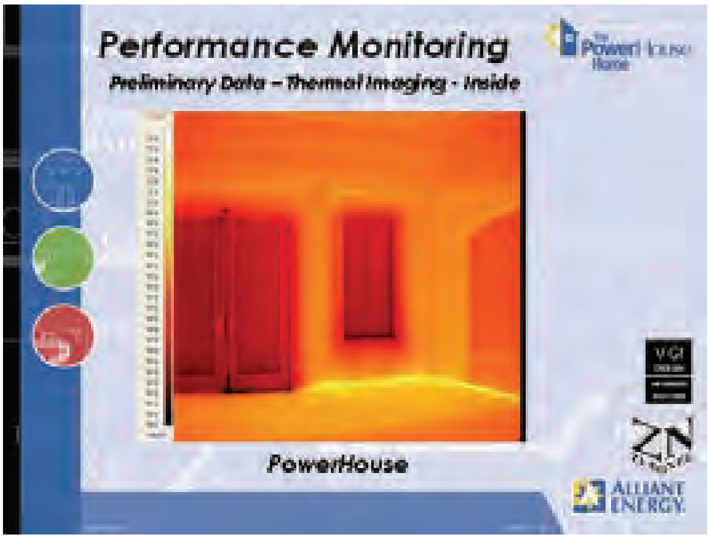

Figure 18

However, this is a same-day comparison with the PowerHouse, inside view:

- the effect of radiant heat floor on ceiling, walls and floor is visible;
- there are no signs of heat loss;
- the 'thermal-proof' behaviour proves the integrated design concept of a composite wall with internal thermal mass from GFRC;
- the radiant effect of in-floor heat is seen;
- If there is no heat loss at the wall, people do not radiate towards the heat loss areas and therefore do not feel cold. In fact, the walls are radiating heat and not losing it.

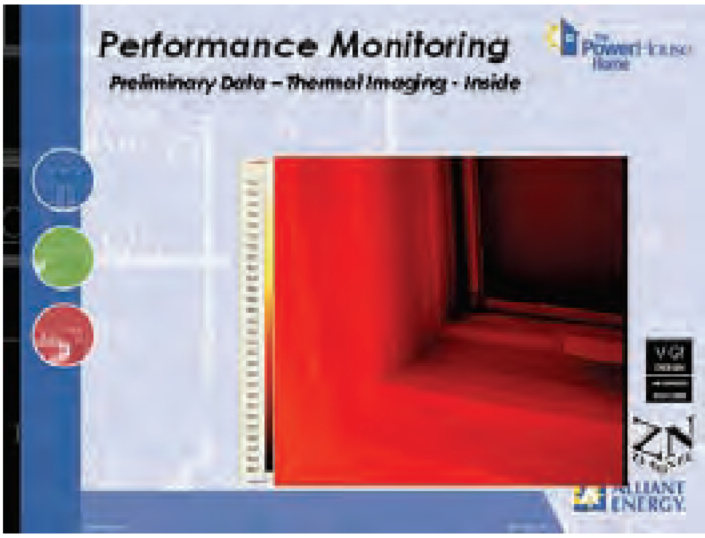

Figure 19

The detail of the window shows that there is very little heat loss at the window opening due to the special attachment technique used with the GFRC composite panel.

Figure 20

A general external view confirms that windows show heat loss compared with the wall areas.

There is no visible heat loss in the composite wall but only a small ribbon of heat loss where the roof meets the wall.

The roof itself is not visible as no significant heat loss is taking place.

Figure 21

The world is in an energy crisis and it is likely to get worse.

The PowerHouse Home project was a collective effort to offer significant change in how we build to conserve energy. It truly is 'energy efficient by design'. It provides alternatives for enhanced living and comfort for less cost. It significantly raises the standards for energy-efficient design and construction. This is surely something that any country badly needs now more than ever.

It is hoped that other like-minded people can see the possibilities and that this could lead to a new industry and new jobs.

We conclude that this is an innovative application of GFRC which we believe can address the global issue of energy efficiency while at the same time enhancing our living environment.