e3Co System

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Abstract
This report describes design enhancements and validation testing of the Ecological Comprehensive Component Construction (e3Co) System. The e3Co System is a prototype stage prefabricated building system which provides an alternative method of construction that is environmentally-friendly, reduces labor time and cost, and cuts down on construction waste. The system is made up of long and lightweight structural insulated panels that are stacked on top of each other, much like logs in a log cabin. With the past design, warped joint splines made panels difficult to assemble, the electrical chase system lacked durability and simplicity, and panels were made from petroleum based products. The focus of the redesign includes improving critical panel connections, developing a new internal electrical and plumbing chase system, and identifying more sustainable component materials. FEA models have been developed to structurally compare the newly designed elements to both previous e3Co designs and typical panelized structures. In addition, infiltration tests were performed on a 9’ by 9’ prototype building, and small scale structural testing was performed with prototype panels. These test results, along with building thermal analysis, show that the e3Co system will comply with International Residential Codes. Valuable comparisons are provided to show advantages of the new e3Co system over past designs and traditional panel construction methods. This information is critical for the e3Co system to progress as a business.
The Need for Project

A more robust and proven e3Co system design is critical to attracting investment and furthering the project. e3Co is currently looking for investors and grant funding to continue its existence. In order to secure this funding it is crucial to have a detailed, proven, and functioning system. A prototype of the past e3Co system has shown flaws in the lateral joint design (Rep. 7.1) as well as a need for reinforced corner pieces. Additionally, a system for integrating plumbing and electrical had not yet been fully developed. Further, no testing had been performed to prove the panelized design would sufficiently meet building code and Structural Insulated Panel (SIP) industry standards.

The Design Project Objectives and Requirements

The objective of this project is to develop a complete and validated e3Co system design that is low cost, light weight, simple to construct, and ecologically responsible. Design Objectives

The objective of this design is to create a fully integrated building system that is easily constructed by two persons in a matter of days. This includes the structural members, plumbing and electrical lines, and interior finish surface. Structural, thermal, and air infiltration analysis will be performed to validate the new design.

Design Requirements

The main requirement of the system is that it be inherently simple. Panel weights are limited to around 120 lbs, an amount that two persons could carry by hand. The cost must be competitive with traditional (larger) structural insulated panels, and the components must be considered environmentally responsible. The design is also limited by minimum performance standards described in the International Residence Code (IRC). The walls, floors, and ceilings must withstand deflection limits under applicable design loads (Rep 3.4). The electrical lines must run a minimum of 1 ¼” from the face of the finish surface. The IRC also requires a minimum R (thermal resistance) value of 3.1 ft²·°F·h/Btu.

Design Concepts Considered

Multiple design concepts were considered for the joints, internal chase system, and component materials. Joints

The structural part of the project focused on two key connections: the corner joints, and lateral panel joints. The past lateral joints consisted of two panels, each with negative space that accepted two
splines. To minimize the number of pieces, a system was designed that uses two panels, one with a negative space being stacked on top of another with a protrusion. The past system formed corners by butting two wall panels next to each other and inserting long screws. Two more robust concepts were generated: a full height, prefabricated corner piece and sheet metal ties to be used with butted wall panels.

**Internal Chase System**

The past system described a foam layer pre-attached to the interior of the panel through which electrical chases would be cut. Three new designs were developed. The first is a system that incorporates a grid-like pattern of oriented strand board (OSB) circles, onto which can be screwed into, embedded in a layer of foam on the surface of the panel. Horizontal chases are cut at 14” and 48”, and vertical chases are cut as necessary. The second is a series of vertical plastic studs for the drywall to be attached to, embedded in a layer of rigid foam, both of which have horizontal chases pre-cut. The third includes panels with the same vertical plastic studs pre-attached. An additional layer of compressible foam is rolled over the wires in the gaps after they are laid, overcoming the need to cut away at foam for vertical chases.

**Materials Assessment**

Alternative materials for the foam core and sheathing were researched and evaluated. Cores made of expanded polystyrene (EPS), extruded polystyrene, polyurethane, and Greensulate™ (Fungi grown insulation) were evaluated by cost, R value, and chemical composition. A thermal analysis provided a heat loss simulation of a structure using various foam insulating materials. Potential sheathing materials made from plywood, OSB, wood fiber-reinforced plastic, wheat board, and bamboo were researched.

**Recommended Design Concept**

Incorporate simple joint components, a prefabricated plastic stud chase system, OSB sheathing, and an EPS core.

**Design Description**

The final connections design incorporates the tongue-and-groove type lateral joints and metal corner brackets. These designs minimize the number of components and therefore simplify construction. The interior design is based on pre-attached vertical studs with chases, and a roll on foam. Typical SIP materials of OSB for sheathing and EPS for the foam core are recommended at this time. Desired alternative
Analytical Investigations

Finite Element Analysis of the lateral joints was performed to compare plausible designs and ensure that a wall consisting of panels will exceed the performance of traditional, full-sized SIP panels and meet building code requirements. All designs proved to meet IRC deflection limits for Axial (1/8”) and Transverse (Panel Length/120) loading. FEA structural simulations of the three corner joint configurations were also used to show the metal brackets achieved better uplift and torsion resistance than the prefabricated corner piece. The optimal internal chase system was chosen by evaluation through a decision matrix based on parameters such as ease of construction, functionality, and manufacturability. Calculations were made of the heat transfer rate, Q, of a typical building made of e3Co panels with either EPS or Greensulate™ core. EPS proved to perform better than Greensulate™ by 20%, due to Greensulate’s™ unsatisfactory R value per inch of 3.

Experimental Investigations

Air infiltration tests were performed on the prototype built from redesigned panels with 3 different joint sealing scenarios (Panel alone, Panel with foam sill seal, and taped joints). With the later set up, it took 875 CFM to develop a pressure of 50 Pa. The airflow required to achieve this pressure is much greater than that of a typical house (120 CFM) due to extensive leakage at the prefab corner joints.

Small scale structural testing was performed on the various lateral joint configurations in both transverse and axial loading scenarios to compare performance. While all designs exceeded requirements, the chosen tongue and groove design performed best under axial loading (holding 2436 lbf at 1/8” deflection) and worst under transverse loading (526 lbf at 1/8” deflection). The construction benefits of this design outweigh its marginally worse transverse performance.

Key Advantages of Recommended Concept

The redesigned concept is focused on ease of on-site construction and ecological responsibility. The new joints minimize components and allow for quicker installation. The vertical stud system allows
maining attachment points for drywall. The result is an inherently simple packaged residential housing system.

Financial Issues

Commercialization of the e3Co system is contingent on maintaining a cost advantage and securing strategic partners. The e3Co System must be able to compete financially with other building construction systems. Panels could be manufactured at existing SIP facilities. Multiple, smaller, more complex panels would make manufacturing costs greater than typical SIPs. However, since construction of e3Co is rapid and only requires two people with basic tools (rather than cranes), construction labor costs will be reduced significantly.

Securing strategic alliances with companies holding emerging technologies, such and Greensulate™ and Zip Wall (vapor barrier system) could prove crucial to maintained a competitive advantage if prefabricated component construction techniques become mainstream.

Recommended Improvements

Development of a better infiltration barrier, along with full scale cost analysis and testing would provide an entrance to the residential construction market. The infiltration tests show a significant issue with infiltration through the joints. Additional sealing mechanisms should be incorporated in the design and a prototype should be re-tested.

Additionally, The cost of e3Co system is greatly dependent on scale of production. Once a business scheme is developed, a full scale cost analysis should be performed. All SIP manufacturers get their products licensed by the industry organization, SIPA, before they are used in construction. This involves testing by an independent agency and can cost upwards of $30,000.