RESIDENTIAL UTILITY CORE WALL SYSTEM - RESCORE

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ABSTRACT

This paper describes activities associated with the RESidential utility CORE wall system (ResCore) developed by students and faculty in the Department of Industrial Design at Auburn University between 1996 and 1998. These activities analyze three operational prototype units installed in Habitat for Humanity houses.

The paper contains two parts:
1) analysis of the three operational prototype units,
2) exploration of alternative design solutions.

ResCore is a manufactured construction component designed to expedite home building by decreasing the need for skilled labor at the work site. The unit concentrates utility elements into a wall unit(s), which is shipped to the construction site and installed in minimum time.

The ResCore unit is intended to be built off-site in a manufacturing environment where the impact of vagaries of weather and work-crew coordination and scheduling are minimized. The controlled environment of the factory enhances efficient production of building components through material and labor throughput controls, enabling the production of components at a substantially reduced per-unit cost.

The ResCore unit when compared to traditional “stick-built” utility wall components is in many ways analogous to the factory built roof truss compared to on-site “stick-built” roof framing.
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Introduction

The Rescore is a manufactured building component that concentrates home utility elements in a minimal space and provides a fast, efficient installation of these concentrated components during home construction. The goal of Rescore is to reduce the cost of building by constructing most of the required utility elements of a typical residence in a factory setting using semi-skilled workers in very efficient setting instead of in the field by skilled construction workers who must endure weather and craft coordination delays.

Rescore is a concept that can contribute significantly to construction efficiency. While the typical “stick-built” approach is useful in specialized, custom situations, Rescore is more efficient in terms of fabrication and installation time than this traditional approach. This is particularly true in situations where large quantities of houses with like floor plans are being constructed. In a typical small to medium size residential application the plumbing, electrical load center, ventilation, and other appropriate utility components can be installed in the house in a matter of minutes as opposed to over several days when stick-building. The comparison is similar to that of stick-built rafters versus pre-fabricated roof trusses, or site-built doors, and windows as opposed to “pre-fabricated” units. These have become firmly established as an efficient alternative to labor-intensive stick-building.

Where appropriate and cost-effective, energy efficient devices can be incorporated into the Rescore unit providing savings to the end user. These include energy efficient ventilating devices like bathroom fans, combustion air intakes for furnaces and water heaters, and kitchen exhaust fans. Fabrication of the Rescore in a factory environment improves the potential to significantly reduce material waste, further adding to sustainability. Materials are better controlled in a factory setting, facilitating efficient material recycling.

History of Project

The Rescore project was developed through the joint efforts of the Auburn University Department of Industrial Design (AUIND), and the U.S. Department of Energy, Oak Ridge National Laboratory (ORNL). The project was funded as a research subcontract to AUIND from ORNL. The faculty, staff, and students (undergraduate and graduate) accomplished all work at AUIND. The AUIND team also relied on advice and critique from Auburn University’s School of Architecture faculty and staff, and a professional advisory committee of construction and manufactured housing industry leaders.

Phase I work started at Auburn in early 1996 and produced a wide variety of concepts that ranged from structures of complete rooms with installed equipment and appliances, to the germ of the ultimate solution, the essential “core” wall.

The complete room units potentially offered a greater degree of control over the unit’s energy efficiency by allowing the manufacturer to provide major and minor appliances. Each appliance could theoretically be an optimal unit in terms of efficiency. This unit would be trucked to the job site by large flatbed tractor-trailer, off-loaded and situated in place by crane, and be essentially ready to use after minimal hook-up. The concept lacked flexibility to serve in a variety of floor plans, and the necessity of using a large tractor-trailer and crane was considered to be undesirable by the design team.

The most significant impact on Rescore was born of the “room” concept. The “room” concept model featured a removable central wall that contained most of the essential utility elements. The students working on the project realized that this was, in fact, the true essence of the “core” concept and this defined a new direction for the project.

The initial prototype of this core wall used “non-load bearing” 28-gage steel for its structure. It was determined that steel offered opportunities for
using recycled material, and would lend itself to the manufacturing process with greater flexibility than wood. The primary benefit of using steel was that it permitted the construction of a lighter, stronger wall than would be possible with wood. The wide variety of fastening options was a primary concern in the selection of steel. Since as the wall would not be used in an exterior location the issue of heat loss through the thermal bridge provided by the steel was not a factor.

This is not to imply that steel was without problems. The first wall unit was built in a “traditional” configuration where the width of the studs determined the thickness of the wall. This meant that each stud would need to be pierced where waterlines, electrical wiring, and drain pipes passed through. This piercing invariably left a sharp edge which required a protective grommet or special edge treatment. The primary problem with the single stud approach was the cost of cutting all of the holes as well as the labor of feeding all the utilities through the holes. This situation was compounded by the difficulty of pulling wiring and plumbing through the maze of studs. While this is typical of “on-site” construction, it was felt the solution was inefficient given the objectives of the project.

In Phase II the team went back to work to further develop the concept from the standpoint of manufacturing efficiency. This effort gave rise to the “layered” approach to wall construction. This approach was adopted and used with good results in both the Phase II and Phase III prototypes.

The Phase II prototype was a single wall unit, roughly sixteen feet long. The wall consisted of two layers of non-load bearing 28 gage steel studs joined at top and bottom to an 8 inch wide steel channel. The two layers provided an inter-plane “raceway” that was clear of obstructions in which the wiring and plumbing elements were placed. The wall was displayed at a Habitat for Humanity convention in Atlanta, Georgia during the summer of 1996, where it generated considerable interest. This actual unit was later modified to accommodate local plumbing codes and placed in a Habitat for Humanity home constructed in Opelika, Alabama.

Phase III was considerably more ambitious than Phase II. Two multi-wall units were built for installation in Habitat homes in Plains, Georgia. The floor plans on these homes provided an opportunity for further innovation. While the room layouts concentrated as much of the utility demand in one area, it was not possible to meet the needs of the plans with a single wall unit. The two houses required double and triple wall configurations respectively. These multiple walls presented special construction and shipping challenges. The Habitat staff at Plains opted not to pursue the concept further. Other affiliates have expressed interest in the concept and are considering implementing it at their location.

One attractive aspect of the Rescore concept to Habitat staff was that it would allow volunteers to contribute their labor whenever they were available for work. They would not be hampered by weather or scheduling constraints. If volunteers could work, for example, weekday evenings only, they could still be a part of the process by building Rescore walls in a warehouse which would be stored for later use on-site.

Analysis

Overview

In the layered approach wall elements are grouped by function. Electrical wiring becomes a group, as does hot water piping, cold water piping, and drain piping. If the demands of the end use home require gas, combustion air intake, or HVAC elements they would also be treated as separate layers.

The steel studs are rotated at 90 degrees to the traditional orientation,
which left the face of the stud parallel to the face of the wall. Two layers of studs were used to yield a "hollow" space in the center of the wall (between each wall half). This allows easy manipulation of the internal components if that became necessary. It also facilitates field replacement of technical components if and when required.

During the manufacturing process each half of the wall is built separately. Each plumbing manifold is fixture built, as is each wiring harness. The elements could then be combined by layers in final assembly, compared by some to the process of building a sandwich. This procedure allows a manufacturer to build wall halves in one work center, plumbing manifolds in another and wiring in yet another. Each of these elements are then quality control checked for leaks or improper wiring before final assembly.

One of the most critical requirements for the economic success of ResCore is that of repeatability. The concept can be used in "one-of-a-kind" construction, but there are less benefits. Apartments, tract housing, hospitals, and any application where many multiples of the same type units are required are locations in which ResCore will yield the greatest cost benefit. The concept is not likely to be viable in small quantity building scenarios; the start-up cost would cut deeply into profits by inflating the per-unit cost.

Analysis of first Prototype

One of the best features of this prototype was its relatively light weight. This single wall unit served a kitchen, bath, laundry, HVAC closet, and provided a 200-amp electrical load center for the entire house. (See FIG. 1.) Total weight of the wall was less than two hundred pounds. It was easily loaded and unloaded from the shipping trailer and moved into place on the slab by four people of average physical ability. There was no need for a crane or special equipment to place the unit. Hookup of the drain, dryer vent, and water lines by a plumber required less than thirty minutes. Because the wall was not load bearing 28 gage studs were used to help conserve weight.

![Floor plan, phase II. ResCore is the solid black line. (Note: The remote bathroom was required to meet the unique needs of the physically disabled occupant and could not be combined into the ResCore without unacceptable house layout changes. The ability to serve multiple bathrooms was demonstrated in the follow-on prototypes.)](image)

Many fastening methods were considered during the development of the steel stud framing. Spot welding, rivets, adhesives, and screws were all considered. Drill point screws were chosen because of their application flexibility. Their integrated drill point cuts a number of holes before becoming too dull to drill which allows for field changes and modifications. Semi-skilled workers readily embraced this technology. There are fewer hazards than those associated with welding (especially when using galvanized materials) and tooling up for screw fastening represents a smaller investment than the other
methods considered.

There were several issues associated with the first prototype in general. One of the more significant was that of trade acceptance. This was dramatically illustrated in the prototype house. Another house of similar size and features was being built concurrently by the same group of people. Both houses used the same plumber. The builder revealed that the plumber purposefully priced the ResCore house at a higher rate because of the ResCore wall. It is not uncommon for prototypic work to be priced at a premium because of the uncertainty associated with newly developed products.

This is an element that should be carefully monitored during the process of gaining acceptance by skilled trades. Historically, similar problems were encountered when other prefabricated components, like roof trusses and window/door units, were introduced to homebuilding. In time trades came to embrace the innovations, use them more frequently, and ultimately reduced their costs by using these products.

Another issue of significance is that of accuracy in placement of connection points. When built in a factory setting very close dimensioning tolerances are easily attainable. Unfortunately, the same is not always true of on-site homebuilding, especially for plumbing rough-in below the slab. Several possible solutions for this problem have been discussed including templates for in-slab pipe location, hung fixtures with no in-slab piping, and radically flexible joints for the final connection between wall and slab plumbing. This was not resolved by the first three prototypes.

During the process of shipping the first prototype unit to and from the Habitat conference in Atlanta, Georgia (over two hours driving time each way) much was learned regarding survival during shipping. This unit suffered some damage in transit due in part to the use of light, 28 gage studs. This indicated the need for a different shipping approach. The unit was shipped vertically to the construction site with no damage. (See FIG. 2.) This method required the use of wooden braces on each end of the wall which were useful during installation, but added to the cost of the unit with little use after installation beyond blocking and "scrap" type uses. (Prototypes 2 & 3 walls were all shipped lying flat with excellent results.)

FIG. 2. Prototype 1 ResCore being delivered to job-site. Wooden diagonal shipping/installation braces are clearly visible.

The light gage studs caused another significant problem. They did not provide an adequate structural element for attaching wall mounted kitchen and bath cabinets. While the steel studs were easily located using a magnetic "stud-finder" they did not have sufficient resistance to screw pull-out to hold the cabinets without additional reinforcement. This caused considerable problems for the cabinet installation crew.
Analysis of Second and Third Prototypes

At the outset of this phase the design/build team concurred that the units should be capable of being shipped horizontally.

FIG. 3. Prototypes 2 & 3 ResCore, both two and three-wall units, ready for shipping on the modified trailer.

The design team's goal was an assembly that could be shipped in a "low-tech" vehicle, possibly a full-size pickup truck. While the units produced were not shipped in a pickup, they were shipped lying flat on a slightly modified sixteen-foot flatbed trailer. (See FIG. 3.) Elaborate commercial trucks and a commercial driver's license were not required to ship the final units. Both prototypes were hauled in one load, pulled by a three-quarter ton pickup truck.

FIG. 4. A simple wooden Fixture aids the accurate construction of ResCore.

Early in the development of Prototype 2 & 3 it was decided that a consistent 16" on center stud spacing would be followed more stringently than on Phase II. One tool used to facilitate this was a simple construction fixture. (See FIG. 4.) Made of wood, it allowed accurate spacing of the studs and squared them to the top and bottom channels. The design of the fixture also enabled two average workers to assemble wall components quickly and efficiently. Wall lengths that were not evenly divided by 16" were easily accommodated in the fixture as well.

The addition of multiple walls to this phase provided far greater flexibility in terms of house plan. (See FIG. 5.) Kitchen and bath layout options opened up considerably with this new capability. One of the lessons learned from the earlier model was that light gage studs were inadequate. In response to this the models featured alternating light (28 gage) and heavier 24 gage "load bearing" studs. This addition added more weight, but greatly enhanced the
stability of the individual walls. Heavier gage floor and ceiling channels were also used on this phase. The problem of wall cabinet installation was addressed by adding horizontal strips of 18-gage sheet metal to the top and bottom of every wall that would receive cabinetry. These strips, particularly when stiffened slightly by sheetrock, became an acceptable structural member for cabinet mounting.

![Diagram of a floor plan showing shaded areas in the partial floor plan are the more complex 3-wall ResCore.](image)

The use of multiple walls created some interesting challenges with regard to the hinging of adjacent walls. The preference was to ship the walls horizontal and compact, so hinging or physical separation would be required in order to allow stacking of wall units. The advantages of hinging, keeping segments together, facilitating free-standing units, simplification of plumbing connections, and others, demanded that the walls be hinged, not separated. After much consideration of hinging alternatives the final solution was a very simple, inexpensive strip of soft steel. (See FIG. 6.) The material was malleable enough to withstand a small number of bend cycles with no failures due to work hardening. The material cost was in fractions of a cent per part and the scrapped "hinge" could be readily recycled if the need or desire arose.

![Image showing a sheetmetal "hinge" used in the joint on multi-wall units.](image)

The multiple wall units developed were HEAVY. While it was still possible to manage the units with manual labor (no cranes), weight did become a factor with multi-wall models. The two-wall unit weighed four hundred and fifty five pounds, and the three-wall unit was five hundred and sixty pounds. Care should
be taken in the further development of ResCore to keep weight below four hundred pounds, which would be a reasonable goal for multi-wall units.

The studs on prototypes 2 & 3 were at 16 inches on center. One suggestion has been made to expand this to 24 inches on center, which reduce the overall weight. However, care must be taken to insure that adequate structural elements are provided for hanging cabinets and other wall-mounted fixtures, which could become a problem with stud spacing greater than 16" on center.

Additional Design Development Needs

A system of location for all in-slab plumbing is also an item that needs additional work. Whether the templates are a one-use sacrificial item (to be left in the slab or discarded after one use) or a permanent building fixture that can be moved from job to job, the need for a better solution in this area is of critical importance.

The development of multiple wall units was one of the most significant contributions of prototypes 2 & 3 multi-walls open up considerable opportunities in terms of plan adaptation and flexibility. One of the weak points in the hinging system used these units was that of the plumbing connections at the joint. The development of a flexible joint for use in this area would have a very positive impact on the future of ResCore.

The three prototype walls were all eight feet tall. A shorter model could potentially be built that would pass through an exterior door opening. This would allow use of the unit as a retrofit for remodeling (without requiring that exterior walls be torn out for installation), or increase its utility in new home construction. Such a unit would allow the house to be “in the dry” and secured by lockable doors before the unit was installed. A shorter height unit would also allow a 10% to 15% weight reduction with a lower center of gravity, both of which would allow greater handling ease. Such a unit would also ship with greater ease by fitting into a typical truck, eliminating the need for a flatbed trailer.

Market Applications

One builder in the Chicago area and one in the Southeast were interested in investigating the applicability of ResCore to their entry-level houses. The builders felt that lowering costs would significantly increase the number of people who will be able to qualify for the houses, which in turn will greatly increase the builder's market share in entry-level homes. In addition, a large Habitat for Humanity affiliate in the Southeast was considering ResCore for use in its housing for low-income residents.

Additional Information

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