Manufactured Residential Utility Wall System (ResCore)

Robert Wendt
Oak Ridge National Laboratory

Clark Lundell
Tin Man Lau
Auburn University

Prepared for the
Energy Efficient Building Association
Excellence in Building Conference
Denver, Colorado

November 6-8, 1997

Document prepared by the Energy Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, managed by Lockheed Martin Energy Research Corporation, for the U.S. Department of Energy under contract number DE-AC05-96OR22464.
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
INTRODUCTION

This paper describes the design and development of a manufactured residential utility wall system referred to as ResCore. ResCore is a self-contained, manufactured, residential utility wall that provides complete rough-in of utilities (power, gas, water, and phone) and other functions (exhaust, combustion make-up air, refrigerant lines, etc.) to serve the kitchen, bath, utility, and laundry rooms. Auburn University, Department of Industrial Design faculty, students, supported by a team of graduate student researchers and the project’s advisory team, developed the ResCore. The project was accomplished through a research subcontract from the U.S. Department of Energy administered by the Oak Ridge National Laboratory.

The ResCore wall system features a “layered” manufacturing technique that allows each major component group - structural, cold water, hot water, drain, gas, electric, etc. - to be built as a separate subassembly and easily brought together for final assembly. The two structural layers are reinforced with bridging that adds strength and also permits firm attachment of plumbing pipes and other systems to the wall frame.

BACKGROUND

This project was begun at Auburn University in 1996. The conceptual development phase occurred during the Winter Quarter and was accomplished as part of a senior level design studio. A mockup of the ResCore wall was developed during the Spring Quarter by members of a senior design studio and graduate students. Fabrication of the first prototype was accomplished by the Department of Industrial Design staff and graduate students. Installation of the first prototype occurred in a Habitat for Humanity home in Opelika, Alabama, in September 1996. The initial ResCore consisted of a single wall serving adjacent kitchen, bath, laundry, and utility rooms.

A follow-on phase during the summer of 1997 refined the initial design and developed two additional prototypes for installation and evaluation. These prototypes were to be installed in Habitat for Humanity homes being built in Plains, Georgia during October 1997. The second and third prototypes differed from the initial prototype in that the utilities were provided in a series of adjacent and connected walls.

The ResCore project’s primary technical goal was as follows:

The project will design and develop an energy-efficient, multi-functional core for
residences containing the kitchen, bath, domestic water heating, electrical distribution, and building heating, cooling and ventilating functions in a prefabricated, manufactured system. The core is to be designed to be mass produced and transported for placement in conventional site-built homes, or to be installed in factory made modular or manufactured housing. The specific configuration and approach to the core design is to be determined through a process of case study analysis and the collective agreement of the project's advisory team. The initial prototype core, to be built for testing and evaluation, will be targeted for use in a lower-end, entry-level housing unit.

The evolution of the concept took it from an all-encompassing "box" complete with all appliances and equipment installed, to a "utility spine" to serve adjacent functions as described later in this paper.

CONCEPT DEVELOPMENT

During the initial concept development, the students focused on ideas supporting the development of an all-encompassing residential utility module or core that was similar to past examples by others. The largest number of concepts presented at the initial concept review meeting with the project advisory team reflected this direction. Through critical analysis of the concept designs, the problems associated with a fully-constructed utility module housing kitchen, bath, laundry, and utility room functions became apparent. The problems included: transportation (weigh, size, in transit protection, etc.), placement on the building site (crane, large vehicle access, etc.), and the interface with traditional construction details (recessed subfloor, etc.).

The most significant issues working against the use of a fully constructed and outfitted utility core were its weight (estimated to be in the thousands of pounds) and size. The cost associated with oversized-load shipment and the use of heavy equipment (cranes, etc.) to place the utility module would most likely offset the cost advantages of prefabrication. The advantages of prefabrication would have to be pursued through the reduction of the weight and the resolution of site placement problems.

One of the early concepts focused special attention on developing the area within the complete module where the utility functions were concentrated. This was the "utility" wall that most fixtures abut. In terms of utilities provided, this wall contained the highest concentration and had the highest level of complexity. Consequently, it was the focus of significant labor and material costs and therefore could benefit significantly from prefabrication. It was determined that by developing the utility wall the advantages of prefabrication could be optimized while maintaining a unit weight that could be managed effectively by manual labor at the building site.

The utility wall was also where the largest concentration of plumbing and electrical crafts labor would occur. Significant time and cost efficiencies from fabrication of the core wall off site in a manufacturing facility could be accomplished, provided that the wall's shipping size and weight were kept within reason.

The utility wall concept became the "agreed approach" between the design and project advisory teams as the most appropriate way of bringing manufacturing efficiency to the provision of utilities in conventional residential building construction.
ENERGY-EFFICIENCY CONCEPTS INVESTIGATED

With a major project goal being energy efficiency, various approaches were investigated. Initially, energy-efficiency gains were thought to be possible in five areas including:

1. Waste energy recovery
   - Heat recovery from exhausted air (could be used to preheat domestic hot water or warm fresh air make-up)
   - Heat recovery from waste water (could be used to preheat domestic hot water)

2. Reduced distribution losses
   - Shorten distribution distances from efficient layout
   - Insulation of duct and piping systems

3. Combined equipment
   - Gas - water heating / space heating
   - Electric - space cooling / water heating

4. Use of non-conditioned air
   - Water heater combustion - if gas
   - Furnace combustion - if gas
   - Refrigerator (condenser coil cooling)
   - Range hood (exhaust make-up)

5. Reallocation of costs
   - Reduced cost associated with the utility wall reinvested in higher-efficiency, cost-effective heating and cooling equipment and/or appliances

Waste energy recovery was determined to be not cost effective given the small amounts of energy involved and the intermittent nature of most of the waste energy sources. Reduced distribution losses were achieved through shortened distribution runs. Insulation was determined to be not cost effective because of the short runs. In addition, insulation would make visual inspection of the piping by the building inspector difficult. Combined equipment was determined to be beyond the scope of this project. However, the close proximity of appliances and equipment to each other would facilitate the use of combined equipment if they are developed by others. The use of non-conditioned air for combustion equipment (furnaces and water heaters) was considered cost effective and a "wise" option to prevent possible back drafting. The prototype ResCore walls were installed in all electric houses and therefore did not include this feature. Other uses of non-conditioned air were considered not cost effective.

The primary means to improve the home's energy efficiency came from the potential to reallocate the construction cost savings from using the ResCore wall. Funds "freed" by the use of the ResCore wall could be reallocated to purchase more energy-efficient equipment than the low-income, or entry-level, home buyer would otherwise be qualified to finance through their mortgage.

For example, if a ResCore equipped home cost $2,000 less than the traditionally constructed home, then the home buyer who qualifies to finance the traditional home has $2,000 available to potentially upgrade equipment. One upgrade could be to go from an 80% AFUE gas furnace to a 92% AFUE unit. The incremental cost of the higher efficiency unit is in the $500-1000 range,
which fits within the available dollars. In colder climates, or areas with higher natural gas costs, this upgrade is cost-effective (i.e., operating costs saved exceed the higher initial cost within the life of the unit). This higher-cost, but more efficient unit would save both energy and utility costs to the homeowner, thereby improving the overall home affordability.

INITIAL PROTOTYPE DEVELOPMENT

A great deal of knowledge was acquired through formal discussion with the industry members of the project advisory team during the initial prototype development phase of the utility wall concept. The design was also significantly enhanced through the process of fabrication of the initial prototype and its installation in a house. The size of the initial prototype wall, 8 inches wide by 8 feet tall by 15 feet long, established limitations and challenges to both vehicular transport and manual placement. The weight of the prototype unit was maintained at under 200 pounds which allowed the available on site labor to readily accomplish its placement in the house and connection to the below floor utility services.

Much additional insight was acquired through conversation with the various building trades associated with the completion of the prototype house’s interior spaces. Suggestions were made by the drywall, paint, and cabinetry trades. Response from tradesmen involved with the Habitat project has been positive. All of these important and valuable insights have lead to improvements in the initial design and have also been incorporated into the design and fabrication of the subsequent prototype walls which will be installed in two additional Habitat houses.

This initial prototype was specifically targeted at housing for the cost-conscious, low-to-middle income home buyer. This prototype of the wall was fabricated and installed in a Habitat for Humanity home in Opelika, Alabama in late 1996 (Figure 1.).

INITIAL PROTOTYPE INSTALLATION

The photo sequence (Figures 2.-5.) illustrates a typical on-site installation. Delivery can be made from either a trailer or flatbed truck. Future versions of the wall will be constructed to permit installation before or after the ceiling is framed. Holes in the standard metal studs serve as holders for lifting rods. This permits the wall to be unloaded and positioned by four "average" laborers. The total weight of the wall is under 200 pounds. Connection to the below floor rough-in plumbing is made when the wall is installed, as are connections to the dwelling’s water, gas, and electrical services. The wooden triangular frames steady the wall during shipment and initial installation. These frames are removed when the wall is tied into the remainder of the structure. The wall is then ready for sheathing with gypsum board. The total time required to off-load, position, install, and connect services is about two hours.

SUBSEQUENT PROTOTYPE DEVELOPMENT

A follow-on phase was developed in 1997 to further refine and demonstrate the concept through installation in two, additional, Habitat for Humanity houses. The floor plans of these three- and four-bedroom, one-and-one-half bath houses, were more challenging than the initial prototype. In one house there will be two interconnected utility walls (Figure 6.). The other floor plan required three interconnected utility walls (Figure 7.).
These additional prototypes present new design challenges such as whether to "hinge" the walls together and provide "flexible" interconnections of the utility services, or provide separate wall segments with "quick connects" for the utility services, or a combination of the two. These issues were still being addressed at the time of the writing of this paper.

The ResCore project team met prior to the start of construction with Habitat’s construction site supervisors regarding the proposed plans for the second and third prototype installations. Because the utility wall is most effective when the greatest number of functions requiring utilities are concentrated adjacent to or within a single wall, adjustments were made to the plans to optimize the layouts. At the same time, care was taken to avoid creating situations where many back-to-back utility functions were crowded into the same space within the limited dimension of the wall. Plumbing fixture sizes were verified and adjustments made to bathroom configurations in order to optimize their spatial utilization. Electrical service requirements were defined and the layout refined. The objective of this process was to accommodate the use of the ResCore utility wall in the existing house plans without compromising the spatial utilization of the rooms. After the review and adjustment process, both plans where functionally improved in terms of their utility configuration and spatial utilization.

SUBSEQUENT PROTOTYPE INSTALLATION

The second and third prototype utility walls were scheduled to be installed in Habitat for Humanity homes to be build in Plains, Georgia, in late October 1997. In addition to photograph and video documentation of the installation process, an industrial engineering evaluation of the impact of the ResCore utility walls on the overall house construction process is expected to be accomplished.

EXPECTED IMPACT OF RESCORE

The objectives of the ResCore project were to design and develop a manufactured utility wall that would increase quality, lower cost, speed construction, and provide better overall housing value. Assuming that the ResCore concept is adopted and widespread manufacturing begun, we believe that these objectives will be accomplished with the following impact:

- Higher quality - The wall will be manufactured in a controlled environment to tight tolerances and rigid quality control standards. Each of the system interfaces (electric, gas, water, sewer, heating ventilating air conditioning, etc.) will be accomplished by design and careful fabrication, rather than as the result of field adaptations that occur with traditional construction. The result will be more capability, operating correctly, within less space. Since only one entity is responsible for production, high quality standards can be readily maintained.

- Lower cost - Savings estimates range from a low of $500 to a high of $2000 for the initial prototype wall, depending on the on-site crafts labor rates of the job. Manufacturing crafts will benefit from an indoor work environment, ample materials inventory, mechanized support, systems subassemblies, and quantity purchasing to dramatically lower costs. On-site installation can be accomplished quickly with semi-skilled personnel. On-site crafts will benefit from the elimination of costly craft coordination "down time" and the ability to focus their efforts on the high-value-added portions of the construction process.
• Faster construction - Based on the prototype, a typical installation of the completed wall is estimated to take between one and two hours. This compares favorably to the days or weeks commonly needed for traditional construction due to weather and craft coordination delays.

• Better overall housing value - The savings accrued from the installation of this wall can either lower the total cost of the house or be reinvested in improvements without increasing the cost to the home buyer. Reinvestment in higher-efficiency, cost-effective heating and cooling equipment, domestic water heater, and/or major appliances can provide a significant return on investment. This is especially important to families at the lower end of the economic spectrum.

FUTURE POTENTIAL OF RESCORE

The use of existing computer-aided design and manufacture (CAD/CAM) technologies to produce the wall will result in the potential for “mass customization” permitting manufacture of the wall for virtually all residences. Other buildings with repetitive utility walls are also candidates for this technology. These include: motels, hospitals, nursing homes, prisons, and similar structures.

Future quality and material improvements, that cannot be afforded on a one-of-a-kind, site-built, basis, will be assimilated into this high-volume manufacturing process. The manufacture of these building components will both reduce waste and facilitate the economical recycle of remaining unused materials.

PRODUCTION DEVELOPMENTS

Concept development, design, construction, installation, testing, and evaluation of prototypes has been completed. Several markets have been identified and initial contacts with potential users established. Initial contacts with several potential manufacturers have also been made. Additional expressions of interest in either the manufacture or use of the ResCore are solicited by the authors.
Captions:

Figure 1. The first prototype of the ResCore wall (black line) was installed in a Habitat for Humanity house in Opelika, Alabama. A bath, laundry, utility, and kitchen are served from the single utility wall.

Figure 2. The first prototype ResCore wall was delivered to the construction site on a small, flat bed trailer.

Figure 3. The trailer was positioned adjacent to the floor slab to permit easy off loading.

Figure 4. Four persons carried the ResCore wall into final position and lowered it over the plumbing stub-ups which penetrated the floor slab.

Figure 5. The ResCore utility wall is shown in final position with connections to the below slab utilities. The total time from off loading to final completion was about two hours. Under "production" circumstances this time would have been less. The triangular braces at the ends were removed with the completion of the adjacent traditionally framed walls which provided bracing to the utility wall.

Figure 6. The second prototype installation of the ResCore utility wall involved two (shaded) interconnected walls. This installation was located in a Habitat for Humanity house in Plains, Georgia.

Figure 7. The third prototype installation of the ResCore utility wall required three (shaded) interconnected walls to serve the kitchen, baths, and utility/laundry area.