reCOVER: Transitional Disaster Recovery Housing

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INTRODUCTION

This paper focuses on the research and development of a transitional disaster recovery housing system currently being prototyped, tested and specified for manufacturing. Project reCOVER brings together academic, civic, and professional organizations in a collaborative enterprise to benefit the common good. Partnerships with non-governmental organizations and humanitarian professionals assisting marginalized communities rebuild after natural disasters are an essential part of this research project and help make viable connections between the impact of local interventions and global humanitarian awareness. Begun in 2007, this research integrates educational objectives in support of the central tenets of public-interest architecture[1] and focuses on a broader client base than the architecture profession has traditionally engaged. A strong emphasis is placed on exploring emerging automated fabrication technologies and manufacturing processes to produce domestic and international disaster recovery housing in service of the highest performance standards and environmental quality. While assisting marginalized communities improve their built environment and helping advance building technologies, architecture students are directly involved in applied research and real world experiences as an important part of their education and engaged scholarship. New applications in the area of building design and construction emerging out of this research underscores the importance of translational research in the architecture academy.

NATURAL DISASTERS

In 2005, the most active Atlantic hurricane season[2] in recorded history produced a series of natural disasters devastating to human loss, the built environment, and the U.S. economy. Although not the sole influence on the initiation of this research project, these catastrophic events motivated a series of questions surrounding the quality of post-disaster recovery housing. Newspapers described the dire living conditions victims of natural disasters were enduring at every post-disaster stage.[3] The focus of the media on this plight was topical, but ebbed and flowed largely influenced by a 24-hour news cycle. The mediocre, even harmful[4], types of temporary housing available to disaster victims in the form of trailers soon became a recurring headline suggestive of a deeper systemic problem. There was clear evidence of genuine support and grassroots effort to address this dire situation, but often resulted in scattered, ad hoc housing solutions falling short of addressing the magnitude and complexity of the problem.

Research into the history of camps established to house internally displaced persons and refugees from natural disasters revealed a chronic housing problem: The housing type intended for finite emergency or relief periods immediately following a disaster had become the long term standard; the temporary tents and trailers, by default, became the permanent solution. Additionally perplexing was the realization that domestic and international government agencies did not have viable strategies in place to address this chronic housing crisis.[5]

These challenges were made even more evident in the way the U.S. Federal Emergency Management Agency (FEMA) responded during the recovery phases in the aftermath of Hurricanes Rita and Katrina by

deploying thousands of travel trailers. This quick-fix response to a large scale predicament further jeopardized the health and wellbeing of a vulnerable population compounded by the failure of regulatory inspections to ensure that the structures met basic building safety standards. The post-disaster recovery housing crisis could be traced back to cultural, organizational and legislative emergency management dysfunctions. Adding to this complex problem was the very classification of natural disasters as low probability, high impact events which had historically influenced a reactionary mindset extending from months to years after a disastrous event.[6]

ANTICIPATORY HOUSING

The reCOVER transitional disaster recovery housing (TDRH) system research and development focuses primarily on the effort to improve housing made available for protracted periods of months and years after a natural disaster strikes. For a problem of this magnitude and complexity, a systemic approach is required with a flexible delivery strategy; a process based on the design/build project delivery system allows for iterative and more responsive design to prototyping and testing cycles. The reCOVER TDRH system employs the use of modular and panelized manufacturing industries' production and deployment expertise to inform the delivery of safer and more accommodating forms of transitional disaster recovery housing.

Conceived of as a housing recovery strategy with a broad anticipatory approach, the research and design development of the reCOVER TDRH is evolving into an adaptable, multidimensional framework which relies on a consortium of suppliers and manufacturers. This multifaceted approach is defined by: advocacy for community-based partnerships; optimization of prefabricated panelized and modular construction applied to the transitional housing typology; application of sustainable building practices and passive design strategies; the formation of a state- and region-wide (eventually national and international) consortium of housing manufacturers capable of executing rigorous building specifications, maintaining a network of suppliers, and producing large-scale quantities; and forging partnerships with government agencies, non-governmental organizations, and consultancy groups to enable viable deployment strategies and on-the-ground logistics support. From research and educational standpoints, this approach is prototypical in nature and generates multi-year, iterative design processes where students learn from direct interaction with community partners, full-scale, hands-on fabrication, and the aggregative effects of interdisciplinary research and collaboration. This effort requires a close coordination of exchanges between students, community partners, professionals, consultants and manufacturers to ensure mutually beneficial dialogues and outcomes.

Figure 1. Rendering of the reCOVER "Breathe House"

The reCOVER framework has four important objectives that define its overall research mission and scope:

The advancement of translational research in the area of building materials, methods, and techniques, defines the primary objective of reCOVER. Focus is placed on the development of each building project on producing two outcomes: First, a viable building solution which meets or exceeds the expectations of the beneficiary community and, second, the prototypical development of new buildings that combine conventional construction with innovative methods of manufacturing and distribution.

The second goal, one that relates directly to architectural education, is to balance the educational purpose of the research with the demands and challenges that come with real projects. Specific research questions about building materials, technologies and construction are framed so that students can engage the work while influencing the development of their own design methodologies. Simultaneously, students work collectively on the overall project development and share the responsibility in executing deliverables. Full-scale mockups and prototypes are utilized as instructional tools to demonstrate workable connections between students' design ideas and building techniques, helping assess the feasibility of a design to be implemented in collaboration with the partner organization and beneficiary community. Classroom lessons and field experiences are synthesized to support overall educational mission and a comprehensive project solution.

Third, mutually beneficial partnerships are established with humanitarian, community-based or-

ganizations who demonstrate a commitment to building sustainably for marginalized communities. It is important that the partner organization has a well-established and trusted presence in the community. The organization's philosophy, history, leadership, structure and financial resources are considered as evidence of commitment and performance. Whether the organization operates domestically or internationally, it is important that its personnel are familiar with and respond appropriately to the cultural, social and political characteristics of the community; an important qualification is a thorough knowledge of the community's history and access to local building resources.

The fourth goal, in the area of large-scale manufacturing of the reCOVER TDRH system, is the development of commercialization strategies to bring product and services to market. Through federally- and state-funded grants, reCOVER is working with modular and panelized housing manufacturers in Virginia to prefabricate and test a series of prototypes for environmental, structural, material, packaging, and deployment performance specifications. These prototypes will be field-tested to demonstrate the efficacy of the reCOVER housing system in relation to industry competitors. Market analysis and business plan development is equally important in this process; in close collaboration with experienced stakeholders in business and governmental sectors, viable market entry points through U.S. and foreign governmental agencies and non-governmental organizations are being identified. Concurrently, efforts in this context are driven by the necessity to generate additional funding for ongoing reCOVER research and development, student scholarships, and program support.

APPLIED DESIGN RESEARCH: THE reCOVER BREATHE HOUSE

The reCOVER Breathe House, currently being fabricated, is scheduled to be deployed and assembled in St. Marc, Haiti the spring of 2012. The reCOVER approach to disaster recovery housing begins with the assertion that safe, healthy and durable housing serves a basic human right.[7] This is especially true for victims in devastated communities recovering from the physical, psychological, and social tolls of natural disasters. This project is coordinated across an interdisciplinary team of architecture, engineering, medicine, business, and commerce faculty, students and professionals at all stages of the project. Equally important to this activity are the teams of builders, fabricators, manufacturers and modular industry consultants who are close collaborators in refining and testing prefabricated building components, staging and deployment scenarios. The management and interaction between these teams is an exciting and important part of realizing this design research. The day to day collaborative problem solving aspect of this work with faculty, students, manufacturers or consultancy groups has an invaluable influence on the trajectory of the project, requiring a flexible mindset.

Figure 2. Prototype assembly review with NGO

Given the complex phases and numerous stakeholders involved in this reCOVER project, from schematic design to what has most recently emerged in the form of commercialization interests, the research and development focus remains the improvement of the quality of housing for disenfranchised communities who find themselves in deplorable conditions. Underlying this philosophy is an ethical mode of practice engaged in the world to effectively address the challenges society faces. This is especially critical as the work models effective behavior for architecture and engineering students, members of a younger generation who are committed to the new roles and responsibilities they will have as members of communities entrusted with the common well-being.

Esther Boucicault, founder of the Fondation Esther Boucicault Stanislas (FEBS), identifies the reasons why improving the quality of housing is important

Figure 3. Groundbreaking ceremony in Haiti

for her community and underscores the gravity of this work:

> "In Haiti, people living with HIV/AIDS continue to be victims of severe stigma and discrimination. They are rejected by society and even their families. Many become homeless. This makes them even more susceptible to infectious diseases like tuberculosis, which is already a serious problem amongst our members. In a society where disease is so much a sign of poverty and where support is so lacking, FEBS's housing project will improve our members' living conditions and provide them with a crucial base from which they can begin to rebuild healthier lives."

This research and development effort identifies critical performance criteria that will lead to the improvement of the environmental and construction quality of housing. The "Breathe House" passive design strategy ensures the effective use of natural light and ventilation to support the wellbeing of the occupants. This portion of the design development, in addition to the point-of-use water filtration, waste management and independent renewable energy systems, is part of an ongoing collaborative effort between reCOVER and the Rodman Scholars Program directed by Professor Dana Elzey in the School of Engineering and Applied Science at the University of Virginia.

An important aspect of the reCOVER TDRH system design, considered when adapting it to different cultures and climactic conditions, is a well-planned spatial organization that supports a family and community's daily life, indoors and outdoors. For example, the housing proposal for Haiti responds to the strong relationship between indoor and outdoor living customs of the Haitian culture; by incorporating a large porch, removable awning and living walls for vertical gardens, the modest square footage of the house takes on an expansive quality. Daily activities are intended to flow freely between interior and exterior spaces and the building's design supports communal interactions. Close attention is given to the outward orientation of the interior spaces towards windows placed at an appropriate height to ensure direct views to the gardens while maintaining privacy of the occupants. It is vital to the project's cultural and social sustainability that it carefully takes into consideration the organization and aesthetic adaptability of each house to work well in a clustered, communal setting. Accessibility for the physically disabled is integrated with the outdoor living porch. These spatial relationships ensure an effective use of indoor and outdoor functions related to safety and convenience of communal activities. While protected from the elements, high visibility is an important aspect of the clustered communal organization of a single unit as well as multiple housing units. The reCOVER TDRH considers the relationship the building has to the ground to be of great importance in terms of ventilation and effectively negotiating uneven terrain. The building envelope is comprised of partially or fully prefabricated panels. The panel frames are fabricated using different materials and prefabrication strategies depending on the application. The integration of a mechanical connection at the vertical seams between panels and the horizontal seams between the wall panels and floor and roof panel system will make the onsite assembly user-friendly and structurally dependable. This locking mechanism, which requires only the use of hand tools, will ensure a tight seal between panels and strong structural integrity of the entire building envelope assembly. The adaptability of the panel cladding allows for a variety of aesthetic options without sacrificing the weather proofing performance of the building envelope. A 'micro-gap' allows for the panel to be naturally ventilated by conductive airflows, reducing the risk of mold or mildew forming in the wall cavities and obstructing the potential transmission of moisture.

The importance of incorporating indigenous building practices and locally-sourced materials to support local building industry and to assist in the recovery of a community is an important part of the design. The reCOVER TDRH system is designed to react to complex logistical requirements of building in a post-

disaster setting by using a hybrid and flexible approach to construction. Comprised of efficient prefabricated building components, the design is based on a simple, safe, on-site assembly process. The entire structure can be assembled by a group of six inexperienced volunteers with the supervision of one experienced builder. The housing unit components can be manufactured in remote or nearby facilities and are designed to be flat-packed and transported to the building site. The system is described as a 'plug-and-play' strategy of prefabricated, panelized components and limits the number of individual building parts necessary to complete the house. This time-saving strategy has a substantial economic impact in terms of reducing overall costs associated with supporting volunteer groups during construction and energy costs associated with assembly. The design of the prefabricated system also takes into consideration the reduction of material and hardware costs as part of the structural and weather proofing detailing of the panels. A long-term cost savings is projected as part of large scale manufacturing and per-unit cost reduction strategy. (Currently being studied with the help of the UVA Office of the Vice President for Research (VPR) "Commercialization Innovation Group") Moreover, the design of the housing unit allows for an interchangeability of cladding materials to address different cost parameters and availability of locally-sourced material stock. The system allows for an efficient increase or reduction of overall square footage per unit to provide a range of sizes. As part of the interior fit-out, a variety of storage and amenities provide different design and organizational options can also be completed by local carpenters and furniture makers.

Figure 4. Prototype panelized wall assembly timing

The reCOVER TDRH prefabricated panelized building system supplements the use of off-site fabrication with a conventional on-site construction and assembly. Combining the two approaches to building (often kept distinctly separate in the building industry) affords a greater degree of adaptability and variety to the system while ensuring a high level of construction quality. This approach is designed to directly involve the local community affected by a natural disaster during the rebuilding process with the intention of contributing to a sense of empowerment during the recovery phase.

The structural system is designed to withstand seismic forces and hurricane winds and is currently being analyzed and tested with the assistance of structural engineers from the architecture and engineering firm of Arup in the UK. The firm's Arup Cause program, initiated in 2006, has a clear mission to raise awareness and understanding of humanitarian relief projects and is strongly committed to projects with a clear focus on the sustainable design and construction of communities in developing countries. The Arup Cause program has established a remarkable record of working with domestic and international non-governmental organizations and academic institutions to conduct important design and engineering research and development projects. It provides a range of in-kind services from specialized technical analysis and simulation, project management, communications support, to financial assistance. In 2008, the Arup Cause program reviewed the reCOVER body of research and determined it to be a significant effort worthy of their mission. This is a distinct honor, and the research team has been working with civil and material engineers with Arup's Cardiff and London offices with enthusiasm. Collaborating with manufacturing partners in Virginia, preparations have been made to test the structural viability of the TDRH prototype to further verify the computer-simulated studies being conducted by the Arup engineers.

The TDRH system also benefits from engineering research and development currently being conducted in collaboration with colleagues in the School of Engineering Computer Science department. The reCOVER TDRH prototype is one of four testbeds funded as part of a 2010 National Science Foundation EFRI (Emerging Frontiers in Research and Innovation) SEED (Science in Energy and Environmental

Design: Engineering Sustainable Buildings) grant. (No. 1038271) The four-year, $2M research grant is led by a principal investigator in the department of Computer Science; and four Co-PIs, one from the School of Architecture, Computer Science, Mechanical Engineering, and Systems Engineering; as well as senior personnel from Darden Graduate School of Business Administration.

The reCOVER testbed is used to study the efficacy of its passive design strategy, in coordination with the distribution of thermal mass, and the use of different panel types and materials. Sensors will be integrated into the prefabricated panel system to measure temperature and humidity fluctuations based on diurnal cycles. This funded research is an important aspect of the framework for the comprehensive and rigorous field testing of multiple TDRH prototypes.[8] In the context of this grant, the TDRH prototypes are used as instruments for exploring and testing improvements and innovations in manufacturing sustainable, affordable, energy efficient, highly integrated, light-weight, transportable building components for disaster recovery applications.

ECONOMIC IMPACT AND MODERNIZING MANUFACTURING

Most recently, the reCOVER TDRH system is one of two featured research projects funded in a one-year, $2.45M Virginia Indemnification and Community Revitalization Commission grant.[9]

The grant, titled "Partnership for Design and Manufacture of Affordable, Energy-efficient Housing Systems" (No. 2338) funds three full-scale reCOVER TDRH prototypes. Building materials, graduate research assistantships, faculty and staff stipends for the purpose of manufacturing specifications development and field testing of the prototypes are included as part of the one-year grant.

Working collaboratively with Phillip Parrish (integrating PI) of VPR and Professors Anselmo Canfora and John Quale, the partnership includes the University of Virginia School of Architecture and the School of Engineering and Applied Science whose participants will be co-located at the Southern Virginia Higher Education Center (SVHEC) in South Boston, VA; SIPS of America, Inc. (Blairs, VA); Cardinal Homes, Inc., (Wylliesburg, VA); the Riverstone Energy Center (REC) and its industrial tenants (Grandview, Inc., the American Wood Finishing Institute (AWFI), and Kyoger, Inc.)

Described in the introduction of the grant proposal:

> "The work focuses on research, development, testing and demonstration of affordable, energy-efficient housing systems for disaster recovery and residential housing markets, encompassing design and computer-aided manufacturing to enable a robust modular and panelized housing systems industry in Southside Virginia based upon structural insulated panels (SIPS), protective coating systems for SIPS to enable protection from moisture and mold, fire, pests, to manage solar loading, as well as UV protection from solar exposure."

Defined as "Task 2: reCOVER Research, Development and Demonstration: Transitional Disaster Recovery Housing System," the research team is working directly with Southside, Virginia partners to setup manufacturing protocols and specifications to be applied to future versions of the reCOVER TDRH with direct impact on the version being deployed to Haiti in the spring of 2012. An important purpose of this grant is to act as a catalyst for economic development in the "Tobacco Footprint" encompassing the Southside and Southwest regions of the Commonwealth of Virginia. To this end, the research team is working closely with the VPR, "Innovation Partnerships and Commercialization" and the Patent Foundation to explore potential large scale manufacturing channels through governmental and non-governmental partnerships.

Figure 5. "Breathe House" prototype review

The core research in this grant is inextricably linked to economic development in Virginia and focuses on the technological modernization of the modular and panelized manufacturing industry in Southside, Virginia. In addition to creating new jobs in the region, the existing labor force will acquire new skills

in computer aided design and computer aided manufacturing (CAD/CAM) technologies and processes while building on their extensive manufacturing experiences and know-how. It is widely accepted that architecture and engineering building practices have drastically changed over the last two decades as a result of the introduction of CAD/CAM technologies. New computer numerically controlled (CNC) fabrication technologies have been introduced with caution and as part of measured and deliberate design and manufacturing strategies. The use of new technologies is most interesting when their added value can be assessed early on in the prototyping phases of the project and ultimately proven through rigorous performance metrics. Working with manufacturing partners on the development of the "Breathe House" prototype, the research team is affecting how automated manufacturing and manual fabrication can be synthesized to improve the overall construction quality, affordability and transportability of transitional housing for disaster recovery. A primary objective of the Tobacco Commission grant is to "develop the industrial design and manufacturing base to produce highly energy efficient, comfortable housing systems." An in important focus is the minimization of material waste and increasing production efficiencies in order to meet future potential demands of the reCOVER TDRH system domestically and internationally. Business consultants from the VPR's "Innovation Partnerships & Commercialization" group are currently analyzing the market for potential competitors and determining viable commercialization strategies. Working with manufacturing consultants, multiple companies have been identifying to establish a consortium of modular and panelized manufacturers to be able to meet probable, future demands in disaster recovery housing.

COMMON BENEFIT

In conclusion, the most notable reCOVER project, the "Breathe House,"[10] has ensured lessons learned in the architectural studio – both as part of an academic exercise and significantly, in the field, as part of a collective humanitarian effort. For the purpose of demonstrating how academic, common good design/build projects can overcome economic and logistical challenges, this project effectively integrates lessons in building sustainably and involves interdisciplinary teams to help solve problems faced by vulnerable communities. The reCOVER research in the areas of off-site construction processes, building craft, and the advancement of new and emerging building technologies and methods is supported by state- and federally-funded grants, private and corporate sponsorship to help address the chronic problems associated with disaster recovery housing.[11] This work necessitates a multi-sectorial, entrepreneurial approach forging new relationships between academic, civic and professional entities, and effectuates the expertise, means and assets each can contribute to serve the purpose of assisting marginalized communities. Students are directly involved in eminently complex and real architectural design problems, accelerating the development of their design and communication skills. This process requires them to listen carefully and encourages them to act deliberately. As a key aspect of engaged architectural education, students' abilities to work collaboratively with multiple project stakeholders are enhanced and prepares them for potentially new and emerging roles they will need to perform in practice and the public realm.

ENDNOTES

1 Kim O'Connell, "Promoting public-interest architecture with a "triple bottom line," ARCHITECT Magazine

2 National Oceanic and Atmospheric Administration (NOAA), National Weather Service: National Hurricane Center (http://www.nhc.noaa.gov/2005atlan.shtml)

3 Shaila Dewan, "Katrina Victims Will Not Have to Vacate Trailers," *New York Times*, June 4, 2009

4 Department of Homeland Security, Office of Inspector General Report (redacted this report for public release), "FEMA Responses to Formaldehyde in Trailers," June, 2009, p.15

5 George Haddow, Jane Bullock, Damon Coppola, *Introduction to Emergency Management*, 3rd Edition (Oxford, Elsevier, 2008) For a thorough and insightful description of disaster relief and recovery management history, policies, practices, procedures, and key players see *Introduction to Emergency Management.*

6 Ibid., Haddow, Bullock, and Coppola outline a comprehensive history of the political challenges FEMA faced from its inception

7 The Universal Declaration of Human Rights, Article 25(1) states: "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control."

8 The portion of the NSF/EFRI: SEED grant allocated to the reCOVER prototype totals $133,398.

9 The portion of the Tobacco Commission grant allocated to the reCOVER TDRH system research and development, and automated manufacturing equipment totals $1,006,378.

10 The reCOVER "Breathe House" was recognized as the 1st place winner in the ARCHIVE Institute, Kay e Santé International Design Competition

11 To date, total funding allocated specifically to the reCOVER research project totals $1,542,576. Since 2007, reCOVER has been a part of federal, state, and University of Virginia grants (including all indirect and shared costs), awards, and private funding totals $8,440,370.