ADAPTIVE REUSE OF PRECAST CONCRETE CLADDING PANELS

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Abstract

An innovative means of sustainable development using precast cladding panels is being implemented as part of the Pathways Research Project at San Jose State University. The research project's main goal is defining the drift sensitivity of precast cladding panels under static seismic loading. But an innovative aspect of the project is related to the disposal of the 18 precast panels after testing is completed. The vast majority of full-scale structural testing research specimens follow one of two post-test paths: solid waste at a landfill or permanent collection at the research lab facility. For this project, means of using the post-test specimens for functional purposes is being conducted. After testing, the panels are cut to usable sizes and are sealed using an innovative sealant to protect the exposed steel from corrosion. The concrete segments are being donated to a local municipality with the intent that the panels can be used in community infrastructure development for Richmond Youth Services and Education (RYSE), an innovative youth center, and as perimeter fences for a blighted neighborhood. The research team is working with local landscape designers and city officials. Research findings will include the benefits received by the project and potential challenges of adaptive reuse of the panels.

Keywords: Adaptive Reuse, Precast Concrete, Building Façade, Green Engineering

INTRODUCTION

One facet of the Pathways Research Project is the exploration of methods of adaptive reuse of building façade panels, particularly the precast concrete panels that typically cover the columns and beams of the perimeter structural system of a commercial, institutions, or residential multi-story concrete or steel frame building. The City of Los Angeles defines adaptive reuse as the adapting of an exiting economically obsolete building for a new more productive purpose (Behdad, 2006). For the Pathways Project, the term is applied more broadly to include the economic reuse of components or sub-assemblies of buildings.

BACKGROUND

One common building façade system is the use of precast concrete panels with inset windows. These systems have been commonly used since the 1950's and account for a significant percentage of building façade systems in 2012. This system uses large precast concrete panels that are bolted to the beams and columns that support the main structure. A typical building may contain 300 individual panels. Shapes vary significantly based upon building architecture, story height, bay length and surface articulation. However, in a typical building there are usually several repetitive sizes and shapes.

Most building panels have some typical characteristics. Figure 1 shows an example building with precast concrete panel façade from the United States and Figure 2 shows a close-up view of one set of the concrete panels tested as part of the original research project. Panels are usually about 125 mm thick and have a single mesh of reinforcing steel at mid-thickness. The exterior surface of the building has several different finishes, including brick veneer, tile or stone, which may cover all or portions of a panel. The interior face of the panel is typically unfinished concrete, as it will be covered by the internal finishing materials of the building interior.

Figure 1. Example of Cladding Panels Mounted on King Library at San Jose State University.

Figure 2. Exterior Face of Precast Concrete Cladding Panels before Experimental Testing

For various reasons, these panels occasionally become functionally obsolete for their intended purpose of providing the exterior façade of a building. These reasons include damage from a severe earthquake or wind storm, remodeling or renovation of a structure involving removal of existing façade, damage to new panels during construction or fabrication, panels fabricated as mock-ups, or aesthetic defects in new panel casting and finishing. In the past, precast fabricators and building owners were limited in their ability to recoup economic value from the obsolete panels. Fabrication yards occasionally are able to extract steel connection components from freshly cast panels, but by and large, most obsolete panels enter the solid waste flow.

Solid waste disposal has become significantly more critical in the past decade. Various factors have contributed to the increased challenge of solid waste disposal, including the health effects of concrete materials (US Dept of Labor, 1995). Landfills are rapidly filling and large construction waste disposal often requires large dumping fees. In California, recent state legislation has been enacted that requires the separation of steel reinforcement from concrete prior to disposal. Federal legislation has identified the calcium carbonate of concrete as a hazardous waste, significantly increasing the challenge of disposal and storage of concrete waste.

PATHWAYS PROJECT

The Pathways Project is a six-year research project with the central mission being the experimental documentation of the damage to precast concrete building panels due to lateral deformation as would be expected during an earthquake (McMullin et al., 2009). The project is funded by the National Science Foundation under the NEESR Program. The main project consisted of experimental testing of six full-scale cladding specimen assemblies, each specimen containing three column cover panels of various size and shape. One of the initial research goals of the Pathways Project was to explore the adaptive reuse of building façade components damaged during an earthquake.

RESEARCH PLAN

The research plan for the adaptive reuse facet included identifying a research need, defining measurable research objectives, outlining a research methodology, collecting critical information, and disseminating research findings. The need for research started with the recognition of the cost of disposal and the need to decrease consumption of natural resources which led to the hypothesis that the adaptive reuse of precast concrete had particular advantages. The research objectives were defined in the 2006 research proposal to the National Science Foundation. The objectives related to adaptive reuse were: 1) to convert damaged specimen components to physical mock-ups for innovative reuse of building components, and 2) to evaluate the use of low-skill labor and manual equipment for the salvage and reclamation of recyclable materials from building components. The research methodology combined literature review, evaluation of public policy issues, and a case study of the physical reuse of sample panel units retrieved from a funded research investigation of seismic damage to cladding façade systems. This physical reuse portion of the research is being conducted in 2012. Collection and evaluation of critical information related to economics, municipal green engineering goals, the energy and carbon evaluation of manufacturing is on-going. The dissemination of research findings includes the presentations at engineering conferences and the preparation of peer-reviewed journal articles for permanent archival use.

ADAPTIVE REUSE APPLICATIONS

Panels designed and built for a building may become unusable or obsolete for various reasons. During fabrication, some panels are cast incorrectly or have noticeable imperfections that prevent their use on a project and require the fabricator to cast replacement panels. In other projects, due to construction delivery timelines, panels may be cast prior to finalization of building financing and when developers lose financial backing for a project, some of the architectural panels may already have been made and are now of limited value. Once installed in a building, panels may be damaged during severe wind, earthquake, blast or handling during construction. This damage is usually restricted to a few small locations rather than completely damaging an entire panel. In addition, the surface finish of a panel will age and remodeling of a building may require replacement or removal of a large number of panels.

The goal of the Pathways Project is to explore alternative use of these panels so that obsolete panels can be harvested into new functional uses. When panels become functionally obsolete, they typically become part of the solid waste stream. Since panels are large, roughly 4 meters by 1.5 meters, disposal of a few panels quickly grows to a significant amount of solid waste. Harvested panels are expected to be usable in a wide variety of forms. Initial brainstorming ideas for harvested panel use included: large-scale landscaping and smaller panel blocks can be used as garden pavers. Larger pieces can be used in defining sides of trails, making small retaining wall structures, or staircase steps for outdoor trails.

While most of the building panels are Flat Panels, corners of buildings usually are made using Return Panels, a panel that has two outstanding legs, usually with one longer than the other. Return Panels present unique opportunities. While they can be converted into two Flat Panels by cutting at the intersecting leg, it is also believed that the unique L-shaped configuration can be utilized into unique configurations, such as a planter box or self-standing boundary.

Alternative uses beyond landscaping have been identified. Structural usage of harvested panel blocks may be found, with certain limitations. Panels are usually reinforced with light reinforcement to control cracking and provide structural integrity to the panel. Thus the harvested panels would need to be used in configurations where out-of-plane bending is small. In addition, water control and erosion protection are other potential uses. Panels are large and it is likely economically prohibitive to make inter-panel edges water-tight, so expected use in water control should be restricted to redirecting water flow such as the possible redirection of water coming from a storm drainage sewer. Erosion control may be more suitable, such as installment and/or replacement of rip-rap at ocean edges, protection of soft soils at critical river bends, or absorbing the impact of water momentum in streams or creeks.

DECONSTRUCTION PROCESS

After testing, panels were removed from the experimental test facility and stored at the lab site. The damage to panels due to cracking and connection damage were noted, and discussions about specific adaptive reuse were developed.

A potential consumer was identified. The lab site is located in the city of Richmond, CA, a 103,701 (2010 U.S. Census) population size industrial suburb in the San Francisco Bay Area. As with many resource-limited municipalities, the city has limited budget for addressing various infrastructure needs. The project personnel spent considerable time contacting various city officials about potential use of the harvested panels.

During discussion, the following specific uses were identified in late 2011:

- Project 1: City of Richmond Youth Center. Construction of a new youth center outdoor space includes significant landscaping possibilities.
- Project 2: Pathways Phoenix Project. Rehabilitation of a blighted property in a neighborhood by using the cladding panels to build a perimeter fence. E.g., building cladding panels can be converted into high-quality yet low-maintenance fences for low-income housing, which will provide continuous opportunities for diversion from landfills with local jobs to improve communities, and reduce carbon footprint of transporting panels to a nearby residential neighbor instead of high processing for concrete waste at a farther dumpsite. This community improvement on a micro level can be validated with a halfway house conversion to a secure residential property.

Vallier Design Associates, a local design service provider, as the youth center design team is committed to provide functional, outdoor spaces for the facility. The firm has been a key player in the City of Richmond’s revitalization efforts for the past 20 years. Richmond, CA is one of the first cities in the country to adopt an innovative general plan which includes a comprehensive element dedicated to promote community health and wellness through sustainable development.

Greenscend, a local design-build firm, is working with a local property owner to renovate a former halfway house into usable single-family housing as part of the Pathways Phoenix Project. The property had been a problem for the neighborhood as a vacant structure since 2010, often attracting vagrants and squatters. In 2011, the property value was downgraded by the County Assessor and was sold by public auction to a senior citizen on a limited income. After purchase, significant structural and utility issues were found by the new owner causing significant strain on the owner’s financial resources. The need for a secure property boundary could be met by the utilization of the cladding panels to define the property.

These projects offered the desired opportunities with several expected benefits. The industrial-image panels matched the industrial heritage of the city. The shortage of construction funding required careful consideration of the spatial definition desired. The close proximity of the lab to the construction sites reduced the transportation expenses. In addition, the panels may be identified with placards explaining their origin and prior use, helping to provide green education to the community.

In spring 2012 the project began in earnest. The design firms for the two projects, the city engineering office, and the Pathways Project personnel met and discussed specific uses and the required adaptation of the panels for each project. Three panels are expected to be utilized in their entirety without additional prep work for the Pathways Phoenix Project. These panels are to be installed in summer 2012. The remaining panels are destined for installation at the RYSE youth center. These panels require basic work for adaptation, including cutting the panels to usable size, application of steel protection epoxy. This work will be completed at the testing lab.

Identifying the impact of the work is critical to conducting research. The project has quantified the following impact of the work:

1. A cost of $8000 dollars for the landfill disposal of the cladding panels from the research lab was eliminated due to the adaptive reuse of the panels. To achieve this savings, a modest cost of rental of a concrete saw, paying for labor, and shipping was required to be paid by the project.
2. New garden and staging structures were built for the youth center. These structures provide an industrial garden environment to the exterior of the youth center. The City of Richmond received these structures without financial expenditure but did provide resources of city engineering time, landscape architect fees, city maintenance labor, and assumption of long-term ownership of the concrete. The city estimates that comparable structures would have significant cost to purchase and install.
3. A template of how to broach, converse, and commit nearby residential owners to accept a role for reusing and showcasing the panels, which can save each home owner hundreds of dollars in fence cost, improve the home curb and help to lift the neighborhood from blight, while creating meaningful local jobs to transform such panels into modern functional sculpture pieces toward community wellness.

The work to do the adaptation of the panels was performed with common industrial skills, showing promise that the adaptive reuse does not require extreme levels of skilled labor. Much of the work was conducted by graduate and undergraduate research students who have basic laboratory skills but are not specialists in construction work. Transportation and installation work were comparable to the work required of general construction. Although heavy lifting did require special equipment, these projects can be suitable for small-scale, informal construction. However, the skills required for adapting the panels for use were seen to represent generalist skills that should be readily available to a city, research facility, landscape architect, or general construction site.

ADAPTIVE REUSE LIMITATIONS

As with all recycled materials, limitations exist. Some of the limitations currently identified to the adaptive reuse are likely to be:

1. Concrete panels are reinforced with small diameter steel reinforcement bars or welded wire fabric. This reinforcement is usually at mid-thickness of the panel. Cutting of the large panels to smaller size will result in the exposing of reinforcing steel to the surface, leading to increased corrosion or the necessity of applying sealant to the cut edges. Corrosion will result in making the blocks more unattractive over time and may lead to leaching of harmful materials into critical fresh water systems. This can be addressed by applying the proper coating to the cut edge, or by placing the crushed rebar end directly into a fresh pour foundation as a vertical element.
2. Blocks will be large and transportation costs will be high. The blocks will weigh between 60 and 100 kg, resulting in the need for sophisticated loading and unloading methods during shipping. These sizes should be easily handled with light end-loader equipment, but for more remote sites the use of block and tackle may be necessary to move blocks to the intended site. With careful planning, these costs can be offset by the original owner's savings in demolition and disposal costs and he new owner's savings from buying virgin material for new construction for the next owner.

ADAPTIVE REUSE ECONOMICS

The economics of adaptive reuse systems is critical. The economics has multiple interacting factors that make the situation dynamic. The fundamental issue is the comparison of the cost of disposal versus the cost of adapting the material to a usable form.

Dollar benefit = Cost of disposal + (Sale revenue – Cost of adaptive reuse)

The cost of disposal includes the dumping fee for disposal of solid waste. In addition, in California, steel must be extricated from reinforced concrete assemblies prior to disposal. This requirement of extrication resulted from the large amount of reinforced concrete rubble resulting from the 1989 Loma Prieta and 1994 Northridge earthquakes. Similar restrictions of dumping are expected at more locations as limitations on available solid waste disposal sites increase. In addition, disposal requires removal of the panels from the building and shipping to the disposal site.

The cost of adaptive reuse can be high, without careful planning before demolition to manage for reclaim and reuse. Since panels mounted on a building are usually attached with several bolts, removal of the panels from the building is expected to be a choreographed process, different from the conventional demolition process with tools not designed for reclaim and reuse. Instead of focusing on destruction and demolition, the goal of an adaptive reuse design team is to plan out in detail how the panels should be removed with minimal damage. Particularly in situations where the building is intended to be demolished, the reclamation team needs to strategize before full-scale demolition how to most efficiently, mindfully, and this affordably remove the reusable materials first. Otherwise, protection or reclamation/restoration of the desired materials will be more expensive.

Without careful strategy, reclamation will most likely be expensive. Shipping charges can include moving panels to the reuse plant, moving blocks to a warehousing facility and retrieval from the warehouse when sold. To reclaim and reuse the panels, the reclamation strategy at a very early stage should include panel drawings and pictures that can be shown to local municipalities, non-profits, residential owners, and other possible stakeholders.

Once the learning curve is hurdled from the first time (for owners, designers, and builders), the new mindset would foster better business practices though improved development concepts to encourage more green processes, earlier collaboration through communication/coordination, and most importantly, improved bottom line for all stakeholders. For owners, more upfront fees for design time and coordination would pay off in higher revenue (higher rent or sale price) and less cost (materials, little or no contingencies). For designers, the more time the owners would invest would mean higher revenues, and the added ability to market themselves as green designers able to deliver better quality with lower cost and less contingencies. For contractors, they can get tax credits for creating green jobs and training new skills to benefit society.

Manufacturing of the blocks is expected to use minimal capital investment, with the primary investment being for industrial strength concrete saws and crushers to remove steel embed connections from the remaining concrete. Low skill labor is envisioned for much of the work, thus allowing smaller labor costs and offering employment opportunities in Green Industries to those with minimal job skills. Additionally, storage of the materials is expected to be highly variable with the potential for significant cost. Outdoor storage in arid regions of the western US is expected to minimize the storage cost. Because blocks retain much of the features of the original building, a suitable buyer for a specific lot of blocks may take time to materialize. However, weather damage to the blocks is minimal and so long-term deterioration is not expected to be a concern. An additional factor in the economics is the local and federal tax environment. Environmental benefits are often encouraged by tax credits and financial reward. Recycling of materials is given a significant tax credit in current US tax law. In addition, job creation in Green Industries currently is favorably rewarded through tax benefits and government grant programs.

BUSINESS MODEL FOR IMPLEMENTATION

The Pathways Project has used a handful of panels for adaptive reuse; to increase scale to a size to alleviate current solid waste flows, the adaptive reuse must be scaled to handle hundreds of panels in a commercially viable way. Thus a means of standardizing harvested shapes, storing materials, and identifying potential panel consumers needs to be established. One such business model uses the harvesting means discussed above but builds an online database of harvested materials to allow for identification of potential consumers.

Panels can be harvested, or deconstructed, from their use on a building with minimal alteration. The method of attachment is usually a combination of threaded and bolted or welded connections that may either be flame cut or unbolted to release the panel from the building frame. In addition, the lifting hardware for the panels usually remain intact during the panel's lifetime, as the lifting hardware is installed on the interior face of the panel and covered by the interior building finish surface. This hardware allows for panels to be supported by a construction crane in the reverse operation of the original installation. Once the panels are removed from the building they can be placed on large trucks and shipped to a central adaptive reuse plant.

At the adaptive reuse plant, the panels can be fabricated to a size and shape that allows for easier usage. The majority of panels on a building are Flat Panels. These panels are rectangular in shape with constant thickness. Panels can have a variety of sizes, but many are roughly 4 meters by 1.5 meters. Panel thickness is very constant between building applications with an industry standard of 125 mm. Connections to the building are usually concentrated in a few locations, specifically the four corners of the panels and perhaps one or two interior locations. While connections come in a wide variety of configurations, most are small steel plates embedded in the panel, as shown in Figure 2. The large Flat Panels can be cut into sizes more easily transported by use of a circular saw. Shapes in the range of 1.5 meter by 0.5 meter by 125 mm are expected to be the most easily handled and economically manufactured as they require only a single cut of the original panel, while a smaller shape of 0.5 meter by 0.5 meter by 125 mm may be an appropriate size for landscaping. Panel regions around the steel embed plates for panel connections is expected to be scrap material, the large variety and complex geometry of the steel connection making it difficult to identify wide scale application possibilities. Hence, the steel embeds once removed from the concrete is expected to be sold as recyclable steel scrap. When cut, the panels now have an exposure of the interior reinforcing steel. This steel must be protected from moisture prior to use of the panels. An innovative treatment compound has been identified by the project to provide moisture protection at exposed steel or in locations where the concrete has been severely cracked prior to harvest.

Once the large panels have been reduced in size according to the methods discussed above, the panels will be catalogued and digitally identified. The critical information would include the three dimensions, the color, texture and appearance of the exterior and interior faces, and the existence of steel reinforcement in the panel. A database of geometric information and photographic appearance would be developed and maintained for marketing purposes. Storage of the smaller panels is expected to be in a large-scale architectural warehouse, most likely outdoor in the remote, arid regions of California.

Marketing of the panels would be through online auction. A sizable amount of material, roughly 2000 square meters, could be harvestable from a moderate size building. Panel materials from a building would have a consistent style, coloration and reinforcement. For these reasons of consistency, it is expected that a single user will likely purchase a sizable amount of the panel harvested from a building. The available panels will be listed on eBay under construction/landscaping materials. Bidding will be held for approximately four weeks as the market for such material is likely to be only a handful of buyers considering a few large-scale applications.

CONCLUSIONS

With the growing concern about carbon release, energy conservation, and global warming, issues related to the energy impact of all processes are becoming more critically reviewed. Adaptive reuse of material decreases the environmental impact of producing new bulk concrete. Concrete is considered a toxic waste, due to the calcium carbonate composition. In addition, during mixing and manufacturing, energy is required and toxic fumes are released. The adaptive reuse of precast concrete cladding panels shows the potential to remove a portion of the solid waste disposal stream and convert the material to a usable form. The use of current online database management and marketing allows for consumers of these materials to locate and purchase harvested materials.

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