Panelized Workforce Housing

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This study analyzes the utility of a panelized exterior wall system in workforce housing. First, it introduces why the need for the project exists. Second, it touches on how Cal Poly procured the project and who the client is. Third, it lays out how the project was dealt with as far as its structure and the roles of the students taking part in the cohort. Fourth, it looks at the process of designing the panels, the various restrictions the students had to deal with in designing them, and how the panels changed over time due to new constraints being made or due to the constraints being loosened. Fifth, it discusses why certain panel design decisions were made and how the design of the panels affects the overall design and cost of the house. Finally, the study concludes by explaining the lessons learned from this panel design process and what the advantages and disadvantages of panelization were. The method of panelization discussed is not the most sustainable building method, however, in this specific case, panelization did provide for a large labor cost saving for the client. Since the primary goal of the project was to help working families to afford a home, panelization helped to make the project a success.

Key Words: Panelized Wall System, Workforce Housing, Disaster Relief, Integrated Project Delivery, Collaboration.

Introduction

Cal Poly students had the opportunity to work in a collaborative design cohort in the fall quarter of 2017 where students from multiple disciplines would be able to work together toward the common goal. The purpose of the cohort was to aid a company called Great Northern Services (GNS) in developing workforce housing for the city they operate in, Weed, California. The need for workforce housing came from the disastrous Boles Fire in 2014 that wiped out a substantial portion of the city's housing. Since Weed's population is under the minimum number required to receive disaster relief from FEMA, GNS decided to take matters into their own hands and began to develop workforce housing. To effectively develop the plot of land they had acquired, GNS would have to be cost-effective in their design and construction methodology.

One way in which GNS thought they could help develop more cost-effective housing was to bring the project to Cal Poly for the design work. Cal Poly faculty thought this project would be a good fit for the Fall 2017 Integrated Project Delivery (IPD) class project. In this class, students were placed in interdisciplinary cohorts consisting of Architecture, Architectural Engineering, and Construction Management students. The teams each came up with a design that had the knowledge of all three disciplines of the built environment in mind. Every other week, the collaborative student teams would present their design to GNS for updates and feedback. Allowing students to design the housing was more time intensive, but it ultimately served as a good cost-saving method.

Another aspect of the project that was intended to help drive the cost of the house down even further was to panelize the exterior panels of the house. Those panels would then be built by Cal Poly students with lumber donated from a national lumber manufacturer who operated a local plant. The purpose of this study is to analyze the utility of those panels and how those panels affected the design and price of the house overall.

Process

The original plan for the panels was for the students of the IPD class to design the panels and then for a different class, the residential construction class, to actually build the panels under the instruction of the IPD class' students. Since the residential construction class is comprised of mostly inexperienced sophomore students, the design had to be simple enough to understand while still being sufficiently detailed to ensure precise panels were to be built. The panels also had to be light and small enough for students to be able to handle them without damaging themselves or the panels. This constrained the panels to be a maximum of eight feet wide by eight feet tall and weighing a maximum of 150 pounds. These sizes were also chosen to fit the panels within a shipping container, the most feasible method of shipping the panels to Weed. The opening dimensions of a shipping container were only slightly larger than eight feet, so the panels had to be restricted to eight feet in either width or height.

In order to simplify the design, the panels were designed as squares or rectangles. Additional material would be built on top of the panels in the field in areas of the house where the roof was pitched. However, the engineers quickly dismissed this idea because it created a moment or hinge point where the studs meet the panel. This is not structurally sound. Instead, panels were developed that would be placed on top of the square/rectangular panels in the areas where the roof was pitched. This was a better method since the two panels could be joined together by metal straps in the stud bays that would, in theory, negate the hinge that would otherwise be created. The metal straps would be fastened around the top plate of the bottom panel and the bottom plate of the top panel. They would be tightened to a certain tension that the engineers would have calculated had that been the design that was ultimately chosen.

By the winter quarter of 2018, the cohort was finished and only a few students would continue working. They worked in a collaborative group alongside faculty and GNS to deliver the remainder of the project. It was at the beginning of the winter quarter when the idea of utilizing the Residential Construction class to physically build the panels was scrapped due to quality control concerns. Instead, the students who were continuing to work with GNS would build the panels. That meant that the panels could be more complex. The design was still restricted by the dimensions of the shipping container but now the panels could be built as a continuous piece instead of two pieces being strapped together. This was more sustainable and cost-effective since the fewer top and bottom plates would be used and metal straps were unnecessary. It also resulted in fewer panels built. That meant a lower chance for error when the panels would actually come together in the field. It was also more structurally stable overall to design the panels this way.

The panels were designed concurrently with the design of the building. AutoCAD was used to create 3D models of the panels and shop drawings so that the shape of the building would lead to more uniform panel sizes where possible. The only constraint was the panels had to be eight feet or less in either height or width. Many of the panels in the areas without the pitched roof ended up being eight-foot-high and very long, up to twenty feet long in a few places. In the places where the roof was pitched, the panels were eight feet or less in width with heights up to around eighteen feet. Since these taller panels were supporting a roof, the tops of the panels were slanted to follow the 3:12 roof line. This was something the students felt comfortable with doing.

The panels were to be built using conventional framing methods. They have 2x6 studs and 16" O.C. spacing along with one bottom plate and one top plate. A second top plate would be installed in the field. It overlaps panels in order to help tie them together. Even though 16" spacing was maintained, the students found that due to many of the panels being eight feet wide the final bay would only be 14.5”. That bay would be shorter by a stud width. This was not a problem as much as it was simply an oversight that led to dimensions on shop drawings that could have been confusing. In panels where there were penetrations for windows, doors, and in one case a sliding glass door, the entire penetration’s assembly was built into the panels. The king studs, jack studs, trimmers, cripples, sill plates, and headers would all be built into the panels. As the panels were delivered to the site, all the carpenters would have to do would be to figure out where the panel goes, fasten it down, and then nail the panels together where their end studs met. This was supposed to save labor costs since the framers would only have to stand the panels up and fasten them down.

By the time the spring quarter began, and materials were to be ordered, a roadblock was hit. The lumber manufacturer that was supposed to donate all the material to Cal Poly was acquired by another company. The lumber manufacturer’s representative that GNS had been in contact with left the company. The lumber manufacturer was still willing to donate material toward the project, however, they required GNS to present them with a building permit; as proof that the material would go toward its intended purpose. With construction documents not yet being ready, the actual building of the panels was postponed to a future date. This wound up working out because GNS decided that they were not ready for the panels to be built anyway. It will be the responsibility of future Construction Management students to build the panels.

Lessons Learned

In the beginning, the design of the panels seemed very straightforward. The Construction Management students presumed to take the Architect’s design of the house and panelize it. Many different iterations of panelization were developed by student teams in the IPD class. Each iteration had its advantages and disadvantages. The best approach was a bit different from what most groups did. Most groups designed from the inside out. This means that they would design the footprint of the house first and then would make panels fit that footprint. This led to less uniform panel sizes and more variation between panels. By designing the panels, or at least their main constraints and sizes, first and then using those panels to create the footprint of the house, the panels never had to be odd sizes and the variety of panel types could be limited. By designing from the outside in the footprint may have contained odd dimensions but it helped to keep the panel dimensions more consistent. With a general footprint designed the Architects could begin laying out the interior of the house to fit the panels rather than the Construction Managers and Engineers designing the panels to fit the footprint. The ultimate outcome of this design strategy was more simplicity in the overall panel design as well as less material being wasted due to smaller panels being needed to fill gaps in the standard panel sizes.

Another lesson learned was that, at least in the way Cal Poly approached the project, panelization was not the most sustainable building method. This was because Cal Poly could not spend thousands of dollars on research and development to make a new type of building method adopted by code. To adopt new building methods into codes, thousands, if not millions of dollars would need to be spent in the testing of the new building method. Since the funding was not available for that level of development, traditional building methods had to be maintained. This led to extra material being required where the panels met. At the meeting of each panel, two studs would be back to back. Since Cal Poly also didn’t have capital invested in automatic machinery or robotics that would help make the panels very large, the panels were designed to be rather small. This led to more panels being required. The meeting of panels wastes one stud per panel total, and since there were a total of twenty-two panels, that meant twenty-two extra studs would be used. That is not a huge amount of waste, but if this method of panelization were adopted on a much broader scale then it would lead to quite a bit of waste indeed. However, the panels did result in a large labor saving for GNS that they could use to help working families to find a place they could call home. So, despite the added waste, the project would still be a success, at least theoretically until the panels are actually built since its ultimate goal of making a home more affordable was indeed met.

Further Reading

If you are interested in reading about the other aspects that went into this study, please read the following papers:

Resiliency vs. Reality by Ainsley Henderson

Material Choice and Pricing for Great Northern Services (Weed Cohort) by Ryan O'Neill

Weed Cohort Panelized Housing by John Theofanides