Trends and Opportunities for Precast Concrete in Residential Design

— Richard Garber, AIA

It should come as no surprise that with an uptick in sustainable and high-performance housing projects, there has been increased interest in the use of precast concrete for residential design. Some virtues of precast concrete construction are well known, such as rapid assembly and minimal site impact. Others such as high thermal efficiency and aesthetic versatility can provide incredible benefits as designers learn how to optimize projects. The application of precast concrete construction once thought best for larger scale developments has found increasing relevance in residential projects of small to mid-size scales.

Single-Family Residential Design Trends

With sustainability remaining of keen interest in building design, a simple way to ensure energy efficiency is to utilize a highly insulative material, such as a precast concrete system, to minimize the escape of conditioned air. In residential design, we are seeing a move from traditional solid precast walls, sometimes used

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Figure 1: PREttyFAB, Jersey City, N.J., GRO Architects PLLC, 2009. Credit: Fabian Birgfeld/photoTECTONICS.

for foundations and basements, to sandwich panels for walls, floors, and roofs. A sandwich panel is comprised of two layers, interior and exterior wythes of precast concrete, as well as a layer of rigid insulation between. Sandwich panels can also address thermal bridging by using a non-ferrous connection through the insulation to tie the wythes together. Additionally precast concrete can theoretically be made in any shape. This lends itself to novel solutions in which the architect or designer can specifically form the panels to respond to environmental factors such as prevalent winds, solar exposure, and day-lighting. It should also be stated that precast concrete is increasingly valued as a recycled material, adding to its sustainable benefits.

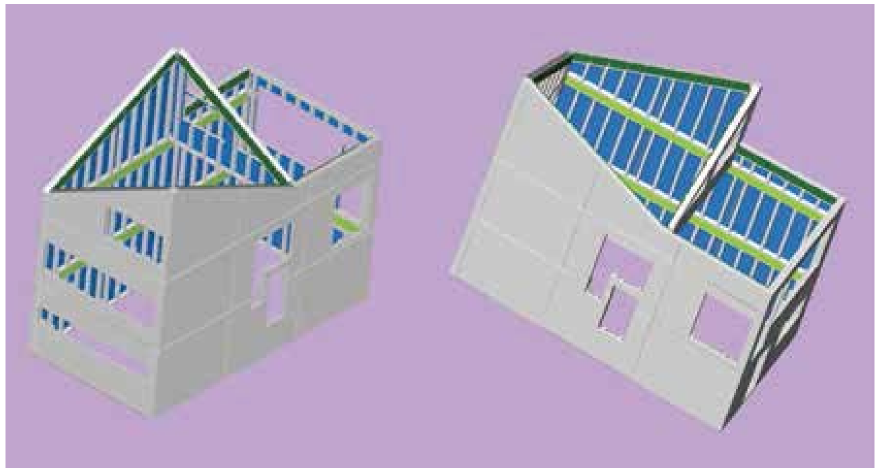

Figure 2: Three-dimensional views of PREttyFAB's panel system as extracted from GRO Architect's digital design model and transmitted to the concrete fabricator in a popular 3D format for the production of shop drawings. Note the precast wall system and insulation are simulated in the model, including ledger boards for the framing of floors. Credit: Notheast Precast.

PREttyFAB, a precast concrete, single-family house, was originally conceived as a prototype for urban infill housing in residential districts. The house was designed and built in 2008-2009 in Jersey City, N.J., for a total construction cost of $250,000 or just over $150/square foot. The private client acquired a small piece of vacant land—ultimately classified

Figure 3: eNJoy! House—New Jersey Institute of Technology and Rutgers University, 2011, U.S. Department of Energy Solar Decathlon competition. Credit: Solar Team NJ.

as a nonconforming undersized lot—and wished to build a 1,600-square-foot house. The house had to produce its own energy and have minimal to no maintenance costs. The owner was originally interested in concrete for this purpose, but as the design commenced, our firm became increasingly interested in how concrete, and specifically highly insulated precast panels, could be integrated into a total passive and active sustainable solution. The final design also contained a small photovoltaic array, a green roof for additional insulation, low-emissivity glazing, and radiant heating. The house's high insulative value is aided by the building's split level reverse living design—the bedrooms are in the lower level, which is at 5'-0" below grade, ensuring they remain cool during the warmest times of the year.

In a second single-family house, the eNJoy House, a sandwich panel system was used with fiberglass trusses joining the inside and outside wythes of the panels. This project was the New Jersey Institute of Technology's (NJIT , where I am a faculty member) entry to the 2011 U.S. Department of Energy Solar Decathlon. The low thermal conductivity of the fiberglass trusses would maintain temperature differences on the interior and exterior sides of the wall. We also used a special graphite impregnated expanded polystyrene in the sandwich panels. The graphite both reflects and absorbs energy, further decreasing thermal conductivity while increasing the wall's insulative value. The graphite also slows the flow of heat through the insulation layer, giving the wall a higher level of performance.

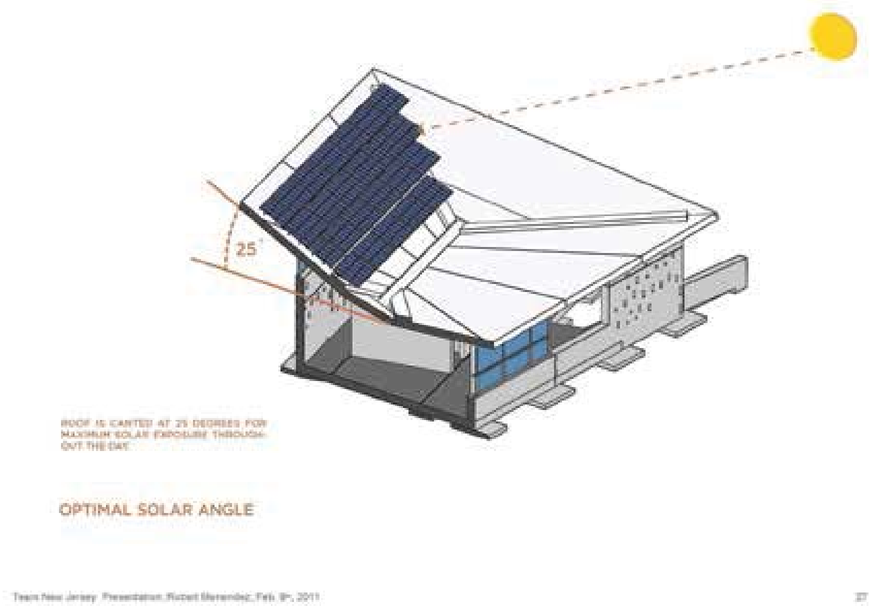

Figure 4: Passive Optimization—Optimal Solar Angle. The eNJoy House utilized an inverted-hip roof with two south-facing panels canted at 25 degrees for maximum solar exposure throughout the day on the panels facing due south. Credit: Solar Team NJ.

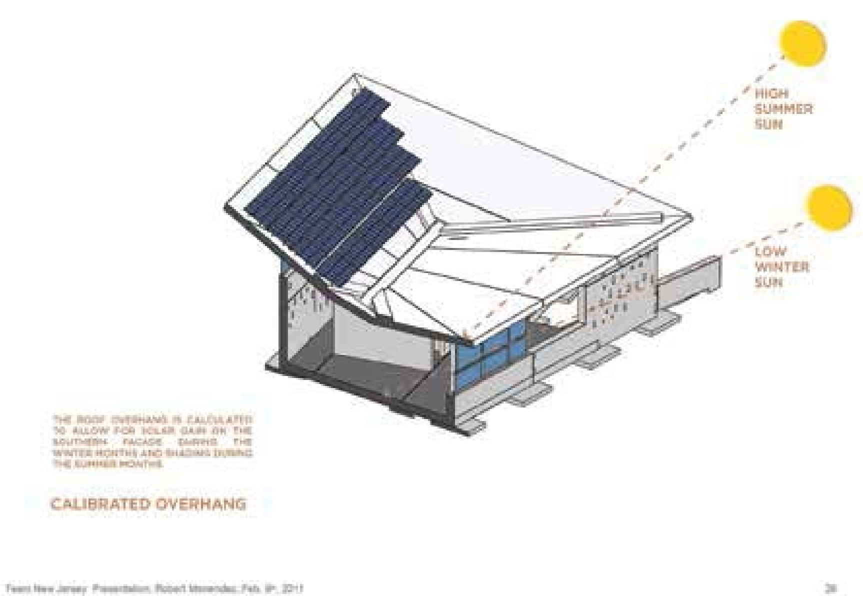

Figure 5: Passive Optimization—Calibrated Overhangs. The roof overhang on the south side of the eNJoy House is calculated to allow for solar gain on the southern façade during the winter months and shading during the southern months working passively to prevent excess cooling and heating respectively. Credit: Solar Team NJ.

High Performance and Resiliency in Multifamily Design

Resiliency, especially in the greater New York/New Jersey area, has become a very hot topic. New rules for setbacks, base flood elevations, and insurance requirements have made the post-Sandy world a difficult one for architects to navigate. The Federal Emergency Management Administration (FEMA) guidelines for revised base flood elevations (BFE) affect many areas and many construction projects, both urban and less dense. Focusing on the urban implications of FEMA's requirements are of utmost importance currently, especially in multifamily residential design. To effectively ensure an urban project in a Special Flood Hazard Area (SFHA), a Letter of Map Amendment (LOMA) must be obtained to officially remove a property from flood hazard on a National Floor Insurance Program map. For sites below the base flood elevation, an effective strategy has been to elevate the site to the BFE + 1'-0" with fill held by retaining walls. Again, a precast concrete panel system—in this case used as a site foundation—can be used to hold the fill within the raised site and form the foundational "plinth" upon which the structure above sits.

In this case, the site is raised at its extents, and then a second foundation wall is inset 3'-0" which becomes the wall that supports the building. It is possible to cantilever the building above the first floor to the edge of the lot lines to regain the offset of space at the "new ground" level. While this is an accepted strategy for map amendment, it does raise questions for architects and planners. First, what becomes of the "right-of-way?" The sidewalk, especially the urban sidewalk, is a place of vibrancy and the relationship of the vertical building wall to the horizontal sidewalk is an important one. By raising the ground plane to meet the BFE, accessibility challenges are created, magnified by low lying urban areas where the new BFE can be 6'-0" or more above actual grade. Next, by setting the building back to accommodate the fill area, the idea of "zero-lot line" building, which is an at-grade characteristic of many urban areas, is no longer possible. These are all important aspects of design to contend with, and although a precast concrete panel system is an excellent way to achieve the map amendment described, these questions are larger than a single site and solution.

New Challenges and Opportunities

Precast solutions allow for sustainable buildings that require minimal maintenance of a structure or façades. These should be seen as very desirable attributes for affordable multifamily housing projects. This is an area where we are interested in seeing an expanded use of precast concrete in residential design as affordable housing projects continue to be constructed in many cities. In New York City, Mayor De Blasio has called for the preservation or creation of 200,000 affordable homes for half a million New Yorkers over the next 10 years. We have seen precast solutions priced out of the market due to the low budget of construction for many of these projects. When thinking about the life-cycle use costs of such projects, however, precast concrete certainly has a role to play. In addition to fast assembly times and less site mobilization costs, as a monolithic structural system, precast concrete is less prone to issues and problems that framing and other smaller component structural and cladding systems are susceptible to. This means lower costs over the life cycle of a project, and signals that new financial strategies that amortize cost over the life of a building might be called for in such projects.

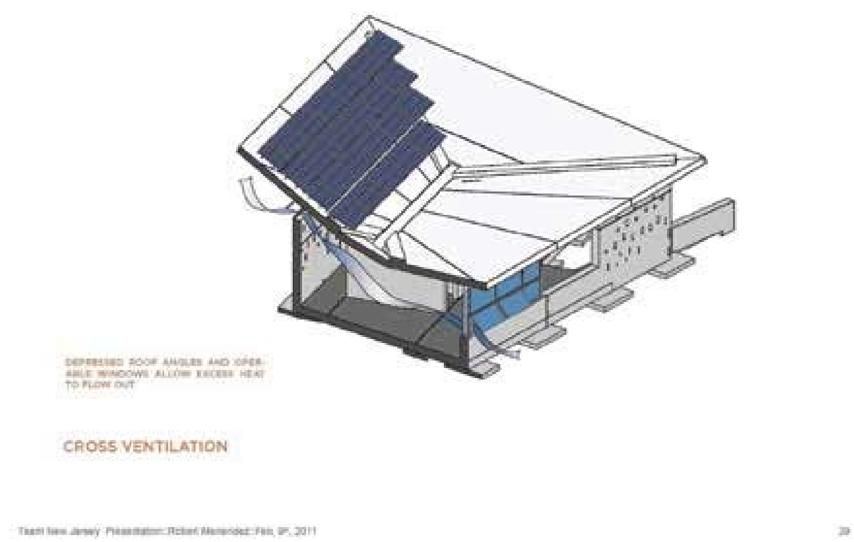

Figure 6: Passive Optimization—Cross Ventilation. The depressed roof angles of eNJoy House made possible by the inverted-hip roof and operable windows (low on the south façade and high on the north façade) allow excess heat to flow out of the house. Credit: Solar Team NJ.

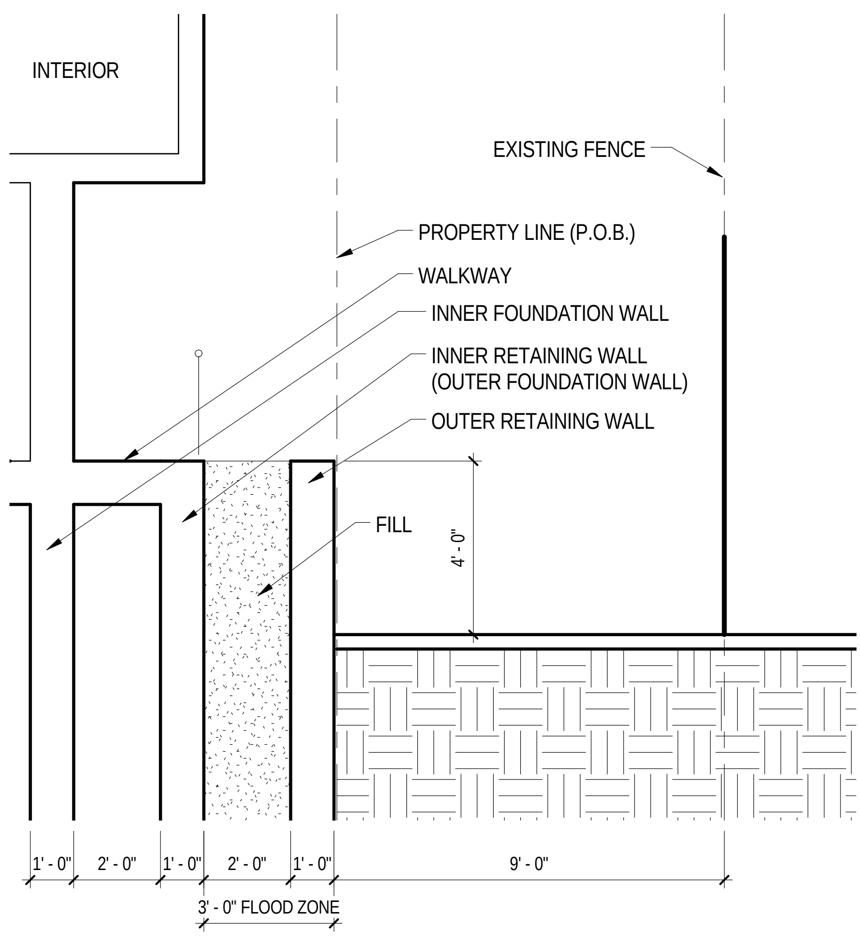

Figure 7: Section of a precast plinth foundation system required for a Letter of Map Amendment in Flood Zones. Credit: GRO Architects.

Conclusions: Engaging Our Students

At the NJIT College of Architecture and Design, we have been working with the PCI Foundation and the Mid-Atlantic Precast Association (MAPA) for the last few years on bringing precast concrete into the Special Topics upper level design studios. The studios introduce precast concrete as a plastic material that is inherently formable, and students initially work geometrically in three-dimensional space to find solutions to the design problems given. Key to this experience is the interaction with precast concrete manufacturers and the forming processes they utilize. Students visit precast plants, and many times fabricators will come to our university to review student work. The need for more sustainable and resilient housing, especially in the wake of natural disasters, has made students and design faculty very aware of the applicability of precast for these problems. To this end, the university has created the Center for Resilient Design, in which architects and engineers from NJIT engage students in the very real problems of housing and sustainable infrastructure in flood-prone areas. Precast concrete figures prominently into this equation, and I suspect the professional and academic opportunities that have presented themselves in our current context allow us to expand our use of precast in both sustainable and resilient design solutions for our cities and towns.

For more information on these or other projects, visit www.pci.org/ascent.

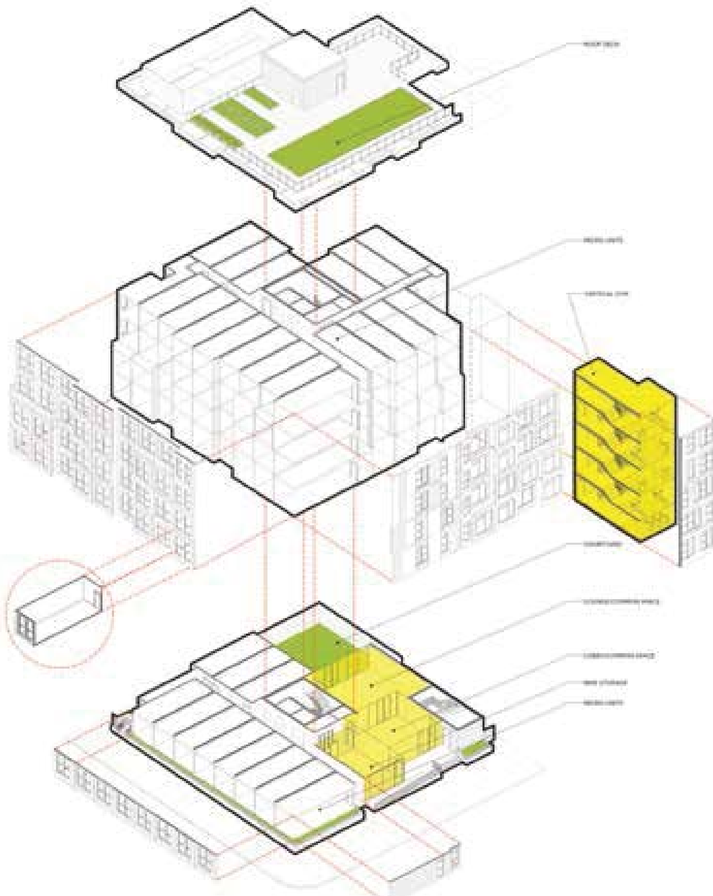

Figure 8: GRO Architects is currently designing a microhousing project in Jersey City, N.J., that is imagined as a 4 over 1 building. Credit: GRO Architects.

Figure 9: GRO Architects has proposed an eight-unit affordable housing project in the Oliver section of Baltimore, Md., utilizing precast concrete for the foundation, wall, and floor and roof systems. Credit: GRO Architects.