# NEW TYPOLOGIES: USE OF PRECAST CONCRETE IN THE ACHIEVEMENT OF DENSE URBAN MICRO-HOUSING

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## ABSTRACT

Precast insulated concrete panels and floor planks are a central feature in the design of an innovative new type of housing project in a transitional neighborhood in Jersey City, New Jersey. This new typology, known as micro-housing, is defined by highly efficient units ranging in size from 200-400sf and larger than typical amenity spaces located elsewhere in the building for communal use. This project, by a PCI award-winning architect, will demonstrate both the design opportunities and constraints of this new type of residential building and how precast concrete is used in the exterior walls, cores, and floors to achieve a non-combustible and cost-effective solution that capitalizes on the material and geometric characteristics of precast concrete. The use of precast concrete furthers the project objectives to achieve economical, environmentally sustainable and a formally innovative design. The construction of the building, currently in construction documentation, will be possible in a matter of days, which reduces the on-site labor costs and maximizes precision and execution of the architect's design intent. Additionally, the paper will address the adoption of new technologies in architectural design and coordination with the precast plant, including innovative ideas in the creation of shop drawings and the fabrication of precast panels using Building Information Modeling (BIM) systems advanced fabrication techniques. The project celebrates the use of precast concrete, utilizing a strategic range of variation in panel sizes to maximize efficiency while creating differentiation and architectural effects expressive of this new typology.

**Keywords:** Precast Concrete, Micro-Housing, Density, Building Information Modeling, Sustainability, Capsule, Shop Drawings

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Figure 01: GRO Architects Micro-Housing Project, Jersey City, NJ. The building contains 122 units that range in size from 200 to 260 gross square feet.

## A BRIEF HISTORY OF MICRO HOUSING

Micro-housing is not a new concept, but is currently enjoying a great deal of interest in urban US markets, first in the Northwest and now increasingly in the Northeast. Cities such as Seattle and San Francisco have been home to the concept for both post-college young adults and the elderly. The concept is simple enough: that individual dwelling units are designed to be as small and efficient as possible, and that the common amenities are larger than those found in typical residential apartment buildings, including gyms, laundry rooms, and lounges. The amenity spaces allow for greater social interaction within the buildings, encouraging more of a community atmosphere. This idea of compactness allows for densities that are ultimately more sustainable than typical apartment buildings, as building services are provided to more people over the same size footprint. Another important aspect of micro housing is its location within the city. Especially on the East Coast, with its fairly robust transit systems, these projects are sited in areas where multi-nodal transit opportunities such as subway, bus, and light-rail are available and the use of the automobile is diminished. The proposal for Journal Square in Jersey City discussed here does not have an automobile parking component.

As the micro housing movement increases in the US, it is important to understand some of the history associated with this housing typology. Perhaps the most well known example of micro housing was built in Japan in 1972, some 43 years ago. Architect Kisho Kurokawa (1934-2007) designed his Nakagin Capsule Tower in Tokyo as a housing structure for the future. Kurokawa was a student of the Japanese architectural movement known as Metabolism which fused ideas about large-scale buildings with those of biological growth. Kurokawa attended the University of Tokyo and studied with the architect Kenzo Tange (1913-2005). Tange was at this time a revered architect of international standing who introduced the concepts of Metabolist Architecture to the Congrès International d'Architecture Moderne (CIAM) in 1959 and first experimented with these ideas in design studios he taught at the Massachusetts Institute of Technology in the early 1960's.

It is also important to ground this interest in broader technological shifts of the time. Peter Cachola Schmal, who is the Director of the Deutsches Architekturmuseum in Frankfurt, has linked the interest in the capsule, or unit, to the technologies that allowed for the possibility of space travel in the 1960's. "A cosmonaut complete with his life-supporting system had no problem fitting into the first Russian capsules with their 2.3 m (7'-6") diameter. In this time of enthusiasm for technology, the space capsule was seen as a symbol of progress – a small oasis of human civilization underway to distant worlds, a sort of hypermodern car in space. Their form greatly influenced architects and designers."[1]

**THE NAKAGIN CAPSULE TOWER**

Figure 02: The Nakagin Capsule Tower by Kisho Kurokawa, façade detail.

The Nakagin Capsule Tower was designed as the first "capsule" architecture building in the world. The 13-story building was composed of 140 prefabricated capsules that were cantilevered from steel and precast concrete cores. The capsules, which will be referred to as units here, were approximately 100 square feet in area with a minimalist exterior punctuated by a single round window. In contrast the interiors are intensively fit-out with sleek furniture, fixtures, and equipment. When first sold, the units came equipped with "bed, storage cabinets, bathroom, color television set, clock, refrigerator and air conditioner. Optional amenities included a stereo, air cleaner, sink, table light, and desk calculator."[2] The units took advantage of a design strategy still valid today in the design of micro housing – one wall on the long side of the unit was utilized for kitchen appliances and cabinetry. In micro-unit design, the increased building systems required in spaces generally allotted for fewer units require designers to find ways to group horizontal and vertical runs of plumbing and mechanical systems efficiently. While this is typically done in residential buildings, it is intensified in micro-housing due to the number of units.

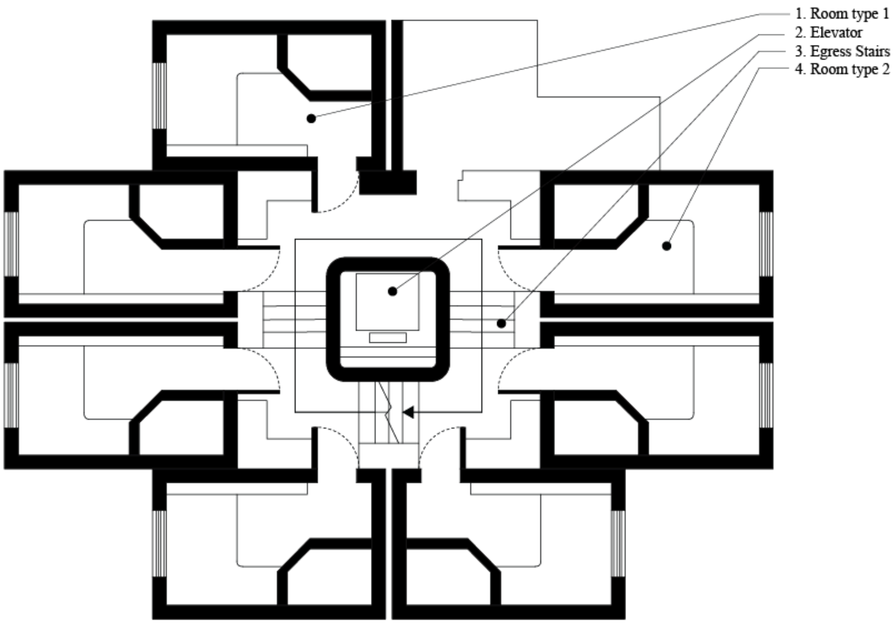



Figure 03: The Nakagin Capsule Tower, typically upper-floor unit cluster.

Each of the capsule units were bolted to a steel frame with only four bolts, making the units easily installed or demounted, which was Kurokawa's intention for servicing and upgrading the units. The capsules were constructed off-site with light gauge steel members and were clad in a gloss-painted metal panel giving the building a sleek and futuristic look.

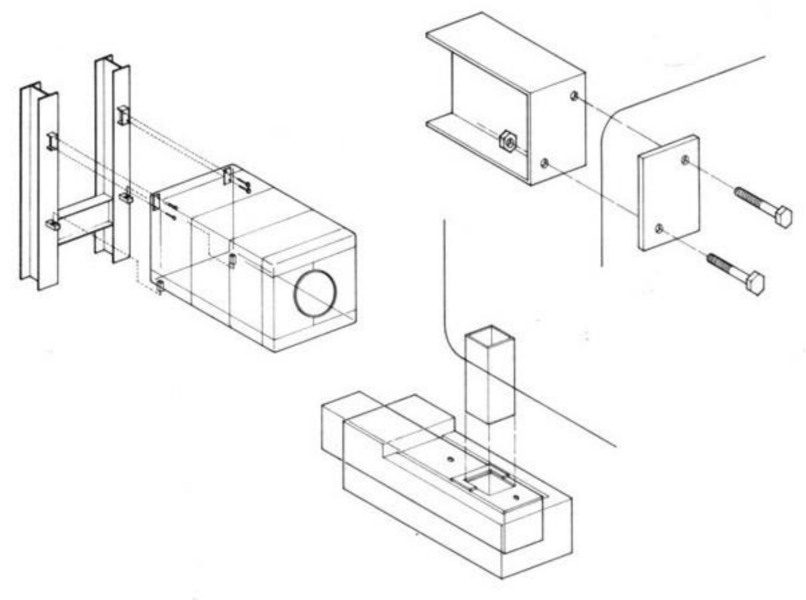


Figure 04: Units that make up the exterior of the Nakagin Capsule Tower were bolted to a steel frame with only four (4) tension bolts making it feasible to remove units for servicing.


Figure 05: The Nakagin Capsule Tower by Kisho Kurokawa, interior view of a unit.

**MICRO-HOUSING IN THE USA**

The micro-housing movement in the US is firmly routed in the urban Pacific Northwest. At the time of writing, there are some 780 micro-units currently in Seattle, with another 1,600 slated for construction[3]. The units, most of which measure between 200 and 300 square feet in size are attractive because of lower rents and their location in prominent urban centers.

City officials tend to be welcoming of micro-apartments, citing their commonality in Japan and European cities, and their location in walkable urban centers in contrast to sprawl[4]. This type of density is often seen as sustainable in that it concentrates people in areas where they can access building and community services while decreasing their reliance on automobiles. "Tiny apartments are hardly a new thing, but they've attracted attention and controversy" in Seattle "because developers have been building them at a quick clip — sometimes over the objections of neighbors — and filling them quickly with people seeking rents that match their circumstances and mobile lifestyles"[5].

This trend of housing has spread east, with micro housing in Boston and New York City. In the latter, former Mayor Michael Bloomberg launched in 2012 a turnkey design competition for a mixed-use project that would contain 55 micro-units on East 27th Street. New York City Zoning currently sets minimum unit size to 400 square feet, but waived this requirement for the contest. The winning team, led by New York-based nArchitects imagined units ranging from 250-370 square feet with high ceilings, small balconies, and concealed storage ideas.

Figure 06: The nArchitect's scheme, called MyMicro, was selected winner of a micro-housing competition sponsored by the City of New York in 2012.

**MICRO-HOUSING IN JERSEY CITY**

GRO Architects has had the opportunity to engage in the design of a micro-unit project in Jersey City. Located in the dense Journal Square neighborhood of the city, the project site is located adjacent to a transit hub that supports NJ Transit buses, taxis, and the PATH train, which travels to the World Trade Center site in Lower Manhattan and Penn Station. The project's site is 92'-6" wide and 100' deep, and its bulk is controlled by the Journal Square Redevelopment Plan, which encourages a fairly dense development strategy for this part of the city. The project is also novel as it will utilize precast concrete panels for its cores, shell, and floors.

The project is designed to accommodate 122 units, ranging in size from 200 to 280 square feet each. An intensive discussion was had with representatives with the New Jersey Department of Community Affairs, which regulates building codes and standards in the state to ensure that the units met all building and accessibility standards, we commenced with the design of the units themselves to ensure feasibility prior to the overall building bulk, which was controlled by the redevelopment plan.

The basic unit is designed for a single occupancy with the standard unit module being 10'-0" wide and 20'-0" deep. The module is subdivided into a "wet zone" which is 9'-0" x 10'-0" and a "dry zone" which is 11'-0" x 10'-0". The wet zone, which is positioned at the unit's interior, contains the requisite bathroom fixtures including shower, toilet, and vanity; however these are organized individually within the space, with accessibility constraints being understood by fixture as opposed to grouping them into a separate bathroom. The unit owner enters through the wet zone, which has individual rooms dedicated for the toilet and shower, which are grouped on one wall. The sink and storage closets line the opposite wall.

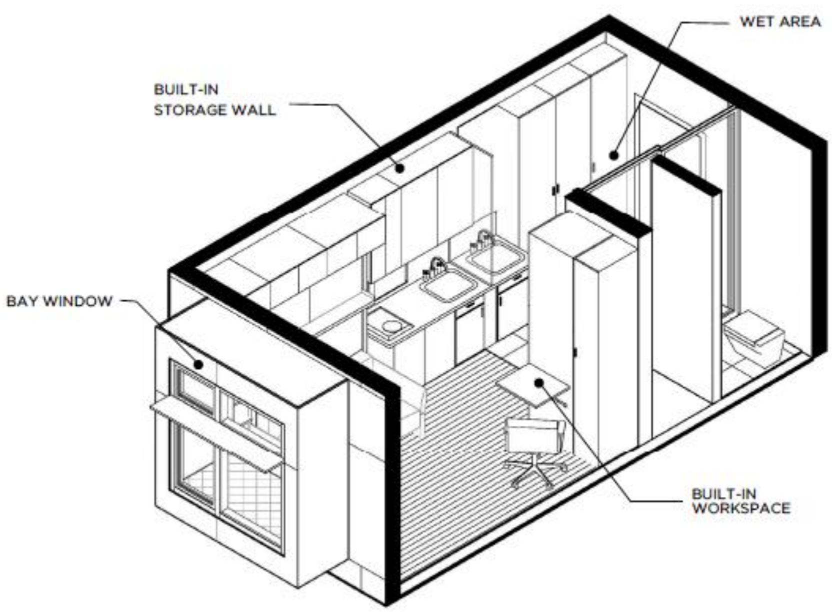



Figure 07: Cut-away of the 200 square foot unit design in GRO Architects' Micro-Housing proposal for Jersey City, NJ.

The dry zone contains a kitchen area with sink and refrigerator as well as a 2-burner cooktop with a convection microwave mounted above and a living area with a fold out couch for sleeping, ample storage, and a small fold-down desk. The GRO team has worked closely with Resource Furniture in New York on a series of space-saving furniture pieces that will be installed in the units during construction – all units will be rented as furnished, the concept being that occupants need only to arrive with their clothing and a laptop.

The south-facing units at the front of the building each contain a cantilevered window box the interior of which is upholstered and can accommodate two seated people. The window boxes contain a high awning window for ventilation, as well as an operable casement window and a horizontal shade that is calibrated with the building site to allow winter sun to penetrate deep into the units while shading the more intense summer sun. Solar path and angle throughout the year were simulated so as to best understand the optimal length of the shade, which is 12".

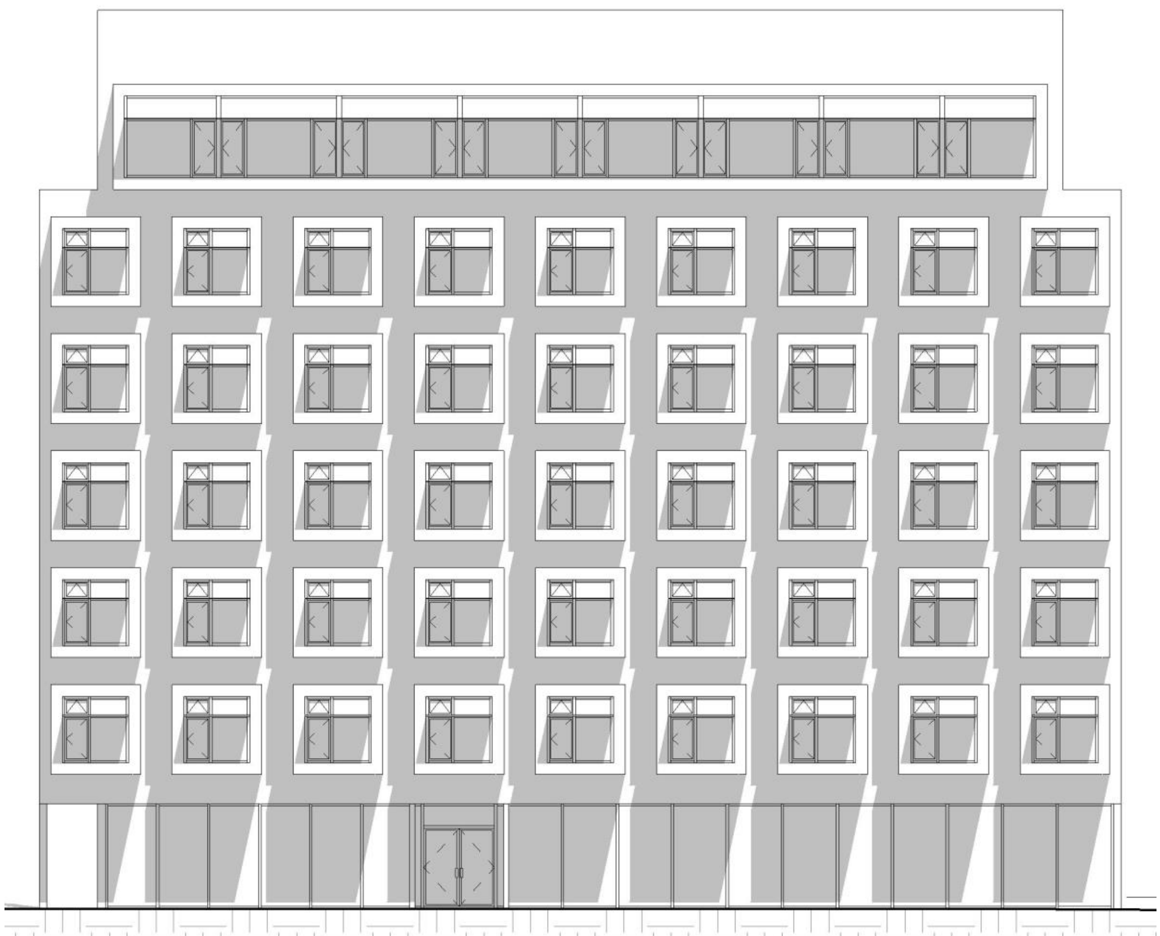


Figure 08: Simulation of shadow produced by the 12-inch horizontal solar shade. The shade was calibrated to ensure the majority of summer light and heat is kept from entering the units, while allowing ample day-lighting in the winter. Such an understanding combined with the choice of precast concrete contributed to the building's sustainability.

**BUILDING BULK AND SITING**

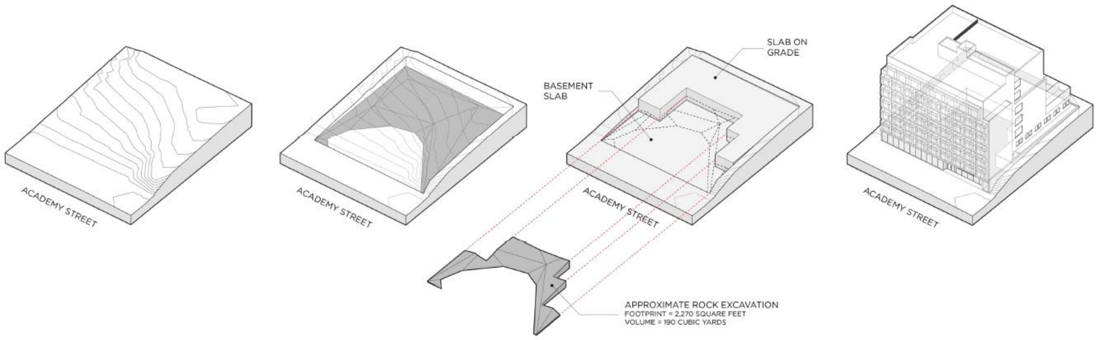
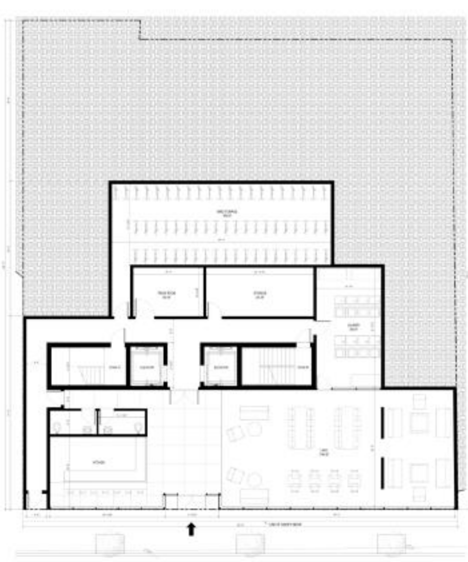



Figure 09: The sloping site in the Journal Square section of Jersey City is utilized to accommodate a basement that is accessed from sidewalk grade. The basement's perimeter is coordinated with the occurrence of rock just below grade at different locations of the site.

The Journal Square Redevelopment Plan largely controlled the design of the building's bulk, however, the site itself offered some noteworthy opportunities. Based on the redevelopment plan, the building could be a total of 6 stories, with 100% coverage on the ground floor and the upper floors controlled by a 30-foot rear yard set back. Small side yard set backs were also provided on the 6th floor. The site slopes from the rear to the sidewalk frontage over 10 vertical feet and has solid rock fairly close to grade. The existing slope allowed the architects to insert a basement that is at the level of the sidewalk, with the ground floor, which is the first floor with residential units, at near 100% coverage above. The surface depth of the rock was located through a geotechnical exploration, so that the perimeter condition of the basement itself was coordinated with the most efficient and minimal excavation of rock. The basement, which is accessed directly from Academy Street, is programmed as a café that is open to the public, with other amenity spaces including bicycle storage and a laundry room that are used by building residents.



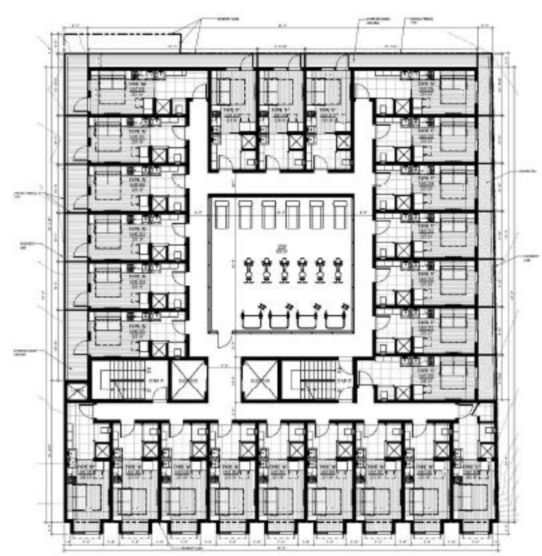


Figure 10: Basement and Ground Floor Plan, Jersey City Micro-Housing proposal, note the ground floor is actually up a story due to the slope in the site.

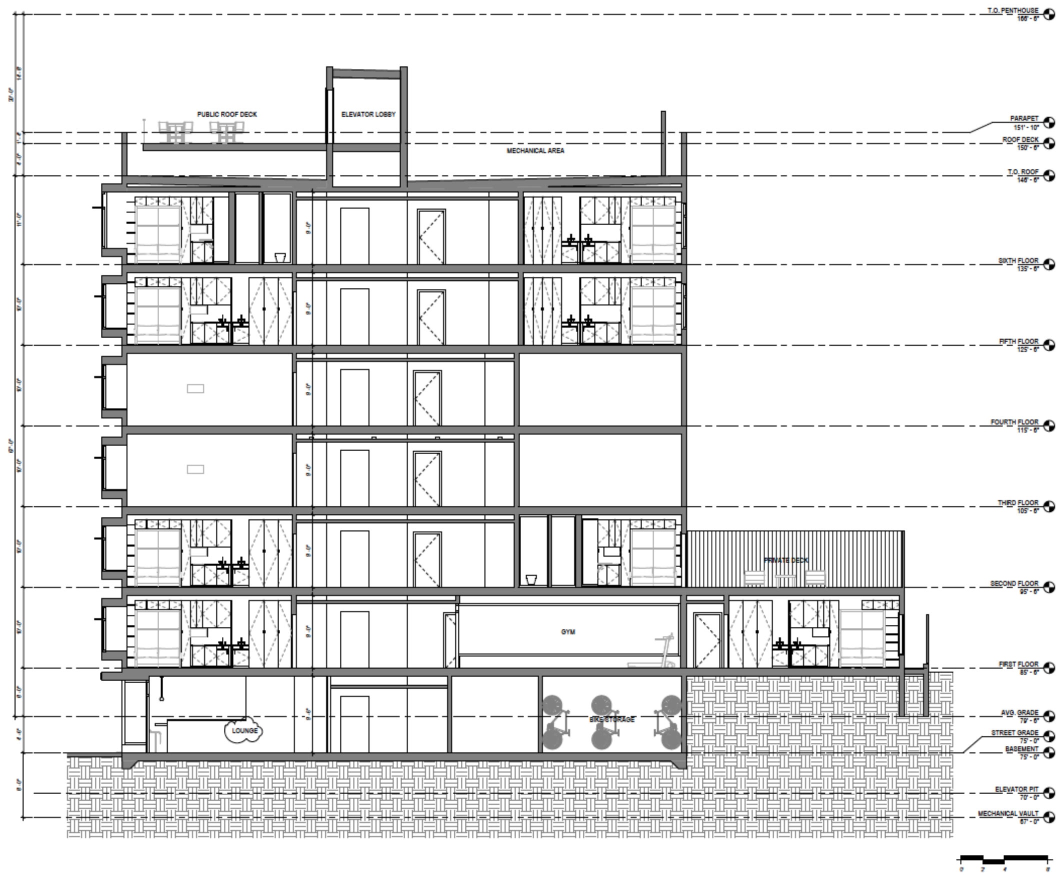



Figure 11: The existing slope of the site allowed for a basement programmed with amenity spaces including café, laundry room, and bicycle storage to be accessed directly from the sidewalk, giving the building the appearance of a 7-story building where only 6 are permitted. The first residential floor is at grade at the rear of the site, but one story up at the sidewalk.

The ground floor plan covers most of the site as permitted by the redevelopment plan, and sits on a series of spread footings in the rear of the site that bear on the existing rock. In addition to residential units, there is a centrally accessed gymnasium for residents' use as well. Above the ground floor, the building is set back from the rear of the site, and the average unit count per floor is twenty units.

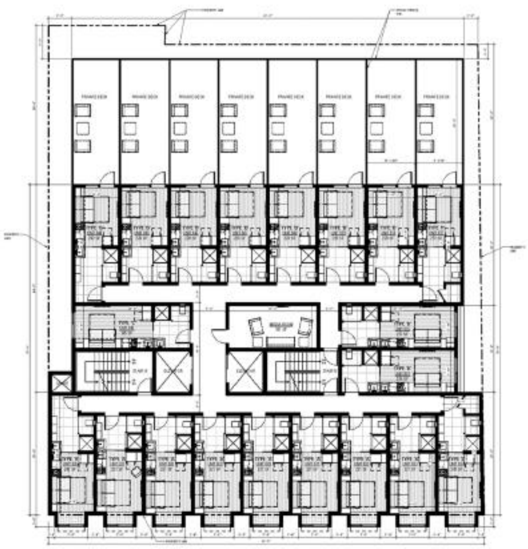


Figure 12: Second floor plan, Jersey City Micro-Housing proposal; the floors stack on levels 2-5 with additional side yard setbacks on the 6$^{th}$ floor.

**DESIGN COORDINATION, BIM, AND PRECAST CONCRETE**

Micro-housing brings with it some challenges beyond more standard types of residential buildings. First, there is generally a higher degree of coordination required across the design and construction team due to the density of units. If an average one-bedroom apartment containing a bathroom and kitchen is 750 square feet in area, then there are three times this amount of plumbing and gas risers, equipment, and fixtures within the same 750 square feet taken up by three micro-apartments. In many instances the mechanical, electrical, and plumbing (MEP) consultant will show this information as single lines, however, it was decided that all plumbing and gas runs would be modeled three dimensionally and integrated with the architectural and structural scope to ensure there are no spatial conflicts between trades.

In compliance with construction code, the size of the building defined its construction classification and will be constructed under Type IIIA, which is described as having exterior walls of noncombustible materials and the interior building elements are of any material permitted by this code – which is generally light gauge steel or wood interior framing. The term non-combustible materials can be broadly interpreted to mean a construction assembly that is fire resistant at its interior and exterior, which can be achieved through cementitious sheathing. The state Department of Consumer Affairs, which regulates building codes, however recently issued a Formal Technical Opinion (FTO) that the use of non-combustible materials will have “the same structural properties as concrete or concrete masonry units.”[6] This clarification quickly limited the number of choices for the building’s shell, the most common solution being CMU block, which would be require a 12” thickness for a six-story building. Upon exploring this option, the architects found that the framing, insulation, and interior and exterior cladding would yield exterior wall thicknesses as much as 16” to 18”. Given the small size of the units, the GRO team needed to find an alternative, thinner, assembly because in a micro-unit every inch counts. Based on this objective, a decision to use insulated precast concrete panels for the shell and building cores was made. The insulated panels only need to be sheathed on the interior, which allows a 10-inch wall assembly to be achieved, which would not decrease the interior area of the units themselves. The utilization of precast concrete requires a high level of coordination during the shop drawing process for the precast company selected for the project, and the precast scope was expanded to include floor slabs as well.

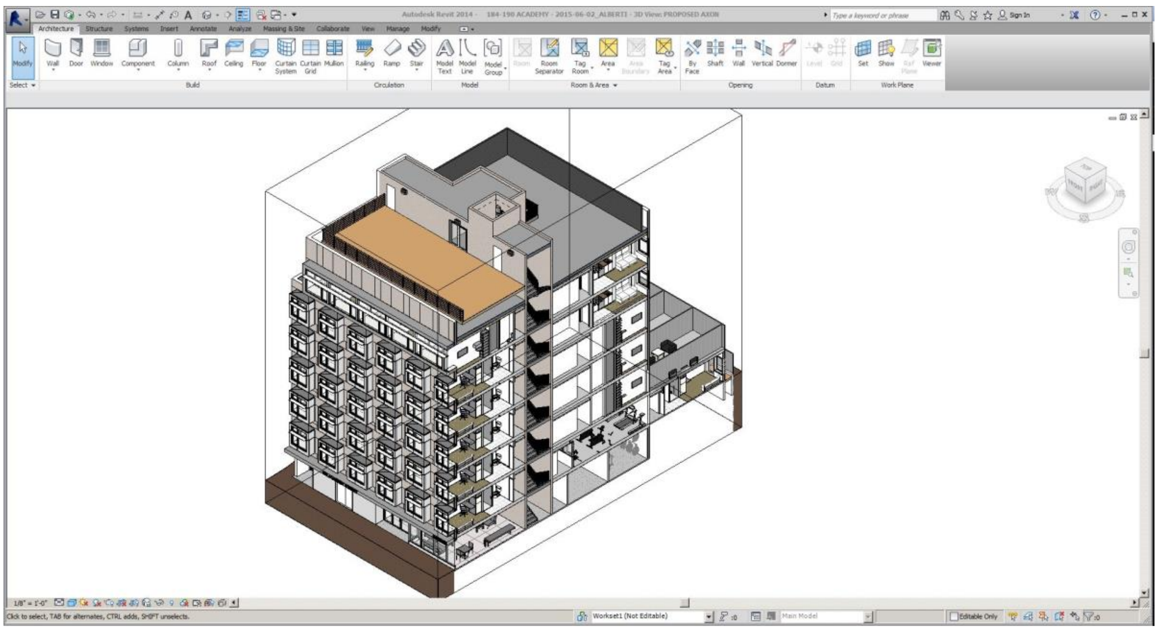


Figure 13: The architects used BIM package Autodesk Revit® to complete schematic design and move into the construction documentation phase of the project.

GRO utilized Autodesk Revit®, a Building Information Modeling platform, to complete the schematic design phase and further during the construction documentation and coordination process. While design intent was set by the architects and transmitted to others on the design and construction team, the coordination workflow worked somewhat differently. Design loads were calculated by the precast concrete company and transmitted to the structural engineer for foundation design, while the architects worked with the MEP consultant to determine which building services needed to be coordinated with the precast walls. The architect continues to work with the precast concrete company to semi-automate panel counts and sizes by linking Microsoft Excel to the Revit model to populate information such as panel type, length, width, area, and quantity.

**PRECAST CONCRETE AND THE SHOP DRAWING PROCESS**

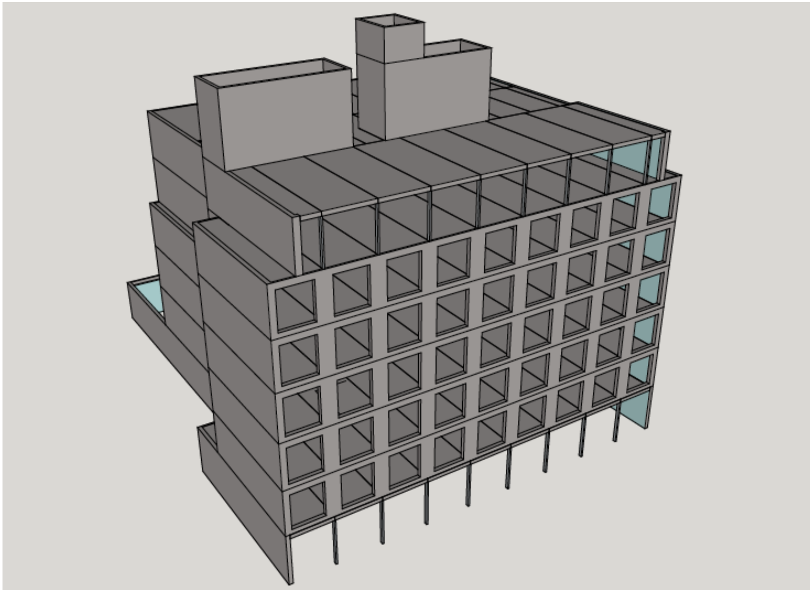


Figure 14: The selected precast company received digital data from the architect's building information model to do an initial panelization scheme for initial material take-offs and cost estimation.

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 2 | Basement | | | | | | | | |
| 3 | Walls | | | | | | | | |
| 4 | Item | Height | L.F. | Sq.Ft. | | | | | |
| 5 | 8" Superior Wall | 11'4" | 221.41 | 2508.5753 | | | | | |
| 6 | 8" Solid Wall | 10'4" | 42 | 433.86 | | | | | |
| 7 | 8" Solid Wall | 11'4" | 154.6 | 1751.618 | | | | | |
| 8 | | | | | | | | | |
| 9 | Plank | Qty | Length | Width | Sq. Ft. | Total Sq. Ft. | Area | | |
| 10 | 12" Plank | 5 | 17.75 | 8 | 142 | 710 | Bike Storage | | |
| 11 | 12" Plank | 1 | 17.75 | 6.66 | 118.215 | 118.215 | Bike Storage | | |
| 12 | 12" Plank | 5 | 16.58 | 8 | 132.64 | 663.2 | Trash/Storage | | |
| 13 | 12" Plank | 1 | 16.58 | 3.17 | 52.5586 | 52.5586 | Trash/Storage | | |
| 14 | 12" Plank | 1 | 26.5 | 8 | 212 | 212 | Laundry | | |
| 15 | 12" Plank | 1 | 26.5 | 6.5 | 172.25 | 172.25 | Laundry | | |
| 16 | 12" Plank | 2 | 5.66 | 6.58 | 37.2428 | 74.4856 | Stair A hallway | | |
| 17 | 12" Plank | 1 | 14.66 | 4.33 | 63.4778 | 63.4778 | Stair A hallway | | |
| 18 | 12" Plank | 11 | 25 | 8 | 200 | 2200 | Front Area | | |
| 19 | 12" Plank | 1 | 25 | 4.5 | 112.5 | 112.5 | Front Area | | |
| 20 | 12" Plank | 2 | 7 | 4.66 | 32.62 | 65.24 | Elevator Corridor | | |
| 21 | | | | | | | | | |
| 22 | Columns | Qty | Length | L.F. | | | | | |
| 23 | 12" X 12" | 4 | 10.33 | 41.32 | | | | | |
| 24 | | | | | | Total | Total | | |
| 25 | L-Beam | Qty | Depth | Length | Sq. Ft. | L.F. | Sq. Ft. | | |
| 26 | Beam | 1 | 2 | 29.58 | 59.16 | 29.58 | 59.16 | | |
| 27 | Beam | 2 | 2 | 31.45 | 62.9 | 62.9 | 125.8 | | |
| 28 | Beam | 1 | 2 | 7 | 14 | 7 | 14 | Elevator Corridor | |
| 29 | | | | | | | | | |

Figure 15: The selected precast company is working with the architects to devise data translation methods that will assist and semi-automate shop drawing production, such as data querying the BIM to populate critical dimensions in a spreadsheet.

The shop drawing process for this project is active and ongoing at the time of writing. The architect and precast company imagined a new series of workflows to complete this process in a 10-week period. The precast company first calculated all loads and fire ratings. Per the New Jersey edition of IBC, exterior walls will have a two-hour rated assembly, as will the vertical circulation cores. A three-hour rated assembly has been devised between the basement and first residential floor. Design loads were set ay 40 lbs. per square foot for the residential units and 100 lbs. per square foot for amenity spaces including gym, public roof deck, and café.


Figure 16: After the decision was made to investigate a precast concrete system, the precast company suggested a system to the design team that would include insulated and studded panels for both floor and walls.

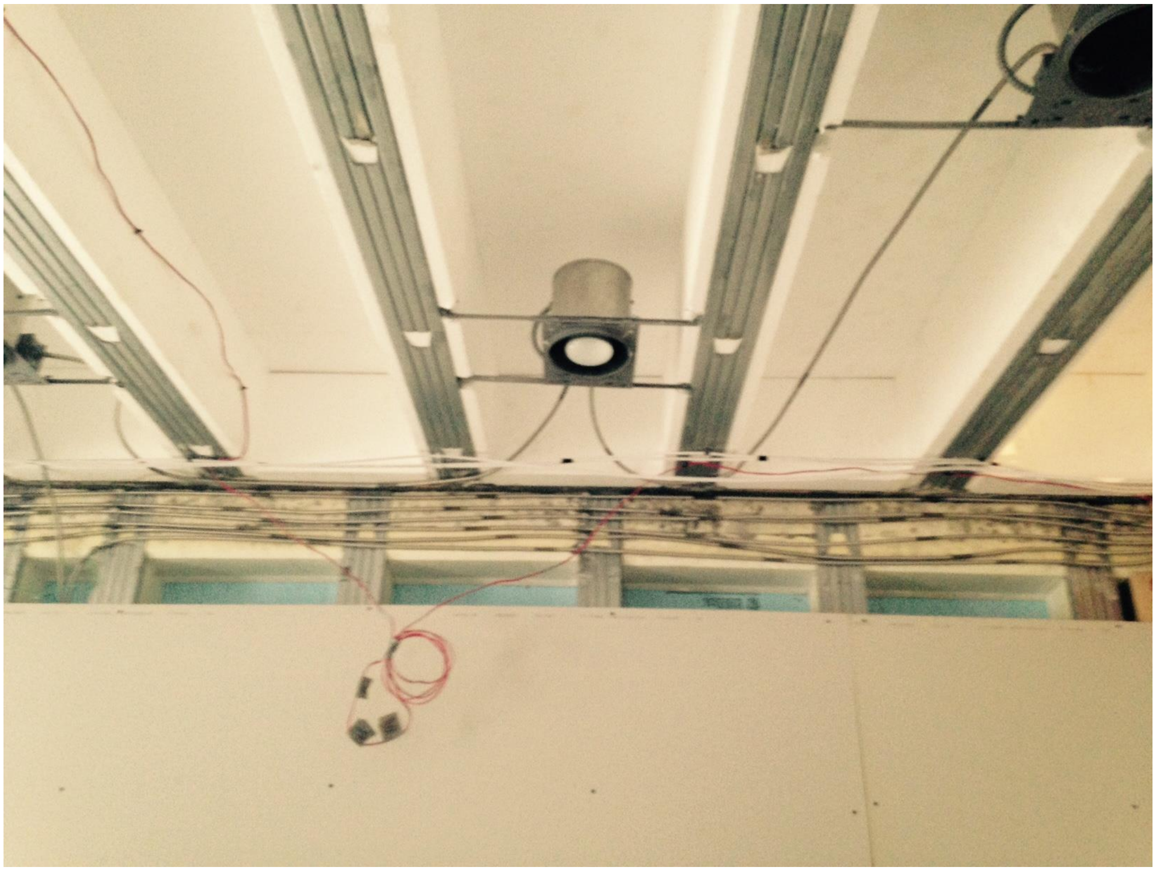


Figure 17: The wall and floor panels permit the running of plumbing and electrical systems within their assembly dimension. The piping and wiring were coordinated between the architect and precast company.

The precaster presented to the architect a panelized solution that utilizes a Superior Wall-type technology for both walls and floor planks, so that standard interior finishes such as gypsum board could be used, and plumbing and electrical work could occur within the walls themselves. Using such a system would provide excellent insulation values that will ultimately conserve energy over the life of the building. Additionally, micro-housing projects are generally seen as having higher rent turnovers than other types of housing, and the precast concrete will ensure durability of the building over time.

The architects took the two-dimensional piping and wiring diagrams from the MEP consultant and modeled them as actual pipes and chases in their Building Information Model so that the true sizes and lengths could be understood by the design team and ultimately represented in the fabrication drawings the precast company will utilize in the forming process of the panels.

Ultimately, the idea is that the Building Information Model used to coordinate the engineering consultants will be the same that includes data on the panelization of the project as well as all pertinent information for panel forming. The idea of extracting data from the BIM to create shop drawings and fabrication tickets is novel for a project of this size. The design team believes this will greatly streamline the time needed for fabrication documentation allowing the precast company to move into production at an earlier period in project development thus saving potentially 4-6 weeks in the overall project period.

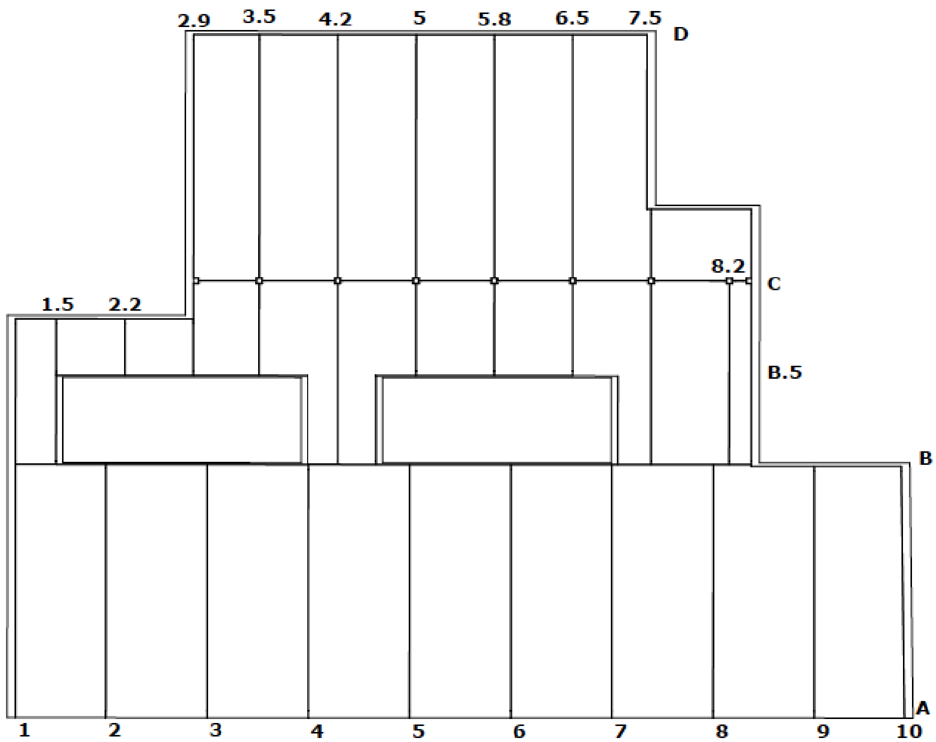



Figure 18: At the time of writing, a preliminary floor and wall plank layout had been arrived at and input into the architect's Building Information Model. The three-dimensional data would ultimately be extracted to produce the two-dimensional fabrication drawings to ultimately form the panels.

## FLOOR, CORE, AND SHELL DESIGN

GRO detailed the precast connections of floor planks to core and shell walls based on structural data analyzed by the precast company. The shell panels are studded to receive an interior finish of gypsum board, which also allows for additional insulation to be utilized. Core walls range from 8" – 12" solid concrete walls, which carry through the building and ultimately bear on precast columns in the basement.

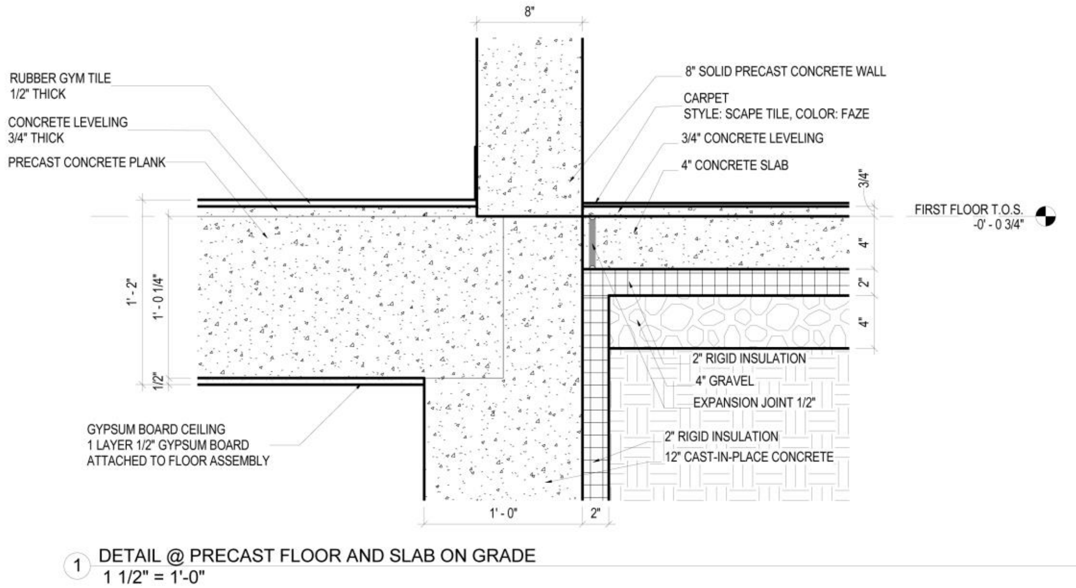



Figure 19: Precast plank to wall detail at grade. Due to the slope of the site, the building has a basement level lobby and café, which "walks out" to the sidewalk. This work is coordinated with a cast-in-place slab at the rear of the building.

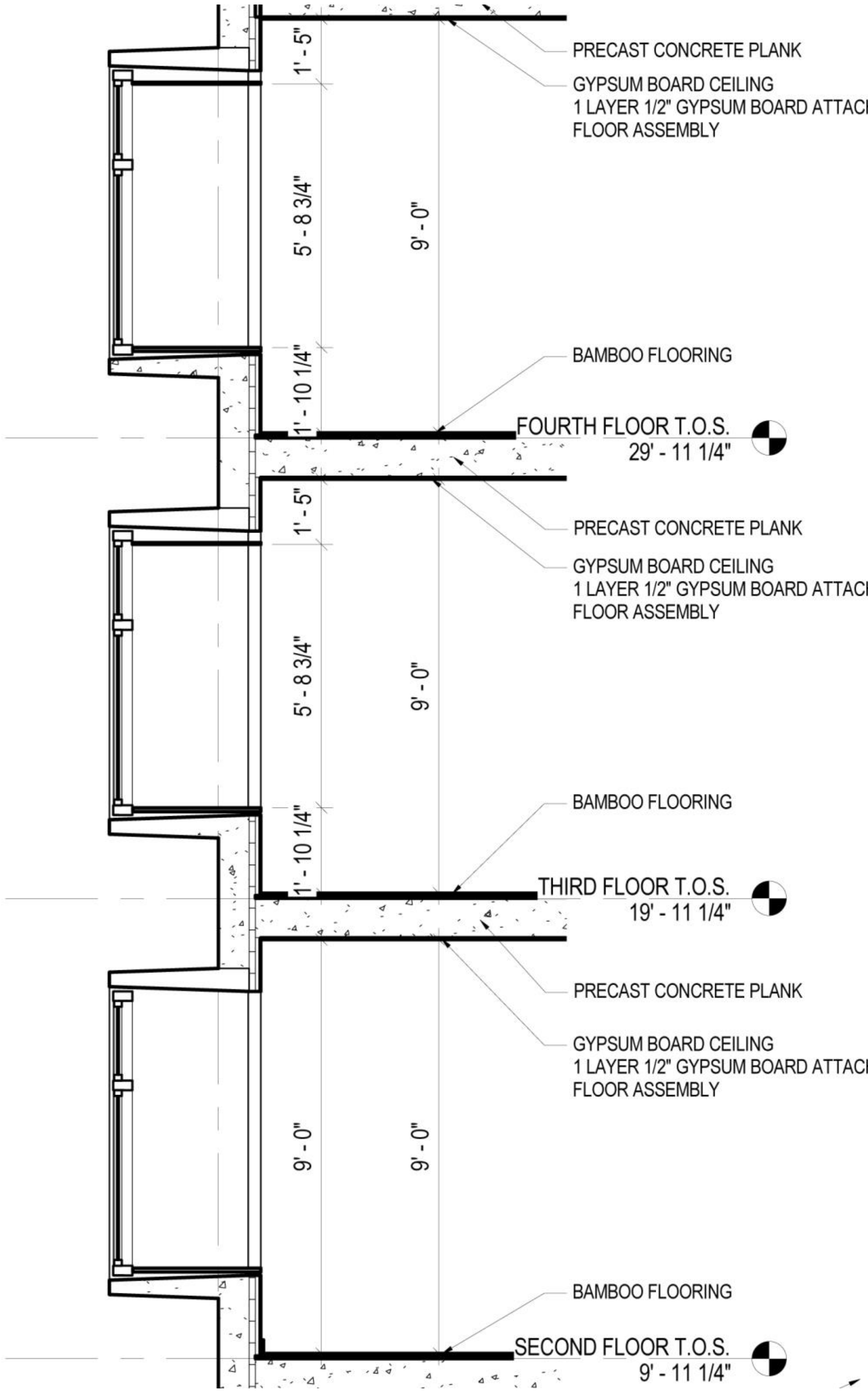



Figure 20: Shell walls use a studded precast cavity wall that connects to precast floor planks via welded steel plates. The cavity wall allows for additional insulation, which ultimately increases the energy performance of the building.

## WINDOW BOXES

A main feature of the building is a series of forty-five window boxes, which extend the south-facing micro-units an additional two feet.  The window boxes were originally conceived as framed stud walls which would be anchored to the exterior south-facing precast wall; however, after engaging the precast company it was decided to develop a mono-poured panel that would include the window boxes in the casting of exterior panels.  The boxes would taper from 10” to 6” at the window, adding interest to the front façade of the building. The south façade panels are being developed to be poured with three window boxes each, so there will be a series of 15 precast panels that make up the primary front façade.

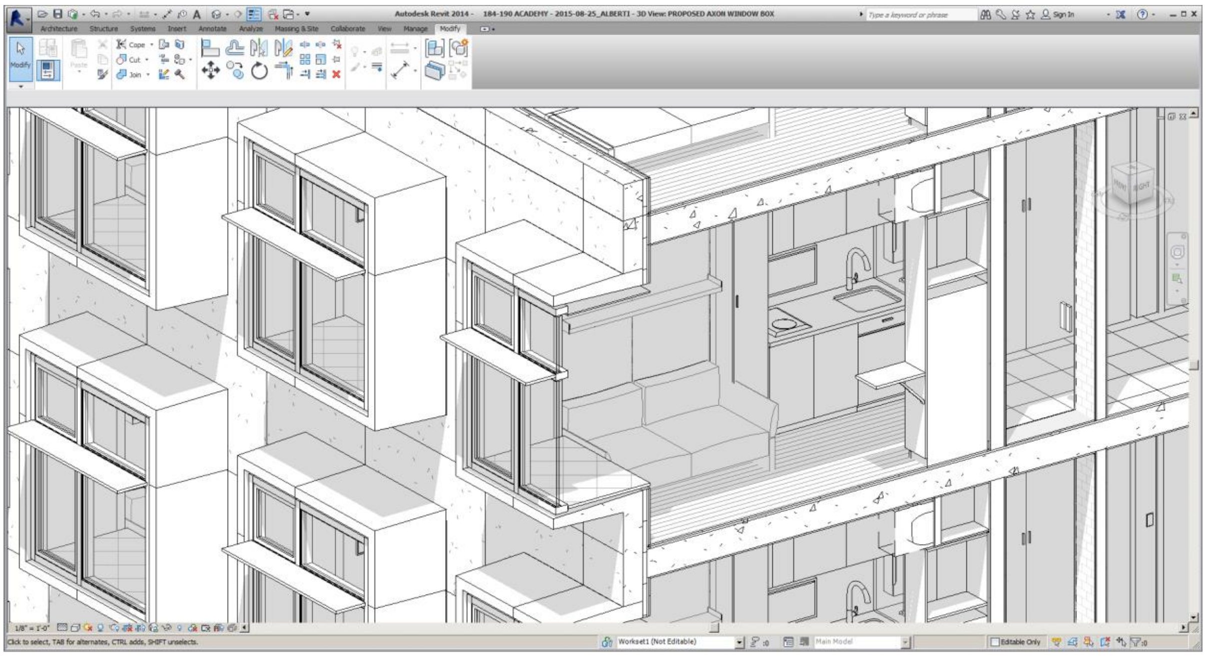



Figure 21: A cutaway section thorough the building’s south façade reveals the monolithically poured front panels that contain the window boxes.

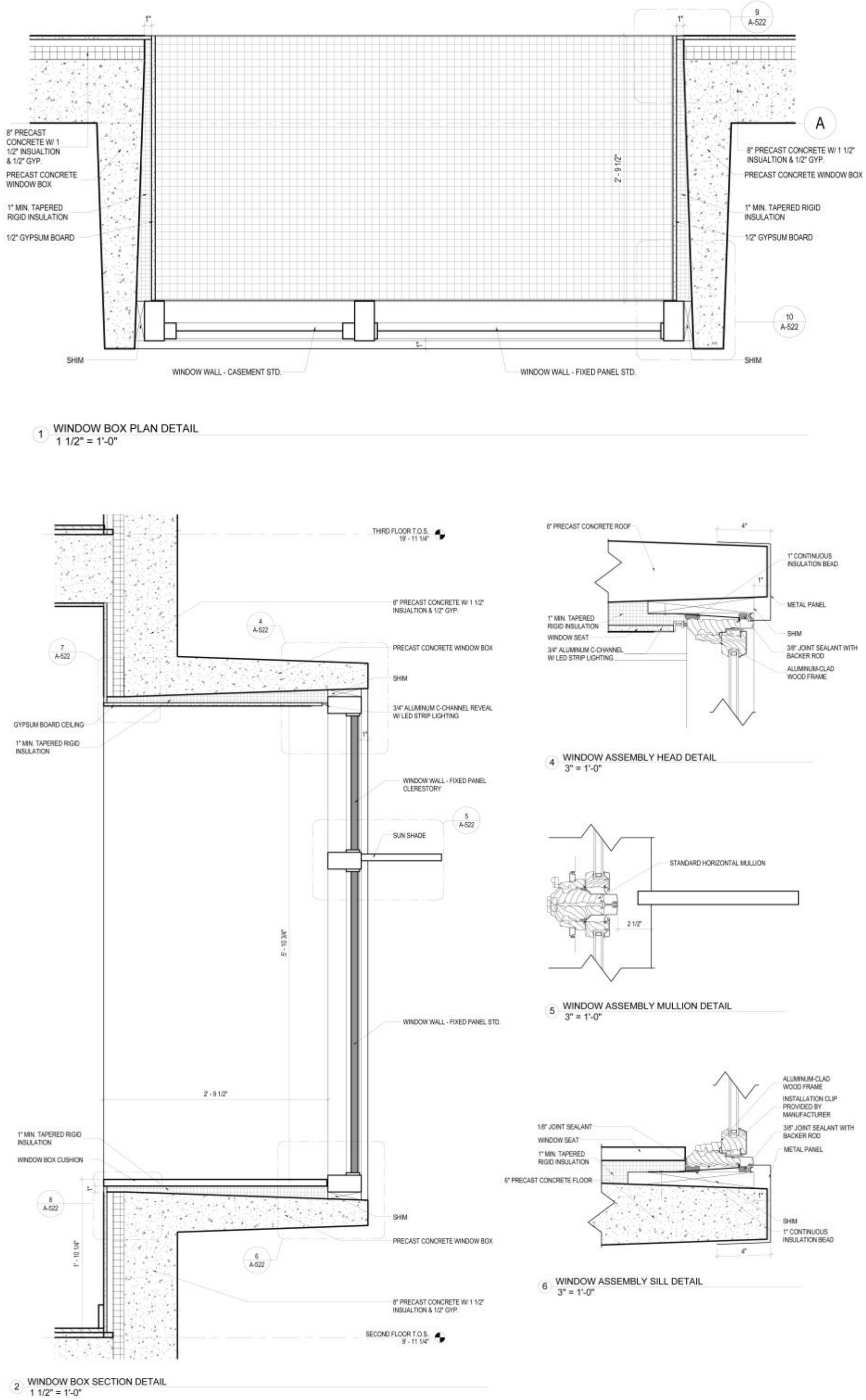



Figure 22a and b: Plan and section details of the window boxes show their inclined form. The inclusion of the window boxes into a monolithically poured façade panel adds interest to the building while removing the need to frame each box on site after erection of the precast panels.

## CONCLUSIONS AND PROJECTIONS

GRO Architects' proposal for Journal Square in Jersey City represents a precedent in a housing type that will ultimately find more benefit in our dense urban areas, and the trend for micro-housing in cities seems to be increasing. Density is ultimately a sustainable condition, where services can effectively be provided for a larger group of people. Offsite construction of precast elements reduces on-site construction activity and materials storage requirements in tight urban areas. The use of precast concrete for such a project furthers its sustainable goals by providing a high mass, well-insulated material for the super structure of the building. As architects are increasingly asked to consider sustainable opportunities and understand design decisions over a building's life cycle, and precast concrete can find novel and significant purpose in this new type of urban housing. This project exemplifies how the material features inherent to pre-cast insulated concrete are in strong alignment with the broader objectives of dense urban living central to the micro-housing movement.

**NOTES**

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[1] Schmal, Peter Cachola; "Capsule Architecture, Revisited" in Kisho Kurokawa: Metabolism and Symbiosis, jovis Verlag GmbH, 2005, page 64

[2] Watanabe, Hiroshi; The Architecture of Tokyo: An Architectural History in 571 Individual Presentations, Edition Axel Menges, 2001, page 149

[3] *http://www.seattletimes.com/pacific-nw-magazine/seattles-micro-housing-boom-offers-an-affordable-alternative/*

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[6] *http://www.state.nj.us/dca/divisions/codes/publications/pdf_fto/fto_14.pdf*