Penthouse View

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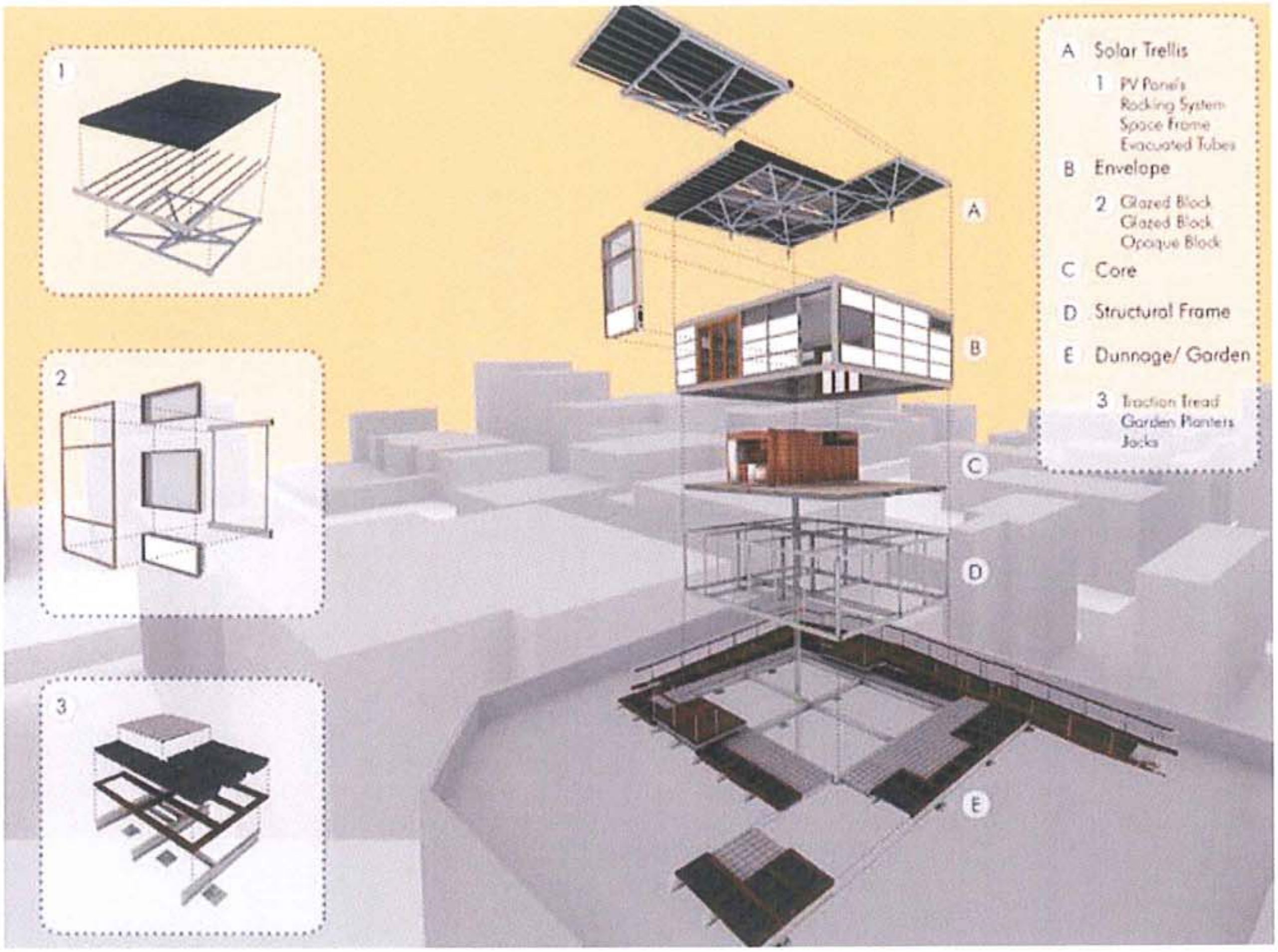
A new modular structure provides an option for unused rooftop space.



The modular construction design allows the two modules to maintain structural stability during installation and transportation.

THERE'S PLENTY of underutilized roof and air space atop typical New York City mid-rise residential buildings. But the creators of the Solar Roofpod are hoping to change that.

The 100% renewable energy-powered penthouse is the creation of Team NewYork (TNY), a selection of architectural and engineering students and faculty advisors from The City College of New York (CCNY) and dedicated team sponsors, and was an entry finalist in the 2011 U.S. Department of Energy Solar Decathlon.

The modular one-story structural steel-framed dwelling unit, designed to bear on a customized dunnage system compatible with existing building's roof structure, presents a viable option for adding an energy-efficient structure atop multi-story residential buildings. It includes a 64-piece customizable exterior window/wall cladding system, an 18-in.-high rooftop space frame with a solar array on top and a rainwater cistern suspended underneath the floorboards. It is 23 ft wide by 33 ft, 9 in. long and 15 ft high from bottom of floor to top of trellis finish. Total weight of the roof pod is approximately 16 tons, with steel framing—including the steel rooftop space frame—accounting for roughly 7 tons.

Working together with TNY, Dominick R. Pilla Associates, PC (DRPILLA), a New York-based consulting engineering and architecture firm, provided structural design services from initial concept to construction completion. DRPILLA's charge was to design a NYC code-compliant structural system that accommodated different dunnage and cladding configurations, and was sized to be constructed, disassembled, transported and reassembled multiple times. The initial prototype was built atop the Marshak Building roof terrace at the CCNY campus. Inspected and approved by the NYC Department of Buildings, then disassembled and freighted to Washington, D.C., the structure was reassembled for the com-

▲ The Solar Roofpod offers a unique location for a sustainable urban dwelling.

▼ The framing system and dunnage girders.

▼ The simplicity of the highly refined steel structure and the adaptability of the modular envelope will potentially appeal to the eco-conscious urban dweller.

petition and then deconstructed and returned to CCNY to be permanently installed atop the Spitzer School of Architecture.

Why Steel?

Initially, DRPILLA designed a wood post-and-beam system to complement the wood-framed cladding system design by TNY; however, challenges arose with lateral resistance. DRPILLA experimented with creating a shear wall by either post-tensioning the wood frames of the interlocking exterior panels or bolting the individual panels together with continuous steel plate connectors. Both solutions were dismissed because they limited the flexibility of the cladding system and complicated its assembly.

Consequently, a steel moment frame scheme was selected. The moment frame consists of HSS 4x4 posts at building corners, perimeter HSS 6x4x¼ roof beams and HSS8x4x¼ floor beams. Not only would the steel moment frame resist lateral loads and create a seamless transition between the exterior shell, the space frame above and the W12x30 dunnage girders below, it would also be durable enough to withstand the rigorous travels and the potential of being disassembled and reassembled multiple times.

Sized to fit on the back of a flatbed truck, the Roofpod is composed of two equal modules that are joined along the middle longitudinal plane (i.e., the splice plane). Each module is built as a rigid box by welding perimeter steel tubes to keep its stability during

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installation and transportation. During assembly of the pod, two corner posts of each module in the splice plane were designed to be removed. In order to achieve the aesthetic continuity of the Roofpod's envelope, DRPILLA designed an inner sleeve tube moment connection to splice the edge tube beams. The sleeve tubes are hidden inside one of the edge tube beams and can be slid into the design position through access holes on tube webs. Nuts are pre-welded on outside surfaces of edge tubes so that all bolts can be installed inside the tube connectors. DRPILLA also designed shear plate connections to tie together the module's longitudinal beam in the splice plane. As a result, the assembled pod remains a rigid frame system to resist gravity and lateral forces.

The framing structures of the floor and the roof are typical 4-ft-wide, one-way, lightweight, energy-saving ThermaSteel panels. The exterior walls, landscape deck and ramps are built by multiple timber-framed or metal-stud-framed modules. The floor and roof decks are 7½-in.-thick panels spanning between girders. These composite panels perform three functions in one: They have integral flat-placed, light-gauge steel studs at the top and bottom faces for framing; contain modified expanded polystyrene (EPS) for insulation; and provide a vapor barrier lining.

Space Frame Adaptability

Relying solely on power generated by the solar panels, the orientation of the Roofpod's PV array was critical and was fine-tuned continuously as the mechanical performance systems were being optimized. Since the panels were integral components of the space frame, as moment connections, DRPILLA used STAAD (finite element software) to account for adjustments to the PV array and created a series of finite element models to simulate the integrated roof, body and base girder frames.

Ultimately, the space frame can resist 20-psf design snow load and 5-psf superimposed dead load by solar PV panels and relevant accessories. The final design yielded a space frame design composed of 102 pipes with a maximum 2⅞-in. diameter and 0.148-in. wall thickness. It weighed 1,740 lbs. in total for a 33-ft × 22-ft footprint. The final design of the space frame reduced the number of members by 36% and total weight by 44%, compared to the preliminary design, via optimized placement and determination of the space frame supports on the roof pod body using STAAD models.

A Real Estate Reality

The Solar Roofpod may be only a prototype today, but TNY and DRPILLA look forward to seeing these pragmatic penthouses spring up on rooftops throughout New York City and beyond. The simplicity of the steel structure and the adaptability of the modular envelope offer the flexibility to meet market segment demands and appeal to the eco-conscious urban dweller who desires to live lightly and act as a steward of a more resilient urban environment. MSC

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