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Building Over an NYC SUBWAY STATION

An Engineering Marvel

State Renaissance Court Is Being Constructed Above an NYC Subway Station and With Building Codes That Have Yet to Be Written

If geologists were able to warn New Yorkers of an impending earthquake of epic proportion, residents of at least one particular building would likely take the news in stride. That's because the building is being built under seismic design and engineering standards unprecedented in the history of New York City residential construction.

When construction is completed early next year, it will be one of only 90-something buildings in the world—mostly in Japan and California—with seismic engineering measures able to withstand the catastrophic force of a 500-year earthquake. The building is also being constructed with unparalleled vibration and acoustic design and engineering standards.

Why all the fuss for a seemingly ordinary 8-story building? It's hardly an ordinary construction project.

In New York, this construction is the first ever residential building, called State Renaissance Court, whose vertical support will come from one of the subway structures of the city's underground rapid transit system. And although the subway structure will be its vertical support, the building is being constructed independently of (a soft interface) and completely isolated structurally from (minimal lateral load transfer) the subway structure itself, making this project unique and unparalleled in New York and the United States.

The centerpiece of this complicated, unprecedented engineering and design is a Steel Spring Isolator—a device custom-designed specifically for this project by Vibration Mountings & Controls, Inc., a New Jersey–based nationally renowned authority in vibration isolation.

The building structure sits on these isolators over the New York City Transit Authority (TA) structure and is tethered, as it were, by deep pile foundations at east and west locations at the rear of the building. The first floor is like a 440-

foot-long by 90-foot-wide truss turned sideways, sitting on isolators above the TA load points and supported at each end by pile foundations. As a result of the isolators, seismic and lateral forces bypass the TA structure and instead are transferred to the pile foundations. The isolators also protect the building from subway vibrations.

"The first floor is essentially a 'floating' platform, analogous to a tabletop without legs, that sits on a complex network of 270 Steel Spring Isolators that allows a soft connection with the subway structure, keeping the building from making a fixed contact," explained John J. Frezza, president and CEO of New York–based Strategic Construction Corp., the general contractor and developer of State Renaissance Court—158 market rate and affordable housing units, 20,000 square feet of ground level retail space, and indoor parking being constructed directly above the Hoyt/Schermerhorn Street subway station in downtown Brooklyn, N.Y. The project encompasses a total of 196,000 gross square feet.

The developers are a joint venture partnership of Strategic Development and Construction Group and IBEC Building Corp., both based in Brooklyn.

They Had to Establish a Science

"Building above New York City's subway system is not new; in the past, all buildings over subway structures were anchored into the neighboring ground.

But constructing a residential building whose vertical support will be provided by the existing subway structure—without the building's first floor actually being rigidly affixed to the subway structure itself—is exciting and unprecedented engineering in New York," Frezza said.

So exciting that the amount and type of engineering and design going into this construction is groundbreaking in New York City, according to the project's co-structural engineers Neil Wexler, president and CEO of renowned engineering consultants Wexler & Associates, and Stanley Gleit, president of Gleit Engineering Group, P.C., both based in New York.

"All engineering projects have a scientific base usually found in existing building codes. But that wasn't the case with this project. The science did not exist because earthquake force was only introduced into New York City's building codes five years ago, and the city has yet to adopt stringent seismic performance standards from the International Building Code. Therefore, we had to establish the science, then apply it to the engineering, design and construction process," Wexler said.

The result, according to Frezza, is "engineering that rivals" high-rise construction in Japan and buildings in San Francisco and other West Coast cities where activity of earthquake force is frequent. "In fact, the engineering is more equivalent to the structural design standards of a nuclear power facility, rather than an ordinary residential building," he said.

The science and engineering had to be developed around parameters mandated by the New York City Transit Authority, the public agency that operates the city's underground rapid transit system.

One absolute mandate by the TA was that the developers had to prevent wind forces and other lateral forces (in the event of an earthquake) from impacting the subway structure.

After researching the TA structure, James McCullar, the project's chief architect and principal of James McCullar & Associates, designed the building to fit over the underground subway

The building structure sits on spring isolators over a subway station and is "tethered" by deep pile foundations at east and west locations at the rear of the building.

structure and coordinated structural and acoustic design in accordance with all required design parameters. McCullar's architectural analysis established design and isolation requirements to meet the 2000 International Building Code seismic code and the strict criteria of the TA.

Acoustic design criteria were then established by New York–based Shen Milsom Wilke, which specializes in acoustical and vibration engineering, followed by VMC's design and fabrication of the Steel Spring Isolator.

The TA does not want the building to pull the subway structure from side-to-side if earth tremors were to occur. Besides the issue of seismic isolation, with trains rumbling through the subway tunnels on a 24-hour basis, vibration and acoustic issues also had to be addressed to ensure quality habitability, according to the developers, who retained VMC and Shen Milsom Wilke for their expertise in this science.

Shake, Rattle & Roll

The TA structure was originally designed in 1936 to accommodate a new building with load points in a grid across the subway roof. Recesses were designed in the TA roof for future cellar mechanical spaces. After the subway station was built, the site remained an open parking lot on shallow fill above the TA structure until the design of State Renaissance Court.

"Although the city's forefathers had the vision to pre-engineer this particular subway structure to support a 40-story building, provisions for earthquakes were non-existent when the subway structure was built 70 years ago," explained VMC President John Giuliano. "Since the building will sit directly above a subway structure that will provide its vertical support, we had to meet seismic and gravity load criteria that does not even exist in New York City building codes."

Wexler said they had to research other sources to establish the scientific base of the project. "It had to be science, design and engineering under the parameters of zero tolerance. The TA would have it no other way," he said.

"The science has established the engineering principles. In turn, the engineering principles have driven the design development and the construction means and methods. Our building will set the scientific standards and engineering performance policies for future residential construction of this nature in New York, as well as other urban areas of the country," Frezza said.

An external support network, or "cushion," had to be created to meet seismic parameters. Thus, VMC designed custom Steel Spring Isolators that separate the building from the subway structure, attenuating vibration and sound from moving trains and, on a greater level, cataclysmic earth tremors.

"A Steel Spring Isolator was used in order to accommodate the site's vibration range of 4-to-90 Hertz for high and low frequency sound and vibration, and to maintain performance over time through all types of environmental factors. The steel also sits on Teflon, a low co-efficient of friction material, so the building can effectively slide over the subway structure in the event of shock loading," said Giuliano, who explained that this was further added to the device as a fail-safe measure.

A "cushion" helps meet seismic requirements. Custom steel spring isolators separate the building from the subway structure, attenuating vibration and sound from moving rains. Also, the steel sits on Teflon so the building can slide over the subway structure in the event of shock loading.

The springs have been designed with a compressibility factor that allows them to maintain their lateral resilience even when the building achieves its maximum dead and live load, or gravity load.

Sounds of the Subway

The 270 Steel Spring Isolators sit on top of 26 concrete-encased steel girders, or "load points" (which are part of the original subway structure), and, in turn, the building sits on top of the isolators. The girders were reinforced with concrete "pedestals" to provide a base for the isolators. The first floor girders of the building sit on the isolators, and thus separate the first floor from the subway structure. The first floor acts as a horizontal diaphragm transmitting all of the forces to the piles in the adjoining lots, explained Raphael A. Marotta, PE, of Gleit Engineering Group, P.C., the project's Engineer of Record. The developers said Marotta and his company have seen the project through since its inception and are responsible for making most of the intricate details actually work!

The entire first floor platform is constructed in a way that allows it to actually displace, or move laterally relative to the subway structure, up to a maximum of a half inch. The isolators provide a "soft" connection, allowing the building to slide over the subway structure as the ground, theoretically, moves during an earthquake, according to Giuliano.

"Seismic design loading is predominantly a horizontal loading due to primary and secondary waves generated by an earthquake," he explained.

"When standing on the first-floor platform, you feel absolutely no vibration when the train passes below. Standing on the existing sidewalk adjacent to the building's first-floor platform, however, is noticeably different, as you feel the vibration of the passing train under your feet."

Frezza said the Steel Spring Isolators accommodate all loading conditions, both static and dynamic, by transferring seismic loads to an external pile matrix through seismic restraint devices connected to the platform's transfer girder system. The isolators also act to attenuate structure-borne vibration and sound generated by the active subway below.

"The fact that the building is being supported by the subway structure raised concerns over vibration and sound. Therefore, the Steel Spring Isolators are designed to accommodate three different performance aspects," Frezza explained.

"In addition to transferring the building's dead and live load, and mitigating significantly the transfer of lateral load to the subway structure, the isolators will attenuate structure-borne vibration and sound caused by the trains—and, thus, maintain a quality level of habitability for the building's future residents," he continued. "This guarantees that there will be no transfer of sound and vibration up and through the building from the subway."

Giuliano said, "As trains move through the subway tunnels 24 hours a day, they create noise and vibration that would be intrusive to the building's inhabitants. Our site surveys determined that a system isolating low frequency disturbances would be required, so we ultimately decided on Steel Spring Isolators."

Hesky Brahimy, one of the development partners, expressed his satisfaction and justification for the significant resources invested on vibration and sound attenuation to assure a high level of habitability for residents.

"The Steel Spring Isolators absolutely work!" Brahimy declared. "When standing on the first-floor platform, you feel absolutely no vibration when the train passes below. Standing on the existing sidewalk adjacent to the building's first-floor platform, however, is noticeably different, as you feel the vibration of the passing train under your feet."

Part of the external support structure includes two separate monolithic pile caps ("thrust blocks") that are 12.5 feet wide, 9 feet deep and 50 and 90 feet long, each placed encasing a deep battered mini-pile system—"the matrix"—containing 140 separately augered mini-piles.

At the pile cap itself, the transfer platform is rigidly connected laterally through the use of seismic restraints ("dumbbells"), which act to transfer the building's lateral loads directly to the pile system, but still allow for vertical displacement because of the spring compression at the application of the final dead and live load. The seismic restraints are secured to the transfer girders and then welded to an embedded plate within the pile cap, which all allow vertical displacement when the Steel Spring Isolators are loaded.

What About the Walls?

Meeting structural, seismic and acoustical standards was one thing for the building's overall construction, but what kind of exterior wall would fit those standards? As it turns out, the final selection of exterior walls also helped get the construction schedule back on track.

The exterior walls are a pre-fabricated panel system manufactured by Island Construction Companies of Long Island, N.Y.

Using a pre-fabricated exterior wall panel system provided several advantages.

First, in dynamic computer model testing, pre-fabricated exterior wall panels proved to be less rigid than standard masonry construction. From a seismic standpoint, less rigidity and greater flexibility allows dynamic forces to dissipate more readily, according to Frezza, noting that the pre-fabricated wall system used in this project helped the developers meet seismic standards and requirements.

Also, the pre-fabricated wall panels are lighter in weight than standard masonry construction, helping the developers meet seismic requirements that dictated a lighter-weight building.

"The system functions like a curtain wall, which helps reduce weight on the building structure itself. The panels are hung from floor-to-floor, with each panel separated by a joint so it has the capability of moving slightly. These characteristics were important to seismic requirements, and the wall system was fabricated with that in mind," Frezza explained.

Other advantages include the following:

Indoor panel fabrication (rather than standard, hand-constructed masonry) allowed for a more controlled, uniform construction of the wall system. "Better construction controls provide a number of benefits, for example, a high thermal quality," Frezza said.

The wall panels were fabricated simultaneous to the construction of the superstructure—a significant advantage, according to Frezza, because "as soon as the superstructure was completed, we were able to immediately install the exterior wall panels since they had already been fabricated. Installation of the pre-fabricated panels took a fraction of the time it would have taken for standard masonry construction," he said.

Pre-fabrication resulted in ease of construction. "Logistically, eliminating the need to assemble scaffolding on site made this part of the construction easier and quicker," Frezza said. "This was important because we lost a good deal of time on the front end during the approval process because of the stringent seismic standards and TA requirements that had to be met," he added.

Architectural Issues

The construction of State Renaissance Court was not without its architectural issues.

"It was initially designed as two separate buildings because of an imposing above-ground subway ventilation structure, which sits on this parcel of land. So the building had to be architecturally designed to hide this eyesore," McCullar said.

"The location of the subway vent structure not only impacted the architectural design, it complicated the layout of the steel and also added to the engineering and structural complexity of the platform design. But the development team made it work," Frezza said.

McCullar added, "Originally, two separate buildings would have been joined by a one-story connecting building with a common lobby. But the project evolved into a 'bridge' building that maximizes the allowable floor-to-area-ratio and a greater number of much-needed affordable housing units. The building is now being constructed around the vent structure, and the 'bridge' allows the building to present itself aesthetically as one building with a uniform façade."

Among other construction and design complexities are the building's elevators. The TA is requiring that the counterweights be equipped with mechanical safety devices that go above and beyond meeting normal standards and requirements of New York City building codes.

"This project would never have gotten off the ground without the much-valued cooperation and teamwork of the TA, and the engineering experts the agency brought to the table. The TA's utmost priority throughout this process has been the safety of the public domain," Frezza said.

"There's a price to pay for being the first-ever project of its kind in New York City. You help establish design and engineering parameters and standards, but there are a [lot] of challenges, constraints and complexities that go along with that. This evolved more into a research and development project because of the learning curve and constant technical challenges," he continued.

"It has been rewarding and exasperating, but in the end we know we will have created the blueprint for all those who come after us with similar projects," Frezza added.

And what did the R&D aspect of the project do to the budget? "That's a story for another day," Frezza said.