State Renaissance Court

Seismic Separation over the NYC Subway

By Neil Wexler, Ph.D., P.E. and Jan Jiroutek

Figure 1: State Renaissance Court.

*Wexler & Associates was presented an Outstanding Project Award in the category of New Buildings $30M – $100M in the NCSEA 2008 Excellence in Structural Engineering Awards program. Information on entering projects in the 2009 Awards program can be found at **www.ncsea.com**.*

This 8-story mixed use apartment building (*Figure 1*) occupies a site extending 447 feet along Schermerhorn Street, and 90 feet along Hoyt Street, Brooklyn, New York. The NYC Subway runs below the building, parallel to the long dimension. The building footprint extends 75 feet above and only 15 feet beyond the subway tunnel. First floor includes the lobby, retail and parking; upper floors consist of 158 apartment units.

The subway was designed and constructed in the 1930s with provisions for the support of a future warehouse or manufacturing building, but with no seismic provisions whatsoever. Column loads are not to exceed the amount noted on the Site Easement Drawings, at designated points, and all design and construction must be approved by Engineers of the NYC Transit Authority.

Figure 2: Spring isolator – subway tunnel.

Figure 3: 1st floor transfer girder with isolator – subway tunnel.

Since nearly all of the vertical support comes from the city underground tunnel housing the NYC Subway system, State Renaissance required acoustic, vibration and seismic engineering standards unprecedented in New York City.

The project had various earlier design cycles, when others attempted, with little success, to develop a cost effective structural design which could also be approved by NYCT.

Design Considerations

The building was framed with a steel structure supporting plank floors, with lateral support provided by steel braces. All building columns were transferred at subway roof level on large steel transfer girders, which in turn were seated on isolators. This transfer level was designed with metal deck and concrete, reinforced with two-way reinforcement bars for a potential "accidental drop" during construction.

Mounting a new building on top of an existing subway tunnel must include special requirements. The building must be isolated from train induced sound and ground vibrations. Also, the tunnel must be isolated to prevent new seismic forces from overstressing it.

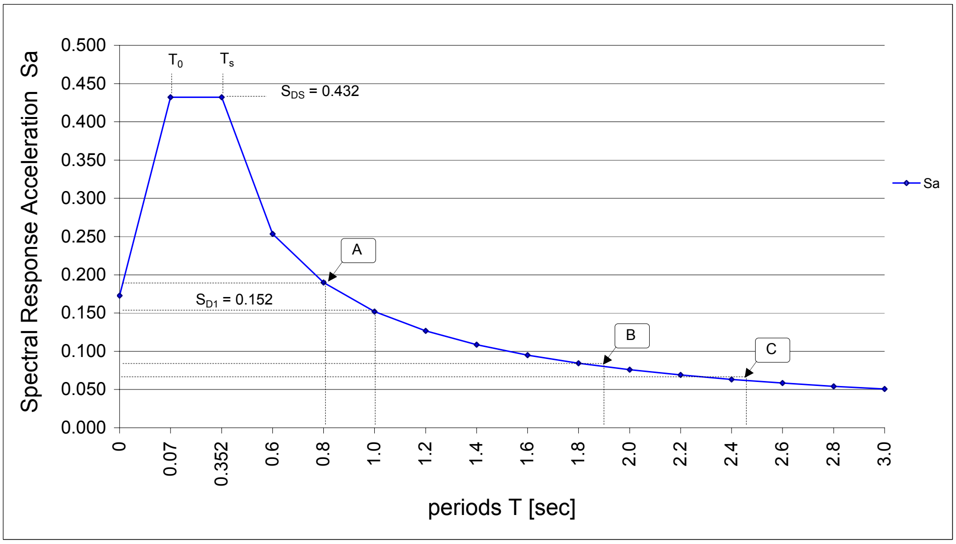
These requirements were accomplished using custom isolators, designed by Vibration Mounting & Controls, Inc. and consultants Shen Milsom & Wilke. They included a system of springs to attenuate mid-range frequencies, rubber for higher frequencies and sheets of Teflon sliding on stainless steel for seismic separation and further isolation (*Figure 2*).

The idea of seismic isolation is not new; however, it has never been used before for a building in the North East, more so for a building in New York City.

For seismic isolated structures, the dynamic properties are modified such as to decouple the dominant frequencies from the characteristic earthquake, thus reducing ground motion effects and lowering frequencies – resulting in decreased base shear. This design addresses the need to protect the residents from sound and ground vibrations, as well as isolate the subway below from seismic forces. However, it was found that, during a seismic event, the deflections of the isolated building above the tunnel were in excess of the values permitted by the NYCT. This problem could not be solved with isolators alone, and required a new design approach.

The solution was the design of two new Reaction Blocks – large concrete pile caps on battered piles located in the 15-foot space between the tunnel and the property line. In this design, seismic forces travel from the steel braces, through the first floor diaphragm, to the Reaction Blocks. The isolators on the Reaction Blocks were modified with snubbing devices designed to carry shear, compression

Figure 4: 1st floor transfer girder with isolator and anchor assemblies – reaction block.



State Reinassance Court - Seismic Design by NYSBC (2002)

A - Equivalent Static Force (fixed base) - T = 0.804 s
B - Modal Analysis (isolated on tunnel & pinned on reaction block) - T = 1.869 s
C - Modal Analysis (isolated) - T = 2.451 s

Figure 5: Chart of Site Specific Response Spectra.

and tension – preventing transmission of subway noise and ground vibrations into the building, and also reducing seismic deflections to acceptable levels. However, with this new design, the building was no longer seismically isolated; nevertheless, it remained seismically separated from the tunnel below. (*Figures 3* and *4, page 49*).

Method of Analysis

Requirements for design of buildings wi seismic isolation are presented in the Int national Building Code; however, details ar method of analysis and design are not y widely developed.

Given the large eccentricities, a Modal Analy was needed and base shears were compared wi the Equivalent Force Method. The isolato were modeled as elastic springs with directior properties; their damping characteristics we inserted into the Site Spectra. Soil-structu interaction was modeled using modified p length and soil properties; torsion effects we carefully evaluated. (*Figures 6* and *7*).

The seismic base shears became larger ar the Reaction Blocks needed to be design for the Maximum Credible Earthquake (r turn period 475 years); this was done by fi... establishing the Maximum Deterministic Earthquake (2% probability of occurrence in 50 years – return period 2475 years) and then reducing it to a median deterministic value (10% probability of exceedance in 50 years – return period 475 years). (*Figure 5*)

Additional design criteria included: 25% live loads added to dynamic mass; 25% orthogonal loads included in all load combinations; MCE used for Reaction Block, piling and snubbed isolators; R=3 for elastic columns and braces (some beam plasticity acceptable); lateral system connections designed to develop 100% member capacity; dynamic base shear scaled to equivalent static forces.

Summary and Conclusions

The State Renaissance represents a new and innovative project in New York City. Supported directly on the roof of an existing subway tunnel, the first floor was designed as a floating platform resting on a complex network of spring, rubber and Teflon isolators. Not fully decoupled from seismic ground motions, the structure was anchored into a Reaction Block, requiring special torsion and deflection calculations, including Modal Analysis and Soil-Structure interaction.

The building was designed using RISA, and then independently checked with StaadPro in order to compare and ascertain proper results. The NYCT Engineers provided significant input and assistance during the reviewing and approval process.

Apartments and the retail spaces were leased during construction, and the building is now fully occupied. The vibration and rumble of subway trains can be felt and heard when standing on the sidewalk near the building, but none is felt or heard inside the building.

The success of this design team to respond properly to the financial needs of the developer, unusual site limitations and the concerns of the NYCT has paved the way for other similar projects over the subway.▪

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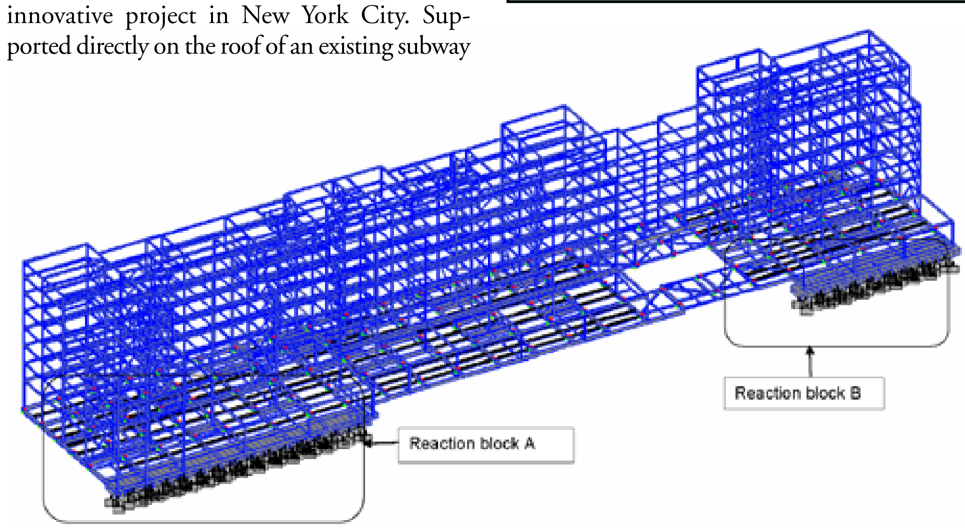

Figure 6 (above): State Renaissance Court – rendered model.

Figure 7 (right): detail of reaction block B – rendered model.