Modern Challenges for a Modern Industrial Heritage

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The North River Water Resource Recovery Facility (the Facility) is a 28-acre facility located at 135th Street & 12th Avenue in the west side of Manhattan. North River is an alternative name for the southernmost portion of the Hudson River in the vicinity of New York City and northeastern New Jersey in the United States. The construction of the facility started in early 1970s (Figures 1-2) and completed in 1982. The Facility is designed to treat up to 170 million gallons per day of Dry Weather Flow and 340 million gallons per day of Wet Weather Flow. The Facility has been in operation since the completion of construction in the 1980's. Adding to the uniqueness of the facility was the addition on the roof, the Riverbank State Park (Figure 3). The facility is a vital component of the New York City Department of Environmental Protection’s (DEP) wastewater treatment infrastructure.

40 years later, this industrial building complex is facing multiple challenges from internal and external side of the structure in order to keep it operational for another 50 years or more. One of the primary areas of concern, similar to many other modern buildings, is the water infiltration issue from the roofs. To be specific, water has been penetrating through the deteriorated roof deck expansion joints, and damaging the equipment and structural members below. In order to address this issue, repair work would have to be conducted from the rooftop park above, which has been in use by public for the past 30 years.

Inherent Challenges

The facility is a great example of modern architecture at the end of its movement. Modern architecture, or modernist architecture, is an architectural style and movement based upon new and innovative technologies of construction, particularly the use of glass, steel, and reinforced concrete; the idea that form should follow function (functionalism); an embrace of minimalism; and a rejection of ornament. It emerged in the first half of the 20th century and became dominant after World War II until the 1980s.

The structure and architectural finish of the facility is exposed reinforced concrete. Before late 19th century, the use of concrete construction, though dating back to the Roman Empire, and having been reintroduced in the early 1800s, was not yet a proven scientific technology. The invention and development of modern Portland cement and iron-reinforced concrete in the second half of 19th century made it possible to build larger and more complexed industrial structures.

The challenge that comes from the structure itself is the way this industrial complex is constructed. The facility is comprised of several structures/buildings that are separated by expansion joints (Figure 4). Even within the same building, due to the size of the structure, expansion joints are required. Expansion joints in concrete are to allow
temperature-introduced expansion and contraction, or vibration, or to allow movement due to ground settlement or seismic activity of a concrete slab or wall without generating potentially damaging forces within the slab itself or the surrounding structures. Expansion joints are usually a complete ‘gap’ between adjacent bays, i.e. there is a definite break in the concrete and reinforcing steel that may be present. When expansion joint assembly is properly installed with appropriate size, it is supposed to be water tight. After installation, periodical inspections throughout the operating life of the system would prevent and minimize expansion joint failure. In this case, the overburden at the park protects the expansion joint assembly from exposing to UV damage and traffic wear but also restricts the periodical inspections and maintenance.

The roof slab is mostly composed of precast prestressed post-tensioned concrete planks supported on structural steel or reinforced concrete framing. Most of the structure below the roof is composed of reinforced concrete beams, columns, walls and slabs. Over a mile of expansion joints traverse each level of the facility along similar planes allowing movement throughout the structure (Figure 4). Approximately 425 roof drains collect water from the Riverbank State Park and route storm water to the wastewater treatment plant outfall into the Hudson River. Clogged drains and lack of maintenance have caused pooling on top of the protective roof slab; deteriorating the existing roof expansion joints and damaging equipment and structural members below. It is obvious that when water comes down from the park level, through the expansion joints of leaking wastewater treatment facility which is in operation, it means potential water pollution of the Hudson River that is located right below the plant. A full expansion joint replacement at the lowest level of the plant took place a few years ago, which stops water from leaking through the expansion joints into the Hudson River. However, water coming into the plant from above, through the roof deck expansion joints, is still ongoing and is getting worse.

The roof deck expansion joint system is typically hidden below the park finish materials, which include; concrete roadway paving, landscape paving, soil within planters, athletic fields and courts, etc. The roof deck expansion joint assemblies are constructed inside the concrete joints that have multiple concrete layers and waterproofing system above the precast planks, including 7 inches of lightweight reinforced concrete fill, waterproofing system, 3 inches of no-fines concrete layer, and 5 inches of reinforced concrete protection slab. The stainless steel angle extrusions that receive expansion joint seals are cast at corners of the protection slab. The park level overburden include landscape and hardscape, with depth varying from two to five feet. At hardscape areas, there are reinforced concrete curbs built on top of the protection slab where the park level expansion joint surface seals are installed (Figure 5).

In order to investigate and repair the existing expansion joints, gaining access to the true line of expansion joint seal at the roof deck level from the park level will involve extensive soil excavation, tree protection and relocation, as well as paving and reinforced concrete material removal.

**External Challenges**
As we know, Le Corbusier's Five Points of Architecture is an academic foundation and architecture manifesto of modern architecture. One of the points is that roof gardens on a flat roof can serve a domestic purpose while providing essential protection to the concrete roof. Also, nature directly enters the building roof without disturbing the structure and its forms. The roof garden is especially useful in cities with high population density and small number of parks. It is a unique relationship between North River Wastewater Treatment Plant and its rooftop Riverbank State Park. The modern recreational life and industrial life taking place simultaneously and yet independently at the exact same geographical location.

The Riverbank State Park is unique for its kind and size. This 28-acre multi-level landscaped recreational park rises 69 feet above the Hudson River and offers a wide variety of recreational, athletic and arts experiences for all ages, interests and abilities. Housed in five major buildings are an Olympic-size pool, a covered skating rink, an 800-seat cultural theater, a 2,500-seat athletic complex with fitness room, and a 150-seat restaurant. Outdoor sports amenities include a 25-yard lap pool, a wading pool, four tennis courts, four basketball courts, a softball field, four hand/paddleball courts, and a 400-meter eight-lane running track with a football/soccer field. At water level, there is a 400-seat amphitheater. The park also has an educational greenhouse, two playgrounds, a water splashing area, a kid inspired carousel and a number of picnic areas. The recreational, athletic, and cultural activities are scheduled all year long. Summer is the busiest time of the year for the park, just like summer is the busiest construction season.

The expansion joints run through most of the recreational and athletic areas and amenities in the park (Fig. 6). For example, there are three expansion joints running and crossing the track and field, where the amenities are used and enjoyed the most; often by residents and athletes all year long. Several expansion joints run through a bus stop loop inside the park where two city bus lines stop here. Expansion joints also run through the roadways and pathways used by daily vehicle and pedestrian traffics. Inspections, investigations, and repair that will be conducted from the Riverbank State Park require long-term coordination with the park and New York City Department of Transportation. All the expansion joint related work need to be carefully planned and phased so that the interruption of civil life can be minimized.

**Long-term Improvement in Progress**

In early 2017, NYC DEP issued request for proposals for design services for North River Wastewater Treatment Plant Structural Improvement Project. Thornton Tomasetti, Inc. has been assigned as the architectural/engineering consultant for assessing and developing design documents for the repair and replacement of the expansion joints located throughout the various levels of the plant.

The procedure of assessing the expansion joint has started with existing document review and non-destructive examination. By early 2021, the non-destructive
examination and reporting were completed. The physical testing is currently in progress, which involves probing of the expansion joints. The purpose of the probing is to expose the roof deck level expansion joints that are the true first line of defense against water infiltration from above at the building structure, and to gather further information from where most superficial defects are identified at the park level, and at the intersections of the expansion joints where workmanship is the most critical and usually fail first. The physical testing also involves flood testing and material laboratory testing.

Representative expansion joints at the park level have been selected for probes. There are generally four types of expansion joint probe locations at the park level. Type 1 is at an expansion joint between roof decks without intersecting any other expansion joint (Figure 7). Type 2 is at a building edge/parapet where there is expansion joint between wall and roof deck (Figure 8). Type 3 is at a “T” intersection where two expansion joints between roof decks join (Figure 9). Type 4 is at a “T” intersection where an expansion joint terminates at a building edge/parapet where there is another expansion joint (Figure 10).

The design team will examine and document existing conditions of the expansion joints at the roof deck level and identify visible defects, including: deteriorated or detached expansion joint surface seal; damaged or missing stainless steel extrusion; deteriorated neoprene strip and/or foam joint filler.

The purpose of flood testing is to verify the water tightness of existing expansion joint assembly at the roof deck level, due to the fact that active leaks continuously occur at a lot of roof deck expansion joint locations. Flood test will be performed only at locations where no active leak is observed. Each water test will take maximum 4 hours for examination from below for water infiltration. Water will be drained completely after flood test is completed. The flood testing will be conducted in accordance with ASTM D5957-98 – “Standard Guide for Flood Testing Horizontal Waterproofing Installations.”

The expansion joints consist of elastomeric compressible seals between stainless steel angles. Although it has been about 40 years since these expansion joints were installed, hidden below the park overburdens, the seal material is protected from UV damage and traffic wear, which should have potentially prolonged its life span much longer than the average. The purpose of material laboratory testing is to verify the longevity of the expansion joint seal material at the roof deck level and provide scientific results to determine the scope of future expansion joint replacement. Elastomeric compressible seal samples will be taken from both deteriorated material and visually observed fair-conditioned material. The elastomeric material testing includes tensile strength and durometer hardness. The tensile strength testing will be conducted in accordance with ASTM D638-14 – “Standard Test Method for Tensile Properties of Plastics.” The durometer hardness testing will be conducted in accordance with ASTM D2240-15 – “Standard Test Method for Rubber Property-Durometer Hardness.”

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Figure 1 (Construction on the North River Wastewater Treatment Plant in Manhattan, New York. Date: April/1974. Source: National Archive Catalog)

Figure 2 (Construction on the North River Wastewater Treatment Plant in Manhattan, New York. Date: April/1974. Source: National Archive Catalog)
Figure 3 (Riverbank State Park and North River Wastewater Treatment Plant aerial view. Date: 6/14/2018. Source: CRIS)

Figure 4 (North River Wastewater Treatment Plant interior plan with expansion joints in red lines. Date: November, 2020. Drawing by Thornton Tomasetti, Inc.)
Figure 5 (Typical roof deck and park level expansion joint detail. Date: June, 2021. Drawing by Thornton Tomasetti, Inc.)

Figure 6 (North River Wastewater Treatment Plant roof deck and Riverbank State Park plan with expansion joints in red lines. Date: November, 2020. Drawing by Thornton Tomasetti, Inc.)
Figure 7 (Type 1 expansion joint - between roof decks without intersecting any other expansion joint. Date: 4/01/2020. Photo by Yifeng Zhang)
Figure 8 (Type 2 expansion joint – between wall and deck. Date: 4/01/2020. Photo by Yifeng Zhang)

Figure 9 (Type 3 expansion joint - “T” intersection where two expansion joints between roof decks join. Date: 4/01/2020. Photo by Yifeng Zhang)
Figure 10 (Type 4 expansion joint - “T” intersection where an expansion joint terminates at a building edge/parapet where there is another expansion joint. Date: 4/01/2020. Photo by Yifeng Zhang)

1 Concrete Joint, Designing Buildings Wiki, [https://www.designingbuildings.co.uk/wiki/Concrete_joint], July 13, 2021.
2 Riverbank State Park (Denny Farrell Riverbank State Park), New York State Parks, Recreation and Historic Preservation, [https://parks.ny.gov/parks/93/details.aspx], July 13, 2021.