Cooperative Innovation at the Manhattan Tunnel Project: Digger Shields with Expandable Segments to Excavate Complex Fill

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ABSTRACT: In what is billed as the most urgent infrastructure project in the U.S., the Hudson Tunnel Project is a critical piece of infrastructure to build two new passenger rail tracks between New York and New Jersey and rehabilitate the century-old North River Tunnel, which was badly damaged during Superstorm Sandy. But building those tunnels below densely populated areas of New York and New Jersey is complex. Due to the presence of historic fill along Manhattan's western shore, the Manhattan Tunnel Project, a component of the Hudson tunnels, requires complex tunneling solutions. JV contractors Frontier-Kemper-Tutor Perini worked together with the Gateway Development Commission and equipment manufacturer Robbins to come up with a unique solution: digger shields to carefully excavate soils near sewer lines, below the Manhattan bulkhead and other obstructions. The machines will operate with expandable segments installed behind. The scope of work entails the design and construction of twin tunnels beneath the eastern shore of the Hudson River to existing cut-and-cover tunnels beneath Hudson Yards, along with an access shaft at 12th Avenue and the Manhattan West Side Highway, which will later become a ventilation facility for the tunnels. In this paper, the authors will examine the cooperative structure that allowed the generation of a singular solution for the Manhattan tunnels, and the design of the machines and segments that are unique to the complexities of this urban infrastructure project.

1 INTRODUCTION

The Manhattan Tunnel Project is a critical segment of the broader Gateway Tunnel Program, which represents one of the most ambitious infrastructure undertakings in the Northeastern United States. Designed to enhance rail connectivity between New York and New Jersey, this $1.18 billion initiative will construct approximately 213 m (700 ft) of twin 9 m (30 ft) diameter tunnels beneath Manhattan's West Side, forming the New York portal for a new trans-Hudson rail crossing. The significance of the Gateway Tunnel Program extends beyond transportation. It is a linchpin in revitalizing the aging North River Tunnel, which sustained severe damage during Superstorm Sandy, and in future-proofing the region's rail infrastructure against climate and capacity challenges. The project is expected to generate over 15,000 jobs during its construction phase and catalyze long-term economic resilience for the Northeast Corridor.

The Gateway Tunnel Program consists of the following:

1. Palisades Tunnel – within the New Jersey Palisades, from Tonnelle Avenue to and including the Hoboken Shaft in New Jersey.
2. Hudson River Tunnel – from the Hoboken Shaft in New Jersey, under the Hudson River to reception tunnels under 12th Avenue in Manhattan, between West 29th and West 30th Streets; and

3. Manhattan Tunnel – from the Manhattan Bulkhead abutting the Hudson River across the West Side Highway (12th Avenue) to and including the 12th Avenue Shaft and fan plant site and continues across 30th Street to meet the west end of the West Rail Yard (WRY) Tunnel also known as Hudson Yards Concrete Casing.

At the heart of this effort is the Manhattan Tunnels, which will deploy advanced Digger Shields, manufactured for Frontier-Kemper Constructors by Robbins, to navigate the complex subsurface conditions unique to this urban corridor (see Figures 1 and 2).

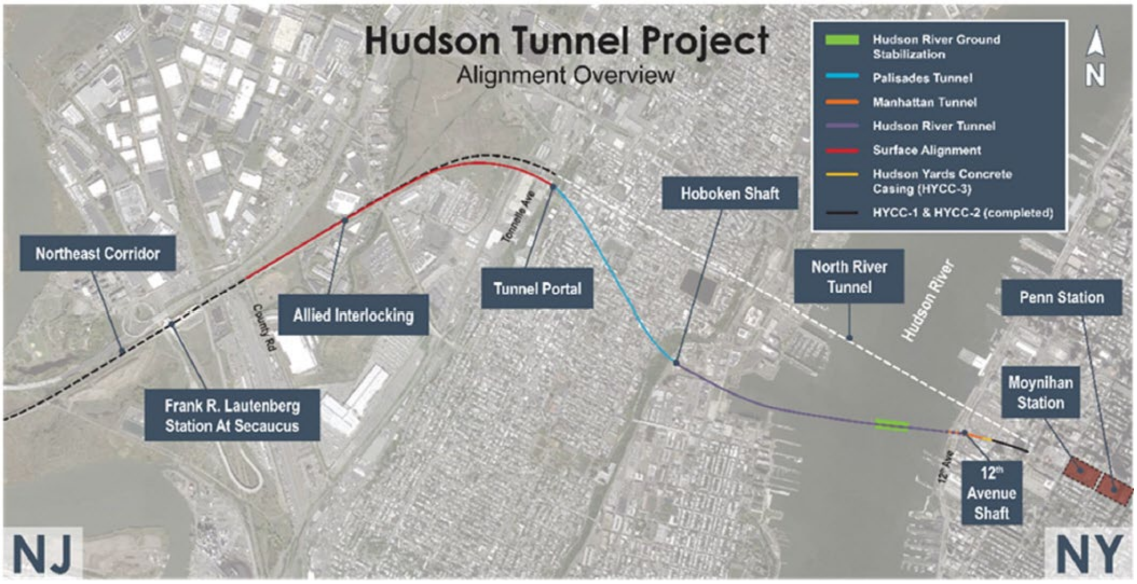

Figure 1. Overall Gateway Tunnel Program.

Figure 2. Closeup of Manhattan Tunnels.

1.1 *Geology*

Tunneling beneath Manhattan presents formidable engineering and geological challenges. The alignment traverses a dense matrix of live utilities, historic fill, and legacy infrastructure—including remnants of the collapsed West Side Highway and active sewer lines. The geology is characterized by variable urban fill, glacial deposits, and fractured bedrock, demanding precise excavation techniques and robust ground support systems. Geology ranges from soft alluvial soils to siltstone and mudstone to diabase.

In addition, the Manhattan Tunnel area is located within the Manhattan Prong of the New England Upland physiographic province. The site region is underlain by a complex assemblage of Proterozoic- to Ordovician-age metamorphic and igneous rocks. The project area is primarily underlain by schist of the Hartland Formation with lesser occurrences of gneiss, gneissic schist, schistose gneiss, pegmatite and granite (see Figure 3).

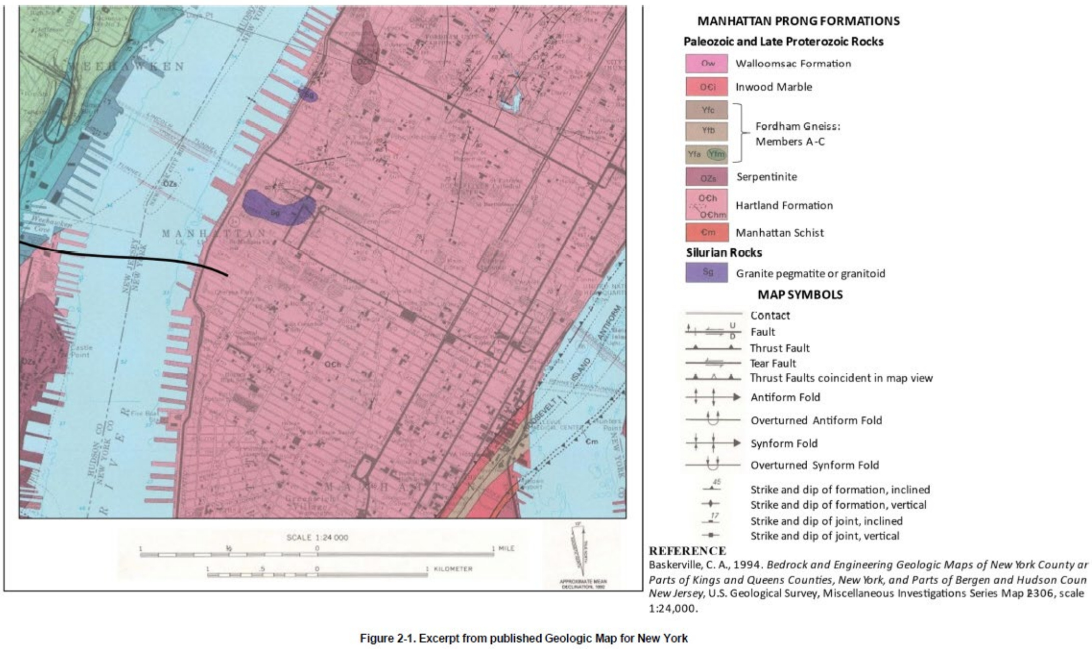

Figure 3. Geology underlying Manhattan.

2 COOPERATIVE STRUCTURE: SELECTION OF DIGGER SHIELDS

The portion between the Manhattan Bulkhead and 12th Avenue will be a temporary tunnel shell with the primary purpose of clearing the pathway for the future final tunnel to be installed by tunnel boring machines (TBMs). These could include remnants of pile foundations from the West Side Highway collapse in 1973 and historic debris, since the area is known for its archeological and structural complexities.

2.1 *Methodology of selection*

Through leveraging of the Port Authority’s relationships with other public works entities in NYC (i.e., ConEd, DEP, HRPT), the contractor was able to streamline coordination and approvals with 3rd party stakeholders for the selection of Digger Shields as the boring method.

Selection of the Digger Shield and the method of ground improvement (vertical jet grouting across 12th Ave and vertical freezing across the Hudson River Park Trust (HRPT) property including out into the Hudson River) allowed for the elimination of the foreseen twin shafts in the HRPT that would have had significant impact to both the Park and the public. This strategy is not only expected to mitigate disruption to surface roads and pedestrian pathways but also to enhance safety throughout the process.

SEM tunneling was originally considered; however, SEM presented challenges primarily related to schedule, which were alleviated with selection of the Digger Shields. Additionally, the presence of a steel shield body while using digger shields, together with a precast loaded segment lining, was chosen for enhanced stability vs. a large SEM style excavation.

A few key points on SEM vs. Digger Shields in the case of the Manhattan Tunnels:

- The steel structure of the shield provides a protective barrier between the face/excavation and the workers/space behind it; this provides stability to reduce face collapse risk, rockfall risk, and the potential for uncontrolled voids.
- The potential for faster advance in favorable ground means less time the face is exposed and thereby reduced duration of risk.
- Less reliance on manual support installation as compared to SEM could mean fewer exposures of workers to unsupported ground.
- Given the urban tunnelling area, digger shields can reduce surface impact, settlement risk, and therefore reduce indirect safety/operational risks (utilities damage, etc.).

3 DIGGER SHIELD DESIGN

To address the geologic complexities, the Digger Shields, manufactured by Robbins, are designed to provide structural protection during excavation, enabling safe passage through obstructions ranging from concrete debris to potential archaeological artifacts.

Two complete systems, each with two shields—one measuring 10.2 m in diameter and one 9.6 m diameter—are being provided along with two complete tunneling systems.

It is anticipated that the excavation will be performed by an articulated boom mounted cutting bucket or by adding a cutting drum, which has adequate mobility and range of motion to excavate each "cell" of the shield face.

During excavation, the shields advance by selectively excavating the face area with the boom mounted excavator, while thrusting the shield body forward with the shield thrust jacks. The thrust jacks react onto the segment ring via individual jacking shoes. The thrust jacks can be controlled in selective groups to provide steering of the shield body.

3.1 *Overcoming Challenges*

The machine design is focused first and foremost on the right technical solutions for the project's challenges (see Figures 4-6):

1. The shield body inherently reduces risk around and under existing structures regarding potential settlement.
2. The shield body provides overhead protection and safe access for removal of existing wood and steel piles under the Hudson River Bulkhead.
3. The machine design features forepoling cylinders and working platforms as a means to provide additional forward support during these operations.
4. The modular design allows for the digging arm to be fitted with various tooling which is useful to remove the obstacles that are known to be within this shield drive as well as changing geology (e.g., bucket, roadheader tooling, hammer).

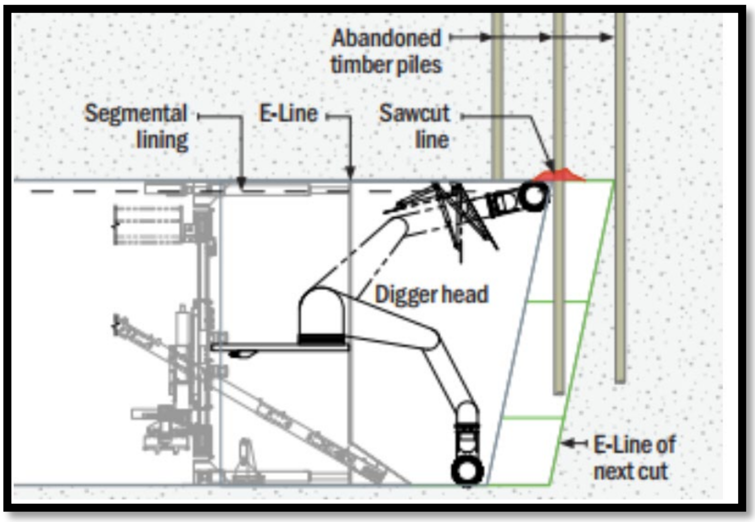

Figure 4. Digger shield excavation.

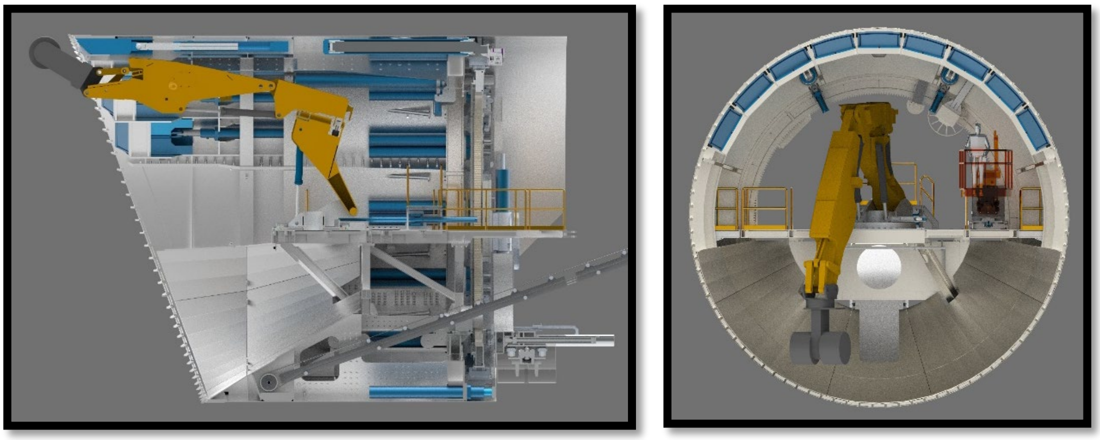

Figure 5. Digger shield assembly – Side View (left) and front view (right)

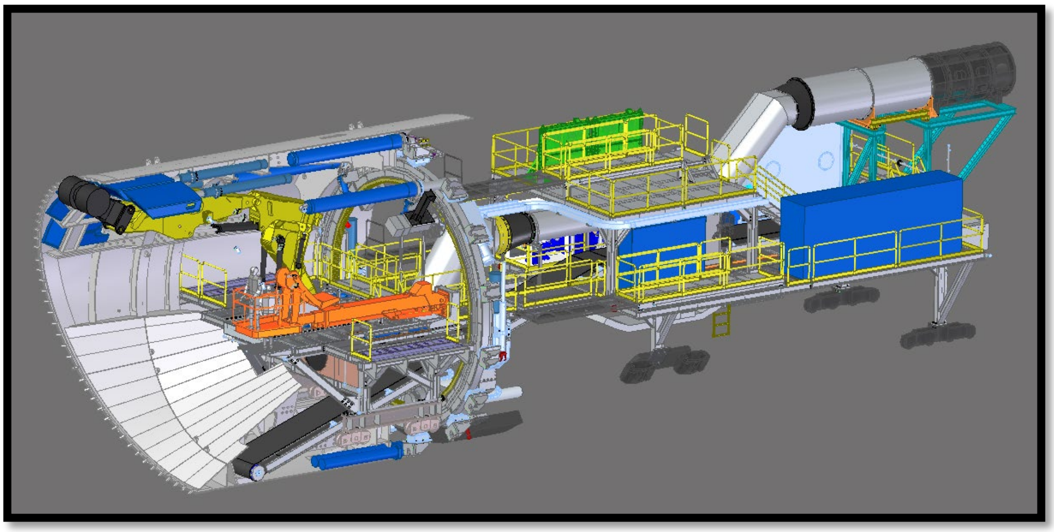

Figure 6. Digger shield – sectional view, showing man basket in orange.

4 EXPANDABLE SEGMENTS

A key component of ground support in the Manhattan Tunnels is the use of expandable segments. The precast, 5+0 segmental rings are expanded once they leave the shield using hydraulic jacks (radial expansion and segment support cylinders), helping to minimize annular gap (see Figure 7).

In the Manhattan tunnel context, because there are known utilities, possible obstructions, historic fill, and the requirement to protect existing structures/lines, this ring approach with expansion and grouting gives enhanced control of ground behavior behind the lining, reduces settlement risk, and provides structural support quickly.

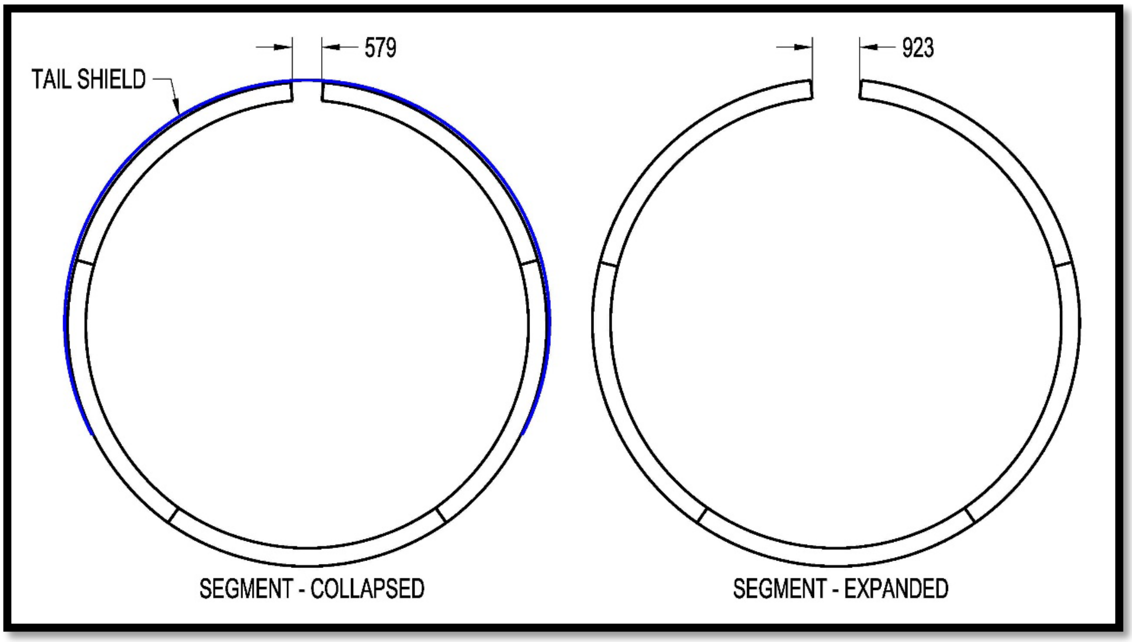

Figure 7. Segment – Collapsed and Expanded

5 LOGISTICS OF TUNNELING

5.1 *Machine assembly & launch plan*

The digger shields will be launched from within a shaft with limited space using the larger, 10.2 m diameter shields. The tight footprint allows for only one gantry behind each machine, as each machine will be launched in parallel, boring in the same direction toward the Hudson River. Once tunnelling is completed in the westerly direction, the systems within the shields will be removed and installed inside the smaller 9.6 m diameter shields to excavate in the opposite direction (see Figure 8). To streamline this process the systems inside the shield, minus the thrust cylinders) and the backup gantry are designed to be removed as a complete unit and rolled back to the launch shaft where they can be modified for the new diameter, rotated and installed in the new shield for the next drive.

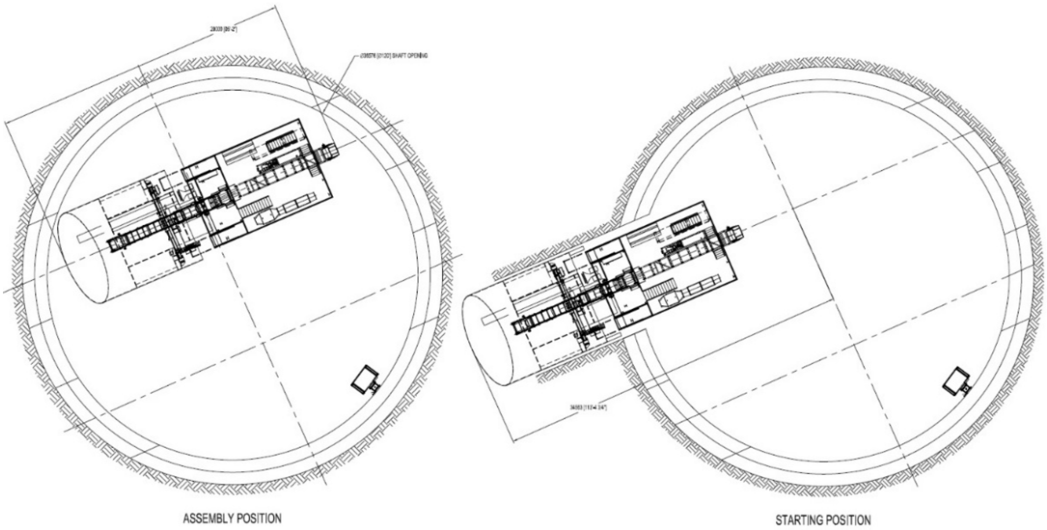

Figure 8. Digger shield in assembly position (left) vs. starting position (right).

5.2 *Muck removal*

During excavation, muck from the face excavation will be loaded into the shield by the boom mounted excavator. This muck is loaded directly onto a single flight conveyor belt which is able to load muck cars located at the rear of the back-up (see Figure 9).

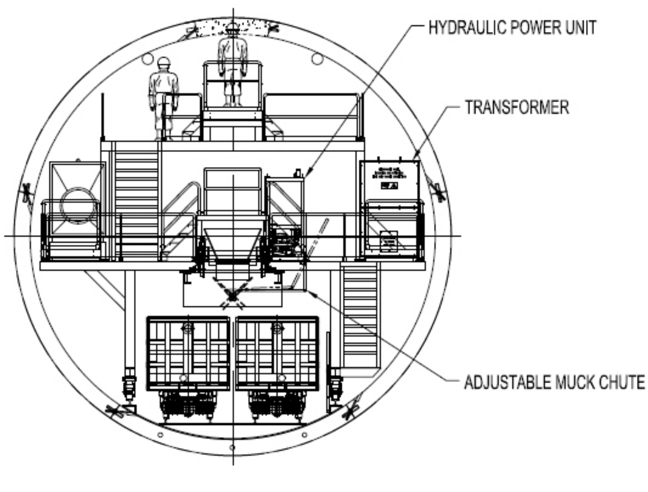

Figure 9. Sectional view of the back-up showing muck cars in place.

6 CONCLUSIONS

In conclusion, the Manhattan Tunnel Project demonstrates how close cooperation between the contractor and equipment supplier is essential to develop solutions for complex geology. Manhattan's west side features challenging ground—historic fill, utilities, bulkhead structures, and obstructions—that demand flexibility and precise control.

Selection of an open-face digger shield provides clear advantages under these conditions. The steel shield protects workers, stabilizes the face, and allows controlled, mechanized excavation while minimizing surface disruption. When the contractor and supplier work together from the start—aligning on ground risks, shield design, and real-time monitoring—the equipment can be tailored to site-specific challenges, reducing uncertainty and downtime. In short, pairing contractor expertise with supplier innovation makes the digger shield method an effective tunneling solution for both the Manhattan Tunnel Project's complex geology and for similar projects in complex ground conditions.

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