Stealth Tunneling below Sensitive, Historic Structures in New York City

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1 Introduction

How do you excavate more than 850,000 bcy (650,000 bcm) of rock and construct a new transit terminal below high-price real estate along Park Ave, Grand Central Terminal (GCT), the Waldorf Astoria and the Helmsley Building in New York City without disrupting the city that never sleeps? The answer is with good planning, coordination and the development of a comprehensive community outreach program. This paper will highlight some of the strategies that the project team developed to minimize the construction impacts on the public, operating railroads and structures.

East Side Access (ESA) is a public works project being undertaken by the Metropolitan Transportation Authority (MTA) in New York City, designed to bring the Long Island Rail Road (LIRR) into a new East Side station to be built below and incorporated into Grand Central Terminal (GCT) in Manhattan. MTA Capital Construction (MTACC) is the MTA agency responsible for the design and construction of ESA. ESA is one of the largest underground rail infrastructure projects under construction in New York City and the USA. The underground openings for this rail link are located below historic structures, high rise buildings, GCT and operational railroad facilities along Park Avenue. This work is underway after years of preparation and negotiation with the railroad, fire department and local community. Figure 1 shows the East Side Access project location.

The MTA is a public benefit corporation responsible for public transportation in the U.S. state of New York, serving 12 counties in southeastern New York, along with 2 counties in southwestern Connecticut under contract to the Connecticut Department of Transportation, carrying over 11 million passengers on an average weekday system wide, and over 800,000 vehicles on its nine toll bridges and tunnels per weekday. LIRR and MTACC are both MTA subsidiary agencies.

For the Manhattan section of the work eight tunnel drives and several large caverns are being mined through more than 4 miles (6.4km) of Manhattan Schist. The main access shaft for these tunnel drives is located in the borough of Queens, and connects to the tunnel drives through the approximately 3 miles (4.8km) long 63rd Street Tunnel, which was constructed in the early 1970’s. The GCT caverns, 60 feet (18 meters) high by 50 feet (15 meters) wide and 1,200 feet (366 meters) long, run parallel and 40 feet (12 meters) below GCT and Park Avenue, are inter-connected by cross passages to GCT by inclined escalator shafts and vertical service shafts. This extended supply line has led to logistical innovations in muck handling, TBM assembly and launching and the location has led to requirements to construct the project with minimal impact to the urban environment and the railroads. Figure 2 shows a profile of the East Side Access tunnels and caverns below New York City.
The planning phase of this project dates back to the 1970’s when a critical link was established between two New York boroughs – Manhattan and Queens. At that time a bi-level tunnel was constructed below the East River. The East Side Access Project uses the existing 63rd Street Tunnel, therefore eliminating additional construction impacts as a new tunnel below the East River does not need to be constructed as this work has been previously completed.

The Environmental Impact Statement that was generated for the East Side Access Project sought to ensure minimal disturbance to the already crowded and overdeveloped area of Manhattan that represents the project environment. This included commitments to minimize the addition of truck traffic, limit the surface footprint, etc. In general these commitments have resulted in a less than ideal configuration for a tunnel project as there is only a single access point located some 3 miles (4.8 kilometers) from where tunnel excavation commences, an extended supply line that stretches from 37th Street in Manhattan to
Queens. Combining these with the absence of a receiving shaft or other means of servicing the tunnel construction other than from the access shaft has resulted in considerable logistical and methodological issues. They have however resulted in a project that is barely registering in the consciousness of the average New Yorker to the limited disruption being caused despite the $5bn in construction ongoing beneath their feet.

The alignment and profile of the tunnel was selected to minimize construction impacts and associated risks. Two major features are that the tunnel invert is approximately 150ft (46m) below street level with a sufficient amount of rock cover and that the alignment follows below the center of Park Avenue to eliminate the highly loaded area below the building foundations.

The work described in this paper is contractually split into two separate contracts, CM009 - Manhattan Tunnels, awarded in 2006, and CM019 - Manhattan Structures I, awarded in 2008, for which the Dragados USA/Judlau Contracting Joint venture, DJJV was the successful bidder on both.

2 Excavation Methods

The choice of excavation methods and location of ventilations shafts etc. together with the design of project monitoring systems were all based in the concept of minimal disruption or as it shall be referred to herein after as the “Stealth” approach to tunneling.

2.1 Drill and Blast

During the early stages of the project planning it was thought that drill and blast excavation would be the primary method of construction both for the running tunnels and caverns as previous instances of the use of TBM’s in the Manhattan Schist had achieved mixed results. However to minimize the impact of the project alternatives to drill and blast were investigated to determine both the technical and economic applicability to the project. This was further exacerbated by the events of 9/11 and a general desire to “fly beneath the radar” especially because of the concern for security and public perception of the use of explosives.

2.2 Tunnel Boring Machines

Advances in cutter tool technology together with increased use of and familiarity with TBM’s in New York led to the realization that the use of TBM’s to excavate, as a minimum, the running tunnels would offer significantly better environmental management opportunities when compared with drill and blast.

When it was bid, contract CM009 included the construction of four separate tunnel drives to be constructed using TBM’s, totaling approximately 25,000ft (7,620m) and stretching from the 63rd St tunnel to 37th and Park Avenue. During negotiations for the CM019 Contract it was agreed that additional lengths of tunnel would be constructed by TBM. This would have the benefit of reducing the amount or rock to be excavated by drill and blast in the caverns beneath GCT. In total, eight separate TBM drives will be constructed and as there is no shaft at the southern end of these drives, introducing logistical difficulties that have been overcome. The Contractor chose to use two different 22ft (6.7m) diameter TBM’s, a Robbins mainbeam TBM, previously used in Australia for the Parramatta Airport Link, and a SELI double shield TBM, originally manufactured by Robbins.

Investigations into the potential ground borne vibrations indicated that TBM’s would cause limited perception problems with the public. In addition with the alignment of the TBM’s being located beneath either MNR tunnels, GCT, Park Avenue road tunnel, NYCT subway tunnels and only 150ft (46m) beneath either residential or commercial properties. The potential effects of the TBM on sensitive receivers was considered negligible when compared to drill and blast operations.

2.3 Roadheaders
In 2004 the project had awarded a contract to undertake trials with a road header to determine whether the technology could be used to excavate the abrasive Manhattan schist. It was perhaps unfortunate that the rock at the location of the trials was some of the most massive and hardest, +35,000psi (241 MPa), on the project. As a result the trial was somewhat inconclusive and it was considered that the use of road headers was unlikely. However during the TBM mining operations it was recognized that the rock was less massive and weaker along the alignment. Partially as a result of this, the Contractor decided to investigate the use of roadheaders to assist with cavern construction and procured a Sandvik MT-720 roadheader.

3  Construction Logistics

In order to minimize the environmental impact of the project, the East Side Access Project is utilizing a “Stealth” construction approach, which has increased the complexity of the construction logistics. This is “Stealth” approach is accomplished using existing infrastructure, where possible.

3.1  Access from Queens and Use of the Existing 63rd Street Tunnel

The current ESA project has the benefit of using the existing 63rd Street tunnel constructed in the 1970’s for an earlier incarnation of the project. This is a 2 mile (3.2km) stretch of tunnel from Queens passing under the East River in a double deck immersed tube structure to a location close to the intersection of 63rd Street and 2nd Avenue in Manhattan. In 2003, a contract to excavate an access shaft adjacent to this existing tunnel in Queens was completed by Kiewit Constructors. Once the Contractor for CM009 had mobilized the final connection between the shaft and existing tunnel the necessary construction utilities including water, air, discharge, power, rail and mucking systems were installed. This shaft and tunnel served as the sole point of access for personnel, material and equipment until the Contractor completed one of the five vertical shafts from the future concourse location beneath GCT to the tunnel. However, this new shaft only provided personnel access, which eliminated a 4 mile (6.4km) round trip for personnel assigned to work south of 50th St, while the main access point remained at Queens for materials and equipment.

3.2  Construction Power

Powering two hard rock tunnel boring machines which operate concurrently with 4 miles (6.4km) of support infrastructure required a significant temporary power installation. After extensive reviews of the available power from Con Edison it was determined that power was more readily available in Manhattan as well as the space needed to house the substation. This space was found within the existing ventilation shaft located at 63rd St and 2nd Avenue which also provided emergency egress to the surface at this location. A medium voltage substation to supply the temporary construction power was constructed within the space set aside in the 1970’s for the permanent traction power substation to supply power to the finished project. Construction of the temporary substation was unique in itself as all of the electrical equipment was sized to fit down 8ft x10ft (2m x 3m) sidewalk hatches and was then assembled in the underground space with very limited headroom.

3.3  TBM Assembly Chambers & Design of TBM’s

As noted previously tunnel boring for the new tunnels was to commence at the end of the previously excavated 63rd St. Tunnel. This required starter chambers to be constructed within 6ft (2m) of existing operational NYCT subway lines. It was originally envisioned that a single large chamber some 80ft (24m) by 60ft (18m) chamber located 200ft (61m) from the tunnel face would be excavated to permit launching of the TBM’s. The Contractor proposed two separate chambers thereby significantly reducing the amount of drill and blast required at this location.

Given the proximity of the NYCT lines at this location stoppage of train service was required by NYCT whenever a blast was scheduled to be undertaken and permit inspection of the operational facilities to be undertaken to determine whether any damage had occurred. This interface required careful management and advance coordination and the reduction in blasts required was a significant benefit.
Given the constraints of the existing tunnel, the machines and their methods of transportation were modified to fit through a 15ft (5m) by 15ft (5m) section of tunnel. This also required that much of the assembly occur underground. The contractor assembled the machines within the existing shaft to the greatest extent possible and then finalized assembly within the newly constructed assembly chambers.

3.4 Mucking System

With the extended supply line for the TBM’s and the limited space at the access shaft for handling of muck cars the Contractor elected to use conveyors to remove all the excavated muck. There are a series of nine separate conveyors totaling a length of 6 miles (9.7km) linking together with a crusher installed to ensure the drill and blast excavated rock was of a uniform sizing. Once the main belt reaches the Queens access chamber a vertical belt lifts the muck out of the shaft and on top a conveyor belt that takes the muck across Northern Boulevard to a stacker conveyor where the muck is stockpiled and later removed by truck for beneficial reuse at locations around New York.

3.5 Ventilation

Of all the temporary construction resources, ventilation is the scarcest and therefore the most challenging to implement. For the first three years, there was only one intake source but no exhaust location on the heading side of the Project. This one intake, 2nd Avenue shaft at the TBM starter chamber had to support multiple headings leading to extended ventilation lines together with extended periods for smoke clearance after basting operations. The completion of one of the vertical shafts linking the caverns to the concourse within Madison Yard has helped to improve the ventilation. All of the ventilation fans are located either within an existing MTA ventilation structure as at 2nd Avenue or located away from public areas as at Madison Yard. Noise and placement of these fans has therefore not been an issue.

3.6 Madison Yard

A total of nine shafts will be constructed from within the Madison Yard and connect to the caverns and tunnels below. Madison Yard is a former Metro North Railroad mid-day storage yard that was taken by ESA to make room for the future LIRR concourse. Madison Yard is currently an 8 acre (3.2 hectare) construction site under Park Avenue and an operating Metro North Railroad and has zero visibility from street level. All personnel enter from a very discrete entrance at street level and all new and excavated material and equipment arrive via rail to and from a rail yard in the south Bronx, NY. The Madison Yard is still connected to the mainline MNR tracks.

4 Third-Party Stakeholder Coordination

4.1 Interface with GCT and Metro-North Railroad

Coordination with Metro North Railroad has been ongoing for more than a decade. This coordination was necessary to ensure that the construction of this project did not impact MNR’s operation or structure. MNR participated in several years of planning, coordination of work to be performed directly by the railroads force account and design review.

The future LIRR concourse will use the Western third of GCT’s lower level called Madison Yard. In order to obtain the necessary real estate needed to build the new Concourse, the ESA project constructed a new maintenance facility at Highbridge Yard, for Metro-North Railroad in Bronx, NY. This new yard provides train storage and a maintenance facility for Metro-North Railroad trains previously stored in Grand Central Terminal. Furthermore, this new yard and relocation of MNR facilities allows MNR to maintain the same level of service to its customers while the ESA team begins construction.

Once MNR completed its relocation to the new facility and vacated the GCT Madison Yard, the ESA project began construction of a demising wall along MNR’s Track 115 on the lower level of GCT.
combination of tarps and masonry block walls will act as a necessary barrier to segregate the construction activities from the MNR operations and the public. This wall will serve as the permanent dividing structure between MNR and LIRR in the final build out.

4.2 Interface with Third Party Stakeholders

In addition to MNR, the alignment of this project through Manhattan is within the influence zone of many third-party stakeholders who the project team has been committed to keep informed of upcoming construction activities, project progress and issues which require coordination. Some of the various third-party stakeholders include: MTA New York City Transit, New York City Department of Transportation, Building Owners, Con-Edison and the Community.

4.3 Interface with Community

Throughout the Project, the ESA team is keeping the community informed and addresses any issues that arise by circulating newsletters, maintaining updated information on the MTA web-site and attending public meetings. At the public meetings, questions, comments and ideas regarding the on-going and upcoming construction are welcomed and addressed.

As the alignment of the project passes below or within the influence zone of many building structures, ESA had to undertake a comprehensive outreach program to keep building owners informed of construction activities associated with the East Side Access Project that may have an effect on their buildings. For example, owners of structures that are located above the GCT train sheds were informed of the following:

- Instrumentation will be affixed to building columns and the underside of buildings
- Remedial work may be undertaken to columns and beams to rectify areas of spalled or spalling concrete prior to performing controlled blasting. Owners have been encouraged to undertake inspections and remedial work themselves.
- Mesh may be installed beneath their structures and around building columns to prevent debris falling onto MNR operational areas, such as platforms and sensitive railroad equipment

5 Blasting Risk Mitigation

Blasting risk mitigation has been incorporated into all phases of the project including design development, contract requirements, and coordination with third parties or developments during construction with Contractors means and methods.

The contract requires various provisions of schedules and notifications for blasting. The provision of sufficient advance notice of blasting operations to NYCT and MNR will assist in minimizing disruption both to the blasting operations and impacts on the operating railroads. The Contractor is required to submit monthly schedule updates, six-week look-ahead schedules, and 24 hour blast notices. The ESA team has committed to sending all stakeholders within the influence zone of the blast an email notification and a confirming email before the blast event. These notices are provided to MNR accompanied with influence drawings that show the planned blast at tunnel level, influence drawings for each of the lower and upper levels of GCT superimposed over the railroad infrastructure and instrumentation placement. This information allows MNR to modify their operations for train placement and track usage to accommodate the blast without disrupting their operations.

Many requirements were included into the contract before, during and after excavation to minimize the risks associated with controlled blasting.

- Prior to commencing controlled blasting operations, the following activities were reviewed and completed to minimize the risks associated with the construction:
• Pre-condition Survey of structures were performed to document the existing conditions and raise any concerns prior to commencing activities which can potentially affect a structure; complete remedial activities as required.
• Inspection and repair of fireproofing and spalling concrete on beams, columns, and structure located above MNR revenue operations and critical infrastructure in both the Suburban (Lower) and Express (Upper) levels of GCT.
• Installation of protective mesh over MNR platform areas and critical infrastructure.
• Installation of blast effect monitoring instrumentation, including geophones and dynamic strain gauges.
• The installation of geotechnical and structural instrumentation to measure ground movement and any subsequent structural movement as a result of the creation of underground space by controlled blasting.
• Prior to commencing shaft excavation, the test pits and probe holes were completed to determine the condition of the exposed footings and top of rock elevation beneath footings.
• Prior to blasting at shafts within GCT Madison Yard, the cross-sections of columns adjacent to the shaft excavations were checked. Calculations relating to the effect of blasting on the structures were also performed by the Engineer to verify previously completed calculations based on as-built drawing information.

As excavation progresses, it must comply with various requirements in order to reduce the potential impacts on the public and structures. These include maintaining within vibration and air-overpressure limits, conforming to restrictions in the times blasting is permitted, compliance with the test blast program and per restrictions with shaft blasting.

Excavation must comply with all set limits on vibration and air-overpressure. The vibration limits on historic buildings is 0.5 ips (1.27 cm/sec), non-historic buildings is 1.92 ips (4.88 cm/sec), strain limits are 100 micro inch per inch and air-overpressure is not to exceed 133-dBL. In addition and as a risk mitigation measure, the ESA project required that controlled blasting vibration limits at NYCT structures and major Con-Edison steam pipes are limited. By limiting vibrations at NYCT structures, this allowed NYCT to maintain an uninterrupted service for its passengers. Holding the vibration limits on the Con-Edison steam pipes was a prudent risk mitigation measure based on the background and recorded vibrations of the pipe.

As the excavation progresses and immediately following a controlled blast event, geotechnical and structural instrumentations are monitored to determine the affects of the blast. In addition, based on the vibration readings and proximity of the blast to a structure a post blast inspection is performed of certain structural elements.

In addition, there are requirements for when blasting may occur. In accordance with FDNY regulations blasting is not permitted in residential areas after 10pm and to minimize potential impacts on MNR’s and NYCT train service, controlled blasting is not permitted during the peak morning and evening rush hours.

Further requirements mandate that the Contractor perform test blasts prior to the production blasting to determine and confirm means, methods and procedures to limit potential vibration impacts on critical facilities. The essence of the test blast program is to perform a series of three controlled blasts that gradually progress the maximum charge weight per delay from 25% to 50% and finally to 100% (production blast). Review of the results of the test blasts permits adjustments or modifications to the upcoming blasting program.

Finally, as an added precaution, there are additional restrictions for shaft excavation to be constructed within GCT Madison Yard. The Contractor is not permitted to use controlled blasting to excavate certain sections of the shafts in close proximity to GCT’s structure. Mechanical excavation must be used to excavate rock in the vertical shafts to an elevation of 16ft (4.9m) below the adjacent column footings and at within 10ft (3m) of vertical centerline of any column immediately adjacent to an escalator wellway.
The East Side Access Project is in the process of excavating more than 850,000 bcy (650,000 bcm) of rock and constructing a new transit terminal below New York City. In order to minimize impacts to the community, the project team began a process of working with third party stakeholders beginning in the planning stages that extends now into the construction phase. The result of this long process is a project design that is using a number of strategies to minimize the construction impacts on the public, operating railroads and sensitive, historic structures. One strategy is to use existing infrastructure, where possible. Construction phase power and ventilation are being obtained using an existing ventilation shaft at 63rd Street and Second Avenue. All equipment, supplies and excavated material are being sent into and out of the tunnel using the existing 63rd Street Tunnel. Another method is to minimizing the addition of truck traffic and limiting the surface footprint in Manhattan. The project elected to not have a receiving shaft in Manhattan, which has resulted at considerable logistical and methodological challenges.

Coordination with Metro North Railroad has been ongoing for more than a decade and continues in the construction phase daily. This coordination has been necessary to ensure that the construction of this project does not impact MNR’s operation or structure. The ESA team is keeping the community informed and addresses any issues that arise by circulating newsletters, maintaining updated information on the MTA web-site and attending public meetings.