WORLD TRADE CENTER
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MMITTEE ON UNDERGROUND
& CONSTRUCTION

by

JOHN M. KYLE, CHIEF ENGINEER
THE PORT OF NEW YORK AUTHORITY

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The project under discussion is the new World Trade Center which The Port of New York Authority is building in Lower Manhattan Island to accommodate all segments of international commerce. These buildings, when completed, will be occupied by U.S. Customs, by foreign and domestic trade development bureaus, by freight forwarders and customs programs, and others engaged in the promotion, sale and handling of articles of international commerce.

The area, which occupies 16 acres, will include 10 million square feet of usable area and include the two highest tower buildings in the world, as well as a series of seven-story, low-rise buildings surrounding a huge plaza. Each tower, which is 209 feet square, will contain 110 stories and will be 1,350 feet above the plaza. This site is adjacent to all rapid transit facilities in Manhattan, and, in fact, is crossed by one north-south subway line, and the Port Authority's own PATH tunnels are actually located in the basement of the building which provides transportation to and from our sister state - New Jersey.

Of particular interest to this group, I think, is the method of construction which has been adopted for the 70-foot-deep basement of the building between West, Vesey, Greenwich and Liberty Streets (see map).

This area of Manhattan Island is one of the most difficult on which to construct foundations, particularly for high-rise buildings. It is outshore of the original Island of Manhattan. Over the years, this area which had previously been occupied by piers and wharves, was completely filled thereby creating a new bulkhead line approximately 700 feet from the original shoreline. Lying beneath the fill, in addition to the old wharves, crib walls and bulkheads, is first a layer of organic river silt, weak and highly compressible, then varved deposits (known in the trade as "bull's liver"), which are stable only when confined, but when wet are most difficult to hold. From there down to bedrock is a stable layer containing small boulders in a glacial till. The rock, which is between 60 and 70 feet below the existing surface, is the typical Manhattan mica-schist and when properly handled provides a firm unyielding surface ideal for the support of heavy buildings. The problem is to get down to this layer without disturbing adjacent streets, buildings, subways and utilities.

The historical way of doing foundations in areas of Manhattan has been to surround the site with either steel sheet piling or pneumatic caissons taken to rock. In the case of the World Trade Center, both these methods were considered. The first was rejected because of the presence of so many subsurface obstructions, and the second was rejected because of the price. In addition, we felt it was necessary to construct our 70-foot-deep basement without the normal practice of dewatering the area by the use of either wellpoints or deep wells. If dewatering were allowed

it could have caused settlement problems to adjacent structures. Therefore, it was necessary to find a construction technique which would allow construction of a reinforced concrete basement wall, socketed into the underlying rock to act as a seal for the outside water without the need for dewatering. The method selected has had wide use in Europe, some use in Canada, and practically none in the United States. This technique is known under various names, but for ease in identification it has been called "slurry wall" construction.

This method, with which most of you are familiar, has been used extensively in subway construction in Milan and Toronto, and for building construction throughout Europe and in eastern Canada. It has also been of value in installing cut-off walls underneath a number of dams, one of which is in the United States.

As planned for the World Trade Center foundations, a trench will be excavated down approximately 10 feet to remove surface obstructions, the trench filled with bentonite slurry, and excavation down and into the rock will proceed using one of the conventional slurry wall excavating machines. The contractor will be given flexibility in selecting the equipment he considers most suitable to the work. Among the acceptable systems are the Soletanche reverse circulation machines and the ICOS excavator.

As excavation proceeds downward in the 3-foot-thick, 22-foot-long panels, the material removed is replaced with bentonite slurry. The slurry has the characteristic of lining and supporting the sides of the trench and preventing collapse, without the use of sheeting or bracing. On reaching rock, a trench is dug 2 feet into the rock below the future basement floor to act as a toe for the wall.

This can be excavated with chopping bits, pneumatic or power rotary drills. When excavation is complete, a reinforcing cage is lowered into the trench and the panel concreted by using the tremie method which displaces the slurry as the concrete rises.

Although it is possible to support this wall during excavation by means of conventional bracing, because of the size of the project, 1,200 feet by 600 feet, it was felt that these braces would seriously impede subsequent work of installing steel and pouring floors. With this in mind, the possibility of using rock anchors was considered. On this project, careful analysis, with the use of a computer program, indicates that it would be possible to adequately anchor the wall by the use of 300-ton tiebacks spaced approximately 11 feet on centers horizontally and varying at distances vertically from 5 feet to 9 feet.

Although the stress on the ties is high, a test program has indicated that it is feasible to achieve substantially in excess of this stress in both the rock anchorage and in the tendons. In actual practice, the jacking operation will pre-test each tendon and anchorage beyond the limit at which it will be required to work when excavation inside the walls has been completed.

Among the innovations incorporated in the wall design is the use of castings which pre-position the holes in the wall without the necessity of subsequent drilling. These castings are so designed that they transmit the full jacking load into the reinforced wall and permit the free access of the drilling bit and casing which is forced down through the adjacent soft ground and obstructions and to the rock surface.

Below this point the casing is omitted and the rock drill makes the hole. The anchoring of the tendon is accomplished by the injection of grout under pressure at the bottom of the rock socket which forces out water and extraneous materials and completely imbeds the tendons. The contractor will be given the option of using one of a number of high-tensioned wire systems, all of which have been tested by the Port Authority in a field installation and their structural integrity validated. We will also permit the use of high-strength steel bar lengths coupled together with special castings.

Another interesting but troublesome phase of the project is the maintenance and support of the PATH Railroad tunnels which traverse the site.

This railroad is operated by The Port of New York Authority, and was built in the early part of the 20th Century. The section within the World Trade Center site is actually a cast iron tube floating in the soft ground. As the new buildings go down to rock, it will be necessary to maintain this tunnel in its present alignment while work proceeds around and under the tubes. To provide for this, it is proposed that caissons be installed down to and into the rock prior to excavating below the crown of the tunnel. Once the caissons are in place, steel trusses will be installed on either side of each tunnel from west to east. The contractor will then dig under the cast iron tunnel and install steel saddles which will be supported from the trusses. Upon completion of the excavation down to the new basement floor levels, which in some cases requires the blasting out of 7 or 8 feet of rock, the new PATH tracks will be laid on the sub-grade and a new station constructed at a level one story below the present PATH station. Because the tracks in the tunnels run uphill at a fairly

substantial grade, it is possible to construct the new station without interference of traffic. Once the new tracks and station are operable, trains will be re-routed and the old rails, tubes and supporting structures removed.

Work is going forward on three shafts in the bed of West Street above the PATH tunnels to permit re-routing of vital communication cables in the area. These pits eventually become telephone manholes and are being installed by the slurry wall method, thus permitting both the Authority and the contractors to familiarize themselves with ground and working conditions in this most difficult area.

Contracts for the excavation and the slurry wall will be bid and awarded toward the end of this year. Work will thus be well advanced at the time of next year's convention of the International Committee on Planning and Construction, and we hope to have the pleasure of organizing an inspection trip for interested members of the group to see this tremendous, and, I think, most exciting foundation job this area has ever seen.