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**STATE AUDITOR'S COST RECOVERY REFERRAL
ON CERTAIN ACTIVITIES OF THE
MASSACHUSETTS TURNPIKE AUTHORITY'S
CENTRAL ARTERY/THIRD HARBOR TUNNEL
PROJECT WATERPROOFING**

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INTRODUCTION

Project Waterproofing

As part of the OSA's on-going review of the CA/T project, we examined the project's Quality Program as it applies to waterproofing activities. The proper application of a waterproofing system is a very important construction activity for achieving a watertight structure and reducing future maintenance costs. To evaluate this activity, we selected for review, construction contract C15A1 (I-93 mainline, North Street to New Chardon Street). This contract was awarded to J.F. White/Slattery/Perini/J.V. on March 12, 1997, and a Notice to Proceed was issued on March 21, 1997. The contract award was in the amount of \$377 million and as of July 31, 2003, contract modifications totaling \$120 million have been issued, bringing the current contract value to about \$497 million. The original completion date was scheduled to be December 11, 2001, however the contract was not completed until March 31, 2003. The work under Contract C15A1 includes the construction of portions of the mainline tunnel involving the four northbound and southbound lanes. Also included are major utility relocations and the underpinning of the existing Central Artery structure in that area. Our review focused on a two-part modification to the contract for the revision of waterproofing system in the amount of \$3.34 million¹. Additionally, Project Status Reports indicated modifications for waterproofing related issues were made on a number of contracts indicating that a potential systemic problem with the Project's waterproofing activities might exist.

Based on observations, problems being experienced and lessons learned in implementing its waterproofing systems, CA/T Project officials assembled a Task Force team to assess, evaluate, and make recommendations concerning the Project's waterproofing activities. The task force team members included members from the Federal Highway Administration (FHWA), the Massachusetts Highway Department (MHD), and the Joint Venture (B/PB). The Task Force started its work in March 1997, and a final report, entitled Evaluation of the CA/T Project's Waterproofing Systems and Installations was issued in July 1997.

Documentation reviewed, and discussions with management familiar with the CA/T Project's waterproofing issues revealed that at the time the Task Force was being assembled, virtually all the

¹ Mod A 040 was settled for \$2,839,006 and Issue A 286 in the amount of \$500,000 was included as part of a Global Settlement mod, bringing the total to \$3,339,006.

CA/T Project contracts associated with underground excavation were experiencing some degree of problems with their waterproofing systems. The contracts identified included C04A2, C07A1, C17A1, C11A1, C01A3, C09A1, C09B4 and C09A4. According to Project officials, this was not an all-inclusive list.

Project Quality Program

The objective of the Project's Quality Program is to ensure through appropriate planning, control of work operations, and monitoring that quality products and services are provided. The Project's Quality Program is the total system within which Quality Assurance and Quality Control activities are carried out.

Quality Assurance is the system that provides overall assurance that the Project's control function is designed and operational. Quality Control is the system of inspection and verification that ensures that a specific product or service meets the quality needs of the user. Quality Assurance activities governing waterproofing are primarily the Management Consultant's responsibility, whereas Quality Control activities are primarily the construction contractors' responsibility. The Select Design Consultants (SDC), in completing its design activities can adopt the Project-developed specifications for waterproofing, or if need be, make them more stringent with the Management Consultant's approval.

Referral

As a result of our review, we referred the matters discussed in this report to the C/AT Project Cost Recovery Team on February 2, 2004.

REVIEW RESULTS

Inadequate Monitoring of Construction Waterproofing Activities Results in Unnecessary Project Costs of at Least \$10 Million

A review of the CA/T Project's waterproofing practices for underground structures revealed that the surface preparation, installation and contractor quality control activities were inadequate. The added cost to the Project to correct these problems amounted to at least \$10 million. These costs should be recouped.

During the Project's preliminary design phase, the Project's Management Consultant was responsible for establishing and implementing the standard details and supplemental specifications for the Project's waterproofing systems. The individual Section Design Consultants (SDC) and Construction Contractors were responsible for applying these specifications to the various construction project activities.

About 5 million square feet of waterproofing will be applied throughout the CA/T Project. Accordingly, the proper application of the material is imperative to avoiding substantial cost and schedule increases. To ensure that the material is properly applied, the Project's Management Consultant is required to formulate and implement a quality assurance (QA) plan. This plan must include steps to ensure that personnel are adequately trained in the installation process, and that quality control (QC) staff be on site during the waterproofing application to oversee its proper installation.

Because of the vital importance of waterproofing to the operational success of the project and the fact that problems were being experienced that impacted both cost and schedule, a "Waterproofing Task Force Team" was formed in March 1997. The team was comprised of structural and utility engineers from the Management Consultant, Bechtel/Parsons Brinckerhoff (B/PB), as well as members of the Mass Highway Department (MHD) and Federal Highway Administration (FHWA). The purpose of this team was to observe the implementation of the waterproofing systems in the field, and to provide an analysis of its findings and recommendations for improvement. In its report entitled Evaluation of the CA/T Project's Waterproofing Systems and Installations, dated July 31, 1997, the Waterproofing Task Force Team identified three major problems encountered in the waterproofing process. The Task Force Team reported that the Contractors' quality control (QC),

surface preparation, and installation practices on the CA/T Project were not acceptable. These problems are discussed below.

A. Quality Control

According to the Task Force Team report, 95% of the (waterproofing) problems that have occurred to date can be attributed to unsatisfactory Quality Control.

There are two main steps involved in QC: the formulation of a plan by B/PB, which is called the Quality Assurance (QA) plan, and the ensuing implementation of that plan by the contractors performing the work referred to as Quality Control (QC). The Task Force Team found that, in the vast majority of cases, the contractor had yet to accept first line QC responsibility of the waterproofing installation or develop a QC Plan.

Although the contractor had QC personnel in the field overseeing the application of the waterproofing, the Task Force Team reported that “the Contractors’ QC personnel watch the operation...they do not perform a quality control inspection.” This forces the Project’s Field Engineers (FE’s) to perform the inspection, when it is the Contractors’ responsibility, resulting in added time and labor costs.

In order to ensure that the waterproofing material is being properly applied, Project specifications state that in addition to the Contractor’s QC personnel, a technical representative from the manufacturer must be present for at least the first 40 hours of installation, and for at least one hour per week thereafter. The Task Force Team reported that this was not being enforced in the field.

According to the Task Force Team, it is unacceptable that the contractors have neglected their duties to properly and fully inspect their work. “Steps must be taken to rectify this lack of Quality Control immediately, or the Project will face added time and costs throughout the remainder of the waterproofing process.”

The Task Force Team recommended that B/PB take full responsibility for the QA/QC by developing and implementing a QA/QC plan. The plan should be submitted in writing to the Project office, and should involve full training of the QC personnel, as well as measures to ensure that the QC process is administered throughout the waterproofing application process.

B. Surface Preparation

The CA/T Project uses several different waterproofing systems deemed acceptable by the Waterproofing Task Force Team. As each material is unique, the conditions surrounding the application of the systems differ, as do the attributes and problems associated with them i.e., certain materials are only acceptable in certain conditions, and some materials are better suited for use in particular situations than others. It is the responsibility of the contractor in collaboration with the material manufacturers to determine the proper materials to be applied in a given situation.

Regardless of the material used, the desired result is the same: a dry tunnel that will remain leak free into the future. As any error in the application of the material will lead to future problems resulting in added costs and time, it is the best interest of the Project to ensure the correct application the first time. In order to accomplish this, there must be qualified, fully trained personnel applying the material with qualified, fully trained QC staff working with the manufacturers' designated technical representative overseeing the applications.

The Waterproofing Task Force Team reviewed five of the waterproofing materials acceptable for use on the CA/T Project and observed the field application of three. The following is a summary of the review provided by the Waterproofing Task Force Team of the three waterproofing systems it observed in the field.

1. Bentonite

The Bentonite Waterproofing System is employed on Contract C11A1 and is being considered for use on other contracts. The Task Force Team reported that the Bentonite is not an acceptable material to be used on the CA/T Project except in certain limited circumstances. The Task Force Team cited the unavoidably wet conditions in which the Bentonite must be installed as its reason for this finding. According to product specifications, the Bentonite must be installed in a dry area, but the Task Force Team found it to be next to impossible for the contractor to adhere to this specification due to the type of excavation utilized on the CA/T Project.

The Task Force Team recommended that the Bentonite Waterproofing System be eliminated from further use on the CA/T Project. However, FHWA disagreed with this finding and the latest revision to Specification 727.100 allows for its use under limited circumstances.

2. Polyurethane

Contract C17A2 utilizes a Cold Liquid-Applied Waterproofing System, namely Polyurethane. The Task Force Team reports that the contractor has encountered difficulties with this product, which may render it undesirable for use. During the installation of the Polyurethane system the Contractor noticed the formation of bubbles in the liquid membrane. The Task Force Team feels that it is likely a reaction of the polyurethane to a wet concrete surface. This reaction causes CO₂ to be released into the membrane causing the bubbles and compromising the waterproofing application.

Another problem encountered with the use of Polyurethane is its low adhesion strength. The CA/T Project Lab has performed tests of the Polyurethane on concrete bricks similar to those used in the Project. The tests showed low adhesion strengths. In fact, the adhesion strengths were found to be less than specified in the manufacturer's documentation.

The Polyurethane system requires that multiple layers of the product be applied within a specified time range, and that the placed material be mechanically abraded² to ensure proper adhesion. This leaves considerable opportunities for error in the application.

Based on the above problems, the Waterproofing Task Force Team recommended that Polyurethane be excluded from use of the CA/T Project.

3. High Density Polyethylene (HDPE)

While the High Density Polyethylene (HDPE) systems are the easiest to control and inspect of all the approved waterproofing materials, the surface preparation required is an issue. The product calls for surface protrusions of no more than 1/4" per foot without sharp edges. The product is highly susceptible to inadequate performance should this requirement not be met. While this 1/4" per foot is easily achieved on preformed concrete walls, it is much more difficult to accomplish on slurry walls.

The Task Force Team reported that the cleaning of the surface prior to application was a major issue with the C07D2 Contract. The team stated that the Contractor did not clean the mud slab of debris and stones prior to the application of the sheet waterproofing material. The hard points

² Mechanical abrasion is the process whereby the surface of a product is purposely scratched to create a surface that allows for proper adhesion or bonding of ensuing layer of waterproofing material or concrete.

created from debris and stones under the sheet membrane damage the membrane when the working slab is placed.

It is the responsibility of the Contractor to ensure proper application of waterproofing material; this includes the appropriate surface preparation.

According to the Task Force report, in order to avoid any future problems such as those encountered with this system, the contractor must fully understand all literature provided by the manufacturer, and ensure (as the contract specifies) that a manufacturer's technical representative oversee selected applications to ascertain that the material is being properly applied.

In addition, the Task Force Team recommended that additional QA/QC personnel be delegated to the waterproofing aspect of the Project.

C. Application Practices – Training

After observing the worksite and speaking with application and QC personnel, the Task Force Team reported that those involved with the application of waterproofing are in need of further training. The Team spoke with several applicators and QC staff who stated that they feel that they are not adequately trained. The Task Force Team reported that: “applicators appear to be unfamiliar with the Project's and the manufacturers' requirements for the proper application of the waterproofing system.”

According to the Task Force Report, it will cost the Project time and money to fix problems arising from improper application, when appropriate training would have avoided the problem.

The Task Force Team recommended that specialized training sessions be held for all interested parties, with particular attention to QC and application personnel. They also recommended that Project Field Engineers (FEs) attend the training to gain a better understanding of the work being done, and to identify how they, as FEs, relate to the QC staff.

D. Added Project Costs Due to Waterproofing Inadequacies

OSA staff discussed the waterproofing inadequacies with the former Chief Structural Engineer for the CA/T Project. His tenure on the Project as Chief Structural Engineer was from February 1994 to August 2002. He estimated the added costs to the Project due to inadequacies with the

Waterproofing Systems amounted to at least \$10 million. This, he indicated, was a conservative estimate.

Some of the estimates for inadequate waterproofing repairs came from documentation provided to the OSA by the Federal Highway Administration (FHWA). OSA discussed the various CA/T Project waterproofing issues with a member of FHWA's Boston Office and also reviewed pertinent files that were made available to us. FHWA documentation revealed that the added waterproofing costs for two of the earlier contracts (C04A2 and C07A1) were estimated to be in the \$5 to \$6 million range. There were no estimates available for the remaining underground construction contracts.

Conclusion

The Project's Management Consultant, the SDCs, and/or the construction contractors were individually and/or collectively responsible for establishing and implementing the Project's waterproofing systems. If these entities had fully implemented an adequate QA/QC program, including providing appropriate training, the majority of the problems associated with the waterproofing systems would have been significantly mitigated. Moreover, it is reasonable to conclude that the Management Consultant, the SDC, and/or the construction contractor, before allowing the use of the Bentonite, should have read the literature provided by the manufacturer and therefore been aware of the problems that moisture would cause. One or more of these entities should have been aware of the wet conditions in which the work was to take place, as well as the type of excavation utilized.

Recommendations

The party or parties responsible for the approximately \$10 million in unnecessary waterproofing costs should be identified, and action initiated to recoup these costs. In addition, Project Management should assure itself that all avoidable waterproofing contract costs necessary to correct project-wide deficiencies have been identified and appropriate recovery actions initiated.