THE COMMONWEALTH OF MASSACHUSETTS
OFFICE OF THE INSPECTOR GENERAL

A Review of the Central Artery/Tunnel Project's Use of Anchor Bolts on the C05B1 Tunnel Finishes Contract

Robert A. Cerasoli
Inspector General
December 1998

The Commonwealth of Massachusetts
Office of the Inspector General

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His Excellency the Governor

The Honorable President of the Senate

The Honorable Speaker of the House of Representatives

The Honorable Chairman of the Senate Ways and Means Committee

The Honorable Chairman of the House Ways and Means Committee

The Honorable Chairman of the Senate Post Audit and Oversight Committee

The Honorable Chairman of the House Post Audit and Oversight Committee

The Directors of the Legislative Post Audit Committees

The Secretary of Administration and Finance

Members of the General Court

Omnibus ad quos praesentes literae pervenerint, salutem.

I am today releasing a report concerning a Central Artery/Tunnel (CA/T) Project contract for the Ted Williams Tunnel. In 1993, the Massachusetts Highway Department awarded the $49.5 million C05B1 – Tunnel Finishes contract to prepare the tunnel for opening. This contract included the installation of wall tiles, a ceiling, a roadway, signage, lighting, and finish details. As of October 1998 the value of the contract had grown by 58 percent to $78.2 million.

Our review focused on two change orders relating to the installation of the ceiling support system in the Ted Williams Tunnel. This report documents examples of poor design coordination and unclear contract specifications that led to the payment of $850,000 for two no-bid change orders. Our recommendations aim at proactively assisting Project managers to contain costs as they complete design and award the remaining tunnel finishes contracts, which are valued at more than $200 million.

The Commonwealth faces great challenges as it advances through the peak of CA/T Project construction where the potential for delays and cost overruns increases. Project management is aware of this potential and has committed to controlling Project costs.

CA/T Project managers have been fully apprised of my concerns and accorded ample opportunity to review and comment on the report. The Project's formal written response is included at the end of the report.

Sincerely,

Robert A. Cerasoli
Inspector General

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Executive Summary

The $10.8 billion Central Artery/Tunnel (CA/T) Project involves constructing a new tunnel across Boston Harbor and a new Charles River crossing, and placing the Central Artery underground. The Massachusetts Highway Department (MassHighway) has had the responsibility for overseeing the Project for the Commonwealth. In 1985, MassHighway hired the joint venture of Bechtel Corporation/Parsons Brinckerhoff Quade and Douglas (B/PB) to manage the design, day-to-day operations, and construction of the CA/T Project.

This report focuses on two approved change orders that increased the cost of the $49.5 million C05B1 – I-90 Tunnel Finishes contract by $850,000. The cost of this contract grew to $78.2 million between January 1993 and the completion of the contract in July 1996. The change orders reviewed by this Office relate to work necessitated by ambiguous contract specifications and poor contractor performance. This Office's review disclosed the following:

Finding One: Poor design specifications created construction difficulties that cost almost $800,000 to resolve.

Finding Two: The Section Design Consultant prepared poor design specifications for anchor bolt installation.

Finding Three: The Section Design Consultant prepared unclear testing procedures.

Finding Four: The Project paid the contractor to test improperly installed anchor bolts.

Finding Five: The Project issued a change order to compensate the contractor for poor subcontractor performance.

Finding Six: The Project did not consult with the tunnel designers before allowing the contractor to drill through steel reinforcement in the tunnel roof.

The Project should have given clear specifications to the contractor and should have better coordinated the roof and ceiling designs. Had the specifications been complete and unambiguous, the construction contract bidders would have included the cost of the work and risk in their bid proposals. By relying on change orders, the Project paid a premium price for the extra work during construction.

This Office makes the following recommendations to assist MassHighway -- through B/PB, where appropriate -- in reducing future contract costs:

1) Direct B/PB to develop clear and complete specifications for construction contracts.

2) Ensure better design coordination between contracts.

3) Hold contractors accountable for shoddy work and poor planning.

4) Ensure that Section Design Consultants hired by the Project to complete designs review and approve design and specification changes.

5) Take cost recovery action when costly errors and omissions are discovered.

6) Direct B/PB to ensure that contractors proceed with work only under approved procedures.

Project management must act now to avoid unnecessary and costly contract increases. Project costs are rising and so is the Commonwealth's share of that cost. Although design is nearly complete, opportunities still exist to ensure that construction contract specifications are clear and readily applicable to a given contract. The Project stands to benefit by applying these lessons to upcoming tunnel finishes contracts, which have a current total value of more than $200 million.

INTRODUCTION

The $10.8 billion[1] Central Artery/Tunnel (CA/T) Project involves constructing a new tunnel across Boston Harbor, placing the Central Artery underground, and constructing a new Charles River crossing. The Federal Highway Administration (FHWA) was funding approximately 81 percent of the Project cost but the new formula for federal transportation funding will decrease this percentage dramatically. The CA/T Project is scheduled for completion in 2004. As of October 30, 1998, the Project reported that it has completed approximately 40 percent of construction and 97 percent of design work.

Since the early 1980s, the Massachusetts Highway Department (MassHighway) has had the responsibility for planning and overseeing the Project for the Commonwealth.[2] In 1985, MassHighway hired the joint venture of Bechtel/Parsons Brinckerhoff (B/PB) to manage the design, construction, and day-to-day administration of the CA/T Project. B/PB prepares preliminary design documents, manages final design contracts and construction, and provides administrative and technical support.

As construction manager, B/PB managed the C05B1 – I-90 Tunnel Finishes contract. This contract was for the installation of wall tiles, a ceiling, lighting, signage, and other items needed to make the tunnel usable.

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[1] A July 1997 report released by the U.S. General Accounting Office estimates the current Project cost to be $11.6 billion. A Massachusetts Turnpike Authority (MTA) preliminary official statement for the Metropolitan Highway System bond issue estimates the cost at $11.44 billion ($4.6 billion expended as of June 30, 1997; $6.84 billion projected through June 30, 2005).

[2] Project responsibility is shifting with the enactment of Chapter 3 of the Acts of 1997, which established a plan for operating and financing a network of roadways, including the Central Artery and the Ted Williams Tunnel, called the Metropolitan Highway System (MHS). The law, codified as M.G.L. c.81A, empowers the Massachusetts Turnpike Authority to "own, construct, maintain, repair, reconstruct, improve, rehabilitate, finance, refinance, use, police, administer, control and operate" the MHS.

MassHighway awarded this $49.5 million contract to Walsh Construction of Illinois in January 1993. The contractor began work in January 1993 and completed work in July 1996. At the end of 1998, B/PB is in the final stage of closing the contract out (that is, negotiating a monetary settlement for any outstanding claims and change orders). As of October 1998, B/PB reported a contract value of $78.2 million. The C05B1 contract had increased in value by approximately $28.7 million or 58 percent (from $49.5 million to $78.2 million) as a result of change orders. According to B/PB staff interviewed by this Office, the contractor and its subcontractors did not perform well on this contract.

This Office has reviewed two change orders relating to the installation of the ceiling support system in the Ted Williams Tunnel. These change orders cost the Project a total of $850,000. (See Table One.) Staff from this Office reviewed hundreds of Project documents and interviewed Project staff, construction contractor staff, and design consultant staff.

Table One: Construction Contract Change Orders (PCNs)[3]

PCN	Title	Cost
41	Core Drilling – Rebar Interference	$794,663
50	Anchor Bolt Testing	$55,529
	TOTAL	**$850,192**

[3] According to Project procedures then in effect, change orders (also known as pending change notices [PCNs]) were written notices to a contractor that identified proposed contract changes. An approved change order contained the scope, cost, and estimated time impact of the change. The Project now refers to change orders as contract modifications.

FINDINGS

Finding One: Poor design specifications created construction difficulties that cost almost $800,000 to resolve.

Contract specifications required the use of approximately 26,000 anchor bolts[4] to suspend the more than 20,000 ceiling panels in the Ted Williams Tunnel. Anchor bolts are used to suspend the tunnel ceiling panels from the tunnel roof. The contract called for the contractor to drill 26,000 holes in the tunnel roof to accommodate the placement of the anchor bolts. Drilling these holes created problems that took 13 months and almost $800,000 to resolve.

Problems arose because the tunnel roof contained a dense mesh pattern of steel reinforcing bars, or rebars,[5] as part of its design. The designers made no provision for these ceiling anchor holes in the tunnel roof design. In addition, the ceiling construction specifications did not allow for the removal of any rebar material. The contract specifications stated "if reinforcing steel [rebar] is encountered during drilling, abandon the hole and drill a new hole a maximum of 2 inches away from the initial location shown." In theory, once a rebar is located the anchor holes can be drilled nearby without hitting another rebar. The contract specifications also directed the contractor to "use an x-ray procedure acceptable to the Engineer[6] to locate reinforcement [rebar] in tunnel roof." B/PB assumed that x-ray technology would speed the drilling process, but this technology did not work.

[4] Anchor bolts are fasteners used to attach items to concrete structures.

[5] Rebar is a steel bar used for reinforcing concrete structures and is manufactured in various sizes.

[6] In the construction contract specification the term "Engineer" refers to B/PB's resident engineer (also known as the "RE") or his/her designee for the contract.

The construction contractor tried a number of different technologies, including x-ray technology, to locate the rebar in the tunnel roof with little success. The contractor provided the Project with documents from vendors who provided x-ray services. These vendor documents stated: "the x-ray process cannot be used in the tunnel to locate the rebar."

Because x-ray could not be used, the contractor had a number of firms demonstrate other types of rebar locating equipment. None of the equipment tested could consistently locate the rebar in the roof. Project documents provide three reasons for the inability of the equipment to consistently locate the rebar: 1) the quantity of rebar, 2) the epoxy coating on the rebar, and 3) the dense concrete mix. Because of the large amount of rebar, none of the locating equipment could provide a clear image of any one section of rebar. One layer of rebar masked another layer in the tightly spaced mesh rebar pattern. Additionally, the epoxy coating on the rebar acted to shield the rebar from locating devices. According to the contractor, no method of rebar location met with success.

B/PB and the section design consultant (SDC)[7] should have known about the potential ineffectiveness of rebar-locating methods in this situation. According to the resident engineer for this contract, the SDC should have more thoroughly researched the use of x-ray technology in the tunnel environment. Notified ahead of time about the lack of effective technology, the construction contract bidders could have reflected any added costs for testing or potential schedule delays in their bids. Instead, the bidders could only assume that x-rays would work or that change orders and claims for testing would be likely.

Absent a reliable method for locating rebar in the tunnel roof, the contractor hit rebar in one-half of the drilling attempts. The contractor had to abandon and patch

[7] The SDC completes the final design package based on B/PB's preliminary design.

these holes in accordance with contract specifications. In November 1994, rebar interference began to delay the ceiling installation and the contractor requested permission to drill through the rebar, contrary to the contract specifications. In January 1995, MassHighway, on B/PB's advice, agreed to the change. According to MassHighway, this change would keep the tunnel finishes contract and the opening of the Ted Williams Tunnel on schedule. B/PB issued a change order to the contractor for almost $800,000 to fund a new drilling initiative and to ensure that the ceiling installation remained on schedule.

According to MassHighway's response to a draft of this report, these change orders are "what often takes place in construction, namely an adjustment to specifications when the work moves from paper into the field." However, in this Office's view, the decision to core drill was not an understandable – and to-be-expected – "adjustment," as the Project seems to suggest. Rather, poor design coordination and inadequate oversight by B/PB led to the need for change orders on this contract.

Summary

The SDC was responsible for identifying methods for locating rebar and specifying these methods in the construction contract. B/PB's Preliminary Design Report, prepared in 1990, for the tunnel finish design simply states: "The location of reinforcing bars shall be determined prior to drilling by the contractor. The SDC shall indicate methods of locating rebars in the [contract] specifications." The SDC specified the use of x-ray technology. The contractor found this technology to be ineffective. As a result, the contractor sought approval to use other rebar-locating technology. These attempts to locate rebar failed as well. The SDC may have been at fault for not raising the possibility that locating rebar would be a difficult and costly process. The SDC might have also specified that finding adequate rebar-locating technology would be difficult. The fundamental failure, however, rests with B/PB.

Project design documents for tunnel roof construction make no mention of the ceiling anchoring system except that the ceiling would be installed after the completion of roof construction. Change orders could have been avoided if B/PB had considered the follow-on tunnel finishes design when designing the tunnel roof. B/PB did not adequately coordinate these designs as required by its role as the Project's management consultant.

Finding Two: The SDC prepared poor design specifications for anchor bolt installation.

The SDC for the tunnel finishes contract[8] included an industry-accepted method of anchor bolt installation in the construction contract specifications. However, the installation method in the specification contradicted the installation recommendations of the anchor bolt manufacturer that the construction contractor later chose.

The contract specification directed the construction contractor to "comply with [the] anchor bolt manufacturer's installation instructions and recommendations," but then recommended a specific method: to "thoroughly clean bolt holes . . . with fresh, clean water." The manufacturer chosen by the construction contractor advised against the use of water to clean the holes to be drilled to accommodate the anchor bolts. The manufacturer recommended cleaning the holes with wire brushes and compressed air. The SDC either did not thoroughly evaluate the different manufacturers' installation requirements before preparing the contract specifications or had one manufacturer's recommendations in mind when preparing the specifications.

[8] Domenech Hicks Krockmalnic was the SDC and used the following subconsultants as part of its design team: Bryant Associates; Corrigan and Loverde Group; Corrosion Probe, Inc.; Fay, Spofford & Thorndike, Inc.; Hanscomb Associates, Inc.; Richard E. Palmer, A.I.A. and Weidlinger Associates.

As a result of the contradiction, and before installing the first anchor bolts in April 1994, the contractor submitted Request for Information (RFI)[9] No. 126 to B/PB requesting reconsideration of the specification to use water to clean the holes. B/PB reconsidered and approved the contractor's request to override the contract specification and to follow the manufacturer's instructions. The SDC agreed with B/PB's decision stating: "We will accept [the] manufacturers [sic] recommendations." The contractor did not use water to clean the holes during the installation of the anchor bolts.

Had the contractor used water to clean the holes contrary to the manufacturer's recommendation and caused anchor bolt failure, the Project would have paid Walsh a premium price to correct the problem and the tunnel finish contract would have been unnecessarily delayed. The SDC should not have specified the use of water for anchor bolt installation.

As a result of inadequate management controls, the construction contractor used anchor bolt testing procedures that were not officially approved by B/PB.

Provisions of the C05B1 construction contract require the contractor to submit an anchor bolt testing procedure to B/PB before beginning installation. The contractor submitted a procedure and requested permission to proceed. In this case, the contractor began to install the anchor bolts *more than five months* before receiving official Project approval. By the time the Project finally granted formal approval, the contractor had already tested 600 installed anchor bolts. B/PB should have prevented the contractor from working without an officially approved procedure as required by the construction contract. If B/PB required more time to review the proposed procedures, a written notice of conditional approval could have been granted. Without timely approval of procedures, the potential for

[9] A Request for Information (RFI) is a document used by the contractor to request or to provide additional information clarifying comments relating to the construction contract.

miscommunications, substandard work, and cost and schedule problems increases for all parties.

Finding Three: The SDC prepared unclear testing procedures.

The Project paid the contractor more than $55,000 to perform additional anchor bolt testing. Project management required the additional testing because of a high rate of anchor bolt failure[10] identified by the contractor's testing. The Project agreed to this expense because the contractor claimed that the testing specifications in the construction contract did not clearly define when increased testing should occur.

According to the bolt manufacturer's information, industry standards, and vendors contacted by this Office, when anchor bolts are installed properly the failure rate is minimal (usually around one percent). Routine anchor bolt testing, as required by the contract, is intended to minimize anchor bolt failure through the early identification of installation problems. Contract specifications, although unclear, seem to require that if anchor bolt failures increase, testing frequency increases. According to the SDC, B/PB provided these testing specifications for use in the C05B1 contract. B/PB, as the manager of Project design and construction, failed to identify and remedy the lack of clarity in the specifications. According to Project staff, the lack of clarity in the specifications caused the contractor to dispute the assertion that the specifications required additional testing under these circumstances. To settle this dispute, the Project agreed to pay the contractor for additional anchor bolt testing.

[10] The contractor experienced failure rates between eight and sixteen percent.

To ensure that the contractor installed the tunnel ceiling anchor bolts properly, the construction contract specifications required the contractor to adhere to a progressive testing program. A progressive testing program requires that the number of tested items increase or decrease based on the rate of test failure. If more than the expected number of failures occur, more items should be tested. If fewer failures occur, fewer or no additional items will be tested. The specifications contained in the tunnel finish contract required the contractor to test the anchor bolts according to the following protocol:

> E. After chemical adhesive has cured,[11] proof test[12] anchors to 125 percent of their design load per ASTM E448[13] using procedure described in subparagraph 1 below. Record results of proof test and submit to Engineer. Abandon anchors which fail test. Engineer to review and accept proof test procedure prior to installation.
>
> 1. Anchor Bolt Testing Procedure:
>
> a. Step No. I: Commence testing 20 percent of first 100 anchor bolts installed. Actual anchors tested to be selected randomly by the Engineer.
>
> b. Step No. II: Should an anchor fail during the 20 percent testing, test an additional 50 anchors, including 15 anchors of the particular anchor size which failed. Should none of the 50 anchors fail, proceed to Step III. If any anchor fails, proceed to Step IV.

[11] Chemical adhesive requires a cure time to set up and develop to full strength. Chemical adhesive can cure in a few minutes to a few days. Chemical adhesives used for anchor bolts typically cure between 24 to 72 hours.

[12] A "proof test" is a nondestructive test that loads a component to a load higher then it will be subjected to under actual conditions. If the component is not permanently deformed by the test it is considered acceptable.

[13] The American Society for Testing and Materials (ASTM) is a not-for-profit organization that publishes standards for materials, products, systems and services. The ASTM standards are accepted by most industries in the United States.

c. Step No. III: Test 30 percent of the next 100 anchors. Should no anchor fail go to Step I. If any anchor fails, go to Step IV.

d. Step No. IV: Test 50 percent of the next 100 anchors. Should no anchor fail go to Step III. If any anchor fails, proceed to Step V.

e. Step No. V: Test the next 100 anchors. Should no anchor fail go to Step IV. If any anchor fails, repeat Step V.

F. [Sub-section F not related to testing]

G. Allow Engineer to conduct spot-checks on anchors upon . . . request.

As written, the specification is confusing and unclear. This confusion led to change orders and contract specification changes. For example, the specification raises the following questions and concerns:

- Section E, Step I: The contractor may interpret this protocol to mean that only 20 anchor bolts out of the approximately 26,000 anchor bolts in the tunnel need to be tested. After installing the first 100 anchor bolts the protocol requires the contractor to test 20 percent of the anchor bolts (in this case 20 bolts) selected by Project staff. If none of the 20 anchor bolts fail the test the protocol may be interpreted to mean that the contractor is not required to test any more anchors except for spot-checking as requested by authorized Project staff.

- Section E, Step III of the specification states that if no anchors fail, the contractor should follow Step I. Step I required the testing of 20 percent of first 100 anchor bolts installed. Does this mean that the contractor need only address failures for 20 percent of the first 100 anchors installed?

- Section G of the specification allows authorized Project staff to conduct spot-checks, but does not define spot-checking or set limits. The specifications fail to answer the following questions: Who tests the anchor bolts during a spot-check? The contractor? Project staff? Do spot-checks require a proof test or simply a visual inspection? Can the contractor claim additional money if it deems the number of spot-checks excessive? What should be done if an anchor bolt fails a spot-check?

- The specification directs the contractor to abandon anchor bolts that fail testing. Does this mean that the contractor: 1) removes the failed anchor and installs a new anchor in the same hole; 2) abandons the anchor and drill a new hole for a new anchor; or 3) drills a new hole and installs a new anchor while removing the failed anchor?

- The specification states that the anchor bolt test should conform to the requirements of ASTM E448 - Scleroscope-Hardness Test. This is an error. ASTM E448 relates to material hardness testing. Another ASTM standard, ASTM E488 - Test Methods for Strength of Anchors in Concrete and Masonry Elements, seems a more suitable standard. This standard relates to laboratory testing intended to provide information during the design and qualification of anchorage systems. There is no specific standard for the field testing of anchor bolts.

In May 1992, Project staff conducted a claims avoidance review for the tunnel finishes contract specifications. A claims avoidance review seeks to identify confusing or ambiguous items in the contract specifications that may lead to contractor claims during construction. This 1992 internal review noted that the testing protocol did not have a remedy for a failed anchor bolt or a provision for spot-checking the anchor bolts. B/PB inadequately addressed these issues in the final version of the specification. The specification still had weaknesses that led to

contractor claims. The claims avoidance review did not identify the overall weakness of the testing protocol.

MassHighway has stated that the cost of this additional testing is "the only cost to the Project that is in any sense additional" and argues that it was needed in order "to provide further reassurance that the contractor's [installation] problems were resolved." In this Office's opinion, no additional cost would have been incurred after the award of the construction contract if the specification had been clearly written in the first place. Had the issue been raised before contract award, the contractors would have adjusted their bids on a competitive basis.

Summary

Unclear contract specifications enabled the contractor to initiate claims for additional funding for additional anchor bolt testing. The specification also created the potential for contract delay. If the specification had been clearer the contractor would have known, from the start, the full scope of the testing requirements. Poor contract specifications created a misunderstanding that consumed B/PB staff time and created the need for change orders. The Project might have had to pay for additional testing even if the unclear specification had been identified before the contract was bid. The issue is B/PB's failure to identify the unclear specifications. The Project can ill-afford delays and cost increases caused by unclear and confusing specifications.

Finding Four: The Project paid the contractor to test improperly installed anchor bolts.

Anchor bolt installation began in April 1994. Testing of the bolts began on June 6, 1994. Sixteen percent of the first bolts failed during testing (eight out of 50). The contractor had used an epoxy compound to secure the bolt in the anchor hole drilled into the tunnel roof. The contractor stated that it assumed that the epoxy caused the failure. Project documents indicate that the epoxy manufacturer believed that the failure resulted from the improper mixing of the epoxy. The contractor corrected the epoxy mixture and the failure rate dropped to eight percent (nine out of 114) but then increased again to 13 percent (59 out of 456).

The Project issued Deficiency Report (DR) No. 45[14] to the contractor on August 8, 1994. The deficiency report stated that "anchor bolts installed where visible water was present on ceiling have exhibited extraordinarily high failure rate. Of the first 16 bolts tested there were at least 5 failures." The Project's resident engineer for this contract instructed the contractor to test 100 percent of the anchor bolts being installed.

A field engineer's report dated December 16, 1994, states that the contractor tested 58 bolts and five failed, a failure rate of nine percent. Apparently, anchors continued to fail because the epoxy had not cured long enough. The cold temperature in the tunnel required a longer curing time. Also, according to Project documents, anchors failed because the contractor did not use enough epoxy, drilled some of the holes too deep, or did not properly clean the drilled holes resulting in poor epoxy adhesion.

[14] A Deficiency Report (DR) is used by the Project to document unacceptable contractor performance in the field.

After a number of meetings during the period August 1995 to December 1995 between the B/PB staff and the contractor concerning the high failure rate, the contractor agreed to change its installation procedures. The new installation procedures included specifications for the proper drilling of holes, use of epoxy, and quality assurance inspection requirements. Project documents do not identify any significant installation problems after B/PB and the contractor implemented the new installation procedures. Subsequently, the Project reduced the contract specified 100 percent testing requirement to 20 percent for the duration of the contract.

During this period of negotiation, the Project found that the contractor had installed shortened anchor bolts.

According to B/PB staff, the contractor began cutting anchor bolts to fit anchor holes that should have been abandoned. As discussed earlier, if the contractor hit rebar when drilling an anchor hole, contract specifications required the contractor to patch and abandon the hole. It is unclear whether the contractor condoned this action or if field staff took this step on their own. The short anchors could have created a serious structural flaw in the tunnel ceiling. After B/PB field engineers identified the problem, the contractor performed ultrasonic testing to locate the short anchors. B/PB required the contractor, at no cost to the Project, to replace the 51 short bolts located through ultrasonic testing.

Summary

Increased testing would not have become an issue if the contractor had installed the anchor bolts properly from the start. Exceptionally high anchor bolt failures and shoddy work forced the Project to confront poorly written testing specifications that impeded the Project's ability to correct installation problems. According to Project documents the contractor could have reduced the anchor bolt failures by following the standard installation practices recommended by the anchor/epoxy vendor and maintaining a good quality control program. In addition, B/PB field staff was not as diligent as they should have been. Although B/PB staff finally did identify the

shoddy installation work and the use of shortened bolts, they should have identified the problem before the contractor had installed so many (51 bolts).

Finding Five: The Project issued a change order to compensate the contractor for poor subcontractor performance.

As discussed previously, the contractor had difficulty installing the tunnel ceiling anchor bolts according to Project specifications. In addition, the contractor had difficulty dealing with the large amount of steel rebar in the tunnel roof that was placed in a pattern that made no provision for the installation of a ceiling. To solve this problem, in January 1995 B/PB approved the contractor's request to core-drill through the rebar in order to place the anchor bolts needed to suspend the ceiling. Previously, if the contractor hit rebar during drilling, the contractor patched the hole and drilled a new hole. This process proved to be time consuming and costly and eventually cost almost $800,000. (See Table One.)

PCN 41 relates, in part, to the contractor's decision to hire a subcontractor for $75,000[15] to core-drill through the rebar. On short-term contracts, the contractor hired three subcontractors on a time and materials basis[16] to demonstrate core-drilling in the tunnel. The contractor planned to hire the best of the three firms to complete the core drilling in the tunnel. The three core-drilling subcontractors submitted cost proposals ranging from $57.00 to $93.00 per drilled hole. The contractor rejected these proposals because the subcontractors could not

[15] The $75,000 cost for hiring a subcontractor is part of the total $800,000 cost of PCN 41.

[16] Time and materials payments on the Project are based on union wage rates and fringe benefits, the actual cost of materials, and profit and overhead.

guarantee a production rate that would keep the contract on schedule. The subcontractors could only commit to completing approximately 12 holes per day.

On April 6, 1995, just a few weeks after receiving cost proposals from the three drilling firms, the construction contractor hired a fourth subcontractor, Engineered Products Company, Inc. (EPC), to perform the core drilling. Unlike its treatment of the other three candidates, the contractor did not require EPC to demonstrate its work before being hired. The contractor hired EPC to complete the drilling in the tunnel. EPC agreed to a production rate of 35 to 40 drilled holes per day for a cost of $51.00 per hole (for a minimum of 1000 holes). EPC promised to be three times as fast and about 33 percent cheaper on average than the subcontractors involved in the demonstration project. With the contractor's profit mark-up and overhead cost of $11,380 (22 percent), the total estimated cost of this work would be $62,380, or $62.38 per hole. MassHighway approved the hiring of EPC as a subcontractor on June 6, 1995; about two months after EPC started core drilling in the tunnel. Although the Project did not know exactly how many core-drilled holes would be needed, the estimated total in June 1995 exceeded 2,500.

EPC informed the contractor in May 1995, one month after beginning work (and one month before MassHighway approved EPC as a subcontractor), that work would have to stop because EPC was losing money on the job. The subcontractor had core-drilled approximately 600[17] holes. According to Project documents, the contractor decided that the cost of stopping work and bringing in a new subcontractor would be greater than increasing the per hole price paid to EPC. Subsequently, the contractor renegotiated the per hole price to $67.50 – a 32 percent increase in the contract price. This per hole cost exceeded the per hole cost proposed by two of the original three firms requested by the contractor to prepare proposals. The total per hole negotiated cost (including the contractor's mark up), was to be $82.55 per hole. The contractor, however, did insist that EPC

[17] This amount (600) reflects a production rate of approximately 20 per day, not the 35 to 40 per day the contractor had committed to.

finish drilling the first 1000 holes for the $51.00 per hole price originally agreed upon. Under the construction contract with the prime contractor, any increase in these costs would be the sole responsibility of the construction contractor, as would any routine cost of doing business.

After EPC finished drilling the initial 1000 anchor holes, the contractor required an additional 3750 holes to be core drilled. Because of the renegotiated price the total cost increased by more than $75,000 (including the contractor's mark-up of $13,762), bringing the total change order cost to almost $800,000. The contractor requested and the Project agreed to cover these extra costs. The following summarizes actions taken by B/PB and the contractor that led to these extra costs:

- The contract required the contractor to install the anchor bolts. Poor specifications and a complex roof design made this job difficult. The Project agreed to change the contract specifications.

- When the specification changes did not solve the contractor's anchor installation problems, the Project agreed to allow the contractor to drill through the steel rebar in the tunnel roof in order to place the anchors. If anything, this decision should have *saved* the contractor time and money.

- The contractor asked for more money when its drilling subcontractor did not perform up to expectations. By granting the request, the Project turned what ought to have been the contractor's problem into its own problem. The contractor hired the subcontractor and the contractor was responsible for the subcontractor's performance. If the subcontractor needed more money to complete the job, the contractor -- not the Project -- should have paid. In this case, the Project not only paid the increased cost, but also gave the contractor extra profit, in the form of more than $13,000 in added mark-up. The subcontractor still could not complete the work, and the contractor subsequently hired two other firms to complete the work.

- The contractor also allowed the subcontractor to begin work before MassHighway approved the subcontractor. This action alone should have caused MassHighway to insist that the contractor assume the risk (i.e., the increased cost).

Summary

Project documents give no justification for the decision to approve these change orders except for concern about the subcontractor losing money and threatening to leave the job. The contractor should not have profited from poor performance and should have been financially responsible for correcting its own poor performance and that of the subcontractor (EPC). According to the contractor and Project documents, EPC could not complete the drilling despite the increased price. To complete the core drilling, the contractor had to hire two other firms.

Finding Six: The Project did not consult with the tunnel designers before allowing the contractor to drill through steel reinforcement in the tunnel roof.

B/PB gave the contractor permission to drill through the steel rebar reinforcement in the tunnel roof. The contractor had found rebar in more than 50 percent of the holes drilled. Although the practice would be contrary to contract specifications, B/PB believed that drilling through the rebar would save time and money.

A review of Project documents indicates that the Project did not have any of the three tunnel designers[18] or the SDC for the tunnel finishes contract evaluate the impact, if any, that drilling through rebar would have on the structural integrity of the tunnel roof. The Project paid nearly $9 million in design fees to these designers. In

[18] Sverdrup Corporation designed the Third Harbor Tunnel, HDR Engineering the Marine Industrial Park Tunnel and Gannett Fleming/URS/TAMS the Bird Island Flats Tunnel.

a letter to MassHighway, B/PB states: “[W]e feel that this practice will not have a detrimental affect on the integrity of the tunnel roof due to the probable loss of the insignificant amount of reinforcing steel."

Project documents reviewed by this Office did not contain any evidence of an engineering evaluation performed by B/PB to justify its conclusion to MassHighway that the structural integrity would not be seriously compromised. The structural strength of the tunnel roof *may have decreased*. If the contractor drilled through or cut a number of adjacent rebars, it could affect the local structural integrity of the concrete. The subcontractors completed approximately 7,000 core drills. Potential public safety issues could exist as a result of the drilling. Despite B/PB’s assurances that no safety issues existed, MassHighway should have obtained and independently reviewed B/PB’s written analysis.

This Office has taken the position in the past that the SDC should be consulted whenever a significant change is going to be made in a design or in the construction contract specifications. In this case, the tunnel designers or the SDC for the tunnel finish contract should have been asked to review the decision to cut through the rebar. The SDC, as the Project designer of record, should have an opportunity to comment on all major design changes. The SDC also provides an important check against both the contractor and B/PB. The Project unnecessarily exposes the Commonwealth to financial risk by not involving the designer. The resident engineer for this contract compared the design of the ceiling to a “Swiss watch” because of its complexity. According to the resident engineer, the ceiling design was intricate and extremely difficult to construct, underscoring the need to involve the SDC in any design or specification changes.

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CONCLUSION AND RECOMMENDATIONS

This report discusses our examination of two change orders on the C05B1 – Tunnel Finishes CA/T construction contract. These change orders relate to work necessitated by ambiguous contract specifications and poor contractor performance. MassHighway has claimed that most of the $850,000 paid for these change orders was a "reasonable expense" for necessary work. We disagree. No-bid change orders should not have been needed for this work. The Project should have prepared clear specifications and should have anticipated problems. Apparently, there was no effective coordination between the roof and ceiling designs. Had the specifications been complete and unambiguous, the construction contract bidders would have included the cost of the work and risk in their bid proposals. By relying on change orders, the Project paid a premium price for the extra work. Our review of the two change orders revealed the following problems:

- B/PB failed to coordinate tunnel roof and tunnel ceiling designs causing at least $800,000 in no-bid change orders. Different consultants designed the tunnel roof and tunnel ceiling. The tunnel roof design did not make allowances for the installation of a ceiling supported by the roof. As a result, the ceiling installation was made more difficult, expensive, and time consuming.

- B/PB failed to identify unclear and ill-conceived specifications and testing procedures before construction, despite having conducted a technical review of the contract. Because the designer prepared unclear specifications, the contractor effectively argued that the contract specifications did not require additional testing when contractor-installed anchor bolts failed during testing.

- A high anchor bolt failure rate caused B/PB to require the contractor to increase the rate of anchor bolt testing. The Project paid more than $50,000 for this additional testing rather than insisting that the contractor provide, at no cost, quality control over substandard work.

- The Project compensated the contractor for hiring a poorly performing subcontractor.

- B/PB did not prevent the contractor from proceeding with a new testing procedure before B/PB officially approved the procedure. It was not prudent for the Project to allow the contractor to use an unapproved procedure in the face of the ambiguities that existed over the original testing procedure.

MassHighway must act now to avoid unnecessary costly change orders and overruns. Project costs are rising and so is the Commonwealth's share of costs for the Project. Although design is nearly complete, opportunities still exist to ensure that construction contract specifications are clear and complete, and to ensure that there is adequate coordination between design and construction contracts. With care and commitment, the Project can avoid future cost increases and ensure a high quality facility. The Project stands to benefit in upcoming tunnel finishes contracts,[19] which have a current total value of more than $200 million.

In an August 1998 letter responding to a draft of this report, MassHighway stated:

> . . . [A]s a result of our experience with the roof drilling into the dense rebar network, we have identified a better way to make connections into the roof concrete, a special insert that is

[19] During the summer of 1997, the Project decided to merge a number of the proposed tunnel finishes construction contracts. Previously, the Project had planned to award five contracts: C09B2 – I-90 Tunnel Finishes, C15A7 – I-93 northbound, C15A8 – I-93 southbound, C17AA – I-93 northbound, C17AB southbound. It appears that the Project now plans to award only two.

embedded in the concrete into which anchors can be placed without the need to locate or drill through rebar. This technique will be used in the future on the Central Artery Project.

MassHighway has acknowledged that a "better way" existed for anchor installation. The Project is to be commended for changing the installation specifications for future contracts.

This Office makes the following recommendations to assist MassHighway in reducing the cost of future contracts.

Recommendations

1) Develop clear and complete specifications. The SDC and B/PB should ensure that all construction contract specifications, requirements, testing protocols, and procedures are clear. B/PB should use an aggressive claims avoidance review program to identify and correct potential specification problems before they develop into costly contract change orders.

2) Coordinate designs. The Project should ensure that future tunnel roof designs accommodate tunnel ceilings that are to be installed later. This will avoid costly problems, resolve design coordination issues, and ensure that design quality will not be compromised.

3) Hold contractors accountable for shoddy work and poor planning. The Project should not pay contractors to correct shoddy work. Substandard work should be corrected at no cost to taxpayers. MassHighway should not hesitate to withhold payment for inferior work or backcharge contractors for shoddy work or poor planning that affects other construction contracts.

4) The Section Design Consultant (SDC) should review and approve design and specification changes. The SDC (the designer of record) should be consulted whenever major changes are made to a design or the contract specifications. This will ensure that the designer of record is involved in the design change process. This will help to protect the Commonwealth's interests in the event of a design failure.

5) MassHighway should take cost recovery action when costly errors and omissions are discovered. MassHighway should examine change orders for the C05B1 contract to determine if a cost recovery action should be pursued against the SDC or B/PB for the submittal of ill-conceived contract specifications.

6) B/PB should ensure that contractors proceed with work under Project approved procedures. B/PB should ensure that it is clear to all parties that all risk is transferred to the contractor when the contractor proceeds without written Project approval or uses subcontractors that have not been approved.

APPENDIX A: Project Response to the Draft Report

On June 25, 1998, the Inspector General provided to Project management a preliminary draft of this report. This Office fully considered Project management's subsequent written comments and modified the report where appropriate. On December 10, 1998, the Inspector General sent a final draft of the report to Project management and requested a formal written response. Project management responded on December 23, 1998. Both the Project's initial and final responses are included in Appendix A. This Office appreciates the Project's timely responses to the report drafts.[20]

Project management takes issue with certain of the findings in this report. Nevertheless, the Project's written response states that management has "adopted a new concept for anchoring the ceiling system" and believes that "this new installation detail will minimize some of the difficulties noted" in this Office's report.

[20] The original response letters have been scanned and reformatted for electronic publishing. However, the text of the letters has not been changed.

Massachusetts Turnpike Authority
Central Artery/Tunnel Project

December 23, 1998

Wendy Haynes
Deputy Inspector General for Contract Audit and Review
Office of the Inspector General
State House Station
P.O. Box 270
Boston, MA 02133

Dear Ms. Haynes:

I have reviewed your final draft report on the Central Artery/Tunnel Project's C05B1 Ted Williams Tunnel finishes contract. We have nothing to add to the project's initial response from last August (a copy of which is attached), although I believe it would be useful to reiterate and clarify some of the points made in that letter.

In summary, your report suggests that the project failed to anticipate design issues in the tunnel finishes contract that had to be resolved through change orders, incurring added costs as a result. In a fast-track project such as ours, where the top priority is controlling cost by maintaining the schedule, we expect that conditions in the field will occasionally lead us to change our plans once construction begins. We explained the key to managing costs in a fast-track environment such as this in the August letter as follows:

"Your report seems to suggest that our specifications should anticipate every possibility and circumstance. What is perhaps more important is a system, reflected in our specifications, that recognizes the possibility of changed circumstances, gives us the flexibility to adapt, and allows us to solve problems before they affect our schedule."

In this context, design, constructability, and quality assurance reviews are clearly important management tasks. These tasks were performed effectively on the C05B1 contract. To have anticipated in advance the conditions that led to the change orders, so that they could have been priced by competitive bidding rather than by change order, would not have made a significant difference in the cost of the work and would have led to far more expensive delays to the Ted Williams Tunnel opening. In other words, as we said in the previous letter, "the expenses we incurred by and large would have been incurred anyway had the final specification been part of the originally-bid contract."

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Finally, I want to emphasize that the structural integrity of the tunnel roof was not compromised in any way by the drilling protocol that was ultimately adopted. The drilling procedure was reviewed and approved by senior structural engineers before implementation. On this issue and all others associated with this contract the specified design management mechanisms worked the way they were intended to work, and the tunnel opened on time.

As we noted in the August letter, based on our experience with the Ted Williams Tunnel, we adopted a new concept for anchoring the ceiling system. I want to emphasize that this new anchoring system was developed at the project's direction in a classic example of improving the state of the art through a "lesson learned." We believe this new installation detail will minimize some of the difficulties noted in your report.

I appreciate the opportunity to explain project construction management mechanisms in response to your draft report, and I trust you will append both this letter and the August letter to your final document.

Sincerely,
MASSACHUSETTS TURNPIKE AUTHORITY

William S. Flynn
Deputy Director

Attachment

cc: James J. Kerasiotes
Patrick Moynihan
Kevin Sullivan

1998-0432M
CO-9D3

Massachusetts Turnpike Authority
Central Artery/Tunnel Project

August 10, 1998

Wendy Haynes
Deputy Inspector General for Contract Audit and Review
Office of the Inspector General
State House Station
P.O. Box 270
Boston, MA 02133

Dear Ms. Haynes:

I write in response to your draft report on the Central Artery/Tunnel Project's I-90 tunnel finishes contract CO5B1. To demonstrate that the change order amounts discussed in your report are in fact reasonable expenses, which would have been incurred in any event, I think it is important to review your report in terms of the process by which construction designers and managers respond to conditions in the field.

You reviewed two change orders associated with anchor bolts supporting ceiling panels in the Ted Williams Tunnel. Installation of the bolts required drilling into the concrete roof of the tunnel. Conditions in the field required changes to the specified methods for the drilling. Essentially what took place is what often takes place in construction, namely an adjustment to specifications when the work moves from paper into the field. The contractor in this case was required to bear the cost of correction of all defective bolt installation and of retesting of those bolts. The cost of core drilling was an added cost because it went beyond the original contract requirements entitling the contractor to an adjustment; but this cost would have been included in the bid and borne by the Project had the final specifications (calling for a core drilling) been part of the originally bid contract. The only cost to the Project that is in any sense additional is the approximately $50,000 cost for certain testing beyond that originally specified. That additional testing was conservatively required by the Project after the contractor had resolved its installation problems, to provide further reassurance that the contractor's problems were resolved.

Regarding the drilling into the tunnel roof, the specification on where and how to drill the holes for the anchor bolts followed common practice. However, a confluence of conditions -- including the unusually dense rebar network and concrete mix due to strict Seismic requirements, and the presence of an epoxy coating on the rebar -- compromised the specified x-ray method for locating the rebar before drilling. To keep the tunnel finishes contract on schedule, the Project agreed to allow drilling through rebar, but only after B/PB's analysis confirmed that there would be no reduction in the strength of the tunnel roo£ This was the most economical solution and it did not compromise the design or the schedule. As noted above, the cost of the core drilling, had it been originally specified, would have been in the bid.

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You note that the Section Design Consultant's specifications for preparing the anchor bolt holes contradicted the bolt manufacturer's instructions. Let me point out that the contract does not specify a particular product or manufacturer, and recommends a common preparation method. The specification allows for manufacturer's variations and notes that if a given manufacturer's procedure conflicts with the specification, that procedure would control and should be brought to the Project's attention for resolution during the shop drawing process. In this case, the manufacturer's procedure was adopted. This is an example of the system working efficiently to identify conflicts and rectify them before they become problems. This substitution of manufacturer specifications, with Project approval, is consistent with standard industry practice, and is done this way for good reason including to preserve of warranties and to allow bidders to choose between competing but somewhat different acceptable products.

You assert that management failures resulted in the contractor using unapproved testing procedures. The contractor's original submission was given a 2R rating. This rating, at that time, permitted the contractor to proceed before final resubmission so long as he incorporated the Project's comments. The minor comments provided by the Project did not relate to the testing that was performed. The process was followed, there was no failure of management controls.

You suggest that "[T]he exact location of these [rebar] cuts may not be known." In fact, the Contractor was required to, and indeed submitted, daily sheets identifying the coordinates of each hole drilled and identifying the core taken, which also shows the extend of rebar cut for that bore.

Regarding the improper installation of anchor bolts by the contractor, the circumstances were discovered by our inspections and corrective measures were taken at the contractor's expense. Again, the system worked.

Your report seems to suggest that our specifications should anticipate every possibility and circumstance. What is more important is a system, reflected in our specifications, that recognizes the possibility of changed circumstances, gives us the flexibility to adapt, and allows us to solve problems before they affect our schedule. Let me reiterate that the change orders you studied reflect the cost of doing what needed to be done to complete and open the Ted Williams Tunnel. Had the precise circumstances involved been known to us from the outset, they would have been reflected in the original bids as an increased price. I am satisfied that our specifications worked as they were intended to work and that no improper management was reflected in any of the matters that you raised.

I should also point out also that as a result of our experience with the roof drilling into the dense rebar network we have identified a better way to make connections into the roof concrete, a special insert that is embedded in the concrete into which anchors can be placed without the need to locate or drill through rebar. This technique will be used in the future on the Central Artery Project.

Sincerely,
MASSACHUSETTS TURNPIKE AUTHORITY

Peter M. Zuk
Project Director

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