

Multistory Building Steam Tunnel and Loading Dock Restoration

By David M. Morrison

A steam tunnel with an adjacent loading dock serves a seven-story hospital building on the campus of The University of Virginia-Charlottesville. It appeared to be deteriorating badly and was in need of major concrete repair work. Built in 1957 as an addition, the tunnel width varied from 7 to 11 ft (2.1 to 3.4 m) and, owing to the contours of the previous construction, is generally in the shape of an irregular hexagon. The interior height of the tunnel is 7 ft (2.1 m). The tunnel is 45 ft (13.7 m) long and part of it has a ramping floor. The adjacent loading dock is a 4 ft (1.2 m) high slab-on-grade that extends over the tunnel as an elevated slab, which serves as the soffit of the tunnel (Fig. 1 and 2).



Fig. 1: Elevation view of loading dock, looking west, before restoration. The door to the steam tunnel is behind the car to the left

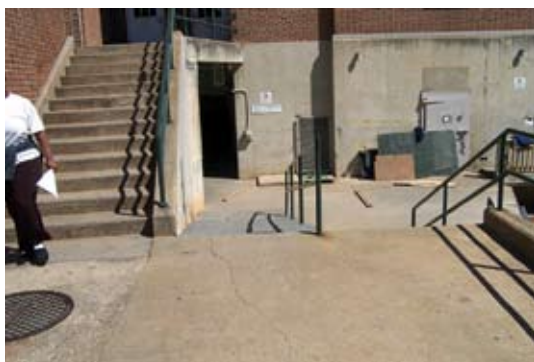


Fig. 2: View of loading dock and ramp, before restoration, as seen from the upper landing and looking north. The two-by-fours in the background approximately delineate the tunnel walls below

The top surface of the structure serves a number of purposes. It acts as a sidewalk, providing pedestrian access to the rear entrance of the multistory building. It includes stairs, a ramp, and a fire hydrant. It also functions as a loading dock.

The utility tunnel below carries steam, electricity, telephone, and fiber optic cable to and from the building. It also contains a water line feeding the fire hydrant. Adjacent to the tunnel and included in the project area are a telephone manhole and an electric manhole.

Problems That Prompted Repair

The owner was concerned that severe deterioration throughout the concrete structure threatened its safety and stability. A network of cracks in the top surface of the slab belied a far more extensive and serious spalling and corrosion problem in the soffit, visible from the tunnel below (Fig. 3). The tunnel walls displayed advanced spalling, delamination, and rebar corrosion (Fig. 4). The common wall between the tunnel and adjacent electrical manhole had spalling and delamination on the tunnel side (Fig. 5) and scaling on the electrical manhole side. A shallow concrete beam in the soffit of the tunnel, which supported the first-floor brick veneer at the southwest corner of the hospital building, exhibited severe spalling and corrosion of reinforcing steel (Fig. 6).

Inspection/Evaluation

The inspection and evaluation method involved a visual inspection to identify and mark trouble spots, hammer soundings to determine the extent of deterioration, and measuring to locate each defect. No tests, other than simple hammer soundings, were conducted.

It is believed that 40 years of winter salt application was the primary cause of the severe deterioration observed in the structure. Heat from the steam piping very likely contributed by melting any snow and ice on the top slab and keeping it in a liquid state, in which it could maintain the concrete in a near-constant condition of electrolytic saturation. This constant supply of salt-laden meltwater is believed to have accelerated the corrosion and spalling process.



Fig. 3: Deterioration in the tunnel soffit



Fig. 5: Delamination, spalling, and scaling in the common wall between the steam tunnel and electrical manhole



Fig. 4: Spalling and reinforcing steel corrosion in northwest diagonal wall. Note section loss in reinforcing steel



Fig. 6: Spalling and reinforcing steel corrosion in the concrete beam over the tunnel

Repair System Selection

Repair system selection fell into three categories, depending on extent of repair and access. First, the top slab and beam required complete removal and repair. For these members, structural design calculations were performed and a highly redundant strategy was specified. The strategy, which was intended to forestall further deterioration, included a custom concrete mixture design, epoxy-coated reinforcing, and an epoxy broadcast overlay. The 4000 psi (27.6 MPa) concrete mixture required a very low 0.35 water-cement ratio, air entrainment, and a corrosion-inhibiting admixture. A superplasticizer was added to ensure workability.

Second, large vertical spalled areas on the walls were specified to be patched using a formed, polymer-modified repair mortar, chosen because thin sections were anticipated at some locations. Smaller areas were specified to be patched using a trowel-applied, polymer-modified repair mortar. In practice, the contractor elected to hand-trowel all patched areas.

Site Preparation

Because the repair work was conducted during December 2003 through March 2004, the site was tented to provide some measure of protection from winter weather for materials and personnel.

Initially, the contractor used jackhammers to remove the top slab. When it became evident that the top slab was several inches thicker than the original construction drawings had indicated, the contractor found it more efficient to sawcut the slab and remove it in large chunks. The contractor used electric jackhammers to remove deteriorated and delaminated concrete in the walls.

Contract drawings indicated simply “roughen and pressure wash” for areas requiring surface preparation. This left maximum flexibility to the contractor for selection of the method. The contractor used electric jackhammers. In addition, where patching was required adjacent to existing reinforcing steel, specifications required the contractor to remove concrete 360 degrees around and behind the bar. The contractor replaced bars exhibiting excessive section loss.



Fig. 7: Soffit of tunnel after restoration (compare to Fig. 3)



Fig. 8: Northwest diagonal wall after restoration (compare to Fig. 4)



Fig. 9: Concrete beam after restoration (compare to Fig. 6)

Application Method Selection

The selection of the application method was determined on the basis of practicality and access. Shotcrete was ruled out because of space limitations and insufficient volume of material (mobilization for such a relatively small quantity of material would have been impractical). Instead, specifications required the contractor to construct one-sided forms for formed repair mortar, and required the application of polymer-modified repair mortar to small areas with a trowel. The top slab was formed and poured. The contractor elected to hand-trowel most of the patched areas.

Repair Process

Execution of the repair process required careful coordination. The adjacent electrical manhole contained two circuits which comprised the main power feed to the multistory building. These circuits were deenergized one at a time, maintaining power to the building, so that the cables could be temporarily moved to the far corner of the manhole and shielded from demolition and restoration work. Pedestrian and truck traffic were rerouted to other entrances. Vertical and lateral shoring, shown in the contract documents, was installed to temporarily replace the support provided by the slab and beam during construction.

In addition, the contract documents required the contractor to protect existing piping and utilities in the tunnel. The contractor achieved this by erecting scaffolding for the slab forms inside the tunnel prior to slab removal. This allowed for the scaffolding to perform double duty as both protection for utilities and support for slab formwork.

With these coordination measures in place, the contractor removed the top slab, replaced the beam, replaced the top slab, placed the ramp, and then moved inside the tunnel to patch the walls. Results may be seen in Fig. 7 through 10.

Unforeseen Conditions

Three unforeseen conditions were found, which required personnel to make adjustments during the construction process. First, the original 1957 construction drawings indicated the top slab to be 7 in. (17.8 cm) thick, and contract documents were prepared on that basis. During demolition the contractor found the slab to be 10 in. (25.4 cm) thick, requiring more effort for removal.

Second, during demolition the common wall between the electrical manhole and the tunnel, which had been slated for full-depth removal and replacement, was discovered to be in better condition than originally thought and was patched instead.

Finally, the new concrete in the beam cured more slowly than anticipated, reaching only 1870 psi (12.9 MPa) at 13 days and creating a minor delay

in shoring removal. Low February temperatures are thought to be the cause. The beam and slab concrete later reached strengths in excess of 6000 psi (41.4 MPa) at 28 days.

Special Features

The multistory building steam tunnel and loading dock restoration project included five special features that make it noteworthy, despite its unglamorous and utilitarian appearance. First and foremost, the engineer was successful in locating the deteriorated areas, in prescribing an appropriate and practical method of repair, and in identifying important issues requiring coordination. All of these were shown in the contract documents, which allowed the contractor to anticipate, plan, and budget accordingly. Second, the contractor was successful in coordinating the many internal and external activities affecting the project, including building access, maintaining power to the building, shoring and bracing, and temporary protection and support of tunnel utilities. Third, the repair strategy included both traditional and innovative methods and materials, including a corrosion-inhibiting admixture, a superplasticizer, epoxy-coated reinforcing steel, an epoxy broadcast overlay, and polymer-modified repair mortars. Fourth, and crucial to the success of the project, construction personnel exercised outstanding craftsmanship under the supervision of an experienced superintendent. Finally, the owner's goal was successfully achieved within budget and with very few change orders. Net change orders were held to approximately 4%. This project is a fine example of an ordinary, functional concrete repair project done well.



Fig. 10: Overview of finished project after restoration



David M. Morrison, MS, PE, is a structural engineer at Dewberry in Fairfax, Virginia. He is experienced in concrete restoration and is currently involved in two projects pertaining to surface restoration of deteriorated concrete in primary and secondary clarifiers. In addition to concrete restoration, he addresses a wide spectrum of structural engineering projects in various materials including concrete, steel, timber, masonry, aluminum, stainless steel, and fiber-reinforced polymer. Projects include retaining walls, civil structures, box culverts, pumping stations, water and wastewater tanks, buildings, bridges, wireless telecommunication facilities (cell sites), bridge inspections, construction inspections, clarifier inspections, and reports. He received his BS and MS degrees from The Pennsylvania State University and is registered in Maryland and Virginia. A Stone & Webster Engineering Corporation Fellow, he supervised the construction of power plants and commercial buildings for 9 years before earning his PE registration and entering the field of design. He is a member of ICRI and ASCE.

Multistory Building Steam Tunnel and Loading Dock

Owner

University of Virginia
Charlottesville, Virginia

Project Engineer

Dewberry
Fairfax, Virginia

Repair Contractor

Martin/Horn
Charlottesville, Virginia

Material Suppliers

Sika Corporation
Lyndhurst, New Jersey

H.T. Ferron Company
Charlottesville, Virginia