Philadelphia School Bus Parking and Repair Facility

The Broad Street Bus Garage, located in Philadelphia, PA, was built in the late 1950s. The structure is a two-story building with a slab-on-ground lower level, a waffle slab second floor, and a steel framed roof with block and brick masonry wall construction on the exterior. Each level consists of approximately 60,000 ft^2 (5575 m^2) of open space.

Causes of Deterioration

The deterioration of the concrete in the garage had reached such levels that netting was being used to catch concrete falling from the ceiling. Half a century of exposure to the extreme cold weather conditions and increasing demand on the use of the structure had gradually taken its toll. Years of exposure to deicing salt and water had caused extensive spalling on both the top surface and underside of the deck.

The structure in general was designed for lighter vehicles. There were areas of the slab that were under-designed for the additional weight of the buses. The root cause of the problems on the top surface was reinforcing steel corrosion accelerated by water. The problem on the bottom side of the slab was carbonation.

Inspection/Evaluation Methods and Test Results

An engineering report detailing the issues that had to be dealt with on the second-level deck reinforced concrete waffle slab listed the following conclusions:

- Pervasive, chloride-induced corrosion of the steel reinforcement is occurring throughout the waffle-slab structure, including the fascia surfaces exposed on the building exterior;
- The corrosion of the steel reinforcement is causing cracking and spalling throughout the fascia, sometimes exposing the reinforcement;
- Petrographic analysis of the concrete indicated marginal quality of the fine aggregates used in the original construction, reducing the integrity of the concrete matrix;
- Petrographic analysis of the concrete indicated a lack of air entrainment, yielding concrete that is more susceptible to distress due to freezing-and-thawing cycles; and
- Lines of major heavy cracking were observed in the slabs that were determined to be the result of concrete shrinkage in combination with a lack of adequate control joints.

The repair strategy formulated to address these issues included a plan for not only the obvious and urgent repairs but also addressed protection.

Repairs Begin

The concrete surfaces were first cleaned to remove all grease, curing compounds, surface treatments, coatings, and oils by using sandblasting and waterblasting. The construction site had to be organized so that driveways and entrances were left clear because the owner needed to use the facility during the school year.

Hydrodemolition was used to profile 45,000 ft^2 (4180 m^2) of the existing second floor concrete slab as well as 5000 ft^2 (465 m^2) of full-depth removal. Sandblasting was used to clean the underside of the waffle pan configuration of the same floor. The minimum removal depth was 1 in. (2.5 cm), but delamination existed beyond that depth. In fact, this process revealed the necessity for full depth replacement in some areas of the floor.

Concrete Overlay

The contract had outlined that 44,000 ft^2 (4085 m^2) of the garage floor would receive a 2 in. (5 cm) concrete replacement, and 4000 ft^2 (372 m^2) of the floor would receive full-depth replacement. As the hydrodemolition started, however, the

Exterior of school bus garage facility

Hydrodemolition of deck

Deck after hydrodemolition

extremely poor condition of the existing concrete resulted in an average 2 in. (5 cm) profiling and a subsequent 3 in. (7.6 cm) concrete overlay.

Based on the initial assessment of a 2 in. (5 cm) overlay, conventional concrete was ruled out by the designers. The product chosen was a bagged concrete material preblended with 3/8 in. (0.9 cm) coarse aggregate, which would have an ultimate compressive strength of 5000 psi (34.5 MPa). To complete the project, 720 super sacks of the concrete repair material, each weighing 2000 lb (907 kg), were needed.

The limited available time to place the overlay and the requirements of placing a prebagged material had made the job challenging. Numerous meetings and discussions between the contractors, material suppliers, and engineers concluded that concrete trucks would be used to mix the material and a concrete pump would be used to pump the material through the window openings onto the slab area.

Nine of the super sacks of dry bagged material were emptied into the concrete truck at a site approximately 30 miles (48.3 km) west of the job site in New Jersey. There were days during the project that 18 trucks were lined up in succession with dry material waiting to be mixed and placed. Water was added, proportionately to the requirements of the material, to the mixture in the truck at the project site. The concrete was then mixed and pumped into the building with a concrete pump. The specification required an independent testing agency to test and inspect at least one composite sample for each 100 yd^3 (76 m^3) of each concrete mixture placed each day.

Waffle Slab Repairs

Each individual waffle form was reframed. New reinforcing steel was coated with an anti-corrosion agent and installed in the waffle frames prior to the placing of the concrete where required. When existing reinforcing steel was encountered with active corrosion, sandblasting to a white metal finish was completed to remove all contaminants and rust. But, where corrosion was encountered due to the presence of chlorides, the steel was high-pressure washed after mechanical cleaning. The clean steel was then primed with two coats of epoxy-cement reinforcement protection. The bonding agent for the repair concrete/mortar was applied by spray to achieve a uniform coverage. A coat of bonding agent was applied before the patching material was applied.

Under the second-floor waffle pan slab, 1400 linear ft (425 m) of structural cracks was repaired using epoxy injection. The structural cracks were repaired using a low viscosity structural epoxy resin.

Structural Strengthening

Four inch (10 cm) wide carbon fiber-reinforced polymer (CFRP) strips were used on the waffle slab to strengthen the structure. A total of 1500 linear ft (457 m) of 4 in. (10 cm) strip were glued to the concrete with a two-component structural epoxy resin. The external structural strengthening was accomplished by using epoxy to bond CFRP laminate strips. All aspects of the fiber-reinforced polymer (FRP) reinforcement were observed by an independent inspection agency on a daily basis.

Waterproofing and Corrosion Protection

After the strengthening and overlay were complete, the entire deck top surface was covered

Mixing super sacks into concrete trucks

Placing pumped concrete

with a waterproofing epoxy overlay to provide a protective, slip-resistant surface. The selected epoxy resin system allowed broadcasting of aggregate in the freshly applied resin to create a durable slip-resistant traffic bearing coating. The coating gave the garage a clean and durable floor that would keep the concrete protected from moisture and chloride ingress.

The underside of the waffle slab and walls were coated with an anti-carbonation waterproofing coating. The coating would stop the water ingress and also be an effective barrier against carbon dioxide diffusion. The underside of the waffle slab was also impregnated with a penetrating corrosion inhibitor.

Other Repairs

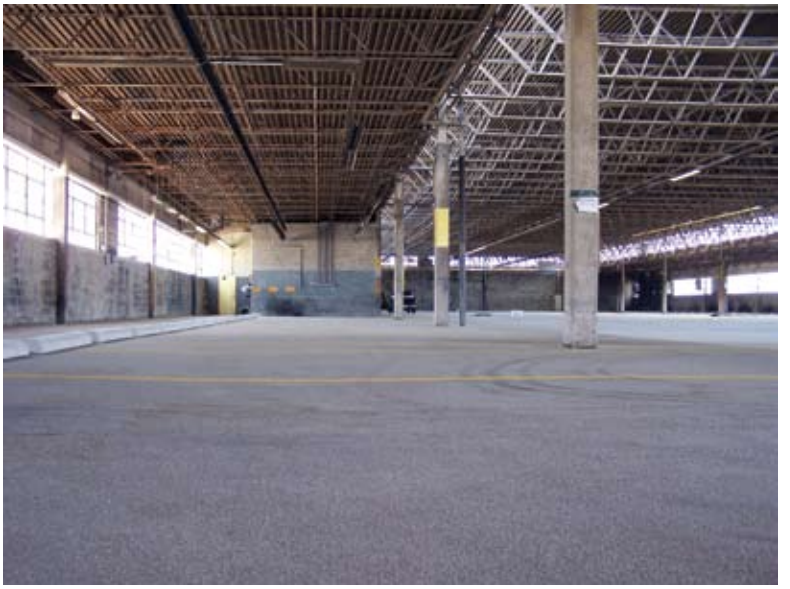
Other repairs that were accomplished simultaneously with the concrete restoration included:

- The interior side of the exterior wall spall was repaired, where necessary, to inhibit moisture intrusion;
- Steel lintels were repaired above the second floor windows;
- Damaged tire stops were replaced on the second floor slab; and
- New light fixtures and associated power components were added to the ground floor level.

On Time and Within Budget

The $2.9 million dollar, 120-day project incorporated a variety of proven and emerging repair techniques. Despite the short schedule, the contractor was able to deliver a value engineered project on time and within budget.

The Philadelphia school district now enjoys a completely renovated school bus garage and maintenance facility. Thanks to technical advancements made by the repair industry, transporting 40,000 school children may have become a little less of a challenge with a functional garage for the school buses of the Philadelphia school district.



Bus terminal repair completed

Philadelphia School Bus Parking and Repair Facility

Owner
Philadelphia School District
Philadelphia, PA

Project Engineer/Designer
Maitra Associates
Somerset, NJ

Repair Contractor
Masonry Preservation Group
Merchantville, NJ

Materials Suppliers/Manufacturers
Sika Corporation
Lyndhurst, NJ

Woodbury Cement Products
Woodbury Heights, NJ

Kenseal Construction Products
Folcraft, PA