

# Montgomery County Underground Garage Restoration

Dayton, Ohio

Submitted by Carl Walker, Inc.

The Montgomery County Administration Building Parking Garage, constructed in 1970, consists of two supported levels and one slab-on-grade parking level—all below grade. The facility was designed to provide approximately 450 parking spaces. The overall dimensions of the facility are approximately 181 ft (55 m) in the north-south direction and 308 ft (94 m) in the east-west direction. The total supported slab area measures approximately 94,000 ft<sup>2</sup> (8730 m<sup>2</sup>) over Levels 1 and 2 with the slab-on-grade Level 3 area provides an additional 56,000 ft<sup>2</sup> (5200 m<sup>2</sup>) of area.

The structural slab system consists of conventionally reinforced concrete two-way flat slabs spanning to reinforced concrete columns. The columns are 1 x 5 ft (0.3 x 1.5 m) and are spaced typically at 28 ft (8.5 m) on center. A 10 x 14 ft (3.0 x 4.3 m) drop panel and 5 x 9 ft (1.5 x 2.7 m) column capital is provided at each column. The slab thickness was designed to be 10 in. (254 mm).

The concrete used for the structural slabs was specified to be a nonshrink concrete with a minimum compressive strength of 3000 psi (20.7 MPa) at 28 days.

As is typical with two-way flat slab systems, the top reinforcement is located along the column strips and the bottom reinforcement is located at the center of the base. Approximately 85% of top of the slab area contains the top of slab reinforcement steel. The 15% of the area with no top steel is typically located at the midbay of the slabs. The minimum concrete cover for the slab reinforcement was 3/4 in. (19 mm).

## Problems that Prompted Repair/ Causes of Deterioration

Several floor repair projects had been done in the past. Numerous previous concrete repair patches were evident along construction joints at Levels 1 and 2.



*Montgomery County Garage Underground Parking Facility*

A chain drag and visual examinations indicated extensive top-of-slab delaminations. From the sounding, over 25% of the top side of the floor surface was delaminated. In several excavation areas, the reinforcing steel had lost over 50% of the cross-sectional area due to corrosion. There was also delamination and spalling of the underside of the



*Hydrodemolition removal of deteriorated concrete*



*Cathodic protection reference electrode installation*



*Concrete ceiling repair demolition*

slabs at the construction joints where chloride contamination had reached the bottom steel. The top of the slabs were heavily contaminated with chloride. In addition, the concrete material was susceptible to freezing-and-thawing damage due to lack of air entrainment. Severe loss of the reinforcing steel cross section as well as debonding of the steel from the base concrete was noted at delaminations in the concrete slab.

There was significant leaking through 3000 linear ft (914 m) of sealant joints.

## Inspection/Evaluation Methods

Inspection methods for this project included:

- Review existing documents;
- Visual walkthrough review of the structure to confirm quantities and locations of items of deterioration such as cracking, scaling, and spalling of concrete structural elements; and
- Chain drag sounding survey of the supported parking slab to quantify top-of-slab delaminations.

## Test Results

- Concrete cover testing was completed and found an average concrete cover of 0.75 in. (19 mm);
- Petrographic analysis of the concrete revealed a very high water-cement ratio ( $w/c$ ) and less than 2% air entrainment; and
- Chloride testing was completed on the supported structural slabs. Chloride levels at the level of the reinforcing steel were much higher than the threshold needed for corrosion to occur.

## Repair System Selection

It was important that selection of maintenance and repair methods for this parking garage considered both short-term and long-term economics. This was of particular importance as the county plaza and building were directly on top of the parking structure. The county intended to occupy the building for another 30 years and the restoration of the parking structure needed to be a long-term repair. The county also desired a repair option with low maintenance.

The study leading to this project presented six options:

- Patch and coat;
- Strip patch;
- Cathodic protection;
- Structural steel shoring;
- Exterior post-tensioning; and
- Slab removal and replacement.

A full economic life cycle analysis was completed to compare the initial versus long-term maintenance costs of these various options.

The only method that would effectively control corrosion of embedded reinforcement in chloride-contaminated concrete is cathodic protection. Once this system is installed and properly energized, the maintenance required is anticipated to be reduced and the corrosion process is largely arrested. Therefore, the potential savings in this type of restoration is decreased future maintenance.

The life expectancy of cathodic protection systems was estimated at 30 years based on corrosion of the sacrificial titanium mesh anode. The structure also would have some residual life expectancy after the cathodic protection system anode is consumed.

Montgomery County selected the cathodic protection system. It included the installation of the system embedded in a bonded concrete overlay. The estimated repair budget was \$1,530,000.

## Site Preparation

All restoration was sequenced to maintain safe Montgomery County office business. Parking operations were maintained at 75% of the total capacity. Ventilation ducts into the occupied building were reviewed and addressed. Dust, noise, and fume concerns were discussed with the owner.

## Demolition Method

Hydrodemolition was used extensively as the demolition method on this project. The hydrodemolition not only removed all concrete at delaminated areas but also removed approximately 1 in. (25 mm) of concrete before to the concrete overlay. As the cathodic protection system would arrest

Ceiling shotcrete installation



The successful repairs in April 2007

the corrosion, the complete removal of all chloride-contaminated concrete around the reinforcing steel was not necessary, saving a significant amount of hand demolition costs.

For the columns and ceilings, delaminated, spalled, and unsound concrete had their marked boundaries saw-cut or vertically chipped in columns and ceilings to a depth of 1/2 in. (13 mm) into the existing concrete, measured from the original surface. All concrete was removed from within the marked boundary to a minimum depth of 3/4 in. (19 mm) around existing reinforcing steel.

### Surface Preparation

All exposed steel within floor cavities in non-overlay areas and column cavities were cleaned and epoxy coated. Loose reinforcing steel was secured by either tying loose top reinforcing bars to partially bonded reinforcing bars or drilling supplemental anchors into the existing floor and installing tie-downs.

Airblasting was required as a final step to remove debris.

All bonding surfaces were abrasive-blasted to remove laitance, concrete fractures, and any foreign material that would impair bonding.

The concrete surfaces were wet and in a saturated surface-dry condition before the concrete overlay placement. A wet concrete slurry bonding grout was scrubbed into the original surface just ahead of the concrete overlay placement.

### Repair Process Execution

The restoration was completed in 1994. All delaminated concrete was removed and a bonded concrete overlay was provided. The overlay was a high-quality conventional concrete with cathodic protection anodes placed within the overlay. All ceiling and column delaminations were repaired. Ten additional drains and drain lines were installed in low areas to eliminate ponding of water. New construction joints were tooled into the topping and sealed with sealant.

The ceiling repair areas were patched with shotcrete.

After the hydrodemolition removed the concrete delaminations, larger areas of existing reinforcing steel was exposed. Wiring and monitoring systems were installed on the reinforcing steel before patching. The deep repair areas were patched first, followed by the installation of the titanium mesh anode and concrete overlay. Silver-Silver reference electrodes were installed in each zone to monitor the performance of the cathodic protection system over time.

### Successful Performance for 13 years and Counting!

The cathodic protection system was set up to be monitored remotely for performance. Quarterly monitoring reports were completed to ensure continued performance of the system. The successful performance was supported by physical, in-the-field chain drags and sounding reviews in 1998, 2001, and 2004. No areas of corrosion-induced deterioration of the top of the floor was noted and only minimal areas of topping debonding. The installation of a high-quality concrete overlay over the poorly air-entrained concrete has also prevented any further freezing-and-thawing deterioration.

## Montgomery County Underground Garage

### Owner

Montgomery County of Public Works  
Dayton, Ohio

### Project Engineer/Designer

Carl Walker, Inc.  
Kalamazoo, Michigan

### Repair Contractor

Lithko Contracting, Inc.  
Hamilton, Ohio

### Material Suppliers/Manufacturers

Elgard Corporation  
Chardon, Ohio

Flow Services Corporation  
Coraopolis, Pennsylvania