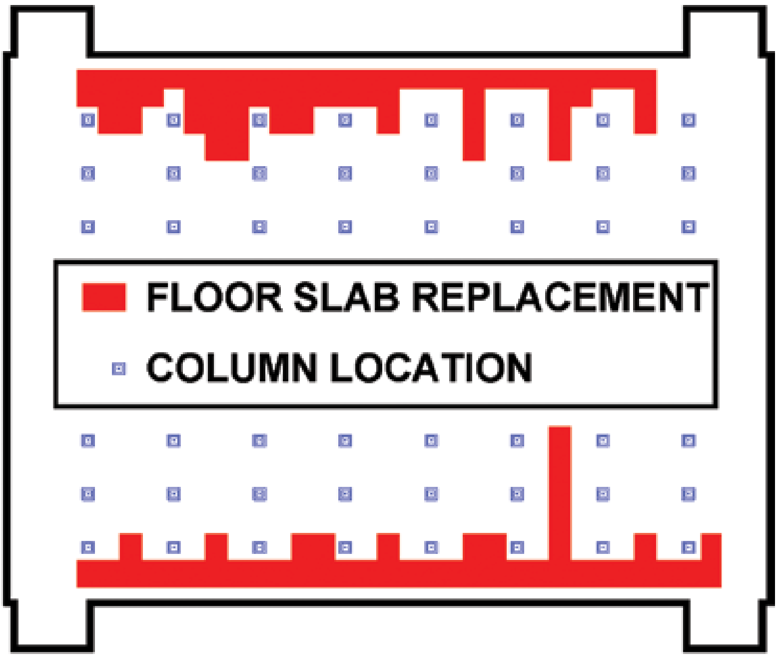
A Comprehensive Approach to a Slab-on-Ground Repair

By Kip Gatto and Rocco Romero

Building owners are often reluctant to repair their distressed and minimally-functional slab-on-ground floor systems due to both the cost of repair and interruption of business. Adequate planning and scheduling for a repair project are often sacrificed to emergency repair work required in critical areas of the building. The long-term continued use (and abuse) of an already damaged floor system can rapidly exacerbate existing damage and produce new areas of distress, which are often adjacent to low demand areas with little or no current distress. For example, a forklift travel lane typically incurs higher demand than that of a goods storage area.

A facility in Kent, Washington, experienced these conditions. The building is a nearly square 150,000 ft^2 (13,935 m^2) area warehouse used for low-hazard storage. The floor system was originally constructed of self-consolidating 6 in. (15.2 cm) thick unreinforced concrete slab-on-ground with glass fibers added for shrinkage control. Control joints were cut 1-1/2 in. (3.8 cm) deep by 1/8 in. (0.32 cm) wide at a grid of approximately 16 ft (4.9 m). Roof support columns supported by below-grade footings were placed in a 32 x 52 ft (9.8 x 15.9 m) grid.



Floor slab replacement area

Although rubber wheeled forklifts were used, the transport of heavy coffee bean pallets caused significant distress in high traffic forklift travel lanes and areas adjacent to 20 overhead delivery bay doors. The floor slab was distressed to a point that operations in the facility were significantly affected. The travel lanes were critical to facility operations and down time needed to be planned and minimized.

Evaluation

A condition survey was conducted that included sound testing the slab, documenting distressed areas, and observing the layout and use of the facility. It was readily apparent that damage was most severe in the forklift travel lanes and near the delivery bay doors. A petrographic study (ASTM C 856, "Standard Practice for Petrographic Examination of Hardened Concrete") of concrete core samples removed from the floor slab and a review of previous geotechnical reports related to soil conditions below the slab were used in the development of repair documents.

Several repair methods were considered, including a concrete overlay (which required careful detailing of all the slab interfaces with columns, doors, and walls) and even complete replacement of the slab-on-ground. The following criteria were used to evaluate the various repair options:

- Cost of repair
- The effect on building operations (down time and phasing)
- Required floor quality and durability
- Reasonable future maintenance and repairs that require minimum disruption to the tenant
- Slab distress conditions that included random hairline and small cracks in addition to severely cracked and displaced floor slab sections
- Control joints that had experienced spalling, raveling, and minor curling

Ultimately, a selective approach was used where portions of the slab were repaired according to the type of damage. This approach included selective slab replacement, slab repair, control joint reconditioning, and crack repair. Most of the original slab remained in serviceable condition and did not require significant repairs.

Repairs

Heavily Damaged Slab Replacement

Near the delivery bay doors, the slab-on-ground had experienced severe distress. Large areas of cracking, displacement, and delaminations were common. At these areas, (approximately 20,000 ft^2 [1860 m^2]) the slab was removed and replaced.

These high demand areas showed a vulnerability to damage, so these sections of the slab were replaced using concrete reinforced with deformed steel bars. Given that the primary purpose of the reinforcement was to minimize shrinkage cracking, which can initiate further damage, the subgrade drag formula given in ACI 302.1R "Guide for Concrete Floor and Slab Construction" was used to determine the minimum level of reinforcement. No. 4 reinforcing bars at 18 in. (46 cm) on-center were ultimately chosen to be placed in the top half of the slab. The bars were terminated just short of the planned control joints that were to coincide with the original joints.

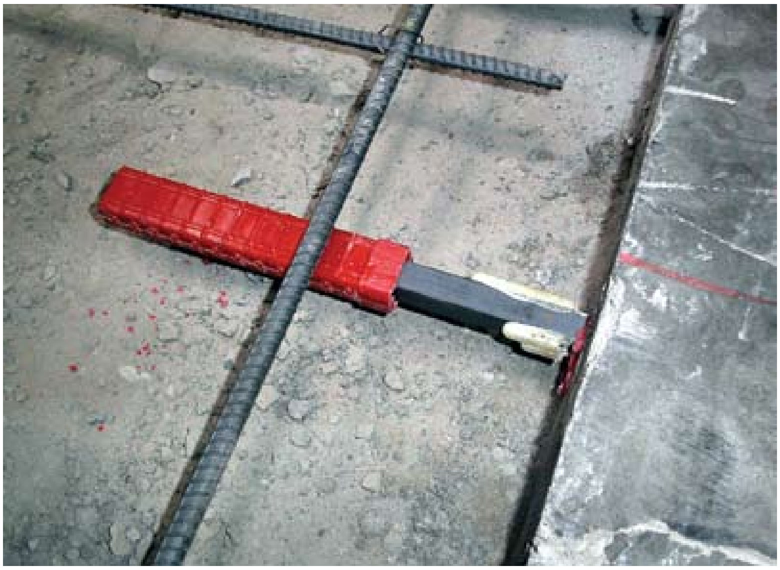
At control joints between new sections of slab, 16 in. (41 cm) long, 3/4 in. (1.9 cm) diameter greased round dowels were placed at 12 in. (30.5 cm) on-center. The dowels provided vertical load transfer across the joints but allowed shrinkage movement to occur with limited restraint in the direction of the dowel.

There was concern about the interface between the existing concrete that was to remain and the new long narrow sections of slab that were to be replaced adjacent to the delivery bay doors. Although round dowels can accommodate movement perpendicular to the construction joint, parallel movement is restrained. This is generally not a problem in new slabs because movement parallel to the construction joint is approximately the same on each side. In a "new-to-existing" slab construction joint, however, the existing slab obviously does not shrink, but the new slab will shrink and likely induce stresses at the dowel locations. To address this issue, 3/4 in. (1.9 cm) square dowels were used with plastic slip sleeves installed that theoretically accommodate movement in all directions except vertical. The sleeved dowels were intended to provide vertical load transfer across the new-to-existing construction joint while accommodating shrinkage stresses in all horizontal directions.

Considerable attention was given to subgrade compaction and grading, concrete mixture, concrete quality, slab curing, and timing of control joint cutting in an effort to maximize slab quality. These tasks are sometimes performed in a more informal manner, which reduces quality control and can result in increased cracking, curling, settlement, and general poor slab performance.

Modified proctor testing (ASTM D 1557, "Standard Test Methods for Laboratory Compaction

Greased round dowels at new-to-new slab joint



Square dowel with slip sleeve at new-to-existing slab joint

Floor slab curing

Characteristics of Soil Using Modified Effort") was used to verify subgrade compaction. Batch tickets were checked on site to verify compliance with the mixture design and admixture allowances. Slump, temperature, and strength testing were performed to determine if the concrete was consistent with the design intent. Slab control joints were soft cut approximately 3 h after hard troweling and a continuous wet cure was maintained for seven days. Attention to these construction activities is a critical aspect of repair, potentially even more important than the design.

Smaller random areas of localized slab distress also required replacement. Conditions such as broken-off slab corners at cross-joint intersections, due to curling or poor subgrade conditions, required removal and replacement of smaller sections of slab.

These repair locations were treated in a manner similar to the large area replacement except that deformed bars were placed at the new-to-existing slab construction joints. Deformed bars were used because of the small area of replacement and existing joint intersections that were present at the repair locations, where any movement could be accommodated (the joints were recut at the original locations).

Medium Damaged Slab Repairs

Several small distressed areas where the damage was isolated to the upper portion of the slab required only partial depth repairs. At these locations the damaged area was chipped out to a depth of roughly 3 in. (7.6 cm). Deformed bars were doweled vertically into the remaining slab and a nonshrink repair concrete applied to the location. The nonshrink concrete was used to minimize any separation at the edge of the repair and eliminate the need for special detailing and control joints.

Cutting of semi-rigid epoxy filler at control joint

Control Joint Reconditioning

The control joints were frequently a source of edge spalling and distress. Some of the joints had already been filled with an inappropriate sealant that was ineffective in protecting the edge of the joints from forklift impacts. Filling the control joints with a semi-rigid epoxy, which is now recommended by ACI 302, "Guide for Concrete Floor and Slab Construction," was performed at both existing and new joints.

The existing filler was removed and the semi-rigid epoxy applied. Bagged silica sand was used at the bottom of the joint to prevent epoxy from seeping away. The general procedure was to overfill the joint with epoxy, let it cure, then cut the surface flush using heat to facilitate the cutting. Power sanding was used to produce the desired profile at some areas where slight curling existed or the epoxy cut was irregular.

Small edge spalls and raveling at the joint were repaired during this process by grinding feathered edges square and filling the area with semi-rigid epoxy. Silica sand was mixed with the epoxy to increase the resiliency at larger spall areas. Curling present at the slab joints, which usually compounded the edge spalling condition, was addressed by grinding off the raised edge and/or profiling the epoxy accordingly to create a smooth transition. Approximately 16,000 linear ft (4,889 m) of control joints and small edge spalls were repaired.

Crack Repairs

Significant localized cracking was present throughout the slab. Cracks that ranged from 1/8 to 1/2 in. (0.3 to 1.3 cm) wide were repaired by grinding the crack to a square and uniform profile, then filling with semi-rigid epoxy similar to the control joint application. Like at the control joints, spalls at crack edges were ground square and filled with epoxy, with silica sand mixed in for larger edge spall areas.

One Year Review

A one year review was conducted to assess the performance of the repairs. In general, the repairs were performing admirably. The new sections of slab showed almost no signs of cracking or curling and the nonshrink repair concrete used at smaller repair areas appeared to be living up to the name.

The semi-rigid epoxy applied at cracks and joints had largely appeared to be unaffected by the significant forklift traffic imposed over the year. At some locations where the epoxy was used to repair an edge spall, the repair had dished down leaving the edge again exposed. However, this was much more the exception than the rule. At one location the concrete had delaminated around the epoxy in a high traffic area leaving the epoxy in place. This is an area where a more aggressive repair may have been required, but in general, the choice of repairs appeared appropriate to the distressed conditions.

Epoxy applied at the new slab control joints was separating due to slab shrinkage intended to be accommodated at the joint. The epoxy was installed after the slab was cured for only 30 days, due to the building tenant requiring use of the repaired areas as soon as possible. Semi-rigid epoxy manufacturers recommend a waiting period (typically 1 year) before the epoxy is applied to prevent this condition from occurring. Given that the epoxy was reasonably effective in protecting the joint, however, even in the separated condition, it seems appropriate to apply it before the slab is used. Separated epoxy can always be repaired at a later time (the same product should be used when supplementing existing epoxy).

Epoxy separation after one year at new slab joint. Note that epoxy is still providing some protection of slab edge

Epoxy joint and spall repair in existing slab after one year

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