Vacuum drilling holes in concrete girders. Ideal locations of holes shown on engineering plans are marked on bridge deck by red dots and identified by yellow letter-number combinations. Actual drilling locations are adjusted, based on pachometer readings, so drill does not hit transverse reinforcing steel.

Kansas bridges renovated by post reinforcement and thin bonded concrete overlay

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For several years the Kansas Department of Transportation (KsDOT) was faced with shear cracks in the concrete girders of two-girder reinforced concrete bridges. The Department tried repairing some of these by epoxy crack injection, but this didn't last because the epoxy repair didn't improve the shear capacity of the girder. Some severely shear cracked girder sections were removed and replaced, but this cost $30,000 to $40,000 for each section and it increased the shear capacity of the repaired area only. Not many bridges were repaired because it would eventually be cheaper to build a new bridge. But Kansas could not afford to replace the state's 84 or more bridges susceptible to girder shear cracking.

A technique that would repair the cracks and increase the girder's shear capacity was needed instead. *Post reinforcement*, a repair method that does both of these things, was developed and is now used by the KsDOT. It consists of the following four steps:

1. Seal all cracks in the girder with a silicone sealant.

2. Vacuum drill l-inch-diameter clean, dust-free holes at a 45-degree angle to the deck near the girder centerline in the pattern specified in the engineering plans.

3. Pump epoxy into the drilled holes and into cracks intercepted by these holes.

4. Insert a #6, Grade 60 rebar cut 3 inches short of full hole depth into each hole.

An efficient repair crew can completely post reinforce a 3-span bridge in less than one week. This raises the girders' shear capacity to 10 percent above 1981 AASHTO requirements. Another advantage: traffic can usually be maintained on one lane of the bridge during repair. In some cases, the final step is construction of a thin bonded overlay, but if the bridge deck is still in good condition, this isn't necessary.

Post reinforcement procedure

Contractors are supplied construction plans and specifications for performing a post reinforcement repair. If the bridge is covered with an asphalt wearing surface, before drilling can begin, the asphalt must be removed. Cracks on the surface of the girders are sealed with an elastic silicone sealant. The clear sealant bead is applied over the crack, then pressure screeded into the crack using a specially shaped spreader. On wide cracks some buildup of sealant may be needed. To avoid trapping rainwater in the cracks, they are not sealed much in advance of the repair.

While sealing is in progress the drill entry points are marked on the bridge deck near the measured centerline of the girders. After the ideal design positions are marked, the actual entry points are established using a pachometer (metal detector) to find the transverse deck rebar. The actual drill entry position will usually be within 2 inches of the design position shown on the plans. Without the pachometer location of the rebar, the drill crew stands a high chance of hitting rebar, which causes tip breakage and lost time.

Drilling should start at the center of the span and progress toward the pier. This avoids having the drilling rig set up over holes that are already drilled. To commence drilling, the trailer or truck on which the drill is mounted is centered over the entry point, and the drilling equipment is leveled side to side using hydraulic stabilizers. Next, the gantry that supports the drill is raised to a 45-degree angle, locked at this angle, then moved so the drill tip is at the entry point marked on the bridge deck. A drill entry gouge can be spot-faced in the deck using a light chipping hammer. This facilitates drill entry into the concrete and also reduces tip breakage. Once the tip is in position, the desired hole depth is marked on the drill steel. Drilling the hole generally takes less than 1 minute, and turn-around time from hole to hole is usually less than 3 minutes. The number of holes drilled in a day is limited by the number that can be injected with epoxy on the same day.

After drilling, each hole is measured for depth, and a rebar is cut 3 inches short of full hole depth. This keeps the top of the bar below the path of the grinder used to prepare decks topped with a thin bonded concrete overlay.

The epoxy injection crew can start work after drilling is completed on one girder part. Injection starts with the deepest hole—the hole closest to the pier or the abutment. After the hole is about half filled with epoxy, the bar is slowly inserted and gently tapped to be sure it is seated on the bottom of the hole. The nozzle is then reinserted, locked in place, and the hole is filled under pressure.

Any crack in the girder will likely be intercepted by at least one drilled hole. To fill tight cracks with epoxy a sustained pump pressure of 100 psi is usually required. Less pressure is required to fill wide cracks. Consequently, the operator should not try to increase pump pressure to 100 psi when wide cracks are encountered. To do so might cause a rupture in the silicone material sealing the crack exterior. Instead, the operator should watch the air cylinder shaft of the pump for any displacement. As long as the air cylinder shaft is moving and no leaks from the surface cracks are present, the crack filling operation is progressing satisfactorily. Pumping should continue until either epoxy is detected in the next hole or the air cylinder shaft stops moving.

Cracks on surface of girders are sealed with silicone before drill holes are injected with epoxy.

The injection crew should constantly check previously injected holes, and if a lower level of epoxy is noted in the holes, they should be refilled. In very hot weather, coarse aggregate can be poured into the hole on top of the bar to cool the epoxy. Otherwise, the heat of polymerization may cause the epoxy to boil and foam, or cause thermal contraction cracks at the epoxy surface.

Equipment needed

To perform the post reinforcement repair a contractor must have certain equipment. The 1-inch-diameter holes must be clean, dust-free and dry. The depth of holes must be controlled, and the holes must be straight

to accept a #6 rebar. Drilling angle must be accurate and repeatable, and the rate of drilling should be fast. To achieve these requirements, Kansas requires the use of a vacuum drill that sucks up dust through the center of the hollow drill bit. A proprietary trailer-mounted vacuum drill is available for less than $40,000. A truck-mounted drill is available, too, but it costs more.

A pachometer, which usually costs less than $3000, is needed to locate the transverse bridge deck reinforcement. Without this instrument, too many carbide drill tips would be broken and much production time would be lost trying to locate holes by trial and error.

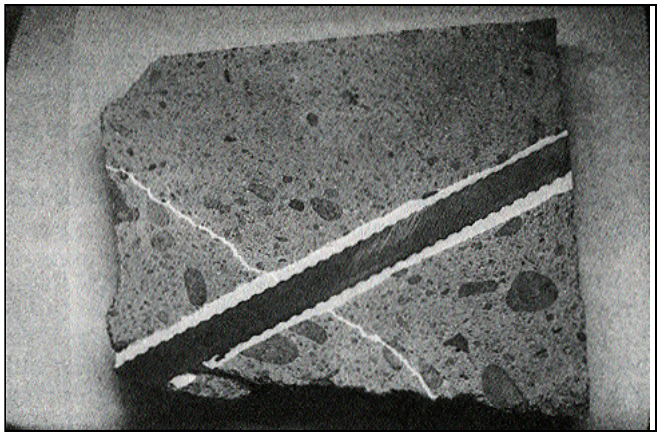
The epoxy injection pump must also meet certain specifications. The pump must be positive displacement and deliver a certified volume ratio of hardener to resin in the temperature and pressure range needed to perform the injection. It must be able to deliver a sustained pressure of 100 psi and must be controllable between 20 and 100 psi. The injection nozzle must lock in the hole and hold 100 psi without leaking. The nozzle is a device which the contractor can build himself or have a local machine shop build from a KsDOT design at minor cost. Epoxy components must be kept separate and mixed just ahead of the injection nozzle.

Thin bonded concrete overlay

If the bridge deck is badly deteriorated, it can be repaired by applying a thin bonded concrete overlay, once the epoxy for the post reinforcement has fully set. Work on a thin bonded concrete overlay can also be done while traffic is carried in one lane.

About ¼ inch of the concrete deck surface is removed by cutting, milling, or abrading, to clear away laitance, oil, asphalt or spilled epoxy. Chain drags and tapping hammers are used to locate delaminated concrete and other unsound concrete; this is removed with 15- to 30-pound jackhammers. In some areas the concrete may be removed full depth and replaced with a full-depth, high-quality concrete patch. The full-depth patch must be placed at least 24 hours before the overlay. Shallow excavated areas of unsound concrete are not patched; they are filled by the overlay instead. These excavations usually stop at the level of the top reinforcing steel because the concrete is generally sound below the steel. Kansas does not require removal of sound concrete even if it is contaminated by chlorides. The bridge designers believe that maintaining as much steel-concrete bond as possible is more important than removing the salt-contaminated concrete. Hence, in delaminated areas, if the lower half of a rebar is well bonded to sound concrete, that bond is left as undisturbed as possible.

Rust and scale are removed from the exposed steel reinforcing bars by blast cleaning. The area is thoroughly cleaned by air blast and inspected to see that all loose material and deteriorated concrete has been removed. Bond between the overlay and the old deck is obtained with a grout consisting of a one-to-one mixture (by weight) of portland cement and fine aggregate, with enough water to produce a consistency of heavy cream. The grout is scrubbed onto the existing deck just a few feet ahead of the concrete overlay. For a bond to develop the overlay must be placed while the grout is wet.



Cross-section of post reinforced bridge girder. Photographed in ultraviolet light to better show the fluorescent epoxy, this 5x7-inch chunk of concrete removed from a bridge several years after repair shows the rebar crossing a crack. The crack is filled with epoxy, and the rebar is encapsulated in epoxy and bonded to the sides of the drilled hole.

The air-entrained overlay concrete must have a minimum of 625 pounds of portland cement per cubic yard and a water-cement ratio of no more than 0.40. Slump must not exceed ¾ inch. The overlay is generally placed 2¼ inches thick over the entire prepared deck, though it will be thicker where it fills in the depressions left by the removal of unsound concrete. The overlay concrete must be consolidated to 98 percent or more of the rodded unit weight; in-place density is monitored with a nuclear density measuring device. Finishing, texturing, and curing of the overlay are done according to regular practices.

Extra life for bridges

Since 1981, over 20 bridges have been fully post reinforced either by state forces or by private contractors. Additional bridges were let to contract this summer as part of a 5-year program aimed at upgrading all of the state's two-girder reinforced concrete bridges. Kansas also has about 25 thin bonded concrete bridge deck overlays that are now 15 to 23 years old and still in service. There are almost that many that are 10 to 14 years old and many others less than 10 years old. Many of these overlays are now older than the original bridge decks were when they were overlaid. Thin bonded overlays have bought a lot of extra life for Kansas bridge decks. KsDOT expects the combination of thin bonded concrete overlay and concrete girder strengthening by post reinforcement to do equally well.

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For more information

See the Buyer's Guide in the December 1983 issue of CONCRETE CONSTRUCTION or see the Concrete '84 SourceBook for more information on epoxy injection equipment and pachometers. In both places, look under "Epoxy Injection Equipment" and "Reinforcement Locators," respectively.

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