Special Report

CONCRETE PAVEMENT TECHNOLOGY & RESEARCH

INCLUDES:

Cross-Stitching Details

Slot-Stitching Details

Recommended Rewards

Common Questions

American Concrete Pavement Association

International Grooving & Grinding Association

Stitching Concrete Pavement Cracks and Joints

There are two stitching methods used to repair and strengthen cracks or joints in concrete pavement. The first, and most common, is cross-stitching. Cross-stitching uses deformed tiebars epoxied or grouted into holes drilled at an angle through a crack. The second, slot-stitching, uses deformed tiebars grouted into slots cut across a joint or crack. Each technique is beneficial for certain circumstances. Recommendations on where to use these methods are outlined in this special report.

Stitching is applicable for a number of situations where strengthening joints or cracks is required. Among these are:

- Strengthening longitudinal cracks in slabs to prevent slab migration and maintain aggregate interlock
- Mitigating omission of tiebars from longitudinal contraction joints due to construction error
- Tying roadway lanes or shoulders that are separating and causing a maintenance problem
- Tying centerline longitudinal joints which are starting to fault
- Strengthening keyed joints for heavy loads (aircraft, gantry cranes, straddle carriers, etc.)

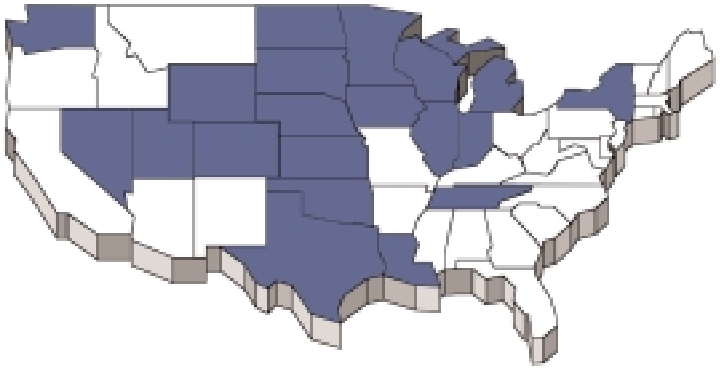
History –

The first reported attempt at cross-stitching was performed by the Corps of Engineers, Waterways Experiment Station. The Corps performed a study(1) on strengthening keyed longitudinal joints for airport pavements placed on low-strength subgrades in 1971. Their report outlines testing of a variety of joint strengthening methods and concludes that cross-stitching is one of the best strengthening techniques.

In the study, an 11-inch concrete pavement was placed directly on a low-strength clay subgrade with a keyed longitudinal construction joint. Amongst other methods, drilling holes at 45° through the joint and epoxying 325-mm (12.75-inch) long, 25-mm (1.0-inch) diameter bars into the holes strengthened the keyed joint. A 1600 kN (360,000-lb), 12-wheel gear load, simulating one main gear of a C-5A aircraft, was used to test the joint. At the end of the test, the cross-stitched joint withstood the repeated loading even better than the surrounding pavement. The report concludes that cross-stitching is viable and effective.

The first known use of cross-stitching on a US highway was in 1985 by the Utah Department of Transportation.(2) Engineers used cross-stitching to strengthen uncontrolled cracks on a new section of I-70 through the mountains of central Utah. The pavement was a 225-mm (9-in.) plain jointed concrete pavement resting on a 100-mm (4-in.) thick lean concrete base. Much of the

States Which Have Used Stitching to Repair Cracks



Since the first known cross-stitching project in Utah, many roadway agencies are known to have employed stitching (see map).

Cross-Stitching Technique –

Cross-stitching is a repair technique for longitudinal cracks and joints that are in reasonably good condition. The purpose of cross-stitching is to maintain aggregate interlock and provide added reinforcement and strength to the crack or joint. The tie bars used in cross-stitching prevent the crack from vertical and horizontal movement or widening.

Cross-stitching uses deformed tie bars inserted into holes drilled across a crack at angles of 35-45 degrees depending upon the slab thickness. A 20-mm (0.75-in.) diameter bar is sufficient to hold the joint tightly together to enhance aggregate interlock. The bars are spaced 600-900 mm (24-36 in.) from center to center and alternate from each side of the crack. A 900 mm (36-in.) spacing is adequate to effectively repair highways or roadways. Heavy truck traffic or airplane traffic requires a 600 mm (24-in.) bar spacing for added strength.

The process of stitching requires the following steps and considerations:

1. Drill holes at an angle so that they intersect the longitudinal crack or joint at about mid-depth. *(It is important to start drilling the hole at a consistent distance from the crack or joint, in order to consistently cross at mid-depth.)*
2. Select a drill that minimizes damage to the concrete surface, such as a hydraulic powered drill. Select a drill diameter no more than 10 mm (0.375 in.) larger than the tiebar diameter. Choose a gang-mounted drill if

uncontrolled cracking in the pavement was reflection cracking in areas where the surface concrete bonded to the lean concrete subbase. The cracks of major concern were the longitudinal cracks in or near the wheel tracks in the driving lanes. At that time, ACPA recommended replacing the shattered slabs (slabs with 3 or more cracks) and using cross-stitching only for longitudinal cracks within the wheel paths. In the spirit of testing the limits of cross-stitching, the project team's decision was to perform only two methods of repair regardless of the degree of uncontrolled cracking:

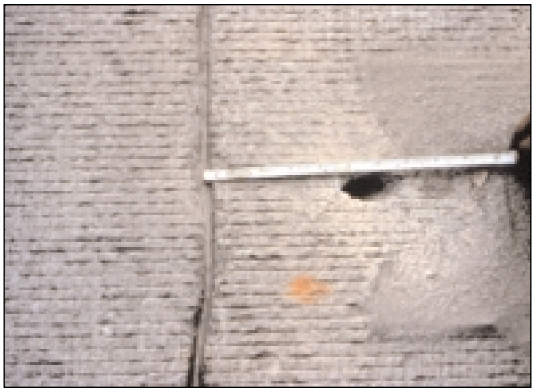
- Epoxy non-working joints close to cracks.
- Cross-stitch the longitudinal joints in or near the wheel tracks in the selected areas.

A total of 1081 holes were drilled on the project, which resulted in about 548 m (1800 ft) of cross-stitching.

A review of the I-70 project in February 2000, after 15 years of service, found the project to be in generally good condition, with some faulting across undoweled transverse contraction joints. The performance of cross-stitched cracks was favorable in most areas. In some areas, spalling was noted between the holes drilled for the cross-stitch tiebars; cracks also traced from hole-to-hole in these areas. However, the cross-stitch cracks performed well overall, preventing lane separation and minimizing the settlement of the slabs.

1. Drilling hole for tiebar along longitudinal crack using frame-mounted drill rigs.

2. Simple drill rig that controls the starting location of drilling to ensure that hole intersects crack at about mid-depth.



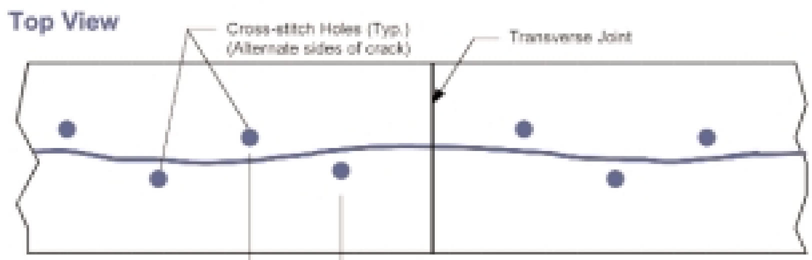
3. Checking hole location.

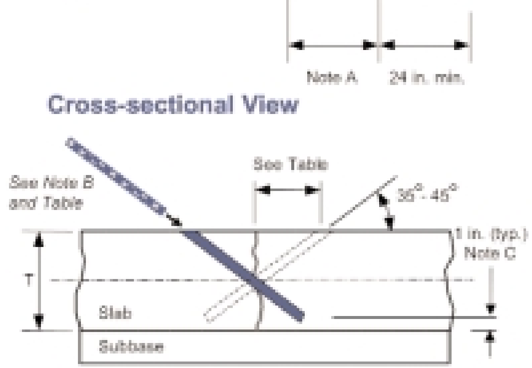
4. Pouring epoxy into drilled holes. (Injecting epoxy is preferable for large quantities.)

5. Inserting bars into prepared holes containing epoxy. (Note: The bars shown here are in position but not fully inserted.)

6. Completed cross-stitching on longitudinal crack.

Cross-Stitching Details





Cross-Stitching Bar Dimensions and Location of Drill Holes

	Slab Thickness (in.)							
	8	9	10	11	12	13	14	15
	Distance to Hole (in.)							
35°	5.75	6.50	7.25	7.75	8.50	--	--	--
40°	--	--	--	6.50	7.25	7.75	8.25	--
45°	--	--	--	--	6.00	6.50	7.00	7.50
	Length of Bar (in.)							
35°	9.50	11.00	12.50	14.50	16.00	--	--	--
40°	--	--	--	12.50	14.00	16.00	18.50	--
45°	--	--	--	--	12.00	14.00	16.50	18.00
	Diameter of Bar (in.)							
	0.75	0.75	0.75	0.75	0.75	1.0	1.0	1.0

Note A: *Distance between holes is 24 in. for heavy traffic; 36 in. for light traffic.*
Note B: *Epoxy deformed bar into hole. Length shown in table provide 1 inch cover at surface and assume drilling per Note C.*
Note C: *Do not drill hole completely through slab. Stop drilling so epoxy/grout will not run out of the bottom while backfilling.*

higher productivity is needed for larger jobs.

3. Airblow the holes to remove dust and debris after drilling.

4. Inject epoxy into the hole, leaving some volume for the bar to occupy the hole. (Pouring the epoxy is acceptable for small quantities.)

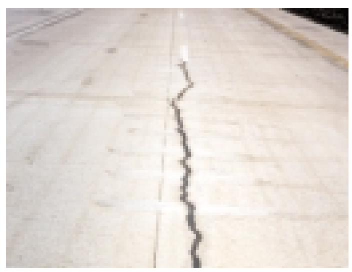
5. Insert the tiebar into hole, leaving about 25 mm (1 in.) from top of bar to pavement surface.

6. Remove excess epoxy and finish flush with the pavement surface.

Slot-Stitching Technique –

Slot-stitching is a repair technique for longitudinal cracks or joints. Slot-stitching is an extension of the more recent dowel bar retrofit technique, which is used to add dowel bars to existing transverse joints.(3)

The purpose of slot-stitching is to provide positive mechanical interconnection between two slabs or segments. The deformed bars placed in the slots hold the segments together, serving to maintain aggregate interlock and provide added reinforcement and strength to the crack or joint. These bars also prevent the crack or joint from vertical and horizontal movement or widening. Larger diameter bars [>25 mm (>1.0 in.)] also serve to provide long-term load transfer capabilities.

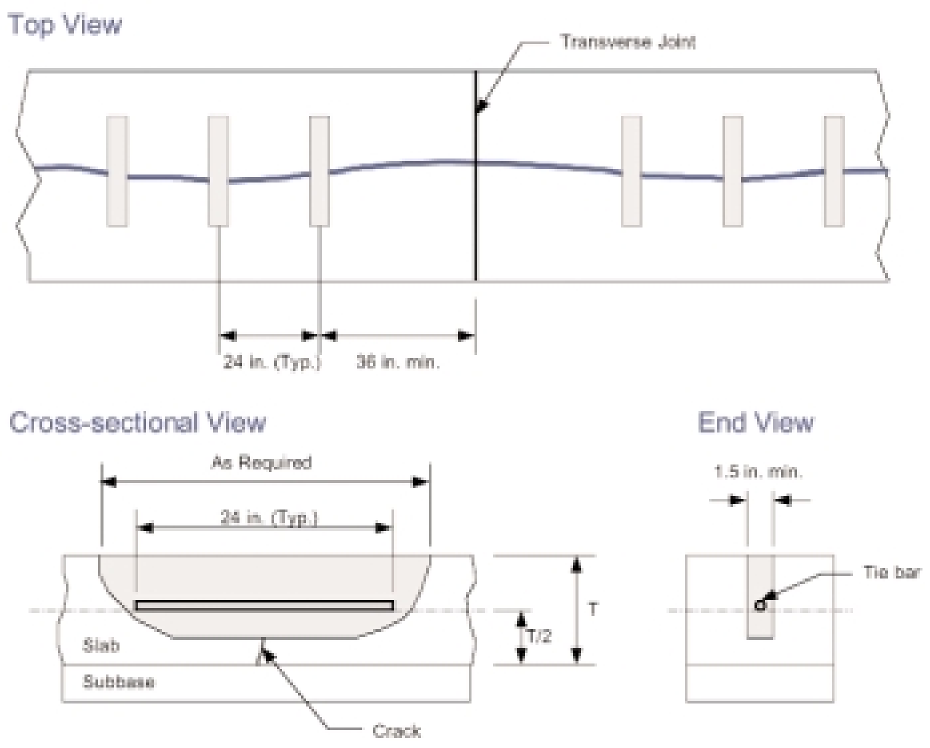


Stitched longitudinal joint and crack.

Slot-stitching requires the following steps and considerations:

1. Cut slots approximately perpendicular to the longitudinal joint or crack using a slot cutting machine or walk-behind saw. Unlike dowel bar retrofit, precision alignment is not critical since deformed bars will hold the joint tightly together preventing the slabs from separating.

2. Prepare the slots by removing the concrete and cleaning the slot. If the slabs have separated, consider using a joint reformer and caulking the joint or crack to prevent backfill



materials from flowing into the area between the slabs.

3. Place deformed bars into the slot.
4. Place backfill material into the slot and vibrate it so it thoroughly encases the bar. Select a backfill material that has very low shrinkage characteristic. (3)
5. Finish flush with the surface and cure.

Common Questions –

Which Stitching Method Should I Choose?

Either method is effective. However, cross-stitching generally holds these advantages over slot-stitching:

- Less intrusive to the slab.
- Less exposed surface area.
- Less backfill material.

Contractors and agencies should evaluate the costs and use the method that provides the optimal combination of strength, installation time and cost. Because more materials are required, slot-stitching is generally more expensive than cross-stitching.

Is Stitching Needed for All Uncontrolled Cracks? How do I Know if the Cracking is too Severe?

Stitching is an excellent non-intrusive procedure to repair uncontrolled longitudinal cracking. However, in some cases it may not be advisable or necessary. Some cracks can perform well simply by sealing and maintaining the crack properly.

Both methods of stitching are not intended for severely deteriorated cracks. If the cracks are in moderate or fair condition, stitching is effective. Experience on Utah's first-ever highway cross-stitching project demonstrates that stitching is not a substitute for slab replacement if the degree of cracking is too severe.

The table (next page) provides recommended repair procedures for various types of cracking, including the appropriate use of stitching.

Can I Stitch Transverse Cracks?

Do not stitch transverse cracks. Transverse cracks often form active boundaries to slabs or segments of

Slot-Stitching Details

For more information see ACPA publication JP001P "Guide for Load Transfer Restoration." (Reference 3)

Recommended Repairs of Cracking in Concrete Pavement Construction

Defect	Orientation	Location[a]	Description	Recommended Repair	Alternate Repair
Plastic Shrinkage	Any	Anywhere	Only partially penetrates depth	Do nothing	Fill with HMWM[b]
Uncontrolled Crack	Transverse	Mid-panel (Mid-slab)	Full-depth	Saw & seal crack	LTR[c]
Uncontrolled Crack	Transverse	Crosses or ends at transverse joint	Full-depth	Saw & seal the crack; Epoxy uncracked joint	
Uncontrolled Crack	Transverse	Relatively parallel & within 4.5 ft of joint	Full-depth	Saw & seal the crack; Seal joint	FDR[d] to replace crack and joint
Saw cut or Uncontrolled Crack	Transverse	Anywhere	Spalled	Repair spall by PDR[e] if crack not removed	
Uncontrolled Crack	Longitudinal	Relatively parallel & within 1 ft. of joint; May cross or end at longitudinal joint	Full-depth	Saw & seal the crack; Epoxy uncracked joint	Cross-stitch[f] or Slot-stitch crack
Uncontrolled Crack	Longitudinal	Relatively parallel & in wheel path (1-4.5 ft from joint)	Full-depth, hairline or spalled	Remove & replace panel (slab)	Cross-stitch[f] or Slot-stitch crack
Uncontrolled Crack	Longitudinal	Relatively parallel & further than 4.5 ft from a long. joint or edge	Full-depth	Cross-stitch[f] or Slot-stitch crack; Seal long. joint	
Saw cut or Uncontrolled Crack	Longitudinal	Anywhere	Spalled	Repair spall by PDRe if crack not removed	
Uncontrolled Crack	Diagonal	Anywhere	Full-depth	FDR[d]	
Uncontrolled Crack	Multiple per panel (slab)	Anywhere	Two cracks dividing panel (slab) into 3 or more pieces	Remove & replace panel (slab)	

[a] 1 ft = 0.3048 m

[b] HMWM = High molecular weight methacrylate poured over surface and into cracks. Surface is sprinkled with sand for skid resistance.

[c] LTR = load-transfer restoration; 3 dowel bars per wheel path grouted into slots sawed across the crack; Slots must be parallel to each other and the longitudinal joint. Backfill with non-shrink, cement-based mortar (see reference 3).

[d] FDR = full-depth repair; 10 ft long by one lane wide. Extend to nearest transverse contraction joint if 10-ft repair would leave a segment of pavement less than 10 ft long (see ACPA publication TB002P).

[e] PDR = partial-depth repair; Saw around spall leaving 2 in. between spall and 2-in. deep perimeter saw cuts. Chip concrete free, then clean and apply bondbreaker to patch area. Place a separating medium along any abutting joint or crack. Fill area with patching mixture. (see ACPA publication TB003P)

[f] Cross-stitching; for longitudinal cracks only, drill holes at angle, alternating from each side of joint on 24-36 in. spacing. Epoxy deformed steel tiebars into holes.

[g] Slot-stitching; for longitudinal cracks only. Deformed bars grouted into slots sawed across the crack; Backfill with non-shrink, cement-based mortar.

concrete and undergo thermal expansive and contraction movements (opening and closing). Cross-stitching prevents opening or closing of joints and cracks. If joint movement is restrained, stresses can build within the slab and result in spalling and cracking near the ends of the bars. These effects have been observed on highway applications where stitching was tried on transverse working cracks.

Should I Move Drifted Slabs Together Before Stitching?

Do not attempt to move drifted slabs back into position against adjacent slabs. First, there is usually no real concern or maintenance expense if slabs drift apart. Therefore moving the slabs may be a waste of resources. Second, the mechanical energy required to push the slabs would make this impractical in most cases.

How Do I Connect Drifted Slabs?

Of primary concern in connecting slabs that have drifted apart is preventing the backfill (either epoxy or grout) from flowing into the space between slabs. To prevent this, clean and fill the space between the slabs before stitching. A sand-cement grout is a suitable backfill for this purpose. However, due to concern over FOD (Foreign Object Damage) we would not recommend this at airport facilities.

Can I Use Cross-Stitching to Tie New Lanes?

Do not use cross-stitching to tie a new lane to an existing lane. Wherever possible, it is advantageous to drill laterally into the side of an existing lane and then epoxy tiebars into the holes, rather than to use a diagonal configuration as in cross-stitching.

Is Slot Stitching Better Suited for Multi-Lane Cross-Sections?

There is no evidence that either stitching alternate is better when applied within a multi-lane cross- section. By theory slot stitching may be better suited than cross-stitching for a crack in a panel tied to three or more lanes, because it has a longer length of embedded steel to distribute tensile stresses. However, there are no field experiences to substantiate this theoretical advantage and cross-stitching has performed well on multi-lane cross sections.

What are the Backfill Material Requirements for Slot Stitching?

Backfill materials for slot stitching should have little or no shrinkage, should gain sufficient strength in the period before loading, and should have a Coefficient of Thermal Expansion similar to the surrounding concrete. General requirements for rapid set materials for use in slot-stitching are found in ACPA publication JP001P "Guidelines for Load Transfer Restoration."

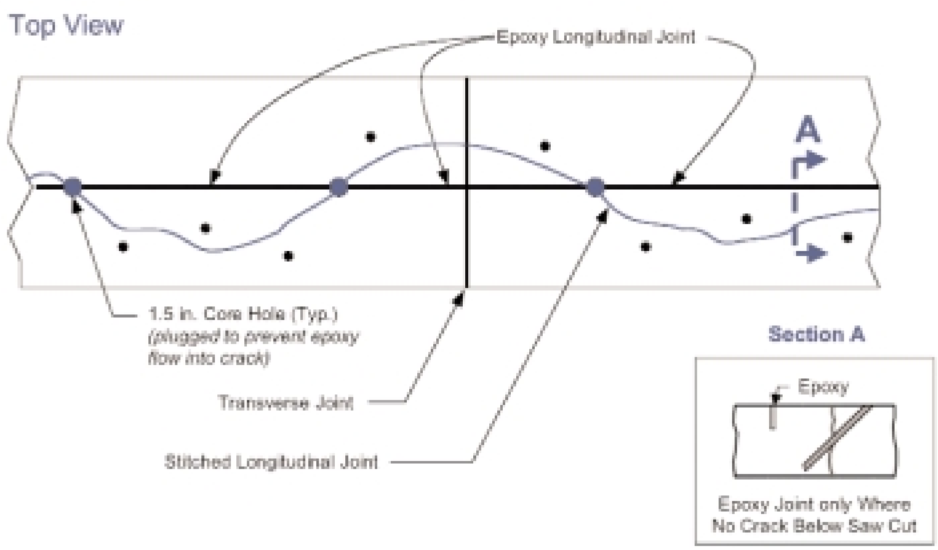
How Do I Treat the Joint Adjacent to a Stitched Crack?

After stitching a longitudinal crack, it may be necessary to treat a nearby longitudinal joint. The primary concern is whether a crack has formed below the saw cut for the longitudinal joint. If a crack has occurred and the joint functions properly, then no treatment other than joint sealing is warranted. However, if there is no crack extending below the joint cut, then it is advantageous to fill the saw cut with epoxy to strengthen the slab at this location (see figure). If the joint is not functioning, but a joint sealant has already been installed, then no further action is recommended.

A careful review of the joint is necessary to render a decision on whether epoxy treatment is necessary. Several cores should be taken along the joint to determine the prevailing condition (cracked or un-cracked). If the joint warrants epoxy filling, then the following process obtains best results:

- Clean the saw cut with water. Allow reservoir to dry.

Details for Epoxying Joint Reservoir Near Stitched Crack



- Drill plug holes at any location where the crack crosses the non-functioning joint to a depth below the saw cut.
- Place compression plugs or cement grout plugs into plug holes.
- Pour epoxy into saw cut using properly sized nozzle. (Do not overfill.)

References –

1. Burns, C.D., R.L. Hutchinson, "Multiple-Wheeled Heavy Gear Load Pavement Tests, Design, Construction, & Behavior Under Traffic," (WES-TR-5-71-17, Waterways Experiment Station, Vicksburg, MS, Nov. 1971.

2. Investigation of Pavement Cracking Utah I-70, Project ID-70-1(31)7 Clear Creek to Belknap, American Concrete Pavement Association, Arlington Heights, IL, 1985.

3. Guide for Load Transfer Restoration, JP001P, American Concrete Pavement Association, Skokie, IL, 1998.

4. Voigt, G.F., "Specification Synthesis and Recommendations for Repairing Uncontrolled Cracks that Occur During Concrete Pavement Construction," Volume 2, Proceedings, Sixth International Purdue Conference on Concrete Pavement Design and Materials for High Performance, Indianapolis, IN, 1997, pp.13-28.

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