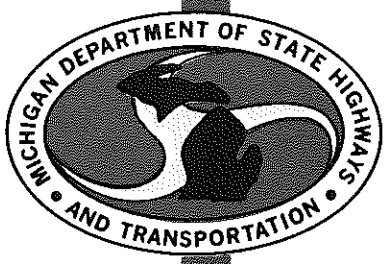
INVESTIGATION OF PARKING RAMP LEAKAGE THROUGH THE UPPER LEVEL SLAB AT THE CAPITOL COMPLEX



TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

INVESTIGATION OF PARKING RAMP LEAKAGE THROUGH THE UPPER LEVEL SLAB AT THE CAPITOL COMPLEX

H. L. Patterson

Research Laboratory Section
Testing and Research Division
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Michigan State Highway Commission
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A cursory inspection of the top and bottom surfaces of the Capitol Complex upper parking level floor revealed concrete deterioration to a varying degree that appeared to be typical of the entire vast area. This inspection was requested by Sue Anderson of the Department of Management and Budget and approved by K. A. Allemeier's memo of January 11, 1978. Several spot checks established that corrosion of the top reinforcing bars in the slab, in combination with very shallow concrete cover, had produced prominent delaminations in the concrete slab at apparently every location where vehicles are parked as well as various other ramp and corridor locations. The degree of the damage ranged from delaminations that were small and obscure to those that were fully spalled with distressed concrete extending full-depth through the slab. Extensive full-depth cracking has resulted in leakage of water and de-icing salts onto the lower level as well as adding to the spalling problem.

The severest afflicted areas of the slab ought to be repaired as soon as possible, but the complete restoration of the entire slab to its original integrity would probably be financially prohibitive, at least to do it all at one time. However, if the surface were sealed against further moisture intrusion the rate of deterioration of the less damaged areas could probably be attenuated.

It is recommended that the following procedure be considered in effecting the restoration of this upper level slab.

The entire area should be surveyed to assess and record the severity of the deterioration. This could best be done with a chain drag (Fig. 1) to locate the delaminations and then a visual inspection to categorize them. These proposed categories are illustrated in Figure 2 and can be described as follows:

Case I - Any delamination that is free of perimeter cracking and/or incipient spalling.

Case II - Any delamination that has developed perimeter cracking and/or incipient spalling totaling less than 1 sq ft in combined area.

Case III - Any delamination that has over 1 sq ft of total spalled area.

Also to be noted and recorded are all expansion joints and cracks in the concrete that have allowed leakage through the slab. This full-depth leakage is indicated by white salt and lime residues on the underside of the slab.

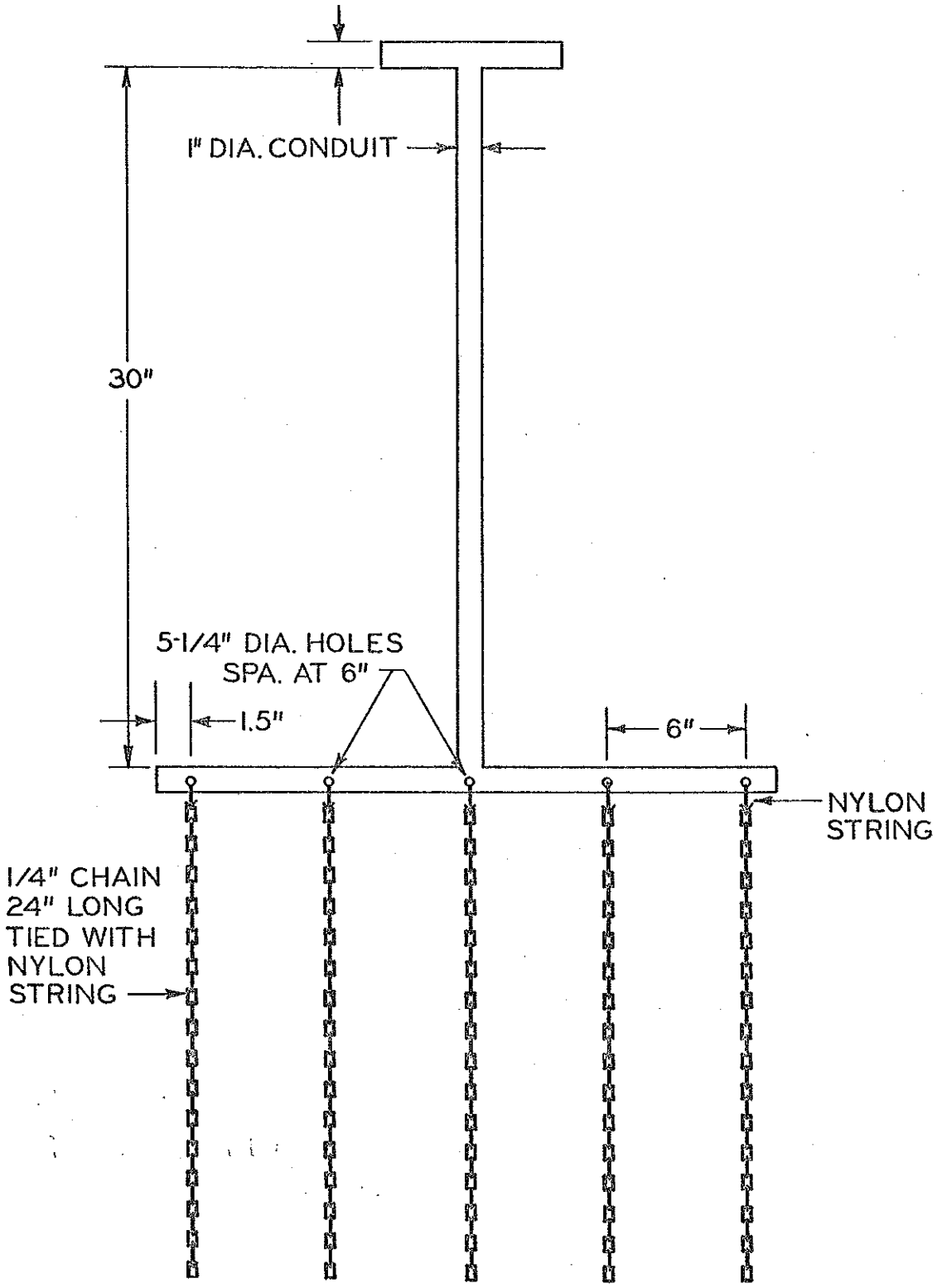

Figure 1. Chain drag used to detect delaminated areas.

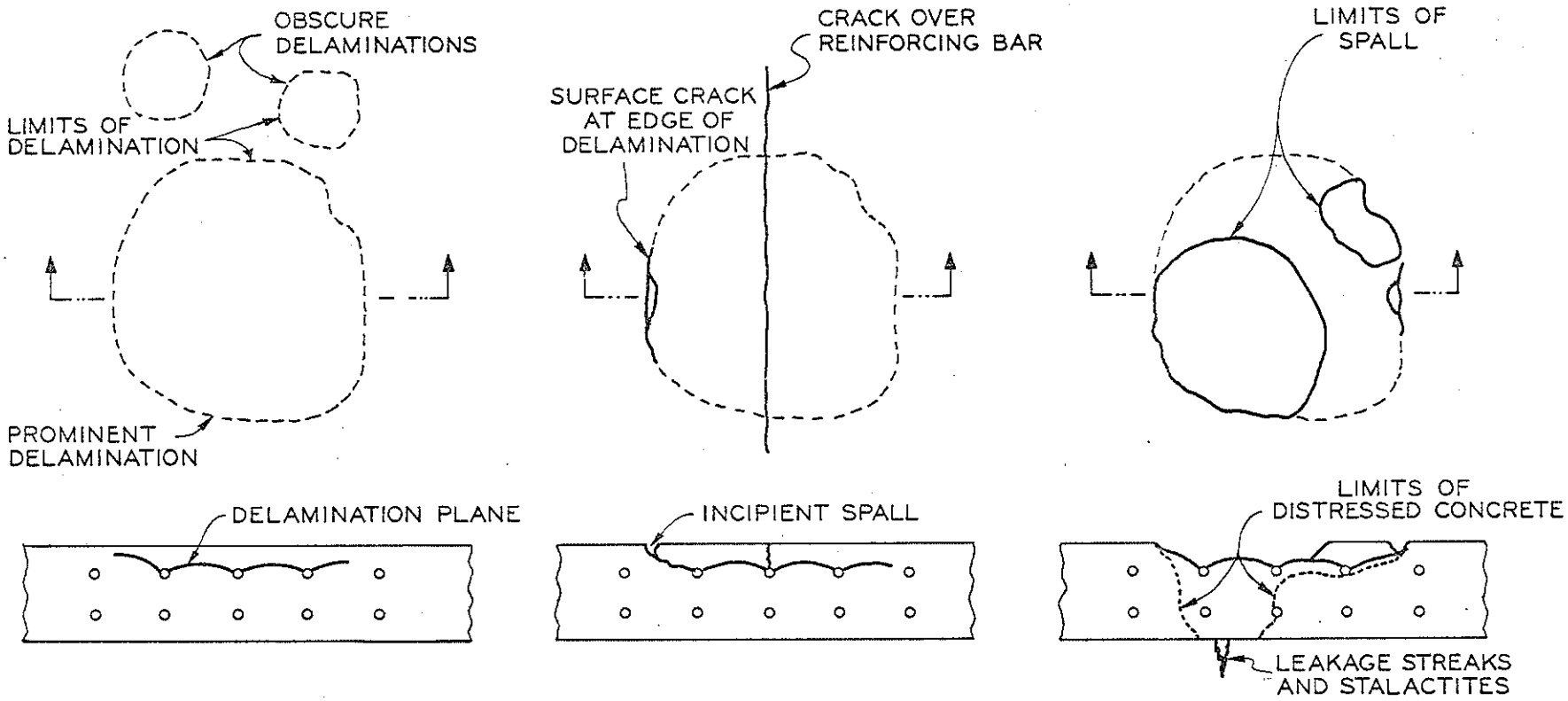

Figure 2. Categories of deterioration in concrete slab.

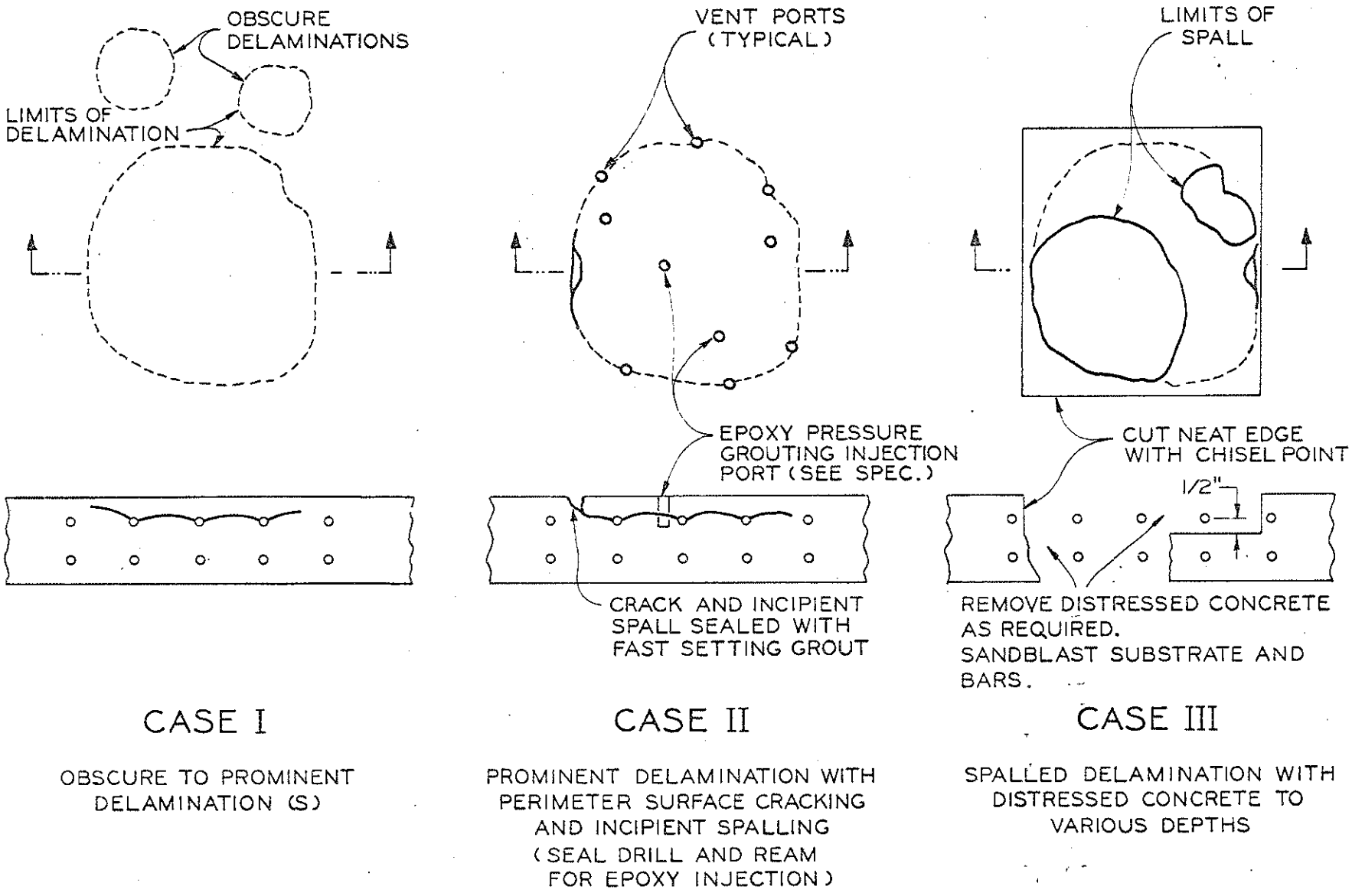

Figure 3. Preparation procedure for repair work.

The work involved in all three cases should be performed in the designated contract area with all Case III and Case II locations completed first along with the repair of expansion joints and the sealing of all full-depth flexure cracks. The general cleaning and sealing work for Case I delaminations will then be performed over the entire area. All three cases are illustrated in Figure 3 and are described below in the order they should be performed, except that Cases III and II can be performed simultaneously as long as they are not mutually interfering.

Case III - A rectangular area should be drawn that encompasses the entire spalled delamination if it is isolated, or groups of spalled delaminations if they are immediately adjacent. The perimeter lines paralleling the top reinforcing bars should be located such that they run between adjacent bars; a pachometer is used to locate the bars. The concrete within this rectangular area should then be removed with air hammers to the bottom of the top reinforcing bars or to the full-depth of the distressed or 'punky' concrete. The perimeter cuts need not be sawed if they are neatly cut with an air-hammer chisel point after the interior concrete within 3 in. of the line has been removed. Care will be taken to not damage the top or bottom bars. The chipped-out area is then sandblasted to clean all the exposed reinforcing bars and to remove any incipiently fractured concrete chips. The patching concrete with which these areas are to be repaired contains 8 sacks of cement/cu yd, a crushed gravel coarse aggregate with 95 to 100 percent passing a 1/2-in. sieve and 0 to 12 percent passing a No. 4 sieve, a concentrated vinsol resin type air entraining agent, and a commercial shrinkage compensating metallic admixture such as Embeco, Vibrofoil, or equal. The field worksheet, as shown in Figure 4, is used to correctly proportion a 2 cu ft concrete patching mix. The component weights are shown on the first line with typical moisture absorption values for both fine and coarse aggregates; these absorption values, though not exact for aggregates from every pit, will give a reasonably accurate moisture adjustment for any washed (2NS) sand and washed (26A) crushed gravel. The bottom line shows an example of the aggregate moisture adjustment calculation using hypothetical measured values.

The concrete should be mixed at the job site in either 2 or 4 cu ft batches in an engineer-approved rotary drum mixer. The moisture content of the aggregate is to be measured and the aggregate and mix water weights adjusted according to the procedure on the worksheet. The components for the mix are to be initially weighed in galvanized steel containers that are then marked for subsequent volume measurements. The final mix weights should be checked by the engineer or inspector before proceeding further. The mixed concrete will have a slump between 1 and 3 in. and an air en-

PATCHING CONCRETE FIELD WORKSHEET
(Components for two cubic feet.)

Date	Time	Fine Aggregate (2NS)							Admixtures		
		A	B		C		D	E	TYPE I		
		Oven Dry Weight, lb	Required Absorption Water		Actual Moisture Content		B - C Moisture Adjustment (±)	A + C Wet Weight, lb	Cement, lb	Vinsol Resin Type Air Entrainer, ml	NON-SHRINK METALLIC AGG., LB
			Percent	Weight, lb	Percent	Weight, lb					
		83	1.00	0.83					56	18	22
EXAMPLE		83	1.00	0.83	3.71	3.08	-2.25	86.08	56	18	22

Coarse Aggregate (26A)							Water				Priming Slurry	
F	G		H		J	K	L	D	J	M		
Oven Dry Weight, lb	Required Absorption Water		Actual Moisture Content		G - H Moisture Adjustment (±)	F + H Wet Weight, lb	Required Mix Water, lb	Fine Agg. Moisture Adjustment (±)	Coarse Agg. Moisture Adjustment (±)	L + D + J Total Water Required, lb	Cement, lb	Water, lb
	Percent	Weight, lb	Percent	Weight, lb								
113	0.65	0.73					21				11.3	4.7
113	0.65	0.73	0.47	0.53	+0.20	113.53	21	-2.25	+0.20	+18.95		

Figure 4. Field worksheet showing component weights and typical moisture values on the first line, and an example on the bottom line using hypothetical measured values.

trainment level between 5 and 8 percent. Prior to placing the concrete, the substrate of the patch area should be spray moistened with water such that the entire surface is wetted but no puddles formed. The priming cement slurry is then broomed into the substrate, the concrete placed, and consolidated with a probe vibrator. The surface can then be trowelled to a finish compatible with the surrounding concrete and cured with a white membrane curing compound applied at the rate of 200 sq ft/gal.

Case II - The delaminations falling into this category should be repaired by epoxy injection grouting. This repair work should not be started unless the temperature is 60 F or higher and the concrete has been continuously dry for 72 hours. The following procedure should be followed by a contractor who is familiar with, and experienced in this type of work.

The limits of the delamination are sounded by tapping with a hammer and marked with a felt pen or other semi-permanent marker. The top mat of reinforcing bars running in both directions are then located with a pachometer and their positions marked across the entire surface within the limits of the delamination. As illustrated in Figure 3, an injection port is then located between each of the top bars at the 'hollowest' sounding part of the delamination. As shown in the figure, two vent ports are drilled for each injection port; each one located at opposite limits of the delamination between the same two top bars as the injection port. The ports should be constructed, and epoxy pumped, in accordance with the MDSHT Supplemental Specification in the Appendix. Only a contractor familiar with, and experienced in this type of work should be considered eligible.

Case I - The expense of repairing the multitude of delaminations in this category will be avoided if possible; hopefully, sealing the concrete against further moisture intrusion (see below) will arrest the growth and development of these delaminations and hold them in a static condition.

Full-Depth Flexure Cracks - As illustrated in Figure 5, these cracks are to be routed-out their full length with a concentrated sandblast and, following the general application of the polyurethane sealant (which serves as a primer), will be filled with a two-component polyurethane joint sealant. The flexible nature of this material will allow it to maintain a seal on even a moving crack.

Expansion Joints - As illustrated in Figure 5, leaking and spalled expansion joints should be repaired by removal of the old defective joint, sandblast cleaning the entire area including all spalled areas, and repairing as shown in the figure. The repair of the spalled areas should be accomplished with the procedure described in the 1976 MDSHT Standard Speci-

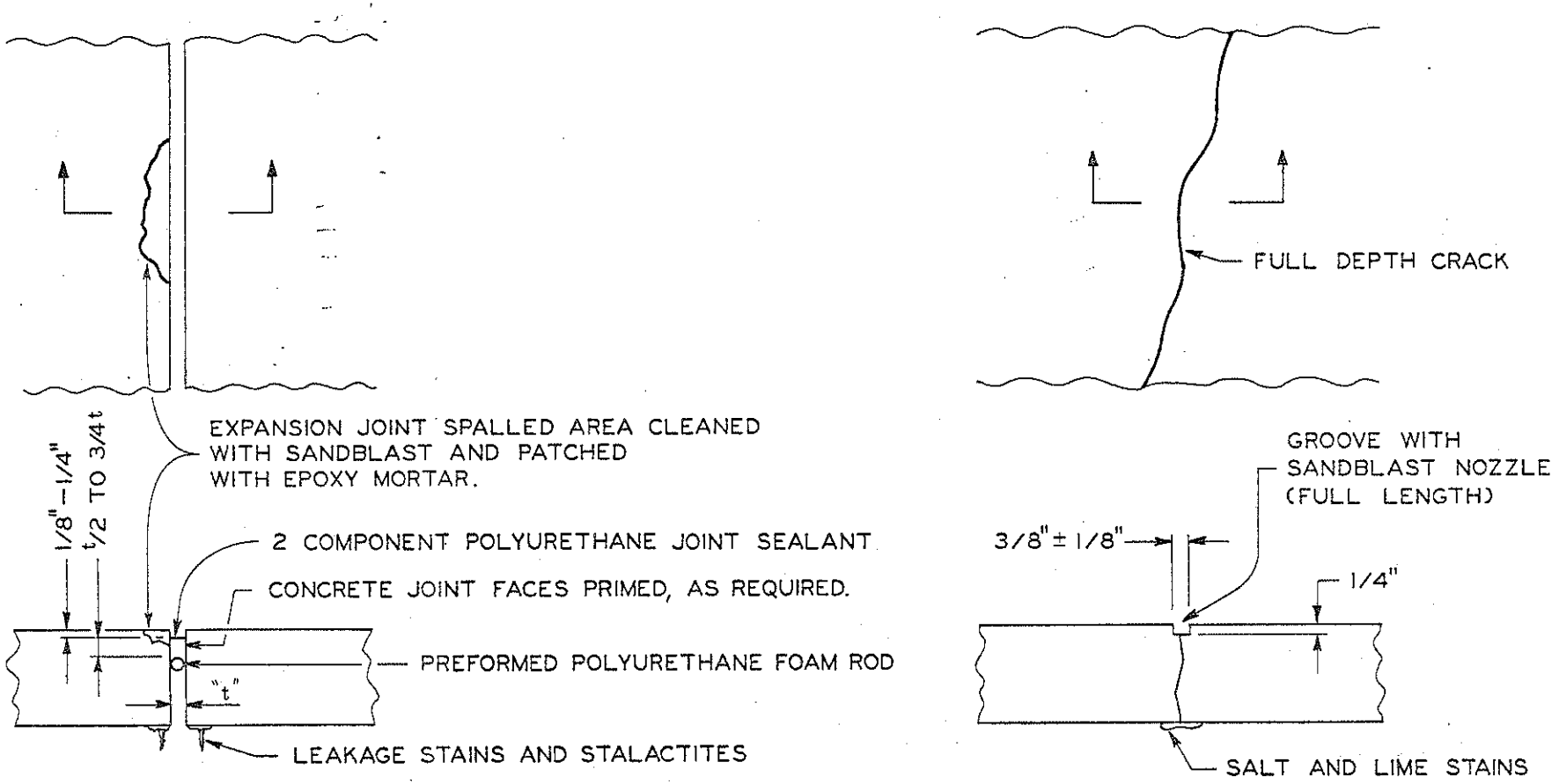

Figure 5. Crack and joint repair.

fications Section 4.50.20 using the materials described in Section 8.16.05 for a Type I epoxy binder (see Appendix). After the general concrete area has been sealed, as described below, the joint is resealed using the materials and procedures shown in Figure 5.

General Sealing of Concrete - After the epoxy injection repair of Case II delaminations, the patching of Case III spalls, the sandblast grooving of full-depth flexure cracks, and the epoxy mortar repair of expansion joints, the entire area ought to be given a light sandblasting to remove all dirt, oil, and grease, and to expose a sound concrete surface. The entire surface should then be given a two-coat application of a two-component polyurethane sealant, diluted with the solvent xylene to affect better penetration. The first coat consists of two parts polyurethane to one part solvent by volume and applied at the rate of 250 sq ft/gal. The second coat is diluted 4 to 1 by volume and applied at 400 sq ft/gal. The solvent shall not be added to the two mixed components of polyurethane until five minutes after the time they are stirred together. All mixing should be done with a slow speed (375 rpm) power drill using a double bladed 'Jiffy' type paint stirrer or equal. No more polyurethane should be mixed than can be applied to the concrete in 30 minutes. At least 18 hours ought to be allowed between successive applications and no applications made unless the concrete and air temperatures are over 55 F. Long handled 9-in. paint rollers are preferred, but sprayers can be used. If a sprayer is used, however, 25 percent more material will be used to compensate for losses into the air. Good ventilation should be present when the material is applied, but direct air blowing on the concrete should be avoided. No smoking or use of spark producing engines should be allowed in the coating area since the solvents used are highly flammable. In areas where increased traction is required, 1.0 to 1.25 lb of masonry sand shall be broadcast per sq yd while the polyurethane of the second coat is still 'wet.' A hand cranked rotary seeder effectively broadcasts the sand. The polyurethane sealant should conform to the following physical properties.

	Part A	Part B	Mix 1:1 by Volume
Specific Gravity	1.12	0.94	
Viscosity, cps	220	40	(Brookfield #2 at 20 rpm)

The combination of parts A and B should contain 60 percent solids by weight.

The polyurethane is available in 2-gal kits and 55-gal drums. Several companies are capable of supplying this material; one of them is the Harry S. Peterson Company at 4150 S. Lapeer Rd in Pontiac, Michigan, 48057.

Although we do not have labor, equipment, and material costs available for each of the repair procedures recommended in this report, we do have some costs that might be useful. They are as follows:

Epoxy Injecting Grouting (includes labor, equipment, and materials)	$90.00 per sq yd
Polyurethane Sealant	12.00 per gal
xylene thinner (55-gal drums)	1.15 per gal
Combination (material cost only)	
2:1 applied at 250 sq ft/gal	8.38 per gal or 0.30 per sq yd
4:1 applied at 400 sq ft/gal	9.83 per gal or 0.22 per sq yd
Polyurethane Joint Filler (material cost only)	20.00 per gal

To accomplish the badly needed and recommended repairs it would be most logical to do them on a priority basis and divide the parking ramp into particular work areas each year.

APPENDIX

MDSHT SPECIAL PROVISION FOR REPAIR OF BRIDGE DECK DELAMINATIONS AND PERTINENT EXCERPTS FROM MDSHT STANDARD SPECIFICATIONS

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

SPECIAL PROVISION
FOR
REPAIR OF BRIDGE DECK DELAMINATIONS

a. Description.-This work shall consist of furnishing all labor, equipment, and materials required for the drilling of injection and vent ports and injecting an epoxy grout into delamination planes in bridge decks.

The Engineer will locate the delamination planes, reinforcing bars, and injection and vent ports.

b. Materials:

1. Sealing Material.-The sealing material for forming a temporary seal around injection ports and for sealing spalls and blemishes on the bridge deck shall be any fast-setting material which will effectively seal the injection epoxy up to a pressure of 100 psi within 4 hours after application at temperatures of 60 F.
2. Injection Epoxy.-This material shall be a two-component epoxy resin, containing no solvents or fillers, for pumping into the bridge deck delamination planes. The mixed epoxy shall conform to the following physical requirements when combined at the proper volumetric ratio. Tests on cured epoxy shall run after curing for 24 hours at 75 $\pm$ 3 F.

Physical Properties	Test Values
Viscosity of Combined Epoxy, immediately following mixing, at 77 F, poises	
Brookfield No. 2 at 10 rpm	3-6
Gel Time, minutes (100 gm at 77 F)	15-30
Tensile Strength at Yield, psi at 77 F	4,000 min.
Tensile Elongation, percent	1-8
Ultimate Shear Bond Strength (dry), psi	500 min.
On Sawed Concrete at 77 F (wet), ssd	300 min.
Absorption, percent by weight, 24 hrs. in water	0.6 max.

c. Epoxy Injection Equipment.-The epoxy injection equipment shall independently pump each epoxy component in the correct proportions to the mixing head. The components shall be homogeneously combined in the mixing head immediately prior to entering the injection nozzle. The pump speed shall be variable to permit regulating the nozzle pressure accurately through pressures up to 100 psi.

d. Temperature and Weather Limitations.-The drilling of injection and vent ports shall not commence until 48 consecutive hours have elapsed

since a rain, until the forecast is for continued fair weather, and until the daily high air temperature is predicted to reach or exceed 65 F.

The injection of epoxy into delamination planes shall not commence until both the air and the concrete temperatures are at least 60 F and rising.

e. Constructing Injection and Vent Ports.-The Engineer will mark the limits of the delamination planes, the location of the reinforcing bars, and the location of injection and vent ports.

The Contractor, using a rotary impact drill, shall bore 3/8 inch injection and vent ports at the designated locations and to such depth as to intercept the delamination plane (usually something less than 2 inches). Only such holes as can be injected the same working day shall be drilled.

All drill dust shall be removed from the injection and vent ports with an approved vacuum cleaner.

Injection ports shall be reamed and vacuumed with a 7/16 or 1/2 inch hollow vacuum bit which is connected to a heavy-duty vacuum cleaner, removing all drill dust from the hole and leaving a clean entrance into the delamination plane.

f. Repairing Blemishes and Spalls.-To prevent the injection epoxy from escaping, the Contractor shall use the sealing material to repair all obvious blemishes and spalls adjacent to the delaminated area.

g. Injecting Epoxy.-After the sealing material has set sufficiently to contain the epoxy under pressures of 100 psi, the injection nozzle shall be placed in the port and the epoxy injected at a pressure of 50-100 psi. The nozzle shall be held in each port up to 4 minutes duration or until epoxy begins to flow from all the vent ports in that delamination plane. As epoxy appears and begins filling each vent, that vent shall be sealed and pumping continued. If epoxy begins a strong flow from a previously unnoticed blemish, pumping shall be discontinued. If there are two or more injection ports in one delamination and pumping at one for 4 minutes has produced no results, the injection gun shall be systematically moved to each of the other ports and then returned to the resistant ones. If pumping at one port causes epoxy to flow from another port, that port should be sealed and pumping continued.

h. Cleanup and Opening to Traffic.-Upon completion of the epoxy injection of all delamination planes on a given working day, all protruding sealant material shall be removed flush with the surface of the deck. The deck shall then be opened to traffic, unless otherwise directed by the Engineer and provided that a minimum of 2 hours has elapsed since the injection of the last delamination plane.

i. Method of Measurement:

Injection Ports will be measured as units.
Injection Epoxy will be measured by volume in gallons.

j. Basis of Payment.-The completed work as measured for REPAIR OF BRIDGE DECK DELAMINATIONS will be paid for at the contract unit prices for the following contract items (pay items).

Pay Item	Pay Unit
Injection Ports	Each
Injection Epoxy	Gallons

Payment for the item of injection ports includes furnishing all incidental material, labor, and equipment to construct injection and vent ports, to seal minor spalls and blemishes, and to pump epoxy into those ports.

Payment for the item of injection epoxy includes furnishing the injection epoxy and removal of excess sealant material from the deck at the end of each day's operation.

EXCERPTS FROM THE 1976 MDSHT
STANDARD SPECIFICATIONS

4.50.20 Patching Transverse Joints.-After the joints have been sawed and cleaned as specified, all joints shall be inspected for spalls and voids.

All loose, unsound, or damaged concrete shall be removed to the satisfaction of the Engineer.

Spalls and voids will be classified as minor, intermediate, or major spalls and shall be repaired accordingly.

a. Minor Spalls.-Any spalls or voids which have increased the specified size of the joint groove beyond any of the following limits but less than 36 square inches, shall be repaired by patching with an approved epoxy mortar before the seal is installed.

1. Spalls which extend more than 1/4 inch from the joint face and over 1/2 inch below the surface of the pavement.
2. Spalls which extend more than 1/4 inch from the joint face and 2 inches or more in length, regardless of the depth of spall below the surface of the pavement.
3. Void areas larger than 1/2 inch in diameter in the upper 1 inch of the joint face or larger than 1 inch diameter regardless of location.

The spalled concrete surface shall be thoroughly cleaned by sandblasting or power wire brushing. Hand wire brushing may be permitted by the Engineer for limited patching. The patch area shall then be blown clean with a jet of compressed air. A rigid polyethylene sheet, or other rigid material covered with polyethylene film, shall be inserted into the joint groove and held tightly against the joint face that is to be patched.

The concrete shall be clean and dry at the time of placing the epoxy mortar. ...

Type I epoxy binder shall be used for temperatures from 50 to 104 F. ...

The epoxy binder will ordinarily be a mixture of 2 parts epoxy resin to one part curing agent, by volume; however, the material containers should always be checked for any deviations from these proportions.

Unless the entire contents of the original containers are used in one batch, a mechanical volumetric dispensing device which dispenses each component within an accuracy of $\pm$ 2 percent by volume shall be used for proportioning. The dispenser shall meet the approval of the Engineer.

A clean metal or polyethylene vessel shall be used for mixing. The curing agent component shall be gradually added to the epoxy resin component with constant stirring. A low speed air or electrically driven stirrer shall be used for this purpose. The stirring shall be continued for a period of 2 to 3 minutes until a uniform mixture is obtained.

After the epoxy binder is thoroughly mixed, a small portion shall be reserved for priming. The dry 2MS sand shall be uniformly blended into

the balance of the mixture to give an epoxy mortar of stiff but trowellable consistency. (Approximately 3.5 parts of dry sand, by volume, to one part of mixed binder.)

The spalled surface shall be primed with the freshly mixed epoxy binder. This prime coat shall be scrubbed into the surface with a suitable brush to insure complete wetting and coverage of all areas to which the epoxy mortar must bond. Immediately after priming, the epoxy mortar shall be placed in the spalled area and finished to the shape of the original pavement surface. If the bond coat is not tacky when the mortar is placed, due to hot weather or delays, a second application shall be made. The edge of the patch shall conform with the rest of the joint groove. Dry 2MS sand shall be sprinkled onto the fresh epoxy mortar surface to eliminate any gloss. After the epoxy mortar has cured sufficiently so that it will not be damaged during sealing operations, the polyethylene insert shall be carefully removed. ...

8.16.05 Epoxy Binder for Joint Spall Repair.-The epoxy binder material to be mixed with dry 2MS masonry sand for the repair of spalls adjacent to longitudinal or transverse joint grooves shall consist of one of the following types. The type to be used shall depend on concrete temperature conditions at the time of patching.

Type I shall be used when the concrete temperature is within the range of 50-104 F.

~~Type II shall be used when the concrete temperature is within the range of 20-50 F.~~

Type I and Type II epoxy binders shall be formulated such that all components are of low viscosity and easily measured and mixed in the field. Both types shall be formulated to be mixed either at a 1 to 1 or a 2 to 1 ratio, by volume. The proper volumetric mix ratio shall be clearly indicated on both component containers. Both components of each type of epoxy binder shall be composed of 100 percent non-volatile materials containing no solvents and no pigments. All ingredients of the epoxy binder shall be reactive to become a permanent part of the cured adhesive system and must be able to tolerate small amounts of moisture which may be present in the concrete repair areas.

The epoxy binders shall have the following specific test value.

Part A, Epoxy Resin Base Polymer	Type I	Type II
Viscosity, poises at 77 F (Brookfield viscometer, No. 2 Spindle)	5-30	5-20
Part B, Modified Curing Agent		
Viscosity, poises at 77 F (Brookfield viscometer, No. 2 Spindle)	3-30	3-20

Mixture A and B

Gel Time, minutes (100 g initially at 77 F)	25-50	8-15
Tensile Strength at yield, psi at 77 F	3,000 min	2,500 min
Elongation, Ultimate, percent	12-30	15-35
Tensile Modulus of Elasticity, 10^6 psi at 77 F (initial tangent)	0.20-0.35	0.10-0.25
Absorption (24 hr in water at 77 F), percent by wt	1.0 max	1.0 max
Shear Bond Strength, psi (On sawed concrete at 77 F)	400 min	400 min
Cure Time for Test, hours at 77 F	96	24

Note: Viscosity tests are performed in accordance with ASTM D 1084, Method B. Tensile tests are performed at 0.2 inch per minute in accordance with ASTM D 638, Die C. Tensile, elongation, and absorption tests are performed on specimens cut from a cast sheet, 1/8 inch thick, of cured epoxy binder.

Containers shall be plainly marked as to Part, Type, Lot or Batch number, and volumetric proportioning ratio.

A sample of epoxy binder shall consist of one quart of each batch of each component represented in each shipment. Test samples must be received by the Testing and Research Division at least two weeks prior to intended use.

A batch of each component is defined as that quantity of material which has been subjected to the same unit chemical or physical mixing process intended to make the final product substantially uniform.