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These **Digests** are issued in the interest of providing an early awareness of the research results emanating from projects in the NCHRP. By making these results known as they are developed, it is hoped that the potential users of the research findings will be encouraged toward their early implementation in operating practices. Persons wanting to pursue the project subject matter in greater depth may do so through contact with the Cooperative Research Programs Staff, Transportation Research Board, 2101 Constitution Ave., N.W., Washington, D.C. 20418.

Responsible Staff Engineer: Crawford F. Jencks

Rapid Replacement of Portland Cement Concrete Pavement Segments

An NCHRP digest of the essential findings from the final report on NCHRP Project 10-24, "Rapid Replacement of Portland Cement Concrete Pavement Segments," by R.F. Carmichael III, A.H. Meyer, L.L. Caldwell, and B.F. McCullough, ARE, Inc., Austin, Texas.

INTRODUCTION

The objectives of this study were to identify, describe, and evaluate methods that have been, and are being, used for rapid replacement of full lane-width segments of both continuously reinforced and jointed portland cement concrete (PCC) pavements relative to costs, placement conditions, traffic characteristics, performance, and expected service lives. The research has accomplished these objectives and the results have been documented in the agency final report. Useful results were achieved and are reported in this Digest to provide adequate circulation of the outcome of the research. Persons having a deeper interest in the subject matter may obtain on a loan basis, or for purchase at a nominal cost, a copy of the agency's final report by writing to the NCHRP.

The specific research activities addressed in the agency report include the following:

- Background state-of-the-art elements of slab replacement techniques.
- Study design and repair performance.
- Interpretation of the findings and conclusions and recommendations in the areas of planning, design, construction, and performance.

Appendix items cover detailed discussion relative to:

- Potential study site locations.
- Literature review of rapid replacement techniques of PCC pavement segments.
- Data collection and site evaluation procedures.
- Site and repair information.
- Database contents.
- Repair placement analyses and criteria.

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THE PROBLEM AND ITS SOLUTION

States and local agencies are spending millions of dollars annually for the repair and replacement of worn-out portland cement concrete (PCC) pavements. Much of the money is being spent on improvement and repair projects requiring work to be completed at spot locations in less than 24 hours. Information on the relative effectiveness of the various rapid repair techniques to replace full depth, full lane-width segments of PCC pavement is needed.

NCHRP Project 10-24 identified, described, and evaluated methods that have been, and are being used, for rapid replacement of full lane-width segments of continuously reinforced (CRCP), jointed reinforced (JRCP), and jointed nonreinforced (JCP) concrete pavements. In CRCP, the steel reinforcement is continuous throughout the length of the pavement. No joints are used in CRCP except construction joints at the end of a placement. JRCP contains reinforcing steel in the form of deformed steel bars, deformed steel mats, or welded wire mats. JCP is a jointed concrete pavement in which no steel reinforcement is used. The joints in either JCP or JRCP may be doweled or undoweled and sawed or formed.

ARE, Inc., engineers in cooperation with state personnel established 32 sites in six states to evaluate repairs. The state of the art in rapid repair of PCC pavements and results of 52 months of repair performance evaluations on the 147 patches at these 31 sites are summarized below.

Rapid slab replacement techniques have become routine in some states. In other parts of the nation, only a few experimental installations have been placed. For example, in some of the largest metropolitan areas with extremely heavy traffic volumes, routine procedures for rapid permanent repairs of PCC pavements have not been developed.

Maintenance engineers in jurisdictions that are not currently performing rapid slab replacement work indicated that they could foresee a need to perform this type of work in the future. Engineers in some of the states that are currently performing rapid replacements indicated their dissatisfaction with some of the methods presently being used.

Cast-in-place repairs are the most common approach to the replacement of full depth, full lane-width segments. Since labor costs are generally the most expensive element of the repair cost, some savings are realized by the cast-in-place methods over precast options because of the reduced number of people required for construction. Equipment and hardware used for handling and placing the heavy precast slabs are not required for cast-in-place repairs. However, most cast-in-place repair materials demand longer lane closure times because of curing requirements. The application of traffic onto some repair materials, prior to their development of maximum strength, shortens the potential service life of the repair.

Not as much use of precast slabs for rapid repairs was found as hoped. Although they offer a potential of shorter lane closer times over many cast-in-place techniques, some agencies have discontinued their use because of reportedly high cost and complexities in construction. Higher cost is attributable to the requirement for larger construction crews and greater equipment requirements. Some agencies report difficulty in establishing full support beneath the slabs which, in time, start to rock and break under traffic loads.

It is apparent that the design and placement of long-lasting pavement repairs requires a basic understanding of the mechanics involved with pavement behavior and the development of distress in PCC pavements. Little is gained by approaching pavement repair with the philosophy of removing the "bad" and replacing it with "good." If the mechanism causing the distress is not also addressed through the repair procedure, the repair will surely fail by the same mechanism. Mistakes have also been made by not recognizing the fact that the pavement structure expands, contracts, and moves in response to traffic and environmental effects. One such instance is the replacement of a deteriorated joint with a patch in which either no new joint is provided or the newly formed joint is not in line with the existing joint in the adjacent pavement. A transverse crack will form in line with the existing joint, which may or may not be detrimental to the repair's service life.

The summary findings for planning, design, construction, and performance are a result of initial literature surveys and interviews with state and national agencies in 1982, initial site visits by the researchers in 1983, long-term repair performance monitoring from 1983 to 1987 (48 months), and final repair visits and reviews in 1987.

FINDINGS

Planning

Most agencies do not use formal procedures to determine the need for a repair. Predominantly, the decision to repair depends on the judgment of an engineer or experienced maintenance personnel. The limits of the repair are also usually established based only on a judgment decision. Some agencies have, however, set minimum and maximum repair lengths. The use of agency personnel or contracting for the work is a function of the size of the project.

Based on this study, the findings on repair planning are as follows: (1) A very difficult problem in any repair operation is selecting the extent of the area to be repaired. Numerous observations were made where the repair was performing well, but the adjacent area was performing poorly. The implication is that an inadequate amount of the existing slab is taken out for repair or that the entire existing pavement section is approaching the end of its usefulness. More formal measurement procedures should be used in selecting the extent of the area to be repaired. (2) Experience in the various states has indicated that the use of precast slabs is feasible, although one state has pointed out that the economics are questionable. Before a final decision can be made as to the use of precast slabs, the total cost, including both construction and user delay cost, should be estimated. (3) Experience in several of the states shows that the repair procedure can utilize an assembly line approach, thus expediting the operation and minimizing the cost both to the agency and to the user.

Design

Most agencies base the repair thickness on the existing pavement cross-section thickness or, in some cases, a thicker repair is designed. To aid the engineer in design of rapid repairs, the research on this project used mechanistic analysis to develop criteria concerning (1) the maximum length of the repair, and (2) the time to first saw cut. These analyses include such factors as existing base type, expected temperature drops during construction, and strength properties of the repair material.

Based on this study, the findings on repair design are: (1) If the slab placement lengths are too long (≥ 10 ft) without an interim joint, random transverse cracking occurs. (2) If the slab placement lengths are too short (≤ 4 ft) longitudinal cracking occurs. (3) Existing steel reinforcement and joint load transfer details should be matched.

The JRCP (jointed-reinforced concrete pavement) computer program developed at the University of Texas at Austin (see Ref. 1) was used to estimate the critical state of stress under a factorial of conditions for those factors influencing repair performance. These stress envelopes were compared against the expected strength gained at a particular time for the mean and two confidence levels.

Tables 1 and 2 show the effects of the different variables considered in the analysis on the maximum placement length. The two tables represent two different confidence levels that may be interpreted as reliability in a risk analysis. For example, a 95 percent reliability means that for a number of placements, there would be a 5 percent probability that a placement length shown in the table would experience intermediate cracking. A 99 percent reliability implies only a one percent probability of intermediate cracking. The subbase types represent the range of possible conditions that may be encountered in the field. The temperature change represents the difference between the maximum and minimum concrete temperature during the first 24 hours after placement. The cement types represent a range of materials that may be used. The more exotic cements have a faster strength gain during the critical first 24 hours. The morning and evening placement implies concrete placed before and after 12 noon, respectively.

A review of Tables 1 and 2 indicates that for the following conditions, shorter slab lengths are required: (1) higher reliability against midslab cracking, (2) afternoon placements, (3) greater daily temperature changes, and (4) rougher subbase layer texture (i.e., more friction).

Another consideration for reducing the stress that increases with time, and thus preventing random cracking, is to develop criteria for the optimum time in sawing the joints of slabs. Using the computer program discussed previously, a stress-time history for the various parameters previously examined was performed. In simple terms, if the stress envelope is above the strength envelope developed by the repair, a crack has occurred. Thus, sawing should be performed prior to the time the stress envelope exceeds the strength envelope. Tables 3 and 4 present the maximum allowable time before sawing is required for a 95 percent reliability and a 99 percent reliability, respectively. Thus, for a given set of conditions, the designer may establish the maximum allowable time before sawing is required. The NS in the tables refers to applying the normal specification requirement of the agency, because cracking within the first 4 to 18 hours is not a problem. The term NF implies that the combination is not feasible because the stress buildup in the early hours is such that it exceeds the strength, thus random cracking will occur. The general observations in this case are very similar to those discussed in connection with Tables 1 and 2.

Following are the sequential steps that may be used by the designer to select maximum slab lengths and maximum time of sawing to prevent midslab cracking from occurring. The designer must first establish the environmental conditions and constraints, and follow the procedure step by step.

1. The first step is to establish a desired reliability and, since tables have been provided for the 95 percent and 99 percent reliability levels, one of these must be selected.

2. The daily concrete temperature during the first day of construction must be estimated. In the absence of concrete temperature data, it is suggested that the U.S. Weather Bureau air temperature data be used to simulate the slab temperatures. It should be kept in mind that the daily temperature change will vary significantly during the year. Therefore, the designer must anticipate what season of the year the slab replacements will be made. The daily temperature changes will vary significantly with the season of the year.

3. The next step is to select the representative subbase type.

Table 1. Maximum placement lengths for repair areas (feet) (95% reliability level)

Subbase Type	Time of Placement	15° Temp Change				25° Temp Change				35° Temp Change			
		Type I Normal Cement	Type III Cement	Exotic Cement		Type I Normal Cement	Type III Cement	Exotic Cement		Type I Normal Cement	Type III Cement	Exotic Cement	
				A	B			A	B			A	B
Rough Texture (Stabilized)	(Evening)	10	12	120	37	7	8	120	21	7	8	120	15
	(Morning)	18	47	120	76	15	29	51	39	13	22	35	28
Average Texture (AC)	(Evening)	24	38	120	114	19	30	120	69	15	24	120	52
	(Morning)	68	120	120	120	51	103	120	120	43	85	120	115
Smooth Texture (VISQUEEN)	(Evening)	36	50	120	120	22	35	120	70	19	30	120	58
	(Morning)	73	120	120	120	63	120	120	120	57	120	120	120

Exotic Cement A = HYDRASET Calcium Chloride Accelerator with Type I cement
Exotic Cement B = ACCELGARD Calcium Chloride Accelerator with Type I cement

Table 2. Maximum placement lengths for repair areas (feet) (99% reliability level)

Subbase Type	Time of Placement	15° Temp Change				25° Temp Change				35° Temp Change			
		Type I Normal Cement	Type III Cement	Exotic Cement		Type I Normal Cement	Type III Cement	Exotic Cement		Type I Normal Cement	Type III Cement	Exotic Cement	
				A	B			A	B			A	B
Rough Texture (Stabilized)	(Evening)	8	10	120	28	6	8	120	17	5	8	60	13
	(Morning)	16	38	80	55	14	24	40	32	13	19	29	24
Average Texture (AC)	(Evening)	17	33	120	102	14	25	120	58	13	20	120	18
	(Morning)	60	120	120	120	46	90	120	115	39	72	117	96
Smooth Texture (VISQUEEN)	(Evening)	32	44	120	102	19	29	120	60	15	24	120	50
	(Morning)	63	120	120	120	52	120	120	120	49	120	120	120

Exotic Cement A = HYDRASET Calcium Chloride Accelerator with Type I cement
Exotic Cement B = ACCELGARD Calcium Chloride Accelerator with Type I cement

Table 3. Maximum allowable time before sawing is required (hours) (95% confidence level)

Subbase Type	Slab Length	15° Temp Change				25° Temp Change				35° Temp Change			
		Type I Normal Cement	Type III Cement	Exotic Cement		Type I Normal Cement	Type III Cement	Exotic Cement		Type I Normal Cement	Type III Cement	Exotic Cement	
				A	B			A	B			A	B
Rough Texture (Stabilized)	15'	NF	4	NS	NS	NS	4	NS	4	NF	4	NS	4
	30'	NF	4	NS	NS	NF	NF	NS	4	NF	NF	NS	NF
	60'	NF	NF	NS	5	NF	NF	5.5	NF	NF	NF	4.5	NF
	120'	NF	NF	6	4	NF	NF	5	NF	NF	NF	4.5	NF
Average Texture (AC)	15'	NF	NS	NS	NS	NF	NF	NS	NS	NF	NF	NS	NS
	30'	NF	NS	NS	NS	NF	NF	NS	NS	NF	NF	NS	NS
	60'	NF	NF	NS	NS	NF	NF	NS	4	NF	NF	NS	4
	120'	NF	NF	NS	NS	NF	NF	NS	NF	NF	NF	NS	NF
Smooth Texture (VISQUEEN)	15'	NS	NS	NS	NS	4	NS	NS	NS	4	4	NS	NS
	30'	NS	NS	NS	NS	NF	4	NS	NS	NF	NF	NS	NS
	60'	NF	4	NS	NS	NF	NF	NS	4	NF	NF	NS	4
	120'	NF	NF	NS	4	NF	NF	NS	NF	NF	NF	NS	NF

Exotic Cement A = HYDRASET Calcium Chloride Accelerator with Type I Cement
Exotic Cement B = ACCELGARD Calcium Chloride Accelerator with Type I Cement
NS = Normal Specification requirements
NF = Not Feasible

Table 4. Maximum allowable time before sawing is required (hours) (99% confidence level)

Subbase Type	Slab Length	15° Temp Change				25° Temp Change				35° Temp Change			
		Type I Normal Cement	Type III Cement	Exotic Cement		Type I Normal Cement	Type III Cement	Exotic Cement		Type I Normal Cement	Type III Cement	Exotic Cement	
				A	B			A	B			A	B
Rough Texture (Stabilized)	15'	NF	4	NS	NS	NF	4	NS	4	NF	4	NS	4
	30'	NF	4	NS	4	NF	NF	NS	NF	NF	NF	7.5	NF
	60'	NF	NF	11	NF	NF	NF	5	NF	NF	NF	4	NF
	120'	NF	NF	6	NF	NF	NF	4	NF	NF	NF	3.5	NF
Average Texture (AC)	15'	NF	NS	NS	NS	NF	NS	NS	NS	NF	4	NS	NS
	30'	NF	4	NS	NS	NF	NF	NS	NS	NF	NF	NS	NS
	60'	NF	NF	NS	NS	NF	NF	NS	NF	NF	NF	NS	NF
	120'	NF	NF	NS	4	NF	NF	NS	NF	NF	NF	5	NF
Smooth Texture (VISQUEEN)	15'	NS	NS	NS	NS	4	NS	NS	NS	4	4	NS	NS
	30'	NS	NS	NS	NS	NF	4	NS	NS	NF	NF	NS	NS
	60'	NF	4	NS	NS	NF	NF	NS	4	NF	NF	NS	NF
	120'	NF	NF	NS	4	NF	NF	NS	NF	NF	NF	NS	NF

Exotic Cement A = HYDRASET Calcium Chloride Accelerator with Type I Cement
Exotic Cement B = ACCELGARD Calcium Chloride Accelerator with Type I Cement
NS = Normal Specification requirements
NF = Not Feasible

a. A rough interface would be a cement or asphalt-treated base that has not been rolled to a smooth plane. An aggregate base with large aggregates in the surface would also be in this category.

b. A medium friction condition would be a smooth stabilized base where the surface has been rolled very smooth, and there is little macrotexture in the surface.

c. A smooth surface would be the use of a Visqueen or polyethylene at the interface. *As a word of caution, the application of a Visqueen on top of a very rough surface does not necessarily move it into the smooth category.*

4. The next decision is to select the time of day the concrete is to be placed. The day has been divided basically into two periods: placement before noon (morning) and placement after noon (afternoon). As may be seen, the maximum allowable spacing differs considerably between these two limits.

5. From the appropriate cell in the factorials of Tables 1 and 2, the designer may select the maximum placement length for the prescribed conditions in order to prevent mid-span cracking. The tables may be used in two ways: (a) using a prescribed length, the designer may select the appropriate cement type to ensure that this length will be satisfactory, or (b) if the designer plans to use a specific cement type, he may establish the maximum permissible placement length.

6. After selecting the proper slab length, the designer can use Tables 3 and 4 to select the maximum allowable time to sawing. Again, for the appropriate cell, the designer selects a time wherein all sawing of the transverse joints must be made. If the sawing occurs after that time period, it is quite possible that stresses may have built up to a point that random cracking has occurred.

Construction

Construction practices vary widely, but several important findings are apparent. Traffic control for this type of construction is very important because the roadway usually is still serving traffic. The old pavement is typically removed by saw cutting and breaking out by pieces. Most states require that all loose base material be removed and replaced with new base material or the repair material.

Portland cement concrete with calcium chloride as an accelerator is the most widely used repair material for achieving the fast strength requirements for rapid completion of the job. Other types of repair material, such as rapid hardening cements and polymers, require special handling and cost more and, thus, are not typically used for large repairs. Curing time ranges from 4 to 8 hours, with some agencies allowing up to 24 hours. Flexural strength in the range of 300 psi to 350 psi is used by some agencies to determine when traffic will be allowed on the repair. The number of repairs possible to place per day was found to be a function of the construction process and the size of the repairs. As few as 5 to 7 or as many as 70 to 100 repairs can be placed per day. Accurate cost information on the repair process is generally difficult to obtain. Detail costing of the different phases of the repair process (traffic control, old pavement removal, repair placement) is generally not available.

Based on this study, the construction findings are: (1) To prevent separation, adjacent lanes should be tied together along the longitudinal joint. (2) As pavement is removed, care should be exercised to replace existing joints, because if not done, stress build-up may be excessive and results in transverse cracking. (3) When the continuity of existing steel will not be maintained, the best removal method for preventing damage to the surrounding pavement is to saw the repair limits full-depth and, then, lift out the pieces to be removed. (4) A higher reliability against midslab cracking requires shorter slab lengths. (5) An afternoon placement requires shorter slab lengths. (6) A large expected daily temperature change requires shorter slab lengths. (7) A rougher subbase layer texture (i.e., more friction) requires shorter slab lengths. (8) Sawing should be accomplished as soon as feasible as long as the blade does not dislodge the aggregates.

The absolute costs for individual activities associated with rapid patching of PCC pavements were difficult to obtain for a number of reasons. Most construction bid documents lump many activities into composite costs. (For example, repair costs may include removal, placement of base, replacement of pavement, dowel bar installation, reinforcement, and curing.) Many rapid repairs are placed along with other improvements, such as repair of longitudinal joints, undersealing, and grinding; and some costs are shared, such as traffic control. Also, bid documents, which are the usual source of data, may not reflect total expenditure by item.

Table 5 gives cost data collected from participating states. Inspection shows that smaller projects have higher unit costs (for example, Virginia site 2, Michigan site 5, Minnesota site 4, and California site 3). However, the cost of traffic control is not necessarily affected by the size of the job. As an example, Virginia's site 2 has 5.5 times as many cubic yards of patching, but the traffic delay costs are only 63 percent of the site 1 cost. This may result from the specific site conditions or bid distribution practice by the contractor.

Table 5. Unit costs per square yard for rapid PCC repairs.

State-Site#	Area s.y.	1 Cost of Traffic Control ($1,000s)	2 Cost of Removal & Replacement ($1,000s)	1 + 2 Total Cost of Patching ($1,000s)	Cost of Rapid Repair ($/s.y.)	Total Contract Amount* ($1,000s)
Virginia						
Site 1	572	19	292	311	544	387
Site 2	3,132	12	408	420	134	554
Site 3	8,214	62	951	1,013	123	1,274
Site 4	9,323	111	1,006	1,117	120	1,620
Site 5		No unit prices available				
Michigan						
Site 1	28,044	17	1,455	1,472	52	2,116
Site 2	5,867	10	284	294	50	300
Site 3		No unit prices available				
Site 4	25,481	44	1,200	1,244	49	1,279
Site 5	4,197	7	270	277	66	370
Site 6	26,266	14	1,305	1,319	50	2,049
Minnesota						
Site 1		No unit prices available				
Site 2	2,410	1	178	179	74	192
Site 3	231	7	73	80	346	609
Site 4	75	7	128	135	1800	148
California						
Site 1	1,935	15	93	108	56	110
Site 2	1,900	16	57	73	38	106
Site 3	800	8	88	96	120	189
Site 4	847	7	36	43	51	45
Site 5	1,265	32	101	133	105	413
Site 6		No unit prices available				

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* Includes other activities

In general the cost per square yard of patching ranged from \$50 to \$500/sq yd. Our information indicates that approximately \$75/sq yd is the best average cost estimate, which is calculated by dropping the three highest values and averaging the data.

Repair Performance

Most agencies do not have formal procedures for monitoring their repairs. In general, repair performance is monitored by periodic observation. The performance of repairs under study in this project was monitored by highway department personnel throughout the duration of the project. ARE, Inc, personnel made the first and last ratings.

Subjective reviews of cracking and other distress ratings were extremely useful in developing these results. It is recommended that the photographic and crack mapping methods used in NCHRP Project 10-24 be used to monitor other repairs performance. Supplemental deflection and radar measurements should be considered as additions to any long-term performance studies of rapid repairs. Table 6 gives the criteria found from this study for determining repair limits or when an existing repair is near failure or in a "failed" condition.

CONCLUSIONS

The results from this long-term performance monitoring of rapid placed ($\leq$ 24 hours) full depth, full lane-width PCC repairs lead to a number of conclusive statements:

1. Specific criteria should be developed using subjective distress surveys and physical measurements of deflection and/or radar for void detection to establish the limits of each repair.

2. Full-depth sawing and removal by lifting are the most efficient and effective methods of removing the existing pavement.

3. Unstable or poor subbase or support material should be completely removed down to good material.

4. Minimum repair length should be 4 ft and maximum repair length should be 10 ft, or an interim joint or reinforcement should be considered (except for CRCP pavement) to avoid transverse pavement cracking from environmental and traffic load stresses.

5. If an old joint is removed, the new repair should replace the removed joint, so that the existing joint spacing is reestablished.

6. All reestablished joints should have load transfer devices to prevent faulting or tilting.

7. All steel in CRCP should be retied and the repair should reestablish longitudinal steel continuity.

8. Adjacent lanes should be tied together.

9. No significant benefit was noted for the use of the "inverted T-repair" and, in fact, there was some evidence that the T-wings may easily break off.

10. Repairs made with Type III cement with an accelerator added can be opened in 6 to 8 hours after placement. The review conducted in this research did not disclose any agency that made extensive use of exotic concrete mixes or new materials for these large repairs.

11. Repairs in adjacent lanes should line up so that the joint or end of a repair in one lane is not located mid-panel or offset from the joint in the adjacent lane.

12. Full depth, full lane-width repairs should not be abutted up to partial width repairs because these tend to cause longitudinal cracks in the full-width repair.

Table 6. Criteria for pavement repair.

The following criteria define different possible conditions a slab can exhibit when it shows its first signs of failure or actual failure. These are suggested values generated from the expertise of the researchers and from interviews with other highway engineers.

	Warning	Failed
Surface Deterioration	Loss of coarse aggregate on less than 26% of surface area	Loss of coarse aggregate on over 26% of surface area
	Some coarse aggregate exposed on less than 50% of surface area	Some coarse aggregate exposed on over 50% of surface area
Longitudinal Cracks	One crack	Two or more cracks
Transverse Cracks	Two or three cracks	Four or more cracks
Number of Cracks Spalled (A)	Two or less cracks of minor severity	More than two cracks of minor severity or one severe crack
Number of Punchouts (B)	Two or less punchouts of minor severity	More than two punchouts of minor severity or one severe punchout
Pumping (C)	Minor	Severe
Longitudinal Repair Edges	None	Poor condition w/open crack, spalling, or faulting
Transverse Repair Edges-Faulted (D)	If less than 1/2 inch dropoff	If greater than 1/2 inch dropoff
Transverse Repair Edges-Spalled (D)	If less than 1 inch wide	If greater than 1 inch wide
Transverse Repair Edges-Sealed	If partially sealed	If not sealed
Transverse Joints-Faulted (E)	If less than 1/2 inch dropoff	If greater than 1/2 inch dropoff
Transverse Joints-Spalled (E)	If less than 1 inch wide	If greater than 1 inch wide
Transverse Joints-Sealed	If partially sealed	If not sealed

FOOTNOTES TO TABLE 6.

A. NUMBER OF CRACKS SPALLED: Minor - less than one inch wide
Severe - greater than one inch wide

Note: Both minor and severe crack spalling may be observed. Count longitudinal and transverse crack spalling together.

B. NUMBER OF PUNCHOUTS: ( ) N.O. - none observed
Minor - closed cracks, no movement
Severe - open cracks, rocking, pieces of pavement missing

C. PUMPING: ( ) N.O. - none observed
Minor - visible stains and fines
Severe - deposits of material on the shoulder

D. TRANSVERSE REPAIR EDGES: Rate only the transverse edges. If a transverse edge of the repair is also a joint, rate only as a transverse edge. For the repair, rate only the transverse edges that are physically part of the repair (i.e., do not rate the transverse edge of the upstream/downstream adjacent pavement). When rating upstream/downstream adjacent pavement, rate only the edges next to the repair and do not include the transverse edge of the repair itself in the rating.

Faulting - Warning if less than 1/2 inch
Failed if greater than 1/2 inch

Spalling - Warning if less than 1 inch wide
Failed if greater than 1 inch wide

E. TRANSVERSE JOINTS: Rate only the transverse joints. Joints which are located at the repair edge should be rated under TRANSVERSE REPAIR EDGE. If multiple joints exist, rate the poorest performing joint.

Faulting - Warning if less than 1/2 inch
Failed if greater than 1/2 inch

Spalling - Warning if less than 1 inch
Failed if greater than 1 inch

By adding these simple conclusive findings into the development of a rapid repair design and construction specification the agency can be assured of the best performing rapid repair.

APPLICATIONS

The application of the information presented in this report will benefit maintenance, pavement, and materials engineers; specification and standards writers; and pavement contractors. The one-volume agency final report, entitled "Rapid Replacement of Portland Cement Concrete Pavement Segments," March 1988, may be ordered, as noted earlier in this Digest, through the National Cooperative Highway Research Program, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

REFERENCE

1. Vallejo, Felipe R., B. Frank McCullough, and W. R. Hudson, "Drying Shrinkage and Temperature Drop Stresses in Jointed Reinforced Concrete Pavement." Center for Highway Research, Report 177-1, August 1975.

OTHER SUGGESTED READINGS

Additional reading materials are listed, as follows. These documents summarize the results of recent research and should be of interest as they relate to full-depth patching of portland cement concrete pavement.

- American Concrete Pavement Association, "Guidelines for Full-Depth Repair." *Technical Bulleton, TB 002.0 CPR*,1989.
- American Concrete Pavement Association, "Guidelines for Partial-Depth Repair." *Technical Bulletin, TB 003.0 CPR*, 1989.
- Federal Highway Administration, "Pavement Rehabilitation Manual." *FHWA-ED-88-025*, February 1989.
- Mark B. Snyder, Michael J. Reiter, Kathleet T. Hall, and Michael I. Darter, ***Rehabilitation on Concrete Pavements***. Volume I--"Repair Rehabilitation Techniques," FHWA/RD-88-071, April 1989.
- ERES Consultants, Inc., *Techniques for Pavement Rehabilitation, Training Course*. U.S. Department of Transportation, Federal Highway Administration, National Highway Institute, October 1987.

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National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418