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16. Abstract

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The research is valuable to the Department because it shows that (1) with proper calibration, the impact hammer can be used to provide an indication of the compressive strength of a patch, (2) with the development of appropriate regression models, maturity calculations can be used to provide an indication of the compressive strength of a patch, (3) patches subjected to traffic at an age of 6 to 9 hours showed the most deterioration, (4) patches with a temperature matched cured strength greater than 4,500 psi when opened to traffic showed the least deterioration, and (5) all patch types evaluated performed satisfactorily over the study period with the exception of some faulting and early deterioration of some full-width, full-depth, Type I patches without load transfer devices that were $\leq$3 ft long. A longer evaluation period is needed to better assess the relative performance of the patch types.

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FINAL REPORT

EVALUATION OF CONCRETE PAVEMENT PATCHING TECHNIQUES

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(A Cooperative Organization Sponsored Jointly by the Virginia Department of Transportation and the University of Virginia)

In Cooperation with the U.S. Department of Transportation
Federal Highway Administration

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INTRODUCTION

The Virginia Department of Transportation is responsibile for maintaining the portland cement concrete (PCC) pavement on approximately 281 miles of interstate roadway and 219 miles of primary roadway (1). The percentage of the mileage on these roadways requiring patching and other maintenance has increased annually as the pavements have been subjected to stress and have reached or exceeded their design life. It is necessary to develop cost-effective methods for repairing these pavements so that concrete will be competitive with asphalt. Concrete pavement restoration techniques have been used successfully in Georgia and have proven to be more economical using a life cycle cost analysis than overlaying with asphalt (2). This report covers patching, which is an important part of the restoration process.

Background

In the 1970s, considerable patching was done by the Department's maintenance forces, but by the end of the decade, the magnitude of the work required had increased to the point that most of it was let to contract. The early work was usually tailored to the particular project or to the capability of the maintenance crew, and few patches were constructed the same way or with the same materials. Research efforts by Tyson, McGhee, and Creech helped in the identification of problems with PCC pavement repairs and in the development and refinement of repair techniques (3,4,5,6,7). Wyant summarized the Department's experience with the various patching materials that have been used over the years and concluded that the failure of most repairs stemmed from installation procedures rather than the materials (8). An educational package on concrete patching was prepared as a part of Wyant's research effort.

During the time this work was being done, the Maintenance Division of the Virginia Department of Transportation in cooperation with the Research Council developed special provisions and design standards for patching concrete pavements. The special provisions and standards have been modified and refined, and new standards have been developed as more has been learned about the art of patching. When this study was initiated in 1984, the Department was using six design standards, and as needs for additional standards arose, such as a standard for the repair of continuously reinforced concrete pavement, new standards were developed and will likely continue to be developed. The six standards for permanent pavement repairs in use when the study was initiated are included in Appendix A and are briefly described below. In addition, a proposed Type V-F standard used on one job in 1982 (9) (the repair type requirements for the job are included in Appendix A) and a proposed Type V-P standard, which has not been developed or used, are described below.

Design Standards for Pavement Repairs When Study was Initated in 1984

Type I (see page A-2)

Full-lane-width, full-depth, 2 ft (0.6 m) to 42 ft (12.8 m) long patch on soil cement base (Section 307 of VDOT Road and Bridge Specifications). Concrete is sawed full depth. No load transfer is provided.

Type II (see page A-3)

Full-lane-width, full-depth, 2 ft (0.6 m) to 42 ft (13 m) long patch on aggregate base (Section 308 of VDOT Road and Bridge Specifications). Concrete is sawed full depth. Load transfer is provided by inverted tee shape. Welded wire fabric is placed in patches 20 ft (6.1 m) or more in length.

Type III-F (see page A-4)

Full-depth concrete spall repair. Concrete is sawed to depth of 2 in (5 cm) and removed full depth. The minimum size is 2 ft (0.6 m) by 2 ft (0.6 m). The maximum width is 8 ft (2.4 m). If the width of unsound concrete exceeds 8 ft (2.4 m), a Type I or II repair is made. Load transfer is provided by a bond between the existing pavement and the patch (an EP-4 bonding epoxy is applied to the existing pavement face).

Type III-P (see page A-5)

Partial-depth concrete spall repair. Concrete is sawed to a depth of 3 in (8 cm), and unsound concrete is removed up to a depth of 4 in (10 cm). If unsound concrete extends below a 4 in (10 cm) depth, a Type III-F repair is made. Load transfer is provided by a bond between existing concrete and the patch (a cement slurry bonding agent is applied to the existing pavement surface).

Type IV-A (see page A-6)

Full-width-and-depth reinforced concrete slab replacement on aggregate base. Load transfer is provided by steel dowels or other approved mechanical devices.

Type IV-S

Full-width-and-depth reinforced concrete slab replacement on soil cement base (same as IV-A except for base material).

Proposed Type V-F (see page A-7)

Full-width-and-depth continuously reinforced concrete slab replacement. Similar to Types IV-A and IV-S, except the slab is sawed to the depth of the top of the longitudinal reinforcement and removed full depth with jackhammers; the continuity of the reinforcement throughout the pavement is maintained.

Proposed Type V-P

Partial-depth continuously reinforced concrete spall repair is similar to a Type III-P repair. No standard has been developed since this type of repair has not been done in Virginia.

Design Standards for Pavement Repairs in 1988

In 1988, five design standards for pavement repairs were being used. The Type I repair was still being used but less than in 1984. A Type II repair (with dowels) had replaced the Type II (inverted tee), the Type IV-A, and the Type IV-S repairs. Minor revisons had been made to the standards for the Type III-F and III-P repairs, and a new Type IV repair had replaced the proposed Type V-F repair. The revised standards in effect in 1988 are included in Appendix A and briefly described below.

Type I (see pages 2 and A-2)

Type II (with dowels) (see page A-8)

Full-lane-width, full-depth, 4.5 ft minimum length patch. Concrete is sawed full depth. Preformed bituminous expansion joint filler is placed against runoff side of the adjacent pavement. Load transfer is provided by dowels 18 in long by 1 1/4 in in diameter. Welded wire fabric is placed in patches 20 ft or more in length. (Replaces previous Type II, Type IV-A, and Type IV-S.)

Type III-F (see pages A-9, A-10)

Same as previous Type III-F, but includes replacement of damaged or missing dowels.

Type III-P (see page A-11)

Same as previous Type III-P, but requires application of EP-4 bonding epoxy rather than cement slurry and requires application of hot-pour sealant.

Type IV (see pages A-12, A-13, A-14)

Full-lane-width, full-depth, 4.5 ft minimum length continuously reinforced concrete slab replacement. Concrete is sawed to the depth of the top longitudinal reinforcement at the ends and sawed full depth 18 inches from each end. Concrete is removed full depth throughout, and new reinforcement is lapped 16 in with old reinforcement at each end. (Replaces proposed Type V-F).

Special Provisions

The Department's 1984 and 1988 special provisions for patching PCC pavement are shown in Appendix B. Both require that the patching concrete have a minimum compressive strength of 3,000 lb/in^2 at 24 hr. A patch must be cured with wet burlap and polyethylene for a minimum of 6 hr prior to being opened to traffic.

Research Needs with Respect to Performance

The performance of each of the types of patches needs to be monitored so that the standards can be refined. Patches constructed under each of the standards can be identified, but information on the installation procedures, the properties of the materials, and the concrete strengths at the time the patches were subjected to traffic is not available for individual patches. There is a need to identify patches constructed under each standard, to collect detailed data on their installation, to monitor the performance of these patches, and to identify a nondestructive method for predicting the strength of a patch at the time it is subjected to traffic.

Other concerns that were cited at the time this study was initiated are as follows:

1. Are steel load-transfer devices needed for Type I and II repairs?

2. Should an EP-4 bonding epoxy be applied to the existing concrete face for Type III-F patches?

3. Should a bonding slurry of cement paste be applied to the existing concrete face for a Type III-P repair? And, if so, why not use it rather than epoxy for Type III-F repairs?

4. Should sawcuts outside of the boundaries of the area to be repaired be allowed? And, if so, should they be repaired, and how should they be repaired?

5. What compressive strength should a patch have at the time it is subjected to traffic?

Since the initiation of this study, observations by the Department's PCC pavement managers have resulted in an answer to concern No. 4. Sawcuts outside of the boundaries of the area to be repaired should not be allowed because they cause deterioration of the adjacent area.

Research Needs with Respect to Compressive Strength

Detailed information on the compressive strength of the concrete used in a patch at the time it is first subjected to traffic, and the relationship between this strength and the long-term performance of the patch is not available. For a given set of mixture proportions and curing conditions, the strength of a patch is a function of the curing time and curing temperature. The curing temperature is a function of the initial concrete temperature, the mass of concrete, the ambient temperature, and the temperature of the adjacent concrete and base material. Therefore, concrete cylinders cured independently of the patch do not provide an accurate indication of the early strength of the patch. A core from the patch would provide the best indication, but it is not desirable or practical to core a large number of patches. Also, coring a patch at an early age may damage the patch and the core.

For the same length and type of cure, patches having a smaller mass, such as Types III-F and III-P, have a much lower early age strength than other types. On the other hand, patches having a larger mass, such as Types IV-A and IV-S, are more prone to shrinkage cracks resulting from higher curing temperatures. Therefore, it should be determined if different special provisions are needed for different patch types to ensure that they have the proper strength when opened to traffic. In addition, a rapid nondestructive method is needed for estimating the compressive strength of a patch just prior to subjecting it to traffic so that the patches determined to have a less than adequate strength can be kept isolated from traffic for a longer period or be removed.

Temperature matched curing (TMC) is being used in the precast industry to ensure that test cylinders are cured at the same temperature as the concrete product. With TMC, test cylinders are heated or allowed to cool within an insulated mold based on a signal from a thermocouple placed in the concrete product (10). The TMC apparatus, marketed under the trade name of Sure Cure, is probably not practical for routine use in concrete patching operations because it is delicate and expensive. However, it could be used in research to identify relationships between compressive strength, curing time, temperature, patch type, and patch size and to accurately establish the compressive strength of selected concrete patches when first subjected to traffic. The information would be useful in evaluating the long-term performance of these types of patches.

According to the Prestressed Concrete Institute (PCI) and others, the nondestructive impact hammer can be used to supplement cylinder tests (11,12,13). The hammer must be calibrated on concrete for which the compressive strength is known. A test result is based on the average of 10 readings (ASTM C805-79)(14). It is anticipated that a practical nondestructive test method for determining the early in-place strength of concrete patches could be developed around the impact hammer. Its accuracy could be determined by correlating readings taken on selected patches with compressive strength data provided by the TMC apparatus. A major concern is the precision of the hammer at low compressive strengths. Impact numbers for concrete compressive strengths below 1,000 lb/in^2 were not found in the literature.

PURPOSE AND SCOPE

The purpose of this research was to improve concrete pavement patching techniques (15). It was believed that the best way to improve these techniques was to identify a sample of patches of each type used in Virginia, obtain detailed information on the construction of the patches, determine the compressive strength of the patches at the time they were first subjected to traffic, observe the performance of the patches over a 5-year period, and prepare a report that illustrates deficiencies in each of the patching techniques and provide any necessary recommendations for improving the techniques.

The scope was limited to a study of approximately 3 randomly selected patches of each type installed under two or three conditions for a total of 46 patches. Examples of different conditions included patches installed at different ambient temperatures, patches that have different masses, patches opened to traffic at different ages, and patches installed with and without steel load transfer devices.

Construction Projects from which Patches were Selected

A number of contracts for PCC pavement repairs during the 1984 construction season provided ample opportunities to conduct the needed research. These included a contract to restore the 14.55-mi(23.41-km) section of concrete pavement on I-81 in Botetourt County, which was the first attempt in Virginia to completely restore a section of concrete pavement (16). The contract required the patching, subsealing, and grinding of pavement slabs, the sealing of pavement joints, and the installation of drains.

This contract provided an opportunity to evaluate Type II and Type III-P patches (site 1). In addition, evaluations of Type I repairs were made on I-64 (job 404-83) in the Suffolk District (site 2), and additional evaluations of Type I and Type III-P repairs were done on I-95 (job 425-83) in Greenville County (site 3). Evaluations of Type IV-A and Type III-F repairs were made on I-64 in the Richmond District (site 4), and an additional evaluation of a Type II repair was made in Ashland (site 5) and of a Type IV-A repair near Hampton (site 6). See Appendix C for site locations.

Also, ARE, Inc., engineering consultants, conducted NCHRP Project 10-24 entitled "Rapid Replacement of Portland Cement Concrete Pavement Segments" (17). For the project, they monitored the performance of pavement repairs at five test sites in Virginia, as well as projects in other states, over a 5-year period. The evaluation of the repairs in Virginia included in the project provided additional data on the performance of Type I repairs made at site A-4 on I-64 (job 106-81 in Norfolk) and site A-5 on I-95 (job 84-83 in Greenville County), and Type II repairs made on I-64 at sites A-1 (job 113-82 in Henrico County), A-2 (job 252-81 in York County), and A-3 (job 209-82 in Newport News).

Tasks Completed

Four tasks were completed to fulfill the requirements of the study. For Task 1, installation data were collected for each of the patches to provide a data base for evaluations. For Task 2, data on the compressive strength of the patches were collected; this is probably the most valuable data to come from the project. For Task 3, data was recorded on the condition of the patches once every 5 to 21 months for a period of 33 to 81 months. For Task 4, this report was prepared.

INSTALLATION DATA

Installation data recorded for patches of each type included the patch location; patch identity; patch size; subbase type; traffic data (see Appendix C); placement date; mixture proportions; the properties of the concrete used in the patch--such as slump, air, temperature, and time of set; the time traffic was allowed on the patch; the time required for the various installation activities and subsequent curing of the patch (see Appendix D); the temperature and time data necessary to compute the maturity of the concrete (see Appendix E); the compressive strengths of two or more concrete cylinders cured by TMC and cured in air; the maturities of the cylinders and the patch; and the impact numbers for the patch (See Appendix F). Data on mixture proportions and batch properties were not available for the patches included in NCHRP Project 10-24 because the patches were installed prior to the initiation of this study. The data should be similar to that obtained for the other patches since they were constructed under similar special provisions.

THE COMPRESSIVE STRENGTH OF CONCRETE USED IN FULL-DEPTH PORTLAND CEMENT CONCRETE PATCHING

Introduction

Emphasis was placed on the early-age compressive strengths of patches (the strength at any time within the first 24 hours after batch time) and an evaluation of the techniques used in estimating those strengths (18). Once early-age strengths were determined, the use of maturity functions and the impact hammer to estimate early age strength could be evaluated, the influence of the age and strength of the patch at the time traffic was applied on long-term durability could be examined, and the issue of whether or not the patches were being loaded prematurely could be addressed.

The current practice is to approve the mixture proportions for concrete pavement patches based on compressive strength tests performed on air-cured cylinders in accordance with the ASTM designation C31-84 (19). The mixture proportions are approved if the compressive strength at 24 hr is ≥3000 psi, and traffic may be placed on the repair when the strength is ≥2000 psi (20).

Mixture Proportions

The mixture proportions for patches 15, 16, 17, and 18 are shown in Table I. The mixtures are typical of those used in all the patches evaluated (see Appendix D).

Test Procedure

Rather than purchase 24 Sure Cure cylinder molds to collect the required TMC data, a cylinder curing cabinet was constructed. The cabinet surrounds 14 concrete cylinder molds with water having the same temperature as the concrete that is being match cured, which for this study, was the center of the patch (see Figure 1). The cabinet consists of the bottom section of a 55-gal drum, four submersible 200-watt electric heaters controlled by a modified Sure Cure temperature control box and a small 10-watt electric motor and impeller, which evenly distributed the heated water throughout the chamber. A temperature controller senses the temperature in the center of the patch and turns the electric heaters in the cabinet on and off as needed so the temperature of the water surrounding the cylinders in the cabinet follows the patch temperature as it climbs and subsides during the curing process. A thermocouple placed in a 4-in by 8-in cylinder showed that the temperature of the center of the cylinder was close to the temperature of the patch.

TABLE 1

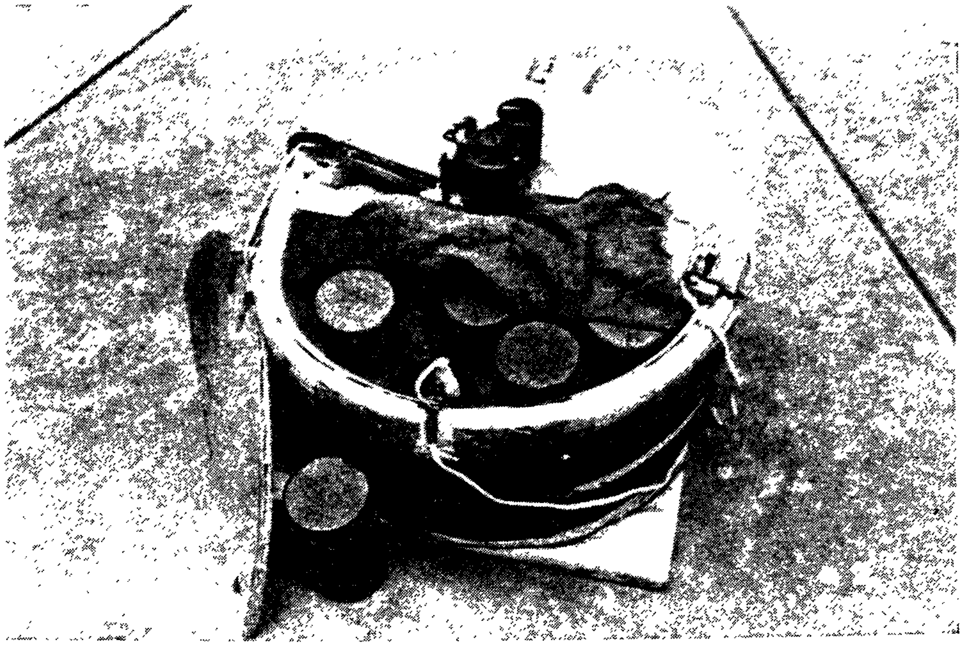
Mixture Proportions

Mix	Patch 15	Patch 16	Patch 17 (HRWR)*	Patch 18
Cement, lb/yd^3	800 (Type II mod)	752 (Type III)	800 (846±) (Type II mod)	776 (Type III)
Water, lb/yd^3	336	271	336 (265±)	279.3
C.A., lb/yd^3	1655	1900	1655 (1750±)	1950
F.A., lb/yd^3	1002	916	1002 (1059±)	819
w/c	.42	.36	.42 (.31±)	.36
Admixtures	MBVR**, 122-N	MBVR,122-N 122-H.E.	MBVR,122-N 122-H.E.,400-N	MBVR Pozz/122-N
Slump	3	2.5	0 (4)	2.25
Air, %	7.6	5.0	- (5.5)	5.2

* Water added to get slump of 0" to 1/2" prior to on-site addition of 400-N, high range water reducing admixture.

** Master Builders vinsol resin air entraining admixture.

The following procedures were followed for the evaluation of each patch. The first step was to set up the equipment so the patch could be monitored conveniently and continuously without interfering with concrete installation equipment and crews (see Figure 1). Thermocouple wires were prepared to go into the patch, and equipment was readied for making the 4-in by 8-in test cylinders used to evaluate the patches. Fifty four cylinders were prepared to evaluate patches Nos. 15, 16, 17, and 18, but only 12 to 18 cylinders were prepared for Nos. 1 through 14 since the curing cabinet was not fabricated until after the first 14 patches were installed.



Curing cabinet.

Temperature matched curing and compressive testing equipment.

Figure 1. Typical equipment setup for temperature matched curing.

When the concrete arrived, care was taken to obtain the sample from the batch of concrete reserved for the patch to be monitored. For patches Nos. 15 through 18, 50 4-in by 8-in cylinders were fabricated in plastic molds and four Sure Cure specimens were fabricated in the Sure Cure II TMC cylinder molds. Fourteen specimens (TMC) were placed in the curing cabinet (the capacity of the cabinet). Eighteen cylinders (patch top) were placed under wet burlap and polyethylene, and 18 (air-cured specimens) were placed under wet burlap and polyethylene on the shoulder of the road in the vicinity of the patch. Beginning at the nearest hour from batch time following initial set, a cylinder from each group, excluding the Sure Cure cylinders, was tested for compressive strength every hour for the first 6 hr. Then, one cylinder from each of these groups was tested every 2 hr for the next 4 hr. Impact hammer readings on the patch surface were also taken at the same time as the compression tests. At 24 hr, two cylinders from all groups were tested and a pair of curing cabinet cylinders and two pairs of the air and patch top cylinders were removed from their molds and placed in the moist room (moist cured). The other cylinders were stored outside in the plastic molds (air cured), and tops were placed on the molds to prevent moisture loss. The two cylinders cured in the Sure Cure molds were stripped at 24 hr of age and placed in plastic molds with tops. At 7 days, two air-cured and two moist-cured cylinders from the air- and moist-cured groups were tested. At 28 days, two air-cured and two moist-cured cylinders from all groups were tested, except that the two from the Sure Cure group were only air cured. Data collected on a multichannel temperature recorder were used to compute the maturities of the concretes. The information was used to develop the following relationships between time and temperature, time and strength, TMC and air-cured compressive strength, impact number and TMC compressive strength, and the natural log of maturities and TMC compressive strength.

In an effort to try to cure cylinders under the same conditions as the patch, a unique curing procedure was used to cure six cylinders for patch 14. Six forms for molds, which consisted of a plywood base and a sheet metal side, were placed on the base material and the concrete for the patch was placed around the forms (see Figure 2). Prior to covering the patch with wet burlap, six 4-in by 8-in cylinders fabricated in plastic molds were placed inside the forms. The cylinders were cured under the same conditions as the patch for 24 hr. The compressive strengths at 24 hr and 28 days were as follows: Sure Cure - 3,920, 5,370 psi; patch cure 3,570, 5,770 psi; air cure - 1,770, 5,760 psi. It is believed the cylinders cured in the patch are the most representative of the strength of the patch. The cylinders cured in the Sure Cure molds were cured at a temperature that was higher than that of the patch. The 28-day strengths of the cylinders cured in the patch and in the air were about the same. The technique of curing the cylinders in the patch was not used on subsequent patches because of the holes left in the patch and because the curing cabinet was constructed to provide a similar curing condition.

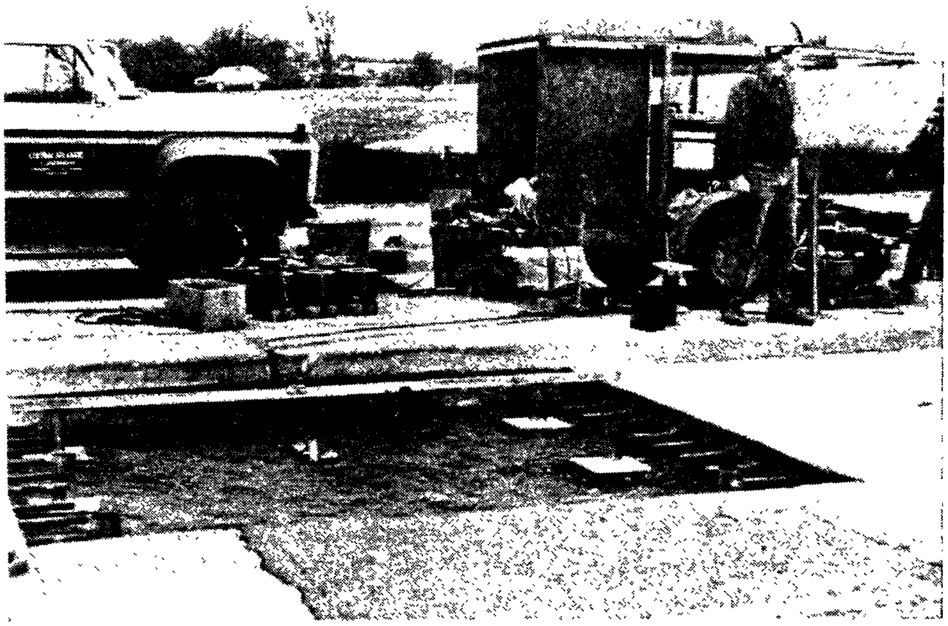


Figure 2. Cylinders are cured inside patch 14.

Curing Temperatures

Thermocouples and a multichannel recorder were used to show the relationships between time and the curing temperature of 4-in by 8-in cylinders cured in the Sure Cure molds, the curing cabinet, in air on top of the patch and in air in the vicinity of the patch; the curing temperatures of the surface, the center, and the bottom (next to the subbase) of the patch; and air temperature (see Appendix E). The relationships between time and temperature for patch No. 17 are shown in Figures 3 and 4. Figure 3 shows the temperature data for the air and the top, center, and bottom of the patch. Figure 4 shows the temperature data for the center of the 4-in x 8-in cylinders cured four ways, the center of the patch, and the air.

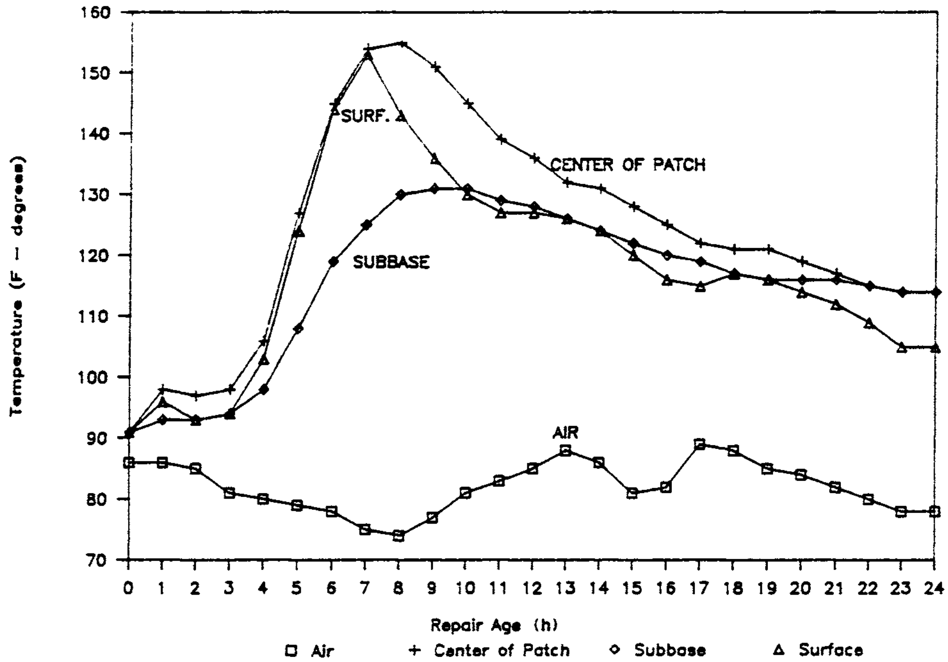


Figure 3. Temperature distribution for patch 17 as a function of time.

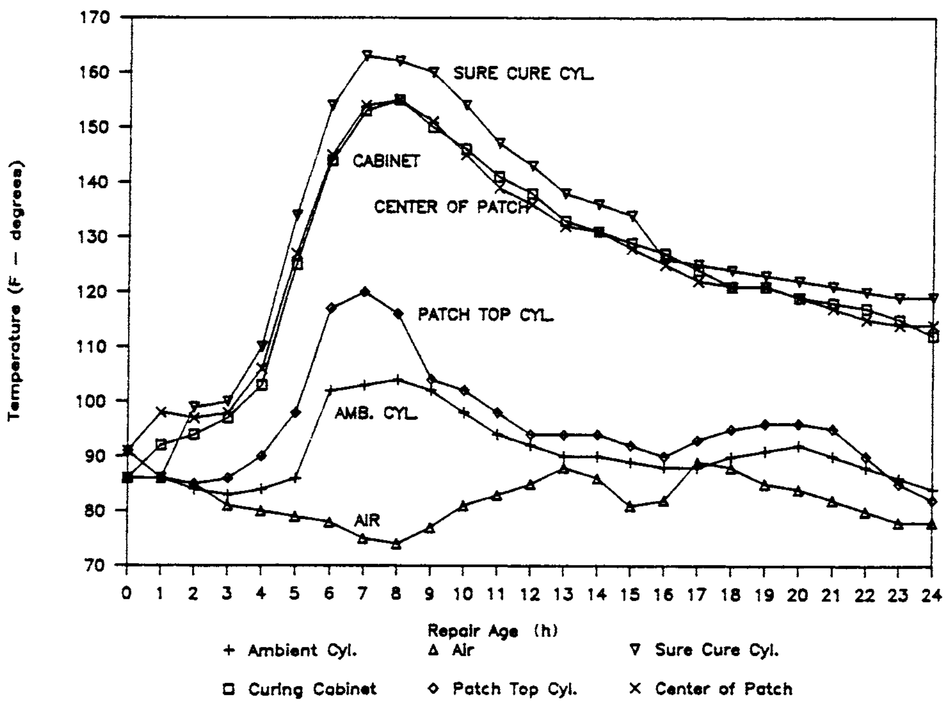


Figure 4. Temperature of specimens cured with patch No. 17 as a function of time.

TMC in Cabinet vs. Sure Cure Molds

The reliability and accuracy of the TMC equipment was a major concern. For comparison with the cylinders cured in the curing cabinet, four of the Sure Cure molds used to temperature match cure concrete for patches No. 1 through 14 were used for patches Nos. 16, 17, and 18. The strengths obtained with the two types of equipment based on the average of two specimens tested at 24 hr and 28 days (dry cure) are shown in Table 2.

TABLE 2

Sure Cure vs Curing Cabinet Cylinder Compressive Strengths

Patch	Curing Cabinet (24 hrs)	Sure Cure (24 hrs)	Curing Cabinet (28 days)	Sure Cure (28 days)
16	3960	4340	6050	5290
17	5410	5870	8710	7180
18	4380	4770	5950	6010
Avg.	4580	4990	6900	6160

The time/temperature relationships shown in Figures 3 and 4 indicate that the cylinders cured in the curing cabinet matched the repair as well as or better than these cured in the Sure Cure molds. Typically, the Sure Cure specimens were more mature at 24 hrs (see Appendices E and F), which would explain the higher strength. It was observed that on occasion the TMC cylinders for patches Nos. 1 through 14 did not match the patch as well as desired; therefore accurate curing temperature data must be recorded when using TMC equipment. The 28-day dry-cured strengths (see Table 2) for the specimens cured in the Sure Cure molds were typically lower than those of specimens cured in the cabinet. This could be the result of the higher curing temperature at an early age or of removing the cylinders from the molds at 24 hr and placing them in plastic molds for 28 days, which would allow more evaporation of moisture from these cylinders than from those cured in the cabinet, which stayed in their molds for 28 days.

Air vs. TMC

Figure 5 shows the relationship between the strengths of the TMC and the air-cured cylinders for patches Nos. 16, 17, and 18. On the average, the curves showed the strength of TMC cylinders increasing much more rapidly during the first 12 to 24 hr. Following this period, the differences between the strengths dissipate causing a line with a slope of near unity at 7 and 28 days. The similarity of strengths at later ages is desirable because (1) it indicates that the high temperatures reached by the patch during initial curing do not appreciably affect the ultimate strength of the concrete as compared to the cooler initial curing temperatures of the cylinders cured in air in the vicinity of the patch, and (2) cylinders cured in air can be used to provide an accurate indication of the 28-day compressive strength of the concrete in the patch.

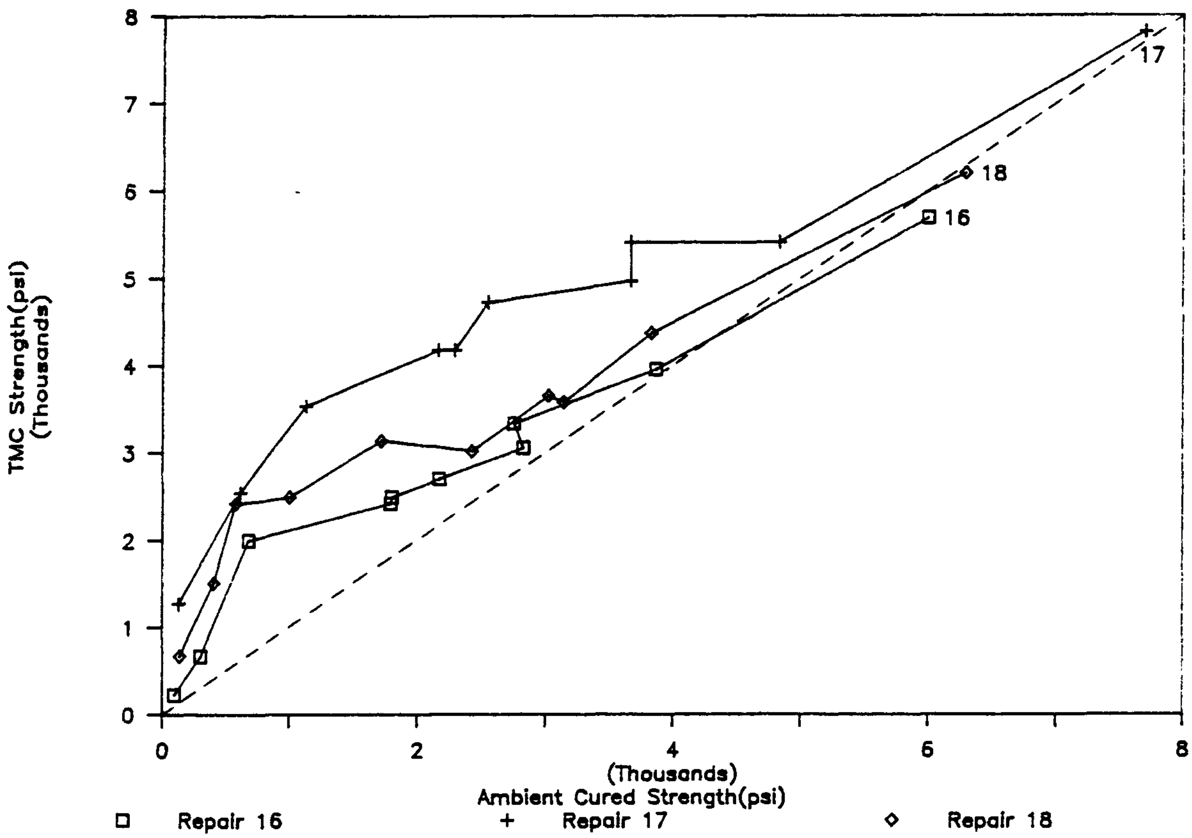


Figure 5. Relationship between strengths for TMC and air-cured cylinders.

The TMC data collected for patch No. 15 were not reported in Appendix F because they were not considered to be representative since as patch 15 was being monitored, an equipment malfunction heated the TMC cylinders to a temperature of more than 140°F about 2 hr before the initial set of the concrete. Very high early strengths were observed for these cylinders in comparison with the air-cured cylinders, but the air-cured cylinders exhibited strengths that equaled or exceeded the TMC strengths at 7 and 28 days. Studies which showed that excessively high temperatures prior to the initial set can have detrimental effects on the ultimate strength of concrete have been conducted by the Prestressed Concrete Institute (21). They indicate that strength loss is caused by expansions of water and air and cracking resulting from the consequent tensile stresses within the concrete.

Another interesting observation is that the 28-day strengths of the dry-cured cylinders made from the concrete used in patch No. 17 were higher than those of the moist-cured cylinders. In fact, the TMC strength of the dry-cured cylinders at 28 days was approximately 1,800 psi higher than the moist-cured cylinders. The concrete mixture used in patch No. 17 was typical of the other patches, except that it had a lower water to cement ratio and a high range water reducing (HRWR) admixture, which was added just preceding the placement of the concrete. It's interesting to note that specimens containing a HRWR admixture exhibit higher durability if they are allowed to air dry prior to testing them using ASTM C666 Procedure A (22)

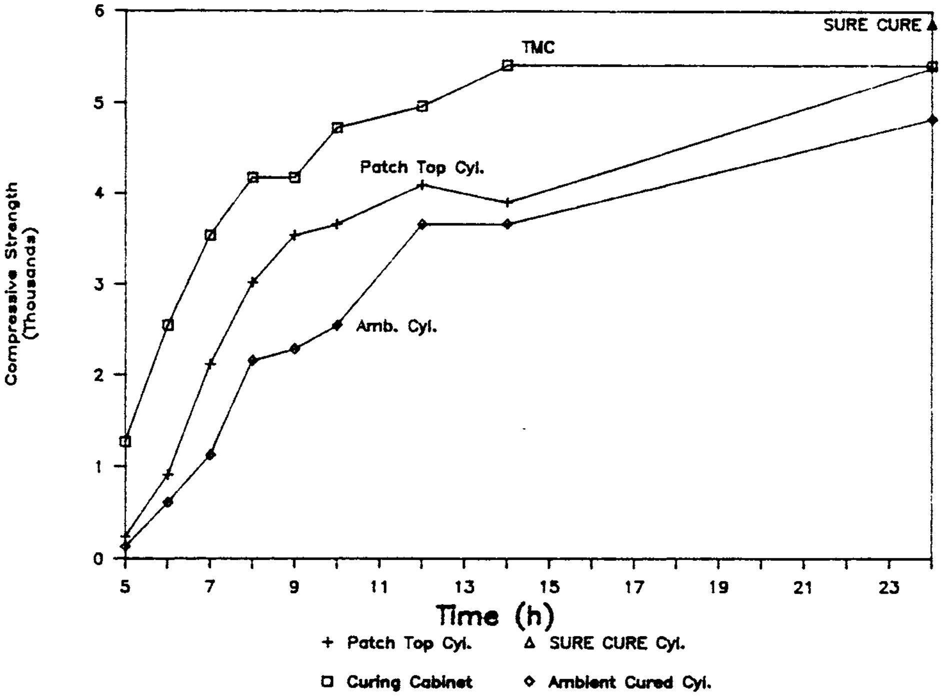
TMC vs. Patch Top vs. Air

For the most part, compression test results at 24 hours and 28 days did not differ for patches Nos. 1 through 18. The most complete relationships between compressive strength and age were obtained for patches Nos. 16, 17, and 18. Average strengths for the initial tests, at the opening of the patched lane to traffic at 12 hr and at 24 hr are reported in Table 3 and Figure 6.

TABLE 3

Average Compressive Strengths for Different Curing Methods for Patches Nos. 16, 17, and 18

Time	TMC (psi)	Patch Top (psi)	Air (psi)
Init. test	730	180	120
Traff. open.	3030	2210	1650
12 hr	3990	3510	2880
24 hr	4580	4460	4170



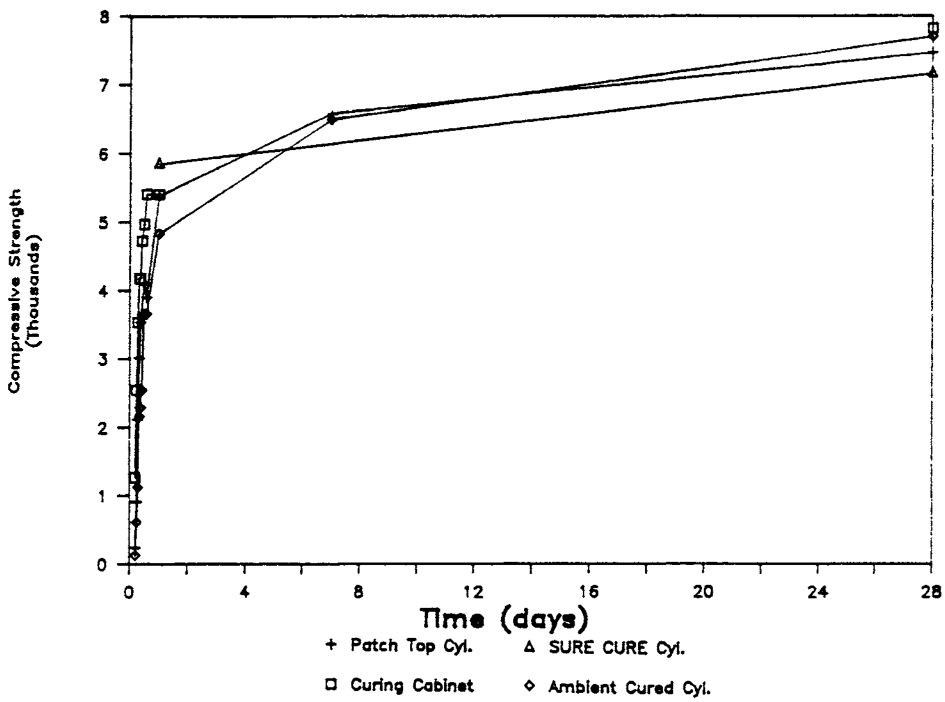


Figure 6. Compressive strengths of 4-in by 8-in cylinders cured with patch No. 17 as a function of time.

Differences between TMC and air cylinder strengths at the time the patches were opened to traffic ranged from as little as 530 psi (patch No. 16) to as much as 1930 psi (patch No. 17). The smallest early strength differences were obtained for Patch No. 16 (Appendix F). The largest differences were obtained for the HRWR concrete used in Patch 17 (Appendix F). These differences may be partially accounted for by the 5 to 10 degree differences in hydration temperature between the two patches. Although the internal temperatures of patch No. 17 reached and held a noticeably higher level than patch No. 16, the curing conditions reflected by the maturity data for the air-cured cylinders were essentially the same for both sites. In other words, the TMC cylinders for repair No. 17 were more mature than the ones for patch No. 16 but the air-cured cylinders had similar maturities.

COMPRESSIVE STRENGTH OF THIN OVERLAYS

The scope of the working plan had included the evaluation of Type III-P partial depth repairs. Unfortunately, very few Type III-P repairs were done at a time that conveniently allowed the strength development and temperature to be monitored. Since the thickness of a Type III-P repair is about 3 in, it was felt that the curing temperature of a latex modified concrete (LMC) overlay could be monitored to provide an indication of the curing temperature of a Type III-P repair. Also, since LMC is regularly used to restore the top surface of older bridge decks, it was desirable to monitor the curing temperature and study the strength development of the concrete in the LMC overlay to see if there is a potential for a difference between the strength as determined using air-cured cylinders and that determined by using TMC cylinders. Although the evaluations of the LMC overlay were not as extensive as those conducted on the pavement patches, data shown in Appendix E were collected on the temperature of the concrete in the overlay and the temperature of the concrete in air-cured cylinders during the first 24 hr. Evidently, because of the thickness of the overlay (2.5 in) and the slow strength gain of the Type II cement used in the overlay, the temperature of the concrete in the air-cured cylinders was similar to the temperature of the concrete in the overlay. Therefore, it can be concluded that air-cured cylinders provide a good indication of the strength of the concrete in an LMC overlay or other thin overlay or in a partial depth repair and that the air-cured cylinders can be used to determine that an overlay has adequate compressive strength for traffic.

SUBJECTING REPAIRS TO TRAFFIC

Implications of TMC Cylinder Strength

In accordance with the Virginia Department of Transportation's Road and Bridge Specifications, PCC patching is not subjected to traffic until the materials used have reached a compressive strength of 2,000 psi, and the materials are deemed unacceptable if they do not reach a compressive strength of 3,000 psi in 24 hr (20). Also, the requirement for a minimum of 6 hr of moist cure would result in traffic being placed on a patch no sooner than about 7 hr after the concrete is batched.

The data in Table 4 show the compressive strengths at 5, 6, and 7 hr after batch time of cylinders cured by the different methods for patches Nos. 16, 17, and 18. Based on the tests of the TMC cylinders, these patches, which are typical of the patches evaluated (see Appendix F), achieved 2000 psi in less than 7 hr and achieved 3000 psi in 7 to 10 hr. It is evident from the data in Table 4 that based on the TMC compressive strength results, full-depth pavement patches constructed with concrete mixtures and placed and cured at temperatures like those of patches Nos. 16, 17, and 18 can be subjected to traffic 5 to 6 hr after the concrete is batched. This practice would not be supported by tests on air-cured cylinders and would not be possible at curing temperatures significantly lower than those encountered in the study.

TABLE 4

Strengths for Different Curing Methods for Patches Nos. 16, 17 and 18 at 5, 6, and 7 Hr

Age	Patch	TMC (psi)	Patch Top (psi)	Air (psi)
5 hr	16	2010	1500	680
	17	1270	240	130
	18	680	130	140
	Avg.	1320	620	320
6 hr	16	2430	2200	1790
	17	2550	920	620
	18	1510	370	410
	Avg.	2160	1160	940
7 hr	16	2510	2590	1810
	17	3540	2120	1130
	18	2430	900	580
	Avg.	2830	1870	1170

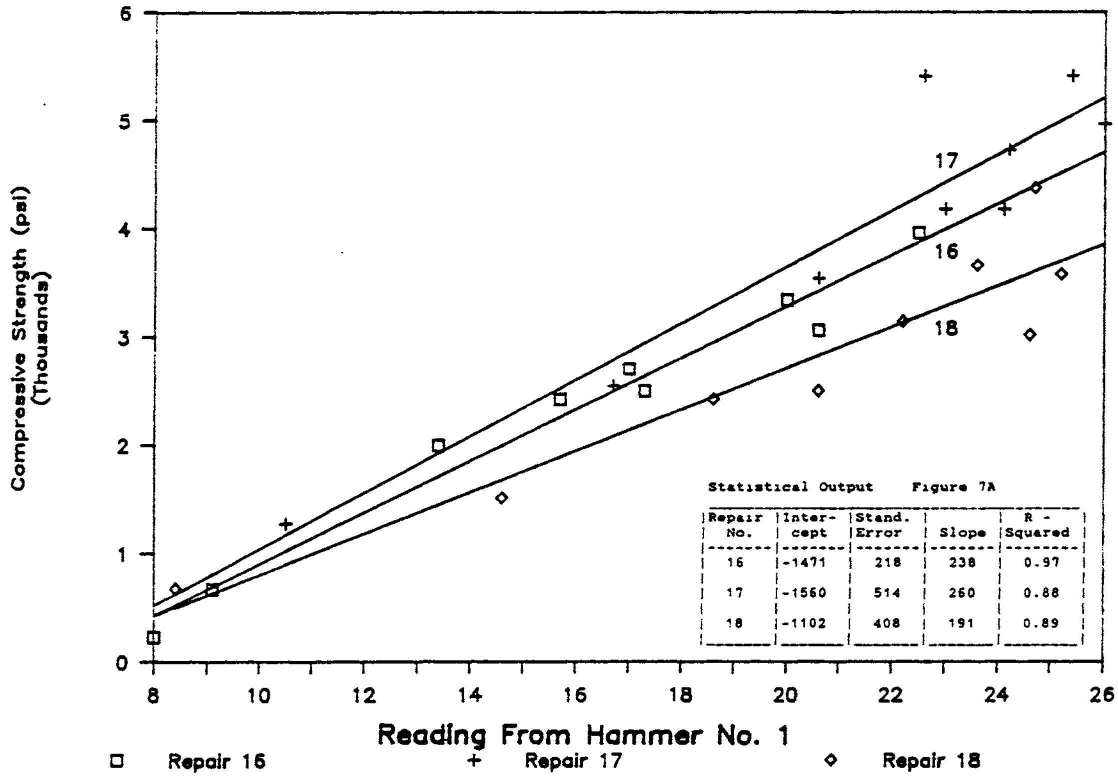
These results could prove valuable in a number of ways. The contractor, for example, may place concrete for 6 hr a night, instead of the currently typical 4 to 5 hr left after concrete removal begins. If traffic needs are more demanding, lane closures at 8:00 or 8:30 in the evenings instead of 7:00, or lane reopenings at 4:00 to 4:30 in the morning instead of 5:00 and 5:30 may be possible. Also, the results imply that it might be possible to place certain concrete mixtures for full-depth patches at temperatures lower than 55°F with the same or slightly longer lane closure time. Of course, the current practice of requiring a 6-hr minimum period of moist curing is probably reasonable for concrete placements at a 55°F air temperature and provides a factor of safety at the higher placement temperatures typical of those involved in the evaluations.

Implications of Tests with the Impact Hammer

Two impact hammers were used to measure impact numbers for the top of each patch each time a cylinder was broken in compression during the first 24 hr. The numbers are reported in Appendix F. A fairly linear relationship between the impact number and strength was found for each patch and each hammer, which is indicated by the high values for the correlation coefficients (see Figure 7). However, there was little correlation between one project and the next or one hammer and the next.

The data support the findings of others who report consistent correlations between impact numbers and the compressive strengths of concrete. However, they stress that because the wide range of variables involved when placing concrete, impact numbers are at best relative rather than absolute (23). The following variables are reported to affect the impact number (24):

- smoothness of surface under test
- size, shape, and rigidity of the specimen (a factor in small partial-depth repairs)
- age of test specimen
- surface and internal moisture conditions of the concrete
- type of coarse aggregate
- type of cement
- type of mold (not a concern in our work)
- carbonation of concrete surface (applies to aged concrete only)



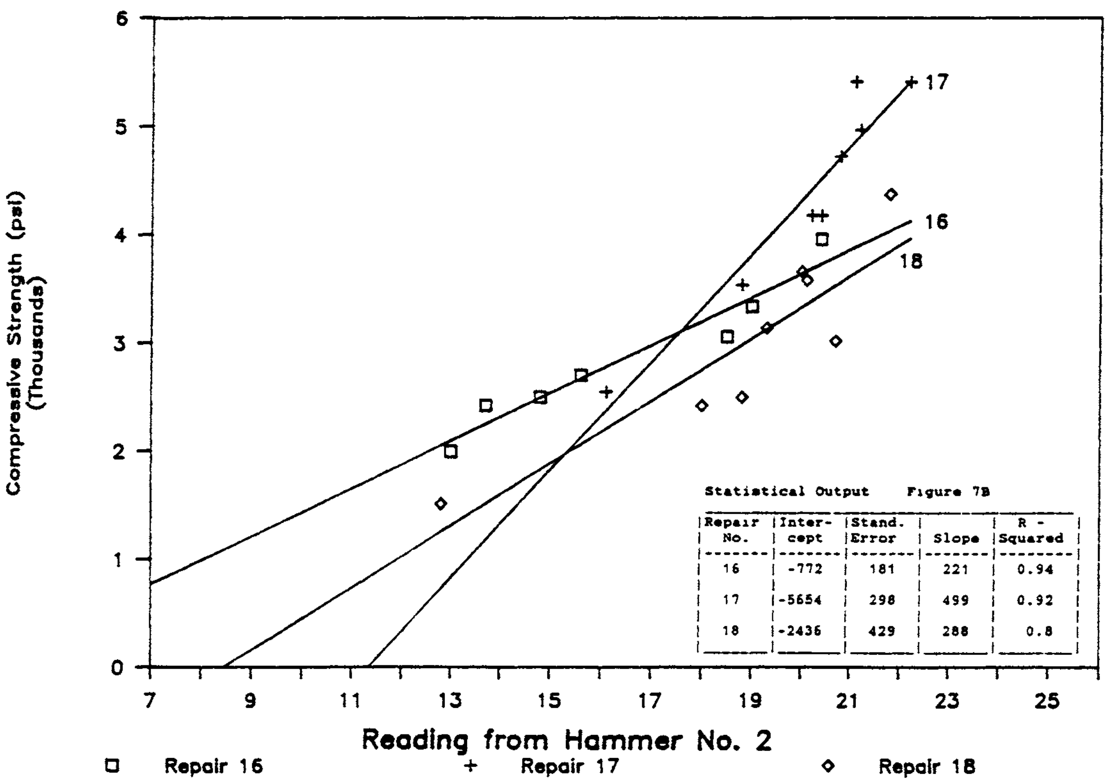


Figure 7. TMC strength vs. impact number for patches Nos. 16, 17 and 18.

Because of these restraints, the estimation of the strength of concrete with an impact hammer within an accuracy of ±15 to ±20 percent can only be achieved for specimens cast, cured, and tested under the same conditions as the specimens used to establish the calibration curves (24). An accuracy of 20 percent requires an impact number comparable to a minimum strength of 2500 psi to insure a minimum strength of 2000 psi.

Based on the data collected for the 18 patches evaluated, it appears that the impact hammer may be used to supplement compression tests. It should be possible, for example, to calibrate a hammer for a patching contract and use it as a strength monitor to help identify significant changes in strength at the time patches are opened to traffic and to confirm that a job is continuing satisfactorily. However, it would not be practical to use the impact hammer independently of compression tests on cylinders because it would be necessary to develop regression models to handle the many variables that affect the hammer and to include a 20 percent factor of safety.

Implications of Maturity Calculations

Recent studies support the theory that samples of concrete with the same ingredients have equal strengths at equal maturities regardless of the history of the time/temperature relationship (25,26). Maturity was determined using the Nurse-Saul Maturity Law, which is given by the expression:

$$M = \sum_{t=o}^{t=t} [T(t) - T_o]dt \quad (26)$$

where

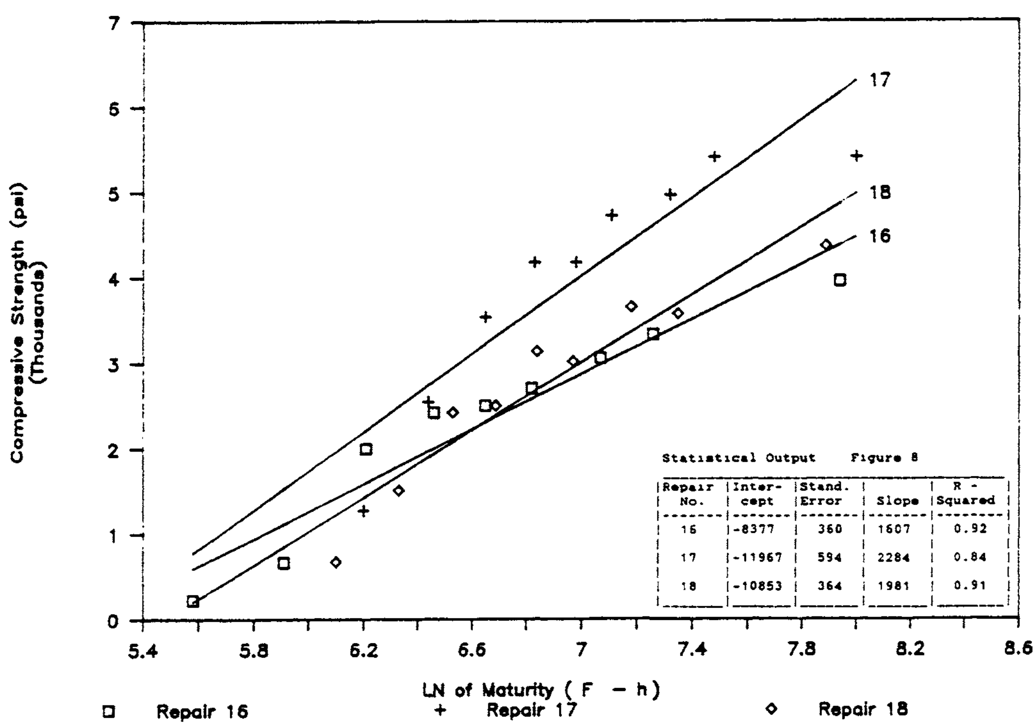
M = maturity at time t
$T(t)$ = temperature of the concrete at time t
T_o = datum temperature

Results of these studies were in many ways similar to the results of investigations conducted on the rebound hammer. It was found that the accuracy of the method depended largely upon material and curing factors. It was found that strength/maturity relationships for early age concrete are governed by

- curing temperature
- aggregate type
- cement type
- water-cement ratios.

This necessitates the development of many independent regression models to effectively use the method (26).

Based on $T_o = 0^{\circ}F$, the relationship shown above was used to calculate the maturity of the concrete in the patches and in the cylinders cured by the three methods each time cylinders were tested in compression during the first 24 hr (see Appendix F). A plot of the compressive strength of 4-in by 8-in TMC cylinders versus the natural log of the maturity of the TMC cylinders for patches Nos. 16, 17, and 18 produced the linear relationships shown in Figure 8. Note that 84 to 92 percent of the variation in strength is explained by the variation in the maturity. The results are similar to those reported by others (25,26). Also, the results are similar to those found for the impact hammer in that a good relationship was found for the concrete used in one patching contract, but the relationships did not carry over from one contract to the next because different materials were used and placement and curing conditions were different. As with the impact hammer measurements, the maturity calculations could be used to monitor the strength gain of patches on a contract. However, it would not be practical to use the maturity calculations independently of compression tests on cylinders, because it would be necessary to develop regression models to handle the many variables that affect the maturity and to include a factor of safety.



Statistical Output Figure 8

Repair No.	Intercept	Stand. Error	Slope	R - Squared
16	-8377	360	1607	0.92
17	-11967	594	2284	0.84
18	-10853	364	1981	0.91

Figure 8. TMC strength vs. natural log of maturity for patches Nos. 16, 17, and 18.

CONDITION OF PATCHES INITIALLY AND AFTER 33 TO 81 MONTHS IN SERVICE

Rating

Patches were rated shortly after the wet burlap was removed and once every 5 to 21 months thereafter (depending upon the availability of manpower) for a period of 33 to 81 months. All patches were rated in the Spring of 1988 prior to the preparation of this report.

Patch ratings were recorded on a data sheet developed by ARE, Incorporated as shown in Appendix G. Each patch was rated as follows:

- surface deterioration: 0 = none, 1 =loss of macrotexture, 2 = coarse aggregate exposed, 3 = loss of coarse aggregate
- number of cracks in longitudinal and transverse direction
- number of cracks with minor spalls (<1 in) and number of cracks with major spalls (>1 in)
- number of minor and major punchouts
- minor or severe pumping
- condition of longitudinal repair edge: good, poor
- condition of transverse repair edge: faulted (0 = none, 1 = ≤1/2", 2 = >1/2"); spalls (0 = none, 1 = ≤1, 2 = >1); and sealed (0 = none, 1 = partial failure, 2 = sealed)
- condition of transverse joints: faulted (0 = none, 1 = ≤1/2", 2 = >1/2"); spalls (0 = none, 1 = ≤1, 2 = >1); and sealed (0 = none, 1 = partial failure, 2 = sealed).

In addition to rating the patches, a 25-ft to 50-ft section of pavement upstream and downstream from the patch was rated, and the pavement in the adjacent lane was rated.

Initial Condition of Patches

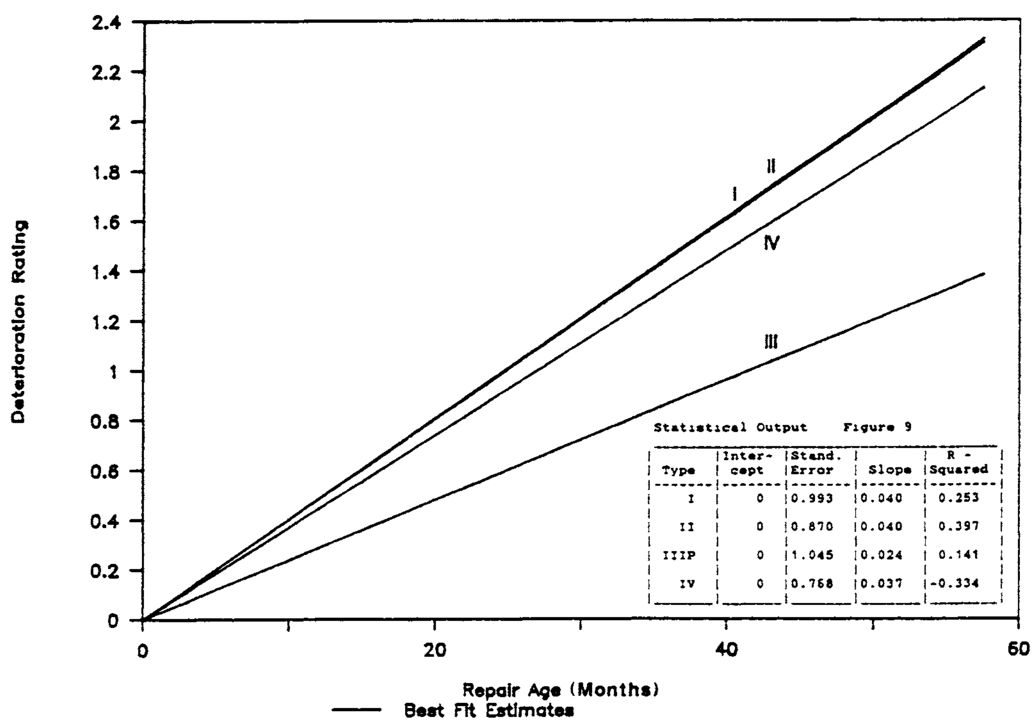
As would be expected, patches were in excellent condition when first opened to traffic. No signs of cracking or distress were recorded initially for patches opened to traffic at an age of only 6 hr. Only patch No. 14, which had a spalled repair edge when first constructed, exhibited an initial deterioration rating greater than 0.

Later Age Condition of Patches

To aid in the evaluation of the patching techniques based on the deterioration of the patches over time, a number of regressions were done in which the relationships between the ratings and selected variables were made for the different types of patches. For the regressions, deterioration was defined as D = 1/5 x surface deterioration + 1/2 (crack and spall deterioration) + pumping + faulting; where crack and spall deterioration = no. longitudinal cracks + no. transverse cracks + no. cracks with minor spalls + 3 x no. cracks with major spalls + 2 x no. spalls in worse repair edge. Pumping and faulting were not included in some regressions between rating and strength because they are not related to strength.

Deterioration vs Age

Figure 9 shows the average relationship between deterioration and age for patch Types I, II, III, and IV. It shows that all types deteriorate with age. On the average, the full-depth patches showed the most deterioration and the Type III patches the least deterioration. A bar graph that related deterioration at the last rating to patch type also showed no significant differences between the full-depth patch types. The minimum, maximum, and average deterioration at the last rating was about the same for all the full-depth patch types.



Type	Inter-cept	Stand. Error	Slope	R - Squared
I	0	0.993	0.040	0.253
II	0	0.870	0.040	0.397
IIIP	0	1.045	0.024	0.141
IV	0	0.768	0.037	-0.334

Figure 9. Deterioration vs. age for four patch types.

Since deterioration with age could be influenced by other factors such as compressive strength at 24 hr and 28 days, the cumulative number of equivalent single axle loadings, the compressive strength, and the age at which traffic was first applied to the patch, other regressions were done.

Figure 10 shows the relationship between the age at which traffic was first allowed on the patch and the deterioration at the last rating and suggests no relationship for opening at an age of 6 hr or later.

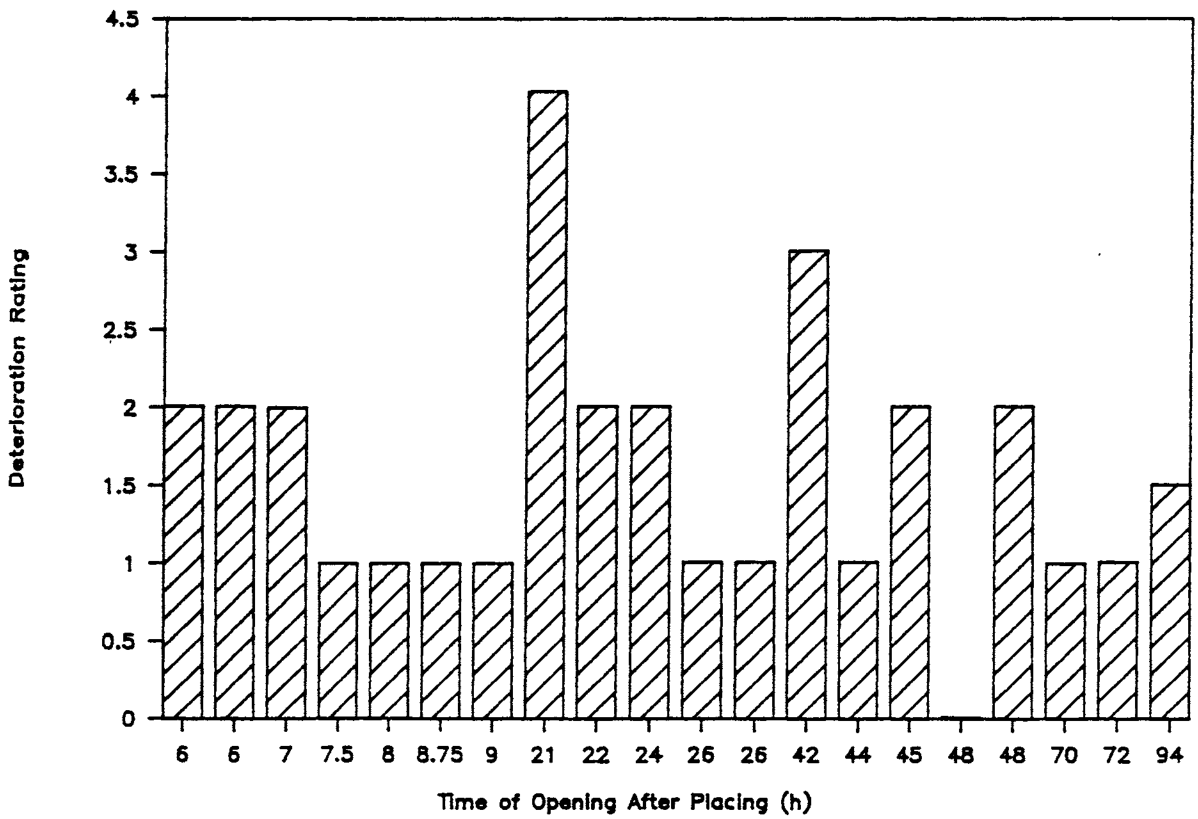


Figure 10. Deterioration at 33 to 45 months as a function of age at which patch was opened to traffic.

Deterioration vs. Strength

Figure 11 shows the relationship between 28-day TMC strength and deterioration at the last rating as reflected by surface scaling and the number of cracks and spalls. The curve that best fits the data in Figure 11 indicates deterioration is less for the patches with the highest 28-day TMC strength. But specifically, patches constructed with mixtures with a 28-day TMC strength ≤6,200 psi deteriorated the most during the 33- to 45-month evaluation period. When pumping and faulting were included in the rating, the 28-day TMC strength had less effect on the rating.

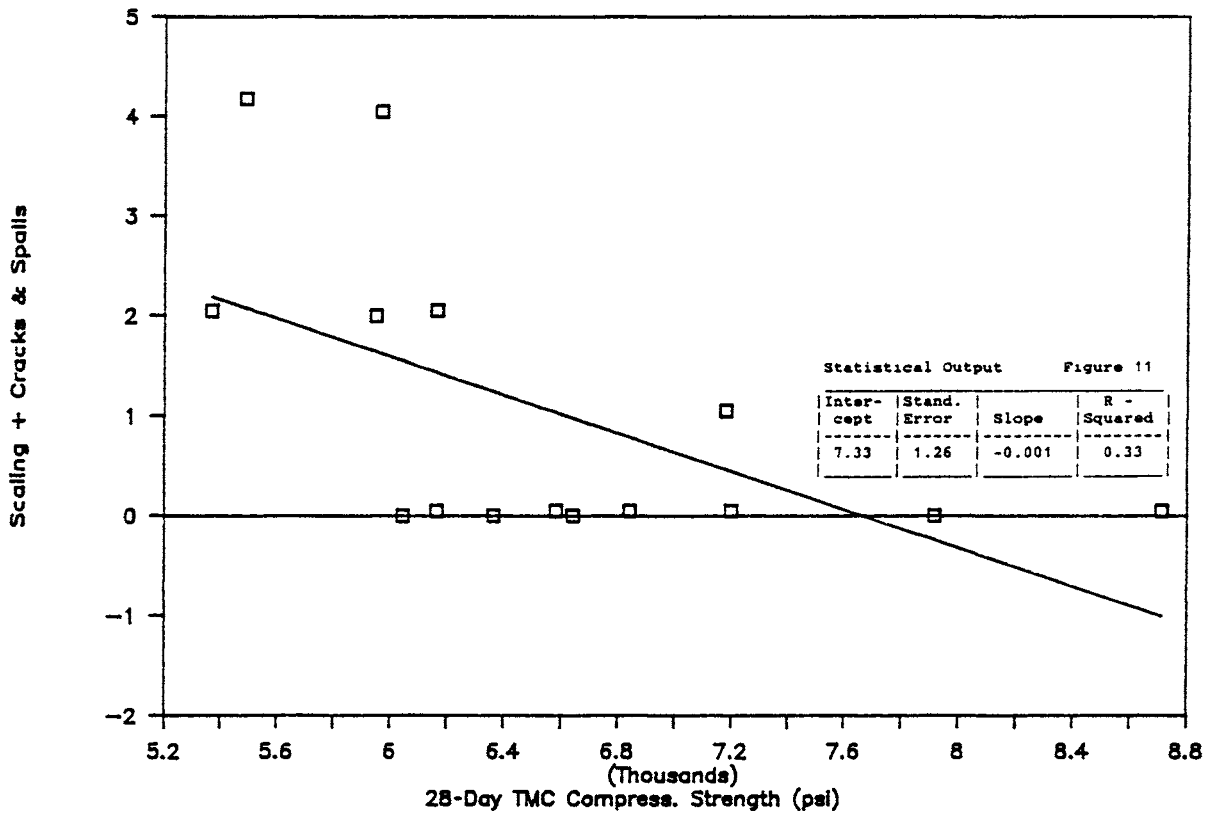


Figure 11. Deterioration as reflected by scaling and number of cracks and spalls at 33 to 45 months as a function of 28-day TMC strength.

Figure 12 shows the relationship between deterioration at the last rating, as reflected by surface scaling and the number of cracks and spalls, and the 24-hr TMC compressive strength. The curve that best fits the data indicates that as strength increases the deterioration decreases. Patches constructed with mixtures with a 24-hr TMC compressive strength $\leq$4,600 psi deteriorated the most. When pumping and faulting were included in the rating the 24-hr TMC strength had a negligible effect on the rating. In other words, deterioration as reflected by pumping and faulting is independent of 24-hr and 28-day TMC strength, but deterioration as reflected by surface scaling and the number of cracks and spalls is dependent on these strengths.

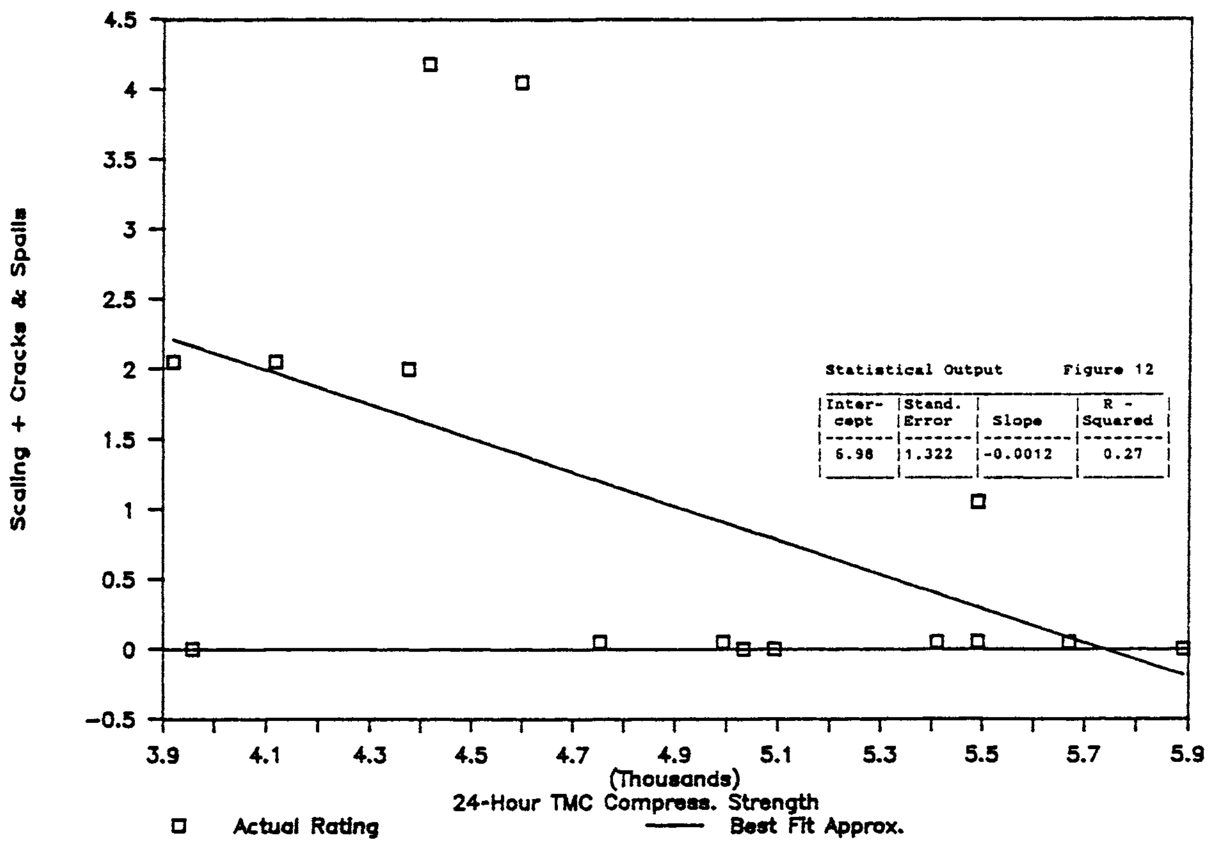


Figure 12. Deterioration as reflected by scaling and number of cracks and spalls at 33 to 45 months as a function of 24-hr TMC strength.

Figures 13 and 14 show the relationships between the TMC and the air-cured compressive strengths at the time the patches were opened to traffic and the deterioration at the last rating. There is no good relationship between deterioration and strength for ambient-cured, patch-top-cured, or TMC cylinders, which suggests that some other relation would be better, such as deterioration versus cummulative equivalent single axle loadings for various TMC strengths.

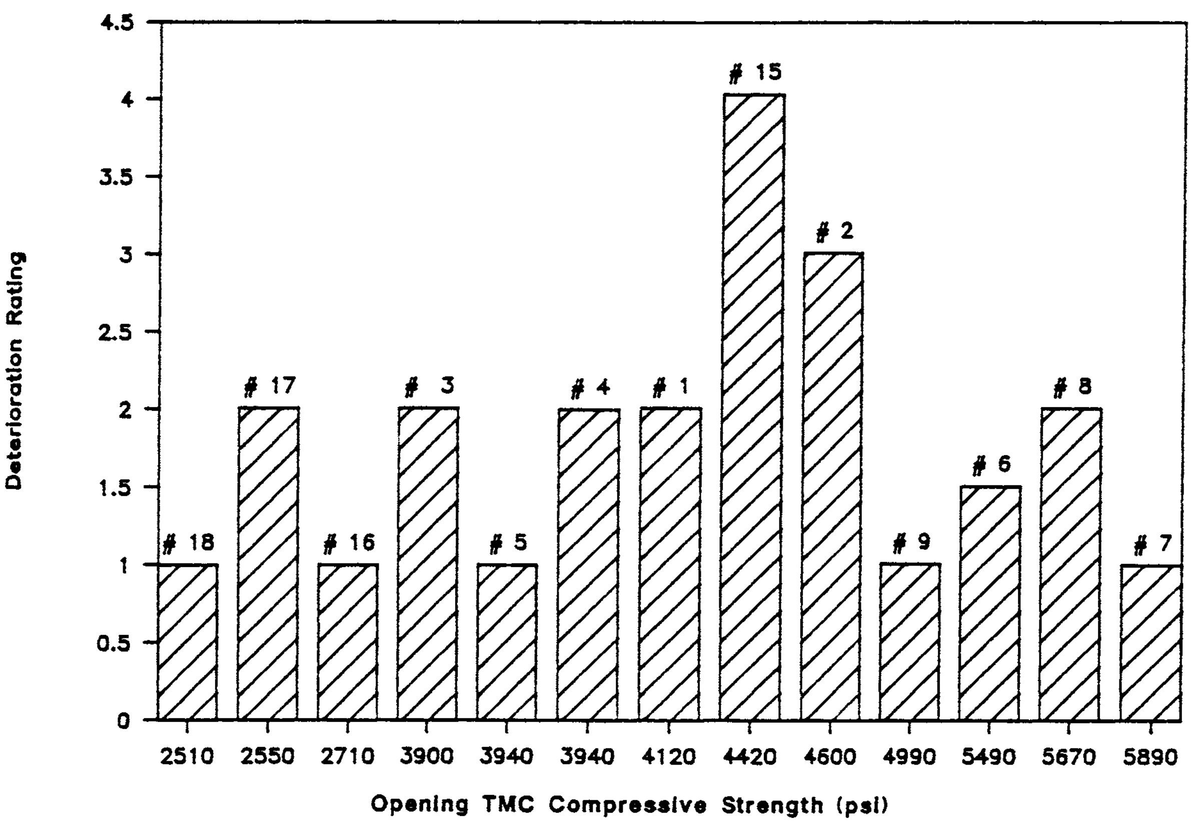


Figure 13. Deterioration at 33 to 45 months as a function of TMC strength at which patch was first opened to traffic.

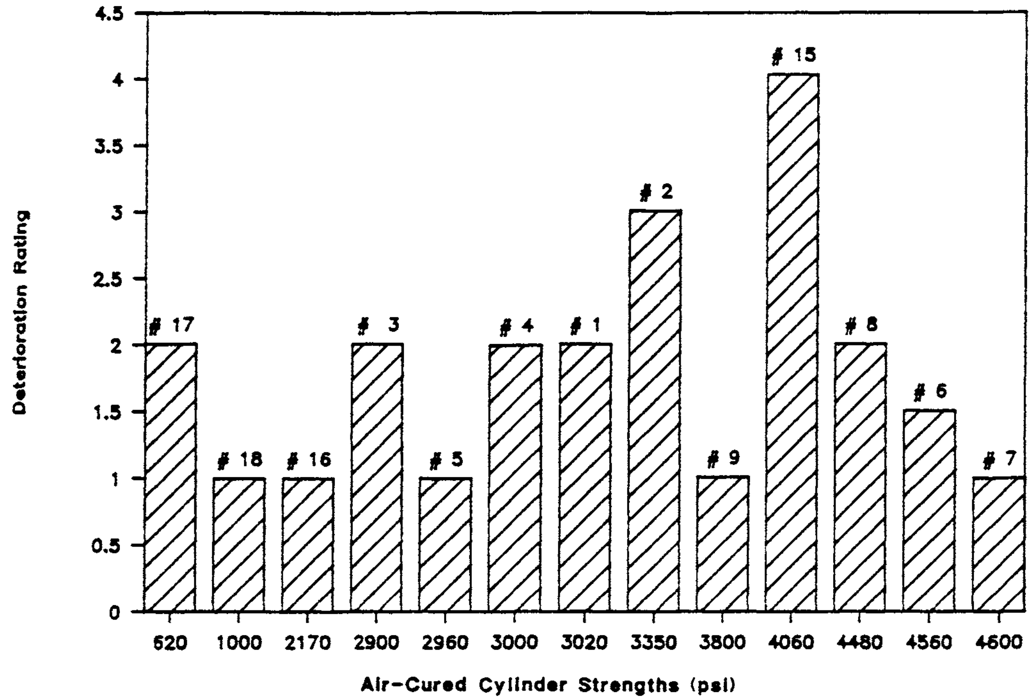


Figure 14. Deterioration at 33 to 45 months as a function of air-cured strengths at which patch was first opened to traffic.

Deterioration versus Patch Type

The data showed that on the average Type II patches fault slightly more than Type I patches, which is interesting since the purpose of the inverted tee is to minimize or prevent faulting.

Figures 15 and 16 show the relationship between the length of Type I patches and deterioration at the last rating. Figure 15 indicates that short patches show the most deterioration, which is reflected by scaling and the number of cracks and spalls. With the exception of patch No. 13A, which is not included in Figure 15 because it deteriorated as a result of poor construction practice, patches over 3 ft in length did not deteriorate much during the evaluation period. Figure 16 shows that deterioration such as pumping and faulting increases as the length of the patch increases.

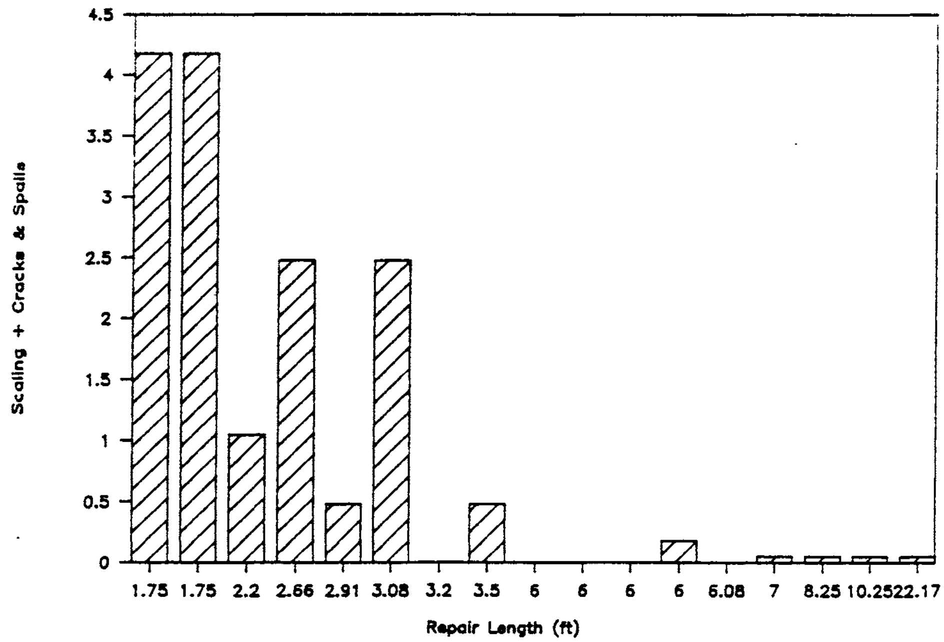


Figure 15. Deterioration as reflected by scaling and number of cracks and spalls at 33 to 81 months as a function of length of Type I patches.

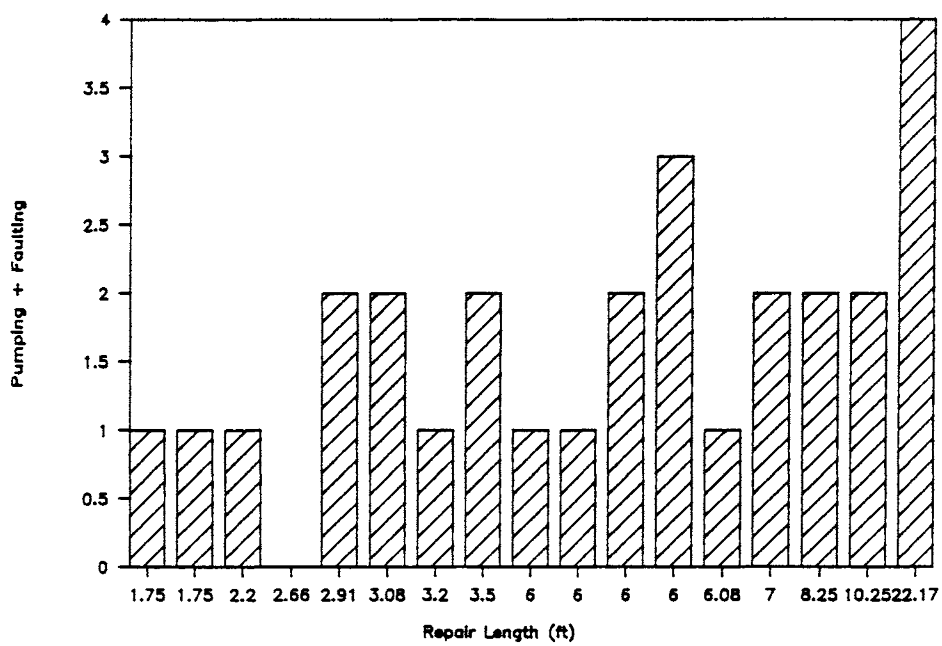


Figure 16. Deterioration as reflected by pumping and faulting at 33 to 81 months as a function of the length of Type I patches.

Figure 17 shows that a greater percentage of Type I patches (greater than Type II or Type IV-A patches) were pumping at the last rating done at 33 to 81 months . This is interesting since all Type I patches were placed on cement-treated bases, and the other patches were placed on aggregate base. If pumping were given a heavier weight in the deterioration rating, Type I patches would show the most deterioration and Type IV patches the least deterioration (see Figures 9 and 17), which supports the Department's move toward the use of more Type lV (currently called Type II with dowels) and fewer Type I and II patches.

None of the patch types showed a relationship between the degree to which the transverse joints were sealed over the life of the patches and the degree of pumping at the last rating. However, water can enter and leave through the longitudinal joints, which were not rated.

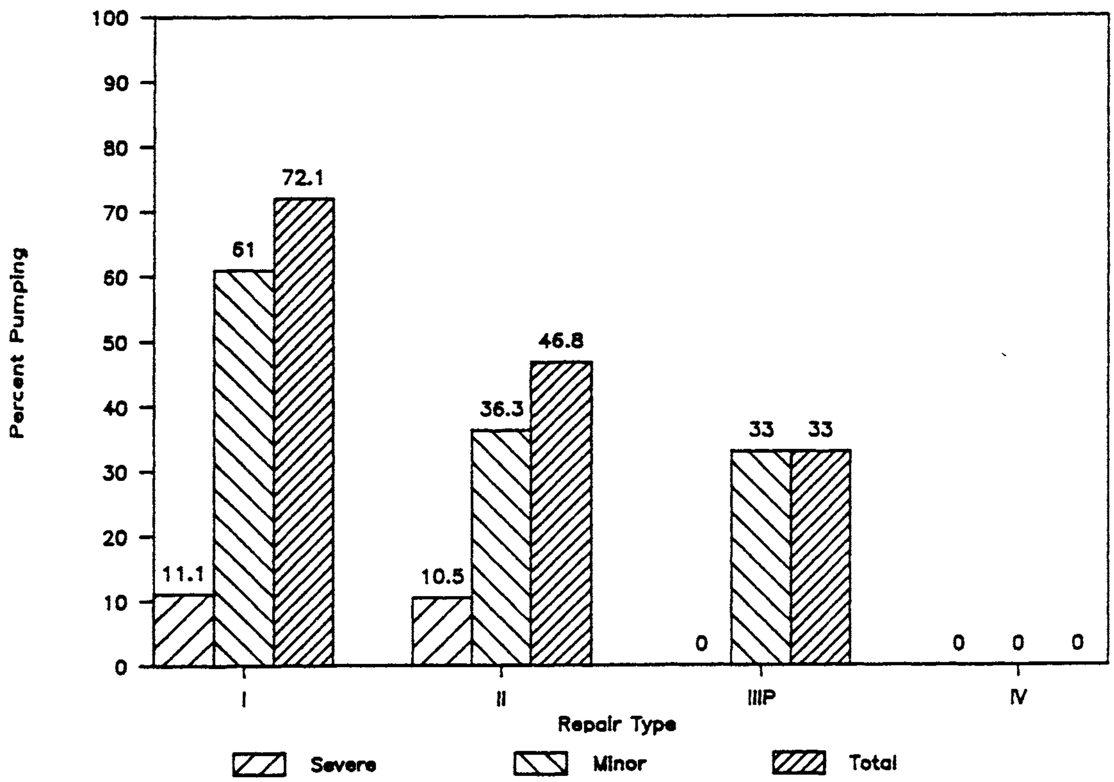


Figure 17. Percent of patches pumping at 33 to 81 months.

Deterioration versus 18 kip Cumulative Equivalent Single Axle Loading

It has been shown that the 18 kip cumulative equivalent single axle load has more effect on deterioration than ADT. Therefore, the relationship between deterioration and the 18 kip cumulative equivalent single axle load was examined from the standpoint of the age at which the patches were first subjected to traffic, the TMC strength at which the patches were first subjected to traffic, the TMC strength at 24 hours and 28 days, and the type of patch.

Figure 18 shows the deterioration versus cumulative equivalent single axle loadings for three ages at which the patches were opened to traffic. Figure 18 indicates that most deterioration occurs in patches opened at 9 hr or less of age.

Figure 19 shows the deterioration versus cumulative equivalent single axle loading for the TMC strength at which the patches were first opened to traffic. Figure 19 indicates that patches with a TMC strength above 4,500 psi when opened to traffic had deteriorated less at 33 to 45 months of age.

Figure 20 shows the deterioration versus cumulative equivalent single axle loadings for three patch types and indicates that Type II patches show the most deterioration and Type III-P patches show the least deterioration.

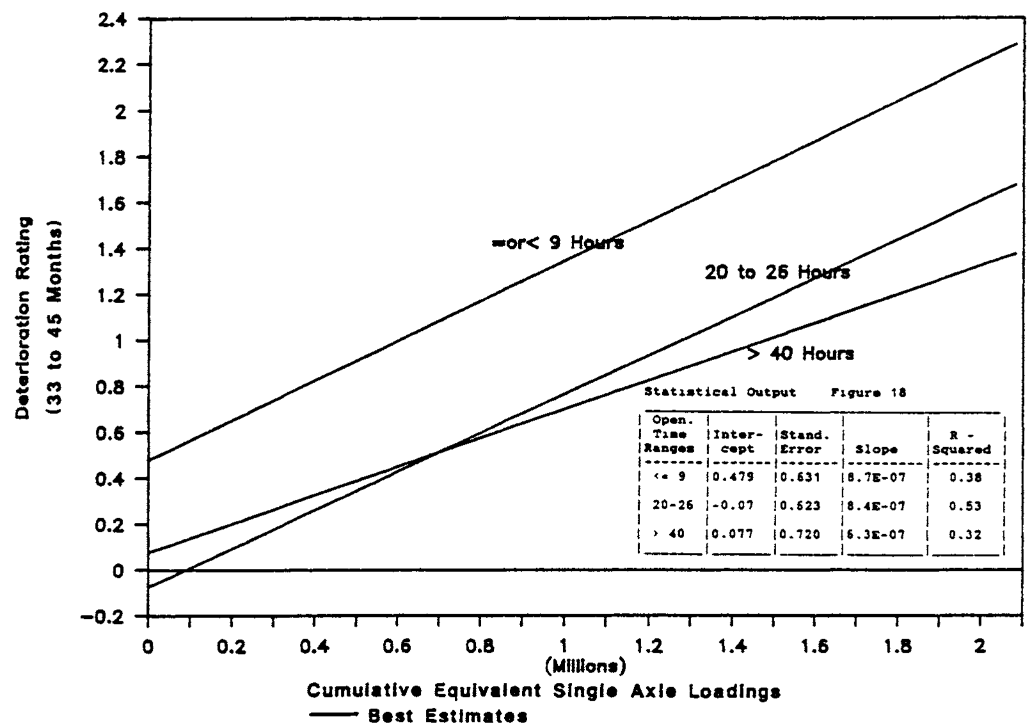


Figure 18. Deterioration at 33 to 45 months vs. 18 kip cumulative equivalent single axle loadings for three ages at which patches were first opened to traffic.

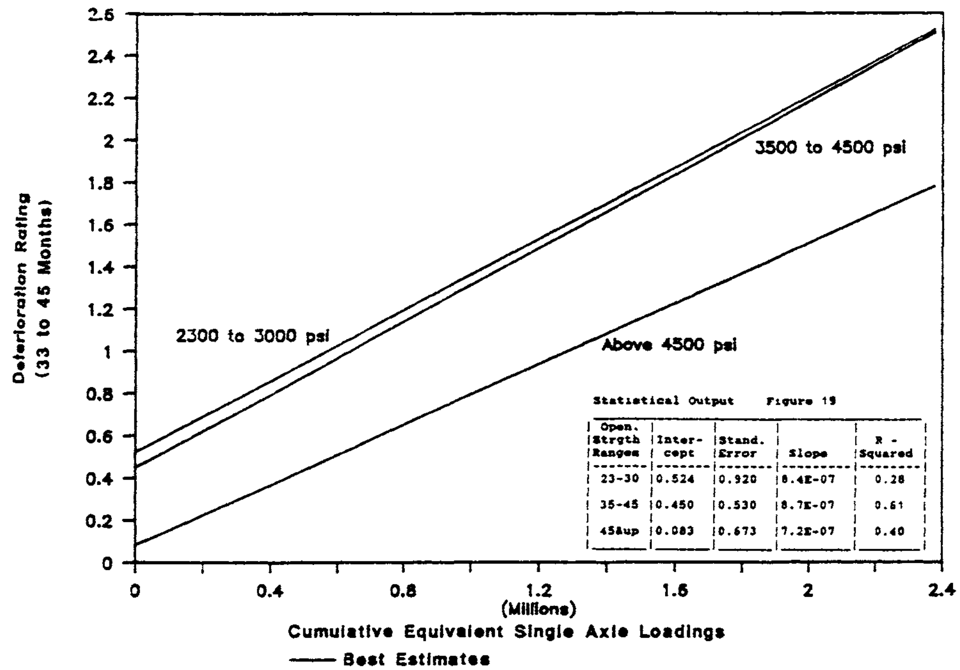


Figure 19. Deterioration at 33 to 45 months vs. 18 kip cumulative equivalent single axle loadings for TMC strengths at which patches were first opened to traffic.

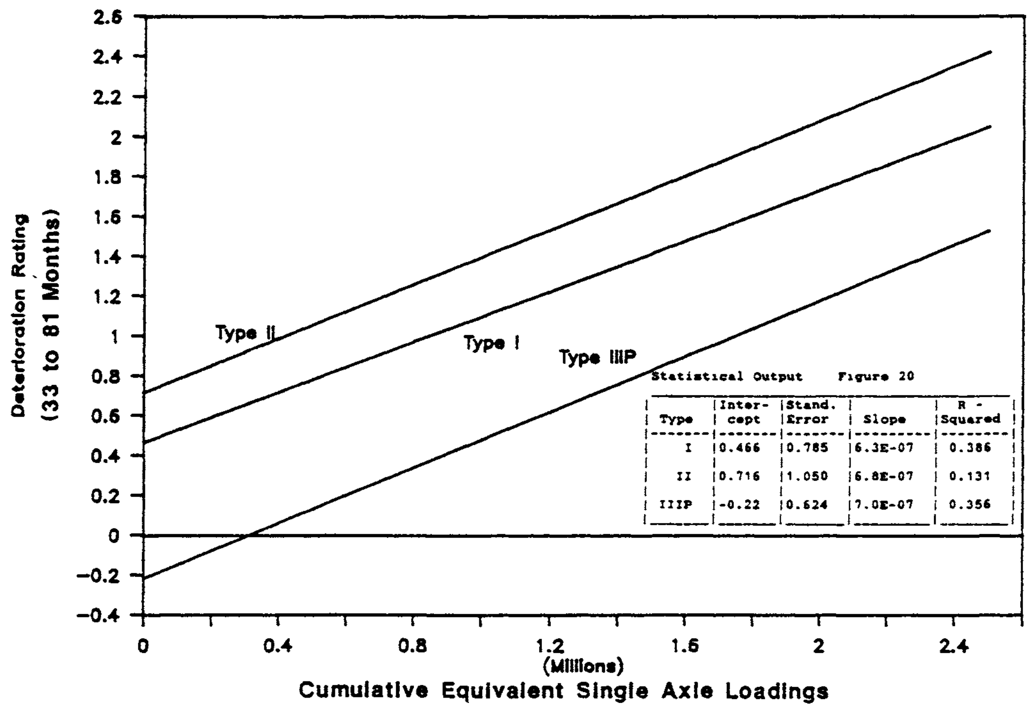


Figure 20. Deterioration at 33 to 81 months vs. 18 kip cumulative equivalent single axle loadings for three patch types.

CONCLUSIONS

1. A cylinder must be temperature matched cured to provide an accurate estimate of the early age compressive strength of a full-depth PCC patch.

2. The 28-day compressive strengths of both field-cured and moist-cured cylinders that are not temperature match cured are similar to those of cylinders which are temperature match cured for the first 24 hours and subsequently field cured or moist cured.

3. Impact hammers and maturity calculations can be used to estimate the compressive strength of a patch once suitable calibrations are made for the concrete mixtures and placement conditions.

4. Type I patches having a length ≤ 3 ft deteriorate much more rapidly than longer patches.

5. When compared on the basis of the number of 18 kip cumulative equivalent single axle loadings, patches opened to traffic in 6 to 9 hr showed more deterioration than patches opened at later ages.

6. When compared on the basis of the number of 18 kip cumulative equivalent single axle loadings, patches opened to traffic with a TMC compressive strength greater than 4,500 psi showed the least deterioration.

7. When compared on the basis of the number of 18 kip cumulative equivalent single axle loadings, Type III-P patches showed the least deterioration, and Type II patches showed the most deterioration at 33 to 81 months of age.

8. The three types of full-depth patches evaluated -- Type I, II and and IV -- performed about the same over the 33- to 81-month evaluation period, which suggests that the decision as to patch type should be based on cost. However, if pumping were given a heavier weight in the deterioration rating, Type I patches would show the most deterioration and Type IV patches the least deterioration, which supports the Department's move toward the use of more Type IV (currently called Type II with dowels) and fewer Type I and II patches.

9. The current practice of allowing a minimum of 6 hr of cure prior to subjecting full-depth patches to traffic appears to be reasonable for the placement temperatures, mixture proportions, and traffic conditions studied.

RECOMMENDATIONS

1. The current concrete pavement patching techniques being used in Virginia appear to be reasonable and should be continued.

2. The performance of Type II patches with dowels and Type II continuously reinforced concrete pavement patches should be evaluated because they were not evaluated in this study.

3. Although some reduction in service life can be expected, a study should be made of the effect of opening patches to traffic in less than 6 hr.

4. The Department should use the impact hammer or maturity calculations to estimate the compressive strength of patches so that more accurate decisions can be made as to when to open patches to traffic and when not to patch because compressive strengths cannot be obtained within a given lane closure time and with anticipated curing conditions.

5. The Department should continue to evaluate the patches to better assess the relative long-term performance of the patch types.

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REFERENCES

1. "Mileage Tables for the State Highway System," Virginia Department of Highways & Transportation, Richmond, Virginia, December 31, 1987.

2. "Historic Pavement Site of CPR Demo," American Concrete Pavement Association, Newsletter, Vol. 19, No. 5, 1983.

3. Creech, M. F., "Partial-Depth Precast Concrete Patching," VHTRC 75-R13, Virginia Highway & Transportation Research Council, Charlottesville, Virginia, October 1974.

4. Tyson, S. S., and K. H. McGhee, "Deterioration of Jointed Portland Cement Concrete Pavements," VHTRC 76-R19, Virginia Highway & Transportation Research Council, Charlottesville, Virginia, November 1975.

5. Tyson, S. S., "Full-Depth Repair of Jointed PCC Pavements: Cast-in-Place and Precast Procedures," VHTRC 76-R44, Virginia Highway & Transportation Research Council, Charlottesville, Virginia, March 1976.

6. ____________, "Partial-Depth Repair of Jointed PCC Pavements: Cast-in-Place and Precast Procedures," VHTRC 77-R37, Virginia Highway & Transportation Research Council, Charlottesville, Virginia, January 1977.

7. McGhee, K. H., "Evaluation of the Effectiveness of Pressure Relief Joints in Reinforced Concrete Pavements," VHTRC 76-R48, Virginia Highway & Transportation Research Council, Charlottesville, Virginia, March 1976.

8. Wyant, D. C., "Evaluation and Performance of Concrete Patching Materials," VHTRC 84-R35, Virginia Highway & Transportation Research Council, Charlottesville, Virginia, April 1984.

9. "Bid Proposal Job Designation 252-81," Virginia Department of Highways & Transportation, Richmond, Virginia, October 20, 1981, (bid opening).

10. "Sure Cure II Cylinder Mold System," Products Engineering, Post Office Box 1096, Boulder, Colorado.

11. "Manual for Quality Control for Plants and Production of Precast Prestressed Concrete Products," Prestressed Concrete Institute, Chicago, Illinois, Publication MNL-116-77, p. 67.

12. Brown, H. E., "A Resume of the Published Work on the Schmidt Concrete Test Hammer," Virginia Council Highway Investigation and Research, September 1962.

13. Malhotra, V. M., "Testing Hardened Concrete: Nondestructive Methods," American Concrete Institute, 1976, pp. 9-25.

14. "Rebound Number of Hardened Concrete," American Society for Testing and Materials, Inc., ASTM C805-79, ASTM Part 14.

15. Sprinkel, M. M., Working Plan -- "Evaluation of Concrete Pavement Patching Techniques," VHTRC 84-WP23, Virginia Highway and Transportation Research Council, Charlottesville, Virginia, April 1984.

16. "Bid Proposal Job Designation 105-84," Virginia Department of Highways and Transportation, Richmond, Virginia, March 20, 1984, (bid opening).

17. Carmichael, R. F., A. H. Meyer, L. L. Caldwell and B. F. McCullough, "Rapid Replacement of Portland Cement Concrete Pavement Segments," NCHRP Project 10-24, Transportation Research Board, Washington, D. C., March 1988.

18. McGhee, Kevin K., "Comparison of the Compressive Strength of Portland Cement Concrete in a Repair to That in 4 In. x 8 In. Test Cylinders," Virginia Highway & Transportation Research Council, Charlottesville, Virginia, September 1985.

19. "Making and Curing Concrete Test Specimens in the Field," ASTM Designation C31-84, American Society for Testing and Materials, Philadelphia, Pennsylvania, 1984.

20. Virginia Department of Highways and Transportation Road and Bridge Specifications, 1982, pp. 577-578.

21. Wiss, Jenny, Elstner and Associates, Inc., Energy Efficient Accelerated Curing of Concrete - A State-of-the Art Review, Prestressed Concrete Institute, Chicago, April 1981.

22. Sprinkel, M. M., "Superwater Reduced Concrete Pavements and Bridge Deck Overlays," TRR No. 720, Washington, D. C., 1979, p. 26.

23. Troxell, G. E., E. D. Harmer, and J. W. Kelly, Composition and Properties of Concrete, 2nd Ed., McGraw-Hill Civil Engineering Series, New York, 1968.

24. Malhotra, V. M., "Testing Hardened Concrete: Nondestructive Methods," Journal of American Concrete Institute, 1976, pp. 9-25.

25. Halstead, Woodrow J. and Celik Ozyildirim, Tests for Early Acceptance of Concrete," VHTRC 86-R2, Virginia Highway & Transportation Research Council, Charlottesville, Virginia, July 1985.

26. Parsons, Thomas J., and Tarun R. Naik, "Early Age Concrete Strength Determination by Maturity," Journal of Concrete International, February 1985.

APPENDIX A

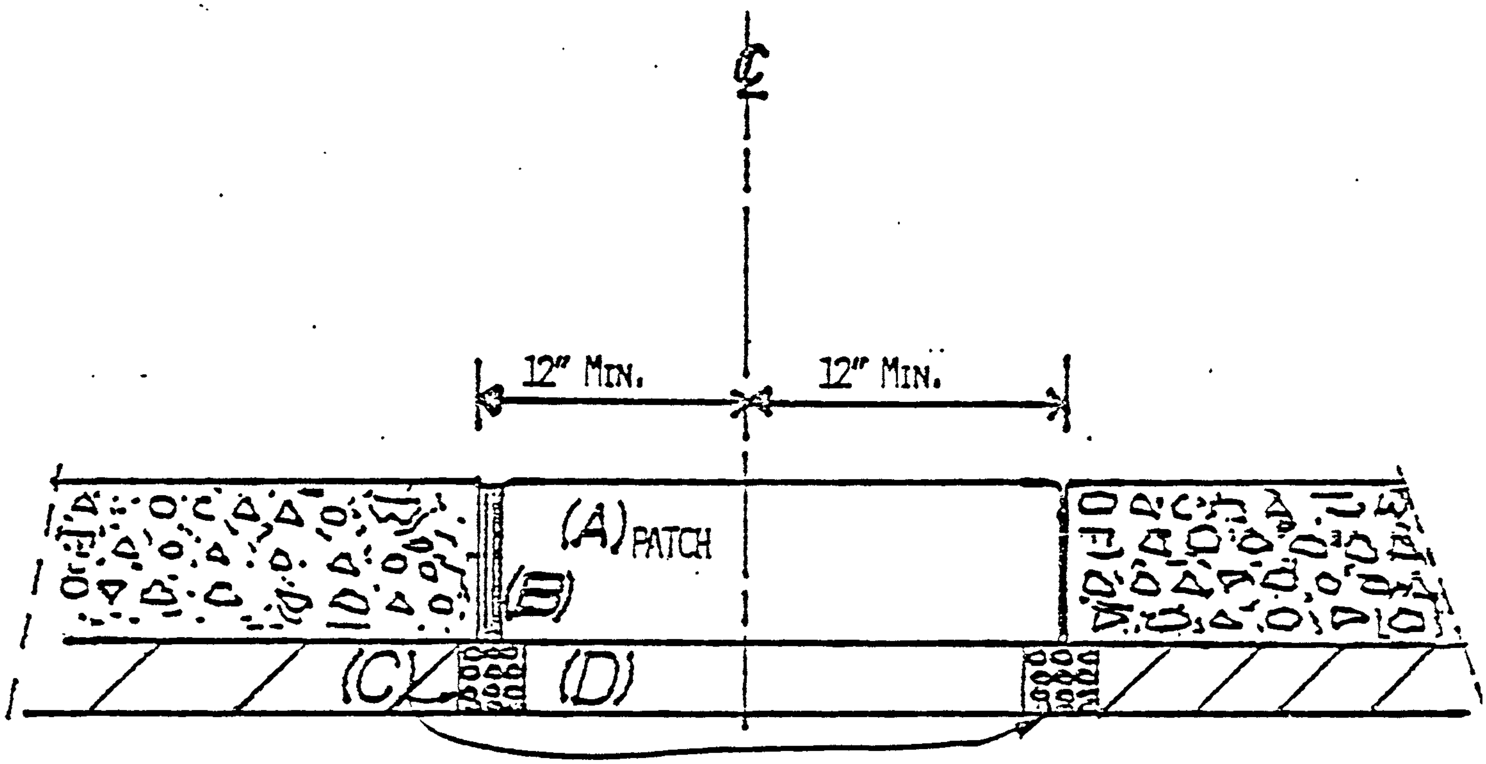
Design Standards for Patching Portland Cement Concrete Pavement

CONCRETE PAVEMENT REPAIR PROJECT FOR

I-64 Cities of Virginia Beach & Chesapeake

PROPOSED METHOD, FULL WIDTH FULL DEPTH
CONCRETE PATCH, ON SOIL CEMENT BASE
Type I

Repairs shall be performed in accordance with this Typical Section, notes and Special Provisions herein.



A. Full length full depth joint replacement will be measured in square yards of pavement surface replaced in accordance with Special Provision for Patching Portland Cement Concrete Pavement herein. Pavement shall be sawed full depth. Rounded or beveled transverse joints shall be provided adjacent to the undisturbed pavement to allow installation of hot pour sealant at a depth of not less than 1/4 inch nor more than 1/2 inch.

B. Preformed bituminous expansion joint filler shall be placed flush with and firmly against the runoff side of the adjacent pavement. The expansion material shall be approximately 1/2 inch in thickness and shall have a depth and width equal to that of the adjacent pavement except that the top of the expansion material shall be not less than 1/4 inch nor more than 1/2 inch below the top of the finished pavement.

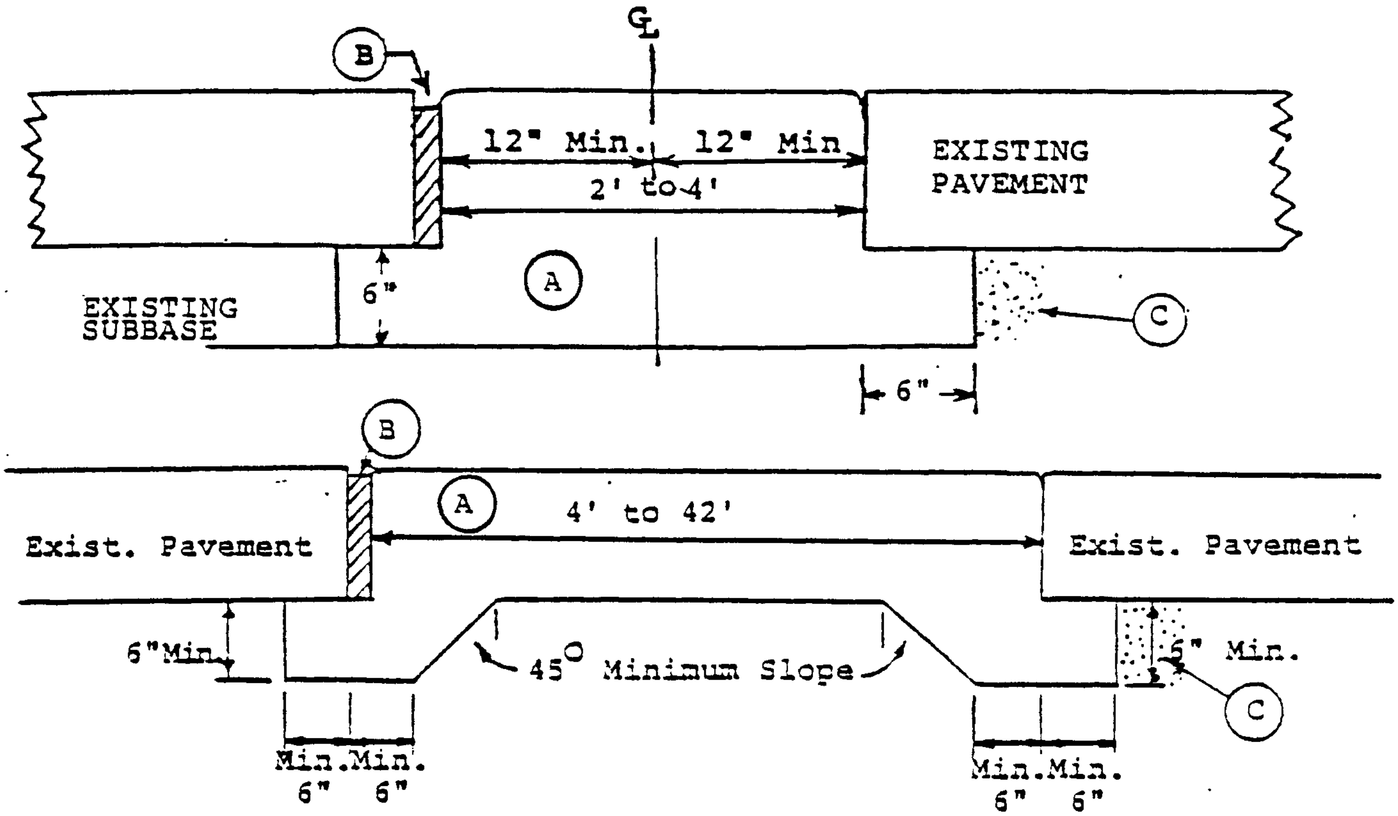
C. When authorized by the Engineer, underdrains shall be installed in accordance with this sketch and Special Provisions for Underdrains for Pavement Repair as directed by the Engineer.

D. Unless otherwise directed by the Engineer, existing soil cement subbase shall not be disturbed.

PROPOSED METHOD, FULL WIDTH FULL DEPTH
CONCRETE PATCH
TYPE II

Repairs shall be performed in accordance with this Typical Section, notes and Special Provisions herein.

TYPICAL SECTION
ELEVATION VIEW



A. Full length full depth joint replacement will be measured in square yards of pavement surface replaced in accordance with Special Provision for Patching Portland Cement Concrete Pavement herein. Pavement shall be sawed full depth. Rounded or beveled transverse joints shall be provided adjacent to the undisturbed pavement to allow installation of hot pour sealant at a depth of not less than 1/4 inch nor more than 1/2 inch. In the event the length of the patch is 20 feet or more, the Contractor shall install welded wire fabric conforming to Section 228 of the Specifications in accordance with Standard PR-2 reinforced concrete pavement.

B. Preformed bituminous expansion joint filler shall be placed flush with and firmly against the runoff side of the adjacent pavement. The expansion material shall be approximately 1/2 inch in thickness and shall have a depth and width equal to that of the adjacent pavement except that the top of the expansion material shall be not less than 1/4 inch nor more than 1/2 inch below the top of the finished pavement.

C. When authorized by the Engineer, underdrains shall be installed in accordance with this sketch and Special Provisions for Underdrains for Pavement Repair as directed by the Engineer.

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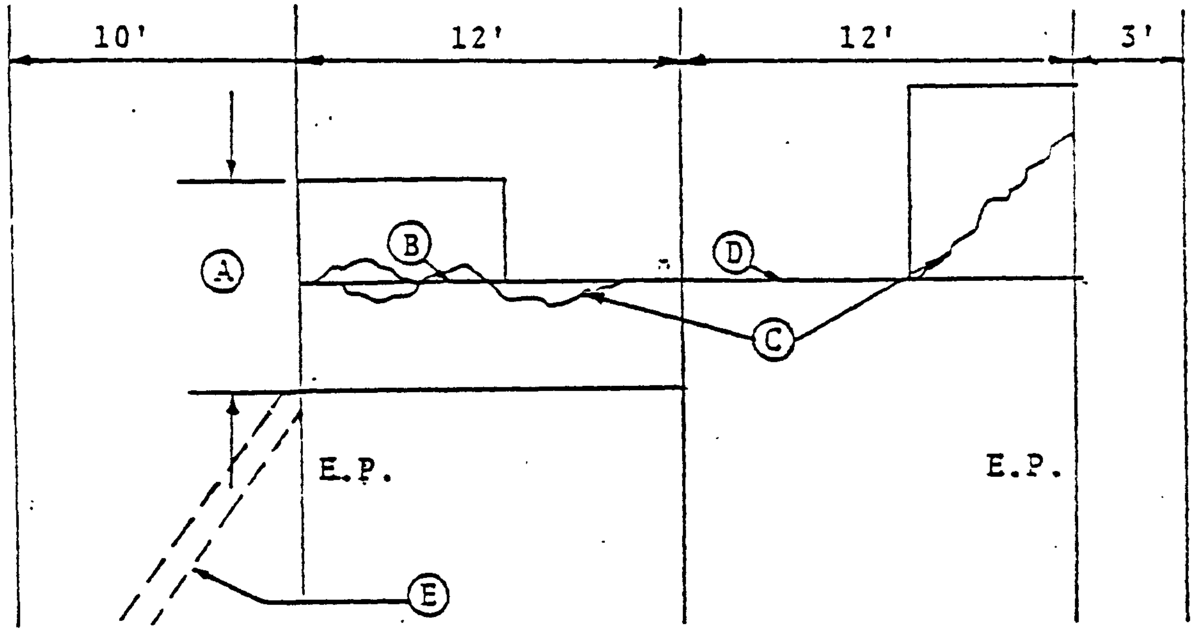
1982

PROPOSED METHOD, FULL DEPTH PAVEMENT SPALL REPAIR TYPE III-F

Repairs shall be performed in accordance with this typical section, and at the locations designated by the Engineer.



A. Full Depth Pavement Spall Repair will be measured in square yards of pavement surface replaced in accordance with Special Provision for Patching Portland Cement Concrete Pavement herein. The minimum size of a full depth spall repair shall be 2 feet by 2 feet. Full Depth Pavement Spall Repair shall be saw cut to a minimum depth of 2 inches and removed full depth for the required distance. Pneumatic hammers shall not be heavier than nominal 35 pound class for the removal of concrete in Full Depth Pavement Spall Repair. Faces of all pavement not being faced with bituminous joint filler shall be bonded with Type EP-4 bonding epoxy prior to the placement of new concrete.

When the spalled area exceeds 8 feet as measured parallel to the joint, the pavement spall shall be saw cut full depth and removed full depth to the longitudinal joint and will be repair and paid for in accordance with the full depth concrete repairs

B. Preformed bituminous expansion joint filler shall be placed in alignment with existing transverse joint in existing pavement. The expansion material shall be approximately 1/2 inch in thickness and shall have a depth and width equal to that of the adjacent pavement except that the top of the expansion material shall be not less than ¼ inch nor more than 1/2 inch below the top of the finished pavement. After completion of patching operation, hot pour sealant shall be applied in accordance with Standard PR-2.

C. Denotes spall.

D. Existing joint.

E. When authorized by the Engineer, underdrains shall be installed in accordance with this sketch and Special Provisons for Underdrains for Pavement Repair as directed by the Engineer.

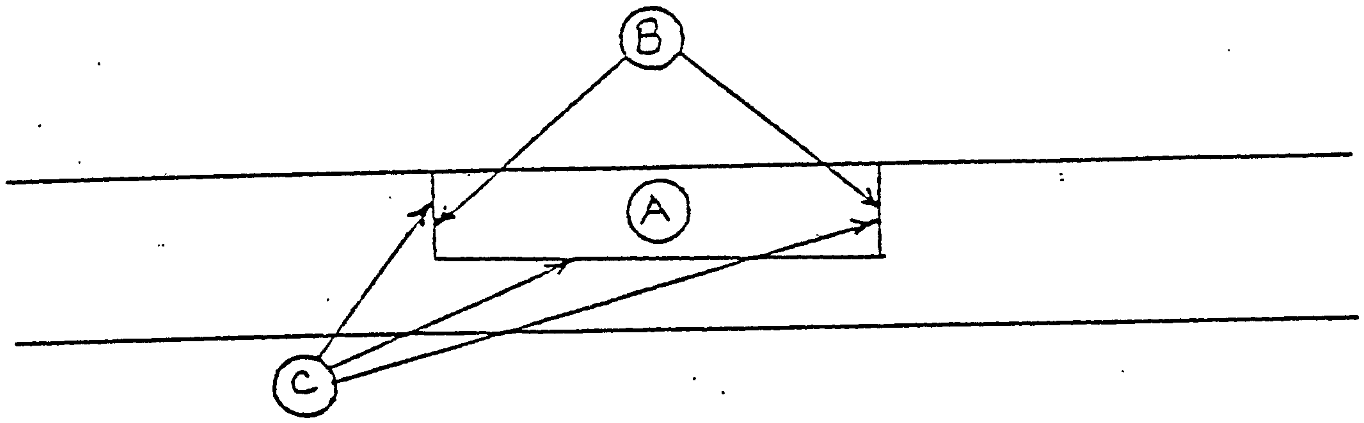
CONCRETE PAVEMENT REPAIR

Proposed Method, Variable Width and Length
Partial Depth Pavement Spall Repair

Type III-P

Replacement shall be performed in accordance with this typical section, notes, and Special Provision herein.

TYPCIAL SECTION
ELEVATION VIEW



A. Area of concrete pavement failure to be removed and replaced. Replacement will be measured in square yards of pavement surface. Pavement shall be removed to a depth that provides sound concrete with the maximum depth of any patch being no more than 4". If sound concrete is not reached at the 4" depth, the entire depth of the slab shall be removed and repaired and paid for in accordance with full depth concrete repairs.

B. Existing pavement at the area of failure shall be sawed perpendicular to the pavement for a depth of 3". The area of failure shall be removed by means of a jack hammer or other methods approved by the Engineer that will not damage the adjacent pavement. No patch shall be any less than 12" in width.

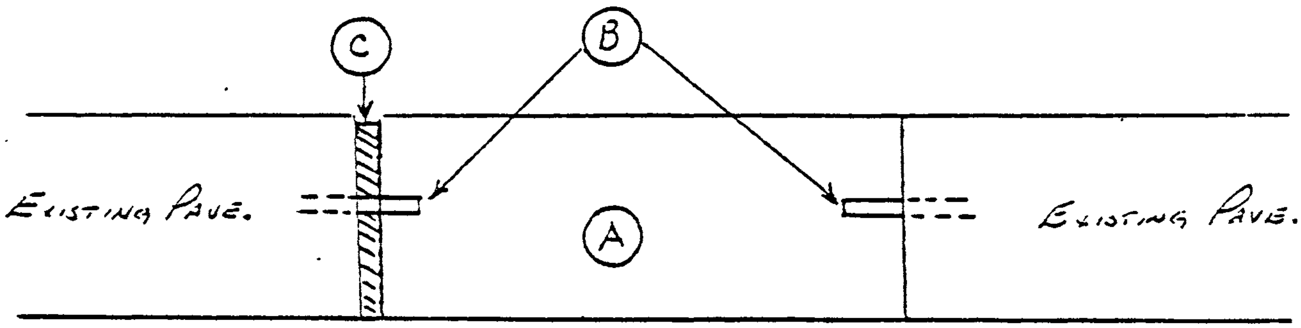
C. After removal of area of failure the entire area shall be thoroughly cleaned with compressed air. Prior to placement of concrete the area shall be moistened and painted with a cement slurry.

CONCRETE PAVEMENT REPAIR

Proposed Method, Full Lane Width and Depth Reinforced Concrete Slab Replacement, on Aggregate Base Type IV-A

Replacement shall be performed in accordance with this typical section, notes, and Special Provisions herein.

TYPICAL SECTION
ELEVATION VIEW



A. Reinforced concrete pavement slabs to be removed and replaced in kind. Replacement will be measured in square yards of pavement surface replaced in accordance with Special Provisions and Specifications for placing PR-2 reinforced concrete pavement. In the areas from which concrete has been removed, the subgrade shall be dressed, brought to grade and compacted. Unsuitable subbase material shall be removed, disposed of and replacement with material in accordance with Section 308. Rounded or beveled transverse joints shall be provided to allow installation of hot pour sealant at a depth of not less than 1/4" and not more than 1/2".

B. The load transfer devices shall be left intact, straightened and utilized for tying in the replaced slab or replaced with an approved load transfer device.

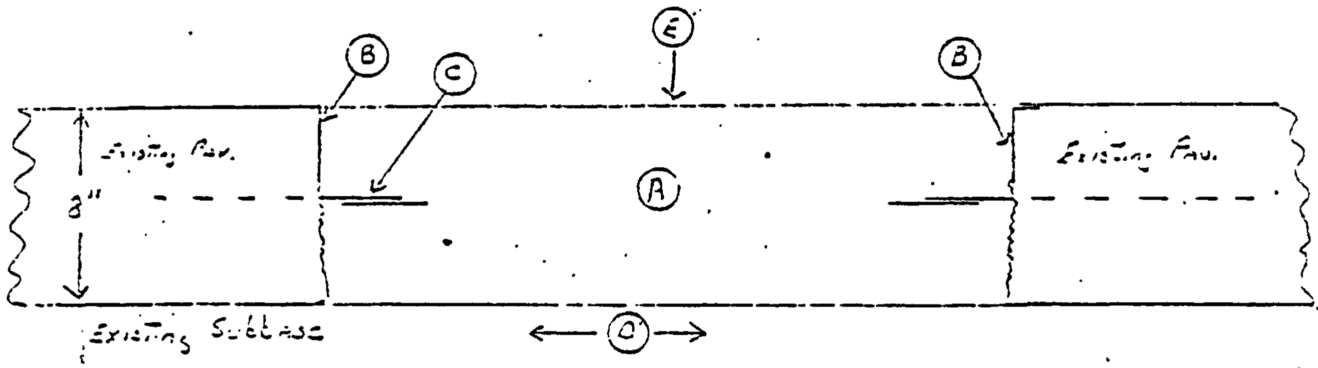
C. Preformed bituminous expansion joint filler shall be placed against the run off side of the adjacent pavement in accordance with Specifications and Standards for placing transverse expansion joint material. The expansion material shall be approximately 3/4" in thickness and shall be a depth and width equal to that of the adjacent pavement except the top of the expansion material shall be not less than 1/4" nor more than 1/2" below the top of the finished pavement.

CONCRETE PAVEMENT REPAIR PROJECT
I-64 James City County

Proposed Method, Full Width-Full Depth
Concrete Pavement Replacement - WB MP 5.47
James City County
Site 2

Replacement shall be performed in accordance with this typical section, notes, and Special Provisions herein.

TYPICAL SECTION
ELEVATION VIEW



A. One (1) 100' X 24' and one (1) 150' X 24' continuously reinforced concrete pavement slab to be removed and replaced in kind. Replacement will be measured in square yards of pavement surface. Replaced in accordance with Special Provisions and Specifications for placing PR-3 continuously reinforced (steel bar) concrete pavement. Pavement shall be removed to full depth.

B. Existing pavement at the area of failure shall be sawed perpendicular to the pavement near the approximate elevation of the existing longitudinal bars. Immediately above the existing longitudinal bars to the bottom of the slab the concrete pavement shall be removed by means of a jack hammer or other methods approved by the Engineer. The longitudinal bars extending from the existing pavement shall be cleaned to the satisfaction of the Engineer.

C. A sufficient length of bars as required by our Specifications for splicing shall be left in place for continuing the steel through the replaced slab.

D. The subbase under the pavement repair areas shall be graded and brought to grade and mechanically compacted using suitable base material as directed by the Engineer.

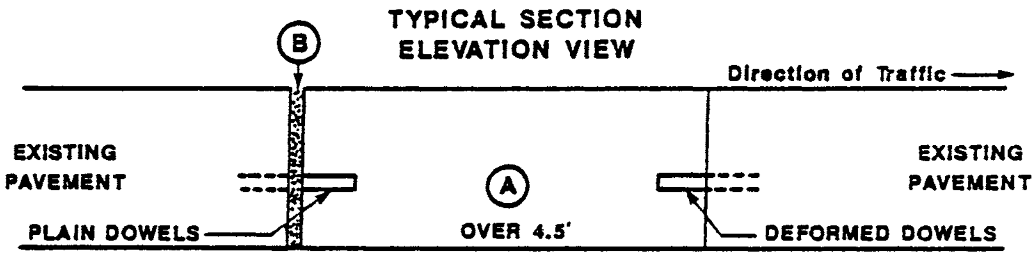
E. The finished surface shall be grooved to match the existing pavement.

F. Shoulders which will become low after pavement replacement shall be corrected by paving with bituminous concrete S-5. This paving shall be performed by means of a machanical paver.

CONCRETE PAVEMENT REPAIR

PROPOSED METHOD, FULL-WIDTH, FULL-DEPTH,
CONCRETE PATCH
TYPE II

Repairs shall be performed in accordance with this Typical Section, notes, and Special Provisions herein.



A. Full-width, full-depth, joint replacement will be measured in square yards of pavement surface replaced in accordance with the Special Provision for Patching Portland Cement Concrete Pavement herein. Pavement shall be sawed full depth and sawcuts will not be permitted to extend into the adjacent concrete except where that concrete is also to be removed. Rounded or beveled joints shall be provided adjacent to the undisturbed pavement to allow installation of joint sealant material. In the event the length of the patch is 20 feet or more, the Contractor shall install welded wire fabric conforming to Section 228 of the Specifications in accordance with Standard PR-2 reinforced concrete pavement.

B. Preformed bituminous expansion joint filler shall be placed flush with and firmly against the runoff side of the adjacent pavement. The expansion material shall be approximately 1/2 inch in thickness and shall have a depth and width equal to that of the adjacent pavement except that the top of the expansion material shall be not less than 1/4 inch nor more than 1/2 inch below the top of the finished pavement. Bond Breaker: 1/8 inch x full depth preformed bituminous or other approved bond breaker shall be installed on all longitudinal joints against the existing concrete.

C. The cost of furnishing and installing dowels is to be included in price bid for Type II patches.

1. The dowels shall have a length of 18 inches and a diameter of 1 1/4 inches. Plain bars shall be used on the expansion end and deformed bars shall be used on the fixed end of the patch.

2. Holes slightly larger than the diameter of the dowels shall be drilled 9 inches into the face of the existing slab starting 12 inches from either edge and then on 12 inch centers for a total of 11 dowels per face, 22 per patch. The holes shall be located mid-depth of the slab. The dowels shall be carefully aligned (within 1/4 inch) with the direction of the pavement and parallel (within 1/4 inch) to the plane of the surface.

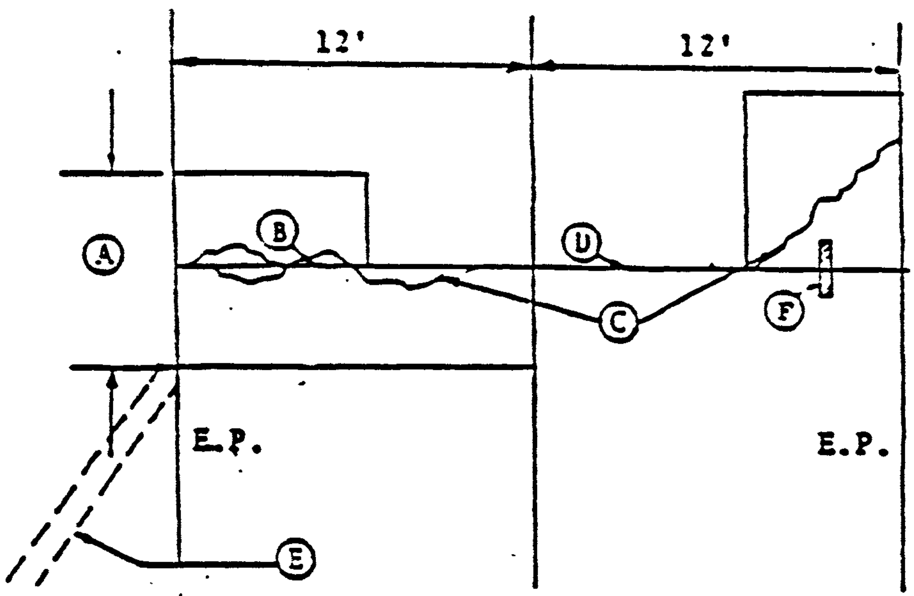
3. A quick setting, non-shrinking mortar or a high-viscosity epoxy shall be used to anchor the dowels in the holes. The holes shall be completely filled around the dowels so as to insure that there can be little vertical movement of the dowels and that the dowels are permanently fastened to the existing concrete. The epoxy or grout is to be put into the hole in sufficient amount so that when the bar is inserted, the material completely fills in around the bar. Only the ends of the dowels on the expansion side that extend into the patch area shall be lightly greased, and dowel sleeves shall be placed in accordance with standard PR-2 transverse expansion joint.

D. In the event the length of the patch is 8 feet or more and the existing joint occurs near the middle of the patch, dowels shall be replaced at the existing joint in accordance with Standard PR-2 for transverse expansion joints or as directed by the Engineer. The dowels placed in the existing pavement shall then be deformed bars and fixed at both ends.

CONCRETE PAVEMENT REPAIR

PROPOSED METHOD, FULL DEPTH.
PAVEMENT SPALL REPAIR
TYPE III-F

Repairs shall be performed in accordance with this typical section, and at the locations designated by the Engineer.



A. Full Depth Pavement Spall repair will be measured in square yards of pavement surface replaced in accordance with Special Provision for Patching Portland Cement Concrete Pavement herein. The minimum size of a full depth spall repair shall be 2 feet by 2 feet. Full Depth Pavement Spall Repair shall be saw cut to a minimum depth of 4 inches and removed full depth for the required distance. Pneumatic hammers shall not be heavier than nominal 35 pound class for the removal of concrete in Full Depth Pavement Spall Repair. Faces of all pavement not being faced with bituminous joint filler shall be bonded with Type EP-4 bonding epoxy prior to the placement of new concrete.

When the spalled area exceeds 8 feet as measured parallel to the joint, the pavement spall shall be saw cut full depth and removed full depth to the longitudinal joint.

B. Preformed bituminous expansion joint filler shall be placed in alignment with existing transverse joint in existing pavement. The expansion material shall be approximately 1/2 inch in thickness and shall have a depth and width equal to that of the adjacent pavement except that the top of the expansion material shall be not less than ???? inch nor more than 1/2 inch below the top of the finished pavement. After completion of patching operation, hot pour sealant shall be applied in accordance with Standard PR-2 in all joints of patch.

C. Denotes spall.

D. Existing joint.

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E. When authorized by the Engineer, underdrains shall be installed in accordance with this sketch and Special Provisions for Underdrains for Pavement Repair as directed by the Engineer.

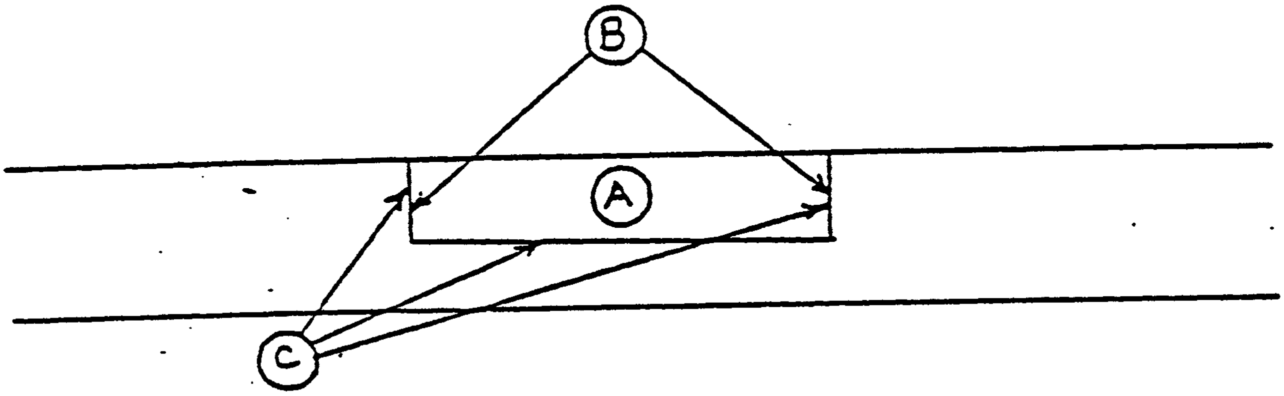
F. Any missing or damaged dowels shall be replaced. Also in the event the patch exceeds 4.0' dowels shall be installed as outlined in Section C on Page D-1.

Proposed Method, Variable Width and Length
Partial Depth Pavement Spall Repair

Type III-P

Replacement shall be performed in accordance with this typical section, notes, and Special Provision herein.

TYPCIAL SECTION
ELEVATION VIEW



A. Area of concrete pavement failure to be removed and replaced. Replacement will be measured in square yards of pavement surface. Pavement shall be removed to a depth that provides sound concrete with the maximum depth of any patch being no more than 4". If sound concrete is not reached at the 4" depth, the entire depth of the slab shall be removed and repaired and paid for in accordance with full depth concrete repairs.

B. Existing pavement at the area of failure shall be sawed perpendicular to the pavement for a depth of 3". The area of failure shall be removed by means of a jack hammer or other methods approved by the Engineer that will not damage the adjacent pavement. No patch shall be any less than 12" in width.

C. After removal of area of failure the entire area shall be thoroughly cleaned with compressed air. Prior to placement of concrete the area shall be moistened and painted with a type EP-4 Bonding Epoxy.

D. After completion of patching operation, hot pour sealant shall be applied in accordance with Standard PR-2 in all joints.

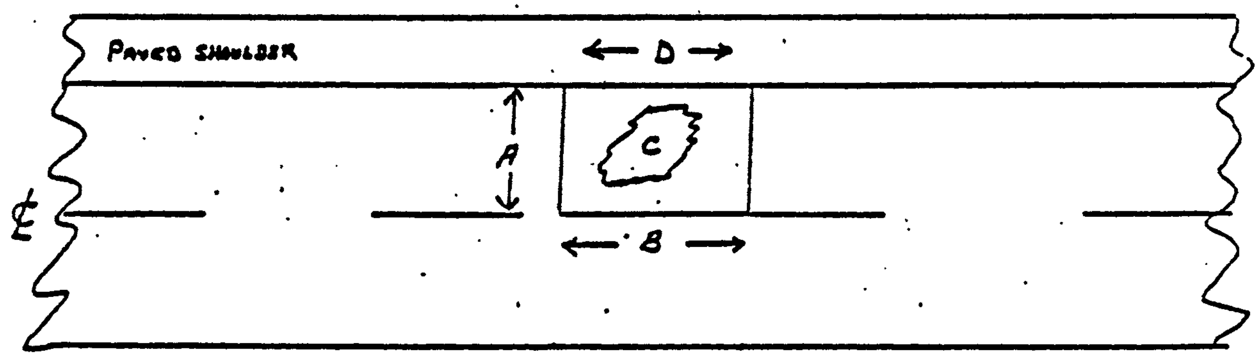
CONCRETE PAVEMENT REPAIR PROJECT

PROJECT PR-5B-86

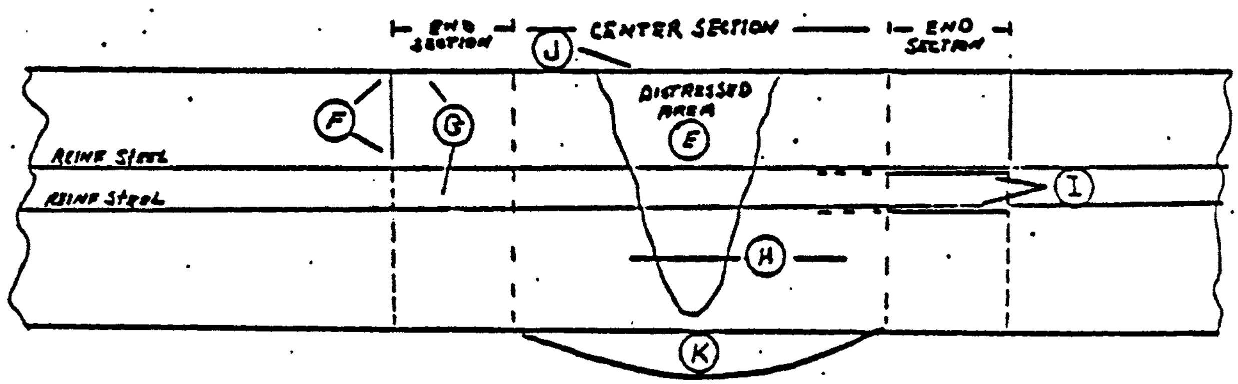
Proposed Method, Full Lane Width - Full Depth
TYPE IV
Continuous Reinforced Concrete Pavement Replacement

Replacement shall be performed in accordance with this typical section, notes, and Special Provisions herein.

TYPICAL SECTION
PLAN VIEW



TYPICAL SECTION
ELEVATION VIEW



A. Continuous reinforced concrete pavement distressed area to be removed the full lane width.

B. The length of repair areas will be variable, however, the minimum length of any patch will be 4.5'.

C. Denotes a distressed area of pavement to be corrected.

D. Shoulders which become low after concrete pavement is replaced shall be corrected by paving with bituminous concrete S-5. This paving shall be performed by means of a mechanical paver unless otherwise waived by the Engineer. All shoulder repair to be included in the price bid for patching cement concrete pavement Type IV.

E. Denotes distressed area of continuous reinforced concrete pavement to be repaired. Replacement will be measured in square yards of pavement surface removed and replaced. Replacement will be in accordance with Section 321 of the 1982 Road and Bridge Specifications and standard PR-3 continuous reinforced concrete pavement in the 1982 Road and Bridge Standards.

F. A partial depth saw cut will be made perpendicular to the pavement along the outer boundary of each section to approximate top elevation of longitudinal bars. Care must be taken not to cut or damage the reinforced steel. (See Figure 1)

G. The "End Sections" shall be removed using care not to damage the reinforcing bars. A jack hammer may be used but shall not exceed the 35# class. Reinforcing bars shall not be bent to facilitate clean out. A sufficient length of bars as required by our specifications for splicing shall be left in place for continuing the reinforcing steel through the replaced slab.

H. Within the "Center Section" the concrete and reinforcing steel will be removed full depth by means of jack hammers or other method approved by the Engineer.

I. Denotes reinforcing steel overlap for splicing. Steel which is left intact for splicing shall be cleaned to the satisfaction of the Engineer. (See Figure 2)

J. The finished surface shall be grooved to match the existing pavement.

K. The subbase under the pavement repair section shall be graded and brought to grade and mechanically compacted using suitable base material approved by the Engineer.

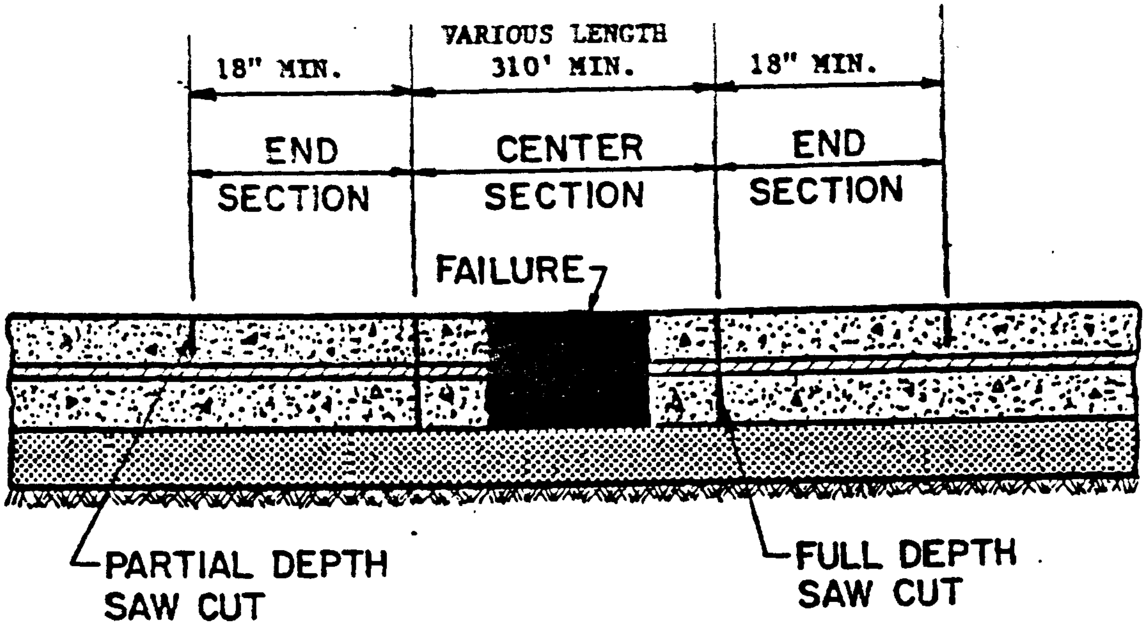


FIGURE 1. Identification of Center and End Sections

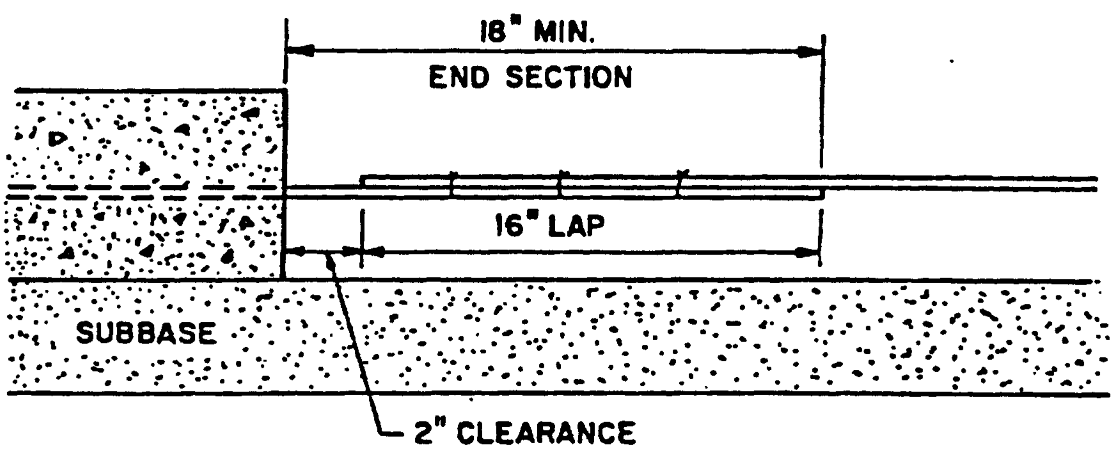


FIGURE 2. Tied Steel Lap Length

APPENDIX B

Special Provisions for Patching PCC Pavements

VIRGINIA DEPARTMENT OF HIGHWAYS AND TRANSPORTATION
SPECIAL PROVISION FOR
PATCHING PORTLAND CEMENT CONCRETE PAVEMENT

1654

January 23, 1984

I. DESCRIPTION

This work shall consist of removing designated areas of defective concrete pavement and unstable subbase material, replacing subbase material where required, and replacing pavement with high early strength portland cement concrete in accordance with this specification and in reasonably close conformity with the original lines and grades or as established by the Engineer.

II. MATERIALS

Concrete for patching portland cement concrete pavement shall conform to Section 219 for Class A-3 paving concrete, except that the minimum compressive strength shall be at least 3,000 psi within 24 hours. The accelerated strength gain shall be accomplished by using 800 lbs. ± 50 lbs./c.y. of Type III cement conforming to AASHTO M-85 and approved air entraining, accelerating and water reducing admixtures conforming to Section 217 of the Specifications. In the event calcium chloride is permitted as an accelerating admixture, it shall be limited to 2%. The air content shall be 6, ±2%. The water/cement ratio shall not exceed 0.42 by weight.

The use of water reducing and accelerating admixtures which have not been tested for compatability with the brand, type, source and quantity of cement proposed for use will not be permitted until such compatability has been confirmed.

The Contractor shall submit mix design(s) prior to commencement of work. The Contractor shall also prepare sufficient trial batches in the presence of the Engineer to verify the strength and workability of the mix design. The continued adequacy of the mix design and minimum compressive strength will be verified monthly by the Engineer. All costs incurred due to adjustments of the concrete mix design and for trial batches shall be borne by the Contractor and no additional compensation will be made or allowed.

Subbase material shall conform to Section 209 of the Specifications.

Preformed bituminous joint filler shall conform to Section 213 of the Specifications.

Curing material shall conform to Section 223 of the Specifications.

Type S-5 bituminous concrete shall conform to Section 212 of the Specifications, except that material may be accepted by certification and visually inspected at the job site.

The Contractor shall be responsible for the quality of the concrete placed in any weather or atmospheric condition. Should a concrete mobile mixer be used for the production of concrete, the Contractor shall assume responsibility for the initial determination and all necessary subsequent adjustments in proportioning of materials used to produce the specified concrete. The Contractor shall arrange for Department personnel to be briefed on the mobile mixer design and concrete producing capabilities. Instructions shall be provided by a knowledgeable manufacturer's representative of the mobile mixer. The concrete mobile mixer shall be calibrated by the Contractor and approved by the Engineer prior to commencement of work.

III. CONSTRUCTION METHODS

Where the existing joint dowel assembly is to be removed full length, existing concrete shall be saw cut and removed a minimum of 1 foot on each side of existing transverse joints. Undisturbed portions of the existing pavement adjacent to the area to be patched shall be left with straight, vertical sides. In the areas from which concrete has been removed, the subbase shall be dressed, brought to grade and mechanically compacted. Existing dowels and assemblies shall be removed and disposed of off the project.

Saw cuts shall not extend into adjacent concrete pavement except when repairs are to be extended at that location.

Unsuitable subbase material shall be removed, disposed of and replaced in accordance with Sections 307 or 308 whichever is applicable.

Where soil cement subbase is present and is found to be sound, excavation below the top of the soil cement line and under the adjacent slabs will not be required.

Preformed bituminous joint filler shall be placed flush with and firmly against the runoff side of the adjacent pavement. The expansion material shall be approximately 1/2 inch in thickness and shall have a depth and width equal to that of the adjacent pavement except that the top of the expansion material shall be not less than 1/4 inch nor more than 1/2 inch below the top of the finished pavement.

The excavated area shall be thoroughly cleaned and moistened prior to the placement of concrete.

The Contractor shall provide forms of sufficient strength to support the plastic concrete without bulging between the concrete patch and bituminous concrete shoulder. The form shall have a depth equal to that of the existing pavement and shall extend a minimum of 4 inches on each side of the patch as measured longitudinally along the edge of pavement.

Existing pavement shall not be removed if such removal will result in concrete being placed when the air temperature is below 55°F, unless approved by the Engineer. The concrete temperature at time of placement shall not be below 70°F nor above 95°F, unless approved by the Engineer.

Concrete shall be deposited on the subgrade, spaded, tamped, and internally vibrated so that it completely fills the area of the patch. Finishing of the plastic concrete shall conform to Section 321 except that the final surface shall be textured similar to that of the adjoining pavement.

Rounded or beveled transverse joints shall be provided adjacent to the undisturbed pavement to allow installation of hot pour sealant at a depth of not less than 1/4 inch nor more than 1/2 inch.

As soon as the concrete has been finished and prior to initial set, the patch and the existing pavement for a distance of eight (8) feet shall be tested by means of a 10 foot straightedge laid parallel to the centerline of the road surface, and irregularities in the patch in excess of 1/4 inch shall be corrected.

Immediately after straightedging and texturing, the concrete shall be moist cured with wet burlap and polyethylene sheeting. In addition, an insulating blanket shall be placed over the polyethylene any time the air temperature is below 65°F during the curing period. Such curing shall continue until immediately before opening to traffic. However, curing will not be required beyond 24 hours. The Contractor shall plan and prosecute repair operations in such a manner as to provide no less than 6 hours of curing for each patch.

All transverse joints at pavement repair locations shall be cleaned and filled with joint sealing material in accordance with Section 321.17 of the Specifications.

Within 24 hours after completion of a patch area, any bituminous concrete shoulders damaged during pavement repair operations shall be reconstructed in accordance with Section 320 of the Specifications with full depth Type S-5 bituminous concrete to match the finished grade. In the event traffic is to be permitted on the patch area prior to reconstruction of the shoulder, the Contractor shall first make such temporary repair to the shoulder as is necessary to avoid any hazardous condition.

IV. METHOD OF MEASUREMENT

Patching concrete pavement will be measured in square yards of pavement surface area, complete-in-place.

V. BASIS OF PAYMENT

Patching concrete pavement will be paid for at the contract unit price per square yard for the type specified; which price shall be full compensation for saw cutting pavement full depth; removal and disposal of existing concrete; preparation of subgrade; furnishing and installing preformed expansion material; for furnishing and placing steel reinforcement, if required; for placing, finishing and curing special design concrete; for cleaning and sealing joints; for repair of shoulders damaged by Contractor's patching operations; and for all materials, labor, tools, equipment and incidentals necessary to complete the work.

Pay Item	Pay Unit
Patching Cement Concrete Pavement (Type)	Square Yard

VIRGINIA DEPARTMENT OF HIGHWAYS AND TRANSPORTATION

SPECIAL PROVISION FOR

PATCHING PORTLAND CEMENT CONCRETE PAVEMENT

Revised March 20, 1985

Second Revision September 21, 1987

I. DESCRIPTION

This work shall consist of removing designated areas of defective concrete pavement and unstable subbase material, replacing subbase material where required, and replacing pavement with high early strength portland cement concrete in accordance with this specification and in reasonably close conformity with the original lines and grades or as established by the Engineer.

II. MATERIALS

Concrete for patching portland concrete pavement shall conform to Section 219 for Class A-3 paving concrete, except that the minimum compressive strength shall be at least 3,000 psi within twenty-four (24) hours. The accelerated strength gain shall be accomplished by using 800 lbs. ± 50 lbs./c.y. of Type III cement conforming to AASHTO M-85 and approved air entraining, accelerating and water reducing admixtures conforming to Section 217 of the Specifications. In the event calcium chloride is permitted as an accelerating admixture, it shall be limited to 2%. The air content shall be 6, ±2%. The water/cement ratio shall not exceed 0.42 by weight.

The use of water reducing and accelerating admixtures which have not been tested for compatibility with the brand, type, source and quantity of cement proposed for use will not be permitted until such compatibility has been confirmed.

The Contractor shall submit mix design(s) prior to commencement of work. The Contractor shall also prepare sufficient trial batches in the presence of the Engineer to verify the strength and workability of the mix design. The continued adequacy of the mix design and minimum compressive strength will be verified monthly by the Engineer. All costs incurred due to adjustments of the concrete mix design and for for trial batches shall be borne by the Contractor and no additional compensation will be made or allowed.

Subbase material shall conform to Section 209 of the Specifications.

Preformed bituminous joint filler shall conform to Section 213 of the Specifications.

Curing material shall conform to Section 223 of the Specifications.

Type S-5 bituminous concrete shall conform to Section 212 of the Specifications, except that material may be accepted by certification anu visually inspected at the job site.

1658 The Contractor shall be responsible for the quality of the concrete placed in any weather or atmospheric condition. Should a concrete mobile mixer be used for the production of concrete, the Contractor shall assume responsibility for the initial determination and all necessary subsequent adjustments in proportioning of materials used to produce the specified concrete. The Contractor shall arrange for Department personnel to be briefed on the mobile mixer design and concrete producing capabilities. Instructions shall be provided by a knowledgeable manufacturer's representative of the mobile mixer. The concrete mobile mixer shall be calibrated by the Contractor and approved by the Engineer prior to commencement of work.

III. CONSTRUCTION METHODS

Where the existing joint dowel assembly is to be removed full length, existing concrete shall be saw cut and removed a minimum of 1 foot on each side of existing transverse joints. Undisturbed portions of the existing pavement adjacent to the area to be patched shall be left with straight, vertical sides. In the areas from which concrete has been removed, the subbase shall be dressed, brought to grade and mechanically compacted. Existing dowels and assemblies shall be removed and disposed of off the project.

Saw cuts shall not extend into adjacent concrete pavement except when repairs are to be extended at that location. Saw cuts shall be straight, heat, vertical and parallel or perpendicular to the centerline as required.

Unsuitable subbase material shall be removed, disposed of and replaced in accordance with Sections 307 or 308, whichever is applicable.

Where soil cement subbase is present and is found to be sound, excavation below the top of the soil cement line and under the adjacent slabs will not be required.

It is the intent that all excavated areas be patched the same night; therefore, after the excavation of each patch has been completed, the Contractor shall conduct his operation in order to place the patch as soon as possible. In the event the excavated area has not been patched within a two hour period, it shall be filled with bituminous concrete, Type S-5. The Contractor shall have a bituminous concrete plant on call at night to assure the availability of the S-5.

Work will not begin until the Engineer has received verification in writing that the Contractor has a bituminous concrete plant on call from 9:00 P.M. to 5:00 A.M.

Preformed bituminous joint filler shall be placed flush with and firmly against the runoff side of the adjacent pavement. The expansion material shall be approximately 1/2 inch in thickness and shall have a depth and width equal to that of the adjacent pavement, except that the top of the expansion material shall not be less than 1/4 inch nor more than 1/2 inch below the top of the finished pavement.

The excavated area shall be thoroughly cleaned and moistened prior to the placement of concrete.

The Contractor shall provide forms of sufficient strength to support the plastic concrete without bulging between the concrete patch and bituminous concrete shoulder. The form shall have a depth equal to that of the existing pavement and shall extend a minimum of 4 inches on each side of the patch as measured longitudinally along the edge of pavement.

Existing pavement shall not be removed if such removal will result in concrete being placed when the air temperature is below 55 degrees Fahrenheit, unless approved by the Engineer. The concrete temperature at time of placement shall not be below 70 degrees Fahrenheit nor above 95 degrees Fahrenheit, unless approved by the Engineer.

Concrete shall be deposited on the subgrade, spaded, tamped, and internally vibrated so that it completely fills the area of the patch. Finishing of the plastic concrete shall conform to Section 321, except that the final surface shall be textured similar to that of the adjoining pavement.

As soon as the concrete has been finished and prior to initial set, the patch and the existing pavement for a distance of eight (8) feet shall be tested by means of a 10 foot straightedge laid parallel to the centerline of the road surface, and irregularities in the patch in excess of 1/4 inch shall be corrected.

Due to the temperature constraints listed above, the work on this project will only be allowed during the following time period : March 1 - November 30.

Immediately after straightedging and texturing, the concrete shall be moist cured with wet burlap and polyethylene sheeting. In addition, an insulating blanket shall be placed over the polyethylene any time the air temperature is below 65°F during the curing period. Such curing shall continue until immediately before opening to traffic. However, curing will not be required beyond 24 hours. The Contractor shall plan and prosecute repair operations in such a manner as to provide no less than 6 hours of curing for each patch.

All transverse and longitudinal joints at pavement repair locations shall be cleaned and filled with hot pour joint material in accordance with Section 321.17 of the specifications.

Within 24 hours after completion of a patch area, any bituminous concrete shoulders damaged during pavement repair operations shall be reconstructed in accordance with Section 320 of the Specifications with full depth Type S-5 bituminous concrete to match the finished grade. In the event traffic is to be permitted on the patch area prior to reconstruction of the shoulder, the Contractor shall first make such temporary repair to the shoulder as is necessary to avoid any hazardous condition.

IV. METHOD OF MEASUREMENT

Patching concrete pavement will be measured in square yards of pavement surface area, complete-in-place.

V. BASIS OF PAYMENT

Patching concrete pavement will be paid for at the contract unit price per square yard for the type specified, which price shall be full compensation for saw cutting the required depth, removal and disposal of exisiting concrete, preparation of subgrade, furnishing and installing preformed expansion material, for furnishing and installation of steel dowels, for placing, finishing and curing special design concrete, for cleaning and sealing joints, for repair of shoulders and adjacent concrete pavement damaged by Contractor's patching operations, for patch area protection, and for all materials, labor, tools, equipment and incidentals necessary to complete the work.

PAY ITEM	PAY UNIT
Patching Cement Concrete Pavement(TYPE)	Square Yards

APPENDIX C

Patch Location, Geometry and Traffic Data

1662


INTERSTATE — ARTERIAL
HIGHWAY SYSTEM OF VIRGINIA
INTERSTATE VIRGINIA 95
37
58
Washington, D.C.
INTERSTATE
COMPLETED
UNDER CONSTRUCTION
PROP. CONSTRUCTION
MILEAGE
1045
37
8
ARTERIAL
COMPLETED
UNDER CONSTRUCTION
PROP. CONSTRUCTION
MILEAGE
1409
28
394
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF TRANSPORTATION
APRIL 1987
SCALE OF MILES
MARYLAND
WEST VIRGINIA
CHESAPEAKE BAY
ATLANTIC OCEAN
NORTH CAROLINA
ROANOKE AREA
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6
Site A1
Site A2
Site A3
Site A4
Site A5
WINCHESTER
FRONT ROYAL
ALEXANDRIA
FAIRFAX
CULPEPER
FREDERICKSBURG
CHARLOTTESVILLE
COVINGTON
LEXINGTON
SALEM
VINTON
ROANOKE
CLIFTON FORGE
FARMVILLE
COLONIAL HEIGHTS
HOPEWELL
WILLIAMSBURG
HAMPTON
CHESAPEAKE
SOUTH HILL
SOUTH BOSTON
DANVILLE
CHATHAM
GRETNA
ALTAVISTA
MARSHALL
WARRENTON
HANOVER
ASHLAND
AMELIA
BLACKSTONE
NOTTOWAY
LUNENBURG
SUSSEX
WAVERLY
WAKEFIELD
SURRY
POQUOSON
EASTVILLE
TAPPAHANNOCK
HEATHSVILLE
MONTROSS
LANCASTER
GLOUCESTER
MATHEWS
SALUDA
CHARLES CITY
PROVIDENCE FORGE
NEW KENT
POWHATAN
CUMBERLAND
GOOCHLAND
LOUISA
PALMYRA
MINERAL
MADISON
ORANGE
STAFFORD
WOODBRIDGE
MANASSAS
LURAY
WASHINGTON
MONTEREY
WARM SPRINGS
BUCHANAN
NATURAL BRIDGE
NEW CASTLE
FINCASTLE
CHARLOTTE C H
KEYSVILLE
HALIFAX
CLARKSVILLE
BOYDTON
LAWRENCEVILLE
JARRATT
EMPORIA
SUFFOLK
PORTSMOUTH
ISLE OF WIGHT
DINWIDDIE
CHESTERFIELD
RICHMOND
BOWLING GREEN
SPOTSYLVANIA
KING GEORGE
HAMILTON
LEESBURG
MIDDLEBURG
FALLS CHURCH
STEPHENS CITY
BERRYVILLE
APPOMATTOX
AMPLIN

APPENDIX C - Patch Locations.

Table C-1

SITE	TYPE	NUM.	DISTRICT, CITY or CO.	LOCATION
1	2	9	Salem	I81, NBL, TL, 3/10 mile north m.p. 147.
1	2	9A	Salem	I81, NBL, TL, 6/10 mile north m.p. 147.
1	2	9B	Salem	I81, NBL, TL, 8/10 mile north m.p. 147.
1	2	2A	Salem	I81, NBL,TL, 441' north bridge over 640.
1	2	2B	Salem	I81, NBL,TL, 469' north bridge over 640.
1	2	2	Salem	I81, NBL,TL, 604' north bridge over 640.
1	2	2C	Salem	I81, NBL,TL, 806' north bridge over 640.
1	2	1	Salem	Botetourt County,I81, NBL, TL, 225' North m.p. 158
1	3P	10	Salem	I81, NBL, PL, 1/10 mile south m.p. 161.
1	3P	10A	Salem	I81, NBL, PL, 225' south m.p.161.
HAMPTON-WILLIAMSBURG PATCHES				
A2	2	A2-1	York	I64 @ Williamsburg, EBL, TL, 100' downstream(east) m.p. 241, 4'.
A2	2	A2-2	York	I64 @ Williamsburg, EBL, TL, 150' downsteam(east) m.p. 241, 22'.
A2	2	A2-3	York	I64 @ Williamsburg, EBL, TL, 210' downstream(east) m.p. 241, 3".
A2	2	A2-4	York	I64 @ Williamsburg, EBL, TL, 270' downstream(east) m.p. 241, 5'.
A3	2	A3-1	York	I64, approx. 300' upstream(west) x-over after m.p. 251, EBTL, 3'-9"x12'.
A3	2	A3-2	York	I64, approx. 240' upstream(west) x-over, EBTL, 3'x12'.
A3	2	A3-3	York	I64, approx. 180' upstream(west) x-over, EBTL, 4'x12'.
A3	2	A3-4	York	I64, approx. 120' upstream(west) x-over, EBTL, 4'-4"x12'.
6	4A	18	Hampton	Hampton-Willmsbg., I64, EBL, PL, 1.4 miles east 143 overpass,56'.
NORFOLK PATCHES				
			(Start approx. 1.5 miles upstream(northwest) intersection of I264&44 Virginia Beach.)	
A4	1	A4-1	Norfolk	I64, EBTL, 25' upstream(west) light pole E507, 3'-6".
A4	1	A4-2	Norfolk	I64, EBTL, 35' downstream(east) light pole E507, 3'.
A4	1	A4-3	Norfolk	I64, EBTL, 95' downstream(east) light pole E507, 3'-1".
A4	1	A4-4	Norfolk	I64, EBTL, 155' downstream(east) light pole E507, 2'-8".
2	1	16	Norfolk	I64, EBL, TL, 2/10 mile east intersection Greenbrier Parkway.
2	1	4	Norfolk	I64, WBL,PL,7/10 miles west m.p. 289, 1.2 miles west Greenbrier Dr.
2	1	3	Norfolk	I64, WBL,TL,8/10 miles west m.p. 289, 1.3 miles west Greenbrier Dr.
2	1	5	Norfolk	I64, WBL,PL,9/10 miles west m.p. 289, 1.4 miles west Greenbrier Dr.
2	1	11	Norfolk	I64, WBL, PL, 3/10 mile west of m.p.288.

APPENDIX C - Patch Locations.

Table C-1

SITE	TYPE	NUM.	DISTRICT, CITY or CO.	LOCATION
EMPORIA PATCHES				
3	1	8	Emporia	I95, SBL,TL, 121 yds. north m.p. 3.
A5	1	A5-1	Emporia	I95, SBTL, 360' upstream(north) m.p. 3, 22'x12', jt. @ 8'.
A5	1	A5-2	Emporia	I95, SBL, TL, 290' upstream(north) m.p. 3, 2'x12'.
A5	1	A5-3	Emporia	I95, SBTL, 210' upstream(north) m.p. 3, 1'x12'.
A5	1	A5-4	Emporia	I95, SBTL, 170' upstream(north) m.p. 3, 1'-4"x12'.
3	1	8A	Emporia	I95, SBL, TL, 3/10 mile south m.p. 3.
3	1	13A	Emporia	I95, SBL, TL, .45 mile south m.p.2 @ guardrail.
3	3P	13	Emporia	I95, SBL, TL, 2/10 mile north m.p. 1.
3	3P	12	Emporia	I95, SBL, TL, 1/10 mile north m.p.1.
3	1	6	Emporia	I95,NBL,TL,.25 miles north of m.p. 6.
3	1	7	Emporia	I95,NBL,TL,100' south m.p. 7
RICHMOND PATCHES				
A1	2	A1-1	Richmond	I64 @ I295 exit,EBL, TL, 150' upstream(west) m.p. 200, 6'x12'.
A1	2	A1-2	Richmond	I64 @ I295 exit,EBL, TL, 25' upstream(west) m.p. 200, 6'-7"x12'.
A1	2	A1-3	Richmond	I64 @ I295 exit,EBL, TL, 40' downstream(east) m.p. 200, 5'-6"x12'
A1	2	A1-4	Richmond	I64 @ I295 exit,EBL, TL, 330' downstream(east) m.p. 200, 4'x12'.
4	4	14	Richmond	Sandston, I64, decel. lane for ramp, 2/10 mile east m.p. 192.
4	3F	15	Richmond	Sandston, I64, Ramp for WBL to Broad Street.
5	2	17	Richmond	Ashland, I95, NBL, TL, 200 yds. before m.p. 84.

'A' denotes originally an ARE test patch

Table C-2

PATCH IDENTITY Type	Site	No.	PATCH SHAPE AND SIZE Dimensions	Volume (ft^3)	SUBBASE: 1-cmt. trt. 2-aggreg. 3-concrete	LATEST AVAILABLE TRAFFIC DATA Single unit trucks 2 axle 6 tire	3 axle 6-10 tire	Trail. Trucks	Buses	Cummulative ESAL
2	1	1	8.25'X12'X9"	74.3	2	450	70	4800	50	2375777.74
3P	1	2A,B	19"X13"X4"	0.6	3	450	70	4800	50	2375777.74
2	1	2C	14.3'X12'X9"	128.7	2	450	70	4800	50	2375777.74
2	1	2	18.6'X12'X9"	167.9	2	450	70	4800	50	2375777.74
1	2	3	7'X12'X9"	63.0	1	2000	790	3800	85	2080713.1
1	2	4	6'X12'X9"	54.0	1	2000	790	3800	85	520178.3
1	2	5	6'X12'X9"	54.0	1	2000	790	3800	85	520178.3
1	3	6	26.5"X12'X9"	19.9	1	600	120	3550	70	1708976.2
1	3	7	38.5"X12'X9"	28.9	1	600	120	3550	70	1672933.67
1	3	8	8.25'X12'X9"	74.3	1	600	120	3550	70	1672933.67
1	3	8A	10.3'X12'X9"	92.3	1	600	120	3550	70	1672933.67
2	1	9	2'X12'X15.5"	31.6	2	520	55	5000	65	2342251.58
2	1	9A	12.8'X12'X9"	115.2	2	520	55	5000	65	2342251.58
2	1	9B	6.4'X12'X9"	57.8	2	520	55	5000	65	2342251.58
3P	1	10A	13"X13"X4"	0.5	3	450	70	4800	50	570137.92
3P	1	10	13"X33"X4"	1.3	3	450	70	4800	50	570137.92
1	2	11	6'X12'X9"	54.0	1	2000	790	3800	85	508834.71
3P	3	12	56"X56"X3"	6.5	3	2000	790	3800	85	2015338.85
3P	3	13	66"X47"X4"	7.3	3	2000	790	3800	85	2015338.85
1	3	13A	15'X12'X9"	135.0	1	2000	790	3800	85	2015338.85
1	3	13B	25'X12'X9"	225.0	1	2000	790	3800	85	2015338.85
4	4	14	11'X12'X9"	96.4	2	No data for ramps.				
3F	4	15	30"X10.4'X9"	19.5	2	No data for ramps.				
1	2	16	6'X12'X9"	54.0	1	2000	790	3800	85	1606709.19
2	5	17	20.5'X12'X9"	184.5	2	1300	340	6900	270	1520637.51
4A	6	18	56'X12'X9"	506.7	2	1500	390	2250	190	241307.17
2	1	A1-1	6.25'X12'X9"	56.3	2	500	95	850	60	626396.34
2	1	A1-2	6.58'X12'X9"	59.2	2	500	95	850	60	626396.34
2	1	A1-3	5.5'X12'X9"	49.5	2	500	95	850	60	626396.34
2	1	A1-4	3.92'X12'X9"	35.3	2	500	95	850	60	626396.34
2	2	A2-1	4.83'X12'X9"	43.5	2	800	210	2150	40	1430019.52
2	2	A2-2	21.7'X12'X9"	195.3	2	800	210	2150	40	1430019.52
2	2	A2-3	3'X12'X9"	27.0	2	800	210	2150	40	1430019.52
2	2	A2-4	5.33'X12'X9"	48.0	2	800	210	2150	40	1430019.52
2	3	A3-1	3.75'X12'X9"	33.8	2	1250	450	2150	140	1525837.76
2	3	A3-2	2.92'X12'X9"	26.3	2	1250	450	2150	140	1525837.76
2	3	A3-3	3.92'X12'X9"	35.3	2	1250	450	2150	140	1525837.76
2	3	A3-4	4.33'X12'X9"	39.0	2	1250	450	2150	140	1525837.76
1	4	A4-1	3.5'X12'X9"	31.5	1	2200	830	3250	200	2597358.22
1	4	A4-2	2.92'X12'X9"	26.3	1	2200	830	3250	200	2597358.22
1	4	A4-3	3.08'X12'X9"	27.7	1	2200	830	3250	200	2597358.22
1	4	A4-4	2.66'X12'X9"	23.9	1	2200	830	3250	200	2597358.22
1	5	A5-1	22.2'X12'X9"	199.8	1	600	120	3550	70	2124776.1
1	5	A5-2	2'X12'X9"	18.0	1	600	120	3550	70	2124776.1
1	5	A5-3	1'X12'X9"	9.0	1	600	120	3550	70	2124776.1
1	5	A5-4	1.75'X12'X9"	15.8	1	600	120	3550	70	2124776.1

APPENDIX D

Installation Data on Selected Patches

APPENDIX D - Installation Data Continued
Table D-1

I.D. No.	Placement Date	MIXTURE PROPORTIONS Cement (lbs)	Fine Aggr. (lbs)	Coarse Aggr. (lbs)	Water (lbs)	BATCH PROPERTIES Slump (in)	Chace % Air	Air Temp. (F)	Conc. Temp. (F)	Cure* Time (hrs)	Batch to Init. Set (ASTM C403) (hrs)	INTERIM TIMES (Relat. to Placement) After Lane Used (hrs)	After Batch (hrs)	Before Init. Set (hrs)
1	6/26/84	799	831	1924	335.7	2.25	4.5	82	74	23	2.75	8	0.66	24
2A,B	6/26/84	799	831	1924	335.7	3	6.6	80	73	24	2.66	72	1.5	26
2C	6/26/84	799	831	1924	335.7	3	6.6	80	73	24	2.66	72	1.5	26
2	6/28/84	799	831	1924	335.7	2.25	4.4	90	78	24	2.66	48	1.75	42
3	7/24/84	752	916	1900	271	3	5		86	5.3	3.5	1.75	0.5	6
4	7/25/84	752	916	1900	271	2.5	4.6		86	6.25	2.75	2	0.58	7
5	7/26/84	752	916	1900	271	2.5	6		84	6.5	2.375	1	0.5	9
6	7/31/84	750	1068	1705	300	2.25	4.3	76	83	24	2.875	8	0.83	94
7	8/1/84	750	1068	1705	300	2.5	4.3	78	83	24	2.5	32	0.58	70
8	8/1/84	750	1068	1705	300	3	4.9	80	90	24	2.25	22.8	0.58	45
8A	8/2/84	750	1068	1705	300	2.25	4.5	85	91	18	2.375	67.5	0.66	22
9	8/6/84	799	831	1924	335.7	1.75	5.9	84	80	24	2.375	10	0.83	72
9A	8/7/84	799	831	1924	335.7	3.25	4.4	87	77	24	2.75	36	0.66	48
9B	8/7/84	799	831	1924	335.7	2	4.4	88	84	24	2.125	34.5	0.58	48
10A	8/9/84	799	831	1924	335.7	2.25	4.4	84	82	16	2.2	48	0.75	20
10	8/9/84	799	831	1924	335.7	2.25	4.4	84	82	16	2.2	48	0.75	20
11	8/13/84	752	916	1900	271	3.25	5	78	84	7		2	0.5	8
12	8/15/84	750	1068	1705	300	3	4.4	85	90	24		4.5	1	49
13	8/16/84	750	1068	1705	300	2.75	4.8	80	90	16		78	0.83	24
13A	8/16/84	750	1068	1705	300	2.75	4.8	80	90	16		6	1	24
13B	8/16/84	750	1068	1705	300	2.75	4.8	80	90	16		6	1	24
14	12/10/84	800	850	1780	336	2.25	7.2	54	70	24	9	8	0.83	44
15	6/24/85	800	850	1780	336	3	7.6	92	93	14	5.75	7.75	0.5	21
16	7/8/85	752	916	1900	271	2.5	5	75	82	7	2.75	1.25	0.5	8.75
17	7/16/85	800	1002	1655	336	4	5.5	85	91	4.75	4.5	4	0.75	6
18	7/23/85	776	819	1950	279.3	2.25	5.2	65	75	5.25	4.25	3	0.75	7.5
A1-1	7/01/83													
A1-2	7/01/83													
A1-3	7/01/83													
A1-4	7/01/83													
A2-1	7/01/82													
A2-2	7/01/82													
A2-3	7/01/82													
A2-4	7/01/82													
A3-1	7/01/83													
A3-2	7/01/83													
A3-3	7/01/83													
A3-4	7/01/83													
A4-1	7/01/81													
A4-2	7/01/81													
A4-3	7/01/81													
A4-4	7/01/81													
A5-1	7/01/83													
A5-2	7/01/83													
A5-3	7/01/83													
A5-4	7/01/83													

* Curing consisted of wet burlap & polyethylene.
Insulated mats were also used on Repairs 14 & 17.

APPENDIX E

Curing Temperatures of Selected Patches

APPENDIX E - Curing Temperatures
Type 3F, Site 4, Repair No. 15

(Temperatures in F-degrees)

Age, hrs.	Air Temp.	Patch Temperatures Top	Patch Temperatures Bottom	Patch Temperatures Center	Cylinder Temperatures Curing Cabinet	Cylinder Temperatures Patch Top Cure	Cylinder Temperatures Ambient Cure
0	100	100	100	100	93	100	100
1	102	106	103	100	110	112	103
2	101	98	98	97	98	104	99
3	100	100	100	99	120	105	99
4	99	101	96	101	144	105	96
5	98	101	97	101	103	106	97
6	84	100	99	102	117	103	100
7	82	113	104	113	119	113	104
8	78	124	115	131	124	129	108
9	80	140	124	145	142	135	110
10	78	144	130	150	157	139	108
11	79	146	133	155	164	140	102
12	79	145	134	155	159	137	97
13	80	143	135	152	156	133	94
14	80	140	134	148	156	128	88
15	77	134	134	143	150	120	84
16	73	129	132	138	144	115	80
17	74	128	130	135	142	113	79
18	76	128	128	133	138	112	80
19	78	128	127	132	137	114	84
20	82	130	125	130	148	117	85
21	88	129	124	130	140	110	85
22	100	133	122	131	144	110	86
23	100	136	121	132	150	110	88
24	96	139	123	136	144	110	92

APPENDIX E - Curing Temperatures
Type 1, Site 2, Repair No. 16

(Temperatures in F-degrees)

		Patch Temperatures			Cylinder Temperatures			
Age, hrs.	Air Temp.	Top	Bottom	Center	Sure Cure	Curing Cabinet	Patch Top Cure	Ambient Cure
0	75	82	82	82	82	82	82	82
1	85	88	90	90	85	85	85	85
2	80	90	94	93	95	93	84	84
3	78	100	102	102	109	95	91	88
4	79	112	110	122	132	114	104	95
5	77	133	125	144	144	140	120	98
6	75	129	128	145	154	143	132	100
7	77	126	129	140	148	140	113	95
8	75	116	127	133	140	137	100	92
9	75	113	125	129	135	128	95	88
10	75	107	124	125	132	130	90	86
11	75	102	122	120	127	125	85	84
12	78	100	120	116	122	124	82	82
13	84	102	116	114	117	120	84	83
14	88	108	115	113	115	117	91	86
15	90	111	113	115	115	115	90	90
16	95	115	113	114	116	115	98	93
17	97	116	112	116	118	116	101	96
18	98	120	112	117	119	117	104	100
19	91	120	112	118	120	119	104	104
20	88	114	112	115	119	117	99	102
21	85	107	112	112	116	115	96	98
22	88	108	110	110	111	114	95	96
23	92	105	110	110	114	112	94	96
24	89	102	110	109	112	112	92	96

APPENDIX E - Curing Temperatures
Type 2, Site 5, Repair No. 17

(Temperatures in F-degrees)

Age, hrs.	Air Temp.	Patch Temperatures: Top	Patch Temperatures: Bottom	Patch Temperatures: Center	Cylinder Temperatures: Sure Cure	Cylinder Temperatures: Curing Cabinet	Cylinder Temperatures: Patch Top Cure	Cylinder Temperatures: Ambient Cure
0	86	91	91	91	86	86	91	91
1	86	96	93	98	86	92	86	86
2	85	93	93	97	99	94	85	84
3	81	94	94	98	100	97	86	83
4	80	103	98	106	110	103	90	84
5	79	124	108	127	134	125	98	86
6	78	144	119	145	154	144	117	102
7	75	153	125	154	163	153	120	103
8	74	143	130	155	162	155	116	104
9	77	136	131	151	160	150	104	102
10	81	130	131	145	154	146	102	98
11	83	127	129	139	147	141	98	94
12	85	127	128	136	143	138	94	92
13	88	126	126	132	138	133	94	90
14	86	124	124	131	136	131	94	90
15	81	120	122	128	134	129	92	89
16	82	116	120	125	126	127	90	88
17	89	115	119	122	125	124	93	88
18	88	117	117	121	124	121	95	90
19	85	116	116	121	123	121	96	91
20	84	114	116	119	122	119	96	92
21	82	112	116	117	121	118	95	90
22	80	109	115	115	120	117	90	88
23	78	105	114	114	119	115	85	86
24	78	105	114	114	119	112	82	84

APPENDIX E - Curing Temperatures
Type 4A, Site 6, Repair No. 18

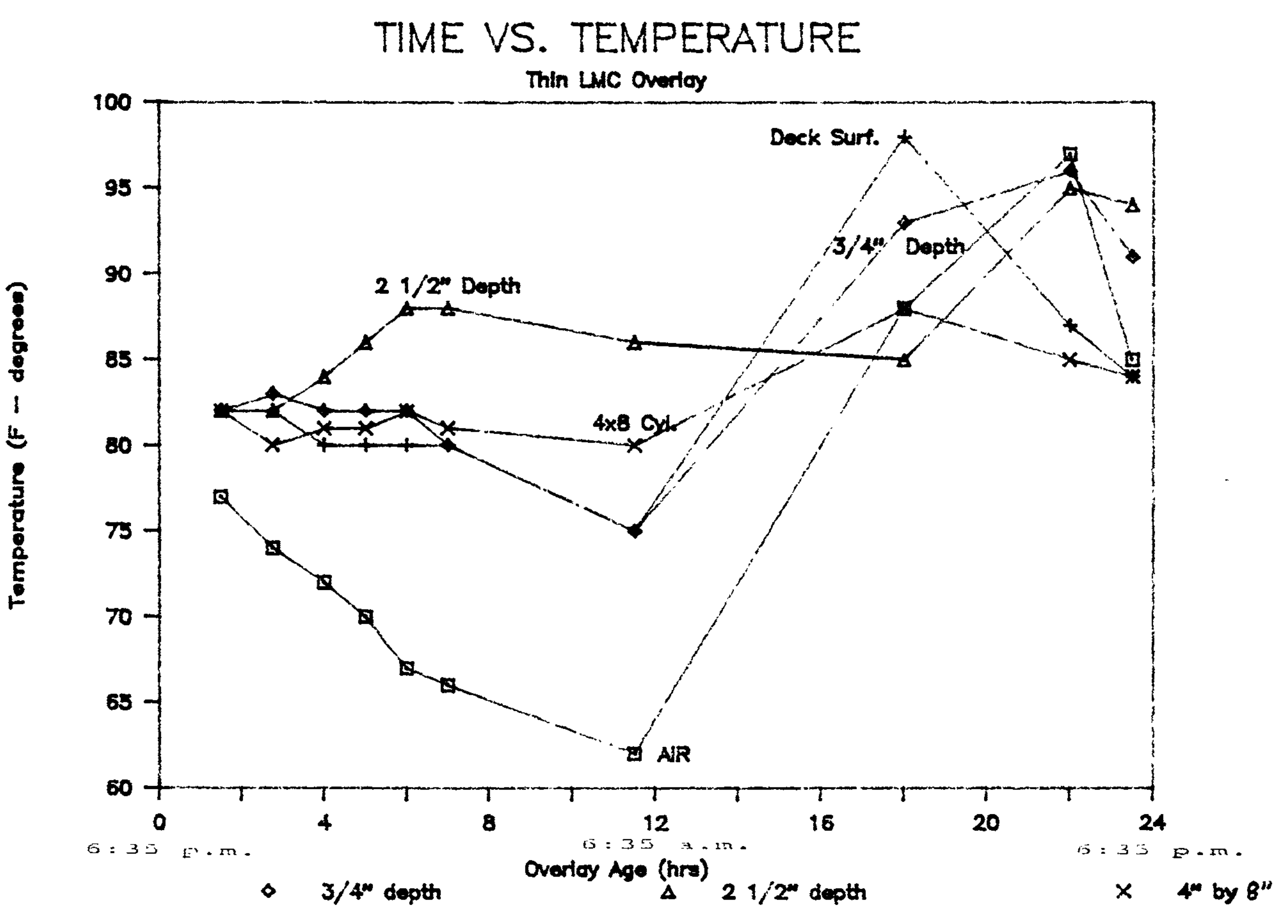
(Temperatures in F-degrees)

Age, hrs.	Air Temp.	Patch Temperatures Top	Patch Temperatures Bottom	Patch Temperatures Center	Cylinder Temperatures Sure Cure	Cylinder Temperatures Curing Cabinet	Cylinder Temperatures Patch Top Cure	Cylinder Temperatures Ambient Cure
0	75	75	75	75	75	75	75	75
1	70	90	88	91	73	88	70	71
2	69	86	90	91	94	88	70	80
3	68	89	91	92	95	88	74	79
4	67	95	94	99	102	95	77	79
5	66	106	100	107	116	105	80	81
6	65	129	110	130	137	122	86	84
7	65	131	113	138	145	124	93	87
8	65	136	116	138	145	127	114	90
9	66	125	120	134	140	132	109	90
10	72	118	119	127	134	129	90	89
11	75	113	118	122	128	125	85	88
12	79	112	116	118	123	122	84	81
13	81	102	116	116	120	119	85	82
14	81	111	113	114	119	117	86	85
15	82	110	112	113	117	114	86	87
16	86	112	110	113	116	113	88	89
17	85	113	110	113	116	113	92	90
18	90	114	110	114	116	113	94	90
19	87	112	110	113	116	113	94	90
20	82	109	109	112	114	112	89	89
21	81	106	109	110	113	111	87	88
22	81	103	108	107	111	110	85	86
23	80	103	107	106	109	110	84	85
24	78	103	107	106	108	110	83	84

APPENDIX E - Curing Temperatures
Thin LMC Overlay
250/250 Bypass
8/27/85

(Temperatures in F - degrees)

Age,hr.	Air	Deck Surface	3/4" depth	2 1/2" depth	4" x 8" cylinder
1.5	77	82	82	82	82
2.75	74	82	83	82	80
4	72	80	82	84	81
5	70	80	82	86	81
6	67	80	82	88	82
7	66	80	80	88	81
11.5	62	75	75	86	80
18	88	98	93	85	88
22	97	87	96	95	85
23.5	85	84	91	94	84



APPENDIX F

Cylinder Strengths, Maturities and Impact Numbers for Selected Patches

APPENDIX F - Table F-2

Repair: Type I, Site 2, No. 16
Date: 7/8/1985

Age (hrs)	Compressive Strengths: Ambient Cured (psi)	Compressive Strengths: Patch Top Cured (psi)	Compressive Strengths: TMC* Cured (psi)	Maturities: Ambient Cured (F-hrs)	Maturities: Patch Top Cured (F-hrs)	Maturities: TMC* Cured (F-hrs)	Impact Hammer Numbers (Avg. of 10 readings): Hammer No. 1	Impact Hammer Numbers (Avg. of 10 readings): Hammer No. 2
3	95	160	227	212	356	267	8.0	0.0
4	300	490	670	303	353	371	9.1	0.0
5	680	1500	2010	400	465	498	13.4	12.9
6	1790	2200	2430	499	590	640	15.7	13.7
7	1800	2590	2510	597	717	781	17.3	14.8
8	2170	2750	2700	691	828	919	17.0	15.6
10	2820	2980	3060	868	1018	1180	20.6	18.5
12	2750	3260	3340	1036	1189	1432	20.0	18.9
24	3860	3840	3960	2169	2333	2827	22.5	20.4
28 day (dry cured)	6130	5810	5530					
28 day (moist cured)	5890	5750	5970					

* Curing Cabinet

APPENDIX F - Table F-3

Repair: Type II, Site 5, No. 17
Date: 7/15/1985

	Compressive Strengths			Maturities			Impact Hammer Numbers (Avg. of 10 readings)	
Age (hrs)	Ambient Cured (psi)	Patch Top Cured (psi)	TMC* Cured (psi)	Ambient Cured (F-hrs)	Patch Top Cured (F-hrs)	TMC* Cured (F-hrs)	Hammer No. 1	Hammer No. 2
5	130	240	1270	426	440	494	10.5	0.0
6	620	920	2550	520	547	629	16.7	16.1
7	1130	2120	3540	622	666	777	20.6	18.8
8	2160	3020	4180	725	784	931	23.0	20.4
9	2290	3540	4180	828	894	1083	24.1	20.2
10	2550	3660	4730	928	997	1232	24.2	20.8
12	3660	4100	4970	1117	1193	1515	26.0	21.2
14	4830	3900	5410	1288	1381	1782	22.6	22.2
24	4830	5390	5410	2229	2302	2995	25.4	21.1
28 day (dry cured)	8110	7620	8710					
28 day (moist cured)	7280	7320	6920					

* Curing Cabinet

APPENDIX F - Table F-4

Repair: Type IV, Site 6, No. 18
Date: 7/23/1985

Age (hrs)	Compressive Strengths: Ambient Cured (psi)	Compressive Strengths: Patch Top Cured (psi)	Compressive Strengths: TMC* Cured (psi)	Maturities: Ambient Cured (F-hrs)	Maturities: Patch Top Cured (F-hrs)	Maturities: TMC* Cured (F-hrs)	Impact Hammer Numbers (Avg. of 10 readings): Hammer No. 1	Impact Hammer Numbers (Avg. of 10 readings): Hammer No. 2
5	140	130	680	387	256	449	8.4	0.0
6	410	375	1510	470	353	563	14.6	12.8
7	580	900	2430	555	465	686	18.6	18.0
8	1000	1520	2510	644	590	811	20.6	18.8
9	1720	2220	3140	734	717	941	22.2	19.3
10	2430	2860	3020	823	828	1071	24.6	20.7
12	2230	3180	3660	996	1018	1322	23.6	20.0
14	3140	3540	3580	1161	1189	1560	25.2	20.1
24	3820	4160	4380	2038	2333	2681	24.7	21.8
28 day (dry cured)	6230	6620	5950					
28 day (moist cured)	6360	6030	6460					

* Curing Cabinet

APPENDIX G

Patch Condition Ratings

PATCH IDENTITY Type	Site	No.	Date of Evaluat.	Repair Age (mos)	LANE: 1-Pass 2-Traff 3-Ramp	Length (ft.)	SURFACE DETERIORATION: 1--Loss of Macro Texture 2--Coarse Aggr. Expos 3--Loss of Coarse Agg % of Area 1-10	11-25	26-50	>50	NUMBER OF CRACKS Long.	Trans.
2	1	1	6/26/84	0	2	8.25	0	0	0	0	0	0
2	1	1	11/20/85*	17	2	8.25	0	0	2	0	0	0
2	1	1	7/28/86	25	2	8.25	0	0	0	2	0	0
2	1	1	3/8/88	45	2	8.25	0	0	0	2	0	0
3P	1	2A,B	11/20/85*	17	2	1.08	0	0	2	0	0	0
3P	1	2A,B	7/28/86	25	2	1.08	0	0	0	2	0	0
3P	1	2A,B	3/8/88	45	2	1.08	0	0	0	2	0	0
2	1	2C	11/20/85*	17	2	14.66	0	0	2	0	0	0
2	1	2C	7/28/86	25	2	14.66	0	0	0	2	0	0
2	1	2C	3/8/88	45	2	14.66	0	0	0	2	0	0
2	1	2	6/28/84	0	2	18.65	0	0	0	0	0	0
2	1	2	11/20/85*	17	2	18.65	0	0	2	0	0	1
2	1	2	7/28/86	25	2	18.65	0	0	0	2	0	1
2	1	2	3/8/88	45	2	18.65	0	0	0	2	0	1
1	2	3	7/24/84	0	2	7	0	0	0	0	0	0
1	2	3	11/26/85	16	2	7	0	0	0	0	0	0
1	2	3	7/2/86	23	2	7	1	0	0	0	0	0
1	2	3	4/12/88	44	2	7	1	0	0	0	0	0
1	2	4	7/25/84	0	1	6	0	0	0	0	0	0
1	2	4	11/26/85	16	1	6	0	0	0	0	0	0
1	2	4	7/2/86	23	1	6	0	0	0	0	0	0
1	2	4	4/12/88*	44	1	6	0	0	2	1	0	0
1	2	5	7/26/84	0	1	6	0	0	0	0	0	0
1	2	5	11/26/85	16	1	6	0	0	0	0	0	0
1	2	5	7/2/86	23	1	6	0	0	0	0	0	0
1	2	5	4/12/88*	44	1	6	0	0	0	2	0	0
1	3	6	7/31/84	0	2	2.2	0	0	0	0	0	0
1	3	6	12/2/85	16	2	2.2	0	0	0	0	1	0
1	3	6	7/2/86	23	2	2.2	0	0	0	0	1	0
1	3	6	3/31/88	44	2	2.2	1	0	0	0	1	0
1	5	A5-2	12/15/86	27.5	2	6	1	0	0	0	0	0
1	5	A5-2	3/31/88	43	2	6	0	1	0	0	0	0

SEALED 0 - not sealed
1 - part. sealed
2 - sealed

Patch No.	SPALLED CRACKS Minor <1"	SPALLED CRACKS Severe >1"	PUMPING: 0-none 1-minor 2-severe	TRANS. REPAIR EDGE Faulted	TRANS. REPAIR EDGE Spalled	TRANS. REPAIR EDGE Sealed
1	0	0	0	0	0	2
1	0	0	0	1	1	2
1	0	0	0	1	1	2
1	0	0	0	1	1	1
2A,B	0	0	0	0	0	2
2A,B	0	0	0	0	1	2
2A,B	0	0	0	0	1	2
2C	0	0	0	0	0	2
2C	0	0	0	1	0	2
2C	0	0	0	1	0	1
2	0	0	0	0	0	2
2	0	0	0	1	0	2
2	0	0	0	1	0	2
2	1	0	0	1	1	2
3	0	0	0	0	0	0
3	0	0	0	1	0	2
3	0	0	0	1	0	2
3	0	0	1	1	0	1
4	0	0	0	0	0	0
4	0	0	0	0	0	2
4	0	0	0	1	0	2
4	0	0	1	1	0	2
5	0	0	0	0	0	0
5	0	0	0	1	0	2
5	0	0	0	1	0	2
5	0	0	0	1	0	2
6	0	0	0	0	0	2
6	0	0	0	1	0	2
6	0	0	0	1	0	2
6	0	0	0	1	0	2

PATCH IDENTITY Type	Site	No.	Date of Evaluat.	Repair Age (mos)	LANE: 1-Pass 2-Traff 3-Ramp	Length (ft.)	SURFACE DETERIORATION: 1-Loss of Macro Texture 2-Coarse Aggr. Expos 3-Loss of Coarse Agg — % of Area 1-10	11-25	26-50	>50	NUMBER OF CRACKS Long.	Trans.
1	3	7	8/1/84	0	2	3.2	0	0	0	0	0	0
1	3	7	12/2/85	16	2	3.2	0	0	0	0	0	0
1	3	7	7/2/86	23	2	3.2	0	0	0	0	0	0
1	3	7	3/31/88	44	2	3.2	0	0	0	0	0	0
1	3	8	8/1/84	0	2	8.25	0	0	0	0	0	0
1	3	8	12/2/85	16	2	8.25	0	0	0	0	0	0
1	3	8	7/2/86	23	2	8.25	1	0	0	0	0	0
1	3	8	3/31/88	44	2	8.25	1	0	0	0	0	0
1	3	8A	8/2/84	0	2	10.25	0	0	0	0	0	0
1	3	8A	12/2/85	16	2	10.25	0	0	0	0	0	0
1	3	8A	7/2/86	23	2	10.25	0	0	0	0	0	0
1	3	8A	3/31/88	44	2	10.25	1	0	0	0	0	0
2	1	9	8/6/84	0	2	2.29	0	0	0	0	0	0
2	1	9	11/20/85*	15	2	2.29	0	2	0	0	0	0
2	1	9	7/28/86	23	2	2.29	0	0	0	2	0	0
2	1	9	3/8/88	43	2	2.29	0	0	0	2	0	0
2	1	9A	8/7/84	0	2	12.8	0	0	0	0	0	0
2	1	9A	11/20/85*	15	2	12.8	0	2	0	0	0	0
2	1	9A	7/28/86	23	2	12.8	0	0	0	2	0	0
2	1	9A	3/8/88	43	2	12.8	0	0	0	2	0	0
2	1	9B	8/7/84	0	2	6.42	0	0	0	0	0	0
2	1	9B	11/20/85*	15	2	6.42	0	2	0	0	0	0
2	1	9B	7/28/86	23	2	6.42	0	0	0	2	0	0
2	1	9B	3/8/88	43	2	6.42	0	0	0	2	0	0
3P	1	10A	8/9/84	0	1	1.08	0	0	0	0	0	0
3P	1	10A	11/20/85*	15	1	1.08	0	2	0	0	0	0
3P	1	10A	7/28/86	23	1	1.08	0	0	0	2	0	0
3P	1	10A	3/8/88	43	1	1.08	0	0	0	2	0	0
3P	1	10	8/9/84	0	1	1.15	0	0	0	0	0	0
3P	1	10	11/20/85*	15	1	1.15	0	0	2	0	0	0
3P	1	10	7/28/86	23	1	1.15	0	0	0	2	0	0
3P	1	10	3/8/88	43	1	1.15	0	0	0	2	0	0

* Pavement surface has been ground since last evaluation.

FAULTED 0 - none observed
1 - less than 1/2"
2 - more than 1/2"

SPALLED 0 - none observed
1 - less than 1"
2 - more than 1"

SEALED 0 - not sealed
1 - part. sealed
2 - sealed

Patch No.	SPALLED CRACKS Minor <1"	SPALLED CRACKS Severe >1"	PUMPING: 0-none 1-minor 2-severe	TRANS. REPAIR EDGE Faulted	TRANS. REPAIR EDGE Spalled	TRANS. REPAIR EDGE Sealed
7	0	0	0	0	0	2
7	0	0	0	0	0	2
7	0	0	0	0	0	2
7	0	0	1	0	0	2
8	0	0	0	0	0	2
8	0	0	0	1	0	2
8	0	0	0	1	0	2
8	0	0	1	1	0	2
8A	0	0	0	0	0	2
8A	0	0	0	1	0	2
8A	0	0	0	1	0	2
8A	0	0	1	1	0	2
9	0	0	0	0	0	2
9	0	0	0	0	0	2
9	0	0	0	1	0	2
9	0	0	0	1	0	1
9A	0	0	0	0	0	2
9A	0	0	0	0	0	2
9A	0	0	0	0	0	2
9A	0	0	0	0	0	2
9B	0	0	0	0	0	2
9B	0	0	0	0	0	2
9B	0	0	0	2	0	2
9B	0	0	0	2	0	1
10A	0	0	0	0	0	2
10A	0	0	0	0	0	2
10A	0	0	0	0	0	2
10A	0	0	0	0	0	2
10	0	0	0	0	0	2
10	0	0	0	0	0	2
10	0	0	0	0	0	2
10	0	0	0	0	0	2

PATCH IDENTITY Type	Site	No.	Date of Evaluat.	Repair Age (mos)	LANE: 1-Pass 2-Traff 3-Ramp	Length (ft.)	SURFACE DETERIORATION: 1-Loss of Macro Texture 2-Coarse Aggr. Expos 3-Loss of Coarse Agg % of Area 1-10	11-25	26-50	>50	NUMBER OF CRACKS Long.	Trans.
1	2	11	8/13/84	0	1	6	0	0	0	0	0	0
1	2	11	11/26/85	15	1	6	0	0	0	0	0	0
1	2	11	7/2/86	22	1	6	0	0	0	0	0	0
1	2	11	4/12/88*	43	1	6	0	0	0	2	0	0
3P	3	12	8/15/84	0	2	4.7	0	0	0	0	0	0
3P	3	12	12/2/85	15.5	2	4.7	0	0	0	0	0	0
3P	3	12	7/2/86	22.5	2	4.7	0	0	0	0	0	0
3P	3	12	3/31/88	43.5	2	4.7	1	0	0	0	0	0
3P	3	13	8/16/84	0	2	5.5	0	0	0	0	0	0
3P	3	13	12/2/85	15.5	2	5.5	0	0	0	0	0	0
3P	3	13	7/2/86	22.5	2	5.5	0	0	0	0	0	0
3P	3	13	3/31/88	43.5	2	5.5	1	0	0	0	0	0
1	3	13A	12/2/85	15.5	2	21	0	0	0	0	0	2
1	3	13A	7/2/86	22.5	2	21	0	0	0	0	0	2
1	3	13A	3/31/88	43.5	2	21	1	0	0	0	1	2
4	4	14	12/10/84	0	3	10.71	0	0	0	0	0	0
4	4	14	7/1/86	19	3	10.71	0	0	0	0	0	0
4	4	14	4/6/88	40	3	10.71	1	0	0	0	0	0
3F	4	15	6/24/85	0	3	3.5	0	0	0	0	0	0
3F	4	15	7/2/86	12	3	3.5	0	0	0	0	0	0
3F	4	15	4/6/88	33	3	3.5	0	1	0	0	1	0
1	2	16	7/8/85	0	2	6.08	0	0	0	0	0	0
1	2	16	7/2/86	12	2	6.08	0	0	0	0	0	0
1	2	16	4/12/88	33	2	6.08	0	0	0	0	0	0
2	5	17	7/16/85	0	2	20.5	0	0	0	0	0	0
2	5	17	7/1/86	11.5	2	20.5	0	0	0	0	0	0
2	5	17	4/6/88	32.5	2	20.5	1	0	0	0	0	0
4A	6	18	7/23/85	0	1	56	0	0	0	0	0	0
4A	6	18	7/1/86	11.5	1	56	0	0	0	0	0	1
4A	6	18	4/12/88	32.5	1	56	0	0	0	0	0	1

* Pavement surface has been ground since last evaluation.

1 - less than 1/2"
2 - more than 1/2"

1 - less than 1"
2 - more than 1"

SEALED 0 - not sealed
1 - part. sealed
2 - sealed

Patch No.	SPALLED CRACKS Minor <1"	Severe >1"	PUMPING: 0-none 1-minor 2-severe	TRANS. REPAIR EDGE Faulted	Spalled	Sealed
11	0	0	0	0	0	0
11	0	0	0	1	0	2
11	0	0	0	1	0	2
11	0	0	0	1	0	2
12	0	0	0	0	0	0
12	0	0	0	0	0	0
12	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
13	0	0	0	0	0	0
13	0	0	0	0	0	0
13	0	0	1	0	2	0
13A	0	0	0	1	0	2
13A	0	2	0	1	0	2
13A	1	1	1	1	0	1
14	0	0	0	0	1	2
14	0	0	0	0	2	2
14	0	0	0	0	1	1
15	0	0	0	0	0	0
15	0	0	0	0	1	0
15	1	0	1	1	1	0
16	0	0	0	0	0	2
16	0	0	0	1	0	2
16	0	0	0	1	0	2
17	0	0	0	0	0	2
17	0	0	2	1	0	2
17	0	0	1	1	0	2
18	0	0	0	0	0	2
18	0	0	0	0	0	2
18	1	0	0	0	0	2

Repairs Evaluated for 'ARE' Project

PATCH IDENTITY Type	Site	No.	Date of Evaluat.	Repair Age (mos)	LANE: 1-Pass 2-Traff 3-Ramp	Length (ft.)	SURFACE DETERIORATION: 1-Loss of Macro Texture 2-Coarse Aggr. Expos 3-Loss of Coarse Agg % of Area 1-10	11-25	26-50	>50	NUMBER OF CRACKS Long.	Trans.
2	1	A1-1	7/11/83	0	2	6.25	0	0	0	0	0	0
2	1	A1-1	11/28/84	16.5	2	6.25	0	0	0	0	0	0
2	1	A1-1	7/8/85	23.5	2	6.25	0	0	0	0	0	0
2	1	A1-1	11/25/85	28.5	2	6.25	0	0	0	0	0	0
2	1	A1-1	7/1/86	35.5	2	6.25	0	0	0	0	0	0
2	1	A1-1	11/24/86	40.5	2	6.25	0	0	0	0	0	0
2	1	A1-1	4/6/88	57	2	6.25	0	1	0	0	0	0
2	1	A1-2	7/11/83	0	2	6.58	0	0	0	0	0	0
2	1	A1-2	11/28/84	16.5	2	6.58	0	0	0	0	0	0
2	1	A1-2	7/8/85	23.5	2	6.58	0	0	0	0	0	0
2	1	A1-2	11/25/85	28.5	2	6.58	0	0	0	0	0	0
2	1	A1-2	7/1/86	35.5	2	6.58	0	0	0	0	0	0
2	1	A1-2	11/24/86	40.5	2	6.58	0	0	0	0	0	0
2	1	A1-2	4/6/88	57	2	6.58	0	1	0	0	0	0
2	1	A1-3	7/11/83	0	2	5.5	0	0	0	0	0	0
2	1	A1-3	11/28/84	16.5	2	5.5	0	0	0	0	0	0
2	1	A1-3	7/8/85	23.5	2	5.5	0	0	0	0	0	0
2	1	A1-3	11/25/85	28.5	2	5.5	0	0	0	0	0	0
2	1	A1-3	7/1/86	35.5	2	5.5	0	0	0	0	0	0
2	1	A1-3	11/24/86	40.5	2	5.5	0	0	0	0	0	0
2	1	A1-3	4/6/88	57	2	5.5	0	1	0	0	0	0
2	1	A1-4	7/11/83	0	2	3.92	0	0	0	0	0	0
2	1	A1-4	11/28/84	16.5	2	3.92	0	0	0	0	0	0
2	1	A1-4	7/8/85	23.5	2	3.92	0	0	0	0	0	0
2	1	A1-4	11/25/85	28.5	2	3.92	0	0	0	0	0	0
2	1	A1-4	7/1/86	35.5	2	3.92	0	0	0	0	0	0
2	1	A1-4	11/24/86	40.5	2	3.92	0	0	0	0	0	0
2	1	A1-4	4/6/88	57	2	3.92	0	0	1	0	0	0

* Pavement surface has been ground since last evaluation.

FAULTED 0 - none observed
1 - less than 1/2"
2 - more than 1/2"

SPALLED 0 - none observed
1 - less than 1"
2 - more than 1"

SEALED 0 - not sealed
1 - part. sealed
2 - sealed

Repairs Evaluated for ARE Project

Patch No.	SPALLED CRACKS Minor <1"	SPALLED CRACKS Severe >1"	PUMPING: 0-none 1-minor 2-severe	TRANS. REPAIR EDGE Faulted	TRANS. REPAIR EDGE Spalled	TRANS. REPAIR EDGE Sealed
A1-1	0	0	0	0	0	1
A1-1	0	0	0	0	0	2
A1-1	0	0	0	0	0	2
A1-1	0	0	0	0	0	1
A1-1	0	0	0	1	1	2
A1-1	0	0	0	1	1	1
A1-1	0	0	0	2	1	2
A1-2	0	0	0	0	0	1
A1-2	0	0	0	0	1	2
A1-2	0	0	0	0	1	2
A1-2	0	0	0	0	1	1
A1-2	0	0	0	1	2	2
A1-2	0	0	0	1	2	1
A1-2	0	0	0	1	2	2
A1-3	0	0	0	0	0	1
A1-3	0	0	0	0	0	2
A1-3	0	0	0	0	1	2
A1-3	0	0	0	0	0	1
A1-3	0	0	0	1	0	2
A1-3	0	0	0	1	0	1
A1-3	0	0	0	2	0	2
A1-4	0	0	0	0	1	1
A1-4	0	0	0	0	1	1
A1-4	0	0	0	0	1	0
A1-4	0	0	0	0	1	0
A1-4	0	0	0	1	1	2
A1-4	0	0	0	1	1	1
A1-4	0	0	0	1	1	1

Repairs Evaluated for 'ARE' Project

PATCH IDENTITY Type	Site	No.	Date of Evaluat.	Repair Age (mos)	LANE: 1-Pass 2-Traff 3-Ramp	Length (ft.)	SURFACE DETERIORATION: 1-Loss of Macro Texture 2-Coarse Aggr. Expos 3-Loss of Coarse Agg % of Area 1-10	11-25	26-50	>50	NUMBER OF CRACKS Long.	Trans.
2	2	A2-1	7/11/83	12	2	4.83	0	0	0	0	0	0
2	2	A2-1	11/28/84	28.5	2	4.83	0	0	0	0	0	0
2	2	A2-1	7/8/85	35.5	2	4.83	0	0	0	0	0	0
2	2	A2-1	11/25/85	40.5	2	4.83	0	0	0	0	0	0
2	2	A2-1	7/1/86	47.5	2	4.83	0	0	0	0	0	0
2	2	A2-1	11/18/86	52.5	2	4.83	0	0	0	0	0	0
2	2	A2-1	4/11/88	69	2	4.83	1	0	0	0	0	0
2	2	A2-2	7/11/83	12	2	21.66	0	0	0	0	0	1
2	2	A2-2	11/28/84	28.5	2	21.66	0	0	0	0	0	1
2	2	A2-2	7/8/85	35.5	2	21.66	0	0	0	0	0	0
2	2	A2-2	11/25/85	40.5	2	21.66	0	0	0	0	0	1
2	2	A2-2	7/1/86	47.5	2	21.66	0	0	0	0	0	1
2	2	A2-2	11/18/86	52.5	2	21.66	0	0	0	0	0	1
2	2	A2-2	4/11/88	69	2	21.66	1	0	0	0	0	1
2	2	A2-3	7/11/83	12	2	3	0	0	0	0	0	0
2	2	A2-3	11/28/84	28.5	2	3	0	0	0	0	0	0
2	2	A2-3	7/8/85	35.5	2	3	0	0	0	0	0	0
2	2	A2-3	11/25/85	40.5	2	3	0	0	0	0	0	0
2	2	A2-3	7/1/86	47.5	2	3	0	0	0	0	0	0
2	2	A2-3	11/18/86	52.5	2	3	0	0	0	0	0	0
2	2	A2-3	4/11/88	69	2	3	1	0	0	0	0	0
2	2	A2-4	7/11/83	12	2	5.33	0	0	0	0	0	2
2	2	A2-4	11/28/84	28.5	2	5.33	0	0	0	0	0	2
2	2	A2-4	7/8/85	35.5	2	5.33	0	0	0	0	0	0
2	2	A2-4	11/25/85	40.5	2	5.33	0	0	0	0	0	0
2	2	A2-4	7/1/86	47.5	2	5.33	0	0	0	0	0	0
2	2	A2-4	11/18/86	52.5	2	5.33	0	0	0	0	0	0
2	2	A2-4	4/11/88	69	2	5.33	1	0	0	0	0	0

FAULTED 0 - none observed
1 - less than 1/2"
2 - more than 1/2"

SPALLED 0 - none observed
1 - less than 1"
2 - more than 1"

SEALED 0 - not sealed
1 - part. sealed
2 - sealed

Repairs Evaluated for ARE Project

Patch No.	SPALLED CRACKS Minor <1"	SPALLED CRACKS Severe >1"	PUMPING: 0-none 1-minor 2-severe	TRANS. REPAIR EDGE Faulted	TRANS. REPAIR EDGE Spalled	TRANS. REPAIR EDGE Sealed
A2-1	0	0	0	0	0	2
A2-1	0	0	0	0	0	2
A2-1	0	0	0	0	0	2
A2-1	0	0	0	0	0	2
A2-1	0	0	0	1	1	1
A2-1	0	0	0	1	1	1
A2-1	0	0	0	2	1	2
A2-2	0	0	0	0	0	2
A2-2	0	0	0	0	0	2
A2-2	0	0	0	0	0	0
A2-2	1	0	0	0	0	2
A2-2	1	0	0	1	0	1
A2-2	1	0	0	1	0	1
A2-2	0	1	0	1	0	2
A2-3	0	0	0	0	0	2
A2-3	0	0	0	1	0	1
A2-3	0	0	0	1	0	0
A2-3	0	0	0	1	0	0
A2-3	0	0	0	1	0	0
A2-3	0	0	0	1	0	0
A2-3	0	0	1	1	0	1
A2-4	0	0	0	0	0	2
A2-4	0	0	0	1	1	2
A2-4	0	0	0	1	1	1
A2-4	0	0	0	0	1	0
A2-4	0	0	0	2	1	1
A2-4	0	0	0	2	1	1
A2-4	0	0	2	1	1	1

Repairs Evaluated for 'ARE' Project

PATCH IDENTITY Type	Site	No.	Date of Evaluat.	Repair Age (mos)	LANE: 1-Pass 2-Traff 3-Ramp	Length (ft.)	SURFACE DETERIORATION: 1-Loss of Macro Texture 2-Coarse Aggr. Expos 3-Loss of Coarse Agg — % of Area 1-10	11-25	26-50	>50	NUMBER OF CRACKS Long.	Trans.
2	3	A3-1	7/11/83	0	2	3.75	0	0	0	0	0	0
2	3	A3-1	11/28/84	16.5	2	3.75	0	0	0	0	0	0
2	3	A3-1	7/8/85	23.5	2	3.75	0	0	0	0	0	0
2	3	A3-1	11/25/85	28.5	2	3.75	0	0	0	0	0	0
2	3	A3-1	7/1/86	35.5	2	3.75	0	0	0	0	0	0
2	3	A3-1	11/18/86	40.5	2	3.75	0	0	0	0	0	0
2	3	A3-1	4/11/88	57.5	2	3.75	1	0	0	0	0	0
2	3	A3-2	7/11/83	0	2	2.33	0	0	0	0	0	0
2	3	A3-2	11/28/84	16.5	2	2.33	0	0	0	0	0	0
2	3	A3-2	7/8/85	23.5	2	2.33	0	0	0	0	0	0
2	3	A3-2	11/25/85	28.5	2	2.33	0	0	0	0	0	0
2	3	A3-2	7/1/86	35.5	2	2.33	0	0	0	0	0	0
2	3	A3-2	11/18/86	40.5	2	2.33	0	0	0	0	0	0
2	3	A3-2	4/11/88	57.5	2	2.33	1	0	0	0	0	0
2	3	A3-3	7/11/83	0	2	3.91	0	0	0	0	0	0
2	3	A3-3	11/28/84	16.5	2	3.91	0	0	0	0	0	0
2	3	A3-3	7/8/85	23.5	2	3.91	0	0	0	0	0	0
2	3	A3-3	11/25/85	28.5	2	3.91	0	0	0	0	0	1
2	3	A3-3	7/1/86	35.5	2	3.91	0	0	0	0	0	0
2	3	A3-3	11/18/86	40.5	2	3.91	0	0	0	0	0	0
2	3	A3-3	4/11/88	57.5	2	3.91	1	0	0	0	0	0
2	3	A3-4	7/11/83	0	2	4.33	0	0	0	0	0	0
2	3	A3-4	11/28/84	16.5	2	4.33	0	0	0	0	0	0
2	3	A3-4	7/8/85	23.5	2	4.33	0	0	0	0	0	0
2	3	A3-4	11/25/85	28.5	2	4.33	0	0	0	0	0	0
2	3	A3-4	7/1/86	35.5	2	4.33	0	0	0	0	0	0
2	3	A3-4	11/18/86	40.5	2	4.33	0	0	0	0	0	0
2	3	A3-4	4/11/88	57.5	2	4.33	1	0	0	0	0	0

FAULTED 0 – none observed
1 – less than 1/2"
2 – more than 1/2"

SPALLED 0 – none observed
1 – less than 1"
2 – more than 1"

SEALED 0 – not sealed
1 – part. sealed
2 – sealed

Repairs Evaluated for ARE Project

Patch No.	SPALLED CRACKS Minor <1"	SPALLED CRACKS Severe >1"	PUMPING: 0-none 1-minor 2-severe	TRANS. REPAIR EDGE Faulted	TRANS. REPAIR EDGE Spalled	TRANS. REPAIR EDGE Sealed
A3-1	0	0	0	0	0	2
A3-1	0	0	0	1	0	2
A3-1	0	0	0	0	0	0
A3-1	0	0	0	1	0	2
A3-1	0	0	0	1	0	2
A3-1	0	0	0	1	0	2
A3-1	0	0	1	1	0	1
A3-2	0	0	0	0	0	2
A3-2	0	0	0	1	0	2
A3-2	0	0	0	1	0	2
A3-2	0	0	0	1	0	2
A3-2	0	0	0	0	0	2
A3-2	0	0	0	0	0	2
A3-2	0	0	1	1	0	1
A3-3	0	0	0	0	0	1
A3-3	0	0	0	0	0	2
A3-3	0	0	0	0	1	2
A3-3	0	0	0	1	1	1
A3-3	0	0	0	1	2	1
A3-3	0	0	0	1	2	1
A3-3	0	0	2	1	2	1
A3-4	0	0	0	0	0	2
A3-4	0	0	0	0	0	2
A3-4	0	0	0	0	0	2
A3-4	0	0	0	1	1	1
A3-4	0	0	0	1	1	1
A3-4	0	0	0	1	1	1
A3-4	0	0	1	1	1	1

APPENDIX G - Patch Condition Ratings [PATCH CONDITION]

Repairs Evaluated for 'ARE' Project

PATCH IDENTITY Type	Site	No.	Date of Evaluat.	Repair Age (mos)	LANE: 1-Pass 2-Traff 3-Ramp	Length (ft.)	SURFACE DETERIORATION: 1-Loss of Macro Texture 2-Coarse Aggr. Expos 3-Loss of Coarse Agg — % of Area 1-10	11-25	26-50	>50	NUMBER OF CRACKS Long.	Trans.
1	4	A4-1	7/12/83	24	2	3.5	0	0	0	0	0	0
1	4	A4-1	11/28/84	40.5	2	3.5	0	0	0	0	0	0
1	4	A4-1	7/9/85	47.5	2	3.5	0	1	0	0	0	0
1	4	A4-1	11/25/85	52.5	2	3.5	0	1	0	0	0	0
1	4	A4-1	7/2/86	59.5	2	3.5	2	0	1	0	0	0
1	4	A4-1	11/18/86*	64.5	2	3.5	0	0	0	2	0	0
1	4	A4-1	4/11/88	81.5	2	3.5	0	0	0	2	0	0
1	4	A4-2	7/12/83	24	2	2.91	0	0	0	0	0	0
1	4	A4-2	11/28/84	40.5	2	2.91	0	0	0	0	0	0
1	4	A4-2	7/9/85	47.5	2	2.91	1	0	0	0	0	0
1	4	A4-2	11/25/85	52.5	2	2.91	1	0	0	0	0	0
1	4	A4-2	7/2/86	59.5	2	2.91	2	0	1	0	0	0
1	4	A4-2	11/18/86*	64.5	2	2.91	0	0	0	2	0	0
1	4	A4-2	4/11/88	81.5	2	2.91	0	0	0	2	0	0
1	4	A4-3	7/12/83	24	2	3.08	0	0	0	0	0	0
1	4	A4-3	11/28/84	40.5	2	3.08	0	0	0	0	0	0
1	4	A4-3	7/9/85	47.5	2	3.08	1	0	0	0	0	0
1	4	A4-3	11/25/85	52.5	2	3.08	1	0	0	0	0	0
1	4	A4-3	7/2/86	59.5	2	3.08	2	0	1	0	0	0
1	4	A4-3	11/18/86*	64.5	2	3.08	0	0	0	2	0	0
1	4	A4-3	4/11/88	81.5	2	3.08	0	0	0	2	0	0
1	4	A4-4	7/12/83	24	2	2.66	0	0	0	0	0	0
1	4	A4-4	11/28/84	40.5	2	2.66	0	0	0	0	0	0
1	4	A4-4	7/9/85	47.5	2	2.66	1	0	0	0	1	0
1	4	A4-4	11/25/85	52.5	2	2.66	1	0	0	0	1	0
1	4	A4-4	7/2/86	59.5	2	2.66	2	0	1	0	1	0
1	4	A4-4	11/18/86*	64.5	2	2.66	0	0	0	2	1	0
1	4	A4-4	4/11/88	81.5	2	2.66	0	0	0	2	1	0

* Pavement surface has been ground since last evaluation.

FAULTED 0 - none observed
1 - less than 1/2"
2 - more than 1/2"

SPALLED 0 - none observed
1 - less than 1"
2 - more than 1"

SEALED 0 - not sealed
1 - part. sealed
2 - sealed

Repairs Evaluated for ARE Project

Patch No.	SPALLED CRACKS Minor <1"	SPALLED CRACKS Severe >1"	PUMPING: 0-none 1-minor 2-severe	TRANS. REPAIR EDGE Faulted	TRANS. REPAIR EDGE Spalled	TRANS. REPAIR EDGE Sealed
A4-1	0	0	0	1	0	2
A4-1	0	0	0	2	0	2
A4-1	0	0	0	2	0	2
A4-1	0	0	0	2	0	1
A4-1	0	0	0	2	0	1
A4-1	0	0	0	1	0	1
A4-1	0	0	1	1	0	1
A4-2	0	0	0	1	0	2
A4-2	0	0	0	1	0	2
A4-2	0	0	0	1	0	2
A4-2	0	0	0	2	0	2
A4-2	0	0	0	2	0	2
A4-2	0	0	0	0	0	2
A4-2	0	0	1	1	0	1
A4-3	0	0	0	2	0	2
A4-3	0	0	0	1	0	2
A4-3	0	0	0	1	0	2
A4-3	0	0	0	2	1	1
A4-3	0	0	0	2	1	1
A4-3	0	0	0	1	1	1
A4-3	0	0	1	1	1	1
A4-4	0	0	0	1	0	2
A4-4	0	0	0	0	0	2
A4-4	0	0	0	1	0	2
A4-4	0	0	0	1	1	1
A4-4	0	0	0	2	1	1
A4-4	0	0	0	0	1	1
A4-4	1	0	0	0	0	1

Repairs Evaluated for 'ARE' Project

PATCH IDENTITY Type	Site No.	Date of Evaluat.	Repair Age (mos)	LANE: 1-Pass 2-Traff 3-Ramp	Length (ft.)	SURFACE DETERIORATION: 1-Loss of Macro Texture 2-Coarse Aggr. Expos 3-Loss of Coarse Agg % of Area 1-10	11-25	26-50	>50	NUMBER OF CRACKS Long.	Trans.
1	5 A5-1	7/12/83	0	2	22.17	0	0	0	0	0	0
1	5 A5-1	11/20/84	16	2	22.17	0	0	0	0	0	0
1	5 A5-1	7/9/85	23	2	22.17	1	0	0	0	0	0
1	5 A5-1	11/26/85	28	2	22.17	1	0	0	0	0	0
1	5 A5-1	7/2/86	35	2	22.17	1	0	0	0	0	0
1	5 A5-1	12/15/86	40.5	2	22.17	1	0	0	0	0	0
1	5 A5-1	3/31/88	56	2	22.17	1	0	0	0	0	0
1	5 A5-2	11/20/84	3	2	6	0	0	0	0	0	0
1	5 A5-2	7/9/85	10	2	6	1	0	0	0	0	0
1	5 A5-2	11/26/85	15	2	6	1	0	0	0	0	0
1	5 A5-2	7/2/86	22	2	6	1	0	0	0	0	0
1	5 A5-2	12/15/86	27.5	2	6	1	0	0	0	0	0
1	5 A5-2	3/31/88	43	2	6	0	1	0	0	0	0
1	5 A5-3	11/20/84	3	2	1.75	0	0	0	0	0	0
1	5 A5-3	7/9/85	10	2	1.75	0	0	0	0	1	0
1	5 A5-3	11/26/85	15	2	1.75	0	0	0	0	1	0
1	5 A5-3	7/2/86	22	2	1.75	0	0	0	0	1	0
1	5 A5-3	12/15/86	27.5	2	1.75	0	0	0	0	1	0
1	5 A5-3	3/31/88	43	2	1.75	0	1	0	0	1	0
1	5 A5-4	11/20/84	3	2	1.75	0	0	0	0	0	0
1	5 A5-4	7/9/85	10	2	1.75	0	0	0	0	0	0
1	5 A5-4	11/26/85	15	2	1.75	0	0	0	0	0	0
1	5 A5-4	7/2/86	22	2	1.75	0	0	0	0	0	0
1	5 A5-4	12/15/86	27.5	2	1.75	0	0	0	0	1	0
1	5 A5-4	3/31/88	43	2	1.75	0	1	0	0	1	0

FAULTED 0 - none observed
1 - less than 1/2"
2 - more than 1/2"

SPALLED 0 - none observed
1 - less than 1"
2 - more than 1"

SEALED 0 - not sealed
1 - part. sealed
2 - sealed

Repairs Evaluated for ARE Project

Patch No.	SPALLED CRACKS Minor <1"	SPALLED CRACKS Severe >1"	PUMPING: 0-none 1-minor 2-severe	TRANS. REPAIR EDGE Faulted	TRANS. REPAIR EDGE Spalled	TRANS. REPAIR EDGE Sealed
A5-1	0	0	0	0	0	0
A5-1	0	0	0	2	0	2
A5-1	0	0	0	2	0	2
A5-1	0	0	0	2	0	2
A5-1	0	0	0	2	0	2
A5-1	0	0	0	2	0	2
A5-1	0	0	2	2	0	0
A5-2	0	0	0	0	0	2
A5-2	0	0	0	0	0	2
A5-2	0	0	0	1	1	1
A5-2	0	0	0	1	1	1
A5-2	0	0	0	1	1	1
A5-2	0	0	2	1	0	1
A5-3	0	0	0	0	0	2
A5-3	0	0	0	0	0	2
A5-3	0	0	0	0	0	2
A5-3	0	0	0	0	0	2
A5-3	0	0	0	0	0	2
A5-3	1	0	1	0	1	1
A5-4	0	0	0	0	0	2
A5-4	0	0	0	0	0	2
A5-4	0	0	0	1	1	1
A5-4	0	0	0	1	1	1
A5-4	0	0	0	0	1	2
A5-4	1	0	1	0	1	1