PATCHING OF PCC PAVEMENTS

FIELD EVALUATION OF MATERIALS & CONSTRUCTION TECHNIQUES

Project Number ST-2019-2

Summary Report

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ABSTRACT

Laboratory and field studies were conducted to evaluate three rapid setting PCC pavement patching materials, the effects of temperature during patch construction, the effects of anchors on patch performance and the effects of sawing to outline patch area on patch performance. Patches were constructed on I-59 in Gadsden and I-85 in Montgomery.

Mix design studies revealed that PCC with and without steel fibers could be produced that provided adequate rapid-setting strength. Four hour strengths of these materials were lower than the proprietary material Roadpatch but after 5 to 6 hours they provided higher strengths.

Anchor optimization studies revealed that the ultimate load that could be resisted by a simulated patch was linearly proportional to the amount of steel and that smaller anchor sizes provided better performance.

Field studies revealed that outlining deteriorated areas with a 1-2 inch deep sawcut aided in patch area preparation. Vibration of patch materials was essential for proper consolidation.

Steel fibrous PCC patches performed best. Patches constructed during warm weather performed better than those constructed during cool weather. Anchors did not appear to improve patch performance. Sawing did not dramatically improve patch performance but did aid in patch construction.

TABLE OF CONTENTS

INTRODUCTION

A key requirement for a pavement patch is that it be durable and long lasting. For heavily traveled roadways, the requirement of rapid constructibility must be added in order to minimize disruptions to traffic flow. For routine operations this means that patches must be constructed between morning and afternoon peak traffic flow periods. This gives total construction time of less than eight hours which translates into even shorter curing times. Six hours, as a target curing time, was suggested by Ross (1) as reasonable for construction within an eight-hour work shift and was used in earlier laboratory studies (2). The need for economical yet durable patches that could be rapidly constructed lead to the research described herein. Patch material and construction techniques were examined.

Research Objectives

The objectives of the research were 1) to identify patch materials and construction techniques that would produce economical durable patches constructed and cured in one working day, 2) to construct a series of patches under a variety of conditions and monitor their performance, and 3) to develop recommendations for PCC pavement patch construction.

Scope of Research

To accomplish research objectives patches were constructed and monitored at two locations (I-59 in Gadsden and I-85 in Montgomery) with three materials (Roadpatch II [1], rapid-setting PCC, and rapid-setting steel fibrous PCC). Patches were constructed during two seasons (warm

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[1] Commercially available patching material marketed by Thoro Systems Products

and cool), with two anchor schemes (anchored and unanchored), and with two patch area preparation techniques (outline sawing and unsawed). Mix design studies were conducted to develop mixture proportions for the three patch materials with local coarse and fine aggregate. A series of tests with simulated patches were conducted to optimize anchor design.

MIX DESIGN STUDIES

Design studies were conducted to select ingredient proportions for a rapid setting PCC mixture and a rapid setting PCC mixture with steel fibers. Manufacturer recommendations were followed for a Roadpatch II[1] mixture. The goal of the mix design process was mix proportions that would provide adequate strength for construction within an eight-hour workday while maintaining reasonable cement content (shrinkage control), accelerator content (manufacturer recommendations), mixability (in small portable mixers), workability and finishability. Coarse aggregate was pea gravel size (3/4" maximum size -- *78 AHD designation) crushed limestone in Gadsden and river gravel in Montgomery. Fine aggregate was natural concrete sand (*100 AHD designation) at both locations.

Type III cement with a "nonchloride" accelerator (ASTM C494, Type C) was used to increase rate of strength gain. The particular brand accelerator used was Master Builders, Inc., Pozzolith 555 Accelerator. Dosage rates were maintained within manufacturer recommended range. No air entraining admixture was used and resulting air contents averaged about 3%. Steel fibers 3/4" long with 0.01" x 0.022" cross section, from Mitchell Fibercon, Inc. were used in the fibrous mix.

Roadpatch II[1] ingredients include a cement-sand grout mixture, 3/8" long 0.01" diameter steel fibers and an acrylic polymer type latex (Acryl

60) modifier. To these ingredients were added coarse aggregate and water to produce a patching mixture.

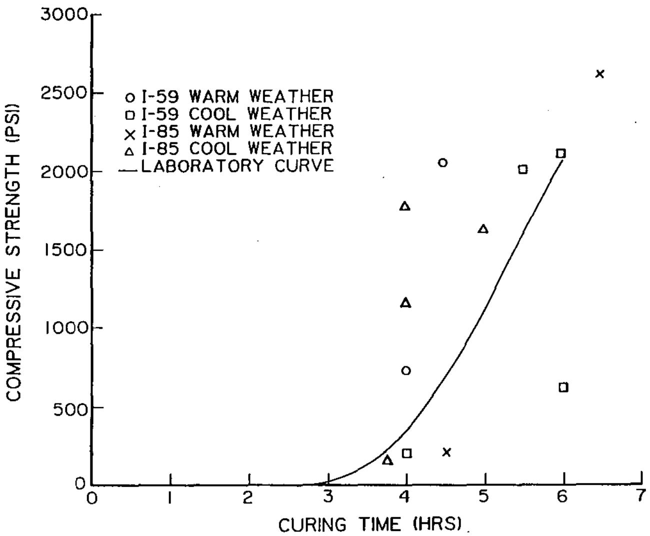
Mixture proportions for rapid-setting PCC and fibrous rapid-setting PCC were selected to provide approximately 2000 psi 6 hr. compressive strength. Early strength laboratory curves are shown in Figures 1a and b. Long term strength curves are shown in Figure 2. Manufacturer recommendations were followed for Roadpatch II and an early laboratory strength curve shown in Figure 1c.

ANCHOR OPTIMIZATION STUDIES

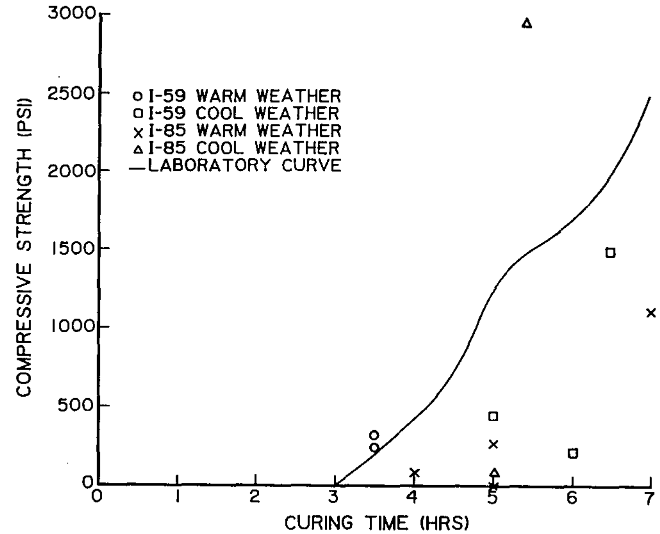
The laboratory study (2) that preceded this study provided some indication that anchors might improve the resistance of patches to loads. A series of tests were conducted to extend the earlier study, and to develop rudimentary data that could be used to select the amount, size and type anchor steel for inclusion in the patches. Blocks of concrete (18" x 6-1/2" x 5-1/2") with various anchor configurations, were cast on the surface of an old concrete pavement slab and loaded horizontally. Reinforcing bars (#3, #4, and #6) bent into a "U" shape and shear connectors (1/2" and 3/4" diameter), as used in composite design, were used as anchors.

There was a general linear increase in maximum load with percent anchor steel. One-half inch diameter shear connectors and reinforcing bars were more efficient than 3/4" diameter, and there was no discernable difference between the effectiveness of reinforcing bars and shear connectors with the same diameter.

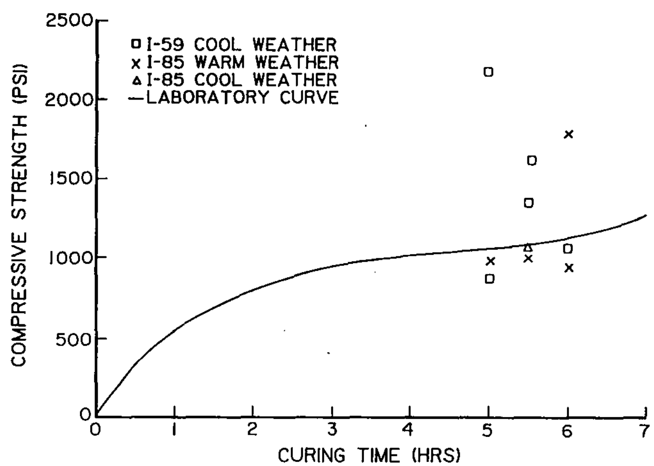
Based on these tests, anchors comprised of #4 reinforcing bars were selected for use in field patches. A target of 0.5% anchor steel was



a. Rapid-Setting PCC

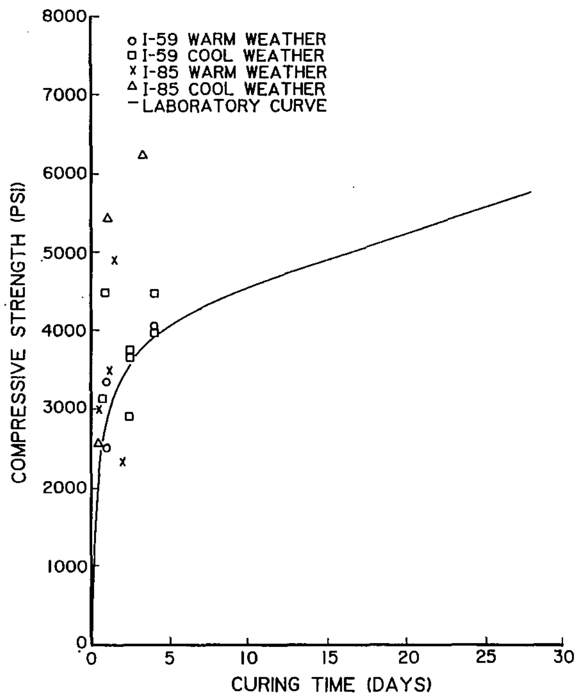


b. Fibrous PCC

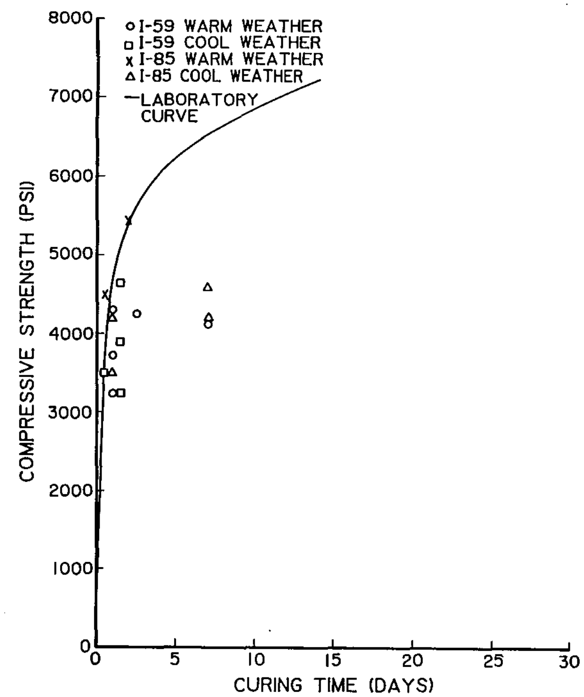


c. Roadpatch

Figure 1. Comparison of Early Lab and Field Strengths



a. Rapid-Setting PCC



b. Fibrous PCC

Figure 2. Comparison of Long-Term Lab and Field Strengths

selected. However, construction considerations prevented achievement of this target and an average 0.3% steel was placed in anchored patches.

PATCH CONSTRUCTION

Gadsden patches were constructed on the southbound lanes of I-59 between the US 431 and I-759 intersections and on the southbound entrance ramp from US 431. The pavement was jointed PCC that had required little previous patching. Twenty-one patches were constructed on the entrance ramp and the inside lane during August 6-11, 1986. Maximum daily air temperature ranged from 90 to 96°F. Twenty-two patches were constructed on the outside lane during December 4-18, 1986. Maximum daily air temperature ranged from 50 - 60°F. Patch size ranged from 1 to 25 sf plan area with an overage of about 6-1/2 sf. The average depth was about 4 inches.

Montgomery patches were constructed on the southbound lanes of I-85 between the Eastern Bypass and Perry Hill Road intersections. The pavement was jointed PCC that had undergone extensive rehabilitation; including undersealing, side drain installation, slab replacement, patching, grinding and joint sealing; several years earlier. Twenty-five patches were constructed on the inside lane during October 31, 1986 to November 10, 1986. Maximum daily air temperature ranged from 70 to 80° F. Fourteen patches were constructed on the outside lane during February 11-20, 1987. Maximum daily air temperature ranged from 50 to 65°F. Patch plan area size was smaller than the Gadsden patches ranging from 1/2 to 15 sf with an average of about 4 sf. The patch depth, however, was somewhat greater with some extending below the welded wire fabric at 5 inch depth. The average depth was 4 to 5 inches.

Patches were constructed by Alabama Highway Department personnel with conventional equipment and procedures. A 1-2" deep sawcut around deteriorated areas made removal of concrete easier, provided uniform patch edge depth, and reduced jackhammer damage when preparing patch areas. Vibration was necessary for consolidating patch material and enhancing bond development.

Field strength values are plotted on early and long-term lab strength curves in Figures 1 and 2, respectively. For rapid-setting PCC, the early field strengths were generally higher while for fibrous PCC the early field strengths were generally lower. For the Roadpatch, the laboratory curve roughly splits the field strength values.

For long term strength, Figure 2, the trends observed are the same as for early strengths, i.e. field strengths for PCC are generally higher than the lab curve and field strengths fibrous PCC are generally lower than the lab curve. Considering field variability, the comparisons indicate that desired strengths were achieved reasonably well in the field.

PATCH PERFORMANCE

Performance of patches was monitored by periodically observing and documenting their condition. The following summarizes the observation schedule for the patches:

I-59 Warm Weather	- 4, 8 & 15 month observations
I-59 Cool Weather	- 4 & 11 month observations
I-85 Warm Weather	- 4, 6 & 11 month observations
I-85 Cool Weather	- 2 & 7 month observations

The following discussion of deterioration mechanisms is based on these observations and the performance rankings are based on the final observations for each patch grouping.

Patch deterioration developed in several stages beginning with localized cracking. Localized cracking progressed until large spalls began to break loose. In some patches, this progressed until it became necessary to completely remove the remaining patch material and replace with asphalt mix. In a few patches, shallow spalling developed along joints and around the patch-slab interface. In no case was this a serious failure mode unless accompanied by cracking.

Loss of bond did not appear to be a serious problem; and may account for the ineffectiveness of anchors. No patches were displaced as-a-whole without being accompanied by cracking. It should be noted, however, that localized cracking may have been caused or, at least, aggravated by partial bond loss.

Based on visual observations of the patches during the final survey, patches were grouped, according to the amount of distress, into the following three categories:

- No distress
- Moderate distress - localized cracking & light spalling
- Severe distress - severe cracking & deep spalling requiring maintenance

Survey results are sumarized in Table 1. Comparison of the performance of patches placed during warm and cool weather reveals better performance for those placed during warm weather. Evidence of this is the larger percentage of warm weather patches falling in the no distress category and the smaller percentages falling in the severe distress category. Improved performance of warm weather patches can be attributed to the more rapid rate of strength gain which reduces early damage when opened to traffic.

Table 1. Performance Evaluation: All Patches

Variable	Percent Patches in Distress Category N*	M*	S*
Warm (46)	59	41	0
Cool (36)	27	42	31
Type III (29)	31	59	10
Roadpatch (27)	26	52	22
Fibrous (26)	81	12	7
Unanchored (42)	43	45	12
Anchored (40)	47	38	15
Not sawed (23)	34	44	22
Sawed (59)	50	40	10
All patches (82)	44	42	14

*Distress Category:
N - No distress
M - Moderate distress
S - Severe distress

Numbers in parentheses indicate number of patches.

Comparing the performance of the three patch materials reveals that the fibrous PCC patches performed best. Fibrous PCC had, by far, the largest percentage of patches in the no distress category, and the smallest percentage in the severe distress category. The superior performance of the fibrous PC is attributed to the larger tensile strength and ductility of the fibrous PCC, which enabled it to better resist cracking and subsequent spalling.

Comparing of the performance of anchored and unanchored patches reveals no appreciable differences. The percentages in all three distress categories for each location is approximately the same. Loss of bond did not appear as significant as originally thought. Failure appeared to start with localized cracking which progressed until large pieces or spalls broke loose. Anchors did not decrease the propensity for this to happen. Because of limited patch depth and, thus, limited cover; anchors may have actually accelerated cracking and breakup for some patches.

Comparing the performance of patches with sawed edges with those that were not sawed reveals contradictory implications. For I-59 patches, sawing appeared to be beneficial; but for I-85 patches, the opposite is indicated. However, when combined, as in Table 1, a moderate beneficial effect of sawing is indicated.

CONCLUSIONS AND RECOMMENDATIONS

Patch materials using Type III cement and a nonchloride accelerator developed strength rapidly enough to allow patch construction and reopening to traffic in one working day. The inclusion of 1.2% by volume, 3/4 in. or longer steel fibers enhanced patch performance. The inclusion of anchors in patches did not significatly improve performance. Patches constructed during warm weather (+70°F) performed better than those constructed during cooler weather. A sawcut to outline the patch area aids in construction, and there is some evidence to indicate that a sawcut improves patch performance.

Fibrous PCC patching mixes should be designed with Type III cement and a nonchloride accelerator to achieve a six-hour compressive strength of approximately 2000 psi. Patches should be constructed when the maximum daily temperature will be greater than 70°F. Construction operations should be scheduled to provide a minimum of 4 hours wet curing. Patches should be covered with insulation to prevent heat loss and speed hydration during wet curing. A membrane curing compound should be applied prior to opening to traffic.

Areas of deteriorated concrete should be identified and outlined with a sawcut 1 to 2 in. deep. The area outlined with the sawcut should be about 1 ft. larger on all sides than the apparent deteriorated area. The smallest jackhammer possible should be used to remove damaged concrete; if possible, 30 lb. or less. Patch material should be consolidated with vibration.

REFERENCES

1. Ross, J.E., "Rapid Setting Concrete Patching Study," Research Report No. 84, Louisiana Department of Highways, March 1975.

2. Parker, F., G.E. Ramey, and R.K. Moore, "Evaluation of Rapid Setting Materials and Construction Techniques for Concrete Pavement Patches," Final Report Project No. 930-107, Alabama Highway Department, October 1983.