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A Survey on the Use of Rapid-Setting Repair Materials

D.W. FOWLER, GEORGE P. BEER, AND A.H. MEYER

The current state of the art for rapid-setting materials used to repair concrete in Texas and selected other states is reviewed. Texas districts were surveyed for a listing of rapid-setting materials that they have used over the past 10 years. Twenty-seven materials were reported. The districts also provided an evaluation of the materials based on their use in different types of repairs, cost, use in different climatic conditions, durability, bond to concrete, and appearance. Nine states were asked to provide the same information requested of districts; eight responses were received. Districts and states were also asked to provide a ranking of material characteristics and properties.

Rapid-setting repair materials for portland-cement pavements and bridge decks are in great demand. The higher traffic volumes and the advancing age of many pavements and bridges have created serious maintenance problems for state highway forces.

A wide range of repair materials is available (1, pp. 115-160). The materials have been categorized as portland cement, other chemical-setting cements, thermosetting materials, thermoplastics, calcium sulfate, bituminous materials, composites, and additives used to alter mix characteristics (2).

Many different brands of materials are available, and considerable variation in properties is likely for each category from brand to brand. There is considerable variation in cost per unit weight, and the final in-place cost must take into account the ratio of binder to aggregate. Some materials are designed for temporary repairs and others are designed for permanent repairs. Some are to be used in limited ambient temperature ranges, and some cannot be used in wet weather. Some can be used at feathered edges, but most require a chipped or sawcut boundary.

There is a pressing need for information on which to base selection of rapid-setting materials for different applications. However, there is a serious lack of reliable information from manufacturers and users. Mechanical and durability properties, when available from the manufacturer, are often given without reference to the test methods. The continuing introduction of new products and the modification of old ones makes evaluation and selection more difficult. There has been a paucity of performance information from users.

SCOPE OF STUDY

A research study was begun in September 1981 with the following objectives: identify candidate materials, evaluate selected materials in the laboratory, determine optimum placement methods, test materials and methods in the field, and disseminate results. The first part of this study, a survey of the Texas State Department of Highways and Public Transportation (SDHPT) and transportation departments of selected states to determine their experience with rapid-setting repair materials, is summarized here. No attempt is made in this paper to recommend materials. Future research in this study will provide a basis for methods of evaluation of rapid-setting materials.

USE OF RAPID-SETTING REPAIR MATERIALS IN TEXAS

Many rapid-setting repair materials have been used by SDHPT. Most districts have used one or more of these materials to repair concrete. The Materials and Tests Division (D-9) has tested many of the materials used by the districts. Each district was asked to provide information on the use of rapid-setting materials and D-9 was asked to provide specifications and test results on materials tested. Their response is summarized in this paper.

Survey of Districts

Each SDHPT district in Texas was sent a questionnaire to obtain their experience with rapid-setting repair materials. The questionnaire, which is included in a report by Fowler et al. (3), asked for (a) a ranking of characteristics and mechanical properties of repair materials in order of performance and (b) for each repair material used, the volume per year, relative performance for different types of repairs and weather conditions, appeal to workers, and relative appearance. All but four districts responded to the survey. The materials and their respective ratings by the districts are summarized in this section. The rankings of characteristics and mechanical properties are given later in this paper.

Materials Used

Table 1 summarizes by district the use of rapid-setting materials. All materials reported are shown. The amount, if any, indicated by each district is shown by a symbol representing the range of the amount in pounds per year. The absence of a symbol indicates that no use of the material was reported by a district. The questionnaire asked for all materials used in the past 10 years; 27 materials were reported.

Evaluation of Use and Performance of Materials

Districts were asked to rank the materials on a scale from 1 to 5, in which 5 indicated highest or best, for performance in different types of repairs; cost; mixing, placing, and finishing; durability;

Table 1. Materials used in districts.

District[a]	Alcrete	Bostik 276	Cel-Set	Crylcon	Duracal	B-102 Epoxy	Fast Fix	Ferrolith G	Fondu Calcium Aluminate	Gilco Rapid Patch	Gilcrete	Hub Chem Emulsified Asphalt	Horn 240	Hydraset	Mite 150	Neco-Crete	Plexicrete	Polymer Concrete (UT)[b]	Quik Crete	Set 45	Set 45 (Hot Weather)	Sika Set	Silikal	Speed Crete	Tapecrete	Tiger Crete	Zip-Crete
1														B													
2			A				X							B					X	X				B			
3														B				C		A							A
4					C																						
5		A				A																					A
7																											
8						C												A						C			
9			B			B																B					
10			C																								
11									X								X	X							X		
12																											
13	C			A	C						C																
15																				X			A			X	
16						B																				A	
17																		A									
18				X						A			A					C		B	C		C				
19															B												
20																				B				B			
22																											
23								A										A									
25												A						A		A							
26																B		C		C			C				

Legend: A: 10 to 1000 lb ; B: 1000 to 25,000 lb ; C: More than 25,000 lb ; X: Amount not reported

[a]Questionnaires not received from Districts 6, 14, 21, and 24

[b]UT Polymer Concrete is material developed by Center for Transportation Research

appeal to workers; bond to concrete; and appearance. Table 2 summarizes the evaluation. The numerical rating is an average of the ratings provided by each district and is not weighted for the amount of material. From Table 1 the quantities of each material can be determined. It should be noted that the evaluations for materials that have been used only in small quantities by one or two districts may not be meaningful.

OTHER STATES' EXPERIENCE WITH RAPID-SETTING MATERIALS

Questionnaires similar to those sent to districts were sent to nine states. Most states did not provide an evaluation of materials. Some provided specifications, lists of approved materials, or general comments. A summary of the responses of each of the states is given in the following.

California

California had one of its 11 highway districts fill out the material evaluation questionnaire. They reported using three materials for bridge-deck spalls: Set 45, Horn 240, and Fondu calcium aluminate (C_3A). Table 3 is a summary of California material evaluations.

Florida

Florida is currently in the process of evaluating five rapid-setting materials; final acceptance or rejection of these products has not yet been made.

Georgia

Georgia has used seven rapid-setting repair materials. Limited testing has been performed on these materials; Table 4 presents Georgia's evaluation.

Iowa

Iowa has no special provisions for repairs of pavements and bridges except to use concretes with high cement contents and to use calcium chloride as an accelerator.

Kansas

Kansas has no standard practice for rapid repairs of pavements or bridge decks. It has tested many materials but none has proved entirely satisfactory.

New York

New York currently uses epoxies for repair of pavements and bridge decks. The New York State Department of Transportation specifications cover the details of repairs and epoxies. New York also has made some repairs with polymer concrete, which is covered by a special specification. The Highway Maintenance Division also has a list of approved products for repairs of pavements and structures (3).

Oregon

Oregon does not have a standard practice for rapid repair of pavements and bridge decks. It reports the use of five separate repair materials, of which a summary is given in Table 5.

Pennsylvania

Pennsylvania currently uses a broad range of materials for repair of bridge decks and pavements. It uses epoxy mortars, polymer concretes, polymer-modified mortars, and magnesia phosphate. These products are covered in the Pennsylvania Department of Transportation specification for rapid-setting repair materials. The Pennsylvania Department of Transpor-

Table 2. Summary of material evaluations.

Material	Type of Repair					Cost	Mixing, Placing and Finishing				Durability	Appeal to Workers	Bond to Concrete		Appearance
	Wide Cracks	Bridge Deck Spalls	Pier or Abutment Spalls	Pavement Spalls	Punchouts		Normal Temp	Low Temp	High Temp	Use in Wet Weather			Horizontal Surface	Vertical Surface	
Alcrete	NR[a]	2.0	3.0	3.0	3.0	3.0	4.3	2.0	3.3	1.5	2.7	3.7	3.0	3.3	4.0
Bostik 276	NR	5.0	NR	NR	NR	5.0	2.0	NR	NR	NR	5.0	4.0	5.0	NR	2.0
Cel Set	3.0	NR	5.0	5.0	2.0	3.3	4.7	3.3	4.3	2.0	4.0	4.3	3.7	3.3	4.3
Crylcon	NR	3.0	4.0	5.0	4.5	5.0	4.5	2.5	3.0	1.0	4.5	2.5	5.0	5.0	5.0
Duracal	5.0	4.5	4.0	4.5	3.7	4.3	3.8	2.9	2.7	3.5	4.0	4.2	4.3	4.3	4.5
B-102 Epoxy	3.7	3.3	3.0	4.0	5.0	3.5	3.5	2.7	2.3	1.5	2.5	3.0	3.8	3.0	3.7
Fast Fix	2.0	2.0	NR	2.0	NR	3.0	4.0	3.0	2.0	1.0	3.0	3.0	3.0	NR	NR
Ferrolith-G	NR	3.0	NR	NR	NR	3.0	4.0	2.0	4.0	2.0	4.0	3.0	4.0	NR	3.0
Fondu C_3A	NR	NR	NR	4.0	NR	2.0	5.0	4.0	4.0	5.0	4.0	4.0	4.0	4.0	4.0
Gilco Rapid Patch	NR	NR	NR	NR	4.0	2.0	5.0	NR	NR	5.0	5.0	5.0	3.0	NR	4.0
Gilcrete	NR	NR	NR	2.0	3.0	3.3	3.7	1.7	2.0	1.0	2.3	2.7	2.0	2.7	3.0
Hubchem Emulsified Asphalt	NR	NR	NR	4.0	4.0	3.0	4.0	4.0	4.0	5.0	5.0	5.0	3.0	2.0	3.0
Horn 240	NR	NR	NR	NR	4.0	4.0	4.0	NR	NR	1.0	3.0	4.0	3.0	NR	NR
Hydraset	NR	3.0	NR	3.0	4.5	2.3	4.0	3.7	3.3	2.7	4.7	4.0	4.7	3.7	5.0
Mite 150	NR	NR	NR	5.0	5.0	3.0	2.0	2.0	2.0	NR	5.0	5.0	NR	NR	5.0
Neco-Crete	NR	3.1	3.1	3.1	3.3	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Plexicrete	4.0	NR	NR	4.0	NR	5.0	5.0	4.0	4.0	4.0	5.0	5.0	4.0	4.0	5.0
Polymer Concrete (U.T.)	3.2	3.7	3.3	3.3	4.3	3.4	4.6	2.5	3.8	1.0	4.3	2.7	3.9	3.8	4.1
Quik Crete	2.0	2.0	NR	2.0	NR	3.0	4.0	3.0	2.0	1.0	3.0	NR	3.0	NR	NR
Set 45	4.5	4.0	3.0	4.2	3.9	3.7	4.2	4.3	2.8	4.0	4.5	4.8	4.3	3.3	4.3
Set 45 (Hot Weather)	4.0	4.0	NR	NR	4.0	2.0	5.0	5.0	4.0	5.0	4.0	5.0	3.0	NR	5.0
Sikaset	3.0	NR	NR	NR	4.0	5.0	5.0	3.0	2.0	1.0	4.0	5.0	2.0	1.0	4.0
Silikal	3.7	4.2	3.3	4.2	4.4	5.0	4.0	4.0	2.5	1.0	4.5	2.0	4.5	4.0	4.5
Speed Crete	1.0	2.0	2.0	1.5	2.5	2.0	5.0	5.0	5.0	1.7	1.7	4.3	2.0	2.0	3.7
Tape Crete	NR	NR	NR	5.0	NR	3.0	5.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0
Tiger Crete	5.0	3.0	1.0	1.0	NR	4.5	5.0	4.0	4.0	5.0	3.0	4.0	1.0	5.0	4.0
Zip-Crete	NR	2.0	4.0	NR	NR	2.5	4.0	1.0	4.0	NR	3.5	5.0	4.5	3.0	5.0

Evaluations are based on a subjective scale of 1 to 5 with 5 representing the best performance or highest cost

[a] NR indicates no response

Table 3. Evaluation of rapid-setting materials by the state of California.

Material	Usage lb /yr	Bridge Deck Spalls	Cost	Mixing, Placing and Finishing				Durability	Appeal to Workers	Bond to Concrete		Appearance
				Normal Temp	Low Temp	High Temp	Use in Wet Weather			Horizontal Surface	Vertical Surface	
Fondu C_3A	15,000	3.0	3.0	4.0	5.0	3.0	NR	3.0	3.0	3.0	NR	2.0
Horn 240[a]	10,000	5.0	4.0	4.0	5.0	2.0	NR	4.0	NR	5.0	NR	4.0
Set 45	25,000	4.0	3.0	4.0	5.0	3.0	NR	4.0	4.0	4.0	NR	5.0

[a]Same as Darex 240

tation also has a list of approved commercial rapid-setting materials (3).

DESIRED CHARACTERISTICS AND MECHANICAL PROPERTIES

Districts and other states were asked to rank characteristics and mechanical properties of rapid-setting repair materials. Eight characteristics and eight properties were listed, and other items could be added.

Response of Districts

The ranking of characteristics and properties by districts is as follows:

Characteristics:

1. Setting time;
2. Performance (durability);
3. Working time;
4. Ease of mixing, placing, and finishing;
5. Use over wide temperature range;
6. Use in wet weather;
7. Cost;
8. Similarity to color of adjacent concrete; and
9. Availability.

Properties:

1. Bond strength to concrete,
2. Flexural strength,

Table 4. Evaluation of rapid-setting materials by the state of Georgia.

Material	Usage lb/yr	Wide Cracks	Bridge Deck Spalls	Pier or Abutment Spalls	Pavement Spalls	Punchouts	Joint Repairs	Cost	Mixing, Placing and Finishing			Use in Wet Weather	Durability	Appeal to Workers	Bond to Surface		Appearance
									Normal Temp	Low Temp	High Temp				Horizontal Surface	Vertical Surface	
Duracal	10,000	NR	3.0	NR	2.0	NR	3.0	3.0	3.0	3.0	3.0	2.0	4.0	2.0	1.0	3.0	
Epoxy	NR	2.0	3.0	NR	2.0	3.0	5.0	2.0	2.0	1.0	2.0	3.0	1.0	4.0	4.0	NR	
Horn 240	1,000	NR	NR	NR	4.0	NR	4.0	3.0	4.0	1.0	1.0	4.0	3.0	3.0	3.0	3.0	
Polymer Concrete	10,000	NR	3.0	NR	4.0	NR	5.0	3.0	3.0	2.0	1.0	5.0	2.0	4.0	4.0	4.0	
Roadpatch	1,500	NR	NR	NR	4.0	NR	3.0	3.0	2.0	1.0	3.0	3.0	3.0	3.0	3.0	3.0	
Set 45	100,000	NR	NR	NR	3.0	NR	4.0	3.0	5.0	1.0	1.0	2.0	2.0	2.0	2.0	3.0	
Speed Crete	NR	NR	NR	NR	1.0	NR	2.0	3.0	2.0	2.0	3.0	1.0	3.0	1.0	1.0	3.0	

Table 5. Evaluation of rapid-setting materials by the state of Oregon.

Material	Type of Repairs						Mixing, Placing and Finishing				Durability	Appeal to Workers	Bond to Concrete		Appearance	Cost
	Wide Cracks	Bridge Deck Spalls	Pier or Abutment Spalls	Pavement Spalls	Punchouts	Joint Repairs	Normal Temp	Low Temp	High Temp	Use in Wet Weather			Horizontal Surface	Vertical Surface		
Concreasive 2020 Polymer	NR	5.0	NR	NR	NR	5.0	5.0	3.0	2.0	1.0	5.0	5.0	5.0	5.0	5.0	5.0
Crylcon	NR	5.0	NR	NR	NR	5.0	5.0	3.0	2.0	1.0	5.0	5.0	5.0	5.0	5.0	5.0
Niklepoxy Product #4	NR	4.0	NR	1.0	NR	NR	4.0	2.0	2.0	1.0	4.0	3.0	4.0	4.0	3.0	5.0
Type III Portland Cement Concrete (w/c = 0.30)	NR	4.0	NR	3.0	NR	NR	3.0	3.0	3.0	2.0	5.0	3.0	4.0	2.0	5.0	1.0
Set 45	NR	2.0	NR	2.0	NR	NR	5.0	2.0	2.0	3.0	2.0	3.0	3.0	2.0	3.0	3.0

3. Shrinkage,
4. Compressive strength,
5. Ductility,
6. Wear resistance,
7. Coefficient of thermal expansion, and
8. Stiffness (modulus of elasticity).

Setting time, performance (durability), and working time were rated the top three characteristics. Bond strength to concrete, flexural strength, and shrinkage were rated the top three mechanical properties.

Response of Other States

The ranking of characteristics and properties by other states is as follows:

Characteristics:

1. Performance (durability);
2. Ease of mixing, placing, and finishing;
3. Cost;
4. Setting time;
5. Working time;
6. Use over wide temperature range; and
7. Use in wet weather and similarity to color of adjacent concrete (tie).

Properties:

1. Bond strength to concrete,
2. Compressive strength,
3. Shrinkage,
4. Flexural strength and coefficient of thermal expansion (tie),
5. Wear resistance,
6. Ductility, and
7. Stiffness (modulus of elasticity).

Other states ranked performance (durability), ease of mixing and placing, and cost as the top three characteristics. The top three mechanical properties were bond strength to concrete, compressive strength, and shrinkage. The states ranked the same four mechanical properties at the top of the list as the districts did, although the order was slightly different.

CONCLUSIONS

There is an urgent need for dependable rapid-setting materials for the repair of concrete pavements and bridge decks. Many types and brands are currently available, but the selection of an appropriate material is complicated by the lack of reliable data

from manufacturers and users. There is no standard evaluation procedure for these materials.

All of the SDHPT districts in Texas were surveyed to determine their experience and evaluation of rapid-setting repair materials. Quantities of each repair material used per year were obtained. Evaluations of each material were made on the basis of types of repair, cost, climatic conditions, durability, bond to concrete, and appearance. Considerable variation was noted for the 27 materials reported.

Other selected states were surveyed to determine their current experience. Six of the eight states responding listed specific materials that were currently being used. Three states provided an evaluation similar to that provided by the SDHPT districts.

The SDHPT districts provided a priority order for characteristics and mechanical properties. Setting time, performance (durability), and working time were ranked as the top three characteristics, whereas bond strength to concrete, flexural strength, and shrinkage were rated the top three mechanical properties.

The survey of the other states indicated performance (durability); ease of mixing, placing, and finishing; and cost as the top three characteristics. Bond strength to concrete, compressive strength, and shrinkage were given as the top mechanical properties.

RECOMMENDATIONS

It is recommended that further research be conducted to establish appropriate evaluation procedures for rapid-setting repair materials, evaluate the most common materials, and determine the field test performance of different types of repairs.

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Design of Polymer-Concrete Runway Repairs

B. FRANK McCULLOUGH, A.H. MEYER, AND D.W. FOWLER

Portland-cement-concrete airfield pavements with polymer-concrete (PC) repairs were analytically modeled to develop design criteria for determining the required repair thickness. A previously developed computer program for analyzing discontinuous orthotropic plates and pavement slabs was used to analyze the pavement. Two representative aircraft, the F-4 and the C-141, were used. Different repair sizes, support values, and runway thicknesses were tested. A sensitivity analysis was performed to determine which variables have the greatest effect on the stresses. For the purpose of developing design charts, the critical positions of the wheel loads for the different size repairs were found. The magnitude of the existing runway support (K-value) outside the repair section was found to have little effect on the stresses in the PC repair, although the existing runway thickness did. Because of the emergency nature of the repairs, the repair support values and thicknesses may be significantly different from those for the existing pavement. Consequently, these values have a significant impact on the repair results. Design charts were prepared that give the flexural stress as a function of repair thickness for three repair sizes, two repair support values, and two runway thicknesses. The allowable stress level for the polymer concrete has been reduced for the number of loading repetitions.

The U.S. Air Force, through the University of Texas, has recently studied the rapid repair of runways by using polymer-concrete (PC) materials (1). In some cases a section of a runway can be partitioned off and rapid repairs made so that the field can continue to serve its functional purposes. The results of this study are believed to be applicable to all runway types and thus the information is presented to add to the status of knowledge. In this paper the primary concern is the design aspects; for the material properties, see the papers by Meyer et al. and Fowler et al. in this Record.

Polymer concrete has been shown to be an effective material for rapid repair of bridge decks, pavements, and runways. PC materials consist of aggregate with a polymer binder instead of portland cement. Polymer concrete made with methyl methacrylate develops a strength of 6,000 psi in 1 hr or less (almost the ultimate value), is more ductile than portland-cement concrete (PCC), and bonds well to normal concrete.

In this paper the mechanistic modeling of concrete pavements with PC repairs is described to develop criteria for determining repair thicknesses. The behavior of the repairs was predicted for a wide range of support and loading conditions expected at North Atlantic Treaty Organization (NATO) bases in Europe. Then field tests were made at Tyndall Air Force Base in Florida to experimentally verify the boundary conditions on the charts. Design charts are presented for quickly determining the thickness of repairs required for the anticipated conditions.

It is essential in any analytical approach that techniques be used to properly model the load, geometry, and material properties to reliably predict