Table 2. 1980-1981 Bay Area ongoing maintenance costs.

Maintenance Category	1980-1981 Budgeted Expenditure ($000 000s)	Estimated Essential Need ($000 000s)	Shortfall ($000 000s)
Cyclical	42	118[a]	76
Routine	30	40	10
Nonpavement			
Street lighting	29	33	4
Traffic safety	17	19	2
Street cleaning	10	13	3
Landscaping	11	15	4
Miscellaneous	10	10	0
Other (administrative)	18	20	2
Total	167	268	101

[a]Estimated by applying the standard cyclical maintenance treatment program. All other expenditures and needs are as reported on MTC's inventory and adjusted to average costs per mile for each line item.

method used to determine ongoing maintenance expenditures and needs and resultant shortfalls. In Table 2 the results for the base year, FY 1980-1981, are summarized.

Clearly the pavement-related categories are where the greatest shortfalls are occurring. Eighty-five percent of the $101 million shortfall occurs in these categories; 75 percent is in the important category of cyclical or preventive maintenance. Most of the nonpavement and other categories represent more of the fixed-cost type of expenditures, which are more difficult to cut back or defer in times of severe budget problems.

As illustrated with backlog costs, the future increases in maintenance shortfalls over those attributable to inflation are significant. The same is true for future ongoing maintenance shortfalls. The FY 1980-1981 shortfall has been projected to FY 1986-1987 to illustrate the rapid escalation of the cyclical maintenance costs in millions of dollars. The base-year shortfall of $101 million more than doubles to $241 million. This is occurring primarily because many streets and roads are reaching an age in this decade where more expensive treatments, e.g., overlays and restoration, are necessary.

RECOMMENDATIONS

The analysis and results discussed here have been published (1,2). Because of the magnitude of the deficits estimated in these reports, the technical study phase was extended in order to publicize the problem and work toward possible solutions. Toward this end 2,500 copies of a summary report were distributed, primarily to locally elected officials. A slide show was also prepared and presented to more than 50 groups in early 1982. Maintenance shortfalls were converted into gasoline-tax equivalents to illustrate how much increase would be required. These efforts helped foster a movement in the Bay Area by which 48 of 58 cities in four counties endorsed a 5-cent gasoline-tax increase to be placed on the ballot for voter approval.

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Abridgment

Field Tests of Rapid Repair Methods for Bomb-Damaged Runways

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

Rapid repair of bomb-damaged runways is of vital concern to the U.S. Air Force. The results of field tests conducted under the direction of the Air Force Engineering and Services Center at Tyndall Air Force Base are presented. These tests were of various rapid repair techniques that use methyl methacrylate (MMA) polymer concrete. This includes both user-formulated and commercially available MMA polymer concrete. Both spalls and craters were repaired. Full-depth polymer-concrete (PC) repairs, at-grade precast units, and precast units with PC caps are reported. The repairs were trafficked with both F-4 (27,000-lb single wheel) and C-141 (144,000-lb dual-tandem wheel) load carts. All of the crater repairs performed satisfactorily as did most of the spall repairs, which demonstrated the feasibility of using PC methods for the rapid repair of bomb-damaged runways.

The rapid repair of bomb-damaged runways is of vital concern to the U.S. Air Force. Airfield pavements must be repaired rapidly after attack so that aircraft can be launched. Current repair procedures, specified in Air Force Regulation (AFR) 93-2 (1), are based on North Atlantic Treaty Organization (NATO) damage criteria, which require that three 750-lb bomb craters be repaired in 4 hr. The repair procedures in AFR 93-2 include backfilling the crater with debris within 1 ft of the surface, removing upheaved concrete, filling the top of the crater with select fill, and then the placing and anchoring metal matting over the surface of the backfilled crater.

New developments in weapons technology have altered the repair criteria. The current threat includes many smaller weapons. As a result, instead of only a few large craters as envisioned in AFR 93-2, the repair procedures must also be able to handle many small or medium-sized craters.

The Air Force Engineering and Services Center is currently engaged in a research and development program to improve the rapid runway repair (RRR) capability. New materials and techniques are being investigated by the Engineering and Services Laboratory at Tyndall Air Force Base. The objective of this study is to develop rapid repair techniques that use methyl methacrylate (MMA) polymer concrete, which has been successfully used for repair of highway structures (2,3).

SPALL REPAIRS

A series of 15 simulated spalls was made in the Tyndall research pavement. The section of pavement used consisted of a clay subgrade covered by 12 in. of portland-cement concrete (PCC) overlaid with 4 in. of asphalt-cement concrete (ACC). This pavement cross section is similar to that which exists at several U.S. Air Force bases.

The series was made up of five sets of three spalls, each set having a small, medium, and large spall. Type A spalls were small, type B were medium, and type C were large (Figure 1). Three sets were repaired by using the user-formulated (UF) system and an in-line mixing gun. From this series of tests, the concept of the in-line mixing gun was verified. This concept allows the chemicals to be mixed at the point of application and minimizes exposure of personnel to the chemicals. The tests also verified that debris can be used for at least part, if not all, of the aggregates required, provided some select material is available for finishing. It should be noted that the debris used did not contain large chunks or a significant amount of asphaltic materials.

CRATER REPAIRS

Three methods of crater repair were tested at the pavement research facility at Tyndall Air Force Base. Three 20 x 20-ft test pits were prepared with clay as the base material.

The first two crater repairs (pits 2 and 3) were made with precast slabs. The precast slabs were prepared from normal PCC. The slabs were nominally 6 x 6 ft square and of two thicknesses, 12 in. and 8 in. All slabs had concave keyways on all sides. All slabs were cast with quick-release lifting eyes and threaded drag eyes. Concrete was placed in the wooden forms, consolidated, and allowed to cure more than 28 days before use.

The 6 x 6-ft size was selected to match the 20 x 20-ft pit to be repaired. Using nine slabs in the repair area resulted in a gap of approximately 6 in. between slabs and edges for the polymer-concrete (PC) bonding material. The 12-in.-thick slabs weighed about 5,200 lb each, and the 8-in.-thick slabs weighed about 3,500 lb. Both of these weights were well within the handling capabilities of the front-end loaders, small cranes, and forklifts usually available at most bases.

Pit 2 was repaired by using the at-grade precast slab method. The base of the pit was a clay layer some 21 in. below the grade surface. A 6-in. layer of crushed limestone was compacted over the clay, and a 3-in. sand leveling course was placed over the crushed limestone. Figure 2 gives a plan view and a cross section of pit 2.

Pit 2 was then tested with the load cart; 150 coverages of the F-4 load cart and 70 coverages of the C-141 load cart were used. A coverage is a function of the number of operations at full load, configuration of the wheels, and wander of the aircraft. One coverage of the F-4 load cart is roughly equivalent to 50 passes of the aircraft and one coverage of the C-141 load cart is roughly equal to 10 passes. The repair showed no visible signs of deterioration. The profile of the repair remained virtually unchanged from the beginning to the end of load-cart testing, and from the profile data the riding quality was excellent, because there was little change in elevation across the slab.

Pit 3 was repaired by using a combination of the precast slab and the cap methods of repair. The base of the pit was a clay layer [California bearing ratio (CBR) = 4] covered with 6 in. of compacted,

Figure 1. Typical spall repair sections.

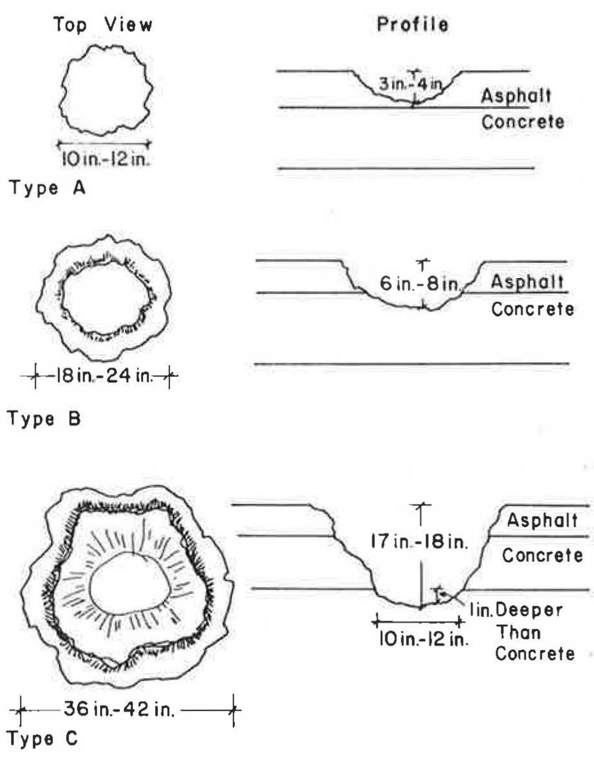
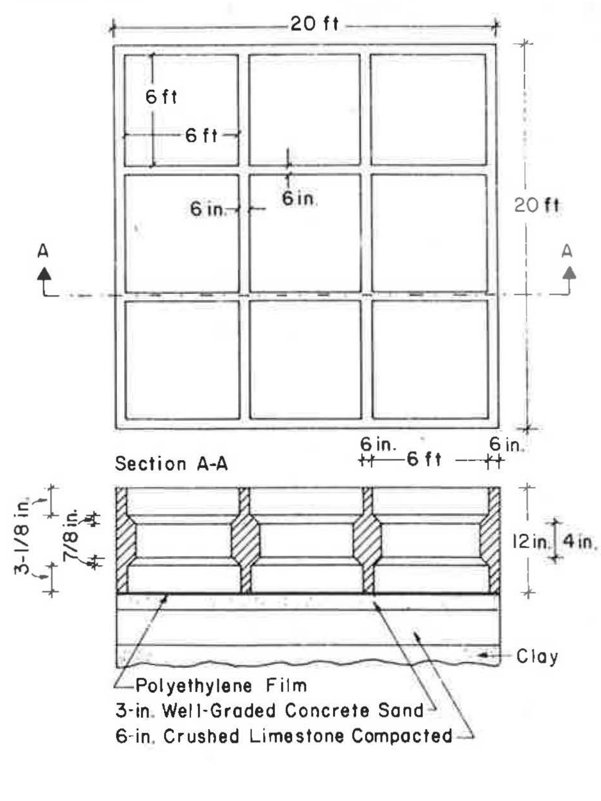


Figure 2. Pit 2.



crushed limestone. The 8-in. precast slabs were then placed on the crushed limestone. Polymer concrete was placed around and over the slabs to bring the repair to grade. The PC cap over the slab was nominally 2 in. thick (Figure 3).

Pit 3 was load-cart tested in the same manner as pit 2, and analysis of the profile data revealed essentially no change in profile from beginning to end of load-cart tests. The profile data also illustrate excellent riding quality in that the maximum change along any profile line was 0.09 ft (1.08 in.) in 20 ft.

Figure 3. Pit 3.

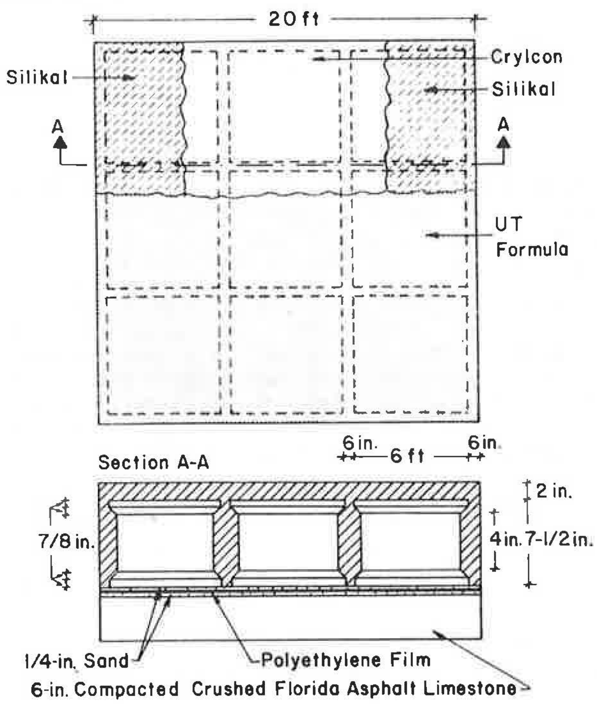
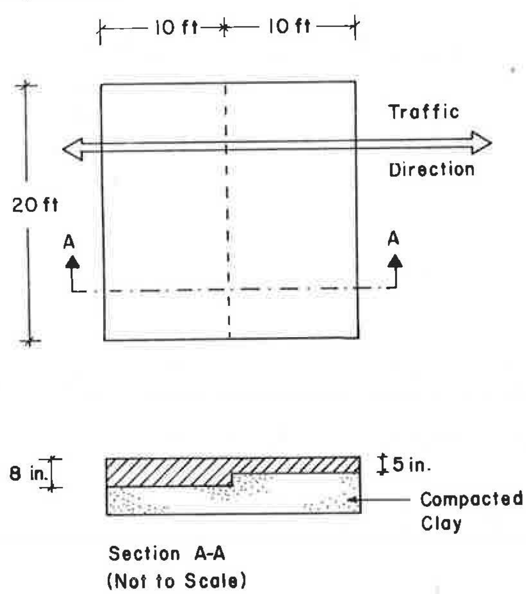


Figure 4. Pit 1.



This method of repair offers some distinct advantages:

1. The bulk of the surface layer (top 12 in.) of the repair is constructed of materials of known and controlled quality (the precast slabs);
2. The precast units do not have to be aligned as required with the at-grade precast repair; and
3. The method significantly reduces the volume of polymer concrete required compared with that for a full-depth PC repair. This lower volume reduces the storage time of chemicals with limited shelf lives.

Pit 1 was repaired by using UF polymer concrete. The base of the pit was clay. The repair consisted of two parts; half of the PC cap was nominally 8 in. thick and half of the repair was nominally 5 in. thick (the actual average thickness was 4.5 in.). A cross section of pit 1 is shown in Figure 4. The clay under the 8-in. section had a CBR of 6, and the clay under the 5-in. section had a CBR of 3.

The UF polymer concrete was placed in pit 1 by using the concrete mobile as in pit 3. After placement, the polymer concrete was screeded and finished. Thermocouple data from both the 5-in. and the 8-in. sections revealed expected values for both peak temperature (approximately 80 to 90°C) and time to peak exotherm (approximately 30 to 35 min).

The repair was load-cart tested with 150 coverages of the F-4 load cart and 70 coverages of the C-141 load cart. Analysis of the profile data reveals no significant changes in elevation from beginning to end of load-cart testing. The average change in elevation is 0.002 ft (0.03 in.); the maximum difference at any location is 0.03 ft (0.4 in.). Analysis of the profile lines reveals a maximum change of 0.08 ft (0.96 in.) in 20 ft. This indicates that the riding quality would be adequate for air traffic.

SUMMARY

In summary the following conclusions can be stated:

1. All repair methods and materials were adequate for the load-cart tests performed, including the 4.5-in.-thick UF PC slab over the CBR 3 clay subgrade;
2. Polymer concrete is structurally adequate for airfield pavement repairs;
3. Regarding time and equipment requirements, the cap method is probably the most efficient if the concrete mobile is used and can be continuously available; and
4. The UF PC system offers a distinct advantage in that the amount of chemicals can be adjusted to satisfy temperature demands in order to keep cure time relatively constant.

ACKNOWLEDGMENT

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Notice: The views expressed in this paper are those of the authors, who are responsible for the facts and accuracy of the data. The contents do not necessarily reflect the official views or policies of the University of Texas at Austin or the U.S. Air Force. This paper does not constitute a standard, specification, or regulation.

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 saw-cut 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;