Study of Soil-Cement Base Courses on Military Airfields

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A group of military airfields with pavements composed of soil-cement base courses and asphaltic-concrete surfacing was studied. Laboratory tests were performed on samples of the soil-cement from four fields; observations were made on the remaining fields. The natural soils used in the soil-cement ranged from beach sand to lean clay and traffic varied from very light training planes to cargo craft.

The soil-cement performed reasonably well under the imposed loads and showed no signs of deterioration with age. The investigation also indicated that small percentages of cement tended to reduce the plasticity in some borderline base-course materials and aided construction with some rounded cohesionless sands.

● A NUMBER of military airfields in the United States have been constructed with soil-cement base courses. An investigation of several of these fields was made by the Waterways Experiment Station to determine the behavior of the base courses under the conditions to which they had been subjected. This paper presents the results of the investigation. Studies were made at the following airfields where a portion of the paved facilities were constructed with soil-cement base courses: Turner AFB, Albany, Georgia; Moody AFB, Valdosta, Georgia; West Palm Beach AFB, West Palm Beach, Florida; Hot Springs, Arkansas, Municipal Airport and Adams Field (Little Rock, Arkansas, Municipal Airport); Clovis AFB, Clovis, New Mexico; and Edwards AFB, Muroc, California. Detailed visual inspections were made of all the pavements, and field and laboratory tests were performed at West Palm Beach, Moody, and Turner AFB's and at Hot Springs Municipal Airport.

INVESTIGATION

The soil, climate, and traffic varied considerably for the fields investigated. In order that these differences may be clearly understood, a brief description of each field is given in the following paragraphs.

Turner AFB

This field is located near Albany, Georgia, in the East Gulf Section of the Gulf Coastal Plain. The climate is warm and humid. Natural soils at the site ranged from nonplastic silty sands to clayey sands with maximum plasticity index values of about 20. The 6-in. base course on three runways and connecting taxiways was constructed of the natural soils, nonplastic and plastic, mixed with about 10 percent cement. The pavements were constructed in the period 1941 to 1943. The asphaltic-concrete wearing course was placed about nine months after the base course was completed. For six years after construction, the pavements were used by planes with about 12,000-lb wheel loads and tire pressures of about 65 psi. In 1951 and 1952, planes with 7,000- to 10,000-lb wheel loads and tire pressures of about 200 psi used the field. Observations and tests were made in late 1952.

Moody AFB

Moody AFB is near Valdosta, Georgia, and is also in the East Gulf Section of the Gulf Coastal Plain. The climate here, too, is warm and humid. The natural materials were silty and clayey sands, ranging from nonplastic to plastic with a plasticity index of 10. In 1951, a part of the east N-S runway was constructed with a soil-cement base course, 8 to 10 in. thick, consisting of natural materials and about 10 percent cement. The area was paved with 1½ in. of asphaltic concrete about a year later. The pavement received intense traffic from planes with about 7,500-lb wheel loads and tire pressures of about 200 psi and also from planes with 16,000- to 24,000-lb wheel loads and tire pressures of about 65 psi. The facilities were open to traffic both before and after the asphaltic concrete was laid. Observations and tests were made in late 1952.

West Palm Beach AFB

This field is situated on typical beach sands at West Palm Beach, Florida, in an area of subtropical climate. The 6-in. base course of a parking apron was constructed of soil-cement during 1934-1937. The sands in the mix contain fragments of shell and shell marl. The percentage of cement used is not known exactly, but is believed to be above 10. Asphaltic concrete was placed over the base course in 1942. The pavement has been subjected to traffic since the construction of the base course. Prior to 1942, traffic was composed mainly of very small planes; after 1942, planes with assembly loads ranging from 24,000 to 87,000 lb and tire pressures of about 75 psi used the field extensively. Planes with assembly loads of 80,000 lb and tire pressures of about 175 psi also used the pavements extensively. Tests were made in late 1952; last observations were made in early 1957.

Hot Springs Municipal Airport

Hot Springs Municipal Airport is located in the Ouachita Mountain Section near Hot Springs, Arkansas, in the area of the Novaculite Uplift. The climate is warm and moderately humid. Lean clays and shales are typical natural soil of the site. The base course and asphaltic-concrete pavement were constructed in 1943. The untreated base course material was a crushed stone with binder of natural lean clay with some plasticity. About 5 percent cement was added to the 6-in. base course on portions of the runways, taxiways, and apron to reduce the plasticity index to an acceptable value. Traffic has been composed of a few cycles per day of DC-3 (12,000-lb wheel load) and smaller planes, all with tire pressures of 60 psi or less. Observations and tests were made in early 1953.

Adams Field

Adams Field is located in the Arkansas Valley near Little Rock, Arkansas, which also has a warm, moderately humid climate. The natural material at this site is a nonplastic silty sand which is an alluvial deposit of the Arkansas River. About 10 percent cement was added to this soil to form the base course of a parking apron. The 6-in. soil-cement base course and asphaltic-concrete pavement were constructed in 1941. Traffic has been composed of a few light training and passenger planes. Observations were made in 1952.

Clovis AFB

Clovis AFB is located near Clovis, New Mexico, in the physiographic area known as the Llano Estacado. The climate is warm and semi-arid. The natural soil at the field is a lean clay, but caliche with some plasticity was obtained from nearby sources and mixed with about 10 percent cement to form a soil-cement base course about 6 in. thick for the east N-S runway. The base course was completed and a bituminous seal placed in early 1954. Traffic has consisted mostly of planes with 12,000-lb wheel loads and tire pressures of about 60 psi. Observations were made in the fall of 1954.

TABLE 1

Field	Pavement Age Years	Percentage of Cement	Natural Soil LL	Natural Soil PI	Soil-cement LL	Soil-cement PI	Percentage Loss after 12 Cycles, Brushed: Wetting-drying	Percentage Loss after 12 Cycles, Brushed: Freezing-thawing	Maximum Allowable* Loss, %
Turner	10	10	29	17	--	NP	12.9	35.8	14
Moody	1	8	25	12	--	NP	9.2	11.5	14
West Palm Beach	15	10+	--	NP	--	NP	**	24.7	14
Hot Springs	9	5	27	12	--	NP	---	---	14

* Not a standard, but recommended by PCA.
** Specimens disintegrated after seven cycles.

Edwards AFB

This field is located near Muroc, California, in the Mojave Desert along the west shore line of Rogers Dry Lake. The climate is hot and dry. The natural soils at this site range from nonplastic silty sands to plastic clayey sands with plasticity index of 8 to 12. The base course for certain streets and drives at the field were constructed of a mixture of mostly nonplastic silty sand and about 10 percent cement. Part of the base course was completed in 1942 and was paved with asphaltic concrete in 1943; the remainder was constructed and paved in 1953. All traffic was vehicular, but included appreciable amounts of moderate-weight trucks. Observations were made in 1954.

TEST DATA

The pavements on each field were observed very carefully to determine the surface conditions. In-place tests were performed at Turner, Moody and West Palm Beach AFB's and Hot Springs Municipal Airport, and samples were obtained for laboratory testing. In-place tests included determination of moisture content and density on the base course and CBR on the subgrade, and the laboratory work included Atterberg limits, freezing-thawing, and wetting-drying tests. In-place CBR tests were considered inapplicable to soil-cement because of its hard, brittle nature. Results of the laboratory tests are summarized in Table 1.

ANALYSIS

Behavior Under Traffic

Observations of the surface conditions of the various pavements revealed cracks in all the pavements. The cracks usually formed rectangular patterns of varying size (Fig. 1) and occurred in areas untouched by traffic as well as traveled areas. The distribution and spacing of cracks varied somewhat over each field, but generally the condition was the same on all the fields. The age of the soil-cement base course at the time of placement of the bituminous paving varied from a few months to eight years, but in each case cracks appeared within a few months after pavement was placed. No measurable permanent deformation was found at any of the cracks or in any other areas of the fields. It appears that the cracking was caused by shrinkage of the soil-cement and was not connected with overload.

Accelerated traffic tests conducted by the Corps of Engineers showed that the soil-cement base course along construction joints did not afford the same protection to the underlying layers as that in the interior of construction lanes (1). No evidence of lack of protection at the joints was noted at any of the fields; however, all but one of the fields were capable of carrying heavier planes than those in use, as shown in the following analysis. In-place CBR values for subgrades at Turner, Moody, and West Palm Beach AFB's and at Hot Springs Municipal Airport were 15, 15, 20 and 15, respectively. Experience has shown that sands such as found at West Palm Beach develop high strengths when confined, although the high values may not be measured by the CBR test. Thus, the CBR value of 20 is believed very conservative for this field. Hot Springs Municipal Airport received so little traffic that it is not considered as having been proved satisfactory, although no distress developed. Using the subgrade CBR value of 15 and thickness above the subgrade of 8 in. for Turner AFB, the pavement

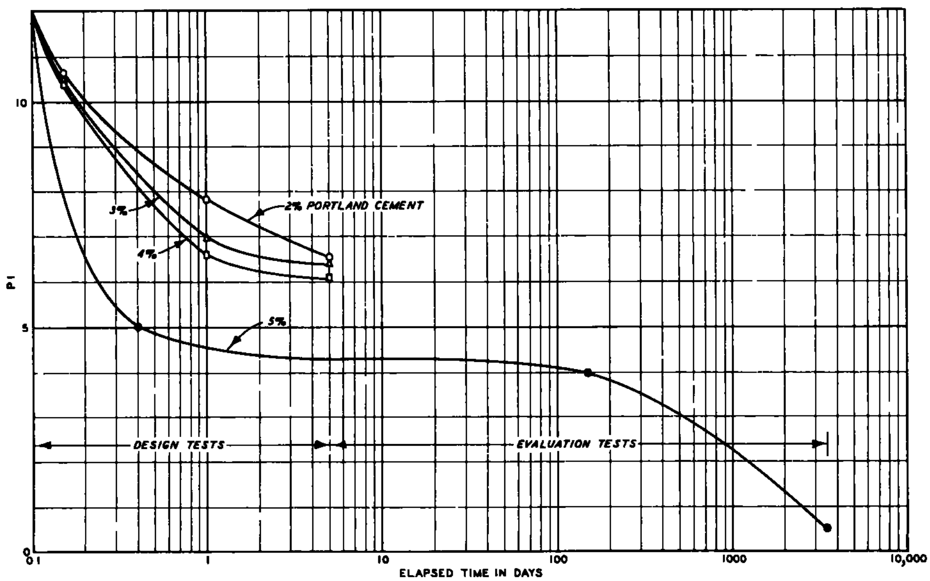
Figure 1. Typical cracking pattern.

would be adequate for unlimited use by planes with assembly loads of 12,000 lb and single wheels with either low- or high-pressure tires. Based on a subgrade CBR of 15 and a thickness above the subgrade of 10 in., the pavement at Moody AFB would be satisfactory for unlimited use by planes with 19,000-lb load on single wheels with low-pressure tires, or planes with 16,000-lb load on single wheels with high-pressure tires. The pavements at Moody AFB would probably carry wheel loads up to 25,000 lb for one or two years, but could not support an imposed wheel load of 24,000 lb for an unlimited period.

The Corps of Engineers also found poor bond between pavement and soil-cement at Beltsville, Maryland (2), and Barksdale, Louisiana (3), and noted slippage of the pavement in some of these areas. Good bond between pavement and base was found on all the fields tested in this study, and observations revealed no evidence of slippage on any of the pavements.

Wetting-Drying, Freezing-Thawing Tests

The results of 12 cycles of wetting-drying and freezing-thawing tests on samples of soil-cement from three of the four fields tested are shown in Table 1. There is no



PLASTICITY INDEX VS TIME
SOIL-CEMENT MIXES
HOT SPRINGS, ARK

standard specification for the maximum allowable material loss, but that recommended by the Portland Cement Association for each of these tests is 14 percent. The loss from specimens from West Palm Beach AFB exceeded 14 percent in the wetting-drying tests, and the loss from specimens from Turner and West Palm Beach AFB's exceeded 14 percent in the freezing-thawing tests. Since none of these fields are in areas of appreciable frost penetration, prototype behavior cannot be compared with that predicted by the freezing-thawing tests. However, presumably all were subject to wetting and drying, and it is considered significant that materials from one of the fields failed the wetting-drying test but behaved satisfactorily in the prototype.

Reduction in Plasticity

For many years the plasticity index has been used as an indicator of base course quality; construction specifications usually contain a maximum allowable value. These maximum allowable values have varied considerably since they are usually based on local experience, but it has been generally agreed that materials with low plasticity or nonplastic materials are more satisfactory than those of higher plasticity. On this basis, it is believed that the plasticity index is one of the more important indicators of soil-cement base course quality.

The data in Table 1 show that those materials having plastic binders at the time of construction were nonplastic when tested one to ten years later. A study of the effects of cement on plasticity index with time can be made from data available from Hot Springs. In arriving at the figure of 5 percent cement to be used in the base course mix, a laboratory study was made using percentages of cement varying from 2 to 5. Atterberg limits tests were performed in connection with the laboratory design work at the end of a few hours, one day, and five days; and tests were performed on samples of the base course at 150 and 3,500 days after construction. The results of these tests are shown in the plot of plasticity index values versus time for varying percentages of cement on Figure 2. These data indicate that all percentages of cement reduced the plasticity index of the material considerably in the first 24 hours, the amount of reduction increasing as the percentage of cement increased. Results of tests at 150 and 3,500 days indicate that the plasticity index of the mixture with 5 percent cement continued to decrease. Many similar instances of successful use of small percentages of cement (usually less than 5) to reduce the plasticity of a borderline base course material to a satisfactory value are cited in highway literature.

Healing of Cracks

Examination of samples of soil-cement from Moody and West Palm Beach AFB's showed that numerous cracks in the material had been filled by a deposit of calcareous material. The specimens showed no tendency to break along these cracks; on the contrary, they usually broke in uncracked portions.

Compaction

In-place density was determined at the four fields tested, but laboratory curves were not available from which the degree of compaction could be determined. However, knowledge of the compaction practices at the time the older pavements were constructed and of the specified compaction for the newer pavements suggests that the degree of compaction probably ranged from 85 to 95 percent of modified AASHO maximum density. Since the behavior of the soil-cement was the same on all the fields and since the wheel loads and intensity of traffic varied rather widely, it is indicated that any lack of compaction must have been adequately compensated for by cementation

DISCUSSION

The investigations indicated that cracks in the various soil-cement bases were caused by factors other than the imposed loads. The amount of cracking did not vary noticeably from field to field and cannot be related to type of material. The only explanation that seems reasonable is that the cracking is caused by shrinkage of the soil-cement. The presence of cracks appeared to have no effect on the ability of the soil-cement to carry the imposed loads or on the durability of the soil-cement mixture. The thickness of pavement and base and the quality of base at Turner AFB appeared to be adequate for indefinite operation of the imposed loads; those at Moody AFB appeared to be adequate for at least limmited operation of the imposed load. No comparison between construction joints and interiors of construction lanes can be made from this study since all were equally satisfactory. The bases provided adequate protection for the subgrades in all areas and were structurally adequate within themselves. Absence of pavement slippage appeared to be due to the good bonds between base and pavement noted on these fields.

The wetting-drying tests did not satisfactorily predict the behavior of the soil-cement base courses at West Palm Beach, but did indicate that the base courses at Turner and Moody AFB's would be satisfactory. Therefore, this test may not be indicative of the behavior of the mixture when the natural material is a beach sand.

The Atterberg limits tests indicate that cement reduced the plasticity index of the various plastic materials and that the reduction has been permanent. The amount of reduction varied directly with the percentage of cement used; the time required to produce a given reduction varied inversely with the percentage of cement used when the percentages were 5 or less.

No method was found to evaluate the effects of the healing of cracks by deposition of a calcareous material. It is not known whether the material was deposited before or after the cracks occured in the asphaltic concrete. However, from observations of the healing, it is strongly suspected that the calcareous material was deposited after the original crack appeared since the crack seems well cemented by the deposit.

SUMMARY

The following summarizing statements are believed warranted:

a. Cracks occurred in the soil-cement base courses on all the fields, but appeared to have no connection with traffic.

b. For the traffic imposed, the soil-cement base courses were structurally adequate and produced satisfactory protection for the subgrade materials.

c. The results of wetting-drying tests did not corrèlate with prototype behavior in every case.

d. The plasticity index of materials with excessive plasticity was reduced to values at or near zero by the addition of 5 to 10 percent cement.

e. The reduction in plasticity appears to be permanent, and durability of the soil-cement is satisfactory in all cases.

REFERENCES

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2. Corps of Engineers, Waterways Experiment Station, "Summary Report, Accelerated Traffic Tests." Vicksburg, Miss. (February, 1947).

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Discussion

E. G. ROBBINS, Soil-Cement Bureau, Portland Cement Association, Chicago—Mr. Redus' study of soil-cement paving confirms the observation that reflection cracking of a soil-cement base through the bituminous surface is not associated with structural failure, but rather that cracking is a function of the drying and hardening of the base.

Calcareous deposits have also been observed in cracks and around aggregate in freshly broken soil-cement samples. Laboratory tests have demonstrated the "healing" ability of soil-cement. Specimens fractured in compression testing after 7-days moist curing and then returned to the moist room and rebroken at 28 days, have had compressive strengths only 10 percent lower than the strengths of specimens cured continuously 28 days in the moist room.

Wet-dry and freeze-thaw tests are empirical laboratory procedures to determine how much cement is required to harden a soil adequately. For specimens made of sandy soils, the allowable 14 percent loss resulting from 12 cycles of testing is a criterion based on the results of thousands of tests and on the effects of weathering on laboratory specimens subjected to outdoor exposure. It was not unusual for losses resulting from 12 cycles of wet-dry and freeze-thaw testing of cores taken from pavements to be higher than losses observed in tests of laboratory specimens. The tests and criteria, however, have been successfully used to build many thousands of miles of roads and, as Mr. Redus indicates, many airports which are giving good service. It is not unusual for laboratory soil-cement specimens made of dune or blow sand to have higher losses in the wet-dry test than in the freeze-thaw test.

Tests also show that the effect of cement in reducing the plasticity index (PI) of a soil continues for a long period of time, although most of the reduction occurs in the first 3 to 7 days. For example, a clay with a PI of 14 was treated with 7 percent cement. Immediately after construction, the PI had dropped to 11, and after 6 years the material had PI's of 5 to 11.

Most highway specifications require compaction of at least 95 percent of standard AASHO density. This requirement is readily attained during construction. As a soil-cement base cures, the cement hardens the material in this dense state, and there is no appreciable further densification under traffic. Only enough initial compaction is required to bring the soil grains into intimate contact with the cement. Higher densities, however, are beneficial to the quality of soil-cement provided enough water is available for cement hydration.