

**SOIL-AGGREGATE CUSHIONS FOR PREVENTION OF  
REFLECTION CRACKING OF RESURFACED PAVEMENTS**  
First Progress Report

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Michigan State Highway Department  
John C. Mackie, Commissioner  
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## SOIL-AGGREGATE CUSHIONS FOR PREVENTION OF REFLECTION CRACKING OF RESURFACED PAVEMENTS

### Synopsis

A 4-in. deep soil-aggregate cushion was constructed over a severely cracked rigid pavement and covered with 250 lb of bituminous concrete per sq yd, to investigate feasibility of this treatment for improving the performance of resurfaced pavements. Four typical Michigan soils were used for the cushion.

On the basis of early performance of the cushion sections, some materials can definitely be eliminated from further consideration. The soil-aggregate mixture meeting Departmental specifications for 22A gravel appears to be the most promising. This mixture was easy to use in constructing the cushion and has held up well under traffic.

Gradation of the material used for the cushion is very important. If it contains a high proportion of minus 200 material, the cushion becomes unstable under traffic loads and plastic deformation results. The bank-run sand used in this test was not satisfactory, being unstable due to a lack of clay binder. Asphalt-stabilized gravel showed considerable promise as a cushioning material, but appears to be more expensive than the other mixtures. The experimental sections will be inspected periodically for conclusive evaluation of the relative merits of the various cushion treatments.

As the mileage of bituminous resurfacing of rigid pavement has increased, reflection cracking has become an increasingly important problem in highway maintenance. The present policy of accepting reflection cracking as inevitable and attempting to maintain the pavement by sealing has proved costly and unsatisfactory. The riding quality of the road is directly affected by the cracks, and foreign matter easily penetrates crack openings causing further damage to the pavement.

Reflection cracks apparently are caused by horizontal and vertical movement of the resurfaced rigid pavement. The rigid slabs deflect and rock under heavy traffic loads and also are subject to thermal expansion and contraction. During cold weather, the joints and cracks in a rigid pavement are open to their maximum, and the bituminous surface is least flexible and most susceptible to cracking.

Use of soil aggregate cushions placed between rigid pavement and the bituminous surface has been tried in several states, with varying degrees

of success, on the assumption that the cushion would absorb most slab movement without transmitting detrimental effects to the resurfacing.

At the request of Howard E. Hill, Managing Director, and with the approval of the Bureau of Public Roads, in August 1962, the Research Laboratory Division established a research project with the following specific objectives:

1. To determine whether a soil-aggregate cushion would significantly reduce or eliminate reflection cracking when bituminous concrete is used to resurface rigid pavements.

2. To determine whether a soil-aggregate cushion would provide sufficient thermal insulation to prevent blow-ups in the original rigid pavement.

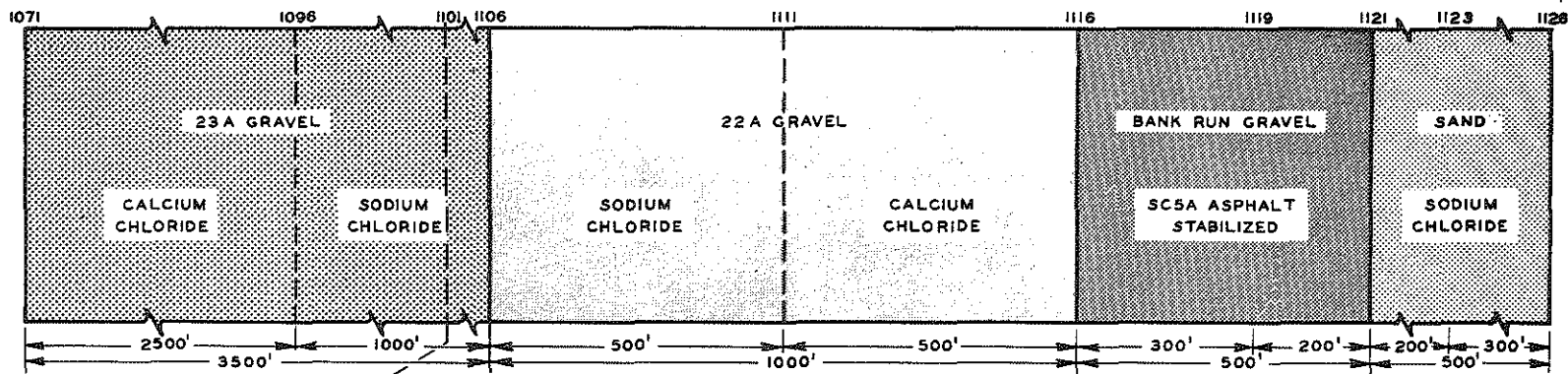
3. To investigate the relative effectiveness of various aggregates as cushion material.

4. To determine whether a soil-aggregate cushion may be stabilized economically by admixture or mechanical means, in order to carry traffic loads prior to the construction of the bituminous concrete surface. This is a very important consideration in areas where traffic cannot conveniently be detoured during the construction period.

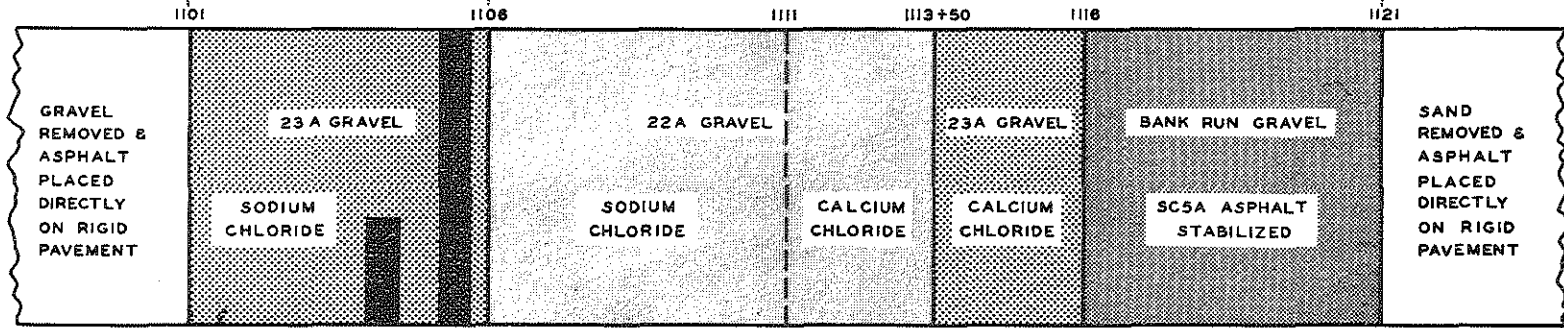
#### Description of Test Area

A 3-mile section of M 60, northeast of Leonidas in St. Joseph County, was selected for the investigation (Fig. 1). Before initiation of the research project, this highway was being widened and resurfaced under Construction Project F 78042C, C3. The rigid pavement apparently had been constructed over an old gravel road and directly on B-horizon soil. In preparation for resurfacing, the rigid pavement was widened to 24 ft. In areas of considerable frost heave the old base material had been replaced with granular soil and surfaced with new concrete over the rebuilt areas.

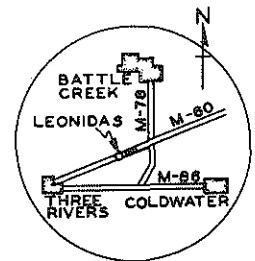
The soil-aggregate cushions were placed over the rigid pavement for 5500 ft of its total length. The remaining length of pavement, used as a standard of comparison, was resurfaced conventionally by placing bituminous concrete directly on the rigid pavement. The entire 3-mile length of rigid pavement including the soil-aggregate cushion was covered with 250 lb per sq yd of bituminous concrete. All sections of the soil-aggregate cushion were constructed to a uniform compacted depth of 4 in.



PROPOSED LAYOUT OF SOIL AGGREGATE CUSHION



ACTUAL LAYOUT OF SOIL AGGREGATE CUSHION



23 A GRAVEL REMOVED & REPLACED WITH 20 A GRAVEL

Figure 1. M 60 test site for soil aggregate cushions.



The old pavement was condition surveyed (Fig. 2) and roughness measurements were taken using the Michigan Roughometer. These procedures are to be repeated periodically to provide a performance history of the resurfaced pavement. Figs. 2 and 3 show the generally poor condition of the rigid pavement prior to resurfacing. This pavement had a mean average of about 10 transverse cracks per slab and a history of blow-ups. Fig. 3 shows a patch applied at the site of an old blow-up. This surface was likely to provide a rigorous test for the soil-aggregate cushion. Construction data were as follows:

Construction date	1929
Pavement width	20 ft
Pavement thickness	9 in. at edges, 7 in. at center
Expansion joints	1 in. wide spaced at 100 ft intervals
Load transfer	none
Contraction joints	none
Traffic (current data)	3300 vehicles per day, 525 commercial vehicles per day
Foundation soil	Foxseries; 2 to 3 ft of sandy loam B-horizon overlaying sand and gravel
Reinforcement	type not specified

#### Construction Procedure

Construction procedures were in accordance with 1960 MSHD Standard Specifications for Road and Bridge Construction. Because this research project was begun near the end of the fall construction season, it was decided to incorporate the experimental work into Construction Project F 78042C, C3 and limit material for the soil-aggregate cushion to that readily available at the construction site. The processed gravel to be used was obtained from available stockpiles. The bank run gravel was selected from a pit then currently in use. The two types of processed gravel used in the soil-aggregate cushion were 22A and 23A. Both had been mixed with 6 lb of Type 1 calcium chloride per ton of gravel in the stockpiles. The 22A gravel contained approximately 5 percent soil particles passing a No. 200 mesh sieve, and the 23A gravel about 12 percent.

The 23A had a plasticity index of approximately 15 (determined on the minus 200 fraction) and contained about 5 percent clay and 7 percent silt. Fig. 4 indicates that the stockpile contained considerable cohesive material. Previous experimental work by the Laboratory\* indicates that a sodium

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\*Greenman, R. L. "Michigan Experiments with Sodium Chloride Stabilization." ARBA Tech. Bull. 247 (1960).



Figure 3. Original rigid pavement. Note transverse patch replacing blowup.

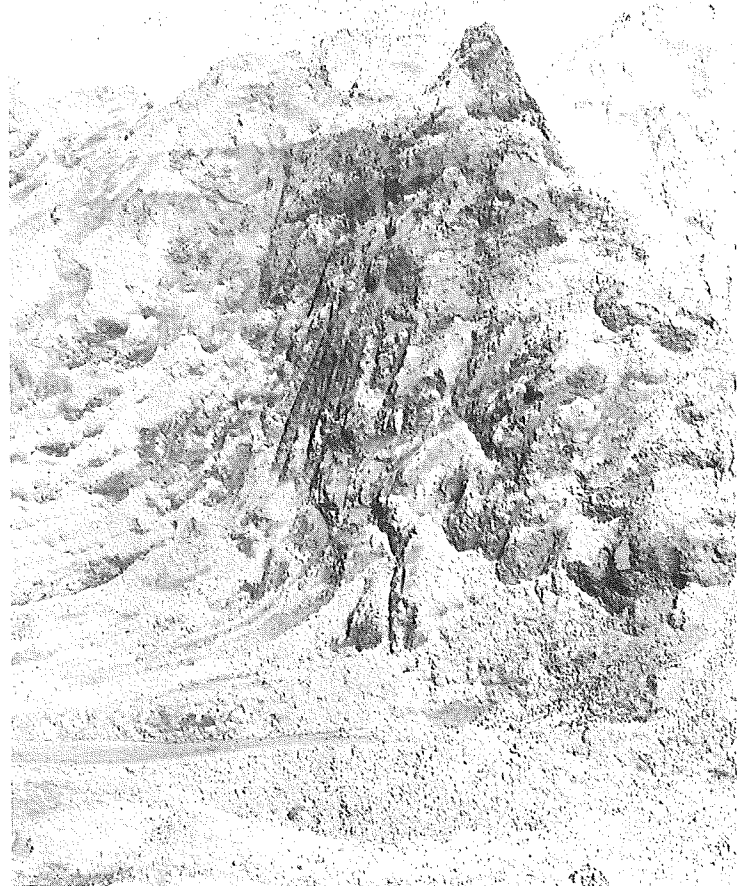


Figure 4. 23A gravel stockpile. Note striation of vertical surface.

chloride admixture might improve the performance of gravel base material containing relatively large quantities of fines. Thus, it was decided to add sodium chloride to certain of the soil-aggregate cushion sections. The 22A and 23A gravel to which sodium chloride was added also contained the residual calcium chloride which had been added at the time of stockpiling. Bank run gravel, stabilized with slow curing (SC-5A) asphalt was used in one area. Bank run sand treated with sodium chloride was used in another area. Each of the soil-aggregate cushions was constructed to a uniformly compacted depth of 4 in. The proposed layout of the various sections with types of soil and admixtures is shown in Fig. 1. After the cushions had been constructed, the entire project was covered with two layers of bituminous concrete, consisting of a leveling course of 130 lb per sq yd and a wearing course of 120 lb per sq yd.

1. Calcium Chloride-Treated 23A Gravel. The first section of the soil-aggregate cushion to be placed was the 23A gravel containing only calcium chloride (Sta. 1071+00 to 1096+00). The first portion of this gravel section was placed with a Barber Greene Asphalt Paver (Fig. 5), which performed very efficiently in placing the cushion, but broke down after operating for only a few hundred feet. The remaining gravel was placed by dumping from a moving truck. Compared with the asphalt paver, the dumping method of placement resulted in more wasted gravel and extra effort was required to shape the cushion.

About 800 lin ft of gravel was placed the first day, during which a misty rain fell. However, the remaining 2500 ft of this section was placed during warm sunny weather. Because it was believed that some of the admixture had leached out of the stockpile during its storage period, an additional 4 lb of Type 1 calcium chloride were added to each ton of this gravel placed during the dry weather period. The section of gravel cushion constructed during the rainy period remained quite moist and contained scattered soft spots. Thus, it was necessary to blade the gravel into windrows on the road to allow sufficient drying for proper compaction (Fig. 5). In this instance, the water-retaining properties of calcium chloride appeared to be a liability, because in combination with the large proportion of fines it retained undesirable moisture.

The maximum dry density for this material, based on the standard Proctor test, was about 135 pcf. This density was easily obtained with a self-propelled rubber-tired roller (Fig. 5). Some trouble, however, was experienced in eliminating moist spongy areas in the cushion. Traffic was easily maintained during construction, and upon completion of the cushion, the roadway appeared smooth and stable (Fig. 5).





Figure 5. Construction of 23A gravel section, showing placement of gravel with asphalt paver (upper left), drying of cushion by use of windrow (upper right), compaction in progress (lower left), and appearance of completed cushion (lower right).

2. Sodium Chloride-Treated 23A Gravel. Approximately 4 lb of sodium chloride (rock salt) was added to each ton of gravel as it was hauled to the job site (Sta. 1096+00 to 1106+00), and applied by dumping from a moving truck. Density was readily obtained with a rubber-tired roller. Traffic was easily maintained over the cushion during construction.

3. Sodium Chloride-Treated 22A Gravel. Approximately 6 lb of sodium chloride was added to each ton of gravel as it was hauled to the job site (Sta. 1106+00 to 1111+00). The material was compacted very readily with a rubber-tired roller and traffic was easily maintained over the cushion. No spongy areas developed in this section.

4. Calcium Chloride-Treated 22A Gravel. Approximately 4 lb of Type 1 calcium chloride was added to each ton of gravel as it was taken from the stockpile to the site (Sta. 1111+00 to 1115+50). The material was compacted easily and traffic was maintained over the cushion without difficulty. No spongy areas developed. This section, as originally planned, was to be 500 ft in length, but after 250 ft had been constructed the 22A gravel stockpile was exhausted and the remaining half was constructed with 23A gravel treated with 4 lb of calcium chloride per ton of aggregate. The material was placed without difficulty and carried traffic well.

5. Asphalt-Treated Bank-Run Gravel. The gradation of the gravel used in this test section is given in Table 1. The asphalt and gravel were mixed at an asphalt mixing plant and hauled about 20 miles to the construction area in trucks (Sta. 1116+00 to 1121+00). The bitumen content of the mixture was 4 percent by weight. The temperature of the mix was 250 F. The material was placed with a Cedar Rapids paver and was easily compacted with a steel-wheeled roller (Fig. 6). About 6 hr after compaction, traffic was permitted to travel over the cushion. Slight rutting was evident in the wheel tracks for a distance of about 5 ft at each end of

TABLE 1  
GRAIN SIZE ANALYSIS OF BANK RUN GRAVEL

Sieve No.	Percent Passing	AASHO Textural Classification		Percent Present
		Component	Size, mm	
10	55.2	Gravel	+2.0	44.8
40	34.8	Sand	2.0 to 0.074	51.2
200	4.0	Silt	0.05 to 0.005	2.4
		Clay	-0.005	1.6

Figure 6. Asphalt-stabilized bank run gravel (right), and attempted compaction of bank run sand (left).



the cushion, and also some flattening at the sides of the cushion caused by traffic running off of the transverse edges. The cushion held up very well under traffic, however, especially in view of the heavy trucks traveling over it after such a short curing period. The compacted cushion appeared to be somewhat "rich" in bituminous material and it appears that even better results could be obtained by slight reduction of the bitumen content of the gravel. The unit cost of this asphalt stabilized gravel was about four times that of the 22A gravel.

6. Sodium Chloride-Treated Bank Run Sand. This material was produced specifically for use in this section (Sta. 1121+00 to 1126+00). It contained about 8 percent silt, which proved to be ineffective as a binder material. Each ton received about 8 lb of sodium chloride and was placed with an asphalt paver. The self-propelled rubber-wheeled roller would not operate over it, so a grader was used in an attempt to gain compaction. Despite the addition of water and considerable rolling, the sand could not be compacted well and would not carry traffic (Fig. 6). As a result, the sand was taken away to be used elsewhere and the bituminous concrete placed directly on the old rigid pavement.

#### Completion of Construction

Porous aggregate shoulders were placed to a compacted depth of 4 in., constructed so as to provide adequate drainage for the cushions. Because of the impermeable appearance of the cushion, it was decided to omit the prime coat under the leveling course. A leveling course of 130 lb of bituminous concrete per sq yd of area was placed over the entire 3 mi of test area.

#### Early Performance of the Test Sections

After carrying traffic for about one day, signs of failure began to appear in the bituminous leveling surface over the 23A gravel cushion (Figs. 7 and 8). The asphalt surface was spotted with moisture, giving the appearance of water migrating up from the base, and areas of map cracking or longitudinal cracks appeared. Then the asphalt appeared to disintegrate, the damage spreading into large broken areas. However, these failures were confined to the areas of asphalt placed over the 23A gravel, and did not appear to be nearly as frequent or as serious in those areas in which the 23A gravel contained sodium chloride admixture. Attempts were made to patch the distressed areas but the failure became so widespread that it was necessary to remove large areas. These were replaced by asphalt applied directly on the rigid pavement surface.

Figure 7. Behavior of asphalt leveling course, showing map cracking and disintegration (upper right), longitudinal cracking and disintegration (lower left) and moisture spotting (lower right).



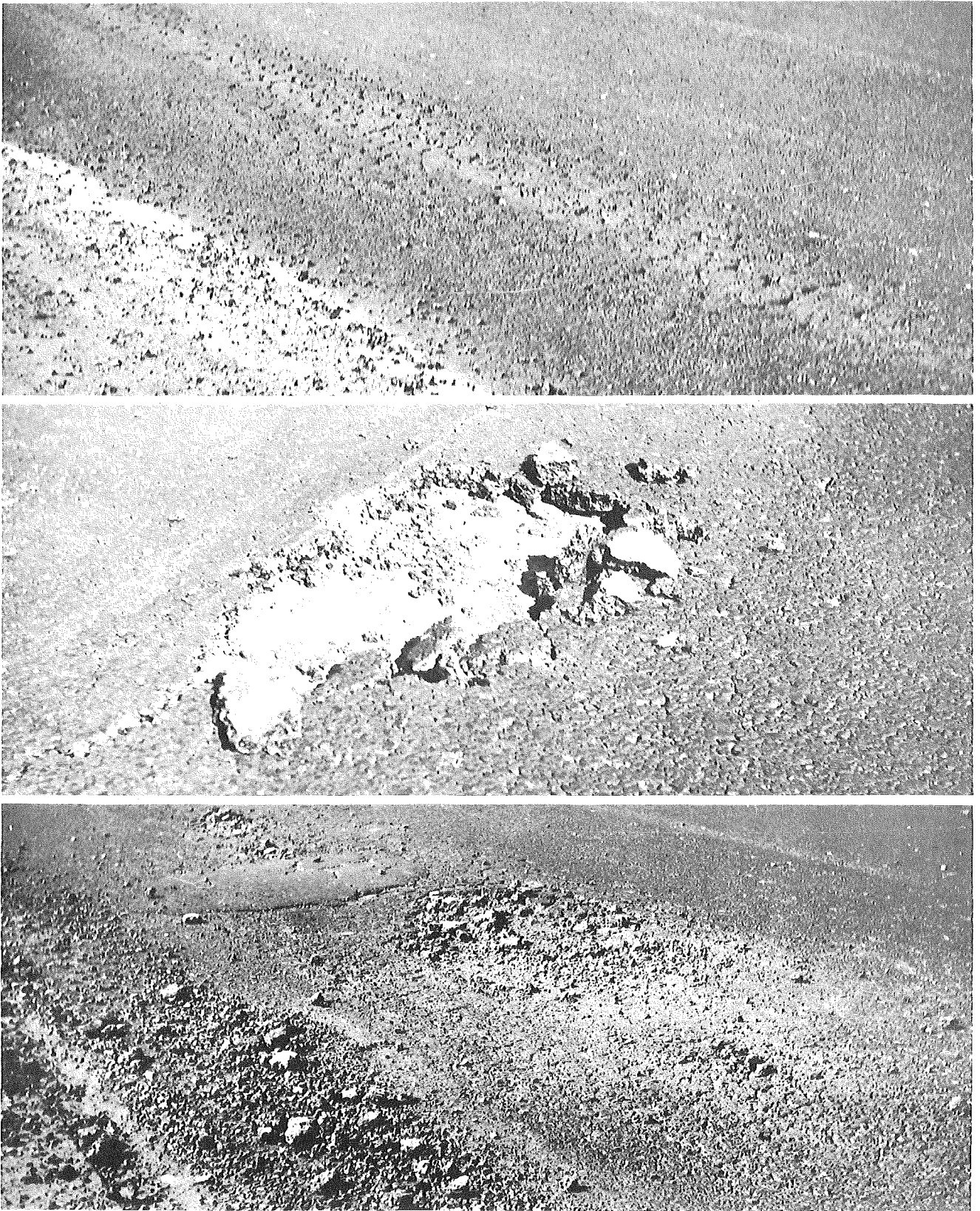


Figure 8. Behavior of asphalt leveling course, showing severe alligator cracking (top) and localized distress (center and bottom).

Inspections of the distressed areas revealed that no bond existed between the asphalt and the 23A gravel. There was a thin film of moisture between the asphalt and gravel which appeared to act as a lubricant. The asphalt could be rolled up like a rug from the 23A gravel (Fig. 9). Tests indicated a moisture content of about 10 to 12 percent in the top 1/2-in. surface of the soil. Below this, the soil moisture content was 4 to 5 percent. Except for a few small soft spots, the 23A gravel still appeared to be smooth and stable when the asphalt leveling course was peeled up from it (Fig. 9). Fig. 1 shows where areas of soil-aggregate cushion were removed from the road.

In retrospect, it appears that some benefit might have been realized from a prime coat placed on the gravel cushion before construction of the leveling course. Use of a prime coat might have prevented moisture accumulation between the aggregate and the asphalt, resulting in a better bond. However, at least part of the surface damage can be attributed to plastic movement of the base (Fig. 9). It is doubtful, therefore, if the 23A cushion would perform satisfactorily unless it could be stabilized more efficiently.

After removing the 23A soil-aggregate cushion where necessary and repairing the asphalt leveling course, a wearing surface course of 120 lb of bituminous concrete per sq yd of surface was constructed over the length of the project. This provided a total thickness of bituminous concrete of about 2-1/2 in.

About one month after completing construction, signs of failure were noticed in wearing surface areas which covered the remaining 23A gravel. Again, the 23A gravel which contained sodium chloride admixture exhibited fewer distressed areas than the 23A gravel which contained only calcium chloride. However, before drawing any conclusions regarding the benefit of sodium chloride as a stabilizer of 23A gravel, further research should be conducted under more controlled conditions. The 23A gravel stabilized with sodium chloride did fail, although apparently at a slower rate than the other 23A areas. Also, it must be remembered that all of the 22A and 23A gravel had been stockpiled with 6 lb of calcium chloride added to the soil at the time of production. Therefore, there were no 22A or 23A gravels containing sodium chloride only. After about one month of use, the two 22A gravel sections and the asphalt stabilized bank run gravel area showed no signs of distress.

Observations of the test site will be continued and will include further pavement condition surveys. The performance of the bituminous concrete overlaying the soil-aggregate cushion will be compared with that placed directly on the rigid pavement.

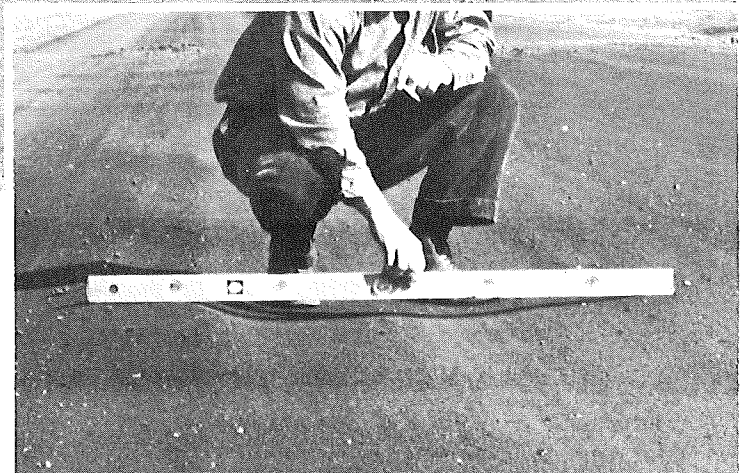


Figure 9. Removal of asphalt leveling course from distressed 23A gravel cushion (top), and appearance of cushion when exposed (center). Rutting is shown at bottom.



## Conclusions

Soil-aggregate cushions can be constructed without serious problems and can carry traffic satisfactorily until surfaced with asphalt. Observations during the next several months should indicate the effectiveness of this type of cushion in preventing reflection cracking. Specific conclusions are as follows:

1. Soil-aggregate cushions should not be constructed of gravel that contains relatively large quantities of material passing the No. 200 mesh sieve, unless an efficient means of stabilization is available. These tests indicate that fines content should not exceed the amount now allowed in 22A gravel.

2. Aggregate meeting Departmental specifications for 22A gravel appears to be acceptable for use as a soil-aggregate cushion. Such material will accept normal traffic immediately after construction without causing serious damage. This may not be true in the event of a heavy rain on the soil-aggregate cushion.

3. Slow-curing (SC-5A) asphalt-stabilized bank run gravel, similar to that used in this test, performed well as a soil-aggregate cushion. However, it appears to be less economical than 22A gravel, and must be allowed to cure for about 6 hr before traffic can be permitted to travel over it.

4. Bank run sand, similar in gradation to that used in this test, should not be used for a soil-aggregate cushion unless an acceptable means of stabilizing it can be found.

5. This test area will be observed periodically in order to compare performance of the soil-aggregate cushion areas with the remainder of the project constructed with no cushion.