FINAL REPORT

# DESIGN OF BITUMINOUS MIXES WITH HIGH SKID RESISTANCE

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Highway & Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways & Transportation and the University of Virginia)

Charlottesville, Virginia

August 1979
VHTRC 80-R11

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# SUMMARY

Certain highway locations need exceptionally high skid resistance because of the alignment, geometry, and drainage of the roadway and the complex turning maneuvers required. Several beam specimens made of bituminous mixes incorporating unconventional aggregates with physical characteristics likely to produce high skid resistance were installed in a pavement and tested periodically for skid resistance. The skid resistance values of the experimental mixes and a conventional resurfacing mix were approximately equal after 700,000 accumulated vehicle passes; therefore, there was no apparent benefit from using the unconventional aggregates.

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## INTRODUCTION

It is essential that good skid resistance be provided on all highway pavement surfaces to prevent skidding accidents during wet weather. The magnitude of skid resistance available on a pavement is primarily dependent on the pavement surface texture, drainage, type of aggregate, and accumulated traffic. In a bituminous surface mix, the gradation of the aggregate and the asphalt content should be such as to ensure a good surface texture, and the aggregate should have a proven high skid resistance. The highway alignment and geometry, posted speed, and type of vehicle turning maneuvers required usually determine the magnitude of skid resistance that is necessary. When the mix is designed properly, locally available aggregates such as granites, quartzites, and crushed gravels will produce satisfactory skid resistance; however, on the basis of the determinative factors cited, certain locations may require an exceptionally high skid resistance to prevent accidents.

Economy usually determines the type of aggregate used; however, the safety of the highway user might require that premium priced skid resistant aggregates be used in some cases. Slag, which is available in West Virginia and Pennsylvania, and lightweight aggregate, which is used in concrete, have been shown to provide exceptional skid resistance. A previous report described the design and field installation of several bituminous surfaces using aggregates having physical characteristics likely to produce high skid resistance. The results of periodic skid tests on these surfaces are described and evaluated in this report.

## PURPOSE AND SCOPE

The purpose of this investigation was to design and evaluate several bituminous surface mixes with high skid resistance being a primary goal. Specimens were prepared in the laboratory, installed in the pavement, and tested periodically for skid resistance.

# LABORATORY PREPARATION

## Mixes

Specimens were prepared in the laboratory and surfaced with different materials; namely, limestone, slag, granite, calcined kaolin, and aluminum oxide. Calcined kaolin is a high aluminum silicate with a hardness of 8.5; it is used in refractory bricks but has potential use as an abrasive. Aluminum oxide is a hard, anti-slip abrasive used on the surface of concrete to provide an anti-slip surface.

An S-5 gradation (Table 1) was used for the limestone, slag, and granite surface mixes. Two gradations (Table 2) of calcined kaolin were sprinkled on the surface of the S-5 granite mix and embedded by compaction. The aluminum oxide (Table 2) was also sprinkled and was embedded in a granite mix with an S-1 gradation (Table 1). It was important that the aggregate sprinkled on the surface be approximately the same size as the maximum sized aggregate in the bituminous concrete. Since calcined kaolin and aluminum oxide are very expensive, the sprinkle application was used in an attempt to hold down the cost of the mix.

Limestone was selected to demonstrate the polishing effect of traffic; slag because it had previously provided good skid resistance; granite for comparison to determine the benefit of the sprinkle aggregate; and the sprinkle aggregates because of their angularity and hardness. The optimum asphalt contents obtained by the Marshall design method were 7.75% for the slag, 5.6% for limestone, 5.8% for the S-5 granite, and 9.1% for the S-1 granite.

Table 1

Mix Gradations

| | % Passing | |
|---|---|---|
| Sieve | S-1 | S-5 |
| 1/2 | | 100.0 |
| 3/8 | | 90.0 |
| 4 | 100.0 | |
| 8 | 97.5 | 44.5 |
| 30 | 72.0 | |
| 50 | 45.0 | 15.0 |
| 200 | 4.0 | 6.0 |

Table 2

Sprinkle Aggregate Sieve Analyses

| Sieve | % Passing | | |
|---|---|---|---|
| | Calcined Kaolin (Designation 3 x 4) | Calcined Kaolin (Designation 1/2 x 1/8) | Aluminum Oxide |
| 1/2 | | 100 | |
| 3/8 | 100 | 84 | |
| 4 | 14 | 1 | 100 |
| 8 | 1 | 0 | 0 |
| 30 | 0 | | |

## Specimen Preparation

Beam specimens 15.0 in. x 3.25 in. x 1.5 in. were made on a modified kneading compactor by a procedure originally designed for making specimens for fatigue tests, and were sawed to provide 7.5 in. x 3.25 in. x 0.56 in. specimens. The beams without sprinkle aggregate were prepared as follows:

1. Aggregate preheated to 300°F and asphalt cement preheated to 275°F were mixed in a mechanical mixer until the aggregate was thoroughly coated.

2. One-half of the mixture was placed in the mold and compacted with 4 passes at a 166 psi foot pressure.

3. The foot pressure was increased to 202 psi and an additional 4 passes applied.

4. The remaining mix was added and steps 2 and 3 repeated.

5. The mix was covered with a metal plate and 6 passes were applied at a 227 psi foot pressure.

6. After cooling, the mold was disassembled and the beam removed.

The sprinkle mix beams were made similarly, except that the precoated sprinkle aggregate was placed in the mold ahead of the bituminous concrete mix. Table 3 lists the amount of AC-20 asphalt cement used to precoat the sprinkle aggregate and the rates of application.

Table 3

Sprinkle Aggregate Precoating and Application Rates

| Aggregate | Precoating, % AC | Aggregate Application Rate, Psy |
|---|---|---|
| Calcined Kaolin (Designation 3 x 4) | 5 | 11.7 |
| Calcined Kaolin (Designation 1/2 x 1/8) | 5 | 11.1 |
| Aluminum Oxide | 4 | 7.6 |

## FIELD INSTALLATION AND EVALUATION

The specimens were installed in the outside wheel path of the southbound traffic lane on Route 29 approximately 4 miles north of the Charlottesville city limits in September 1973. Two beams of each type of mix were installed at each of 3 sites approximately 1,000 ft. apart. Each site contained 12 beams spaced 1.5 ft. apart.

The traffic count in the southbound traffic lane on August 1, 1973, was 1,190 vehicles per day.

The beams were placed on a fresh surface mix immediately behind the paver and rolled into the pavement by the normal rolling procedure. They appeared to be level with the surrounding surface after the rolling; however, careful examination several months later revealed some deformation of the beams. After 15 months, the deformation had been eliminated by the action of traffic. It is believed that the observed deformation was not sufficient to interfere with the tire contact and related polishing action.

The skid resistance was measured periodically with a British pendulum tester according to ASTM Standard Test Method E 303.

## RESULTS

The effect of accumulated traffic on skid resistance is illustrated in Table 4 and Figure 1. The skid resistance of all the materials increased initially and then decreased until a constant level was reached. The initial increase was caused by traffic wearing away the asphalt film and exposing the aggregate surface, and the following decrease resulted from the polishing action. The lowest and highest skid resistance values were obtained on the limestone mix and the surrounding maintenance overlay, respectively.

Table 4

Average Skid Resistance, British Pendulum Number

| Surface Material | Accumulated Traffic, total vehicles | | | | |
|---|---|---|---|---|---|
| | 108,000 | 216,000 | 324,000 | 432,000 | 720,000 |
| Limestone | 36.7 | 49.5 | 46.7 | 37.8 | 42.2 |
| Slag | 57.6 | 64.9 | 67.2 | 62.6 | 62.4 |
| Granite | 59.2 | 67.0 | 66.7 | 62.8 | 61.5 |
| Calcined Kaolin (Designation 3 x 4) | 61.7 | 70.9 | 70.0 | 66.8 | 65.7 |
| Calcined Kaolin (Designation 1/2 x 1/8) | 65.9 | 72.4 | 70.0 | 66.2 | 67.4 |
| Aluminum Oxide | 67.1 | 70.9 | 69.4 | 66.5 | 64.2 |
| Wheel Path* | 70.5 | 73.6 | 69.7 | 66.5 | 66.5 |
| Pavement Edge* (Not in wheel path) | | 75.3 | 74.9 | 76.1 | 74.5 |

*Maintenance surfacing using a metamorphosed basalt.

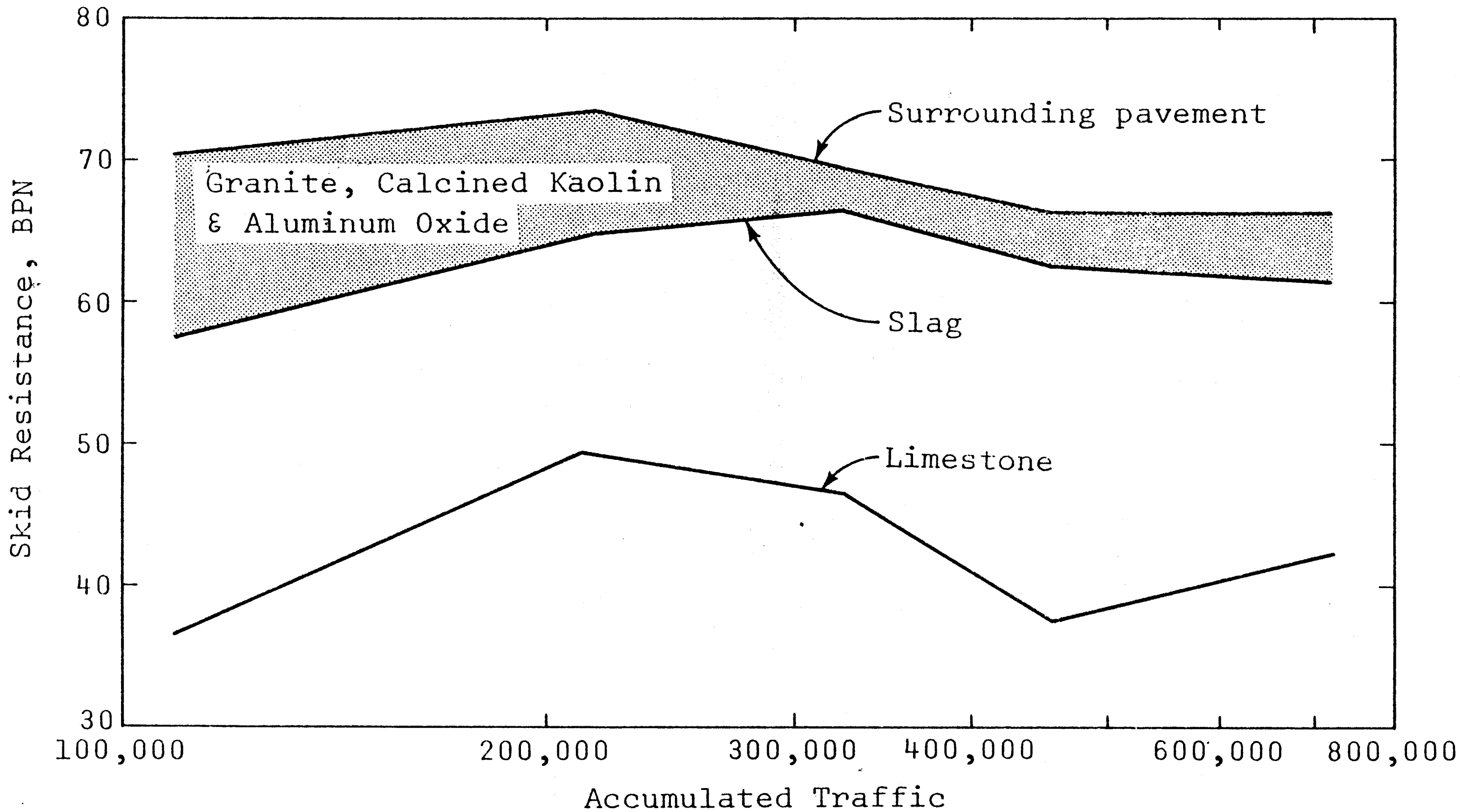


Figure 1. Skid resistance vs. accumulated traffic.

There was no significant difference in the skid resistance of the mixes after approximately 300,000 vehicle passes, except for the limestone mix. The limestone mix was approximately 20 British pendulum number (BPN) units below the other mixes and appeared to still be losing skid resistance after approximately 700,000 vehicle passes. It was anticipated that more skid resistance measurements would be made; however, the test site was resurfaced.

Although the addition of calcined kaolin sprinkle aggregate to the granite mix did not increase the skid resistance significantly, Figure 2 illustrates that there was a slight improvement.

The aluminum oxide sprinkle mix had relatively good skid resistance, but might lack sufficient texture to provide adequate skid resistance for high speed traffic.

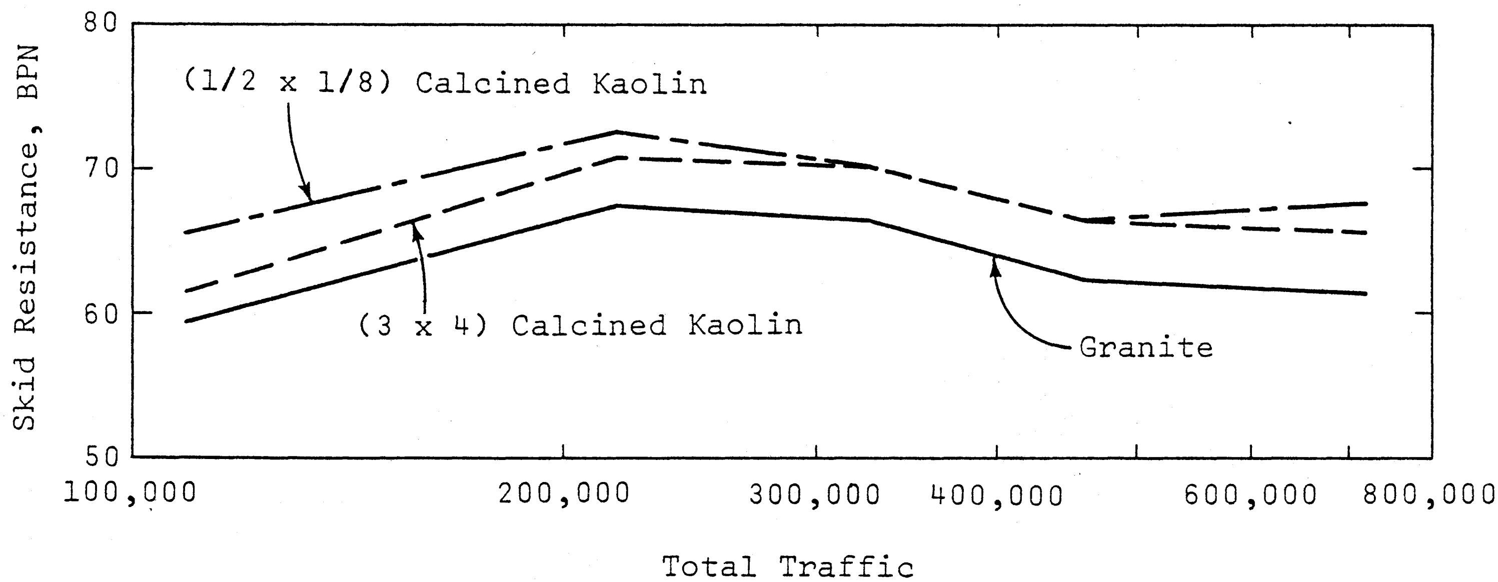


Figure 2. Skid resistance vs. accumulated traffic of S-5 granite and sprinkle mixes.

## CONCLUSIONS

1. There was no significant difference between the skid resistance of the metamorphosed basaltic resurfacing mix and that of the experimental mixes.

2. The limestone mix displayed a low skid resistance, as expected.

3. The calcined kaolin sprinkle aggregate provided a slight but not significant increase in skid resistance to the granite mix.