

Providing Needed Skid Resistance

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INTRODUCTION

I was flattered to receive your invitation to participate in this Road School and I hold this opportunity in high regard. First, because this is where a great deal of the early knowledge relating to pavement skid resistance was developed, and because the people who performed some of the early and very significant research are still very much in evidence in West Lafayette.

As some of you probably know, the most significant get together of people involved in skid resistance research occurred in 1958, when the First International Skid Prevention Conference was held at the University of Virginia. The papers presented at that first international conference were done so well that the authorities in this field have not felt a need for a second conference until now, 17 years later. This Second International Skid Prevention Conference will be held this fall at Penn State University. But to go back to earlier days, let me list for you some of the papers that were presented at the first conference:

“Factors Affecting the Measurement of Skid Resistance,” “A Laboratory Method of Evaluating Slipperiness,” “Effect of Pavement Type and Composition on Slipperiness,” and “Polishing Characteristics of Mineral Aggregate.”

Does it surprise you that all four of these papers came from people at Purdue University? That Harold Michael and Bill Goetz were two of the authors? And that K. B. Woods presided over one of the conference sessions? And by the way, if you look back to the literature of 1950, you will find a document entitled, “Report and Annotated Bibliography on Skid Resistance,” by J. F. McLaughlin.

Just prior to the first skid prevention conference, Virginia held a correlation study in which one of the skid test vehicles was a 1956 Ford from Purdue’s Joint Highway Research Project. The same car returned to Virginia in 1962 to take part in a second correlation study. By the time of the 1962 tests, this Ford from Indiana had won fame as the car that had skidded further than most cars had been driven.

So, the first reason I am so pleased with this opportunity is that I have been invited to speak at an institution with rich background in the very subject under discussion.

The second reason I take such pride in this opportunity is much more personal. The man who employed me in the highway research field, the man who aroused the Virginia Department of Highways' interest and later my interest in skid research, the man who was instrumental in founding the organization for which I work, and the man whose name, Tilton E. Shelburne, now identifies our Virginia highway research facility, was from Indiana. He took his B.S.C.E. and M.S.C.E. degrees here at Purdue, and in 1966 returned to accept an honorary doctor of engineering degree awarded by his alma mater for his contributions to the engineering profession and engineering education.

FRICITION NEEDS

There has been as much, if not more, written and said about pavement skid resistance as about any aspect of providing safe highways. The shelves are full of literature on the subject, so there is no way we can take a look into all of the parameters of skid resistance this morning. I would, therefore, like to concentrate on the few salient factors which must be observed if we plan to provide needed skid resistance. I don't mean needed skid resistance at one location, I mean everywhere; and since we must be concerned with skid resistance everywhere, we must be concerned with economics. There is no way we can provide the needed skid resistance everywhere by selecting one type of surface for universal use. We must determine not only how much, but what kind of skid resistance we need; and then we must optimize the use of local materials. To do less is sinful; it's un-American; and it's downright wasteful. We have no right to design a pavement surface for a low traffic, low speed roadway to the same standards used for the design of a jet runway. There are different needs for different speeds! The relationship of speed to skid resistance is discussed below.

MAJOR FACTORS TO BE CONSIDERED

Always remember that one of the salient criteria for determining needed skid resistance is traffic speed. Of course, there are all sorts of parameters and ramifications within speed as it relates to friction needs—such as curves vs. tangents, open roadway vs. intersections, and, in some cases, unanticipated hot spots or accident-prone locations. We do not have time to discuss these parameters, but suffice it to say that special situations or locations can be taken care of quite easily.

**TRAFFIC VOLUME VS FRICTION
DENSE GRADED ASPHALTIC CONCRETE
(40 MPH TEST)**

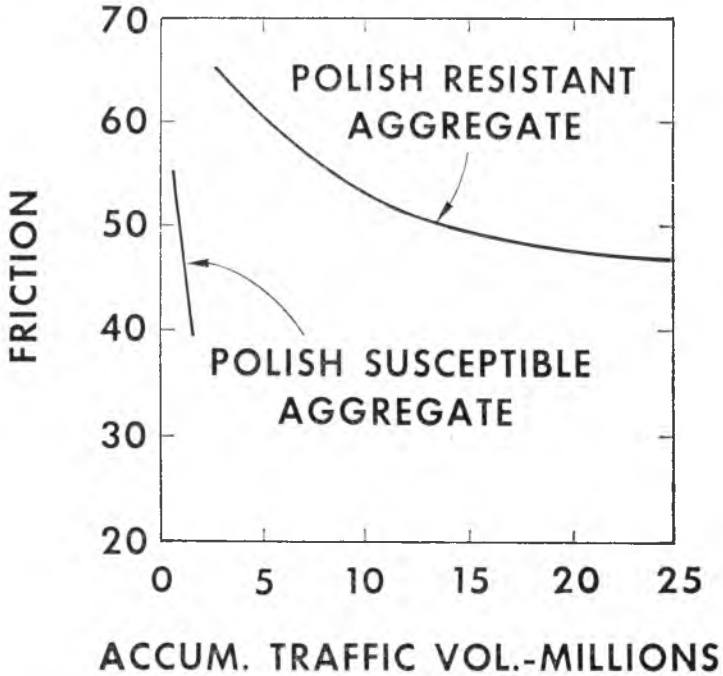


Figure 1

The second very important consideration is how many vehicles will pass over the surface before it has to be resurfaced for some reason other than to restore skid resistance. If a surface is to be subjected to many millions of vehicle passes in its life, it needs to be fabricated from highly polish-resistant aggregate. On the other hand, if the surface is to receive only a few million vehicle passes in its life, it can be built with aggregates that possess much lower skid resistant qualities.

To demonstrate the relationship of the skid resistant qualities of aggregates to accumulated traffic volume, look at Figure 1. On the vertical axis are skid numbers and on the horizontal axis is accumulated traffic in millions of vehicle passes. Notice that although the curve for the polish-resistant aggregates drops with accumulated traffic, it seems to have leveled, and if we consider a skid number of 40 as satisfactory, we can conclude that these aggregates will provide good

skid resistance for the life of any road. On the other hand, the curve on the left shows that these particular limestones, which are the most polish-susceptible limestones we have in Virginia, drop to a skid number of 40 after about two million vehicle passes. So, the questions which need to be answered are: When is it justified to use expensive, imported aggregates? And, where is it justified to use them? How long does it take to accumulate two million vehicle passes? How long does it take to accumulate 25 million vehicle passes? If there is a two-lane road that carries 1,000 vehicles a day (AVD), which, of course, is 500 vehicles per lane, it would require more than 11 years for the skid resistance of this limestone surface to drop to 40 due to aggregate wear. Would such a road justify importing highly polish-resistant aggregate? However, if a dual-divided highway had a traffic count of 100,000 AVD, or 25,000 per lane, it would require only 80 days, or one-quarter of one year, for skid numbers to drop to 40 if 100% of this particular limestone aggregate was used in the pavement surface. Notice I said 100% of this aggregate. We know a blend of about 50% fines from this limestone aggregate source with 50% coarse material from this polish-resistant aggregate source would provide an excellent skid-resistant surface.

At present, we have test sections in Virginia which employ as little as 10% of the nonpolishing aggregate in blended mixes. We have also achieved a great deal of success by sprinkling about five pounds per square yard of precoated, polish-resistant aggregate on 100% limestone bituminous mixes prior to initial rolling. I don't wish to go into any detail regarding blended mixes or sprinkle mixes during my allotted time; however, I will be glad to discuss both of these mixes, as well as any other mixes mentioned later in the talk, during the question-answer period or after the meeting.

Thus far it has been shown that the two most important things in providing needed skid resistance are, (1) to determine what is needed, and (2) to build the surface with materials that will provide this needed skid resistance for the life of the surface.

VIRGINIA METHODS OF MEETING NEEDS

To demonstrate how accumulated traffic and vehicle speed affect skid numbers, observe some figures about pavement surfaces and skid data. There are eight surfaces, namely: five rather *dense-graded bituminous mixtures*, of which two (traffic and passing lanes) are fabricated from a good grade of limestone, two (traffic and passing lanes) from a highly polish-resistant granite and one from a high grade quartzite;

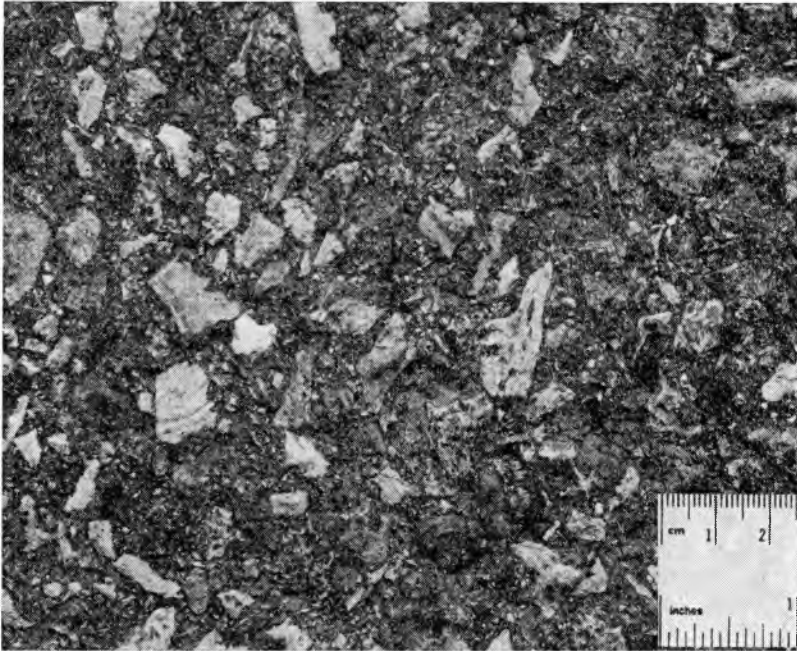


Figure 2

a blended mix, which we call an urban mix; an open-graded or popcorn mix fabricated from a high grade quartzite; and a silica sand mix.

Figure 2 shows the above mentioned passing lane of the dense-graded bituminous mix fabricated with our best limestone, which has experienced about 2.3 million vehicle passes. Before looking at the traffic lane, which has been subjected to over nine million passes, note the texture, not only of the surface in general, but of the individual aggregates. Figure 3 shows the traffic lane, in which the surface has densified and the individual aggregates have polished.

Figure 4 shows skid data for the passing lane of the surface shown in Figure 2. The reader should carefully orient himself since the other graphs are set up the same way. First, at the top of Figure 4 is the accumulated traffic; in this case, 2.3 million vehicle passes. The vertical axis depicts skid numbers and the horizontal axis depicts test speeds in miles per hour. There are data for both treaded and bald tires. Mean test values are shown and the estimated curve of best fit is drawn. The 40 mph test value is above advocated standard and in evaluating these data, the skid qualities would be considered excellent. The data does, however, indicate the danger of employing bald tires. To reference these data, which are for the passing lane,

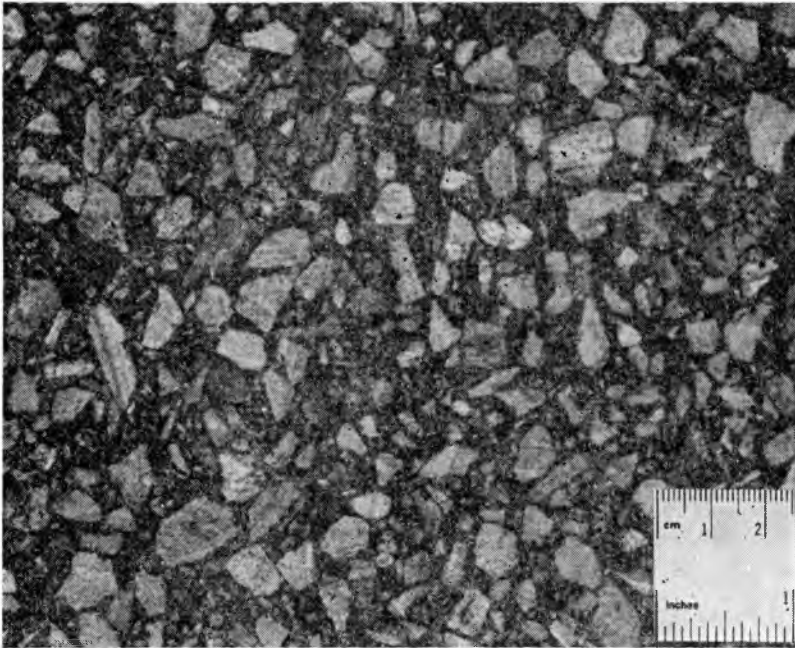


Figure 3

to data for the traffic lane, remember that for about 2.3 million vehicle passes on a surface that shows good overall texture as well as good aggregate texture, the 40 mph skid number with a treaded tire is about 50. Figure 5, which shows data from the polished traffic lane (see Figure 3) that has received 9.4 million vehicle passes, indicates that the 40 mph skid number is 40. The surface is border-line but still acceptable. However, I think most will agree that the curve for the bald tire points out rather dramatically the danger of slick tires.

With Figure 5, one can make a rough estimate as to how many feet would be required to stop an automobile on a wet pavement for some of the skid values and speeds shown. For a car with good tires traveling at 40 mph, about 133 feet would be required; for the same car with bald tires, about 266 feet would be required. At 70 mph the same car on the same surface would skid about 600 feet with good tires, but with bald tires would skid more than 1,600 feet—more than five times the length of a football field. Again, I would like to emphasize: don't allow your state to permit worn-out tires. Your state can't afford to build pavement surfaces to compensate for bald tires.

Figure 6 shows another dense-graded mix, the one fabricated from a good, polish-resistant granite. This surface has carried about 4.5

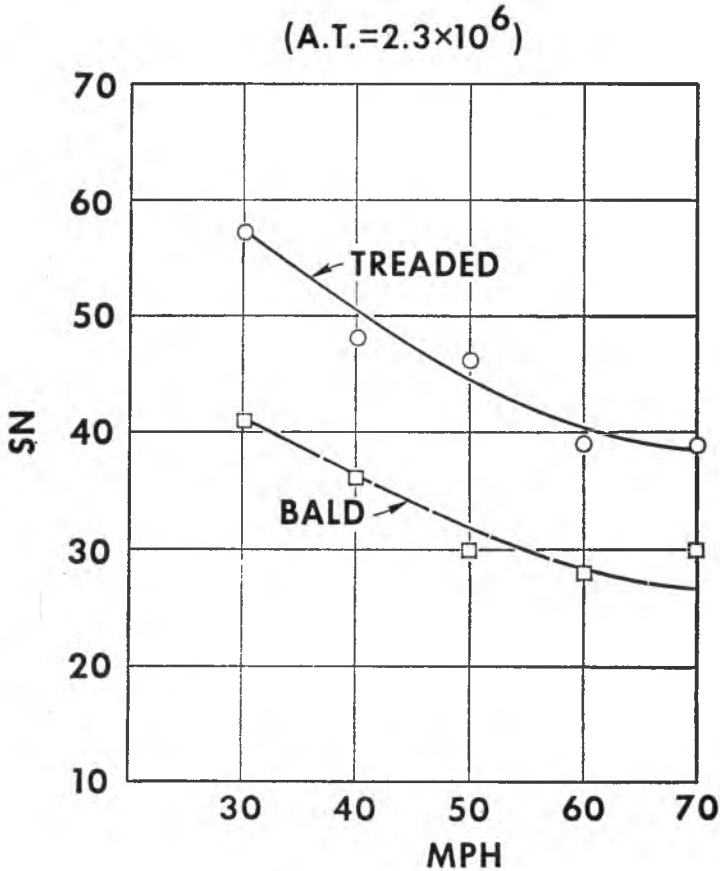


Figure 4

million vehicle passes. Note in Figure 7 that the relationship between bald and treaded tires is about the same as for the last surface discussed. However, this surface, because it is made up of polish-resistant aggregate, will remain close to its present skid resistant level for many, many more million vehicle passes.

The next two surfaces discussed were also made from dense-graded mixes, but because they were fabricated from 100% quartzite, the general surface texture is much harsher than the texture for the previously shown limestone and granite surfaces. This additional harshness is accredited to the plucking out of the quartzite fines as the asphalt strips from this portion of the mix.

The passing lane, shown in Figure 8, has experienced about 3.3 million vehicle passes. This surface is brown in color. Note the general

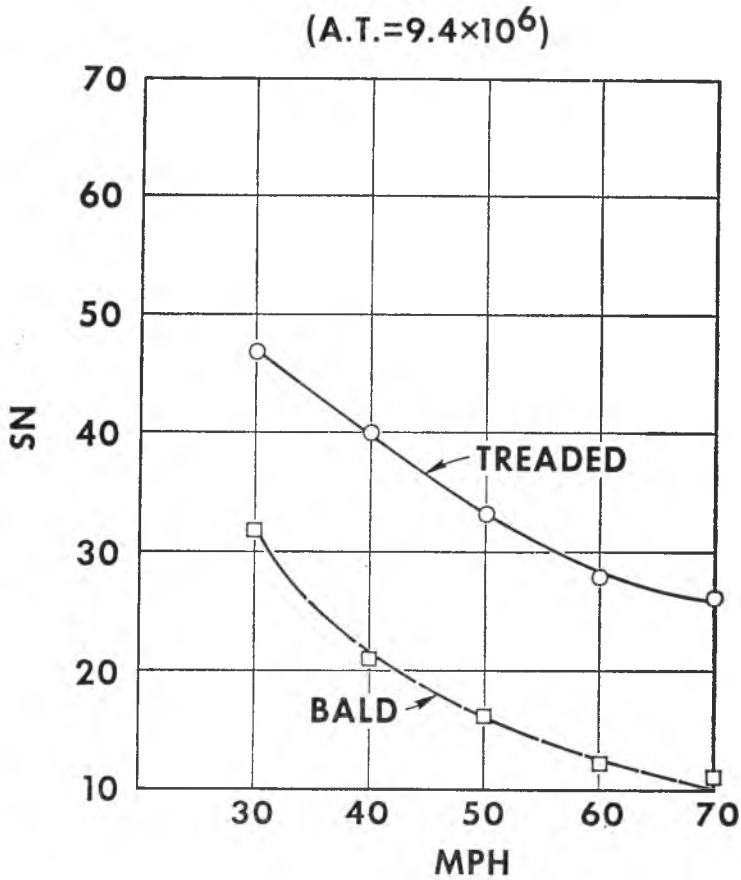


Figure 5

harshness. Figure 9 shows the traffic lane, which has received over nine million vehicle passes. The surface has begun to densify a little, but it is still quite harsh.

Figures 10 and 11 show that there has been a difference in the loss of skid numbers between the surface with 3.3 million and that with 9.2 million vehicle passes. However, the most significant thing about this surface is that bald tires provide skid numbers that are as high as those for the treaded tires. This, of course, is due to the fact that the pavement surface texture is harsh enough to provide excellent skid resistance, but mixes fabricated from it have a stripping problem.

Now consider the urban mix. Our bituminous technologists developed this mix to withstand slow loading rates and lateral stresses

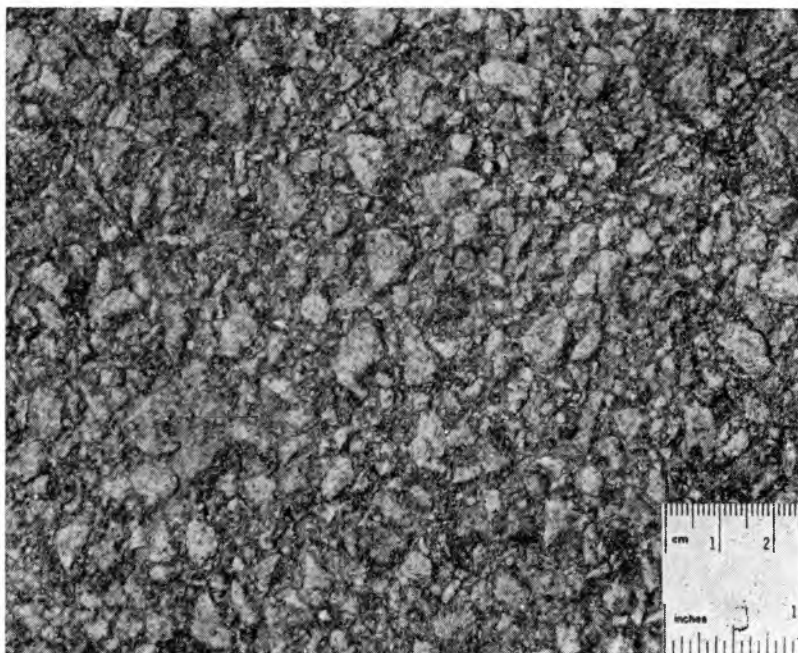


Figure 6

found at bus stops and traffic lights. The mix design is directed toward obtaining maximum aggregate interlock and reducing the influence of the asphalt. In the design, the asphalt content is reduced to minimum consistency with reasonable stability and density. In order to provide a stiff mix, a harder than usual grade of asphalt is used; i.e., a 60-70 penetration or AC-40, and in order to assure high densities during construction, a vibratory roller is employed. As with the other dense-graded mixes, a minimum density of 92% of the maximum theoretical density is specified.

Note in Figure 12 that the surface has a harsh macrot texture. This particular application has a blend consisting of 40% polish-susceptible fine aggregate and 60% polish-resistant coarse aggregate. Figure 13 shows that this mix has the same characteristics with regard to bald tires as did the previously discussed quartzite mix. However, rather than being due to stripping, the mix's harsh surface texture is accredited to the gap between the large top-size aggregate and the rest of the mix. One of our district materials engineers is so pleased with the overall characteristics of the mix, especially its skid resistance, that he plans to use it with slight modification for much of his general resurfacing schedule.

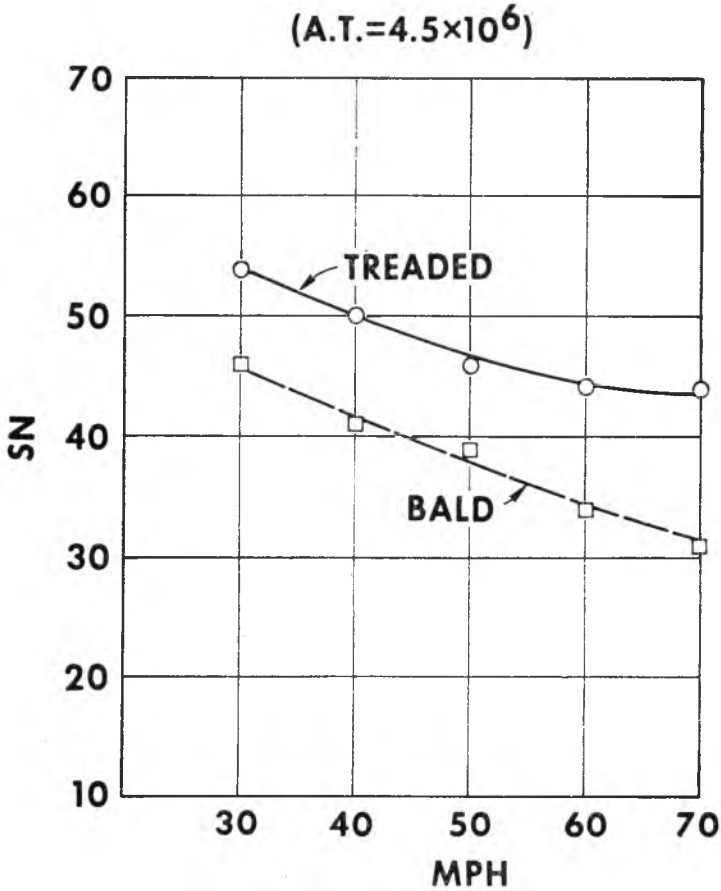


Figure 7

In my opinion, the last two surfaces discussed are extremely good examples of why there are different needs for different speeds. The two surfaces are the open-graded or popcorn mix that recently has been given so much attention, especially by the FHWA, and the long used sand mix. Figure 14 shows the popcorn mix and as can be seen, the mix is quite open. The mix has its advantages and disadvantages. The August 1974 *Maintenance Aid Digest*, which is published by the FHWA and AASHTO, lists ten advantages and 18 disadvantages. We do not have time to go into them here.

Many are familiar with the sand mix shown in Figure 15. This mix is similar to the old Kentucky Rock asphalt, or Kyrock. There is no telling how many miles of this mix has been placed or how many lives it has saved.

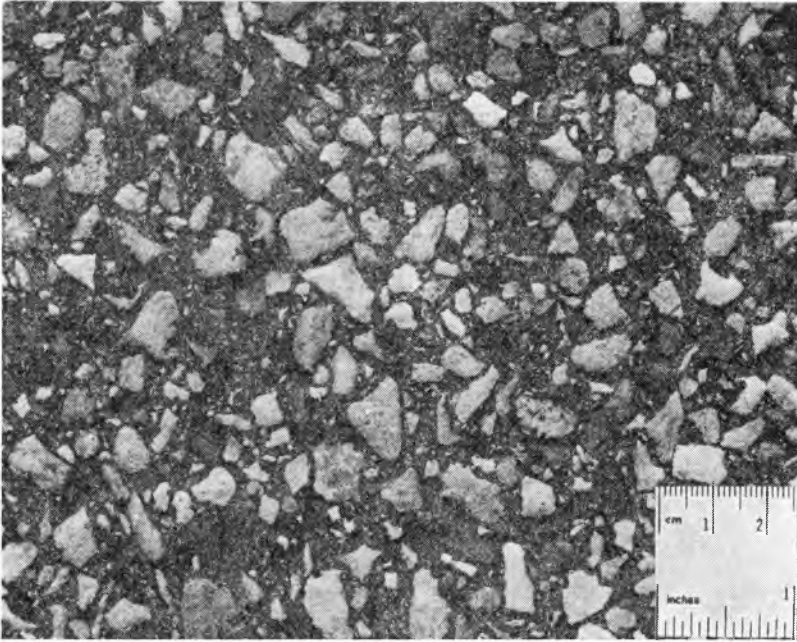


Figure 8

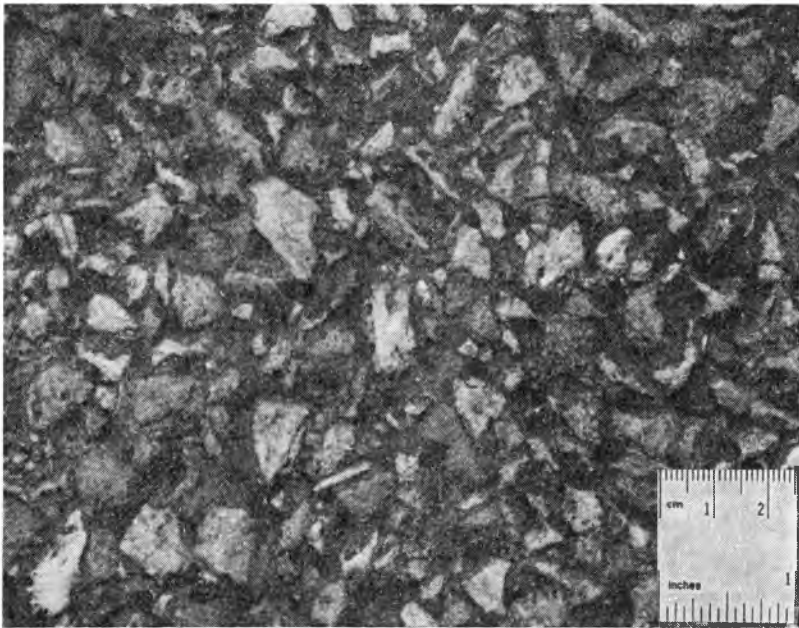


Figure 9

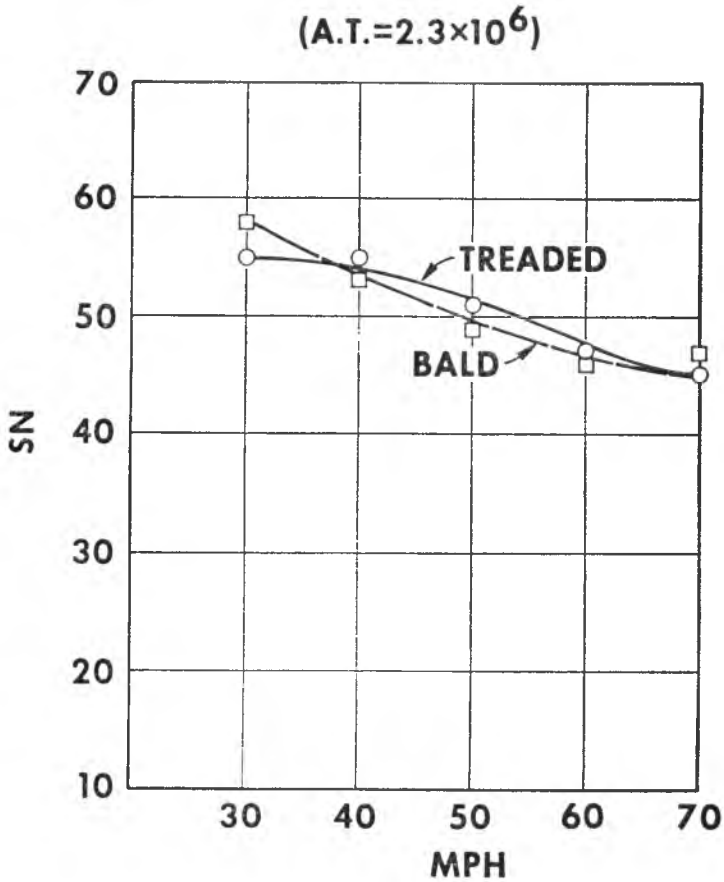


Figure 10

These two mixes, popcorn and sand, are as different in their skid resistant qualities as they are in their appearance. The popcorn mix, Figure 16, does not possess real high skid numbers at low speeds or low skid numbers at high speeds. In fact, the difference between skid numbers at 30 mph and 70 mph is not significant. Also, note there is no difference between the bald and treaded tires at the high speeds and that the bald tire holds an advantage at the low speeds. On the contrary, on the sand mix, Figure 17, the treaded and bald tires react quite differently from each other. It is again obvious that we cannot tolerate worn out tires. Note that for the treaded tire the skid resistance is real high at the low speeds and fairly high at the high speeds. In addition to its excellent skid resistant quality up to about

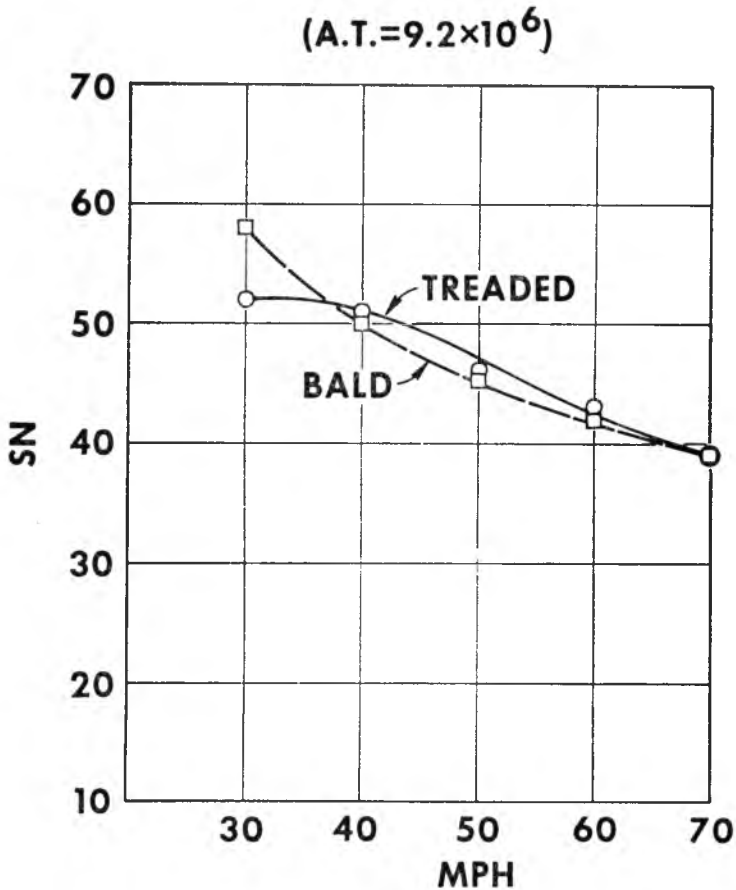


Figure 11

55 or 60 mph, this mix has the extremely desirable quality of replenishing itself; i. e., the individual sand particles pluck out before they become polished, and thus the skid resistance remains high for the life of the pavement. I don't see how anyone could argue with the fact that this is a very desirable mix for providing skid resistance for speeds up to 55 and 60 mph. On the other hand, for roads which carry traffic at 70, 80, and 90 mph in the rain, the popcorn mix is much more desirable.

Again, notice in Figure 16, that the skid resistance is quite high for high speeds but not real high for low speeds for the popcorn mix, whereas, the skid numbers for the sand mix are adequate at high speeds and quite high at low speeds.

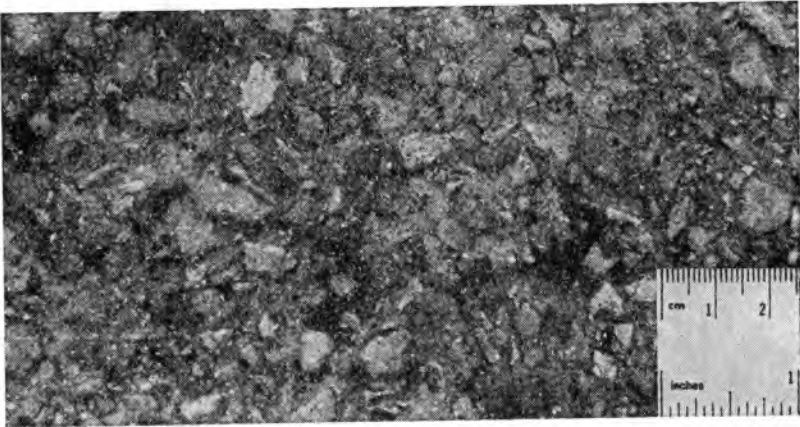


Figure 12

(A.T. = 3.3×10^6)

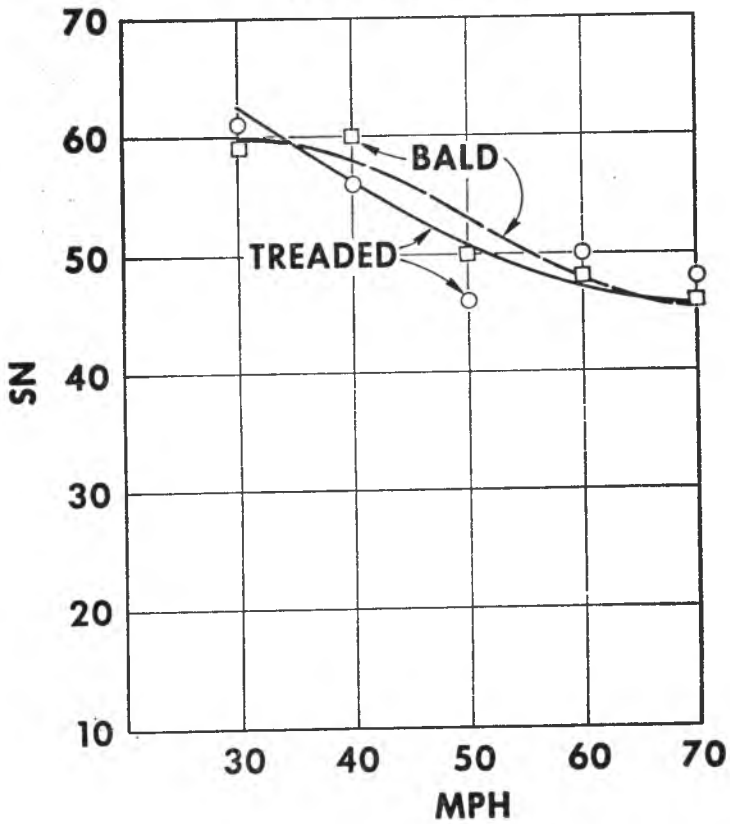


Figure 13

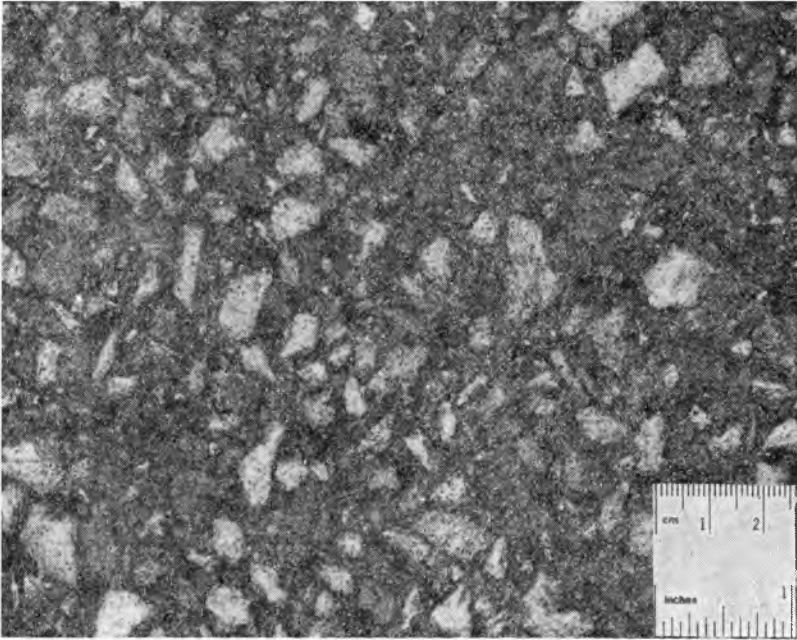


Figure 14

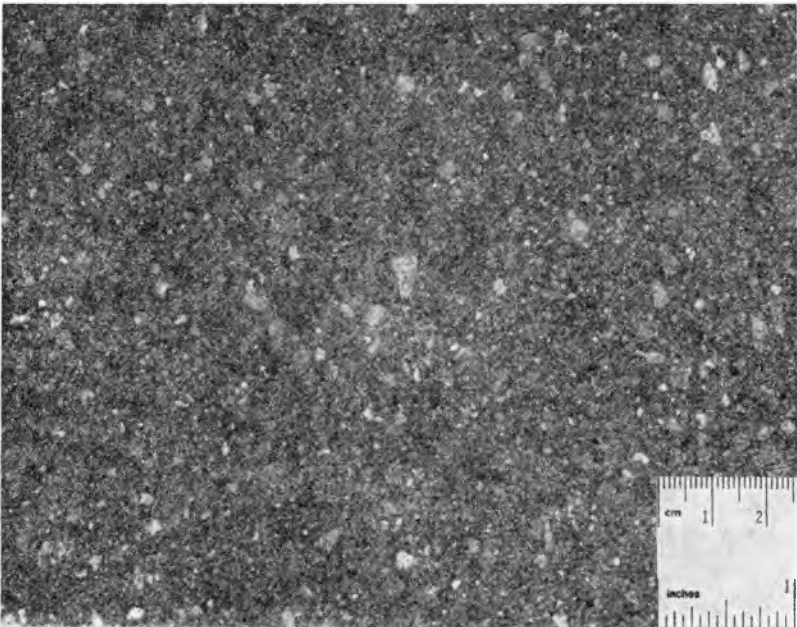


Figure 15

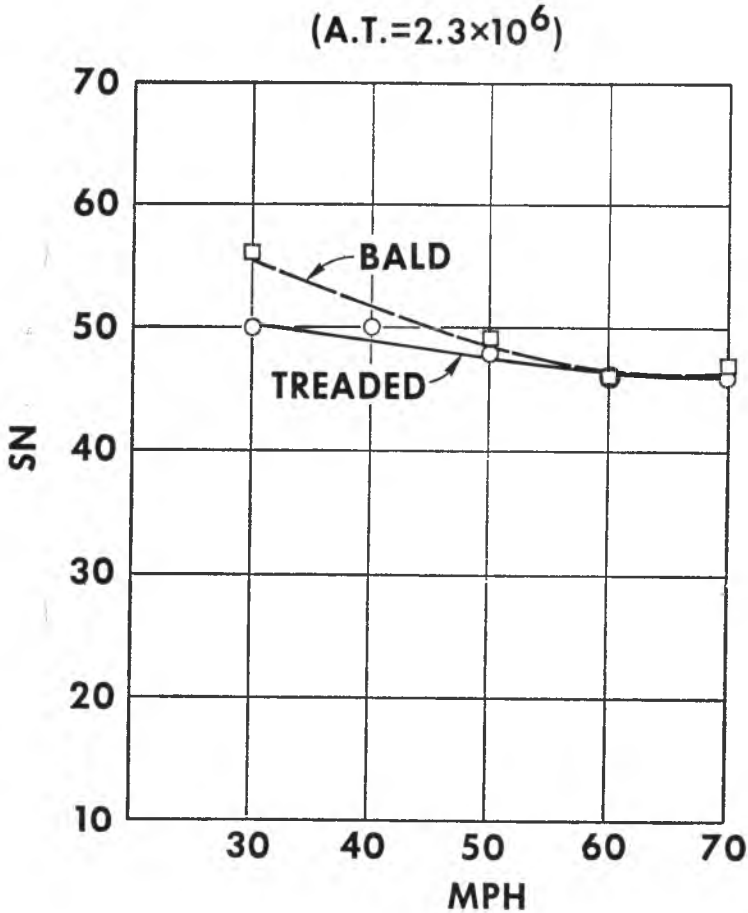


Figure 16

SUMMARY

In summary, I would like to again call your attention to the following: (1) when we say needed skid resistance, we must remember there are different needs for different speeds, and there is a wear rate for every aggregate; (2) because of economics, we must make maximum use of local materials to provide needed skid resistance; and, (3) we cannot tolerate worn out tires.

Don't place all sand mixes, don't place all popcorn mixes. Just about every mix has its safe and economical place. Optimize the use of natural resources and money in providing needed skid resistance.

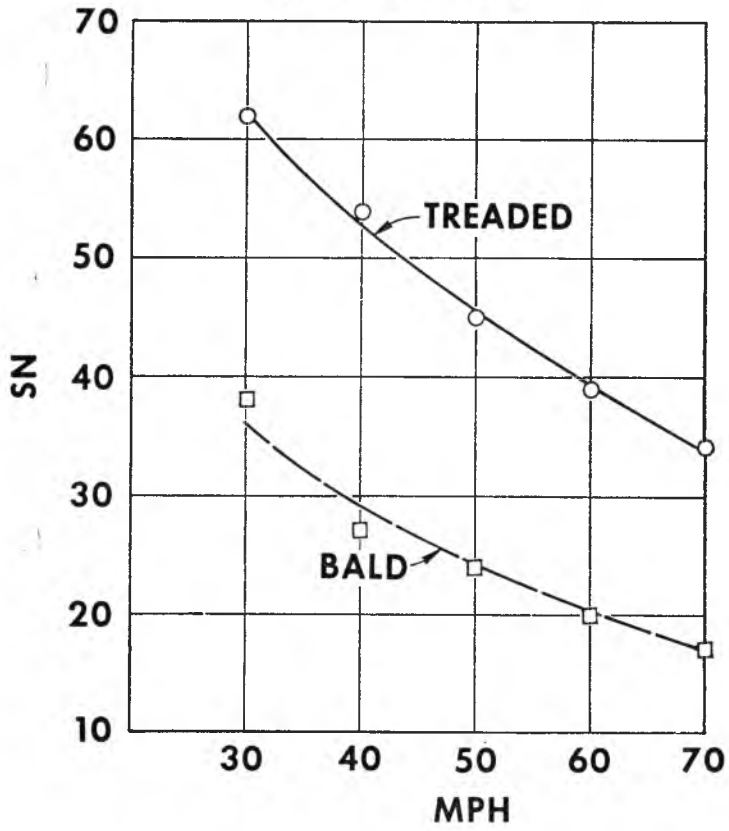
$(A.T.=3.2 \times 10^6)$ 

Figure 17