Effect of Studded Tires on Aggregate and Related Effects on Skid Resistance

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•DURING the past 2 or 3 years in Minnesota, we have witnessed a startling increase in the amount of surface wear in the wheelpaths on both bituminous and portland cement concrete pavements. Prior to this period, pronounced surface abrasion of this type occurred usually in isolated instances only. When an occasional bituminous pavement suffered such attrition, it generally occurred fairly early in the life of the surface and was likely to be related to some accountable deficiency such as unfavorable construction conditions, or possibly marginal materials or mixture design for the particular circumstances or traffic demands involved.

The wear related to studded-tire effects is, however, different in several respects. It has affected pavements of the highest quality in Minnesota, including some that had been in service for several years before being subjected to studded-tire traffic and others that were exposed to studs in their initial year. The phenomenon has developed during the past 4 years, the period in which studded tires have been legally permitted during the winter months on Minnesota's highways. Because the severe wear has developed concurrently with the studded-tire usage, it is quite natural that the highway engineers generally blame the wear on the studs. There are others, however, who ascribe the attrition to increased use of salts and sand, contending that the chemicals attack the pavement materials and that they, together with abrasive sand, make the pavement surfaces readily susceptible to wear from the studs. This argument, however, overlooks the fact that salt and sand have been used freely for many years with little or no damage to pavements.

This brief history of studded tires in Minnesota will provide some background. In 1964 when they first began to appear, studs were ruled illegal under the then-existing law. The highway department initiated some limited field-driving tests with studs, and these continued during winter intervals into January 1967. Results indicated definite possibility of objectionable wear, but the tests were not extensive enough to convince the lawmakers that studs should not be permitted in the interest of safety. The 1965 legislature authorized a 2-year "trial" period for the winters 1965-66 and 1966-67, after which the 1967 and the 1969 legislatures again authorized additional 2-season extensions. Therefore, we are now in the fifth winter of studded-tire traffic. Use of studs has increased phenomenally in this period.

During the first winter, the number of studded tires used in the metropolitan area was very low; only about 3.8 percent of the cars were so equipped on the rear wheels. During the second winter, the proportion of cars with studs increased to about 9 percent. During the third winter, the number increased substantially to 23 percent, and by the 1968-69 winter it had reached almost 32 percent. These proportions are based on surveys conducted on randomly selected parking lots and street parking. It is estimated that during the 1969-70 winter the proportion reached about 40 percent, and that 90 percent of all snow tires sold were studded.

While authorizing the latest time extension for studs, the legislature also directed the Commissioner of Highways to make an in-depth study of the studded-tire problem to determine (a) the damage, if any, to pavements that results from the use of metal tire studs, salt de-icing materials, and other materials of a chemical or a physical

Paper sponsored by Committee on Bituminous Aggregate Bases and presented at the 49th Annual Meeting.

nature; (b) whether such damage, if any, could be reduced by making changes in asphalts, concrete aggregates, or other highway surface materials; and (c) the effects, if any, that discontinuing the use of studded tires will have on highway safety.

Studies in these areas are being conducted (two under separate contracts with independent research agencies and others through our own continuing field investigations) to develop information to report to the legislature in 1971. Unfortunately, at this stage not enough data have been developed to provide significant quantitative evidence in response to the questions imposed. However, our field observations during the past 4 years when studs have been used during the winters have revealed some interesting facts.

The amount of pavement wear that developed in the first 2 winters was relatively minor, apparently because of the small number of cars equipped with studs. As the proportion of users increased rapidly in the third winter, the wear became pronounced. By the end of the fourth winter, the wear had become severe on some roads, reaching a depth as much as $\frac{1}{4}$ in. in the wheelpaths on both bituminous and portland cement concrete.

Wear measurements made at a limited number of test points at the beginning and end of winter seasons indicated that the amount of wear occurring during the summer months was much lower, in some cases insignificant, compared with that experienced in the winter months.

Based on our earliest field-driving tests with studs, which were necessarily very abbreviated as compared with highway traffic, it had been anticipated that the most severe abrasion might develop at locations of channelized traffic with concentrated stopping and starting actions, such as at semaphore-controlled intersections. This appears now to be less critical than first expected, apparently because of the lower speeds, acceleration, and volumes.

The most severe wear has developed on high-speed, high-volume roads such as the Interstate and other freeways and expressways within and around the metropolitan area. The rate of pavement wear thus appears to be definitely related to both speed and number of stud applications. No general quantitative relationship has yet been established, but, as an example, at one location where the wear depression was about $\frac{1}{4}$ in. it was estimated from traffic data that there had been about 1.6 million stud applications during the 4 winters of exposure.

In contrast, on rural roads having low traffic volumes the wear is slow to develop, even though travel speeds are high. On the other hand, on urban streets with high traffic density the wear rate is also low, evidently because of the slower speeds. However, where there is a concentration of fast acceleration or heavy braking action, such as on entrance or exit ramps to or from freeways, the wear is quite pronounced.

The manner in which the abrasive wear affects pavement surfaces appears to be substantially the same for both bituminous and portland cement concrete pavements. As the surface film or coating of either asphalt or cement mortar wears away, the coarse aggregate particles are gradually exposed to view so that the first clearly visible evidence of significant wear is the mosaic-like appearance of the surface.

As the wear progresses the matrix is eroded from between the harder coarse aggregate particles. It is noticeable that, where the coarse aggregate either is crushed rock consisting entirely of hard wear-resistant igneous particles or is crushed gravel containing a high proportion of igneous pebbles, these hard particles are left protruding above the surrounding matrix. This produces a knobby, rough-textured surface that is readily discernible, visually and by sound and feel, as a car travels over the pavement. The area affected in the wheelpaths is generally approximately $2\frac{1}{2}$ ft wide for each wheelpath.

Coarse aggregate consisting of relatively soft limestone tends to wear down more or less with the removal of the matrix. The result is that the wheelpath surface is not as rough and may not appear to be as badly abraded as is the case with the harder rock materials or gravel aggregates of mixed composition. The limestone coarse aggregate may even at times wear somewhat more rapidly than the matrix so that the surfaces of the coarse aggregate particles are actually slightly depressed below the matrix. This situation would be dependent largely on the composition and character of the matrix, including the quality of the sand and the proportion of binder material in the mixture.

These observations with reference to the aggregates are only generalizations at this point and need verification before any firm conclusions may be drawn. It is apparent, however, that the kind of aggregates used, both coarse and fine, may have significant influence on the rate of pavement wear. It is expected that further light on this will be gained from the laboratory project and the related field studies that have been initiated.

The development of wheelpath wear produces, in effect, shallow surface ruts that may possibly have some effect on the skid characteristics of the pavement. Our plans to make skid test measurements during the fall months failed to materialize because of the late delivery of the 2-wheeled trailer type of skid tester that had been purchased by the highway department. However, a limited number of measurements were made with the trailer test unit of an outside agency.

At a number of locations, readings were taken both within the wheelpath and outside the worn area of the wheelpath. In nearly all cases, the skid numbers obtained were within 2 or 3 points of one another for companion readings inside and outside the wheelpath. At most of the test points where the comparison readings were taken, a slightly lower reading (2 to 3 skid numbers) was recorded within the wheelpath as compared with that outside the wheelpath. In view of this very slight difference between readings, it can scarcely be regarded as a significant difference in skid resistance other than to suggest the possibility of a trend. On the basis of these readings, any conclusion as to the polishing effect that studs might have on the aggregates or the influence of the aggregates on the skid resistance would be premature.

I believe that we are confronted with a problem that will assume major magnitude in the years ahead. Granted that studded tires prove to be effective as a safety measure, it must be recognized that pavement wear, whether caused exclusively by tire studs or by a combination of studs, salt, and sand, will place new demands on our maintenance and construction efforts and expenditures to remedy or prevent the type of wear that is now occurring.