USES OF SURFACE PROFILE MEASUREMENTS

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The Highway Research Board is listed in the program as a cooperating agency. This means that we support the workshop as being needed and worthwhile but that we do not provide any financial support. I assure you that the Highway Research Board is vitally interested in this workshop, and I believe that this workshop will help to solidify our understanding of what we are trying to do and our knowledge of the instruments that are available to those ends. I am certain that the workshop will make a real contribution toward identification of the directions that need to be followed to make the road meter an accepted and truly valuable tool for pavement evaluation and, more importantly, for pavement design.

I think that each of you is far more knowledgeable than I about the current capabilities of the road meter and other instruments for measuring the surface characteristics of pavements. It would be presumptuous of me to discuss the modern technology in this field, but still I think I have something to say about the reasons behind these activities. I have sensed in recent years a concern for the technology of profile measurements that frequently seems to reflect a lack of concern for the basic issue. I want to bring the basic issue back to your minds.

There are at least 4 fundamental uses of pavement surface profile measurements. First, surface profile measurements can be used as a construction quality-control tool. Limits can be written into specifications, measurements made, and construction contractors required to meet the specifications. I think that this use of profile measurements is highly desirable and that we do not have sufficient knowledge as to how to write specifications such that they truly reflect the surface profile statistics or parameters that we are trying to control. In the beginning, Francis Hveem of California, the great innovator in pavement design and construction, decided that deviation from a planned longitudinal profile of ⅛ in. in 10 ft was the maximum that could be tolerated in a high-speed highway surface. That, of course, is a statistic, and his specifications led to some very fine highways. However, we all know that he was rather lucky because ⅛-in. deviations do not normally occur in a systematic way, and thus he was not faced with periodic aberrations. We now know that ⅛-in. amplitude waves with wavelengths corresponding to wheel-hop frequency can make for a highly unsatisfactory ride. Thus, amplitude alone is not enough. This does not negate the value of profile measurement for quality control. Rather, there is some doubt as to what we should measure and more importantly what we should specify.

The second reason for measurement of surface characteristics of pavements is to locate those points, practically inevitable along any highway, where something has happened that is not what we like to call normal: someplace where the subsurface drainage or subsurface soils were significantly different from those for which the pavement structure was designed. Here, although the structure contained perfectly sound components and although the contractor performed as he was expected to, the pavement in fact broke up or became very unserviceable. Similarly, in this category are those spots where the contractor left cement out of the concrete or the inspection was extraordinarily lax. Early proponents of profile measurement considered this an important function. They thought that they were building pavements that should be perfect and that any aberration was an act of God or bad faith on the part of someone other than the design engineer. Frankly, I think this is a waste of the time and cost of profile measurement. Any good inspector or maintenance man riding over a recently built pavement can pinpoint these areas. Conventional tests on the site can be made to determine the cause of the problem and the action necessary to correct it.

A third use of profile measurements is to establish a systematic statewide basis for allocation of pavement maintenance resources. A word of caution here is in order. In the interest of finding low-cost tools that can be made easily available to each highway department district, there is a tendency to suggest highly simplistic devices. I believe that reliance on these devices may lead to serious mistakes in the development of priorities for maintenance expenditures. It may be far better to use the subjective judgments of state-trained inspectors for this activity.

The fourth reason for making measurements of longitudinal profile of pavements seems to me the most valid one. It is founded in the concept for defining pavement performance that was developed at the AASHO Road Test 15 years ago. I still believe that the philosophy behind those early developments is valid and important, although in our attempts today to simplify or refine measurement tools we sometimes forget why we want to make the measurements.

I would like to discuss what was behind the development of the pavement serviceability and performance concepts developed at the AASHO Road Test. The fourth reason for making surface profile measurements is to provide an objective measure for determining relations between pavement performance and pavement design factors, including materials, construction practices, conditions of traffic loading, and climate. These things, of course, have been expressed in some detail in the literature and are summarized in the following paragraphs.

Prior to the AASHO Road Test, there was no definition of pavement performance. Designers claimed to be designing for "20 years of service life" or for "working stresses of 50 percent of the tensile strength of concrete," or for "pavement structures of such thickness and quality as to be nonsusceptible to frost action." Nowhere was there expressed an objective measure of how changes in design could influence the condition of the pavement during its life. Nowhere was expressed any concern for the relation between the stress in the concrete and the ultimate performance of the pavement. Central to all this is a fact that still exists today. When a pavement starts to deteriorate in 5 years, it does not fall apart uniformly over its entire mileage. Rather, 100 ft in, say, a mile gets extraordinarily rough or deteriorates. If 100 ft per mile of a section of Interstate highway requires heavy maintenance within 5 years of its construction, the design was not adequate. Be careful, though, not to pass the blame to the designer too quickly. He had no definition of what pavement performance was. There was absolutely no distinction in his instructions between whether the 20-year pavement should be completely shot 20 years from the date of construction or whether it should still be in perfect shape after 20 years (but not in 21 years).

This did not seem to be rational, so we tried to define pavement performance. First, we reasoned that the real purpose of a pavement is to serve traffic, not to reduce stress in the subgrade. As you know, we tried to determine how well pavements in various conditions actually were serving traffic on any particular day by asking drivers of trucks and automobiles for their considered opinions. We simply asked the drivers to rate pavements as to the ability of the pavements to serve high-speed, high-volume, mixed traffic (trucks and passenger cars). Again, as you know, these ratings of particular pavement sections were remarkably consistent and showed little or no bias that depended on the drivers' vehicles. Apparently, there was some characteristic of pavement that was central to the opinions of the drivers who were using it.

Next, we set about to determine objective measurements that could be made and combined in some systematic and mathematical way to predict the central rating of any particular pavement. We measured everything that we felt could conceivably influence the feeling of the drivers as to the serviceability of the road. We did not measure stress or deflection because we knew that the drivers could not sense these things.

As a result of hundreds of trials involving multiple regression analyses, we decided that some measure of longitudinal profile would provide the strongest simple predictor of the users' ratings of serviceability and that the transverse profile also played a significant part. Thus we were able to make a few simple measurements on all pavement sections, apply the formula we had developed, and predict with rather good certainty the opinion of the highway users as to the usefulness for highway transportation or serviceability of a particular pavement on a particular day.

If one could in this manner measure serviceability of the same pavement at intervals over several years, and note the rate and manner of its deterioration under known climatic and loading conditions, one would have for the first time a real measure of pavement performance.

Knowing now how pavements perform, one can begin to compare the relative performance of pavements of different designs, pavements subjected to different traffic density, pavements in different climates, and pavements over different soils. When such comparisons can be made, we have the basic necessary elements for a pavement structural design mechanism.

It is only after these fundamentals have been established that we can begin to look at the relations between stress and deflection, the viscoelastic behavior of components, and other mechanistic parameters and how they relate to pavement performance. In short, I find it of academic interest only to predict stress in an element of pavement structure, under idealized or laboratory conditions, unless a relation can be established between the statistical distribution of such stresses over the life of a pavement and the performance of that pavement measured in some real-life way.

I will summarize the fourth reason for measuring pavement profile in this way. The use of a summary statistic, which to my mind must somehow be related to power spectral density analysis of the pavement surface profiles or derivatives thereof, is the simplest objective tool for the determination of the present serviceability of the pavement. Some study of the changes of present serviceability over time and traffic is the only available basis for objective determination of pavement performance. A knowledge of pavement performance, as related to pavement structure, traffic, and climate, is the strongest foundation for rational design.

That, then, is the reasoning behind the relatively sophisticated measurement of road profile, beyond the simplistic counting of bumps. If one uses this line of reasoning, the specifications for the tools used to measure profile, the reliability required, the requirements for data reduction, and the operational simplicity all become relatively obvious.

I believe that performance rests on serviceability, that serviceability depends primarily on surface profiles or other devices that measure the statistical distribution of surface aberrations, and that effective road meters are truly the basis for pavement evaluation.