HOW YA DOIN?

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How ya doin? We use this expression almost every day as we greet our friends and neighbors, but quite often the full import of the question is not intended nor a detailed answer expected. Somewhat akin to this is the question often asked in social gatherings after the initial greetings—How's your wife? A friend of mine always answers this question with another question, Compared to what? Although our happy imaginations can handle such comparisons of wives, or possibly girl friends, we cannot afford such laxity when it comes to highways.

When the question, How ya doin? is applied to a highway, we should have answers available for the implied question, Compared to what? In the not-too-distant past, the attention of pavement design engineers seemed to be confined in large measure to ways and means of formulating or deriving a rational design, or obtaining representative test methods, correlating test specimen conditions to field control, and attempting to reproduce roadway construction and service environments in laboratory test procedures. Theories of stress distribution, strain limits, layer effects, layer equivalencies, elastic moduli, and linear viscoelastic and resilient moduli were advanced, and sometimes applied, as the basis for roadway design methods. Highway Research Board committees reviewed papers on these methods and provided a format for their presentation to the highway practitioner.

These unfortunate people, pressed for some means of conducting their business, selected a design method that, in their judgment, best suited their highway field conditions as well as their available resources, test facilities, equipment, technical expertise, and departmental interest and policy. Generally, these choices involved compromises, and the compromises produced no great uniformity of design procedures, although each and every practitioner would defend his system as being "best for his conditions" as indicated by "performance." Just what the performance consisted of could not, in many cases, stand close scrutiny as to how it was measured or in what units it was presented. When pressed for more details or a more definitive description, the practitioner's definition of "performance" usually boiled down to a lack of persistent complaints by maintenance personnel or by the traveling public.

Perhaps illustrative of this semi-exclusive concentration on the structural design aspect of pavements are the operations of the Triaxial Institute for Structural Pavement Design. This is a loose-knit group of producers, educators, and highway engineers who have been meeting for some 25 years in informal back-room sessions to discuss their current efforts as related to pavement design. Characteristic of this group is the fact that no agenda is tolerated at the annual 2-day meetings so as not to restrict the mutual exchange of information and full discourse on all subject matter. However, some 12 years ago, after they had confirmed the suitability and propriety of the Hveem stabilometer for evaluating specimens of roadway materials prepared by the Triaxial Institute kneading compactor, it seemed prudent to list by priority the various new elements of design to which their attention might be directed. Nine such items were then listed during a discussion period of 2 days. In search of a tenth item to round out the list, a subject was offered by some attendees who had recently graduated from one of the management courses for state highway personnel. The suggestion was that perhaps it might be well to consider a subject having to do with "control."

In management parlance, control is a means of ascertaining the effectiveness of management techniques. As applied to pavement design, control would be a means of checking the effectiveness of design systems. It was pointed out that our attention had been exclusively devoted to the input for the structural design of pavements and that it was about time that attention was directed to what the output looked like at the conclusion of the design period.

Although this happened about 12 years ago, it was not necessarily unique. Over the years, similar thoughts had been quietly developing from the old-style basic approach of condition survey—mapping surface cracks and other distress. Literature references depict the growing awareness of roadway condition, and thus we find a departure from the early subject of "sufficiency ratings."

The publication that sets the theme for this workshop, or provides a basis for what our present concerns are for pavement condition ratings, is Highway Research Record 40, which was sponsored by an HRB committee chaired by Eldon Yoder. Evidence of his concern in this area is still evident today, some 9 years later. He is still trying to promote what we all are coming to recognize as a very important, if not the most important, element of pavement design—the feedback or control mechanism for measuring performance.

While this groundwork was being carried out, the Canadian Good Roads Association, now the Roads and Transportation Association of Canada, had implemented its own means of checking on the performance of Canadian roadways. Undoubtedly this stemmed from the Association's observation of AASHO Road Test evaluations, and it was apparent that the Association moved quickly to establish this vital part of a pavement management system. In the 1962 International Conference on Structural Design of Asphalt Pavement, the Canadian Good Roads Association paper describes a "present performance rating" based on Benkelman beam deflections. It further described how the present performance data were analyzed and translated into an overall measure of performance for various types of roadways. This gave Canadians a basis for predicting needs and programming rehabilitation.

Some of us in the United States are just now getting around to thinking that this is a good thing—some 10 years later. We now see this element in the various systems approaches to pavement design and pavement management.

What means are used to tell "how we're doin" with respect to roadway design and maintenance? The answer may rest with the activities at accelerated road tests or test tracks where such measurements are, of course, an integral feature.

Maryland Road Test 1 on concrete pavements measured performance by the physical evidence of defects such as extent of structural cracking, observation and identification of pumping, average frequency of first crack, and faulting. Although some measurements of pavement roughness were made with the Bureau of Public Roads (BPR) roughometer, the conclusions of the report are concerned more with performance as measured by structural defects of the roadway slab.

The early California road tests carried out by the Army Engineers at Stockton and by the California Highway Department on flexible pavements measured performance by the rate at which rutting and cracking appeared. On the WASHO test road in Malad City, Idaho, performance of the various structural sections was keyed to the occurrence and frequency of cracking, rutting, and general measurement of the area of distress. Finally, the AASHO Road Test, while measuring structural defects to rate the performance, also brought up the concept of ride—how the defects would affect ride.

We are all familiar, or should be, with the philosophy developed at the AASHO Road Test—roadways were built for people to ride on, and the measurement of how satisfactory the ride was, or is, should be a prime criterion for its performance. Structural defects were not neglected of course at AASHO, but here they were correlated with some measurement of ride. This is not to say that the other test roads ignored measurement of pavement roughness, but the earlier attempts were incidental to the primary purpose of measuring performance by the appearance of structural distress.

The CHLOE profilometer developed at the AASHO Road Test, together with the concept of present serviceability index (PSI), provided a new approach to the matter of rating a pavement's performance in terms of ride while not neglecting the engineer's other concern—structural distress. Although there may be some argument about the relative balance between ride and structural distress that appears in the AASHO serviceability equation, particularly with regard to the elements of distress used in the equation—rutting and cracking—there have been few, if any, proposals advanced that show better correlation with what happened at AASHO.

With the advent of the AASHO test road, we seem to have had an emergence of a new philosophy in rating roadway performance. In the past, the main concern was with the rate at which a pavement would develop structural distress and the extent of this distress. During this time only passing interest was given to the ride or to the roughness of the pavement, and perhaps at legal speeds roughness of the extant pavement was not too great a concern. Even if roughness measurements could be made with profilographs or roughness indicators, there really was no way to translate these readings into an acceptable standard. The work at the AASHO Road Test brought forth the concept of the rating panel and provided a means for establishing standards for road ridability or acceptability to the highway user. As stated before, the test also provided the means for a pavement rating system that considered ride as well as structural distress.

Publication of the AASHO reports and the presentation of the pavement rating concept created a lot of discussion and analysis by highway engineers. It seems that we in the United States devoted considerable time and effort to reanalysis and study and review of this concept to the detriment of its utilization in our own operations. However, as indicated previously, the Canadians were able to readily appreciate the significance of the findings, or at least recognize in them possibilities for implementation in their operations.

The last step in the development of our attempts to gauge performance of pavements seems to have come with the gradual realization that it would be most desirable to establish an inventory of pavement condition for the entire highway and, following the PSI concept, provide for periodic ratings to show performance and possibly to predict time needed for rehabilitation.

With this state of enlightenment came the realization that the tools necessary for rating the pavement must be capable of covering many miles of road in 1 day. Although the CHLOE, with an operational speed of only 3 mph, was satisfactory for the test road with its limited range, there is some doubt that it could be used effectively to rate, say, 7,000 miles of roadway in a time frame considered necessary to meet the requirement for uniform seasonal rating conditions.

This started a whole new series of efforts to develop devices for measuring pavement roughness at near highway speed. At this point, devices for measuring roadway roughness (or smoothness) were brought out of the mothballs and reexamined for their capabilities. The BPR roughometer, which had been around for a long time, and various profilograph devices were studied to determine how they could be converted to greater production.

Concurrent with this were other attempts to develop more sophisticated means of measuring the roadway profile. Typical of these were the University of Michigan and the California Highway Department profilometers that measure the roadway profile on a 30- or 25-ft reference plane. Another example is a General Motors instrument that measures the pavement profile with reference to an inertial platform. None of these vehicles, however, actually simulates the ride experienced by the majority of the highway users—that of a car passenger.

The next attempts then were made to see just what happens in a passenger car. Studies were initiated to measure the response of the vehicle to roadway roughness and the response of the passenger, in terms of human sensibilities, to the vehicle movement thus generated. The disadvantages of subjective ride rating were pointed out. For instance, some ride raters would be influenced by the appearance of a roadway regardless of the ride. Although statistical studies showed that some of these shortcomings could be overcome by utilizing a panel of raters, this idea never caught on too well, and attention then seemed to shift to the desirability of instrumenting a passenger car to achieve objectivity in ride rating.

At Purdue University, the change in tire pressure as related to the ride felt by car passengers was studied. The state of Kentucky instrumented the passenger himself, and thus we find studies on an accelerometer device worn by an individual sitting on the passenger side of the front seat of a sedan. In Washington, the highway department has evaluated the roughness of newly constructed pavements by using a roughometer device that accumulates the vertical excursions of the right front wheel (50-psi tire pressure) as the vehicle traverses the highway at 35 mph.

Although this use of the passenger car as a rating tool seemed to breach the barrier of productivity and allow more miles of road to be rated in a day, there were questions about the precision of the ratings and the actual mechanics of correlating the data to performance.

In retrospect, it seems that the transition from these previous studies to the use of the Brokaw road meter was a rather elementary move. Why not instrument the center of the rear axle and measure its vertical excursions as an indicator of vehicle ride? In this way, all roadway distortions affecting ride could be measured. Also in retrospect, it seems not too unlikely that whatever movement was felt by the passenger would be a consequence of the movement of the rear axle.

Thus evolved the Brokaw, or PCA, road meter. Modifications generated from the original concept have been developed primarily to provide more ready means of accumulating and logging the data. We are going to hear about the Mays meter and the Cox modifications of the road meter to enable this display of data. It appears that we now have the ability to derive some measure of roadway ridability in a manner suitable for periodic inventory of extensive highway systems and at reasonable cost. What appears to remain are attempts to standardize the meters when installed in different vehicles and to provide a means of "calibrating" such vehicles.

Although our efforts at this workshop will be concentrated on theories of roadway ridability, it is well to keep in mind the basic reason for our concern about pavement condition. It perhaps cannot be stated any more clearly than it was by Bill Carey in his preface to the 1963 Symposium on Pavement Condition and Evaluation:

> The most important need for condition surveys of highways is to establish trends of pavement condition with time in order that advance estimates of maintenance needs and costs can be made. Condition surveys are also needed to provide information on the performance of particular materials and construction techniques.

At this same symposium, Al Maner of The Asphalt Institute pointed out that there are 2 objects of condition surveys or evaluations—to determine ridability (how well the pavement rides) and to determine structural adequacy (the ability of the pavement structure to carry its traffic without failure).

If we are going to be able to provide our maintenance and planning engineers with timely estimates of maintenance and reconstruction needs, our evaluation system must be sensitive enough to allow advance programming. In most highway departments, an increasingly large lead time is being required because of all of the paperwork, hearings, impact statements, and approval actions that must be endured and completed. Hopes for future improvement in this area are bleak. Any rating system that we have can measure only the present condition of the roadway, and thus we must rely on trends established by periodic ratings to predict these needs. Therefore, an effective rating system must be sensitive enough to clearly define these trends. Regardless of how precisely we can measure a roadway condition, it will all be for naught if we cannot predict when a roadway will require maintenance. This capability will depend on the rating system.

There are many who believe that poor predictability is one of the dangers of relying solely on ride measurements to define condition and hence performance. As Al Maner indicated, there are 2 considerations—the ride and the structural capacity. Many feel that, although the ride is the most important aspect of roadway performance, we cannot ignore structural considerations and that possibly a measure of this vague property, structural capacity, can be used to temper the ride measurement to the ultimate end of increasing the sensitivity of procedures for determining performance and for predicting future needs. The "ride" situation seems well on its way toward solution. We have an instrument capable of objective measurements and capable of production testing to meet the time requirements for periodic ratings, but as yet we do not have the companion equipment to measure structural capacity with either the precision or the speed to match the ride evaluation.

I would like to include a few thoughts about pavement rating and particularly the means for measuring structural adequacy. Currently, there are several approaches for this; each appears to have its limitations. The cataloging of pavement surface defects is a basic horse-and-buggy approach. It is to a certain extent subjective, and it most certainly does not have a high productivity rating. The only way this could be speeded up would be to travel over the roadway and record the roadway condition on film that could be later analyzed. Several states, Washington included, have photographic vans that cover roadways, taking 35-mm photographs every 50 ft. Although these pictures are good, it would be rather difficult to catalog surface defects from them. However, the scanning angle can certainly be modified to accommodate a better view of the roadway surface and still retain all of the other desirable output features. As a matter of fact, an academic institution in Washington believes photographic techniques can measure not only surface defects but also skid resistance, surface texture, elastic deformation, and surface configuration.

Other engineers are convinced that deflection measurements provide the structural element that is needed in pavement rating. The Benkelman beam is a fine tool for measuring deflection, but it, too, fails on the productivity scale. The state of California tried mechanizing the Benkelman beam with the Grasshopper, but 3 mph is still too slow.

The Dynaflect machine measures response of the pavement surface to vibratory effort, as does the road rater. Although there is some correlation with structural capacity using these devices, they still are slow. They travel quickly between test locations but still have to be stopped and set up before measurements begin.

None of these can match the speed with which ride can be measured, and what is needed is some means of developing this structural aspect of a rating system to match the productivity we have with the ride system.

Washington State University is currently working with what we call the "thumper." It measures the relative response of the pavement to a shock produced by a hammer blow. They tell us that this piece of equipment can be made to operate at speeds of 30 mph, which if successful will move us somewhat closer to the productivity goal. However, the correlation of this response factor to structural capacity will involve much work.

Undoubtedly there are other means being considered for measuring structural adequacy. If they can be properly calibrated or correlated and if they can meet the productivity requirements, we will be in a much better position to meet the prime need for making condition surveys. Probably the best thing that can be done along this line would be to develop instrumentation that could measure structural adequacy and could be incorporated in the skid tester. Highway engineers are going to be measuring skid resistance on a continual basis over the next few years, and skid trailers will probably be operating full time. If at the same time we can evaluate structural capacity, we will save ourselves additional work and time.

The perfect condition evaluation system—one that will provide the pertinent and necessary answers to the design engineer, the maintenance engineer, or the planning engineer when he asks, How ya doin?—will have to meet several challenges.

During the late 1950s, many miles of asphalt concrete roadways were constructed on cement-treated base. Currently, these roadways are exhibiting much evidence of cracking, mostly longitudinal, with some ladder patterns and some general "alligatoring." It is apparent that much more extensive cracking is imminent. We have the general impression that the proper time to resurface such a structural section is 1 year before the appearance of the first crack. This is indeed a difficult condition to predict, and possibly the new pavement management systems being developed and promoted will offer some ready means of assisting in the solution to this problem. The evaluation system and/or the management system is going to have to be very effective to convince some of our maintenance engineers to resurface a roadway that shows no surface evidence of distress.

Another corollary problem that the rating system might be called upon to handle exists on our multilane highways. We have a number of miles of 4-lane divided roadway, the travel lanes of which indicate extreme distress whereas the passing lanes show no such evidence whatsoever. The problem of what to do is perhaps basically a design problem, but the time for that is long past when the distress starts to appear. The rating system must be able to clearly identify and delineate the failure in the travel lane even though the "average" condition, across both lanes, might be tolerable.

A third problem faced by the ideal condition rating system involves the relativity of ride and structural adequacy, i.e., what is true serviceability. On Bainbridge Island in the Puget Sound area, there is a short section of mixed-in-place cement-treated base roadway that exhibits a terrific pattern of block cracking that most people would call advanced structural failure. This condition appeared not too long after the cement-treated base roadway was completed in 1954. Currently, the crack pattern has tripled in intensity. In spite of its appearance, at 60 mph this road produced one of the smoothest rides and has for a number of years. One of these days, the bottom is going to fall out all at once—but when?

Along this same line, there are 2 sections of asphalt concrete pavement in the eastern part of Washington, one of which has transverse cracks from one end to the other. Immediately abutting this is the same type of roadway without a single transverse crack. Both are less than 6 years old. All means of measuring ride show no significant difference between the 2. What should the performance be? Is the serviceability the same? Will one have to be resurfaced before the other? Should design, or construction, or materials be investigated? A perfect rating system should enable us to know.

In Washington, we have a prime example of the need for a closed circuit between rating and rehabilitation. In 1954, we constructed a 4-lane divided highway with a raised sodded median and asphalt concrete over cement-treated base; it was considered the ultimate. Two years later, however, the outside wheel tracks of the outside lane consisted almost completely of advanced ladder cracking. As of today, after many years of makeshift maintenance, we are finally getting around to the reconstruction contract. Any rating system would have noticed this condition, but unless it is coupled closely with rehabilitation programming, the end product suffers.

Undoubtedly there are other anomalies that would serve as challenges to a perfect rating system. It appears though that the equipment needed to implement such a system and clearly rate all of the parameters of pavement performance would be one that measures ride (the PCA road meter or the Mays meter), measures rider response (instrumented driver), evaluates roadway resilience or deflection (California Grasshopper), checks reaction to shock or vibration (a "thumper," Dynaflect, or road rater), measures skid resistance, evaluates appearance, and records all data for future reference.