OBSERVATION OF DISTRESS IN FULL-SCALE PAVEMENTS

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Pavement design principles are commonly indicated to be based on empirical procedures or on empiricism. The dictionary defines the word "empirical" as (a) relying on experience or observation alone, often without due regard for system and theory, (b) originating in or based on observations or experience, (c) capable of being verified or disproved by observation or experience. The key words in these definitions are observation and experience. The implication of this emphasis on the use of empirical procedures is that agencies have been accumulating observations on which current material, construction, and thickness design concepts are based.

With no disrespect intended to those agencies that have been working in this area, it is doubtful if extensive systematic and continuous observations of pavement performance have been accumulated in this country. The literature contains reports of extensive investigations that attempt to define and describe pavement performance and to describe types and causes of distress. Remarkably, very little of this kind of information has found its way, except possibly by inference, into research reports dealing with developments that depend on performance as the dependent variable.

Specific road tests are probably prime examples of the use of systematic and continuing observations to develop a dependent, numerical value from which conclusions are drawn and documented. The WASHO and AASHO projects would be the most widely known examples of the use of empiricism in developing our technology. Investigators in Canada have used field observations of distress (frequency of transverse cracks) as a dependent variable in trying to develop empirical and theoretical correlations to thermal cracking. Most researchers would like to believe that observations of performance can be related to theory, and it is for this reason that a workshop was held.

As is implied by the third definition of empirical, observations and experience work two ways. In the first instance, it should be possible to determine what the priority needs are in terms of performance. For example, if observations indicate that pavements lose serviceability as a result of a specific type of mechanism, say plastic deformation or distortion, then it should be clear that research should be directed toward solving this problem. When the research is completed and the results are implemented, it will be possible to determine whether a satisfactory solution was obtained, more work is required, or a satisfactory solution has been achieved with a new problem being induced by the solution. Researchers need to know that the problems they are trying to resolve are real and significant. This can only be determined by systematic and continuous observations of performance of full-scale pavements.

The pavement is an excellent example of the "black box" description of systems engineering. Observations of distress represent a summation of everything, including the variables of materials and construction and the influence of environment, age, and traffic. It is not an easy matter to look at a pavement and conclude precisely what mechanisms are involved or are in control. It is not easy, but it is a beginning. Given enough observations over wide enough areas and long enough times, some patterns can surely evolve and have evolved.

PROCEDURE

It is important to mention briefly something about present techniques for evaluating the condition of a pavement. Observations or condition surveys are made on the basis of subjective evaluations that are primarily aimed at identifying the type of distress

and the level of severity. To evaluate the cause of distress by such techniques has proved somewhat elusive and unreliable except when accomplished by experienced and highly knowledgeable observers. Even then, serious differences of opinion can occur. Probably if more effort had been expended in this area of study, fewer differences would exist and better associations would be possible. For the moment, it is not unlike the doctor who is allowed to look at the patient and possibly feel the patient but is not allowed to perform any tests before making his diagnosis. Thus, present subjective techniques allow the observer to make certain statements about the types of distress (cracking, distortion, and disintegration) and considerably fewer about the causes of distress.

Efforts by a number of agencies are being made to introduce objective measurements into observations of performance. Factors such as riding quality, deflection, surface texture, and coefficients of friction have been or are being considered as supplemental information to assist in defining the causative factors related to loss in serviceability or to occurrence of observable distress.

Lack of uniform terminology to describe pavement performance has not helped in trying to define or to communicate the condition of a pavement or the type of distress being observed. The same type of distress may be described differently or with less emphasis by engineers in various parts of the country or by different agencies. Highway Research Board Special Report 113 attempts to standardize nomenclature for pavement components and deficiencies. It is to be hoped that terminology suggested in that publication can serve as a useful beginning in minimizing some of our communications problems.

TYPES OF DISTRESS

Although complete unanimity does not exist in the literature as to the types of distress, there is some consensus that distress can be grouped into three classes: (a) fracture, (b) distortion, and (c) disintegration. The input factors required to bring about these types of distress become very complicated and involve traffic loading, environment, materials properties, construction, and geometrics (layer thickness). Table 1 in McCullough's paper gives a further breakdown of the possible distress mechanisms. Unfortunately, there is probably a high level of interaction between each observable distress and the mechanisms involved.

Identifying the three types of distress is not difficult, and even this amount of information would be helpful in establishing research priorities. The next major definition or differentiation would be between traffic-associated and non-traffic-associated distress. Traffic-related distress can usually be related to a location within the paved area. If distress occurs or is confined to the areas subjected directly to vehicular loading, it is probably traffic-associated. If it does not appear to be associated with areas in direct contact with loads, it is probably an environment, construction, or materials problem. Obviously, this areal association is an oversimplification, but it should help in estimating the mechanism of distress, which, in turn, should help in defining the type of research needed.

OBSERVATIONS OF DISTRESS

A review of the literature will give the impression that an abundance of distress exists on the highway system. This is to be expected inasmuch as the serviceability of pavements is known to decay with time and traffic. Many pavements observed to be exhibiting distress have simply outlived their design lives and have not received the anticipated amount of rehabilitation. Some pavements exhibit distress somewhat prematurely because the reliability factor of present design methods is, and should be, something less than 1.0. It is the role of research to improve, quantify, and control the reliability factor in order to provide the most economic balance between performance requirements and costs.

There is no single source of information that permits highway technologists to summarize how full-scale pavements perform. The author has been involved in several projects concerned with pavement performance and observations of distress. It is not

suggested that these observations are a rigorous evaluation of how pavements perform; however, the author has made systematic evaluations in 22 states and the District of Columbia that involved more than 150 projects of widely varying designs, uses, materials, construction procedures, and environments. Also, the author has had the opportunity to observe the biweekly performance of the asphalt test sections on the AASHO Road Test during the 2-year traffic period. On the basis of these observations, the author has permitted himself to make some statements, however unreliable, about the occurrence of pavement distress on full-scale pavements.

The questions are asked: How do asphalt pavements perform? What kind of distress is most commonly observed? What might be the mechanism involved? These questions will be partially answered by a summary of the results of three rather systematic pavement evaluation studies. Following this, results reported by other agencies will be used in an effort to show the present performance situation.

A statewide pavement condition survey, involving pavements ranging from 3 to 8 years in service life, in one of the northwestern states in 1966 indicated the following:

1. An observable amount of distortion was occurring on 23 percent of the pavements with 3 percent having progressed to the stage where some maintenance would be indicated;
2. Minor amounts of disintegration had occurred on 25 percent of the projects, all of which could be adequately maintained by the application of surface seals;
3. Fracture was observed on 63 percent of the projects, 31 percent of which would be scheduled for programmed maintenance; and
4. Transverse cracks were noted on 60 percent of the projects, 13 percent of which would be eligible for programmed maintenance.

The riding quality of pavements with transverse cracks was only 0.4 PSR less than pavements without transverse cracks. On the basis of this survey it would be concluded that traffic-associated cracking is of major concern not only in terms of the amount but also in terms of the cost to maintain and rehabilitate.

The second pavement condition survey was part of a Bureau of Public Roads investigation to determine the changes in physical and chemical properties of asphalt and to attempt to evaluate the role of asphalt in the performance of pavements. The investigation included limited but systematic observations of performance in 18 states and the District of Columbia. All of the projects were 11 to 12 years old at the time of the survey and included Interstate highways and local roads and streets. Of the projects observed, 20 percent exhibited traffic-associated fracture at a level suggesting immediate or programmed maintenance. Only 4 percent of the pavements exhibited rutting at a level that could require maintenance, although most of the pavements exhibited some longitudinal distortion (not exceeding ¼ in. average). About 20 percent exhibited surface disintegration indicating the need for immediate or programmed maintenance.

The Sweetwater Test Road in San Diego County is a cooperative project to evaluate the structural capability of eight base types constructed at four levels of thickness. It is significant to discuss the performance of these sections after 4 years of service. None of the sections has exhibited distortion in any significant amount. All of the sections exhibited disintegration, which has been corrected by a slurry seal. Based on observations by the author, 27 percent of the sections exhibit traffic-associated cracking. According to the experiment design, it would be expected that from 25 to 50 percent of the sections would exhibit distress during the 4-year time period. It is significant that much of the distress that has occurred is in the form of traffic-related fracture. It is pertinent to comment that on the Sweetwater Test Road, longitudinal non-traffic-associated cracking is occurring along the outer edge of the paved area. This cracking has made the identification of mechanisms very difficult; nevertheless, some associations are believed to be justified. On the basis of these observations, the following conclusions are suggested:

1. Traffic-associated cracking is one of the first indications of distress observable on asphalt pavements;

2. Traffic-associated cracking can occur with little (less than ¼ in.) surface distortion; and
3. Traffic-associated cracking does not appear to be highly correlated with surface disintegration.

It should be mentioned that one class of distress considered by many, especially in certain northern tier states and in Canada, to be important has not been emphasized by the author—specifically, transverse cracking, believed to be caused by thermal stresses. Although this type of distress has been observed by the author, it has not appeared to be highly significant to the overall performance. Canadian investigators (McLeod, Haas, Anderson, and others) have conducted extensive observations, both systematic and continuous, that strongly indicate that thermal cracking can be a very important design factor for asphalt pavements in particular environments. Several test projects are under way in Canada to determine methods to control this particular type of distress. It must be conceded, therefore, that thermal cracking can be sufficiently important to be assigned a high priority for research needs in certain environments.

One of the most extensive investigations of pavement performance was made in connection with the AASHO Road Test. Possibly the single most significant contribution of this project was the development of a numerical index of serviceability in terms of riding quality. Riding quality, per se, is a summation of everything that can happen to a pavement by all of the mechanisms that will cause a reduction in traveling comfort. In addition to riding quality determinations, considerable effort was made to study the occurrence of distortion in the transverse profile and the occurrence of load-associated cracks. No significant amount of non-load-associated cracking was recorded in the 2-year traffic period. The results of these studies are particularly pertinent to this workshop.

Highway Research Board Special Report 61E summarizes the performance measurements from the AASHO Road Test. The following conclusions about changes in transverse profile are suggested by that report:

1. Nearly all of the sections exhibited some changes in transverse profile at the completion of traffic testing.
2. Profile changes were due principally to decreases in thicknesses of component layers. Although this conclusion may be tenuous for the thinner sections, the evidence was reasonably conclusive for the sections of substantial thickness. Some evidence indicated that sections exceeding 11 in. in thickness exhibited only minor distortion in the underlying layers.
3. Lateral movement of materials was the primary cause of change in thickness. (The author wants to point out that the rate of change in the transverse profile decreased markedly after the first 300,000-lb axle load applications. This would suggest some stabilizing mechanism with time or traffic. Possibly the increase in density occurring in the structural components was causing significant increases in strength that, in turn, reduced the tendency for lateral movements.)
4. A reduction in the amount of change in transverse profile was observed when a stabilized base, either asphalt or cement, was incorporated into the section.

The following conclusions are given for cracking:

1. More cracking occurred during periods when the pavement structure was in a relatively cold condition than when the pavement was warm. (This conclusion becomes rather crucial to the development of damage criteria and is complicated by a lack of information relative to when and where cracks first occur and how they propagate.)
2. Cracking and the extent of change in transverse profile were related.
3. The occurrence of cracking and deflection were related.
4. Cracking and pavement thickness were related.

These suggested conclusions may or may not be truly representative of how pavements will perform if different materials had been used or even if different construction requirements had been specified or if the project had been located in a different environment. They were, nevertheless, indicative of what happened at the AASHO

Road Test and, as such, must be considered to be representative of how some pavements perform. The results from this project would indicate that technology that would reduce, control, or reasonably predict the potential for changes in transverse profile, or for cracking, would be a substantial contribution to the present state of knowledge.

SUMMARY

Based on the observations of the author and observations that have been reported by others, it would appear that traffic-associated cracking would be the number one priority item for improving and extending the performance of asphalt pavement. Also, the systems approach to solving the problem, which implies taking into consideration all of the interactions of materials, construction, maintenance, and environment, should be basic to the solution of such problems. Finally, the solution to traffic-associated cracking problems should not create problems in the distortion or disintegration categories.

Investigators are urged to consider implementing systematic and continuous observation of pavement performance as a prime determinant in establishing research priorities and to confirm the effectiveness of having implemented research findings. Research should have an assignable payoff, and only by observing performance can such a payoff be quantified.