Flexible Pavement Test Sections for Studying Pavement Design

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It is a well-recognized fact that our pavement design procedures are inadequate in general and seriously lacking in many particulars. The fact that this statement can be applied on a county, state or national basis is little consolation to those in Indiana who must design and build pavements, for ever-changing traffic conditions, in such mileage and at such unit costs compared to the funds available that a working margin of safety is practically nonexistent.

Although pavement design procedure went through an uneasy period in the 1920's when increased volume and weight of traffic appeared to be damaging to highways then existing, changes in design of the pavement and the vehicle and, particularly, conversion to pneumatic tires alleviated the situation until in the early 1930's the road system was considered structurally adequate. Commissioner McDonald of the Bureau of Public Roads made a statement to this effect in 1931, and though the statement recently has been misapplied in some quarters, this fact does not detract from its value as representing conditions existing at the time it was made. The total thickness of the flexible pavements of this day was commonly determined by the general practice of the area and frequently was a macadam type of construction; either water-bound, bituminous penetrated or both. At that time, the volume and weight of traffic and the frequency of heavy axle loads were small compared to present conditions and pavement thicknesses determined by rule-of-thumb procedures were generally satisfactory.

Beginning in 1940 the number of heavy axle loads per thousand vehicles began to rise sharply. By 1942 the intensity of heavy axle loads had tripled, and by 1948 the total number of heavy axle loads was 18 times the number in the 1936-37 period. Also, by 1948 the total number of gross loads of 40,000 pounds or more was 12 times as great and their frequency was seven times as great in the 1936-37 period[1].

This tremendous change in the volume and weight of freight movement which has been imposed on our highway system has been the cause of much concern to highway engineers and to the general public. Not only has the geometric design of our highways been changed to accommodate the greater width of trucks—resulting in increased cost of construction—but the life expectancy of our highways has been markedly reduced. This has resulted not only in a greater proportion of highway funds being diverted from improvement of facilities to maintenance of existing ones, but it has necessitated the construction of pavements of greater thickness with a resulting reduction in the number of miles of pavement which can be constructed with available funds. Highway engineers, are faced with a serious problem—the design of pavements which are adequate to withstand the traffic expected throughout their life, while at the same time avoiding over design and excessive costs. In one sense, this may be the root of our dilemma; economic factors require an accuracy in pavement design that is beyond the precision with which we are able to define the conditions for design.

In spite of this situation, we must continue to design and build pavements with funds we know to be inadequate for the needs and with the knowledge that we will receive adverse criticism from some quarters regardless of our best efforts. While these remarks, and the entire thesis of this discussion, apply equally well to the design of both rigid and flexible pavements, our subject is directed specifically to the design of flexible pavements. We look to research to provide the answers to our design problems. But "research" is a broad term and if we are to proceed logically and directly toward the final goal, we must decide which of the possible avenues of research endeavor are most likely to produce the specific information we so sorely need. And so it is our purpose today to present our ideas of what kind of research is needed. To do so requires that we first briefly review the research that the Joint Highway Research Project has already accomplished and that is current.

PAST ACCOMPLISHMENTS

On this occasion a year ago we presented a discussion in which the problems associated with flexible pavements were enumerated

[1] *Public Roads,* Vol. 25, No. 12, pp. 279-286, February, 1950.

and past research on these problems was summarized[2]. At that time we pointed out that flexible-pavement research, or the general problem of flexible pavement design, consists of two parts: the material design of layers which make up the pavement system and the thickness design of such layers.

With regard to subgrade soils, our research has taken the form of strength tests in the laboratory, field strength tests including plate-loading tests and performance surveys of existing pavements. We have utilized both pedological and geological information and have developed techniques to interpret soil conditions from aerial photographs. As a result of this work we view the relationship between pavement design and subgrade soil as a regional problem of soil areas. By this means, we are able to include such factors as climate and topography and the relationship between grade line and the soil profile. Also, such an approach allows the accumulation of performance-survey data on a rational basis and provides a basic grouping on which to conduct strength tests, either laboratory or field.

With regard to granular base materials, we have conducted studies to determine the effect of such variables as grading, compaction, angularity of the aggregates, amount and type of soil fines, and amount of moisture. The studies also have included bituminous bases. Both laboratory and field strength tests have been utilized in making these evaluations. Some work has been done on the evaluation, by means of pavement performance surveys, of various base types as reinforcing layers on different subgrade soils. Also, because economical pavement design is possible only by including local granular materials as a portion of the design, we have extended the area or regional concept of design to include these materials as well as subgrade soils. This area concept also has been extended to bituminous surface courses because in many cases the type of aggregate locally available dictates the type of surface for economical design.

In last year's paper, we also presented a resume of the research conducted by the Joint Highway Research Project on bituminous surface courses. These studies have been many and varied and have been conducted on a variety of surfaces ranging from surface-treatments to hot-mixed bituminous concrete. These latter studies have been aimed at developing a satisfactory method for the design of bituminous-aggregate mixtures and have included the evaluation of such variables as type and grading of aggregate, type and con-

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[2] Proceedings of the Thirty-Sixth Annual Purdue Road School, Extension Series No 71, Vol. 34, pp. 101-111, May 1950.

sistency of bituminous material, amount of bituminous material, density and speed of testing. Among the tests that have been used can be listed unconfined compression, squeeze and impact tests, laboratory tests under moving wheel loads, Marshall and triaxial tests.

This information, collected over the life of our research organization, and impressive as it is when viewed in its entirety, really only forms the background or basic information for the development of pavement designs in the true sense.

CURRENT RESEARCH

In recent years, and especially during the past year, using as a basis the accumulated essential information just outlined, we have directed our efforts more specifically toward the development of design procedure, both with regard to material components and thickness. Our work on the design of bituminous surfacing mixtures continues very active. We are now working with mixtures that have been and are being used in the concrete resurfacing program, not only because the design of mixtures for use in resurfacing is a critical problem in itself, but also because this service condition provides an excellent basis for a study of the properties of bituminous mixtures.

For example, if shoving or rutting occurs in this use, we know it must be due to lack of stability in the mixture itself and not because of the movement of lower layers. Also, if bleeding occurs or the mixture becomes slippery in service, we are quite certain that the mixture itself is at fault, which might not be the case if it had been placed over an old bituminous pavement, particularly if numerous patched areas existed. The fact that a wide variety of mixture types, both with respect to the aggregate and bituminous materials, has been used in our resurfacing program makes this source of information doubly attractive.

With regard to field performance surveys of flexible pavements, we have concentrated our efforts during the past year on those high-type pavements constructed on plastic silty-clay soils and carrying heavy loads. We have found that these pavements, 12 to 14 inches thick and composed in general of two waterbound macadam layers, a bituminous macadam layer and a bituminous concrete surface, have not been adequate structurally and have failed by rutting in the wheel tracks. We have been interested in why this rutting occurred and have trenched several of these pavements in an attempt to find out. At locations where the rutting was definite, we have obtained a cross-section profile of the pavement system by taking elevation readings at one-foot intervals across one-half the pavement on the top of each pavement layer, including the subgrade soil, as it was exposed during the trenching operations.

These measurements cannot be obtained with sufficient accuracy, nor is each pavement layer sufficiently thick, to make it possible to draw conclusions with respect to each layer. However, considering the pavement as a whole and working with differences in elevation between the top of the pavement and the top of the subgrade, we find that the consolidation which allowed rutting to occur has taken place in both the subgrade soil and in the pavement layers themselves. Individual locations vary, but the average values for the rutting in the outside wheel tracks as determined from six trenches in one road showed 1.5 inches at the maximum point in the rut. Of this 1.5 inches, it was determined that 0.6 inches was contributed by consolidation of the subgrade and that 0.9 inches of consolidation occurred in the pavement itself.

From these data we conclude that, to carry heavy traffic on plastic soils in the State of Indiana, we must not only build flexible pavements thicker than we have in the past, but we must also use reinforcing layers that are more stable in themselves. Whether or not this can be accomplished by a change in construction procedure or whether the types of reinforcing layers need to be changed remains to be demonstrated. In this connection it may be well to point out that, in general, those pavements which have rutted or consolidated under traffic and then have been resurfaced seem to be structurally adequate at the present time. This performance survey work has been valuable and more of it needs to be done.

A third phase of our current research program on flexible pavements is concerned with laboratory studies to develop a specific design procedure. This involves the determination of the strength characteristics of subgrade soils and granular base materials. For this purpose we are using the triaxial compression test. We believe that the triaxial test is fundamental and its use will eventually lead to pavement design on a rational basis. This work is being continued, and we have recently purchased new equipment to extend the scope of the program to granular materials with larger maximum aggregate size.

NEED FOR TEST SECTIONS

But with all of this effort, past and present, we feel definitely that our research program on flexible pavement design will remain deficient and fall short of the goal unless our laboratory program is benefited by companion studies in the field. The evaluation of any material in the laboratory, soil, base course or bituminous surface, requires the test specimens of that material be made. The test results are valid only if the specimen is truly representative of the material as it is used in the field. To cite a case in point, evidence from our plate-loading tests on simulated pavement bases indicates that a given thickness of a given granular material compacted in the same way does not result in the same reinforcing layer when placed on a poor soil as when placed on a good one. In addition to such difficulties, it is an indisputable fact that many features of pavement design such as climate, drainage, construction procedure and wheel loadings do not lend themselves to laboratory evaluation.

Most of us, when we think of experiments in the field, think immediately of some kind of a test road. Our original conception may be a modest one, but when we get down to cases we find that to include the variables we would like to compare requires several miles of virgin grade with soil conditions absolutely uniform. We think about it a little longer and we decide that to eliminate chance results each section will have to be duplicated and we double the length of our road. Next, we discover that a location with uniform soil conditions cannot be found, or some other variable conditions beyond our control exists, and we must double our road again. And finally, if we discuss the matter with someone else and consider the inclusion of additional variables he thinks are important, we find that our test road will have to be built under two separate contracts and will have to be doubled again because now the contractor variable will have to be considered!

These remarks are facetious, but they illustrate the point that full-scale test roads incorporating a number of variables are difficult to plan and construct, are expensive, are time consuming and in general yield results applicable to a limited condition of soil, climate and traffic. On the credit side, it can be said that such test roads, when they are well planned and executed, can yield very valuable results. It seems to be a fact that any highway department can stand the strain of a full-scale test road only about once in every 10 years and at that rate we can't hope to keep pace with changing traffic conditions!

Our purpose in making these remarks is not to criticize the building of test roads, we will be happy to participate anytime one is built. We want to make sure that you don't confuse the test sections we propose with the common conception of a test road. We sincerely believe that the most direct and practical procedure to accomplish the field research needed for flexible pavement designs—and the procedure most likely to keep pace with changing traffic conditions—is the installation of planned test sections in as many construction contracts as feasible.

Our procedure would be to plan test sections around the proposed design, keeping them limited to those that would not interfere materially with the regular construction and would therefore involve little or no additional expense. In each case, we would keep the number of variables at a minimum and in many cases we would hope that this number would be only one or two. With this procedure the lengths of the test section would have to be only sufficiently long to be representative of conditions as they existed on any contract job and another condition of soil or traffic would be obtained by repeating this section in another contract or contracts.

There isn't sufficient time here to cover completely the range of variables we would include in such a planned test-section program. An example or two may be helpful in understanding the proposal so that you may evaluate its merits in your own minds. To take a real case, a contract proposal now existing for a high-type flexible pavement to carry heavy loads on a plastic soil specifies seven inches of subbase material extending to the ditch line, seven inches of water-bound macadam constructed in two layers, two and one-half inches of bituminous concrete base, one and one-half inches of binder, and one inch of bituminous concrete surface. You will recognize that this pavement differs from those constructed in the past, which have proved to be inadequate, in three respects. First, the overall thickness has been increased by seven inches of subbase; second, instead of a trench section drainage is provided by carrying the subbase through the shoulder; and third, the bituminous penetration macadam has been replaced with bituminous concrete base and binder courses.

These differences from previous design form the basis for a selection of variables we would include in this contract. It would involve three test sections; one section of the proposed design except that the subbase would be omitted; one section in which the pavement would be trenched and the subbase would not be carried to the ditch; and one section of the proposed design except that the bituminous concrete base and binder courses would be replaced with bituminous penetration macadam.

Some of you will recognize this contract as one for which we have submitted proposed test sections more numerous than has just been outlined. The test sections just enumerated are more in keeping with the proposal we are trying to illustrate.

Another variable that might well be incorporated in a design such as this is that of construction procedure. Our evidence from trenching operations indicates that increased pavement thickness might actually result in increased rutting if the same construction procedure is followed. Therefore, as a test section in a contract of this kind we would include one or more of the following: construct the section with heavier or improved compaction equipment; preconsolidate the non-bituminous layers by the application of similated traffic before placing the bituminous portion of the pavement; or apply a surface treatment to the bituminous concrete base and delay application of the binder and surface courses until traffic had produced consolidation if such were to occur.

To cite another example of a variable or test section that could be incorporated in design similar to that proposed, we would replace the waterbound macadam base courses with a graded stone base. If design specified a graded stone base, we would install a test section of waterbound macadam in some location where use of the material was feasible without materially adding to the cost.

We could cite many other examples of variables we would include in test sections such as, subgrade compaction, different combinations of materials and pavement thickness, but perhaps these cases are enough for illustration. We hope that they will serve to give a clear conception of our proposal.

SUMMARY

To summarize very briefly, we have tried to provide a resume of our flexible pavement research endeavors because we believe that the basic information necessary to the development of flexible pavement design procedure has been largely obtained. Our efforts to develop specific design procedure are to be presented by the next speaker. We feel that a field research program is badly needed and we have suggested that this program take the form of planned test sections to be incorporated into regular contract jobs. Laboratory testing of the materials used would be a part of the test program and adequate field records would be obtained. Economic studies would be applied wherever possible. We realize the idea of constructing test sections is not new and that the State Highway Commission of Indiana has done this in several instances in the past. We do believe that our proposal calls for a new philosophy or plan of action. In short, a construction contract without a planned variable being included would be the exception and not the rule.