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RESEARCH IN PORTLAND CEMENT CONCRETE PAVEMENTS

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As one reviews the progress in the development of a rational method for the design of concrete pavements during the last decade, two facts are apparent. First, that there has been really remarkable progress, and second, that there are still matters which need study and investigation

We are, today, in a position to more nearly design such pavements in a rational manner than ever before and, whatever information may still be lacking, many of the findings of the intensive research of this period have been accepted and are being generally applied This is a definite indication of progress

That there are still questions pertaining to concrete pavement design which must be answered by further research is evident when one considers the variety of practices among the various states concerning certain features of design. That this difference of opinion exists does not necessarily mean lack of progress in this field or that research has failed to supply data on the point in question Rather, it should be taken to mean either that there are factors whose existence is acknowledged but whose influence on the behavior of concrete pavements is not yet fully understood, or that the difference of opinion concerns details rather than principles and that there is need for more information regarding the details

It is entirely possible that there will never be a standard concrete pavement design which can economically be employed in all parts of the United States Moisture and temperature play a very vital part in the life of such pavements and we are all familiar with the wide variation in these factors in the different geographical locations

As a first step in this discussion, it seems reasonable to consider briefly some of the matters pertaining to the design of concrete pavements wherein a lack of agreement is evident

Two very important matters which affect the design not only of concrete but of all other types of surfaces are being treated at length elsewhere in the committee report and will be only touched on here These are the questions of subgrade support and the impact of traffic

The support furnished to a concrete slab by the subgrade is a matter of importance in design because it determines the stress produced in the pavement when a vehicle passes over it. While we know this to be true, we are as yet not able to accurately measure this variable.

Extensive researches have revealed much concerning the causes and the magnitude of vehicular impact We know that it is ever present to some extent We do not yet know exactly what effect these impact forces have on a concrete pavement and, until research supplies this information, such pavements cannot be intelligently designed to resist them.

There is an apparent lack of agreement on the thickness of concrete pavements There are a number of reasons for this In the first place there is a wide variation in the maximum wheel loads permitted by law in the various states Then, too, subgrade conditions vary greatly not only in the different states but seasonally in the same state, and safe designs must recognize the worst conditions of support Another factor which affects the thickness of the pavement is the quality of the concrete and here too one will find a considerable variety of practice. So, to one familiar with conditions, it is apparent that it is not a faulty method for design which is responsible for the differences in pavement thickness

Criticism is made of the fact that there is a lack of standardization in the cross-sectional design That there is some justification for this must be acknowledged However, theoretical analysis, stress measurements and test road behavior, all point to the fact that, if we expect the wheels of traffic to travel indiscriminately over all parts of the pavement surface, the thickened edge cross section is the most eco-

nomical. That this principle is being widely accepted is shown by the fact that over 80 per cent of the Federal-aid projects for 1926 were of this type, and the percentage in terms of mileage would be still higher since the uniform thickness or thin edge designs were on projects of low mileage. Variations will be found among the thickened edge designs and a comparative study of the efficiency or balance of these cross-sections would be most valuable Such a study could probably best be made by stress measurements

Another feature in which a variety of practices is encountered is in the matter of joints At least thirty-seven out of the forty-eight states are now using the longitudinal center joint. There is a difference of opinion about the proper design of the joint because there is little authoritative data concerning the efficiency of the different designs However, it seems clear that the principle of the divided slab is being generally accepted Research can and should supply the missing information.

As to transverse joints, we know that variations in moisture and in temperature cause corresponding changes in the linear dimensions of concrete, and research has revealed the laws which govern these changes But when these changes occur in concrete pavements, apparently our knowledge is not yet complete. There may be some other factor not yet recognized It appears that there are differences in the expansive behavior of concrete pavements in different localities not fully explained by the geographical and climatological differences which obtain. One state finds that it needs transverse joints at 40-foot intervals; another not at all These are not idle selections, but are based on the experience of years There is a reason for this difference and we should seek this reason, for, until it is known, we cannot rationally design this feature of the pavement.

The question of steel reinforcement in concrete pavements is one about which there is still a considerable difference of opinion. There are a number of reasons for this but research has been active in this important field and the various field experiments, test roads, and the recent survey by the Highway Research Board have done much to clarify the problem in the minds of engineers Gradually the true function of steel reinforcement is being better understood, and the results of good and bad practice in its use are being demonstrated Researches now under way should throw considerable light on points which have heretofore been obscure. It is true that there are still a number of questions to be answered but, in general, it may be said that we have

rather definite information on the use of steel reinforcement in concrete pavements

The curing of concrete pavements is not strictly in the province of structural design but since the strength of the structure is dependent on the curing processes, it is a matter of primary importance to the designing engineer There are methods of curing which are generally admitted to be adequate In the effort to reduce the cost of this operation alternative methods have been proposed Engineers have endeavored to determine the efficiency of these methods by tests When these tests were made in different localities under perhaps widely different conditions of temperature and humidity, sometimes different answers to the same question have been obtained This indicates that the importance of these factors on the adequacy of curing processes has not been fully recognized More data are necessary before the engineer can be certain of obtaining concrete of specified strength and durability under various climatic conditions when these curing methods are employed

In the papers which follow, the attempt is made to review briefly the research in the field of structural design, to summarize the knowledge gained, and to point out some of the important matters which need investigation

FATIGUE OF CONCRETE

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The importance of investigating the effect of repeated loads upon concrete is apparent not only from the standpoint of the economical design of road slabs and other structures, but also in the interpretation of failure occurring in concrete structures after years of service It is a well-known fact that metals exhibit the phenomenon of fatigue, and it might naturally be expected that a material like concrete, which possesses only a small degree of elasticity and a large degree of plasticity, would exhibit a similar phenomenon.

THE FUNDAMENTAL INDEX OF FATIGUE LIMITS

"It appears from tests of steel that the fatigue limit is closely related to the elastic limit When the repeated loads exceed the elastic limit and enter the semi-elastic and semi-plastic range, heat develops