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PAVEMENT JOINTS AND THEIR FUNCTIONS

by

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In the early development of the design of concrete pavements, engineers recognized the necessity of dividing a pavement slab into small units in order to control stresses due to temperature changes.

As information was accumulated concerning these stresses and other stresses caused by external loads, we note the beginning of the application of definite principles to the design of concrete pavement slabs, in order to "balance" the design in such a manner, that the combined stresses of temperature and load should be as nearly uniform throughout the slab as possible.

The structural adequacy of a concrete pavement slab from the standpoint of strength and permanency is influenced by the features of design which determine its continuity and dimensions.

Today, it is a recognized principle that slabs should be divided into definite widths and lengths, to provide relief from expansion, contraction and frictional forces.

The sectioning of concrete slabs, and the provisional interruption of continuity by "joints", provides one of the most controversial subjects in the design of concrete pavements. The most desirable concrete pavement would eliminate joints, particularly transverse joints, but because of the nature of concrete, joints are a necessary evil.

During the last twenty years many ideas, devices and materials have been developed in an attempt to solve the problem of "joints" particularly in regard to fillers, sealers and load transfer. Many engineers have been aware of the deficiencies of many of these solutions. Recent years have seen much research instigated and some cases completed on the problem of joints. But, it has been quite difficult for highway engineers to come to definite conclusions regarding basic requirements of joint practice. There seems to be a ^edisparity between engineering practice and fact. This lack of definiteness and apparent incongruity may be attributed to a number of reasons. Many test roads, scientific researches, field investigations have been conducted upon this subject, but because the results of such researches and studies are so scattered and difficult to assemble, the average highway engineer has not had the time or opportunity to organize and reduce the essential conclusions to an acceptable form.

Early in 1940, the engineer-director of the American Road Builders' Association recognized that this chaotic condition might be remedied by the cooperative effort of highway engineer and manufacturer. To this end, a committee was organized consisting of member manufacturers of load transfer devices, joint fillers and sealers and a group of highway engineers. The highway engineers personnel is representative of design, construction and maintenance, as well as geographical location.

The report herein submitted is an abstract of the workings of this committee to date, together with an outline of future work. In connection with future work, several important general principles are discussed.

These principles include; basic fundamentals of design, test and specification requirement, construction and maintenance details.

It is hoped that the report will serve as a guide to the future work of the committee as well as awaken interest in those who are partially informed or indifferent to this most important problem of concrete pavement construction.

The joint committee was not formally organized until the latter part of October 1940. The interim has not given the committee time to develop a report containing definite findings and recommendations. Therefore, this report should be considered as a progress report. Its contents will deal with preliminary background information with which the committee will work and an outline of the contemplated future work.

SCOPE OF WORK

On November 19, 1940 a meeting of the committee was held in Chicago at which time the following scope for the work of the committee was formulated.

The work of this committee will be, at this time, confined to the consideration of the purposes and design of the various functional types of joints used in rigid pavement and bases. The joint shall be considered in detail as a structural element of the pavement or base, but the subject of joint interval will be regarded only insofar as it may influence the design of the joints themselves. The design of the joint will be considered to include all features necessary to installation, performance and maintenance of the joint.

OUTLINE OF PROBLEM

The general outline of the problem for the work of the committee was formulated as follows:

It is intended that this committee in general, shall act as a board of review upon information supplied to it from various subcommittees or other agencies. The principle features of such material will be:

1. Establishment of uniform terminology.
2. Questionnaire survey of current practice.
3. Digest of completed and current research.
4. Analysis of fundamental structural principles.

It is the desire of the committee to provide a full-time capable technical investigator to assist in carrying out the work of the committee. It has been felt, by the membership, that "individual" members can give, at the best, only periodic attention to the work of the committee and can only work efficiently as a board of review. The actual work of collecting and correlating the information must be done by a full-time, capable research engineer to feed the grist to the committee.

The work of the committee has been divided among six subcommittees including terminology, load transfer, fillers and sealers, installations, maintenance and exhibits.

For the purposes of this report each subcommittee chairman was asked to prepare a report reviewing any work which his subcommittee had performed as well as a synopsis of proposed future work.

SUBCOMMITTEE ON TERMINOLOGY

As has already been pointed out, one of the phases of the work of the committee is the establishment of uniform terminology. It is rather surprising and amusing, the confusion of terms which are employed in the designation of various types of joints, as well as the appurtenances. The subcommittee on terminology should have prepared during the next year a complete set of terms and definitions relating to joints.

SUBCOMMITTEE ON LOAD TRANSFER

This subcommittee probably has one of the most difficult phases of the work of the joint committee. The chairman of this subcommittee reports that his group conceives its task to be divided into the -

1. Preparation of a compendium on published literature pertaining to the subject of load transfer and a study, as far as possible, of the results of unpublished work.
2. Development of a simple program of reconnaissance tests to serve as a basis for the preliminary study of the problem.
3. On the basis of preliminary study evolve a program of tests, the results of which would be used to formulate recommendations for design use and other features.

SUBCOMMITTEE ON FILLERS AND SEALERS

The proper design and installation of joints, particularly of the expansion type, in concrete pavements and bases is certainly one of the most important factors in the design and construction of rigid type pavements. The enormous stress created in concrete which is confined and still subjected

to wide temperature and moisture variations, such as is the case with concrete pavements, is easily sufficient to cause failure of pavements which would otherwise prove entirely satisfactory, if provision for free movement was made. Efficient load transfer in a joint unit is necessary to develop uniform structural strength of a pavement slab but the quality and proper installation of the expansion filler and seal is the important factor in regard to assurance of free movement of the concrete.

Expansion joint material has been used for many years and originally was constructed of pre-moulded bituminous material. When this material is first placed it serves very well to permit free movement of the concrete and yet seal the opening against infiltration of water and foreign material; however, such pre-moulded joint material does not have a quality of resilience after compression nor does it cement itself to the concrete so as to insure a closed joint of the pavement slab during contraction of the concrete.

The problem has encouraged research from several of the basic industries and as a result many types of materials including wood, metal, rubber, fiber, cork and combinations have been developed for use as expansion joint materials.

Many of these materials have shown considerable merit from a design standpoint but have not yet been extensively applied because of economic or practical considerations. Modern construction practice require consideration of joint material on a competitive basis of a type that will satisfactorily withstand normal handling and installation usage.

In general we may consider the ideal resilient joint material should completely fill the expansion joint space at all times, compressing and recovering completely with the movement of the concrete slab, due to temperature and moisture variations.

The "air-cushion" metal expansion joint with the copper seal was highly developed a few years ago. Difficulties involved in insuring proper handling, installation, maintaining high ductility of the copper seal, and provision for adequate repair of cut sections resulting from underground activities, are some of the considerations that come to the attention of the engineer in using this type of joint.

Materials having a recovery of at least 90% of the original thickness after laboratory tests are considered to satisfactorily serve as expansion joint material if they exhibit sufficient durability under test, and do not indicate excessive extrusion under compression. Many materials being used for this purpose do not, however, possess this quality of resilience (some expansion joint materials indicate as little as 65% recovery under test) and it is necessary to provide a surface seal when using such expansion joint materials in order to insure proper sealing of the joint under all conditions. These sealers are usually of pouring consistency of bituminous, rubber, and mastic compounds and their combinations. Rubber latex mixed with bitumen, and latex in which mica filler is incorporated and colored to match the concrete have been found to insure good adhesion to the edge of the concrete and compress with a minimum of extrusion.

Joint fillers are important factors in good performance of modern concrete streets and roadways. Positive prevention of water infiltration

which may destroy the supporting power of the underlying subgrade and entrance of foreign material which may cause spalling of concrete edges, are the most important requisites of a good joint filler material.

SUBCOMMITTEE ON INSTALLATION

The term "joint installation" presupposes a premise of panel design and, therefore, the predetermined existence of a means to join these panels into a connected structure which will function satisfactorily as a pavement.

Most of the arguments, research and studies relating to the length of panels, transfer of load, reinforcement, pavement cross-section, stability of subgrade, the characteristics of filler materials, water tightness, etc., do not apparently have a direct bearing on "joint installation." Yet, conversely, all theoretical considerations and computations and all laboratory and related field tests must assume the existence of true and proper joint installations. In other words, the theories and calculations of research, of conclusions drawn, or limitations imposed, of the functional purpose of the joint structure design or even of the pavement design itself, - is of little value when not translated into actual construction accomplishment in conformity with assumptions previously made and visualized by the designer or mathematician.

When the actual installation of designed structures or devices by average workmen under the customary construction experience of weather, machinery and supervision, fail to come within the tolerance error or the limitations of installation refinements, methods or expedients to accomplish that which was intended.

All of the above comments can be shortened to the observation of an inspector who said "All you have to do to get a good joint is to line her up and I mean, KEEP HER LINED UP." A lot of headaches are in store for the conscientious construction engineer who expects to bat anywhere near perfection in joint installation during the placement and finishing of the concrete.

Some desirable objectives for committee study are:

1. That the primary objective in the installation of any joint assembly is to preserve in construction the functional characteristics intended by the joint design and the physical properties of the materials used.
2. To attempt to coordinate the theoretical limitations of the accuracy of placement determined by research and design studies, with the practical limitations which can be economically secured by well-designed installation methods or devices.
3. To determine the practical limitations of the accuracy of placement under actual construction conditions for the essential elements of the joint structure of the various types now accepted as standard construction.

For example, what is the reasonable accuracy of placement to be expected of the following methods:

For tied joints

- (a) Individual chairs or supports left in place or removable.
- (b) Pins or stakes left in place or removable.

For movable joints

- (c) Removable joint assembly racks or supports.
- (d) Left in place or expendable units of bar spacers, braces and socket assemblies.

4. The development of apparatus and means to determine the position of the various essential elements of a joint structure after the placement and finishing of the concrete. Through this information to set up reasonable tolerances which must be observed in order to secure good construction.
5. To approve or suggest installation methods which (in accord with No. 1 above) will assure full opportunity of permitting or preserving the resilient or waterproofing characteristics possible for various materials.
6. Encourage the use of those factors of economy, simplicity and strength in design and assembly which are also usually consistent with simple and adequate methods of installation.
7. Investigate the possibility that installation members or accessories which are left in place may be designed to be of some recognized value in stress reduction reinforcement and so assist in neutralizing a portion of the total assembly cost.
8. To investigate the advantages and limitations of mechanical consolidation of concrete around joint assemblies. To discourage the use of elements having flat horizontal underside surfaces or those which contribute to air pockets or delayed flow of surrounding concrete.
9. Work with the manufacturers of paving machinery to the end that the operation of that machinery will not interfere with the proper installation of joint assemblies.

SUBCOMMITTEE ON MAINTENANCE

The committee has not had an opportunity to collect and compile data from the different states as to their procedure and methods of maintenance

of joints of cement concrete pavements.

Future work of the Maintenance Committee will be to contact and review the experiences of maintenance engineers of State Highway Departments and compile data thus obtained.

It is the intention of the committee to follow somewhat along the following outline in securing data for next year's report:

First Year Maintenance

1. Removal of extruded joint materials.
2. Resealing with a material to avoid infiltration of surface water and evert matter.

Subsequent Maintenance

1. Re-alignment of pavement slabs to original elevation, if necessary.
2. Removal of any joint filler that has become inactive or inadequate.
3. Resealing with a material to avoid further failures.

Failures Due to Defective Joint Filler

Material and Causes

1. Edge and corner.
2. Transverse cracking.
3. Longitudinal spalling and openings.
4. Shoulder function of standard width pavement and effect on pavement slab.

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It must be appreciated that the short time in which the committee has had to function does not allow for a very lengthy presentation of actual findings, but the reports of the various subcommittees indicate a healthy reaction to the potentialities of the problem of joints.

Encouraged by this response, the chairman of the joint committee will endeavor to discuss the problem of joints and their functions and propose, in his remarks, a general outline for the further activities of the committee and subcommittees.

The term "joints", as usually discussed, refers to any planes of division in the concrete which subdivide the pavement into definite slab units. For the purposes of this report only those which are predetermined by design and construction will be considered, although it is recognized that potential joints may exist at undetermined cracks. It might be hoped that with proper and adequate design of pavement slab only the former will exist.

In its generic sense the term "joint" would then only apply to the longitudinal and transverse separation affected. But, since such divisions might cause localized decrease of rigidity and structural inadequacy, certain features of design must be incorporated in the joint in order that it will properly function.

FUNCTION OF JOINTS

It has been quite generally accepted that the main functions of joints in concrete pavements are to allow the slab to expand, contract and warp freely without restraint. A secondary function, not often considered, is the capability of rendering the pavement sufficiently flexible to adjust itself to physical changes of the subgrade.

The function of joints and their relation to the design of a concrete pavement is being quite thoroughly studied by the Public Roads Administration, the Portland Cement Association and a number of state highway departments, as reported in the December meeting of the Highway Research Board.

The functions of a joint and their relation to the detailed structural design of the joint itself has been studied in a number of researches particularly in regard to edge strengthening of transverse joints. However, there remains considerable work to definitely establish fundamental basic principles in the design of the joint itself as related to their functions. Consideration should be given to expansion, contraction and longitudinal joints and specific attention must be given to the subjects of load transfer, fillers and sealers.

LOAD TRANSFER

The necessity of edge strengthening at joint edges can only be determined after adequate consideration of all the factors involved. This need should be defined from the design values of the slab and subgrade, such as thickness, concrete flexural modulus, subgrade modulus, probable warping stresses and maximum wheel loads. But, as yet, satisfactory values for some of these factors have not been determined as well as satisfactory theoretical formulae for determining stresses in finite slabs. Methods must be developed for measuring these coefficients and researches must be carried out to determine necessary adjustments in theoretical formulae for infinite slabs which will apply to finite slabs.

At present, completed research recommends that edge strengthening be required at transverse joints of thickened edge pavements but not necessarily at the joint edges of adequately designed uniform thickness pavements.

Edge strengthening may be obtained, either; by independent edge strengthening including edge thickening and edge bar reinforcement, or; by load transfer including face interlock or auxiliary shear members. Present

practice seems to indicate that edge strengthening is better obtained by load transfer. However, proper study should be made by the committee to evaluate the various methods from the standpoint of efficiency and economy.

Load transfer by special devices which provide inter slab load support have been endorsed, particularly, for use at expansion joints in thickened edge pavements. They are also recommended for pavement of uniform thickness, although not theoretically required, they may be used to prevent faulting of slab ends. Since early in 1934, the Public Roads Administration has required the use of load transfer devices in transverse expansion and dummy contraction joints. In the latter type, a few exceptions have been made under certain special conditions. Objection to these requirements by some highway departments has occasioned a comprehensive, cooperative research investigation by various states and the Public Roads Administration (both field and laboratory). These investigations should be watched by this committee and the conclusions surveyed, to the end that proper recommendations may be made.

Although the need of inter slab load support has been rather widely recognized, there has been a wide divergence of opinion as to how it should be accomplished and a decided lack of agreement on the fundamental structural requirements of the device or how they should be spaced in the joint to work effectively.

Load transfer devices have been used for a number of years, but as yet no definite criteria has been established for their use and design. Many types possess merit while others should not be used, particularly because of their detrimental effect upon the concrete caused by high localized stresses

and consequent impairment of efficiency of the device.

It has been found that many devices are easily installed, while others present installation problems, which add further to the secondary stresses.

Because there is such a diversity in the design use of these various devices, and many are inadequate for the purpose intended, the situation seems to dictate the necessity of definite design criteria.

During the last three years, attention has been given to this important matter. Various methods and theories of design have been advanced for proper spacing of various types of load transfer devices. Such methods aim to determine the maximum permissible spacing of a given device in a given pavement for given subgrade condition. This spacing being determined so as not to exceed the maximum allowable:

1. Shear force in the device.
2. Stress in the slab.
3. Pressure of unit on concrete.
4. Any other stresses.

Many engineers have been aware of the deficiencies of certain types of load transfer devices even the common lowly dowel. These deficiencies in some cases have been of such a degree that many have argued that after a short time of service, certain types will fail to function as a load transfer device. And, because of the failure caused by overloading of the unit, as well as failure caused by high concentrated stresses or failure induced by misalignment in construction, it has been argued, that it is better to use no load transfer device. This attitude has brought about a disparagement between engineering fact and practice.

Present requirements allow the use of 3/4 inch dowels on 15 inch spacings and any device which can perform as good is usually allowed. Sometimes a device which appears to be a little better by visual examination or meager test data is allowed at 20 to 22 inch spacing. No attempt is made to determine relative value of various types of devices, the selection and design use of load transfer devices is practically arbitrary with very little semblance of standardization. Visual inspection and haphazard guesses as to meeting the criterion "as good as an ordinary dowel" are the only methods of approval of proprietary fabricated load transfer devices.

It is to be hoped that the work of the subcommittee on load transfer will aid in the solution of this problem and an agreement brought about between these two principles as there should be in standard engineering problems.

It should be the duty of this committee to encourage the study of load transfer devices to the end that adequate specifications and tests are proposed by this or other agencies and accepted for the use and design of load transfer devices.

The load transfer device is only one detail or element of the joint proper. Adequate details for forming the joint, filling of joint opening and proper sealing are of equal importance in insuring the joint performance over a long period of years. The design of the joint must properly coordinate each detail in order that the function of the joint is not impaired in any way. For instance, the filler must be designed in such a manner that its shape will allow proper placement of concrete and no sections of concrete are formed which may be unduly stressed and ultimately provide a joint opening so large that no load transfer is affected.

It is apparent that adequate specifications must be developed for the combined joint assembly. During the last few years specifications have been tentatively adopted for fillers and sealers but apparently considerable work is still to be done before economical and efficient materials will be guaranteed by such specifications. The committee on joints should direct its attention to the requirements of a satisfactory filler and sealer, encourage the development of such materials and assist as far as possible in the standardization of specifications for such materials.

The development of proper and adequate joints must be coordinated with problems of installation and maintenance.

The best joint, both from the standpoint of economy of efficiency, is that joint which performs the function intended at the lowest annual cost. Therefore, cognizance must be given to the qualities of permanency, ease of installation and freedom of maintenance. It is not necessarily true that the cheapest joint is the best joint.

The subject of economics of joints is a very interesting one and considerable attention should be given to it. The original cost, depreciation and maintenance of the joint itself are not the only factors to be considered. The relation of the complete joint to the life of the pavement is probably the primary consideration. It is possible that it can be shown how many years adequate jointing will increase the life of a concrete pavement. On the basis of the reduction of annual pavement cost, the original cost of any joint assembly may be properly appraised.