ture. With one exception all subbase materials had combined sand and gravel contents of 70 per cent or more. Only three samples had clay contents in excess of 10 per cent. Subbase soils ranged from well graded materials to gradings having as much as 50 per cent of the total material between the No. 20 and 60 sieves. All had little or no volume change and all were densely graded to the degree that they restricted the downward movement of surface water and thus served to protect the underlying plastic subgrade soil.

PUMPING OF CONCRETE PAVEMENTS IN KANSAS

A COOPERATIVE STUDY BY KANSAS STATE HIGHWAY COMMISSION AND PORTLAND CEMENT ASSOCIATION

ABSTRACT

Pumping of concrete pavements in the vicinity of transverse cracks and joints was first observed in Kansas in the spring of 1935. Since 1935, pumping has become more widespread and has occurred in localities where the traffic includes concentrations of heavy industrial trucks.

A cooperative study was made during the spring and summer of 1945 by the State Highway Commission of Kansas and the Portland Cement Association to determine the extent of pumping, its causes, and means of preventing its occurrence on new construction. The study was divided into three phases; reconnaissance, detailed surveys of sections of non-pumping and pumping pavements, and load deflection studies at various locations selected during the detailed surveys. The reconnaissance was made during one of the wettest spring seasons on record in Kansas.

SURVEYS AND TESTS

The reconnaissance survey covered 237.6 mi. of concrete pavement on the heaviest traveled routes in Kansas and was made to assess the degree and extent of pumping on the principal traffic routes during the spring wet weather season when pumping is most widespread, most severe, and easiest to detect. Pumping was divided into three classes: (1) at slab ends at joints and cracks with no evidence of faulting at slab ends or breaking of slabs; (2) pumping accompanied by faulting but with no evidence of breaking of slabs; and (3) pumping accompanied by faulting and breaking of the slab. Sections of each project which appeared to be typical of pumping or non-pumping portions were noted for further observations during the detailed study.

After the reconnaissance survey, a detail study was made of the selected sections, which totaled 54 on 36 projects. Selection was based largely on uniformity of subgrade soil throughout a length sufficient for observing absence or presence of pumping, faulting, joint opening and related items.

The purpose of the detail study was to examine closely all the variables which may affect pumping. Considerable time and effort were expended in the examination of joints. Fillers were removed and excavations made at the edges of the slab to insure that pumping was observed even when it was in its earliest stages. Each section studied was mapped and the subgrade sampled.

Samples of the subgrade were taken from two locations. Those for determination of water content, density, and for routine tests were taken through core holes drilled through the pavement. Those for determining moisture-density relations in the compaction tests were taken under the edge of the slab.

Soil samples were tested in the central soils laboraory of the Kansas State Highway Commission. The following tests were made: liquid limit, plastic limit, mechanical analysis and specific gravity. Standard compaction and optimum water content determinations were made on the large samples taken from under the edge of the pavement.

All observations and measurements made on each section in the detail survey, test data on subgrade samples, and information obtained during the reconnaissance survey were tabulated for study.

Upon completion of the detailed studies, load deflection tests were made at the same transverse joints where soil samples had been taken and field density and water content tests of the subgrade had been made. A four-wheel drive truck was loaded to produce a front axle weight of 8,000 lb. and a rear axle weight of 16,000 lb. Four Ames dials were used for measuring pavement deflection under load and set up so one dial was bearing on each of the four slab corners of one traffic lane at a transverse joint. One observer was assigned to each of the four dials.

Maximum deflections were observed at each of the four dial positions under static loads and at truck speeds of 5, 10 and 20 m p h. The last speed was the maximum at which reliable readings could be obtained by the method of observation used

Comprehensive loadometer surveys were made in Kansas in 1936 while a statewide traffic count was made in 1941. For the pumping study, the 1941 axle loads were estimated by comparing the 1941 and 1936 traffic surveys Only the daily volume of truck traffic was considered in this study and the truck loadings were grouped into single unit and combination vehicles which in turn were classified into axle weight of under 10,000 lb., over 10,000 lb., over 14,000 lb, and over 18,000 lb.

The data from the reconnaissance and detail surveys show the status of pumping on each project for the traffic, the subgrade conditions and the climatic conditions which prevailed prior to and during the survey There were differences of considerable magnitude in the amount and degree of pumping on various jointing designs, subgrade soils and subgrade conditions, and for different concentrations of various axle weights.

Most of the projects surveyed were built with a 9–7–9-in. by 20 ft. cross-section with the transition from the 7-in to the 9-in. thickness attained in 4 ft. The small number of 9–6–9-in and 6–8–6-in. cross-section made it impossible to compare pumping on different cross-sections.

Observations

Seven projects having lip curb on hill sections and no lip curb on the flatter grades were studied to determine the influnce of lip curb on pumping. They were all located on fine grained residual soils derived from limestones and shales, which are considered "potentially pumping soils." No significant difference was found in the amount of pumping on comparable pavements built with or without lip curb, the amount being somewhat greater but of less severity on pavement with lip curb. Edge pumping did not occur and edge deflections were less on pavements with lip curb but such sections of pavement were all on grades which afforded better surface drainage than parts of the same projects without lip curb

Sixty-five projects having eight different jointing arrangements and three projects built with only construction joints were covered in the study Expansion joint spacings with two exceptions (one at 150 ft and one at 353 ft 9 in) were about the same, varying from 100 ft. 4 in to 121 ft. 0 in. However, the spacing of contraction joints resulted in original slab lengths ranging from 25 ft 3 in. to 100 ft. 4 in.

With about the same expansion joint spacing (100 ft. 4 in to 121 ft), pavements with shorter slab lengths pumped less than those with longer slabs. Pavements with original slab lengths of 29 ft. pumped less than those of 40 ft. 4 in , while pavements with original slabs 50 ft. 2 in and 50 ft. 4 in. pumped less than slabs 100 ft. 4 in long.

Construction of relatively short slabs through the use of intermediate contraction joints between expansion joints at relatively long intervals is of aid in the reduction of pumping.

Greater joint opening caused by longer constructed slab lengths or by distributed reinforcing which held intermediate cracks tightly together, thus causing longer slabs to act as units, resulted in increased pumping at these joints.

Distributed reinforcing which held intermediate cracks tightly together prevented pumping at such cracks.

The performance of older pavements having expansion joints packed tightly enough with soil to cause slab restraint indicates the desirability of reducing expansion provisions or spacing expansion joints at long intervals

In comparing pumping at expansion joints and contraction joints, it was found that the sections built without mesh reinforcement showed about twice as much pumping at expansion joints as at contraction joints, based on the percentage of total number of each type of joint. This may be due to greater difficulty in keeping expansion joints effectively sealed This relationship was reversed on the projects which contained mesh, the pumping at contraction joints being about twice that at the expansion joints This may be the result of the mesh holding cracks tightly together and causing the 50-ft slabs (the longest original slab length) to act as units. The resulting large contraction joint openings made it more difficult to maintain an effective seal which in turn allowed the entrance of more water through the joint into the subgrade

Only one type of expansion joint filler appeared to have a major effect on pumping, the air-core "copper seal" type This type was used on nine projects, seven of which were pumping Pumping was three to five times more severe on these sections than on those with other types of fillers Differences between other fillers were less marked and because jointing arrangement appeared to have a major influence, no further comparisons could be made

Pumping occurred at joints having all types of load transfer devices used at both expansion and contraction joints Expansion joints having type A and A-1 devices without intermediate contraction joints developed unusually heavy pumping However, that jointing group included the copper seal filler which is shown above to be an inferior joint filler and seal.

For pavements having a 100 ft 4 in expansion joint spacing and without intermediate contraction joints, direct comparison could be made between the projects using dowels and those with type A-1 load transfer devices In both cases limited extrusion rubber fillers were used. The total percentage of pumping expansion joints having A-1 load transfer devices was about twice that of those with dowels (D-1 load transfer device)

Faulting of joints on the average was greater at pumping joints than at non-pumping joints Some load transfer devices reduced its amount and severity

The amount of faulting at contraction joints was found to be far greater on the projects constructed in 1940 and following years Very little faulting developed on pavements built from 1928 to 1934 with dummy groove and weakened plane contraction joints either with or without load transfer devices The greater amount of faulting on the newer pavements is apparently due to certain design features common to them alone. The pavements built in 1940 and later had full depth metal plates separating adjacent slabs and complete dependency was placed on devices for load transfer and for the prevention of faulting. It was apparent that the added load transference through aggregate interlock at the dummy joint was of value in preventing faulting.

The number of pumping projects having poor seals or no seals at expansion joints was almost three times as great as the number having good or fair seals This ratio increases to four to one at contraction joints In contrast to this, the number of non-pumping projects having poor or no seals at expansion joints was about the same as those having good or fair seals, with the ratio about two to one at contraction joints Considering also the fact that many of the non-pumping projects with poor seals or no seals had subgrades not conducive to pumping, it becomes apparent that sealing of joints is an important factor in controlling pumping.

Drains under expansion joints have been used in Kansas at various times, but because of other factors their value could not be determined with any degree of accuracy

Pavements included in the survey were in eight major physiographic regions No pumping was found on soils of the Missouri loess region. Projects on glacial till and residual soils covered with selected loam and clay loam soils derived from sandstones showed light pumping No pumping occurred on selected sandy loam soils derived from identical sources

Moderate to extremely heavy pumping was found on sections across the Osage Prairie region and in the Cherokee Lowlands The soils in these regions are derived from limestones and silt and clay shales, except for a minor group derived from a comparatively narrow belt of medium grained sandstones

Moderate to light pumping occurred in the Smoky Hills Upland, on materials derived from Rocky Mountain outwash and on alluvial and terrace deposits in the Great Bend Prairie It should be noted that the route across this area carries heavy industrial trucking.

Little or no pumping occurred on the more sandy soils of the Red Hills Upland or on the outwash materials west of Wichita and Kingman.

Pumping was found to occur and not to occur on plastic soils of the A-4, A-6 and A-7 PRA soil groups. In no instance was pumping found on soils of the A-1, A-2 and A-3 groups nor on the more sandy soils of the A-4 group having low plasticity indices.

The most significant single relationship between any feature or combination of features of pavement design, subgrade soil type, traffic or other factor which may affect pumping lies in the textural classification of the subgrade soil immediately beneath the pavement. In no instance was pumping found to occur on subgrade soils or subbases having more than 50 per cent of material retained on the No. 270 sieve in the soils encountered in the survey. Pumping was found to occur and, in some instances, not to occur on soils having less than 50 per cent of material retained on the No. 270 sieve.

Pumping was not found in Kansas on soils having one or more of the following textural characteristics:

1. Less than 15 per cent clay
2. More than 50 per cent sand and gravel (material retained on No. 270 sieve or having grain diameters larger than 0.05 mm.).
3. More than 40 per cent retained on the No. 200 sieve.

Subbases were first constructed in Kansas in 1933 and were built then to control differential volume change of highly expansive clay soils in order to maintain a smooth riding pavement. The more recently constructed subbases were built to serve the combined purposes of controlling soil shrinkage and swell, providing increased subgrade support, and preventing the occurrence of pumping.

Subbases ranged from 4 to 18 in. in design thickness and in width from 2 ft. wider than the slab to full roadway width. The major portion was built 2 ft. wider than the pavement. No relation was found between thickness of subbase and pumping. Pumping was not found on subbase thicknesses ranging from 4 to 18 in where the subbase material had 50 per cent or more material coarser than the No. 270 sieve but it occurred, regardless of thickness, on subbases having less than 50 per cent of material coarser than the No. 270 sieve. In the latter case, pumping was largely of a light nature, with only a small amount of moderate pumping and none was severe.

Measurement of slab end deflections at joints, under moving and static loadings, showed greater vertical movement on pumping pavements than on non-pumping pavements, and that all factors permitting increased vertical movements of slab ends contribute to an increase in pumping.

Differential movements were small at joints on potentially pumping soils and rarely measurable at joints on non-pumping soils. Differential movements were, on the average, less at contraction joints than at expansion joints.

The deflection measurements were of particular value in showing the relative efficiency of the various load transfer devices in reducing the differential slab movements found to be generally associated with pumping

At pumping expansion joints differential movements were smallest where dowels were used as compared with load transfer devices consisting of structural angles with the vertical leg cut into sections bent out to provide embedment in the concrete.

Truck traffic at selected locations, to give results fairly indicative for Kansas, had increased considerably in 1944 over 1936 The percentage of axles weighing over 14,000 lb. increased about three times in the years between 1936 and 1944, while axle weights of 18,000 lb or more increased about fivefold in the same period. These increases in the heavier axle loads undoubtedly are the cause for the more widespread pumping since 1935, at which time it was limited to two miles of pavements

Traffic data were not available in sufficient detail for definite determination of the weight and volume of critical axle loads. In general, total commercial traffic was about the same on pumping and non-pumping pavements but the number of axle loads of over 10,000, 14,000 and 18,000 lb. was substantially greater on the pumping projects.

Recent and detailed commercial traffic data on U. S. 81 south of Salina, Kansas, show a significant influence of the weight and volume of axle loads on the pumping which has developed on the north and southbound traffic lanes on three projects. Faulting was twice as pronounced and pumping was practically confined to the points on the northbound lanes where axle loads of over 10,000, 14,000 and 18,000 lb. were respectively seven, nine and three times greater than for the southbound lanes.

Irrespective of the weight and volume of commercial traffic, pavements placed on natural subgrade soils or on subbases containing more than 50 per cent sand and gravel (material retained on No. 270 sieve) will not pump.

PROGRESS REPORT OF THE COMMITTEE ON MAINTENANCE PERSONNEL

By Rex M. Whitton, *Chairman*
Maintenance Engineer, Missouri State Highway Commission

SYNOPSIS

A second report of a Maintenance Department Sub-Committee on Maintenance Personnel recommends that attention be given the relative salaries or wages being paid for maintenance jobs in view of the fact that there is such a wide variation in amounts paid the same job in the various State highway departments The report further recommends that good work by the maintenance employee be rewarded and encouraged by continuity of service, a salary or wage level comparable to that paid by private industry for similar work, a retirement plan, workman's compensation, vacation and sick leave with pay, and other considerations which would provide a better job for the better employee, to the end that better and cheaper maintained highways will result.

This is the second report of the Committee which was appointed for the purpose of making a study of highway maintenance personnel to the end that a report could be prepared containing information and recommendations that would be an aid to securing better and more efficient highway maintenance thru better and more efficient personnel

The Committee decided to make a study by the questionnaire method of the present personnel policies of the various State highway departments. The Committee's first report was submitted at a meeting of the Maintenance Department of the Highway Research Board at Cincinnati, Ohio, on November 26, 1944, and was subsequently printed in *Highway Research Abstracts.*

In the first report, the Committee reported that only 16 States had a civil service plan; 46 States had workman's compensation (now this has been increased to 47); 18 States had a remunerative retirement plan (this number has been increased to 21). The first report also noted that vacations and sick leaves with pay were almost universally granted.

The first report carried the facts regarding the working hours per day and per week. The length of the working time for field employees varied from 8 to 10 hr. per day, and from 39 to 60 hr per week

A detailed tabulation of the foregoing information was attached and made a part of the first report. Since then the tabulation on policies has been checked by each State and a revised tabulation is now attached and made a part of this report

For the purpose of salary comparison, the first report set up and defined 14 maintenance job titles, and showed for most of the States the range of salaries of these jobs A listing of these definitions is also attached A tabulation of the salary or wage for the various