materials, the stockpiling of the aggregates, and the treatment with chemicals to prevent freezing in the stockpiles.

III Laboratory work to develop certain phases of the above investigation

FILLERS AND BEDDING COURSES FOR BRICK PAVEMENTS

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SYNOPSIS

Brick pavements laid in 1923 on a bedding of sand mixed with tar have been investigated and found to be in good condition Tests of the bedding course reveal some unexplained loss of bitumen Experiments have been conducted with coatings of glycerine and whitewash to prevent adhesion of the filler to the brick surface Asphalt emulsions have been studied for use as filler and in bedding courses Recent experience in construction of brick pavements on a sand mastic cushion in Illinois indicates that more than 4 per cent of bitumen is needed in the cushion

BEDDING COURSES

It has been known for many years that most of the ills to which brick pavements are subject are due to faulty foundations and bedding courses Cracks will form in a concrete foundation These will spread and let the sand cushion run through unless it is bound with some material that will hold it in place With this thought in mind a cushion of sand and cement was tried, and it has been used to some extent throughout the country It never has been thoroughly satisfactory because it makes a rigid layer on which the brick are bedded Hence it is more or less like an anvil and traffic is the hammer

The idea of mixing tar and sand together and laying the mix as a bedding course was first tried out with a wood block pavement in Syracuse, New York, in 1920 The pavement laid there at that time is in excellent condition today, and the engineer in charge states that the cushion has been 100 per cent efficient A mastic cushion was tried at Matoon, Illinois, 1923-24 Here brick pavements were laid over a cushion consisting of clean sand mixed with a light refined tar in the proportion of 96 per cent sand and 4 per cent tar by weight An examination of the pavements in 1931 showed them to be in excellent condition, although no maintenance had been given them during the past seven years Samples of the cushion were removed from the pavements, and these were examined and analyzed at the Materials Testing Laboratory of the University of Illinois. The following results were noted

A visual examination showed that the cushion in place looked like very dark brown to black sand, which was decidedly damp, and which, in several instances, had that iridescence that is often seen when a bituminous emulsion is setting The samples were carefully dried and subjected to the hot extraction test Three pavements had been opened at several points and the samples from each pavement were kept together.

Sample No 1 showed 1 349 per cent of tar present (Coal tar pitch filler)
Sample No 2 showed 1 190 per cent of tar present (Oil asphalt filler)
Sample No 3 showed 0 954 per cent of tar present (Oil asphalt filler)
Average of samples = 1 164 per cent of tar present

If four per cent of tar was mixed with the sand, what has become of the three per cent that is missing? Did ground water rise through the concrete base, form an emulsion and finally leach away the tar that was not too firmly attached to the sand particles? Surface water could not have found its way to the cushion because the joints were apparently well filled and there was no evidence of leakage from the gutters The concrete base was somewhat dark on the surface, but not black enough to warrant the belief that the tar had tried to seep through it

At the moment the committee has not found the answer

During 1931 the State of Illinois resurfaced about seventy miles of concrete pavement with bricks A bituminous sand mastic bedding course was used composed of clean, dry sand and bituminous material in the proportion of 92 to 95 per cent of sand, and 5 to 8 per cent of bituminous material, by volume (By weight these percentages were as follows: asphalt = 4 7, sand = 95 3, asphalt = 2 9, sand = 97.1; tar = 5 5, sand = 94 5, tar = 3 5 and sand = 96 5, on the assumption that the sand weighed 110 lb per cu ft, the asphalt had a specific gravity of 1, and the tar of 1 2) This is the first extensive use of the mastic cushion or bedding course Several items of interest were observed Asphalt cut-back and tar were used on different jobs

It was found that a roller is an unsatisfactory tool for compacting the cushion The mastic sticks to the roller and causes depressions in the cushion to be formed Much better results are obtained if it is struck off or luted, the bricks laid thereon, and rolled with a power roller *after* they have been inspected and *before* the filler is applied

The specifications permitted as little as 5 per cent of asphalt cut-back, by volume, or 2 9 per cent by weight. But 20 per cent of this material is a volatile solvent, which means that only 2 3 per cent by weight, of asphalt is left to bind the sand particles In the case of tar there would be a slightly greater amount of binder. Now, with the experience of the Mattoon pavements in mind it would seem as though 3 per cent of bitumen, or less, is insufficient If cut-backs are to be

used then the amount of material should be stated in terms of the binder before the solvent is added

Trouble was experienced with the cushion composed of sand and cut-back asphalt Contractors would mix it too far ahead of time with the result that it was "set" before it could be spread Then, too, it would "ball up" under the strike board if it were not properly used as soon as mixed A slower setting material and a less volatile solvent would be advisable

Similar trouble was encountered with emulsions that were mixed with sand The tendency was for them to set at unexpected times, since the weather, the condition of the sand, and the manipulation of the mix seemed to affect the setting time of emulsions

Reports have been filed with the chairman of this sub-committee concerning brick pavements in various localities in the United States, laid upon sand-bitumen mastic cushions The behavior of these pavements will be watched during the coming year, and samples of the cushions will be examined and tested

JOINT FILLER

When brick pavements are slippery the cause is usually a film of asphalt on top of the bricks This film or coating is due to the method of filling the joints with asphalt by pouring it over the surface and pushing or squeegeeing in into place If the weather is cool there is likely to be a coating of considerable thickness This lasts for a long time, sometimes for years, and if it does not readily adhere to sand, grit, chips, or similar materials that may be thrown on and rolled into it, it is slippery in wet weather Various schemes have been tried to remove the film It has been suggested that if the pavement were mopped with some material that would prevent the adhesion of the filler as it is being flushed on the surface and into the joints, that the excess could then be peeled off, leaving the uncoated surface of the brick exposed to traffic Glycerine has been tried, and it is successful Whitewash also was satisfactory Sodium silicate has been tried in the laboratory by the chairman with these results If full strength liquid is used an effective coating is given the brick and the excess asphalt may be peeled off With 50 and 25 per cent solutions the asphalt adheres to the brick just as though no sodium silicate had been applied The committee has received no report of the use of this material in practice Another method that is successful in cool to mild weather is the sprinkling of the surface with cold water just before the asphalt is applied In extremely hot weather this method was a failure

SPECIFICATIONS

The question of a specification for asphalt filler for the joints has occupied the attention of the committee It is, of course, highly de-

sirable that some standard be set, provided that suitable variation may be provided to take care of differences in climatic conditions The city of Richmond, Virginia, reports that good results were obtained with a Trinidad asphalt, melting point not less than 55°C, penetration at 25°C 100 g, 5 sec, 40-50, total bitumen not less than 70 per cent It is said that this material did not run in summer, and that the inorganic matter present was sufficient to stiffen this filler and make it stay in the joints Further, there was less trouble with this filler forming a slippery coating on the top surface of the bricks

On October 20, 1931, the brick committee of the American Society for Municipal Improvements adopted tentatively a specification for asphalt filler that requires a harder and somewhat less ductile material than that previously called for. Its general characteristics are. melting point 75 to 85° C penetration at 25°C., 100 grams, 5 seconds, 30 to 45: total bitumen not less than 99 per cent

Its behavior over a period of two years will tell more than reams of discussion

EMULSIONS

The use of asphalt emulsions for both the filler and the sand cushion binder has been proposed from time to time Numerous experiments were tried at the University of Illinois, and at least two trial stretches of brick pavement were laid in Ohio with emulsion fillers The experimental laboratory work was highly interesting, and somewhat illuminative The committee does not say that the tests are by any means conclusive Rather, it would say that much additional study is necessary This will be undertaken during the next six months by some of the graduate students at the University of Illinois The practical work in the field was also most interesting At the moment it cannot be said that the Ohio work was entirely successful, neither was it a failure in any sense. Like the laboratory work, it indicated that much must be learned about emulsions before their use may be general

Since the laboratory work preceded the field work it will be described first In order to form comparisons among the many bituminous materials suitable for mixing with the sand cushion it was decided to try out varying percentages of the following with ordinary sand, Ottawa sand, and specially graded sand The materials selected were: light tar, cut-back tar, road oil, cut-back asphalt, and three emulsions The percentages by weight used were 2, 4, 6, 7, 8, of bitumen content for the tars, road oil, and asphalt cut-back, and 4 or more of bitumen content for the emulsions. The percentage of sand varied, of course, with the percentage of binder used Enough of each mix was made to secure three samples One was spread out and exposed to the atmosphere, one was placed in a small tin can one inch

deep without a cover, and one was placed in a similar can but covered tightly These tests were made about nine months ago The open samples have been exposed continuously since then

The samples were examined daily for a week after mixing, and thereafter at intervals of a week until two months had elapsed After that they were examined from time to time, the latest examination being on November 24, 1931 All samples containing either 2 or 4 per cent of tar were unsatisfactory, they resembled dirty black sand that had no appearance of setting up Those samples with 6 per cent or more were satisfactory from the standpoint of being well bound by the tar, but the specimens bound with tar cut-back were very brittle when exposed to the air for over a month All of the tar cut-back samples hardened rapidly

Samples made with very heavy road oil had no stability, but did not harden nor become brittle In fact, even those exposed to the air for the past nine months are still plastic

Samples made with asphalt cut-back hardened in the closed cans as rapidly as those exposed to the air But these samples have not become brittle, and they still are somewhat " tacky "

Three emulsions were used The sand mixtures were based on the amount of asphalt in each emulsion We then selected several sands that are in common use in Illinois, and also Ottawa sand We used the common sand as it came, and we also washed it Finally we graded it We used it dry and we used it damp We tried it thoroughly wet, as well

Our experiments seem to show that sand containing particles that will pass a No 14 sieve will cause the emulsion to ball up badly, and the larger particles will not be coated at all This was true irrespective of the amount of bitumen used, and with all the emulsions that we tried When coarse sand only was used, such as would be retained on a No 8 sieve, then we found that all of the particles were coated with a sticky asphalt, provided 4 per cent or more of bitumen was used We thought that possibly dirt or clay might be present in the fine particles, so we washed the sand and tried the experiment again, with the same result Ottawa sand coats very well with 4 per cent of bitumen

We sieved out the fine particles from the common sand, washed and dried them, and found that the balling up was very pronounced. We sieved the sands and regraded them in various ways, but we found that whenever the fines were present the same balling up took place

This balling up is so pronounced that it leads us to believe that a satisfactory filler or bedding course cannot be produced from these sands that have much fine material in them The balls of emulsion and fine particles are about the size of peas, and they do not break up

readily, nor does the bitumen present mix with the other sand particles at any subsequent time

Some of the coarser gradings were reasonably coated with asphalt. One of the emulsions required nearly twice as much to be added as the two others, or, in other words this particular brand required over 8 per cent of bitumen to be present before a satisfactory mastic could be produced.

One of the emulsions is very sticky and tacky after a month's exposure The others dry out to some extent

It was stated by one of the manufacturers that his brand would penetrate to quite a depth of damp, clean sand Our experiments did not bear out this statement for we found that under no circumstances did it penetrate to a depth of over 1/16 inch The emulsion would break, leaving a puddle of asphalt on top of the sand: We tried this experiment with coarse and with fine sands There was no penetration at all with the latter

A brick pavement on the Chandlersville road in Muskingum County, Ohio, was used to experiment with an asphalt emulsion as a joint filler It was also hoped that this job would prove that the emulsion would find its way to the sand bedding course and penetrate it sufficiently to make a mastic cushion of it

After the bricks were laid, culled, and rolled a layer of sand was spread over the pavement and lightly swept into the open joints Asphalt emulsion was then sprayed over the pavement from a motor truck distributor Men equipped with push brooms followed the distributor pushing the emulsion into the joints The setting rate was said to be one minute forty seconds Actually it proved to be somewhat irregular The emulsion breaks or sets, and for a time there is a settlement of emulsion and sand in the joints This is probably due to the fact that the setting time is prolonged in the unexposed joints The consequent shrinkage makes it necessary to apply a second coat of emulsion, followed by a sand cover, about two hours after the first.

The sand used all passed a $\frac{1}{4}$ mesh sieve and was retained on a 10 mesh The emulsion was called a 62 per cent emulsion when mixed in the distributor, when diluted to 58 per cent it had a Furol viscosity of 45, and when used at 62 per cent it had a Furol of 40 It was a heavy Mexican asphalt with a penetration at 25° C of 150

Some time after the first application a section of bricks was removed The balling up action that had been observed in the laboratory was evident here, and the joints were indifferently filled There were layers of sand that had not received any asphalt, and there were places where the emulsion had readily run through to the sand cushion At such places it was observed that the emulsion did NOT penetrate the sand, but that it broke on contact with the sand, and the

water ran through the cushion to the bottom while the asphalt that had been in the emulsion remained on top of the cushion in a puddle, exactly as in the laboratory tests.

One very noticeable feature of this emulsion was its stickiness, and its power to hold any sand or stone chips strewn over it This is a very valuable feature because there is the possibility that such a material would firmly hold enough covering material of a coarse nature to insure a skidproof asphaltic layer over the bricks The laboratory experiments also indicated this feature The adhesive qualities of these emulsions are plainly apparent to the pedestrian.

The committee feels that asphalt emulsions have possibilities as fillers and as binders for bedding courses, but that the present methods of application, mixing, spreading, and the like must be improved There is a wide field for investigation, and it is hoped that next year's report will show that some of the problems have been solved.

APPENDIX

Specifications For Bituminous Mastic Bed

ADOPTED BY BRICK COMMITTEE, AMERICAN SOCIETY OF MUNICIPAL ENGINEERS, PITTSBURGH, PA, OCTOBER 20, 1931

Either Tar or Asphalt may be specified as the bituminous material

1 Tar The material covered by these specifications shall contain only coal tar, carburetted water gas tar and/or products derived therefrom

The tar shall be homogeneous and shall meet the following requirements

Water	not more than	2 00%
Specific Gravity at 25°/24° C	not less than	1 09
Specific Viscosity at 40° C		8 to 13
Total Distillate, A S T M E-I Flask Per cent by weight		
0-170° C	not more than	5 0%
0-235° C	not more than	20 0
0-270° C	not more than	35 0
0-300° C	not more than	45 0
Softening Point (Ring and Ball Method) of Distillation Residue	not more than	60° C
Specific Gravity at 38°/38° C of total Distillate to 300° C	not less than	0 96
Total Bitumen (soluble in Carbon Disulphide)	not less than	88%

2 Asphalt Asphaltic Material shall meet the following requirements

Specific Viscosity (Engler) 50 cc, at 50° C (122° F)		—50 to 80
Distillation, per cent by volume		
Total distillate to 225° C (437° F)	not more than	2
Total distillate to 315° C (600° F)	not more than	15
Total distillate to 360° C (680° F)	not more than	25
Tests on Residue from Distillation		
Penetration, 25° C (77° F) 50 g, 1 sec	not less than	360
Per cent Soluble in Carbon Disulphide	not less than	99 0

3 Sand Sand shall consist of any material of silicious or igneous origin, free from soft friable material, shale or slate, vegetable or other organic matter It shall not contain clay or silt in excess of five (5) per cent and shall be uniformly graded from that which passes a one-quarter (¼) inch mesh to that which will pass a No 100 standard mesh sieve

The base course shall be thoroughly cleaned of all dirt and debris Before the mastic cushion is placed all cracks in the base shall be filled with bituminous material suitable for filling cracks

A layer of bituminous mastic mixture shall be spread upon the prepared base to form a cushion of the completed depth of ¾ of an inch unless otherwise specified on the plans The bituminous mastic mixture shall be composed of clean dry sand and bituminous material prescribed above for this purpose, in the proportion of 92 to 95 per cent of sand and 8 to 5 per cent of bituminous material, by volume The materials shall be mixed in an approved batch mixer The mastic cushion shall be shaped to a true surface parallel to the surface of the finished wearing course by means of an approved templet extending the entire width of the roadway, drawn forward from the curbs or other guide rails as provided When the width of the roadway precludes the use of a templet spanning the entire distance, the cushion shall be shaped in sections using temporary guide rails laid upon the base

The mastic cushion shall be prepared at least 25 feet in advance of laying the brick Any portion which is injured or displaced from any cause shall be replaced in a satisfactory manner

When the use of the templet and guide rails is impracticable in finishing the mastic cushion, it shall be shaped to the surface required by hand lutes

If required by the engineer, the mastic material after it has been shaped shall be rolled with a hand roller until well compacted The roller shall be not less than thirty-six (36) inches in diameter, twenty-four (24) inches in width, and shall weigh not less than ten (10) pounds per inch of width Depressions formed by rolling shall be filled and rerolled until the surface of the cushion course is true to grade and cross section as determined by a templet

Specification for Asphalt Filler

ADOPTED BY BRICK COMMITTEE, AMERICAN SOCIETY OF MUNICIPAL ENGINEERS, PITTSBURGH, PA, OCTOBER 20, 1931

(A) Asphalt Filler Description

(a) The asphalt filler shall be homogeneous, free from water, and shall not foam when heated to 200° C (392° F)

(b) Flash Point (Cleveland Open Cup) not less than 200° C (392° F)

(c) Melt Point (Ring and Ball Min 75° C (167° F) Max 85° C (185° F)

(d) Penetration at—

25° C (77° F)	100 gr	5 sec	Min 30	Max 45
0° C (32° F)	200 gr	60 sec	Min 10	
46 1° C (115° F)	50 gr	5 sec	Max 90	

(e) Ductility at—

25° C (77° F) Min 4 C M

(f) Loss at—

163° C (325° F) 5 hrs Not more than 1%

(g) Total bitumen (soluble in Carbon Disulphide) Min 99 0%

(h) Per cent of total bitumen soluble in Carbon Tetrachloride Min 99 0

DISCUSSION ON BRICK PAVEMENTS

ABSTRACTED

MR C. N FORREST, *Barber Asphalt Company* Wet sand makes an ideal bedding course for brick pavement, but to insure permanent wetness it must be wet with liquid bitumen which should be of such a nature that the bedding mixture can be handled at atmospheric temperatures. The bitumen should be a non-volatile kind that will not change its consistency, nor harden in the course of years In a sea beach, which is the best example of wet sand stability, the grains of sand are generally very much one size Therefore, Mr. Forrest thinks that the most stable and satisfactory bedding course would be composed of sand particles as nearly as possible of the same size

MR H G SOURS, *County Engineer, Summit County, Akron, Ohio* Some comments on matters not covered in the committee report are made The use of controlled expansion and contraction joints in concrete bases for brick pavements in order to prevent bedding material from dropping into cracks is gaining in favor If the spacing is properly planned, promiscuous cracks should not occur, and loss of sand can be prevented by filling the bottom one inch of expansion joints with bituminous material and covering with metal plates; the contraction joints should be filled with bituminous material and covered with burlap

Granulated slag is an important bedding material which was not discussed It is highly compactible and has cementing qualities which within a year's time will develop a bed which will not shift under the bricks or filter into cracks

The importance of preparing a smooth and uniform bed for the bricks is emphasized

When the surface is coated with some material to prevent adhesion of the filler, great care must be taken to prevent it from getting into the cracks where adhesion is important The use of grit rolled into the filler immediately after application is of value in preventing slipperiness and facilitates the peeling off of the filler later

The discontinuance of the use of lugless brick is making possible the use of harder fillers, which are reported as satisfactory from regions having extreme temperature ranges.