REPORT OF COMMITTEE ON DESIGN

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THE DESIGN OF BRICK SURFACES TO OBVIATE SLIPPERINESS

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SYNOPSIS

Two developments in recent years have a direct bearing on the anti-skid properties of brick pavement surfaces (1) The surface removal method of bituminous filler applications (2) The vertical fiber lug type of paving brick Tests reported at the Thirteenth Annual Meeting of the Highway Research Board indicated a high coefficient of friction on vertical fiber brick surfaces provided the surface was free of asphalt filler

The surface removal method using whitewash as the adhesion preventative was used at Jacksonville, Florida, in 1929 and in Wilmington, Delaware in 1931 A non-drying moist film was first used in Ohio A calcium chloride solution has been found to be the best medium yet devised for this purpose

The surface removal method permits advantageous direct pouring of asphalt in joints, and because of compensating factors there is no increase in cost because of its use

Vertical fiber lug brick are now available and are recommended because the wire cut surface is desirable from an anti-skid and lugs from an engineering standpoint

Developments of recent years in the use and production of vitrified brick as a paving material that have a direct bearing on the anti-skid properties of brick pavement surfaces are two in number.

(1) The Surface Removal Method of bituminous filler application

(2) The vertical fiber lug type of paving brick

The effect of these requirements in brick pavement construction on the character of the resulting paving surface, and recent research investigation of filler materials that will further improve the anti-skid qualities of brick surfaces will be considered in this report

SURFACE REMOVAL

The flexible or so-called soft filler, has superseded the rigid type for most brick pavement construction because of certain inherent advantages. Difficulties incident to temperature changes are obviated and

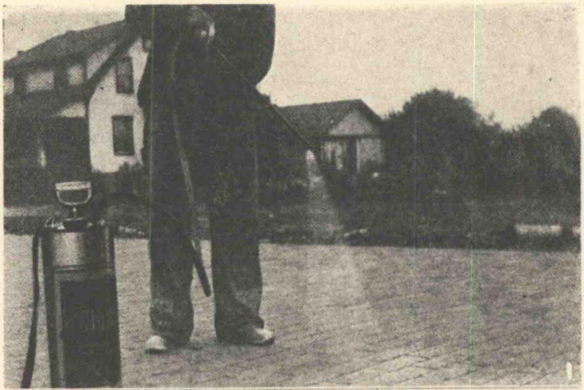


Figure 1. Applying the Adhesion Preventing Solution in the Form of a Fine Spray Just Before Applying the Asphalt Filler.

Figure 2. Pouring the Hot Asphalt Directly into the Joints of the Vertical Fiber Lug Brick without Spreading or Squeegeeing, Which Insures Complete Penetration and Sealing.

Figure 3. Removing the Filler by Cutting (Not Rolling) from the Surface, the Surplus Asphalt Being Reheated and Reused.

the joints are sealed against the entrance of moisture The physical properties of the asphalt filler called for in standard specifications had for years met the requirements of good construction However as the average speed of highway traffic increased there arose complaints regarding accidents alleged to be caused by the slippery condition of pavement surfaces of all types especially in wet weather In investigating brick pavements concerning which there had been complaints of slipperiness in wet weather it was invariably found that the surfaces were covered with asphalt in which the mineral cover material had not been properly incorporated In order to secure an asphalt of the proper consistency for a good filler it was necessary that it have low ductility. The use of such a "short" material called for prompt action in the application of the cover material to insure its proper incorporation in the surplus asphalt left on the surface When this was lacking the result was a non-gritty surface particularly slick when in a moistened condition. Old brick pavements on which the asphalt had been worn from the surface through the action of traffic were not slippery. It therefore seemed highly desirable to construct a brick pavement so as to have the surface free of filler.

The specifications for the brick pavement on the Beaver Street Viaduct constructed in Jacksonville, Florida, in 1929 required that the joints be poured by hand and that no asphalt be left on the surface (1) [1] The contractor requested permission to accomplish the results desired by brush painting the surface of the brick with whitewash and then cutting the excess asphalt from the surface A test produced more desirable results than the hand pouring method and the permission was given In 1931 the whitewash method was used on the Washington Street Memorial Bridge pavement in Wilmington, Delaware (2). In the original and usual method of using whitewash the coating on the surface is allowed to dry and forms a hardened separating layer If this film is undisturbed the pouring of the asphalt filler may be postponed for days. Because of the lasting nature of the film it is necessary to prevent the whitewash from entering the joints

In 1932 on a brick pavement project constructed by the Ohio Highway Department the whitewash solution was applied by means of a hand operated air pressure tank through a nozzle that produced a fine fog-like spray which moistened the surface only with little leakage into the joints (3) Instead of waiting until the application had dried the asphalt filler was applied at once and as it began to cool and congeal was cut off in rolls with tools such as are used to cut ice from sidewalks After considerable experimenting with various fluids a calcium chloride solution with a slight laundry starch content has proved itself to be well adapted as a separating medium, and is now the material usually specified and used. The calcium chloride and starch produce a slightly

[1] Numbers in parentheses refer to list of references at end

gelatinous solution that resists evaporation or quick drying In this method the separation is facilitated by a moist film on the surface rather than by a hardened coating. If the cutting operation is delayed too long the asphalt on the surface cannot be removed The contractor soon learns by experience the proper time to begin the removal operation which varies principally with the air temperature. The temporary nature of the prevention of adhesion makes the slight moistening of the sides of the brick, which sometimes occurs, of no serious consequence There may be "bubbling" when the hot asphalt is poured into the joints but this merely denotes the escaping of steam into which the adhesion preventing fluid has been converted Care should be taken to remove the surface asphalt by cutting instead of rolling so as to avoid pulling from the joints

A few engineers have preferred the hard coating whitewash method as it permits delaying the removal of the asphalt until it has cooled (4). There is then no settlement in the joints However in view of the subsequent extrusion that occurs a preference on this score does not seem logical With the moist film calcium chloride method there is not so much trouble with sediment in the asphalt kettles resulting in frequent cleaning and possible burned out bottoms Also the surface shows no effect of whitewash stain which however, in any case, disappears in a few weeks In either method the asphalt is poured direct into the joints at a high temperature with no spreading or squeegeeing to cause it to cool before entering the joints Thorough penetration to the bottom of the brick is secured No particular care is necessary to secure a thin coat of asphalt on the surface and, as a matter of fact, a rather heavy coat facilitates removal. The reclaimed asphalt can be reused, the usual requirement being that it should be combined in approximately equal parts with new material Reusing of course increases the heating costs somewhat The immediate result is a brick pavement clean of asphalt with flush well-filled joints

Because of the saving in asphalt and the elimination of the covering of screenings or coarse sand the use of the surface-removal method does not entail additional cost The method is illustrated in Figures 1, 2 and 3.

Recommended SPECIFICATIONS for the Surface Removal Method of Filler Application in Brick Pavement construction have been recently adopted by the Brick Pavement Specifications Committee of the American Society of Municipal Engineers

VERTICAL FIBER LUG BRICK

Paving brick are formed by what is known as the "stiff-mud" process of clay products manufacture The shale or clay after being ground very fine is thoroughly mixed with water to the proper consistency. A powerful auger then forces the stiff mixture through a die on to a moving

belt in the form of a column. This column is carried to the cutter where taut piano wires automatically cut it into brick units In so-called vertical fiber paving brick the width and length are determined by the dimensions of the die and the depth by the spacing of the wires on the cutter. In the wire cut lug type the depth is the shorter dimension of the die and the lugs are formed by an eccentric motion given to the cutting wires. In this type the smooth or die side of the brick is in the surface of the pavement When the brick are repressed before burning the surface is also smooth. It has always been considered desirable to have the rougher wire cut face of the brick in the surface, particularly since in recent years anti-skid properties of pavements have become important At the same time, from the standpoint of proper filling and sealing, lugs were considered essential by most engineers Until about three years ago, with the raw material used at most plants, the manufacture of vertical fiber brick with the proper type of lugs was not commercially practical. The difficulties involved have now been overcome and the vertical fiber brick with lugs is in almost universal use in some sections. According to a survey of paving brick shipments made for the Division of Simplified Practice of the U S Bureau of Standards, the vertical fiber lug brick in 1933 constituted the largest single variety being 42 5 per cent of all shipments (5). Briefly the most popular type of vertical fiber lug brick consists of four small lugs on one side which when piled in the kiln on edge—the most economical method for burning—nest in corresponding grooves The grooves also assist in the free flow of the filler Brick without the grooves are also manufactured and meet the usual specification requirements. In either type two bars are formed by the die and the bars are pressed down after the brick are cut forming the four side lugs The grooves when used are also formed in the die

With the surface removal method of filler application engineers were given a good opportunity to view the thoroughness with which the side and end joints were filled The asphalt mat on top no longer covered over the faults in filling It was noticed that in some cases the usual requirement of beveled ends (bulged) did not insure the results desired In consequence end lugs are now required by many specifications The lugs as now designed are on each end and non-meshing, so as to provide for a free flow of the filler They function equally well when the brick are turned

The term "vertical fiber" as applied to wire cut paving brick has been a misnomer from a descriptive standpoint and is especially so since the advent of the de-airing process of manufacture By no stretch of the imagination can the dense homogeneous structure of a de-aired column be considered as having fibers However the old term will no doubt persist and long usage has associated it with a certain type of brick. It has been observed that in de-aired brick the wire cut surface is some-

times not as rough as in the non de-aired unit. However any degree of roughness desirable can be produced by the use of deformed cutting wires.

Recommended SPECIFICATIONS for lugs on vertical fiber brick have been approved by the Brick Pavement Committee of the American Society of Municipal Engineers. Figure 4 shows various types of vertical fiber lug brick.

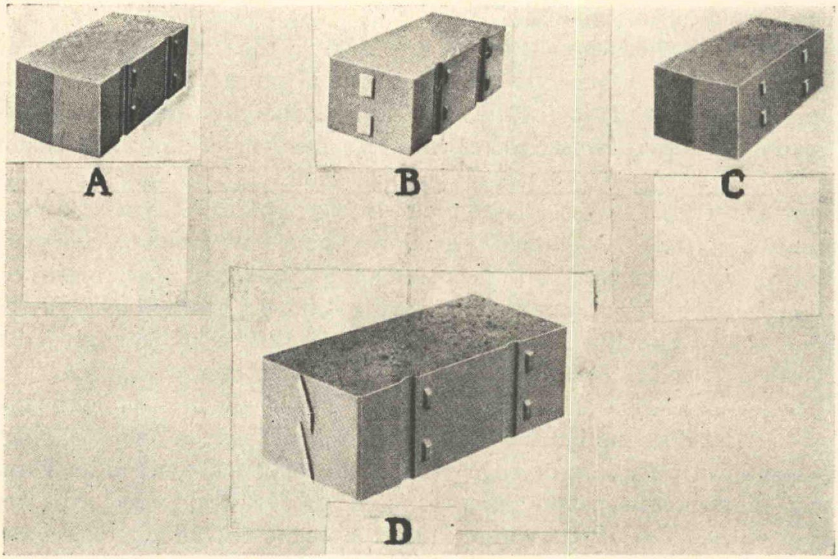


Figure 4. Types of Vertical Fiber Lug Paving Brick. A. Lugs with Grooves and Beveled Ends. B. Lugs with Grooves and Stud End Lugs. C. Lugs without Grooves and Beveled Ends. D. Lugs with Grooves, and Diagonal End Lugs.

FILLER RESEARCH

Investigations by Messrs. Stinson and Roberts, reported at the Thirteenth annual meeting of the Highway Research Board, indicated that the coefficient of friction, both rolling and sliding on "a vertical fiber brick road, free of asphalt filler" was practically the highest of any of the types that were included on their tests (6). Observations made by them on the same pavement during the second and third years after completion indicated a reduction in friction of some 30 to 60 per cent. According to their 1933 report, "During the summer of 1933 the asphalt filler bled from the joints . . . and covered in some places as much as 50 per cent of the road surface." There has been a subsequent further increase in filler exuding. The National Paving Brick Association, recognizing the important bearing of filler exudation on the anti-skid properties of the brick pavement, in December, 1933, began a coopera-

tive investigation with the Engineering Experiment Station of the Ohio State University which had for its purpose the developing of a filler that will be more non-exuding in character than the asphaltic material now in general use The following brief account of the procedure and results of the laboratory phase of the investigation was prepared by Dr Walter C Rueckel, Research Engineer in direct charge of the project

The first step taken in the investigation was to determine the coefficient of thermal expansion for various asphalts, grout mixtures and brick Most of the tests that were planned have been completed to date The only exception being a more comprehensive series of tests of paving brick from various clays and sources The more pertinent data already obtained are presented in Table I

TABLE I

LINEAR COEFFICIENT OF THERMAL EXPANSION DATA

	Coefficient per deg F $\times 10^6$
Asphalts Temperature range 40 to 120°F	
Semi-asphaltic base oil asphalt	117 0
Asphaltic base oil asphalt	80 0
Natural lake asphalt	95 0
Average value for 25 different asphalts (Source U S Bureau of Standards M P 97)	116 0
Average value for two shale paving brick bodies (Temperature range 50 to 126°F)	3 4
Value for plastic sulfur mixed with sand (Source Texas Gulf Sulfur Company)	8 3
Grout mixtures Temperature range 43 to 127°F	
1 part cement—2 parts sand	8 7
2 parts cement—1 part lime—6 parts sand	4 9
1 part cement—4 parts sand	5 0

It can be noted in Table I that the coefficient of expansion of asphalt is about 35 times as great as that of the brick Due to limitations in securing a full joint with asphalt the relation between the volume of asphalt to the volume of brick is at present about one to ten One quarter of an inch of bituminous material is provided to absorb the longitudinal expansion of each brick Whereas the actual expansion of the brick (over the maximum temperature range recorded) is merely 0 0014 in

Using the data contained in Table I it can readily be seen that a major portion of the exuding due to thermal expansion is due to the large volume of asphalt used. This statement has been substantiated by simulative exuding tests wherein the amount of exuding was considerably reduced by using thinner joints and by heating the asphalt as close

to the flash point as possible before applying to the brick (viz. applying less asphalt to fill the joints).

While the expansion data for the lean grout mixtures approximates the value for brick it must be borne in mind that considerable expansion is obtained on hydration of cement mixtures from their dry state.

Datum for 'plastic sulfur' is interesting because this material combines the desirable properties of low expansion coefficient with the ability to be deformed under pressure.

It is recognized that progress in the application of a non-exuding filler must necessarily be slow. Because, while materials now being used are unsatisfactory, variations in processing and application may overcome

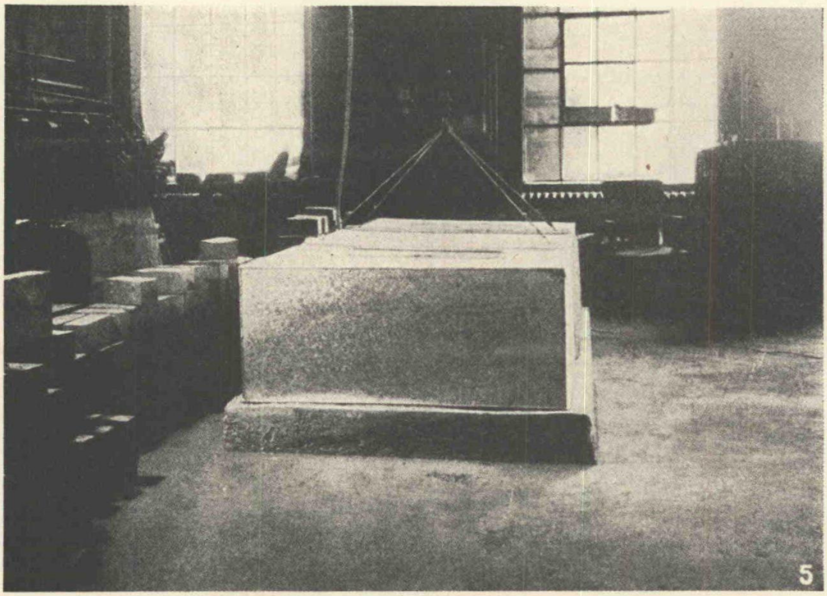


Figure 5. Metal Hood Covering Brick Pavement Panel, with Thermostatically Controlled Electric Heat Raising the Temperature on a Definite Schedule, to Simulate Service Conditions.

their present faults. A perfected form of the materials and methods used at present would doubtless be more readily accepted by road builders than a totally new substance since its use would probably require new equipment as well as the learning of the new method of application.

It was obviously impossible in order to arrive at a satisfactory conclusion to this problem to try a great number of filler materials in their various combinations in actual road construction. Accordingly a test to simulate conditions causing exuding in a road was devised. A description of the test is as follows:

Brick were laid in panels one square yard in area in the normal manner on a concrete base and with a sand cushion These sections were confined by forms (to duplicate forces produced in the road) The joints between the brick in the panel were filled with various materials The excess filler was removed from the top of the panels by using hydrated lime as a separating agent The panels with their various fillers were then covered with a metal hood which contained electric strip heaters thermostatically controlled The temperature on the surface of the brick panels were then raised to 125 to 130°F for a definite period of time and then cooled In order to obtain comparative results all the panels were heated following a definite schedule Fillers on which exuding was minimized were heated for a longer period of time than was designated by the schedule

The various asphalts and admixtures included in the simulative tests are:

a Asphalt produced from semi-asphaltic base oil
b Asphalt produced from asphaltic base oil
c Natural lake asphalt
d Emulsions of asphalt with clay
e Emulsions of asphalt with soap
f Cut-back asphalts with mineral admixtures
g Mastic admixtures of heated asphalt and sand-coke-and other materials
h Asphalts produced from blends of several sources of crude oil
i Synthetic plastics

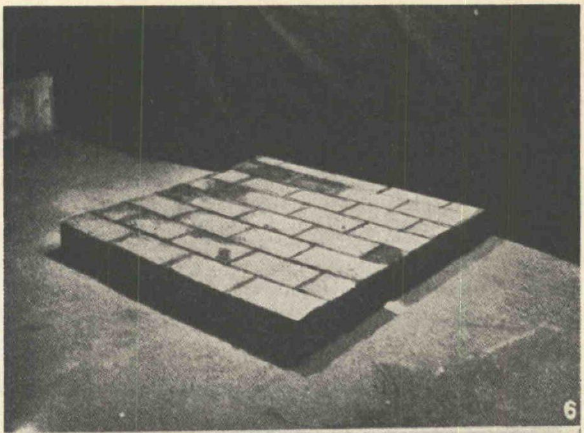
Summary of Results, Simulative Exuding Tests

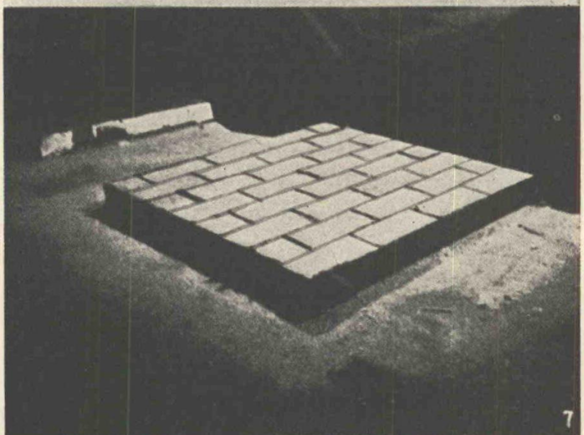
1 Asphalt fillers produced from an asphaltic base oil exuded less than an asphalt produced from a semi-asphaltic base oil

2 Although natural lake asphalt did not exude it escaped from the test panel This was undoubtedly due to its fluidity at the test temperature The Melting point of this material was 122 to 135°F (B & R)

3 Exuding of filler was practically eliminated when sand (in sufficient quantities) was added to a heated asphalt which had been produced from a semi-asphaltic base oil The processing of the asphalt and sand presents considerable difficulty, however, and its practicability must be determined by field application. Attempts to overcome one of the difficulties (settling of sand) with the use of materials with a lower specific gravity was not entirely satisfactory Powder coke, one of the materials tried, was found to have a jellying action which rendered its application as a joint filler extremely difficult

4. Asphalt emulsions alone and with mineral additions present several difficulties that make their practical value questionable It was found that joints filled with asphalt emulsion would form a crust at the top of the joint while the remainder of the joint would retain its moisture for a long period of time. Also the use of an emulsion filler would necessitate the discarding of the excess filler removed from the top of the road





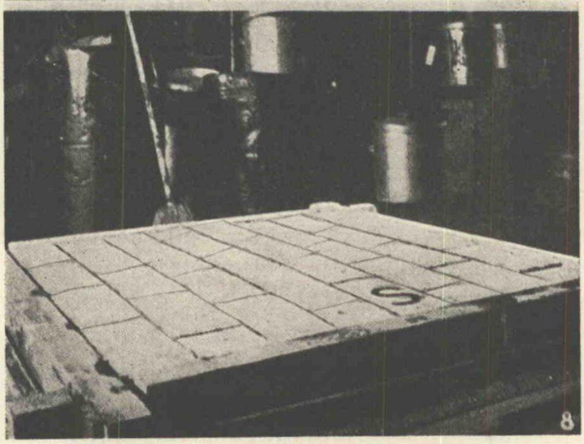


Figure 6. Asphalt Poured at 410°F. and Heated to 128°F. for 33 Hours over a Period of 3 Days—Less Exuding than When Poured at Lower Temperature.

Figure 7. Asphalt Poured at 350°F. and Heated as Above. Notice the increase in exuding as compared with the panel in Figure 6, above.

Figure 8. Asphalt, Produced from Blended Crudes Having Pure Asphaltic and Semi-asphaltic Bases, with Softening Point (B & R) of 220°F., and Penetration (77°F.) of 26. Panel was heated to 125°F. for 108 hours over a period of 7 days. Exuding has been practically eliminated.

5 Cut-back asphalts have the same inherent disadvantages of asphalt emulsions discussed above

6. Asphalts produced from asphaltic base oils are usually resinous in nature and brittle in cold weather As mentioned before they are quite resistant to exuding when used as brick fillers Asphalts produced from semi-asphaltic base oils are less resinous in nature, and are ductile and sticky at low temperatures

It was felt that asphalts produced from a blend of the two types of crude mentioned above when blown to a high melt point should give a much more satisfactory product from the standpoint of exuding and weathering A series of four blends ranging from 100 per cent semi-asphaltic base oil to 30 per cent semi-asphaltic base oil—70 per cent asphalt base oil were prepared and blown to obtain melt points ranging from 190 to 220°F Simulative exuding tests indicated that a blend of 65 per cent of semi-asphaltic and 35 per cent of asphaltic base oils blown to a melt point (B & R) of 220°F , and a penetration of 26 cms , at 77°F was far superior to all other asphalts or mastic mixtures included in the investigation

7. Some work had been done at the Ohio Engineering Experiment Station in advance of the inception of this investigation on the possibility of plasticizing sulfur by the addition of organic materials A short time after the inauguration of the work on this problem contact was made with work being done along similar lines at Mellon Institute for the Texas Gulf Sulfur Company It was found that the development of a 'plastic sulfur' had been carried into a very advanced stage by Dr W W Duecker of the Institute Arrangements were made to try several types of 'plastic sulfur' as paving brick fillers One of these types proved to be eminently suitable in every respect when tested by the laboratory exuding method

It can be noted from Table I that the coefficient of expansion of this material processed with sand is quite low The excess plastic sulfur filler can also be removed from the top of the road by the use of a solution of calcium chloride as a separating agent Also the fluidity of the plastic sulfur at its application temperature is much greater than that of heated asphalt The width of the joints may therefore be reduced and the cost per square yard will be commensurate with that of asphalt filler despite their considerable difference in cost for equal volumes of the two materials

Conclusions which can be drawn from the results of the investigation

1 Asphalts produced from asphaltic base oils show less exuding than do asphalts produced from semi-asphalt base oils
2 The use of cut-back asphalt and asphalt emulsions as fillers are rendered questionable by the necessity for discarding the excess filler removed from the top of the road

3. The exuding of filler can be reduced by the addition of mineral matter with asphalt
4 Exuding of filler can be practically eliminated by the use of a blended asphalt with a high melt point, or 'plastic sulfur '

The laboratory tests are illustrated by Figures 5, 6, 7 and 8

A test road to check the laboratory findings of this investigation has recently been placed under contract by the Ohio Department of Highways and the U S Bureau of Public Roads on a Federal aid project It is located on Ohio State Route No 31, the Columbus-Athens road, in Hocking and Fairfield Counties It will consist of 14 sections of brick pavement each about 500 feet in length in which different varieties of filler material will be used Cement grout filler and plastic sulphur are used on two sections, the fillers on the remaining sections being essentially bituminous in composition

On a brick pavement constructed on the Ohio State University Campus in September 1934 there were test installations of two kinds of filler, applied under the supervision of Dr Rueckel The brick used had been salvaged from an old pavement

The fillers used were an asphaltic base oil asphalt (Texaco 39) and plastic sulfur No difficulties were encountered in applying the asphalt or in removing the excess filler from the top of the road It was noted that this material when heated to 420°F produced joints that were better filled than the remainder of the pavement where the standard F-1 mid continent asphalt was employed The joints in this pavement were much wider than in normal road construction due to the use of salvage brick A solution of calcium chloride was used as a separating agent for both the 'plastic sulfur' and asphalt filled sections

Heating the 'plastic sulfur' by direct fire was unsatisfactory It was found that a great deal of caution must be exercised in this method of heating because decomposition (of the plastic sulfur) resulted from over heating This difficulty can be overcome by the use of an oil bath heating kettle The sulfur filler was found to give well filled joints and the excess material did not adhere to the top of the brick

Cutting through the sulfur filler in the joints proved to be rather difficult A major portion of this difficulty can be overcome by using thin joints The joints in this road varied from one-quarter to three-quarters of an inch in width There is no denying the fact that the plastic sulfur is stiffer and harder to cut than asphalt The latter material when in a leather hard state offers little resistance to a sharp cutting edge.

REFERENCES

1 "Beaver Street Viaduct, Jacksonville Florida," *Dependable Highways*, Nov - December 1932
2 "Replacement with Paving Brick—Washington Street Bridge," by A P Shaw, *Proceedings*, National Paving Brick Association, 1932

3 "The Surface Removal Method of Filler Application in Brick Pavement Construction," by O W Merrell, *Dependable Highways*, May–June, 1933
4 "Resurfacing 82 Foot Street at Richmond, Virginia with Vitrified Brick" by A Mason Harris, *Roads and Streets*, November 1934 This is descriptive of project on which a whitewash separating fluid was used
5 "Report of a Variety Survey in the Vitrified Paving Brick Industry for the year 1933," made at the request of the Department of Commerce of the United States
6 "Coefficient of Friction between Tires and Road Surfaces" by Karl W Stinson and Charles P Roberts, *Proceedings*, Highway Research Board Vol 13, 1933

BEST PRACTICE IN THE ACHIEVEMENT OF NON-SKID ASPHALT SURFACES

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SYNOPSIS

The reports on skidding at the Thirteenth Annual Meeting of the Highway Research Board indicated that certain types of asphalt pavement had the highest coefficients of friction while other types had the lowest From this it is concluded that it is not the asphalt itself but rather the way in which it is employed that determines whether the pavement is non-skid A review of asphalt pavements and accident reports shows that improper cross sections are to blame for many accidents A contributing cause of skidding is the improper use of asphalt Right design and carefully controlled construction operations will produce the non-skid textures desired The paper divides modern asphalt surfaces into six principal groups (a) Dust layers (b) Surface treatments (c) Road-mix surfaces (d) Plant-mix surfaces (e) Penetration macadam (f) Asphalt block The important steps in construction procedure are noted for each type

Skidding accounts for only about five per cent of motor vehicle accidents, but even with this small percentage it was the major cause of 1,740 deaths and 44,510 accidents during 1931 the year which registered the peak in accidents on highways Even the threat of skidding produces a feeling of uneasiness and discomfort when no accidents result, and the psychology of the motorist when operating his car under conditions which appear dangerous is one of great uncertainty which in itself may contribute to accidents for others Many accidents resulting from skidding are due to careless driving, such as failure to slow down on curves and excessive use of the brakes, while others occur during Fall, Winter and Spring because of snow and ice or because of films of wet leaves or soft mud on the pavement For these conditions there is little remedy except the exercise of greater care by the driver

The highway engineer however is directly concerned with providing a pavement which is in the highest degree resistant to skidding so far as