FEDERAL AID HIGHWAY PROJECT NUMBER FIFTEEN
RENO COUNTY, KANSAS, 1922.

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BY

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Approved by the Faculty of
The Graduate School
J. W. Blackmer, Dean.
This is a study of the construction and maintenance of an eighteen foot monolithic brick road 17.572 miles in length on which the Author was engineer. The construction period lasted from May 15, 1919 to Aug. 9, 1921. The maintenance data and conclusions are based on maintenance beginning in December 1920 and ending January 1, 1922. Some data are also drawn from the work on Federal Aid Project No. 27 of 35.187 miles on which the Author was engineer for construction and maintenance.

Hutchinson, Kansas,
April 17, 1922.
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Completed pavement after two years traffic.
FEDERAL AID PROJECT NUMBER FIFTEEN,
RENO COUNTY, KANSAS.

Reno County federal aid road construction is unique among road projects in Kansas for the fact that it is at present the only extensive monolithic brick highway program in the state and that it is the first instance in the state where the Bureau of Public Roads permitted the use of pitrun sand and gravel in base course concrete without repportioning. Information regarding methods of construction and a study of the results obtained should be of interest to those engaged in highway work.

There had been to date federal aid granted on two projects in Reno County, namely No. 15 (17.572 miles) and No. 27 (35.178 miles). Both were inaugurated by petitions passed in the benefit districts, in accordance with the present state law. In each case, the petitioners requested some form of brick surfacing. The Board of County Commissioners in office in 1919, in which year all surfacing contracts on both projects were let, favored monolithic brick instead of bituminous filled brick because of its lower cost.

The first letting was held May 16, 1919 and at that time Sections B and C on Project 15 were awarded to the Stamey-Mackey Construction Co. and Wheeler and Keleher respectively. The third section, A, was not let until

1 See county map in the back of this thesis.
October 15, 1919. Incidentally, on these first two sections the county furnished all materials and the contractors furnished the labor at a price per cubic yard or square yard of finished construction. The annoyance and paper work falling on the county as a result of having to act as a wholesale purchasing agent was so great that on all subsequent contracts the contractors were required to furnish both materials and labor.

The standard typical cross-sections applying to all of Project 15 are shown on a blue-print in the back of this thesis. This is the standard "Sheet 2" of the Project 15 plans. It will be noted that this called for a $3 \frac{1}{4}$ in. x $5 \frac{1}{3}$ in. x $3 \frac{1}{3}$ in. base of 1:3:5 proportions, to the top of which was added a 3/16 in. sand-cement cushion of 1:3 mix. On this base were placed 3 in. vertical fiber paving brick which were bonded to the base with 1:1 grout. The original specifications of 1917 particularly applying to the pavement construction, and under which the contracts of 1919 were let, are on pp.II to VI appendix.

In order that the resultant structure should be as near monolithic as possible, it was required that the various operations necessary to construct such a pavement should be as nearly simultaneous as possible. The pavement construction of 1919 on Sections B and C followed the specifications of 1917 with only one deviation; that of substitution of a pit run base of varying proportions for the 1:3:5 mix.
This was for the sake of economy, for there is no rock of any value in Reno County. However this county abounds in natural deposits of sand and gravel of sufficient coarseness and uniformity of grading that it is cheaper to use this in concrete than to use shipped-in stone. The extra cement required to make a concrete of the necessary strength is more than compensated for by the cost of rock laid down on the job from the nearest quarry producing acceptable material. The Bureau of Public Roads was induced to accept a pit run base in this county's projects after long correspondence and after a very complete series of tests made by Mr. C. H. Scholer, Testing Engineer for the State Highway Commission. Mr. Scholer's tests showed that in well graded pit run sand and gravel aggregate the strength of the resultant concrete varies directly in proportion to the percentage of aggregate retained on a $\frac{1}{4}$ in. screen. His results were embodied in a supplementary specification which is as follows:

"SUPPLEMENTARY SPECIFICATIONS FOR BASE COURSE IN TWO COURSE CONCRETE AND BRICK PAVEMENT.

The following clause shall be substituted for and replace Article 84 of the specifications for portland cement Road Construction and for Brick Road Construction. Kansas Highway Commission, Edition 1917:

1 See appendix p.81 for sample gravel test."
84. Fine aggregate and Coarse aggregate mixed, usually termed "GRAVEL", may be used in the base course, subject to the following requirements:

When so used, frequent tests will be made to determine the relative proportions of fine and coarse aggregate and in case the proportions of the same are excessively irregular so as to make it practically impossible to proportion the concrete properly, the engineer may require the material to be screened and reproportioned.

At least 5 per cent of the gravel used shall be retained on a \( \frac{1}{4} \) in. screen, all of the gravel must pass a 2\( \frac{1}{2} \) in. screen. The material retained on the \( \frac{1}{4} \) in. screen shall be termed coarse aggregate and the material passing the \( \frac{1}{4} \) in. screen shall be termed fine aggregate.

Fine aggregate shall conform to Articles 80 and 81, and coarse aggregate shall conform to Article 82, of the specifications for concrete road construction and brick road construction as contained herein. Flat and elongated pebbles shall not be used.

Gravel concrete for base course shall be proportioned as follows:

<table>
<thead>
<tr>
<th>Percent of gravel retained on ( \frac{1}{4} ) in. screen</th>
<th>Base course</th>
<th>Base course</th>
<th>Base course</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brick Pavem't</td>
<td>Concrete Pvt.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 to 10</td>
<td>1 to 4</td>
<td>1 to 3( \frac{1}{2} )</td>
<td></td>
</tr>
<tr>
<td>10 &quot; 15</td>
<td>1 &quot; 4( \frac{3}{4} )</td>
<td>1 &quot; 4</td>
<td></td>
</tr>
<tr>
<td>15 &quot; 25</td>
<td>1 &quot; 4( \frac{3}{4} )</td>
<td>1 &quot; 4( \frac{1}{2} )</td>
<td></td>
</tr>
<tr>
<td>25 &quot; 35</td>
<td>1 &quot; 5</td>
<td>1 &quot; 4( \frac{1}{2} )</td>
<td></td>
</tr>
<tr>
<td>35 &quot; 45</td>
<td>1 &quot; 5( \frac{1}{4} )</td>
<td>1 &quot; 4( \frac{3}{4} )</td>
<td></td>
</tr>
</tbody>
</table>
When the materials are furnished by the contractor, he may, if he so desires, add additional coarse aggregate to any gravel deficient in the same, in an amount sufficient to produce one of the specified gradings given herein."

Therefore it was only necessary to find close to the job to be constructed a pit which the gravel was uniform in grading and coarseness. By making about ten or twenty field tests a day from the aggregate as delivered to the mixer, the inspector was able to determine the percentage of gravel above $\frac{1}{2}$ in. diameter and to proportion the mix according to the above specification. In case the gravel percentages crossed the line between two mixes at any time during the day, the inspector was instructed to change the mix accordingly. In some cases therefore, two different mixes were used in the same day, and in one extreme case three mixes were used.

The strength required by the Bureau of Public Roads from a 6 in. x 12 in. cylinder from the base at an age of 28 days is 1600 pounds per square inch. The inspectors were required to take at least one cylinder from each day's run as a check on the accuracy of their testing and proportioning. These were cured with the pavement and sent to Manhattan to be broken by the State Road Materials Laboratory. The results obtained were very satisfactory, indicating uniform, strong concrete. The average of nearly
Lakewood Tamper
Note mortar brought to top

Parish Tamper
Showing also all steel gravel conveyor and grout machine mounted on old drag template on the forms.
two hundred cylinders on Project 15 at 28 days was 2305 pounds per square inch. A sample list of cylinders tested is on page VIII of Appendix.

In the middle of the 1920 construction season a departure was made from the original specifications. This was the elimination of the drag template mentioned in Article 100 of the original specifications, and the 3/16 in. sand-cement cushion, and the substitution of the tamping template on the base. (See appendix for original specifications for Art. 100).

The reasons for this change were that the tamping machine would give a denser, stronger base and would by its tamping on green concrete of sufficient wetness bring excess mortar to the top, which would materially aid the grout later applied in bonding the brick to the base. Two different types of tamping machines were used by the contractors in 1920 and 1921. Wheeler & Keleher used a Lakewood on their work on Section C and Stamey-Mackey Construction Co. used two Parrish machines on Sections A and B.

Of the two tampers, it is generally conceded that the Lakewood is the better. The chief advantage it has over the Parrish is that it is reversible, so that any particular portion of base may be gone over as many times as necessary to bring it to the desired smoothness or the desired amount of mortar to the top.
On the other hand, the Parrish travels on the forms by winding up a steel cable staked out about fifty feet ahead. When the end of the cable is reached, the engine on the tamper must be stopped and the cable restaked ahead. The mortar desired to be brought to the top by this tamper can only be obtained by regulating the water valves of the mixer very carefully. For pictures of these two types of machines in operation see Plate\textsuperscript{II} page 8a.

In accordance with the 1917 specifications, the contractors were permitted to dump their aggregate on the subgrade. From there it was wheeled into the skip by wheelbarrows. Wheeler & Keleher, however, in 1920 and 1921, fixed a box in the skip of their machine on Section C and loaded direct into it from either truck or subgrade. The volumes for a three sack batch for the different mixes was marked on the box so that the proper proportions could be maintained at all times for the varying coarseness of the combined aggregate.

On the two sections built by Stamey-Mackey Construction Co. wheelbarrows were used for measurements. As a check on the mix being used, the inspector kept a cubic foot measuring box on the job and would use this to calibrate the wheelbarrows for the different mixes whenever necessary. It was also found necessary for him to check up the volume of sand being placed in the wheelbarrows about every half hour during the day.
Lakewood Tamper packing up after first trip over base.

Wheeler & Keleher - 1920 Construction. Note 10 ft. straight edge.
as that is about the length of time that the average sand shoveler will pay any attention to or remember instructions.

During the 1919 construction season, the cement used in the base was checked up only every hundred feet by the counting of empty cement sacks by the inspector. In 1920, after the Author took charge of construction, the sacks were counted every twenty-five feet in order to keep a closer check between the theoretical mix and the actual mix. This was very effective in maintaining a day's run quite close to the theoretical amount of cement required. Any particular variation in a twenty-five foot period would indicate to the inspector that either too much or too little sand was being used, or that the subgrade was either too high or too low. As a result, most runs in 1920 and 1921 after this system was put into effect did not vary from the theoretical cement required more than 1.5 per cent. The theoretical quantities for the mix are given on p. VII of the Appendix.

Unfortunately, in the Project 15 contracts it was not required that a batchmeter be on each mixer. As a result more or less trouble between the mixer foremen and inspectors ensued in enforcing the minute mix required by specifications. On project 27, there was such a provision in the contracts, so with the batchmeter locked and the key in the inspector's pocket, no trouble arose over this question on this project.
For the best results in surface and bond it was required that the consistency of the mix should be such that after the tamper had passed over the base it should quake slightly and should show a slight shine of mortar on its surface. About 1/32 in. is about the right thickness of top mortar for a pit run base such as we used, as a base giving any more than this will be too soft to work on. In a base too soft the brick will sink, the surface will be lost, workmen can not walk on it and grout results will be poor. This is the one difficulty of using a pit run base for this kind of construction as the variation between amounts of water producing a batch of the right consistency and one too wet is so small that only a skilled mixer operator can produce the required results.

In the matter of brick conveyors several useful changes were evolved in the three years of construction. At first, all wood conveyors were used. In 1920 Stamey-Mackey Construction Co. had all steel conveyors built with the rollers mounted on ball bearings. These were at least 50% more efficient than the old wood conveyors. Wheeler & Keleher have still continued to use a wood conveyor and as a result have to employ an extra man to shove the brick down the conveyor fast enough to supply the brick layers.

Canvas aprons were also added in 1920 to the
conveyors to catch dust and chips from the brick that would otherwise have fallen from the conveyors onto the green concrete base. Two brick layers transferring the brick to the green concrete base were all that were required to keep up with each mixer. They laid the brick in four rows across the pavement at a time. Even on the Stamey-Mackey Construction Co. record run of 1921 of 608.4 feet in one day, two brick layers were able to keep pace with the rest of the work.

The culling of the brick placed on the base was done by the contractor. As this work was considered quite important, it was required that after a man had been educated by the inspector to his task that the contractor avoid changing him to another job if possible. Soft brick were detected by their oversize or by their ready absorption of water sprayed on the pavement before grouting.

Immediately after culling, the brick were rolled with a 100 pound steel roller and the surface tested with a ten foot straight edge. Another feature added by the Author upon taking charge in 1920 was the use of a 2 in. x 12 in. x 16 ft. plank and a 40 pound steel hand tamper. The tamping on the plank was done longitudinally on the pavement or right angles to the brick courses. This was very effective in removing small waves in the green concrete base left by the tamping machine at right angles to the center
Laying Brick.
Note canvas under conveyor to catch dust.

Culling, Rolling, and Testing Surface with straightedge.
line of the pavement, and greatly improved the riding qualities of the pavement. This feature was added to the 1921 specifications by the State Highway Commission for this type of construction. A corollary to this practice is seen in the longitudinal floating of concrete pavements in California referred to on page 163 December 1921 issue of the "Concrete Highway Magazine".

The grouting of this type of pavement is exceedingly important. It was first done by both contractors with a two sack gasoline driven mixer mounted on four wheels and hauled over the pavement on plank. However the weight of this mixer was detrimental to the surface, so when the tamping machines were installed, the contractors were prevailed upon to mount their grout mixers on the discarded drag templates, thus transferring their weight to the outside forms. An example may be seen on Plate III page 8a. This was a great improvement as it prevented the mixer from destroying the surface over the occasional wet spots in the pavement base.

Before the first coat of grout was applied, the brick surface was sprayed with water from a garden hose attached to the two inch water line supplying the mixer. This was to prevent the brick from drying out the first coat of grout and preventing it from penetrating all cracks between the brick and effectively sealing the brick to
Surface Work
Note tamping on plank and roller for smoothing surface. Grout crew behind.

Grouting Up.
Showing grout machine on plank, before it was mounted on forms.
the base. The first coat of grout was of the consistency of cream and the second, which was to supply the body to the grout, was thicker, being more like pancake batter. A batch of the second coat when dumped on the pavement would spread out and stand with an edge about \( \frac{1}{4} \) in. high. The second coat filled all the cracks and left a little excess on top which had sunk after the second application. The time elapsing between each of these three operations depended entirely upon the temperature or how fast the preceding work was setting up. As soon as the previous work began to take on an initial set, the next operation could no longer be delayed.

As soon as the grout began to turn white, it was covered with two inches of dirt and that evening was wet down. The earth covering was kept continuously wet for ten days by the night watchman on each job. Water pressure was maintained up to midnight each night for this purpose, and thereafter during the night the watchman devoted his time to preventing motorists from tearing down barricades and driving over freshly laid pavement. It was found that in clay soils in the summer time the two inch specified covering was hardly sufficient as the clay was hard to put on uniformly and dried out quicker than sandy soils.

The last pavement slab laid on this project was on May 17, 1921, on Section A, Wheeler & Keleher having
Showing slab undermined by flood.

Three miles of pavement under water, June, 1921.
Section C - 15.
completed Section C on April 22, 1921. The entire project was shouldered up and prepared for government acceptance for June 10th. But the Arkansas River flood from Pueblo, Colorado, reached here on June 9th and as the river crosses the project in two places and roughly parallels its entire length, so much damage was done to the earth shoulders that the government engineers delayed final acceptance until August 9th. The greatest damage was done to Section C where the water from the river broke thru the embankments of the A. T. & S. F. Ry. and Mo. Pac. Ry. and covered two miles of pavement for an average depth of fifteen inches for a week. It was two weeks before the waters completely receded and reconstruction could be started by the contractors. Nearly three fourths of a mile of Section A was flooded between Nickerson and the river bridge west of there. The cost of reconstruction to Wheeler & Keleher on Section C was $3500 and to Stamey-Mackey Construction Co. on Section A was $1000.

At only one place was the pavement undermined by the flood waters. This was due to the vigilance of the contractor's forces and the prodigal use of sandbags at the danger points. This place was on Section C near Yaggy where a triangle with an eighteen foot base and an eight foot altitude was cut out of the subgrade for a depth of three feet. A picture of this is shown on Plate VII page 15a.
The pavement showed no settlement or cracks here and was repaired by tamping a 1:8 mix under the pavement to replace the earth cut out. No sign of deterioration is today visible at this point in the pavement.

Upon acceptance of the project by the State and Government in August, the final estimates were paid the contractors, the last federal aid check was remitted by the Bureau of Public Roads and the County Commissioners accepted the road for maintenance. The final cost was computed by the federal aid engineering department here, the project zoned and the benefit district's share of costs computed and distributed by this department. These were embodied in a report to the County Commissioners, which they accepted and the taxes were applied on the regular September tax rolls by the County Clerk.

The benefit district was divided up in quarter mile zones paralleling the pavement. The tax rate was based on accessibility to the pavement so that it was necessary on this basis to take some pieces of land, which were rendered rather inaccessible because of creeks or rivers, out of their regular zone and place them in a zone whose rate was lower. This reason and the irregularity of boundary lines of the benefit district made the various total zone acreages vary in amount. The zones were lettered from A, the two quarter mile zones lying adjacent to the pavement, to H, a zone lying from one and three quarters to
two miles away. Assuming the tax in zone H to be x, then since zone G is one quarter mile nearer, the tax should be 1.25x, etc. Hence with the zone letters representing the number of acres in that zone, this equation was formed:

\[ Hx + 1.25Gx + 1.50Fx + 1.75Ex + 2.00Dx + 2.25Cx + 2.50Bx + 2.75Ax = \text{Total Benefit District Share of Money Required to Retire the 20 Year Road Bonds.} \]

Solving for x will give the rate in the various zones. This system has worked out a satisfactory rate in two benefit districts here and is now in use in other counties.

The actual cost of construction was $830,977.92 or $47,289.90 per mile. The total engineering cost for the project was $28,772.62 or $1637.41 per mile including all plans, inspection, material tests, etc. This amounts to 3.46% of the total construction cost. Had it been possible to have finished the job in a year and a half as was originally estimated, the engineering cost would have been materially reduced.

Monolithic brick built without expansion joints, which were the specifications of 1917, is subject to blowouts, no matter where placed or what the subgrade or climate conditions are. This is a peculiarity of this type of pavement due simply to the combination of the different materials in it; lean concrete base below and vitrified brick and rich cement grout above;
Typical base and brick blowout - note bent rods.

Typical Brick Blowout.
and their behavior under temperature stresses. Old monolithic brick pavements in Washington\(^1\), Iowa\(^2\) and Ohio, laid five or six years ago, still have occasional blowouts in them. The maintenance cost to the road of repairing these blowouts is not excessive and it is doubtful if it will ever exceed the initial cost of placing enough prepared expansion joints in the pavement during construction to successfully take care of most temperature stresses. Such joints would have to be one-fourth to one-half inch in thickness and would have to be placed about 33 feet apart. This would entail a cost at present prices of $600 per mile. Moreover, the placing of such joints does not eliminate quite all the trouble as is shown by an examination of the monolithic brick pavement in Hyde Park, Hutchinson, which is now about five years old. Quarter inch joints were spaced in this about 33 feet apart but today at three or four joints a row of brick adjoining the joint has buckled up, causing the joint to ride high. Instances of a similar nature have been reported in work at Wichita.

In most of the blowouts on Project 15 the base failed as well as the brick surface, however in about a third of the cases it did not. Where the brick alone failed, it was replaced monolithic with grout as before,

1-see King County Engr. letter in appendix
2-Emmetsburg, Iowa, city pavement.
Typical Blowout, showing it to be local and confined to a few feet of pavement.
most of the old brick being used again. In case the base failed also, the crumbled or fractured portion was removed and a new monolithic slab replaced with an inch and a half expansion joint on each side of the break, or in case the blowout was small, with a two inch joint in the center of the new slab. Either a prepared "Elastite" joint or a poured asphalt joint was used. These extended thru both the base and the brick. Two blowouts were repaired in 1920 and thirty-five in 1921 by this method. While these expansion joints have been successful in relieving strain and no further blowouts occurred thereafter closer than 800 feet to them, nevertheless the joints are a nuisance to the maintenance force, requiring no little attention for trimming.

As an experiment last summer, two brick surface blowouts were replaced with asphalt filler instead of grout. For a time these appeared to be riding smooth and no change was taking place there. Of late, however, it has been discovered that the brick are being shoved together at these places, some of the asphalt has been squeezed under them and the surface is rapidly becoming rough. These brick and the asphalt filler sections must now be removed, and a new brick surface grouted in. Each of these two places consists of about eight rows of brick.

For these reasons, it is our intention hereafter
to replace all blowouts monolithic as soon as they occur, taking particular pains to secure as smooth a riding surface in the repair job as possible. It is thought, judging from the experiences elsewhere in older pavements and our experience here since 1919, that by the third season after construction most of the weak spots will have blown out and the forces in the pavement will have practically exhausted themselves.

A chart has been plotted for distances and temperatures for this project, showing graphically all blowouts to date. This can be seen in the back of this thesis. This chart should be of interest for the Author is aware of no other job where this has been done. It will be noted by examining this chart that practically all blowouts occur at construction joints between one day's run and another. Owing to the lack of bond between successive runs, these are naturally the weakest points in the pavement and hence blowout when under excessive pressure.

No blowouts occur during the year that the slab is laid, the first ones come in the following year. This is due to the fact that the shrinkage of the new concrete is going on and the forces of expansion due to temperature are mainly nullified. Bulletin 532, United States Department of Agriculture states that shrinkage of 1:2:4 and 1:3:6 concrete is from .02 to .04 per cent in twenty-eight days and as high as .07 per cent at six months.
Taking the modulus of elasticity of our pit run concrete base as 3,680,000 at twenty-eight days\(^1\), the coefficient of expansion of concrete as \(0.000055\), the natural shrinkage at this age as \(0.00002\), and the average temperature at which the pavement was laid as 50\(^\circ\) F, then a temperature of 110\(^\circ\) F will produce the following stress:

\[
S = 3,680,000 \times (0.00033 - 0.0002) = 480 \text{ pounds per square inch.}
\]

This is much below the strength of the concrete at this age of 1830 pounds per square inch\(^1\). Hence no blowouts will occur during the construction season in which this pavement was laid.

During the winter following construction here the temperature will fall as low as -10\(^\circ\) F. This will produce a contraction equal to 0.00033 which added to the natural shrinkage will equal 0.00053. This amount equals the contraction cracks we attempt to fill during the winter with soft asphalt. It is impossible to fill successfully such small cracks averaging thirty feet apart, as throughout the fall and winter fine dust and sand is deposited in them by wind and traffic. Assuming that the crack filling with asphalt is half successful, then when the pavement returns to a temperature of 50\(^\circ\), it is stressed by an expansion of 0.00007.

1-Bulletin 5, Structural Materials Research Laboratory, Lewis Institute, 1920.
Total contraction in winter filled up by dirt, etc. 

-0.0002

-0.00026

-0.00033 expansion due to rise to 50°

-0.0002 expansion causing stress at 50°

Temperatures of 100°F are common during summer months here. This will produce additional expansion equal to 0.00028. Wet subgrade will produce expansion of 0.0002. Then the total expansion at 100° with wet subgrade is 0.00055.

0.00007 expansion at 50°F

0.00028 additional expansion at 100°F

0.002 additional expansion due to moisture

0.0005 total expansion causing stress under these conditions at 100°F

Then the stress in the concrete at this time is:

\[ S = 0.00055 \times 6,750,000 = 3700 \text{ pounds per square inch} \]

Since the average strength of our concrete is only 4170 pounds per square inch at this age, it is evident that some one part will be weaker than this and will therefore fail by compression. This checks our experience here since all the base blowouts have occurred under a combination of wet subgrade and high temperature in the years following construction.

The blowouts in which the brick alone is effected are to be explained in the following way. After the pavement has formed its contraction cracks, the brick surface will tend to curl up and curl down on the concrete base and hence more or less free itself from the

1-See Bulletin 532, U. S. Department of Agriculture.  
2-See Bulletin 5, Structural Materials Research Laboratory.  
3-See recent investigations on the Bates Experimental Road by Illinois State Highway Department.
base at some of these points. The Author has noted for two years that this is true at a part of the contraction cracks, as the surface there gives out a hollow sound for four or five feet back each way when struck with a hammer during the year following construction. Such curling will sometimes permit a little dirt to get between the brick and the base. If this occurs, then when expansion forces will not act directly against each other and will force the brick to rise in a small, low arch about six or eight feet long. The Author has many times measured such arches during the hottest part of the day and they are all practically identical. Should the expansion forces be such that the arch will rise to two inches or less, the surface will flatten out when the cool temperatures of the evening come on. But if the arch rises to above two inches, the grout will fail by tension and the arch will collapse into an equilateral "V" shaped ridge whose altitude is eighteen inches.

Pictures of some of these blowouts are shown on Plate VIII page 18a. Attention is called to the fact that reinforcing bars are shown in the base in some of these blowouts. These were placed in the construction joints in 1919 and 1920 work for the purpose of bonding one day's work to another and to prevent one side from heaving above the other in the winter under frost action.
These rods were \( \frac{3}{8} \) in. x 3 ft. - 0 in. long and were placed two feet center to center. In the blowouts of 1920-21, it was observed that these bars tended to split the base in half, and for that reason they have been omitted in recent work.

The average cost of repairing a blowout of brick only is $10 and of brick and base together is $50.

Aside from repair of blowouts, the other maintenance expenses have been mowing of weeds, building up earth shoulders, contraction crack filling in the winter, etc. The maintenance costs on Project 15 to January 1, 1922 are as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting weeds</td>
<td>$66.50</td>
</tr>
<tr>
<td>Earth shoulders</td>
<td>164.00</td>
</tr>
<tr>
<td>Wearing surface</td>
<td>1067.17</td>
</tr>
<tr>
<td>Flood protection</td>
<td>31.25</td>
</tr>
<tr>
<td>Misc.</td>
<td>10.86</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1339.78</strong></td>
</tr>
</tbody>
</table>

Taking into account the length of the various sections and the time when they were accepted for maintenance, the above total resolves itself into $104 per mile per year.

The volume of traffic has greatly increased on this road since completion. A traffic census taken in 1919 before construction started and another on February 14, 1922 are compared below:
<table>
<thead>
<tr>
<th></th>
<th>1919</th>
<th>1922</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trucks</td>
<td>4.00%</td>
<td>9.00%</td>
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<tr>
<td>Wagons</td>
<td>7.57</td>
<td>3.00</td>
</tr>
<tr>
<td>Autos</td>
<td>88.43</td>
<td>88.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1040</td>
</tr>
<tr>
<td>Vehicles</td>
<td>251</td>
<td>.1040</td>
</tr>
</tbody>
</table>

The chief point of interest in this comparison, aside from the great increase in traffic volume, is the decrease in wagon traffic percentage and the increase in truck traffic percentage. In fact, the increase in truck traffic, both local and thru, has been so great that the Mo. Pac. Ry. connecting Hutchinson and Lyons has dropped two cars from their local freight train, which were formerly used for local freight between these two points.

In conclusion, experiences on this project here have led to the belief that monolithic brick is a strong pavement and capable of carrying a great volume of traffic. If constructed without expansion joints it is, of course, subject to blowouts which are local in effect and which do not injure the rest of the pavement. In a few years these will practically cease, and if these places have been properly repaired, there has been no harm done aside from temporarily inconveniencing the traveling public. Such a pavement is therefore not a failure. However, considering the constantly increasing volume of traffic
on our roads and the present small difference in cost between monolithic and bituminous filled brick, the Author is of the opinion that we should build all brick pavements hereafter of the latter type.
APPENDIX
SPECIFICATIONS FOR BRICK ROAD CONSTRUCTION.

DESCRIPTION.

78. A brick road shall consist of a wearing course of vitrified paving brick, placed on a properly prepared concrete base in accordance with the following specifications.

MATERIALS.

79. CEMENT. Unless otherwise provided under special clauses, all cement required for the work shall be furnished by the Contractor.

Cement furnished either by the County or by the Contractor shall conform to the following requirements:

The cement shall be some standard brand of Portland cement, which has been in practical use on public works and shall have proved satisfactory therein. No brand of cement shall be used which the Engineer deems unfit for the work, nor shall any cement be used which shall fail to give satisfactory results according to the Standard Specifications of Circular No. 38 of the United States Bureau of Standards. [Third edition, Jan. 18, 1917.]

One sack of cement will be considered as having a volume of ninety-five hundredths (.95) cubic-foot.

The Contractor shall notify the Engineer in writing of the brand or brands he intends to use, and before ordering the cement, shall receive from the Engineer written approval as to the brand selected. It is understood that such approval merely covers the selection of the brand; that the cement may be rejected if it fails to meet the requirements herein specified.

The Contractor shall provide sufficient means to protect the cement against dampness, and no cement shall be used which has become caked.

The Contractor shall furnish the cement so as to give twelve (12) days after delivery on the work in which to make and report the 7-day test. Cement failing to meet the requirements herein may be held awaiting the results of the 28-day test before rejection.

All cement shall be plainly marked so as to be easily identified.

All cement rejected by the Engineer shall be removed from the work at once.

FINE AGGREGATE FOR BASE.

80. Fine aggregate shall consist of clean quartz or other equally hard grains and shall not contain over three (3) per cent by weight of organic matter or clay combined, nor to exceed one-half (1/2) of one per cent by weight of organic matter. The fine aggregate shall be reasonably uniformly graded from a size which will pass through a one-quarter (1/4) inch square mesh to finer particles. Sand containing shale, slate, decomposed limestone, gypsum or other deleterious matter shall not be used. In no case shall fine aggregate containing lumps of frozen material be used. Fine aggregate shall be of such a quality that the mortar composed of one (1) part Portland cement and three (3) parts fine aggregate by weight, when made into briquettes, will show a tensile strength at least equal to the strength of one (1) to three (3) mortar of the same consistency, made with the same cement and standard Ottawa sand.

The percentage of fine aggregate passing screens of various sizes shall be within the limits of the following table:

<table>
<thead>
<tr>
<th>Size of screen</th>
<th>Allowable limits of percentage passing through.</th>
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</thead>
<tbody>
<tr>
<td>1/4 inch square mesh</td>
<td>Not less than 95.</td>
</tr>
<tr>
<td>3/8 inch square mesh</td>
<td>Not less than 80 nor more than 95.</td>
</tr>
<tr>
<td>1/2 inch square mesh</td>
<td>Not more than 20.</td>
</tr>
<tr>
<td>3/4 inch square mesh</td>
<td>Not more than 5.</td>
</tr>
</tbody>
</table>

COARSE AGGREGATE FOR BASE.

82. The coarse aggregate shall consist of clean, hard, sound gravel or crushed stone having a reasonably uniform gradation between the sizes specified. Material composed in part of slate, shale, disintegrated limestone or other equally soft stone shall not be used. Crushed granite, trap or limestone graded to the sizes provided above may be used, but in no case shall coarse aggregate be used which has a French coefficient of wear of less than six (6). The wearing test shall be made in accordance with the method recommended by the United States Department of Agriculture Bulletin No. 347.

Coarse aggregate shall contain no clay or other fine material, and shall be clean. In no case shall coarse aggregate containing lumps of frozen material be used.

The coarse aggregate shall conform to the sizes indicated in the following tables of gradation:
84. Fine aggregate and coarse aggregate mixed, usually termed unscreened gravel, may be used subject to the following requirements:

Each aggregate shall in all respects comply with the preceding specifications for the respective aggregates for the base.

When so used, frequent tests will be made to determine the relative proportions of sand and stone, and in case the relative proportions of sand and stone are excessively irregular, so as to make it practically impossible to proportion the concrete properly, the Engineer may require the material to be screened and reproportioned.

In all cases where unscreened gravel is used, one (1) part by volume of cement shall be used to each three (3) parts of fine aggregate contained in the gravel and the ratio of the fine to the coarse aggregate of the gravel shall not be less than as three (3) is to five (5), nor greater than as six (6) is to five (5).

FINE AGGREGATES AND COARSE AGGREGATE MIXED FOR BASE.

85. Where curbs are required, the aggregates shall be of the same character, quality and gradation as are specified for the base.

LONGITUDINAL EXPANSION JOINTS.

86. Where curbs are required, a longitudinal expansion joint shall be made between the brick edge and one curb. The joint filler shall consist of a suitable high-grade wool felt or bituminous fiber, combined with either coal tar or asphalt. The filler shall contain by weight not more than eight (8) per cent of mineral matter and not less than five (5) nor more than twenty-five (25) per cent of fiber. The felt shall be one-quarter (1/4) of an inch in thickness, of such width as to be flush with the brick of the finished individual curb and in length of not less than four (4) feet.

The Contractor shall submit samples and receive the approval of the Engineer for the particular felt or bituminous fiber to be used before it shall be employed in the work.

WATER.

87. The water used in mixing concrete shall be clean, free from silt, clay, oil, acid, alkali, vegetable or other deleterious matter.

SAND FOR BED AND GROUT FILLER.

88. Sand for the bed and for the grout filler shall be composed of clean, sharp quartz, or other equally hard and durable grains, passing, when dry, a one-sixteenth (1/16) inch square mesh sieve. The sand shall also be of such a quality that the mortar composed of one (1) part cement and three (3) parts sand by weight, when made into briquettes, will show a tensile strength at least one hundred (100) per cent of the strength of one (1) to three (3) mortar of the same consistency made with the same cement and standard Ottawa sand.

The grains shall be rather uniformly graded in size from coarse to fine, but not more than twenty (20) per cent by volume shall pass a sieve having fifty (50) meshes to the inch.

Sand shall not contain more than three (3) per cent by weight, of organic matter and clay combined, nor shall it contain more than one-half (1/2) of one (1) per cent of organic matter.

BRICK.

89. Brick for the pavement shall be of a type, quality and size commercially known as vitrified paving brick. Where it is indicated on the plans or in the proposal that four (4) inch brick are to be used, the brick shall be three and one-half (3 1/2) inches in height, by eight and one-half (8 1/2) inches in length, and from these dimensions they shall not vary more than one-eighth (1/8) of an inch in this direction, nor more than one-half (1/2) of an inch in length. Where it is indicated on the plans or in the proposal, that three (3) inch brick are to be used, the brick shall be four (4) inches in width, three (3) inches in depth and eight and one-half (8 1/2) inches in length, and from these dimensions they shall not vary more than one-eighth (1/8) of an inch in this direction, nor more than one-half (1/2) of an inch in length. They shall be thoroughly annealed, tough, durable and evenly burned. When broken they shall show a dense, stone-like body, fairly uniform in color and free from lumps of uncrushed clay, lime or air pockets, and show but slight laminations or other defects which would tend to depreciate their value as paving material. Kiln marks or surface cracks shall not exceed three-sixteenths (3-16) of an inch in depth. The brick shall be straight with at least one suitable wearing face, and no brick disfigured so as to lie unevenly in the pavement shall be used. All repressed brick shall have at least two (2) and not more than four (4) lugs on one side only. These lugs shall not project more than one-fourth (1/4) of an inch nor less than one-eighth (1/8) of an inch. If the edges of repressed brick are rounded, the radius shall not exceed three-sixteenths (3-16) of an inch. Wire-cut brick shall provide for a uniform spacing of one-eighth (1/8) of an inch to one-fourth (1/4) of an inch. Plane wire-cut brick shall not be used.

The brick shall be tested in the standard rattler recommended by the National Paving Brick Manufacturers' Association. The method of testing shall be that recommended by the American Society for Testing Materials, Year Book 1915, except that the companion pieces are not required. When so tested, four (4) inch repressed brick shall show an average loss by abrasion of not more than twenty-two (22) per cent, and a loss for individual bricks of not more than twenty-eight (28) per cent. Four (4) inch repressed brick showing larger average abrasion losses than twenty-two (22) per cent will be accepted only under the following conditions:
For rolling a monolithic brick pavement, a roller approximately thirty \( \frac{3}{16} \) inch \( \times \) 90. The pavement shall be placed between steel side forms. The side forms shall be of a width equal to the thickness of the pavement at the edge for monolithic construction; and a width equal to the thickness of the base for the sand-cement superfoundation type. They shall be accurately set to the alignment and grade of the pavement, for the monolithic type, and to the horizontal and vertical alignment of the base for the sand-cement superfoundation type, and shall be held securely in place by adequate stakes and bracing. Intermediate and longitudinal form boards will not be permitted between the side forms to support the template.

The forms shall be clean before concrete is deposited against them. The Contractor shall provide sufficient forms so that it will not be necessary to remove them before twenty-four (24) hours after the concrete is placed.

The amount of water to be used shall be that which will give a consistency, after mixing, so that a pile of the concrete will tend to flatten, but not run freely at the edges. The consistency shall be such that the concrete will not require tamping, or, if tamped, the water will flush to the surface with two or three blows of the tamper.

7.99-8
MIXING CONCRETE.

95. Concrete shall be mixed in a batch mixer of a type approved by the Engineer. No mixer shall be used which requires less than one sack of cement per batch.

A mixer provided with either an open chute or boom and bucket for delivering concrete may be used. If the bucket in a boom and bucket mixer is of a type that discharges by the opening of flap doors at the bottom, the doors shall be so designed as to prevent the water or fine material from leaking out before the batch is dumped. Care shall be taken to see that the doors are closed tight before the concrete is discharged from the mixer into the bucket.

When an open chute mixer is used, the pitch of the chute shall be steep enough to deliver concrete of the proper consistency. The angle of the chute shall be at least twenty (20) degrees with the horizontal.

While revolving at a uniform rate of from twelve (12) to sixteen (16) revolutions per minute, all the material for a batch of concrete, including water, shall be mixed for at least one minute. If a thorough mixing of the concrete in the opinion of the Engineer is not effected by this process, a sufficient number of additional revolutions at the same rate shall be given until a thorough mixing of each batch of concrete is secured. The concrete when mixed shall be of a uniform color and consistency.

No material for a batch of concrete shall be placed in the drum of the mixer until all of the previous batch has been discharged therefrom. Water shall be added at the time the materials are being run into the mixer.

RETEMPERING.

96. Retempering of mortar or concrete which has partially hardened—that is, mixed with additional materials or water—will be absolutely prohibited.

CONCRETE SHALL NOT BE PLACED DURING FREEZING WEATHER.

97. Concrete shall not be mixed or placed when the temperature is at or below 35°F.

All concrete placed when the temperature shall reach 35°F. or below within eighteen (18) hours thereafter shall be at the Contractor's risk and shall be replaced at his own expense upon written notice from the Engineer.

Concrete shall not be placed upon a frozen subgrade.

MONOLITHIC TYPE OF CONSTRUCTION.

98. When it is indicated on the plans or in the proposal that the monolithic type of construction is to be used, the following specifications shall apply:

CONCRETE BASE.

99. The concrete for the pavement base shall consist, by volume, of one (1) part cement, three (3) parts of fine aggregate and five (5) parts of coarse aggregate where the fine and the coarse aggregates are used separately. Where unscreened gravel is used, the concrete shall comply with the requirements of Article 84.

The concrete for the base shall be placed between the forms as mentioned, the entire thickness of the concrete being placed at one time. The concrete shall be placed also in successive batches for the entire width of the pavement and in a continuous operation. In placing the concrete base, the workmen shall be guided by a light wood template resting on the side forms, so made as to leave the concrete a little in excess of the depth required. The upper surface of the base shall be smooth, true, uniform and parallel with the surface of the finished pavement.

MORTAR BED.

100. Over the concrete base, immediately after it is placed, shall be drawn a multiple steel template consisting of a six (6) inch I-beam in the front and a six (6) inch channel in the rear, both being placed in a metal frame and fixed two (2) feet apart center to center. At each end the metal template shall be mounted on two (2) rollers, at least three (3) feet apart, which ride on the side forms. The I-beam shall be three-sixteenths (\(\frac{3}{16}\)) of an inch lower than the channel, and shall strike off the concrete base practically to a true surface. The center space between the I-beam and the channel shall be kept filled with dry mortar.

The concrete base shall be covered with a three-sixteenths (\(\frac{3}{16}\)) inch coating of this dry mortar, consisting of one (1) part of Portland cement to three (3) parts of sand. The coating shall be smooth. The rear template distributes the thin film of dry mortar over the surface of the concrete base, leaving the surface entirely smooth.

This type of multiple template, constructed of the I-beam, channels, rollers, etc., is an essential of this type of brick pavement construction and no substitute will be accepted therefor, unless approved in advance by the Engineer.

LAYING BRICK.

101. Before the fine grading is finished the brick shall be hauled and neatly piled without the edging line in sufficient quantities to complete the brick surface.

Clamps and conveyors may be used in connection with this work, but the bricks shall not be dumped from industrial cars or vehicles, nor shall they be thrown to piles or to industrial cars or vehicles. The brick shall not be piled in any place where they will be scattered over or covered with mud or concrete, or otherwise injured.

In delivering the brick from the piles for placement in the pavement, no wheeling in barrows will be allowed on the brick surface, but they shall be carried on pallets. They shall be placed upon the pallets so that when delivered to the dropper they will lie in such order that each brick, in the regular operation of placing it upon the foundation as prepared, will bring the lugs in the same direction with the best side uppermost.

Upon the foundation as prepared the brick shall be laid immediately with the best side up, the lugs (if lugs are used to provide spacing) in one direction and with the courses straight and at right angles to the edging line. All joints shall be closed up and courses straightened by tapping lightly-with a brick on a four-by-four-inch timber, three feet in length, provided for that purpose. Nothing but whole bricks shall be used except in starting and finishing courses, or in such cases as may be directed by the Engineer. The cutting and trimming of the brick shall be done by experienced men, and the fractured ends shall be turned toward the center of the pavement. For closures, nothing less than three (3) inch bats shall be used. Broken and chipped brick suitable for battelling shall be used to the extent of obtaining the necessary half brick for breaking courses and making closures, instead of breaking otherwise whole and sound brick. All brick when laid shall be free from frost and clean, and shall be kept clean and entirely free from dirt or other foreign matter until the pavement is completed. All the work of bricklaying shall be done over the brick already laid.

Immediately after the brick have been laid, the chips shall be swept from the pavement and all soft brick removed. Brick broken or badly spalled or misshapen shall be turned over or removed by the Contractor. Rejected brick, suitable for battling in, shall be carried forward and used for that purpose; the remainder shall be placed in separate piles along the road.
ROLLING BRICK.

102. After the pavement has been swept clean, it shall be rolled. The rolling shall be kept close to the laying and shall be continued until the pavement is smooth. Portions of the pavement inaccessible to the roller shall be tamped by the use of hand tampers applied upon a two (2) inch plank. If, upon inspection of the joints, the foundation has been forced up between the brick more than one-fourth (1/4) of an inch, the brick shall be relaid and rerolled. After the final rolling, the surface shall be tested with a ten (10) foot straightedge laid parallel with the center line of the pavement, and any variations exceeding one-fourth (1/4) of an inch from the surface provided for by the plans shall be corrected. At the end of a working period, the bricklaying, inspection, rolling and grouting shall be complete as far as the foundation has been laid. Under no conditions shall the rolling of the brick be delayed until after the initial set has taken place in the foundation.

CEMENT GROUT FILLER.

103. The cement grout filler used in filling the joints in the brick surface shall consist of one (1) part by volume of cement and one (1) part sand, the materials to be of the character specified herein. The sand, cement and water for grout shall be thoroughly mixed in a batch grout mixer of a type approved by the Engineer. The grout when mixed shall be of a uniform color and consistency, which consistency shall be thinner than thin cream. No grout shall be applied to the pavement if the materials show signs of separation of the sand from the cement.

Immediately after having thoroughly wet the brick surface, the mortar shall be applied thereto. During this application the mortar shall be mixed constantly. Immediately upon reaching the brick, the mortar shall be brushed into the openings between the brick with a coarse rattan broom, the broom being worked across the courses in a diagonal direction. The operation of filling the joints shall be carried along continuously. After the first application has set, and before the initial set has developed, the surface shall be gone over a second time in the same manner, except that the consistency of the mortar shall be somewhat thicker than that which was used for the first filling of the joints, and that a squeegee shall be substituted for the coarse rattan broom for brushing the mortar into the openings between the brick. As many different applications of the mortar shall be made as are deemed necessary, in order to fill completely the openings between the bricks, and each successive application after the first one shall be attended by the use of the squeegee instead of the rattan broom. When completed there shall be practically no excess mortar on the surface. The joint shall be filled flush with the surface of the pavement. As soon as the first one shall be attended by the use of the squeegee instead of the rattan broom. When completed there shall be practically no excess mortar on the surface. The joint shall be filled flush with the surface of the pavement. As soon as the joint shall have been filled the surface shall be inspected, and if approved shall be covered with sand kept wet for ten (10) days, and the Contractor shall permit no traffic on the roadway for three (3) weeks. The entire operation of grouting the bricks shall be carried on in longitudinal sections of the road. While being grouted, each section of the pavement to be separated from the immediately adjacent section by tin headers being placed between two adjacent courses of brick and extending entirely across the width of the pavement. These tin headers shall be effective to the end that the grouting of the bricks in any particular section shall be the delayed against a vertical plane.

The grout filler shall not be applied when the temperature reaches 35° F., and if the temperature reaches 35° F. within one (1) week after the filler is applied, the Contractor shall not permit any traffic on the pavement until so authorized by the Engineer. Upon the close of each day's work the grouting shall be completed on all brick that have been laid.

WIDTH AND THICKNESS OF BRICK PAVEMENT.

104. The brick pavement shall have, after completion, the width and thickness shown on the plans. If a greater width or thickness is laid than that shown on the plans, no extra compensation will be made therefor.

SAND-CEMENT SUPERFOUNDATION TYPE.

CONCRETE BASE.

105. When it is indicated on the plans or in the proposal that the sand-cement superfoundation type of construction is to be used, the following specifications shall apply.

The concrete for the pavement base shall consist, by volume, of one (1) part cement, three (3) parts of fine aggregate and five (5) parts of coarse aggregate where the fine and the coarse aggregates are used separately. Where unscreened gravel is used, the concrete shall comply with the requirements of Article 84.

The concrete for the base shall be placed between the forms aforementioned, the entire thickness of the concrete being placed at one time. The concrete shall be placed also in successive batches for the entire width of the pavement and in a continuous operation.

The base shall be struck true to shape by means of a template, which shall be drawn along supported by the forms. After the base has been placed it shall be kept wet for four (4) days, and no hauling upon it or rolling or tamping of brick will be permitted for two weeks. Should there appear any uneven places in the surface of the base to exceed one-fourth (1/4) of one (1) inch from the proper shape as shown on the plans, then all such uneven places shall be repaired, so that the upper surface of the base shall be smooth, true, uniform and parallel with the surface of the finished pavement.

SAND-CEMENT BED.

106. Before placing the sand-cement bed, side forms shall be in place in conformity with the alignment of the finished pavement. These forms shall be such as to confine both the sand-cement bed and the grout filler, and shall not be removed within twenty-four (24) hours after the grouting of the pavement.

The bed shall consist of one (1) part of cement to three (3) parts of fine aggregate, thoroughly mixed dry until there exists a uniform consistency. It shall be spread dry upon the concrete pavement base to a thickness of approximately three-fourths (3/4) of an inch. After the bed has been carefully spread it shall be struck off to the desired cross-section by means of a template drawn along the top of the forms. The template shall be so adjusted as to give a thickness to the bed of three-fourths (3/4) of an inch. The operation of shaping the concrete foundation for the pavement and of shaping the bed for the brick are considered as of prime importance in elements and to secure skilled men for this part of the work.

All bed placed upon the concrete base shall be covered with brick the same day, and all bed placed in excess of what can be covered with brick the same day shall be removed from the base prior to the close of the day's work.
The Contractor shall take due precaution, by the use of tarpaulins or otherwise, to protect the bed against dampness, dust or dirt, until the brick have been laid and rolled. Bed that becomes moistened or covered with dust or dirt prior to the rolling of the brick shall be removed and replaced with new dry bed by the Contractor at his expense.

Attention is here called to Article 109 of the specifications, which provides for the removal of depressions that appear in the completed brick surface.

LAYING BRICK.

108. The brick shall be laid in accordance with Article 101, as previously specified for the monolithic type of construction.

ROLLING BRICK.

109. The brick shall be rolled with the type of roller heretofore specified, the rolling first being in a longitudinal direction, the roller being moved slowly and worked gradually from the curb to the middle of the pavement. It shall then be taken to the opposite side and the other half of the surface rolled in the same manner. The surface shall then be rolled a second time, the roller being worked diagonally across the pavement at as near an angle of forty-five (45) degrees as is possible on the width of pavement, the roller being manipulated in such a manner as to cover the entire surface during the diagonal rolling. When this has been completed the brick shall be again inspected and any broken or damaged brick removed and replaced, after which the brick shall be rolled a third time, the roller moving diagonally across the surface in the opposite direction from the first diagonal rolling.

After the brick have been given the final rolling, the pavement shall be tested crosswise by means of a suitable template, and any depressions of one-quarter (\(\frac{1}{4}\)) inch or more shall be removed. In like manner the surface shall be tested by means of a ten (10) foot straight edge laid parallel to the center line of the pavement, and any depressions one-quarter (\(\frac{1}{4}\)) inch or more in depth shall be removed. The surfaces of adjacent brick shall not differ in elevation more than one-sixteenth (\(\frac{1}{16}\)) inch. In removing the depressions, all of the brick that are below grade shall be removed and cement and sand added to the bed, which shall be tamped and shaped so that when the brick are replaced and tamped they will conform to the proper surface.

Upon the final rolling of the brick the joints shall be tested, and if in any parts of the pavement it is found that the bed has been rolled up between the brick more than one-half (\(\frac{1}{2}\)) of an inch, that part of the brick shall be removed and replaced in conformity with the above requirements.

CEMENT GROUT FILLER.

110. The cement grout filler used in filling joints shall be mixed and placed in accordance with Article 103 for the monolithic type of construction, and all the requirements of that article shall apply equally to the sand-cement superfoundation type.

WIDTH AND THICKNESS OF BRICK PAVEMENT.

111. The brick pavement and the concrete curbs (if required) shall have, after completion, the width and thickness shown on the plans. If a greater width or thickness is laid than that shown on the plans, no extra compensation will be made therefor.
Standard Proportions for Base, Project 15, Sec. A.
31/2" x 51/2 base - 26852 cu. yds. per 100 feet.

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Computed and recommended for approval
by A. A. ANDERSON
Division Engineer

Approved DEC 2 1920 1920.

M. W. WATSON
State Highway Engineer.
REPORT ON SAMPLE OF Concrete Cylinders

Laboratory No. 2017
Compression Specimens. Received 10-6-20 to 10-21-20
Submitted by W. A. Stacey, Engineer for Reno Co
Sampled from Concrete as run on job

Source of material F. A. P. #15 Reno County Kansas.
Examined for Crushing strength

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<td>28</td>
<td>&quot;</td>
<td>1-4½</td>
<td>2560</td>
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<tr>
<td>23</td>
<td>C</td>
<td>28</td>
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<td>1-4½</td>
<td>3110</td>
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<td>C</td>
<td>28</td>
<td>&quot;</td>
<td>1-4½</td>
<td>2160</td>
</tr>
</tbody>
</table>

2475# av. for 28 days

Cylinders 1 to 8 previously reported under Lab. #1870
Respectfully submitted,

C. H. SCHOLER
Engineer of Tests.
Mr. M. W. Watson,  
State Highway Engineer,  
Topeka, Kansas.

Dear Sir:  

re: Monolithic Brick Failures

I was very much interested in your article on "Monolithic Brick Pavement Failures in Kansas" which appeared in the "Engineering News Record" of September 23, 1920, because of the almost exact similarity between the cases which have come under your observation, and certain failures which we have experienced in King County, Washington, on similar type of construction.

We have in this county a monolithic brick pavement 20 feet in width and 9.6 miles in length known as the Seattle-Des Moines Highway, carrying a very heavy traffic owing to the fact that it is the shortest route between Seattle and Tacoma. This pavement has a concrete base with a thickness of from three to five and one-half inches, a surface of brick block with a thickness of 2 1/2 in. constructed under specifications very similar to yours and designed to make a monolithic structure of the whole. Commenced in the year of 1916, the work was carried on through the winter and the pavement was finally completed in the summer of 1917. The specifications originally called for a pavement without transverse joints and at the end of each day's run the concrete base was finished off with a bevel having a horizontal length of about 1 foot; on the following day this bevel was thoroughly cleaned and painted with cement grout before resuming operations.

In the spring of 1917 during the first heated period when the temperature of the air rose to approximately 90° there occurred numerous failures in the section already completed the action of which and the general appearance were precisely as outlined in your article. These fractures occurred at intervals in one section of the road spaced about 500 feet apart.

In one instance, where the fracture was in process of forming, it was noted that the brick top had separated from the base for a length of about 18 feet measured along the road, making a low flat arch with a rise of four inches. The length of the arch could be clearly defined by tapping the surface of the brick with a pebble and noting where the solid sound gave place to the hollow one noted...
at the line of separation. These breaks all occurred
at the end of one day's work and were apparently caused
by the one section of the base slipping over the
other along the bevelled plane connecting the two days
work. Repairs were effected by cutting through the base
and putting in expansion joints of bituminous material
and relaying the brick surface with a binder of the same
material. The balance of the work thereafter was carried
out by placing regular expansion joints passing through
the base and the brick at intervals of about 30 feet.
Again in 1918 and in each succeeding summer with the advent
of hot weather there have been numerous breaks along this
highway regardless of the fact that expansion joints had
been provided, and, until your article appeared in the
Engineering News, taking away our conceit, also our sense
of lonesomeness, we were beginning to feel that we had
something unique in the form of pavement.

During the past summer in repairing these
breaks, we have excavated through the concrete base for
a width of one foot or more and backfilled the opening
with bituminous concrete carrying it up flush with the
surface of the brick pavement hoping that this would pro-
vide an expansion joint which would prevent further acci-
dents in the immediate vicinity of the broken section.
Like yourself I am convinced that monolithic brick pavements
are not in any sense of the word monolithic structures as
the surfaces and the base in expanding and contracting does
not seem to work together as a single unit. As you may
know, the climate in this section is nearly always uniformly
cool and practically all work of laying concrete pavement
or concrete base is done at relatively low temperature;
any time the temperature of the air rises above 70 or 75
in this section, roads are placed under compressive stress,
however the majority of breaks occurring in the past two
seasons have been in those sections which were laid during
the warmest season of the year. Believing that you might
be interested in the close resemblance between our ex-
periences in monolithic brick failures, I am

Very truly,

(SIGNED)     SAMUEL J. HUMES,
                 KING COUNTY ENGINEER.
REPORT ON SAMPLE OF Sand & Gravel

Laboratory No. 2377  March 3, 1921
Name Sand & Gravel
Identification marks #2
Submitted by W. A. Stacey, Resident Engr.

Sampled from Pit on William Brownley property
Quantity represented 10000 cu. yds.
Source of material Sec 31, T24S, RLOW, Reno county, Kans.
Location used or to be used F.A.P. #27 Sylvia, Reno county, Kans.
Examined for Concrete in base for brick road.

<table>
<thead>
<tr>
<th>SAND</th>
<th>MECHANICAL ANALYSIS</th>
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<tbody>
<tr>
<td>Fraction</td>
<td>%</td>
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<tr>
<td>Retained on ¼” screen</td>
<td>15.8</td>
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<td>Passing ⅛”, retained on 10 mesh</td>
<td>18.0</td>
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<td>Passing 10, retained on 20 mesh</td>
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<tr>
<td>Passing 20, retained on 30 mesh</td>
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<tr>
<td>Passing 40, retained on 50 mesh</td>
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<td>Passing 50, retained on 80 mesh</td>
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<td>1.1</td>
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<tr>
<td>Passing 200 mesh</td>
<td>1.1</td>
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<tr>
<td>Total</td>
<td>99.7</td>
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</table>

Loss by washing (silt and clay) 1.0 %
Organic matter in sand Colorimetric test 0.0 %

<table>
<thead>
<tr>
<th>GRAVEL</th>
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<td>Retained on 1⁄4” screen</td>
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<td>Passing ⅛”, retained on 10 mesh</td>
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<tr>
<td>Passing 10, retained on 20 mesh</td>
<td>0.3</td>
</tr>
<tr>
<td>Passing 20, retained on 30 mesh</td>
<td>0.3</td>
</tr>
<tr>
<td>Passing 30, retained on 40 mesh</td>
<td>0.3</td>
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<tr>
<td>Passing 40, retained on 50 mesh</td>
<td>0.0</td>
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<tr>
<td>Passing 50, retained on 80 mesh</td>
<td>0.3</td>
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<tr>
<td>Passing 80, retained on 100 mesh</td>
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<tr>
<td>Passing 100, retained on 200 mesh</td>
<td>0.3</td>
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<tr>
<td>Passing 200 mesh</td>
<td>0.3</td>
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<tr>
<td>Total</td>
<td>99.8</td>
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Per cent of wear - -
Cementing value - -
Character of material A clean coarse siliceous sand containing some gravel.

TENSILE STRENGTH (Cement-Sand Briquettes—1 : 3)

<table>
<thead>
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<th>Std. Ottawa Sand</th>
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<tr>
<td>3 day 7 day 28 day</td>
<td>3 day 7 day 28 day</td>
</tr>
<tr>
<td>300</td>
<td>300</td>
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<tr>
<td>280</td>
<td>320</td>
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<td>275</td>
<td>310</td>
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<tr>
<td>285</td>
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</table>

Str. Ratio 109

Remarks: Results indicate a material satisfactory for use in concrete and with proper proportioning will give good results.

Respectfully submitted,

Name
Ass't Testing Engr.