NEW DEVELOPMENTS IN MAINTENANCE OF CONCRETE AND BRICK ROADS

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Large sums of money are being invested annually in the construction of concrete and brick pavements. It is important that the most economical means of maintaining and repairing such pavements be determined and put into practice in order that these large investments shall be protected. It is important that every type of road be properly maintained. Unless it is contemplated to properly care for the more costly types of pavement, we can not justify ourselves in building them.

Although the highways are now a controlling factor in our modern civilization and the transportation feature of them is the big development which stands out most prominently and is most impressed upon the general public, yet it is imperative that many little technical details be learned and put into practical effect in order to economically build and maintain a system of good highways.

A number of people throughout the country are now devoting much of their time to a study of the best methods of maintaining such pavements. Almost every year finds some new discovery, or perhaps we better say an old discovery put into practical application, in the maintaining and repairing of our highways. We are doing this year what was never thought of a few years ago or what was done only in a haphazard or an experimental way.

In a discussion of the subject of this paper, I will try and describe briefly some features of this work which are more or less new or which I consider very important in ordinary practice in doing highway maintenance work. The larger part of the paper, however, will be devoted to a discussion of making concrete repairs with quick hardening concrete. The use of such concrete will be a great advantage to the general public in that a road need not be closed long to traffic because of the repairs.

A. Filling Cracks and Joints

Monolithic types of pavement are all subject to cracking. While these differ greatly in degree they are not necessarily any serious detriment to the pavement. Observation will show, however, that usually the more frequently the cracks are found the more defective is the concrete or the poorer the sub-grade.
The cracks and joints in such pavements should be sealed about twice a year so as to keep the pavement water-tight and thus prevent, so far as possible, water from reaching the subgrade. Also, the cracks should be filled to prevent the edges from raveling.

Our experience would indicate that the most suitable material for filling such cracks is asphalt meeting our specification for Emulsified Asphalt A. E.-1 or tar meeting our specifications for Tar T. P.-2. The former material is used cold while the latter has to be heated before it is poured into the cracks.

Both materials are covered with coarse sand, or stone or slag about $\frac{3}{4}$ inch in size. The bituminous material can best be poured into the cracks from a small pouring can preferably not exceeding two gallon capacity. A small can will aid in preventing the use of too much of the asphalt or tar which is very objectionable. The use of an excess of the bituminous material will build up a ridge across the pavement which is quite as objectionable as the unfilled crack. In addition to the neglect to fill the crack, I know of no more frequent mistake than the persistent use of an excess of the bituminous material. The crack should be just filled with the asphalt or tar which should be permitted to lap over on the spalled edges of the concrete no farther than is necessary to merely protect same. Experience and observation will soon teach one how much material to use. After the filler has been subject to traffic for a few days, the crack filler should project above the level of the pavement no more than $\frac{1}{4}$ inch. The filling of the cracks can be properly done if a little care is used in the work. Too frequently the work is done with the grossest carelessness.

Because the filler is splashed out of the crack by traffic going over it just after it is poured, it is desirable on a heavy traffic road to fill the cracks in but one side of the pavement at a time. The filling operations themselves will keep the traffic off the newly filled cracks for a short time which is usually all that is necessary.

The repair of cracks in Monolithic brick pavements can be made in the same manner as cracks in concrete pavements.

Emulsified asphalt, if subjected to freezing temperatures before the water evaporates, will be injured and hence it can not be successfully used during the winter season. Very small cracks may be filled during the winter season, with cold tar meeting with our specifications for Tar T. C. M. This grade of tar cannot be successfully used to fill cracks in its pure state during the summer season as it is too liquid and will readily flow from the cracks.
Where the **cracks are sufficiently wide** the edges should be painted with one of the above grades of bituminous materials and then tamped full of bituminous concrete made by mixing either emulsified asphalt AE-1 or tar TCM with a graded stone. The maximum size of stone should be no greater in diameter than \( \frac{2}{3} \) the width of the crack or the depth of the depression to be filled and should be graded down to \( \frac{3}{4} \) inch size. If tar is used to make the mix it should contain practically no dust and little material that will pass the \( \frac{3}{4} \) inch. If the asphalt is used, 10 per cent to 20 per cent of the stone may pass the \( \frac{3}{4} \) inch and a **small** amount of dust is not objectionable. If there are visible voids in the mixture used to fill the cracks after same are tamped into the crack, they may be filled with a paint coat of the emulsified asphalt or hot tar TP-2 and covered with sand.

**B. Surface Disintegration or Depressions in the Surface**

Very shallow disintegrated areas may be painted with emulsified asphalt or the hot tar and covered with coarse sand or stone or slag screenings. If the depression is of any appreciable depth, after the surface is painted, it should be built up to the proper elevation by tamping into the paint coat one of the bituminous mixtures mentioned above. For this latter purpose rock asphalt or any one of the hot mix bituminous concretes may also be used.

In making such patches it is exceedingly important that the surface be brought to a true and uniform grade so as to have, when completed, a smooth riding surface. A straight edge should be applied parallel with the line of the traffic to aid in determining the smoothness of the surface. It is also important that no great excess of bituminous material be used in painting the old surface and that the **minimum** amount of the bituminous material be used in the mixture in order to reduce as far as possible the possibility of the surface waving and rolling under future traffic.

**C. Sub-grade Defects—Base Failures**

It is not uncommon to find the pavement failing because of a poor sub-grade consisting of clay which saturates badly by capillary attraction. This is frequently a difficult problem to solve. Every effort should be made to drain the sub-grade as frequently springs are found in such clays. Besides having suitable side ditches, french drains can be constructed in the shoulders extending from about 1 foot below the lower edge of the pavement to the side ditches. If these fail to properly drain the sub-grade, the slab will frequently break up in time after much heavy trucking has gone over it. These breaks produce what are
known as a "base failure." Such failures frequently can not be prevented on such clay soils unless a layer of stone, gravel or cinders is placed upon the sub-grade before laying the pavement or the slab made thicker over such soils.

In repairing such base failures it will usually be desirable to make such repairs with quick hardening concrete as described in the next part of this paper.

D. Repair of Concrete (Portland Cement) Pavements with Quick Hardening Concrete Made with Ordinary Portland Cement

1. Importance of Doing Good Work

Where it is desirable to open the patch to traffic as soon as possible after it is made, it is necessary that a concrete be used that will attain strength rapidly. Since the patches are usually small, and hence small amounts of concrete are wanted at intermittent periods, there is much greater danger of making a poor concrete patch than a new concrete slab in the original construction, unless great care is taken in doing the work. Inasmuch as it is desirable to make a stronger concrete and one that will attain strength quicker than in a new pavement, it is extremely important that we comply with every detail for making a good patch, from the preparation of the sub-grade to the finishing of the surface and protecting it against traffic until sufficiently strong. Unless the work is so done as to comply with all the requirements to make a perfect repair it is far better that the repair be made with something else than concrete.

2. Cutting Away the Old Concrete

This can be done with picks, chisels, crowbars or jack hammer drill. The use of a paving breaker operated by a small portable air compressor is the most practical method if any quantity of work is to be done. All the broken and disintegrated concrete should be removed and the old slab cut back until solid, rigid, concrete is reached which has on top a smooth and uniform surface. The top edge of the old concrete should be trimmed by hand (with the use of hammer and chisel) to a uniform and vertical edge for a depth of about one inch below the top surface. The remainder of the vertical edge of the concrete should be left as rough as possible. The base of the old concrete should be thoroughly brushed to loosen any spalled concrete.
3. Preparing the Sub-grade

The sub-grade ordinarily should be excavated to a greater depth than the original slab. At its junction with the old pavement the new slab shall be increased 4 inches to 6 inches deeper than the thickness of the old slab. Also, the new concrete should extend back under the edge of the old slab (see Fig. 2). The depth of the new concrete should depend upon the nature of the subsoil. The old concrete slab has failed for a reason. Quite frequently this reason will be found to be the soft clay subsoil. Therefore, the thinnest depth of the new slab should usually be 2 inches to 4 inches deeper than the old pavement. In very bad spongy clay soil, not only should the depth of the new slab be increased but it is also an added factor of safety to tamp into the sub-grade a 3 inch to 4 inch layer of cinders, gravel, or broken stone with an outlet to the side ditch, as shown in Figure 2.

Fig. 1. Cutting away the old concrete with a paving breaker operated by portable air compressor.
This will reduce capillary action in the clay and also help drain the surrounding sub-grade.

4. Composition and Proportion of Concrete

The concrete for the patches usually should be of a better grade than that used in good new concrete paving construction and it should be a concrete that will attain strength quickly so as to accommodate traffic with little delay. If large areas are to be replaced economy would usually require a mix no richer than the standard mix concrete for paving. If only small areas are to be patched wherein the quantity of concrete involved is small, the added cost due to using a richer mix would not be so important an item. The time that traffic should be kept off the patch will determine the mix that should be used. The quick hardening concrete will depend for its early strength upon: (1) Richness of the mix; (2) freedom from excess water; (3) use of CaCl₂; (4) comparatively high atmospheric temperatures, and (5) coarse sand and properly graded sand and coarse aggregate. All of the above factors affect the time of hardening of the concrete mix. If we combine the most favorable features of all the above factors in one mix, we can make a concrete which assumes as much strength in two or three days as the ordinary concrete mix used in paving assumes in 21 days.

Traffic should be kept off the patch the number of days shown in Table I (page 59). During cold weather, traffic should be kept off the new concrete a longer period than given in the table as concrete gains strength slower at low temperature.

Cement should be tested at the laboratory and a report secured so as to know that it passes the required test. It is imperative that the cement is of good quality. Old cement that has lain around in a damp place until it has partly caked should not be used for this most important work. Some brands of cement attain greater strength than others at an early date. It is desirable to use such cement for repair purposes, if it can be conveniently secured.

Sand should be a comparatively coarse sand, 95 per cent of which passes ¼ inch mesh screen. It should be clean and free from silt or foreign material. The sand grains should be composed of hard gritty material and be what is ordinarily known as a "sharp" sand. Sand from many local banks, which, though graded fairly well, contains a large percentage of soft particles, is not desirable as it may produce a concrete which will not withstand the abrasion of traffic. Any amount of shale in the sand is detrimental to it and may cause failure of the concrete.
TABLE I.—SHOWING THE MIX OR PROPORTIONS OF MATERIALS TO USE TO SECURE CONCRETE THAT CAN BE OPENED TO TRAFFIC AFTER ANY NUMBER OF DAYS.

<table>
<thead>
<tr>
<th>Days Patch Closed to Traffic</th>
<th>Bags of Cement</th>
<th>Cu. Ft. of Sand (0 - ¾&quot;)</th>
<th>Cu. Ft. of Coarse Aggregate (½&quot; - 2½&quot;)</th>
<th>Lbs. CaCl₂ or Qts. of &quot;Standard Solution&quot;</th>
<th>Water Add enough to produce Slump given below</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td>1.9</td>
<td>2</td>
<td>1&quot;</td>
<td>11.8</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0.6</td>
<td>2.1</td>
<td>2</td>
<td>1&quot;</td>
<td>11.2</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1.0</td>
<td>2.7</td>
<td>2</td>
<td>1½&quot;</td>
<td>8.4</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>1.3</td>
<td>3.0</td>
<td>2</td>
<td>1½&quot;</td>
<td>7.6</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>2.0</td>
<td>3.0</td>
<td>2</td>
<td>1½&quot;</td>
<td>6.8</td>
</tr>
<tr>
<td>21</td>
<td>1</td>
<td>2.0</td>
<td>3.0</td>
<td>No CaCl₂</td>
<td>2½&quot;</td>
<td>6.8</td>
</tr>
</tbody>
</table>

(5) This "Standard Solution" is made by dissolving commercial CaCl₂ in water at the rate of one (1) pound to enough water to produce one (1) quart of solution. The pure CaCl₂ should never be added direct to the drum of the mixer. The "Standard Solution" should be added to the water just before it is put into the drum. See instructions under Calcium Chloride.

(6) Standard Slump Test. Fill with concrete a metal form shaped as a frustum of a cone. Form should be 12" high with a 4" top diameter and 8" base diameter. Set the form on a level surface and as the concrete is put in the form, tamp lightly with a rod until a slight film of mortar appears on the surface. Then remove the form and immediately note the settlement or slump of the concrete which is a measure of its consistency.
Coarse Aggregate should be crushed stone or gravel fairly well graded from \( \frac{1}{2} \) inch to 2\( \frac{1}{2} \) inches in size. If the concrete is to be used to fill a crack or very small opening, the maximum size of aggregate will have to be reduced accordingly. It is imperative that this coarse aggregate be clean and free from pieces of wood, dirt, silt, shale, or any soft particles. Rock of shale formation, although apparently hard and sound when first quarried, will cause failure of the concrete even though found in comparatively small quantities in the concrete.

Calcium Chloride will be furnished in 100 lb. bags, which must be kept closed as the exposure of the calcium chloride to the air will permit it to absorb moisture from the air and become liquid. It is quite important that the exact quantity of this material be used in each batch. An excess will weaken the concrete and insufficient calcium chloride will not hasten the time of setting to prevent the pavement from being injured by traffic when opened after the number of days given in the table. The calcium chloride must not be added directly to the drum as small undissolved particles remaining in the concrete will cause the concrete to disintegrate. The calcium chloride shall be added in the form of a "Standard Solution" made by thoroughly dissolving one pound of commercial calcium chloride in enough water to produce one quart of solution. (This is at the rate of about 2\( \frac{1}{2} \) quarts of the \( \text{CaCl}_2 \) to one (1) gallon of water.) This "Standard Solution" should be placed in a keg, jar, or barrel and labeled "Standard Solution." Two quarts of the solution for each bag of cement should be added to the mixing water just before it is put into the drum.

Water must be pure and free from vegetable acids. The amount of water will have to vary so as to make the concrete of the proper consistency. In practice this will usually be found to vary from 2 to 5 gallons of water per sack of cement. However, when all the aggregates are thoroughly saturated with water after a rain it may be found that 2 quarts of "Standard Solution" will be sufficient water to make the required consistency. It should be remembered that excess water will reduce the strength of the concrete and delay the hardening process and not only permanently weaken the concrete, but also lengthen the time traffic will have to be kept off the patch. In order to secure the quick hardening effect, the concrete will have to be a sufficiently dry mix that it will show no more than the slump given in Table I. (See description of slump test in footnote after Table I.) Great emphasis should be placed on the importance of guarding against using too much water. The use of 3 or 4 pints more water than is necessary in a one-sack batch will reduce the strength of the concrete more than it can be increased by ex-
tending the time of mix. Hence, while it is necessary to use enough water to make a concrete plastic enough to be worked and properly finished, guard against using too much water.

5. Dampen the Sub-grade and Old Concrete

The sub-grade and old concrete with which the new concrete comes in contact, should be wetted before the new concrete is placed. The sub-grade should be damp but not soft or sloppy. The edges of the old concrete should be saturated with water. It is very imperative, however, that no free water be present when the new concrete is applied, as the concrete that is to be opened to traffic soon after being placed depends largely for its quick strength upon having no excess water.

6. Mixing Concrete

Only machine mixed concrete should be used. It is almost impossible to get a maximum strength concrete, which is very imperative in repair work, if one depends on hand mixing. The usual time specified for mixing ordinary concrete in a mixer is one minute. However, tests show that the strength of a dry mix may be increased as much as 10 per cent by mixing one and one-half (1½) minutes, instead of one minute and the strength is slightly increased by extending the time to five (5) or ten (10) minutes. Hence, in repair work and where a small mixer is used, which will generally be less efficient than the big paving mixers, and where a dry mix is required for a maximum strength and quick hardening concrete, the time for mixing might well be placed at not less than two (2) minutes. This increased time of mixing will also make the finishing easier.

7. Placing and Finishing Concrete

Concrete should be shoveled in place and thoroughly tamped in layers not exceeding three (3) inches in depth. The secret of the early strength of the concrete will largely lie in a comparatively dry mix hammered in place. A 10 pound concrete tamper can be used for much of this work. A thin edged tamper having a face, say, 1"x6" should be available for tamping in narrow openings and along the edge and underneath the old slab.

The concrete shall be finished with a straight edge and a wood float, to a regular and uniform surface to comply with the edge of the surface of the old pavement and the side forms. The straight edge should be used both transversely and longitudinally on the new concrete where the patch is not too long to do so. Where a full width of pavement is being replaced for a length greater than it is practical to use a straight edge, a templet cut to the proper crown of the road should be used. This templet can be used both as a cutting edge and tamper to produce a
uniform surface. At either end of such a patch or straight edge should be laid longitudinally to insure a proper and uniform junction of the new concrete with the old pavement.

Fig. 3. Finishing the concrete patch. Great care must be exercised in this part of the work to secure a smooth riding surface.

8. Completing Patch at End of Day

Since in making these patches we are dealing with a quick hardening concrete, it is desirable that a patch be entirely completed before leaving it for any length of time. Due to difficulty of shaping up the surface to conform with the old concrete slab with a dry mix, a patch should be entirely finished soon after the concrete is placed. It is necessary that a patch be entirely completed, including the finishing, at the end of a day’s work.

The foreman should so plan his program that he can do other work for a fraction of a day if he has not time to entirely complete a patch before his workmen will quit work. Where large areas are being placed, a form board should be set vertically at the close of the day’s work and the patch, including the finishing, completed to same as is done in the proper construction of a new pavement. No feather edge junction should be permitted. Owing to the fact that we are dealing with a quick hardening concrete when using calcium chloride, it is necessary to do the finishing promptly after the concrete is placed and tamped. After the concrete hardens to any extent it is almost impossible to make a smooth finish. It is important that the template and straight edge be used on finishing a partially completed patch so that the surface of the road will conform with the proper crown of the road and the old concrete surface.
9. Protecting New Concrete Patch While Curing

The newly laid concrete should be protected against any and all kinds of traffic the number of days specified in the Table on page —. It is desirable that extremely heavy trucking be kept off the patch longer than this, particularly if the concrete is laid in cold weather as the concrete will harden slower in cold weather. The new concrete should be covered with six inches of earth or a layer of straw or sawdust, which should be kept dampened with water. Such covering should be kept on the new concrete about 2/3 of the length of the time traffic is required to stay off of same. The concrete should be protected against freezing the same length of time.

E. Cost of Concrete Repairs Made of the Quick Hardening Concrete Made of Ordinary Portland Cement

It will naturally cost much more to make concrete in small quantities as used in repair work than it will cost to make it in large quantities. Also the cost of cutting out the old concrete and making the excavation for the patch will be considerable. Furthermore, because of the variable conditions encountered with the different pavements being repaired, the costs will vary much more than in new work.

The best approximate cost data that we have been able to secure this past summer in making patches 9 inches deep of the quick hardening concrete made of ordinary Portland cement is as follows:

<table>
<thead>
<tr>
<th>First Job</th>
<th>Per Sq. Yd.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting out old concrete and making excavations</td>
<td>$0.83</td>
</tr>
<tr>
<td>Materials delivered (aggregates, sand, cement, CaCl₂)</td>
<td>2.70</td>
</tr>
<tr>
<td>Labor (excluding making excavations)</td>
<td>1.44</td>
</tr>
</tbody>
</table>

Total cost per square yard: $4.97

This cost includes 10 per cent added for equipment charge.

Second Job—$3.10 per square yard. No excavation.

Third Job—$3.10 per square yard. No excavation.

F. Aluminate Cement

A new brand of cement known as Aluminate cement has recently been put on the American market. This cement attains as large a per cent of its full strength in 24 hours as ordinary Portland cement attains in 28 days. For this reason it is very suitable for making repairs where quick strength is required. However, at the present prices quoted, it will cost more to make
concrete from this brand of cement than it will to make quick hardening concrete describe above from ordinary Portland cement. It is hoped that this brand of cement can be reduced in price and that the concrete made from it will not disintegrate or lose strength with age.

G. Blow-ups

Concrete slabs and brick pavements with grout filler occasionally rupture due to high compressive stresses caused by the combined expansive action of heat and moisture. Such ruptures are usually called "blow-ups" and almost invariably occur on a very hot day in the spring of the year when the subgrade is still saturated. The wetting of the pavement from above by a summer shower which is followed by a hot sun produces a maximum condition of expansion which causes the blow-ups to take place.

It is a well-known fact that the better and denser grades of concrete are not only stronger to resist the forces due to expansion, but are also more resistant to absorption and are much less liable to be destroyed by temperature and moisture stresses.

Where such ruptures as described above occur, it is usually desirable to remove the injured concrete and replace it with new concrete as described under heading "D" above.

Where a brick surface has blown up it is advisable after the base is repaired to replace the brick with bituminous filler to provide for future expansion of the pavement and thus aid in preventing future destruction of the pavement by the same means.