the cost to the city for the crushed brick (50 per cent of the coarse aggregate) is only that of crusher operation. Abrasion tests of the crushed brick aggregate were made by the University of Notre Dame Engineering Department, using the Los Angeles Abrasion Machine in accordance with A.A.S.H.O. Method T-96. The percentage of wear by this method was found to be 37.2 per cent. Similar tests of other local concrete aggregates by the same method gave results up to 50 per cent of wear.

In the Public Roads magazine of September, 1935, a comparison of A.A.S.H.O. Methods T-4 and T-96 for abrasion tests of aggregates is given as follows:

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>T-4</th>
<th>T-96</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vermont Granite</td>
<td>2.6%</td>
<td>33%</td>
</tr>
<tr>
<td>Michigan Limestone</td>
<td>3.4%</td>
<td>33%</td>
</tr>
<tr>
<td>Wisconsin Dolomite</td>
<td>4.1%</td>
<td>34%</td>
</tr>
</tbody>
</table>

From the above data, it is concluded that 40 per cent or less of wear by the T-96 method is acceptable.

Cores of brick-aggregate pavement have been taken and show satisfactorily the thickness of slab and physical characteristics of the mix; but the mechanical condition of the coring machine is such that clean-cut cores suitable for strength tests have not been obtained.

CEMENT-BOUND MACADAM ALLEY PAVEMENTS

Harry Overesch,
City Engineer, Lafayette

My subject is supposed to be "Cement-Bound Macadam Alley Pavements," but what I am about to describe is—an orphan. As a prominent cigarette maker says, "Something new has been added." If it doesn't prove out, I suppose I'll be called the orphan. The reason for its being runs like this: One day the Street Commissioner said, "What am I going to do with this alley? It is too far gone to patch. The property owners don't want to pay for materials, and I don't blame them much as the utilities tore it up and our own waterworks was one of the chief offenders." It had been built probably 50 years ago of 4" to 6" cobblestones laid on a sand cushion with the voids filled with sand. We have several miles of the same construction built before concrete or brick came into general use. Well, if the city has to pay for all the cost of materials, naturally you lie awake a few nights (no city engineer has any time in the daytime to think) wishing you were a magician or that you had the golden key to the treasure chest.
We had the WPA; so a high labor cost in proportion to materials was not objectionable. We decided, therefore, to salvage and reuse the boulders and old brick in repairing. We debated whether to break up the old bricks, screen out the fines, and make a regular cement-bound macadam, or to take up the old brick and relay them with a 1/2" joint to insure a better bond for the concrete top.

**Specifications**

The specifications furnished WPA were as follows:

1. Remove all paving material of brick or boulders and clean off dirt or bituminous material adhering thereto.
2. Spread sand cushion of 1 1/2" thickness of No. 3 sand.
3. Set wood side-form of 2" x 6" material to grade and line.
4. Relay paving brick or boulders to even surface 2" below finished grade in case of brick and 1 1/2" below finished grade to the tops of boulders. Brick should be spaced 1/2" apart.
5. Grout in bricks or boulders, using one part cement to three parts No. 3 sand after mixing sand and cement thoroughly, using enough water so that grout will penetrate to bottom of bricks or boulders and fill all voids but not in sufficient quantities to cause separation of materials. Brush the material in place with push brooms.

6. Before the grout sets, spread a layer of concrete, 2" thick on brick and 1 1/2" thick on boulder base, to the true line and grade using a wood strike-off riding on side-forms of the alley. Then wood-float the surface to smooth even grade.

7. Make concrete of 1:2:4 consistency, using No. 4 sand and No. 8 gravel mixed one minute or over in batch mixer to a plastic consistency which when spread and floated will not produce excess water.

8. Cure the surface for a period of three days by constant wetting, or cover it with moist burlap.

9. Permit light traffic by residents along alley after five days.

Expansion joints of 3/4" bituminous-moulded strips are placed 100 to 125 feet apart, and contraction joints or dummy joints are cut at 25-foot intervals. The alley slopes from each side toward the center on a grade of 1/2" to 1'.

The placing of the top of 1 1/2" or 2" of concrete follows almost immediately after the grouting and not over 1/2 hour later. It should not show an excess of water after striking off and wood floating. A final brooming of the surface would be all right, but we omitted it because we felt the surface could be smoother than a street surface.

This gives the appearance of a concrete alley with a light, clean-appearing surface that is highly desirable. I do not want to inject the argument of "Why have alleys?" except to say that if you are going to have them, a light, clean-appearing alley will act as a surface-water drain and prove a great boon to the garbage man as well as the tradesman. An unimproved alley generally becomes one of the foulest places in the city.

Costs

For a boulder-concrete alley the cost of materials was found to be 47 cents per square yard using cement costing $2.28 a barrel at the City Yard, gravel and sand at 70 cents per ton at the plant, expansion joint at 6 cents per linear foot for 3/4" x 6" size, and 4 cents per linear foot for 3/4" x 4" size. For each square yard we used:

- .137 bbl. of cement = .55 bag.
- .158 ton washed gravel and sand = 316 lbs.
- .1 ton pit sand = 200 lbs. @ $0.15.
- .167 cu. yd. cobble stone @ $0.15.

Expansion-joint cost is not much of a factor, being about one cent per square yard.
The cost of materials on a brick-concrete alley was found to be $0.51 per square yard at the above prices for materials. For each square yard we used:

- .156 bbl. cement = .62 bag.
- .205 ton washed gravel and sand = 410 lbs.

On the same basis of cost for materials, a 6" concrete alley would require per square yard:

1 bag cement @ $0.57 = $0.57
1/3 ton gravel and sand @ $0.70 = .23
Expansion joint .01

Total $0.81

Thus, the saving in the cost of material is 42 per cent for boulder-concrete and 37 per cent for brick-concrete over a 6" concrete pavement.

**Results**

These pavements have been down from one to five months. The first pavements were laid during the hottest period of the summer and have already been subjected to below-zero temperatures without excessive cracking and no evidence whatever of a lack of cohesion between the top and bottom layers.

You will note that the boulder-concrete runs 7 1/2" in thickness and the brick-concrete 6" in thickness. When we excavate for boulder concrete, our subgrade is 9" below the finished grade. On most of our brick pavements we had a 5" or 6" concrete base beneath the sand cushion under the old brick pavement; so our brick-concrete pavements are carried on this old base.

The Germans out of necessity have used quite successfully ersatz or substitute material. We may be called upon to do the same. It would be the part of wisdom for all engineers to begin thinking of ersatz materials. In the case of our alley pavements "Something has been added," but all the old paving material was utilized. It is my opinion that old materials in streets can be similarly utilized, with some ingenuity on the part of the engineer, to produce acceptable pavements. So when we hear of a material being put on the critical list, let's have fun finding a substitute that will serve our purpose.

**OIL-AGGREGATE STREET SURFACES**

Frank J. Miller,
City Engineer, Mishawaka

Oil-aggregate has been used in Mishawaka as a street-surfacing material for two years. Prior to that time, the city with the assistance of the Works Progress Administration