

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 |
| | <hr/> |
| 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

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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

graded and graveled approximately 75 miles of secondary streets, which have proved to be both inconvenient and costly because of the creation of a first-class dust nuisance.

The need for a satisfactory, low-cost surfacing or dust-laying material for these streets was urgent in order to appease the citizens and keep the streets in a serviceable condition. Our first thought was of the road-mixing process, from which we obtained fair results. This type of work was abandoned because of the inconvenience of working the gutter lines to a proper grade and also of the handicap of surface inlets and manhole covers found in city streets. Furthermore, the road-mix method did not permit accurate control of the mixture.

In 1936 a contracting firm laid a sample plant-mix oil-aggregate surface on a two-block stretch of one of our city streets. It has been watched with more than the usual interest. After four years an inspection of this surface showed that it had stood up unusually well under some of the most trying conditions. The base of this street consists of gravel and cinders, and at one time State Route 33 was detoured over it for approximately 30 days. No maintenance of any kind has been necessary since this surface was placed.

Early in 1940 we began to gather available information concerning oil-aggregate mixtures. The Michigan State Highway Department, the Asphalt Institute, and the Standard Oil Company of Indiana were asked for information. All were anxious to furnish us with detailed reports of their experiences and research in this type of mixtures. From this helpful information and from some experiments of our own we wrote specifications that we consider satisfactory for our locality.

SPECIFICATIONS

Our specifications provide that the aggregates shall consist of natural, bank-run sand and gravel (crushed or uncrushed), slag, crushed stone, crushed mine rock, or stamp sand, supplied in combination or separately as coarse aggregate and fine aggregate which will produce a uniform gradation within the following limits:

| | |
|---------------------------------------|--------|
| Passing $\frac{3}{4}$ " square screen | 100% |
| Passing $\frac{3}{8}$ " square screen | 65-90% |
| Passing 10-mesh sieve | 40-50% |
| Passing 40-mesh sieve | 15-30% |
| Passing No. 200 sieve | 5-10% |

Because of the prevalence of an abundance of gravel within the City of Mishawaka, we use natural bank-run sand and gravel almost exclusively. Physical requirements for mineral aggregates are few. All sources of aggregate used in oil-aggregate mixes are inspected and approved by the Engineer.

Bituminous materials, SC-2, SC-3, and SC-4, used in oil-aggregate mixes must meet the requirements of the Indiana State Highway specifications for bituminous materials. Specifications for asphalt road-oils recently have been revised by the Asphalt Institute and have been approved by the asphalt committee of the A.A.S.H.O. This revision eliminates the overlapping of consistency requirements between adjacent grades of the different types of oils, and secures greater continuity in the viscosity ratings.

CONTROL OF MIXTURE

Control of the mixture at the mixing plant is very essential. The first requirement is a competent plant manager who, in turn, must see that the following procedure is adhered to:

1. Moisture in the aggregate should be reduced under 1 per cent. In so doing the aggregate should not be heated over 250 degrees F. Temperatures of 150 degrees to 200 degrees F. are preferable.
2. Asphaltic road-oils should not be heated to a temperature of more than 175 degrees F.
3. The mixing time should be not less than 15 seconds for dry aggregate and 45 seconds after the oil is applied.
4. A daily testing report should be made by the plant inspector. At least three bituminous extractions and numerous aggregate gradation tests should be made daily. Composite daily mixture samples and frequent aggregate and filler samples should be taken and forwarded to an approved testing laboratory for check. Daily reports should be made in duplicate, one report forwarded to the office of the city engineer and the other retained by the plant inspector. A continuing daily record of the operations at the plant should be kept by the plant inspector.

PROGRAM RESULTS

During the summer of 1940, we laid 42,495 square yards of plant-mix oil-aggregate 2" thick on gravel bases primed with SC-2 road oil, at the rate of $\frac{1}{4}$ gal. per sq. yard. This was done at a total cost of 25 cents per sq. yd. to the property owners. The city furnished equipment and supervision, and the WPA furnished the labor.

In 1941 a similar program was increased to 84,183 sq. yards of oil-aggregate on prepared gravel bases and 14,670 sq. yards of resurfacing on cement concrete bases. Part of this resurfacing was over an old county highway that passes through Mishawaka. The concrete base was 18 feet wide, and the street was built to a width of 36 feet. A 9-foot gravel base was constructed on each side of the concrete base. The remainder

of the resurfacing was on a main, downtown thoroughfare. The concrete bases were prepared with a prime coat of light R. C. asphalt.

EQUIPMENT

The plant used in preparing this material is a regular hot-mix asphalt plant, with a batch capacity of 1,000 lbs., consisting of a drier, a dust collector, and a twin pug-mill mixer. The plant is equipped with a $\frac{3}{4}$ " square screen to eliminate oversize and a sand screen to separate the aggregate completely into a two-compartment bin. Accurate scales for weighing the aggregate, filler, and oil are also provided.

The equipment used for laying oil-aggregate consists of a spreader towed by the batch trucks. The surface is laid in 9-foot strips and in two layers. As a rule, the first course is laid and rolled; then traffic is allowed on the street, which helps to compact the surface before the second course is laid.

Rolling with an 8- or 10-ton roller is limited to one or two trips in a straight line. Cross-rolling or turning on the fresh mixture is not allowed. In cool weather, the roller follows close behind the spreader, but in hot weather it may be necessary to delay rolling for several hours.

We usually lay oil aggregate as late into the fall season as possible, or as long as the base is dry and free from frost. We expect some day to apply a seal coat to the oil-aggregate surface on some of the more heavily-traveled streets. This will be an RC-1 or RC-2 asphalt with a covering layer of pea-gravel or stone chips. So far, we have not found it necessary to apply a seal coat to any of these surfaces.

When properly laid, oil-aggregate presents a smooth, easy-riding surface that meets the requirements of a good, low-cost surfacing.

FINANCING

Our yearly paving program is built up on a voluntary plan, whereby the property owners, on any given street, sign an order to the City Engineering Department authorizing it to pave the street in front of their properties. On the same order sheet is a cost column setting out the exact cost to each property owner. The signer agrees to pay for the cost of the improvement not later than 12 months from the date of completion.

A \$25,000 appropriation from the city general fund finances a year's program. When this money is returned in assessments, it is placed back in the general fund. In the two years that we have operated we have turned back to the general fund \$27,000, which is a very good average because the remaining \$23,000 will not become delinquent until January 1, 1943. Interest at 6 per cent is charged on delinquent accounts.