

a 2-inch ring, the character of the stone depending a great deal, as in gravel, upon its binding easily. As a rule, limestones are of such a character that sometimes no rolling is required to obtain a smooth and hard surface, while trap rock, on the contrary, must have the interstices filled with fine material in order to get the stone sufficiently bound together. Water-bound macadam was laid in New York State in 1914 at a cost of 30 to 40 cents per square yard for a wearing surface 3 inches thick.

**Bituminous Roads.**—When the automobile, with its pneumatic tires, came into use, it was found that it presented an entirely different problem from the old horse-drawn vehicle with its steel tires. The former caused the macadam to disintegrate and ravel, while the latter had a tendency to compact it in a manner somewhat similar to steam rollers. This fact was recognized first in Europe, because the automobile was used there to a considerable extent previous to its use in America, and different methods of treatment were instituted to overcome the bad effect. The first method was to spray the surface with tar, and after many experiments, schemes were worked out that were fairly satisfactory. This method has been employed to quite an extent in America, but, with surface treatments, asphaltic oils are generally used, as they are cheaper and, some engineers think, better. The volatile parts of these oils evaporate upon exposure, leaving an asphaltic carpet over the surface which is much like an asphalt in its general appearance.

In Brooklyn, New York, nearly all of the park roads are of gravel, and a great portion of them have been treated as follows: Heavy asphaltic oil is spread on the surface at the rate of .7 gal. per square yard. The ruts and holes in the road are all repaired previous to the application of the oil. The oil is applied by gravity distributors, it being taken from tank cars, which are heated to a temperature of about 200° F. before being unloaded. The oil is maintained in the distributor at this temperature and is applied to the roadway surface. After the oil has been applied, a coating of coarse sand is spread at such a rate that 1 cu. yd. of sand covers 53 sq. yds. of surface. The roadway is closed to traffic for 24 hours after the spreading of the sand.

This process has been in use for two or three years and has given good results. It must be remembered, of course, that on the park roads no heavy vehicles are allowed, and it is undoubtedly true that with heavy steel-tired vehicles this treatment would not be satisfactory. Some trouble, even with the automobile traffic, occurs, in the shape of creeping and bunching of the surface, but the bunches are cut out and easily repaired.

The cost of the asphaltic oil delivered in cars is 6 cts. per gal., the cost of sand alongside the road, \$1.35 per cu. yd., and the cost of the complete treatment, including labor and materials, but not including overhead charges, has averaged 8 cts. per sq. yd., for three years.

Another method of building bituminous roads is what is known as the penetration method, when, after the stone is spread upon the road, the upper surface is sprinkled with the bituminous material, whether tar or asphalt, and then rolled and completed with certain surface treatments. In New York State during the past year this treatment has cost from 50 to 60 cts. per sq. yd. for a wearing surface 3 inches thick.

In Massachusetts, by the penetration method, using  $2\frac{1}{4}$  gals. per sq. yd. of Bermudez asphalt, 2 ins. thick, the cost has been 66 to 80 cts. per sq. yd.

In Massachusetts, too, in 1914, there was used a surface composed of oil, asphalt, and gravel, using 18 gals.

of asphalt per cu. yd. of gravel, and spread so as to have a thickness of 2 ins. after rolling, at a cost of 30 to 35 cts. per sq. yd., while with oil, asphalt and sand, mixed and spread to a depth of 4 ins., after rolling, the cost was 54 to 60 cts. per sq. yd. Using the penetration method with tar instead of asphalt, with  $2\frac{1}{4}$  gals. per sq. yd. of surface, 2 ins. thick after rolling, the cost was 45 to 65 cts. per sq. yd. It must be understood, of course, that these costs will vary, as in some cases gravel was used which cost 80 cts. per cu. yd., while in others trap rock was used, which cost \$2.50 per ton, which is considerably more than the cost of gravel per cubic yard.

There are many other methods of using bituminous wearing surfaces. One of these is known as the Topeka mixture, as it was first used in Topeka, Kansas, and has been decided by the courts not to be an infringement on any patents. It is laid much as is sheet asphalt pavement, but with a larger aggregate. In 1912 over one hundred miles of roads were surfaced in the Borough of Queens, New York, with practically this kind of pavement. The specifications for the wearing surface for this work read as follows:

The finished pavement shall contain between 7 per cent. and 11 per cent. of bitumen soluble in carbon disulphide, depending upon its mesh composition, but in all cases sufficient asphalt cement shall be used to thoroughly coat all of the particles of the mineral aggregate.

Mineral aggregate shall be proportioned as follows:

Mineral aggregate passing 200-mesh screen, from 5 to 11 per cent.

Mineral aggregate passing 40-mesh screen, from 18 to 30 per cent.

Mineral aggregate passing 10-mesh screen, from 25 to 55 per cent.

Mineral aggregate passing 4-mesh screen, from 8 to 22 per cent.

Mineral aggregate passing 2-mesh screen, less than 10 per cent.

Screens to be used in the order named.

Roads of this character were laid in New York State in 1914 by the State Highway Department, at a cost of 85 to 95 cts. per sq. yd.

During 1914 some twenty-five or thirty miles of bituminous roads were built at the Ashokan Reservoir of the new water supply system for New York City. The wearing course was formed of stone passing over a  $\frac{1}{2}$ -in. screen and through a  $1\frac{1}{2}$ -in. screen. By an adjustment of the jackets on the screens a sufficiently graduated stone was obtained to produce proper results. The broken stone was heated and mixed, in a machine similar to one used for sheet asphalt, with an asphaltic cement so that the resulting mixture should contain between 5 and 7½ per cent. by weight of bitumen. The mixture was spread upon the road and thoroughly rolled, when a seal coat of hot asphaltic cement was spread over the same, by a proper appliance, and then smoothed off with squeegees. The asphaltic cement was applied on the average at the rate of a little less than 1 gal. per sq. yd. Upon this squeegee coat stone chips were placed, which were thoroughly rolled into the surface, any lack of chips being supplied by a second distribution. The wearing surface 2 ins. thick cost \$1.01 per sq. yd., native stone being used.

It would be difficult, and perhaps unnecessary, to go into a detailed description of the many kinds of bituminous roads. Those herein described give a fair idea of what are in ordinary use.