

the joints at other than 90° with the centre line of the pavement. An angle of 60° with the centre line of the road has been successfully used and found to add much to the comfort of traffic.

Materials.—Attention has been called to the fact that every portion of a concrete road should be of a high-grade concrete and also uniform. Many failures of concrete roads, due to raveling under traffic, may be explained by a lean mixture or a lack of uniformity. If a successful concrete pavement is to be laid, a concrete rich in cement must be used. It is evident that the strength of the pavement to resist the action of traffic depends upon the strength of the matrix or mortar in the concrete, assuming a proper aggregate has been employed. Also, if each particle of the aggregate is to be held in place, it is necessary that there shall be a sufficient amount of matrix entirely to surround each piece. To accomplish this purpose, it is first necessary that the mortar be rich in cement and second that the concrete be rich in mortar. probably quite as many failures have been due to a lack of mortar in the concrete as to a lack of cement in the mortar. If every particle of aggregate is to be surrounded by mortar, there must be mortar in excess of the voids in the coarser aggregate. Therefore, if failures have occurred with mixtures providing but 50% of mortar, as would be the case, for example, in a $1:2\frac{1}{2}:5$ or $1:2:4$ mixture, no great advantage would be gained by merely increasing the amount of cement and leaving a deficiency of mortar, for example, substituting for the above mixtures a $1:1\frac{1}{2}:3$. A mixture that increases this proportion of mortar should generally be used; a $1:2:3\frac{1}{2}$ mixture may be recommended.

Each batch of concrete must be thoroughly mixed and, as it is deposited in the road, great care should be exercised that the mortar does not flow to the edge of the pile and leave a core of aggregate with insufficient mortar. This is quite likely to happen and must be remedied by workmen who should be provided with rakes or shovels to distribute any such nests of aggregate. A little care and watchfulness will entirely obviate any difficulty from this source.

The nature of the aggregate will determine the wearing qualities of a concrete road. It is therefore important that only hard, sound materials be used for this purpose. In general, limestones and similar soft rocks are not to be recommended, while quartzitic or flint gravels afford widely dispersed sources of excellent materials.

Drainage.—It has been observed on some concrete roads that longitudinal cracks had occurred which are thought to have been due to the seepage of water under the outer edges of the concrete slab, thereby softening the foundation and causing a movement of the concrete slab by frost action. To prevent this, it is recommended that a shallow trench about the width of a shovel be constructed under each edge of the pavement, this trench forming a blind drain to be filled even with the subgrade with some coarse material and that lateral blind drains be placed from 40 to 50 ft. apart across the shoulders of the road, these cross drains extending from the longitudinal drains to the gutters or side ditches thereby preventing any seepage of surface water under the edge of the pavement in the foundation.

Two-Course Construction.—Many concrete pavements have been constructed in two courses, using a leaner mixture for the lower course and a richer mixture for the wearing surface. Evidently, this is an economical arrangement and would be recommended were it not for

the unsatisfactory results obtained due to the fact that at the junction of the two classes of concrete there is developed a horizontal plane of weakness which would be caused by even a comparatively short delay in applying the top course. Under exposure to the hot sun, whereby the surface of the pavement becomes of a higher temperature than the lower portion, there is a tendency for the pavement to become slightly convex on the upper or wearing surface. If there is a horizontal plane of weakness near the convex surface, the upper layer of the pavement may become separated from the lower layer. And this has actually occurred. Soon after this takes place, the surface cracks under traffic and rapidly deteriorates. Therefore, unless some method can be found by which the top layer of rich mixture can be deposited simultaneously with the leaner mixture of the lower course, it is recommended that the whole pavement be made of uniform quality throughout equal to that desired for the wearing surface.

Curing the Concrete.—A most important part of the construction of concrete roads, and one that has been very often neglected, is a proper protection for the concrete while setting so that there will be no lack of moisture at this time. As soon as the concrete is a few hours old it should be covered with canvas which is kept moist. This canvas is to be replaced by a layer of earth which should be kept well wet for a period of ten days to two weeks.

Crown.—A concrete road requires perhaps less crown than any other form of paving surface, scarcely more than the eye would demand for appearance sake. One-eighth to one-quarter inch per foot will be found sufficient.

For convenience in construction, the roadbed may be made practically level and, it is evident, should be constructed with considerable care so that it does not become necessary to fill depressions in the roadbed with expensive concrete. The crown may be given by making the roadway slightly thicker at the middle than at the sides.

Thickness.—A thickness of 6 to 8 in. for the concrete seems sufficient for all ordinary conditions. On roads 20 to 24 ft. in width, and average of 7 in. may be used with 8 in. at the centre and 6 in. at the sides.

A form of construction that may prove desirable, where the greatest economy must be exercised, would be to provide a comparatively narrow strip of concrete at the centre with a good macadam construction for the shoulders. This would answer for those roads where the traffic at a given time of day is nearly all in one direction. Under these conditions a strip of concrete 10 to 12 ft. wide at the centre would take practically all the wear while the narrow strip of macadam at either side, 3 or 4 ft. in width, would suffice for the occasional passing of vehicles.

This character of construction is particularly applicable to a vast mileage of highways in America where such an enormous percentage is merely earth roads and where at present the maximum length of roads at the lowest cost possible is of the utmost importance.

Finish.—A concrete road should be left slightly rough as would be effected by a wood float. The templet which is used to give the shape to the surface of the road can be so devised and handled as practically to give the desired finish to the surface with the possible exception of here and there a slight imperfection which should be remedied by men with hand floats working from a lightly constructed bridge thrown across the road. It is highly desirable, however, that as little as possible be left to the