

foundation (and the number of these is very few), it will be necessary to re-grade it and probably to reduce its crown before placing any bituminous surface upon it. In a few cases this can be done by filling up the depressions and building up the shoulders. Wherever possible, this method should be employed, as traffic will compact a road far better than is possible with a roller, and a road surface which has been scarified and then rolled will never be as hard and firm as if it had been compacted by years of traffic. Where new stone is added in depressions or on the shoulders, the road bed on which it is laid should be clean and slightly loosened to insure proper binding of the new stone. The size of the added stone should be the same as that which would be employed in building up the corresponding portions of a new waterbound macadam road and should be thoroughly rolled with a road roller weighing not less than ten tons until it is well compacted and vehicles passing over it do not cause displacement. Water and screenings should be used during rolling to effect this. Unless this work is thoroughly and conscientiously done, the foundation will not be of uniform strength throughout and settlements will probably occur at those places where the new stone has been put in.

If it is necessary to scarify the road surface, this should be done with care not to go deeper than necessary, and the surface of the road should be built up with new material and rolled until the greatest possible compaction is obtained, exactly as if building a new waterbound macadam road. If it is then possible to turn traffic upon it for a few months before laying the bituminous surface, so much the better, as any weak spots will be developed and still greater compaction will be secured. To do all this thoroughly and as it ought to be done (including drainage) will often cost almost as much as putting down 5 inches of concrete. With the concrete, a permanent and satisfactory foundation is assured which may be resurfaced when necessary at the minimum expense. In England a number of fairly heavy traffic roads have been successfully surfaced with sheet asphalt or bituminous concrete using the old macadam as a foundation, but as a rule their macadam roads have been in existence for a long time and have been properly constructed and, owing to their moist climate, have been thoroughly drained. They, therefore, start with a much better foundation on the average than we can hope to obtain. Their winters are mild and frost rarely penetrates to any considerable depth in the earth, hence they are free from heaving and the unstable conditions produced by our spring thaws.

Where the subsoil drainage and climatic conditions are especially favorable, a foundation of 4 to 6 inches of broken stone properly consolidated by rolling may be used for light traffic roads. Except under extremely favorable conditions, the proper construction and drainage of a base of this kind will cost more than would 4 to 5 inches of concrete.

The question of foundation having been settled, the kind of wearing surface must next be determined. The various types of bituminous construction under consideration may be classified as follows: Coarse aggregates—Penetration method, cold mixture, hot mixture; fine aggregates—Topeka, sheet asphalt.

As between coarse and fine aggregates, the heavier the traffic (more especially that carried on iron tires), the finer should the mineral aggregate be. Large particles of stone will be fractured sooner or later by the passage of heavy loads over them. Wherever such a fracture occurs we have two faces which are not cemented together by

bituminous cement. This permits grinding away and the entrance of water, two extremely destructive agencies. As illustrative of this, in certain sheet asphalt pavements laid by the writer in heavily travelled sections of Glasgow, Scotland, it was found to be necessary to exclude grains of sand coarser than those passing a 20-mesh sieve, as even 10-mesh grains would crack and permit the water to enter and destroy the pavement. In a test made last winter in the presence of the writer of a bituminous road surface at the National Physical Laboratory at Teddington, England, in which a road continually flooded with water was tested to destruction by passage of heavily loaded iron-tired wheels over it, it was found that disintegration commenced at those points where large sized grains occurred on the surface. Large sized aggregates give a rougher road surface, and hence better foothold for horses, than do smaller sized aggregates, and automobiles are less liable to skid upon them in wet weather. For light and moderate traffic there is, therefore, much to be said in favor of large sized aggregates. As between penetration methods and mixing methods, the latter are undoubtedly far superior. In the case of Portland cement concrete, except in special forms of construction, grouting is seldom resorted to except where mixing is impossible and in this case we have a fluid cement which readily penetrates the interstices without chilling or becoming solid for a very considerable period of time. When grouting broken stone with a hot bituminous cement its tendency is to chill as soon as it strikes the colder stone. Its distribution is, therefore, very uneven and whenever the interstices are small practically no penetration takes place. Work of this character should never be done except in the hottest weather, and yet we see many of these roads constructed in the late fall. It is really the most difficult kind of bituminous work to execute properly and yet, because of the cheapness of the plant required, many contracts are let to small contractors who have never done such work before. A few years ago suitable portable mixing machinery was not available for work of this kind except in the vicinity of railroads and hence some type of bituminous construction had to be developed which was cheap and could be put down without the use of heavy and non-portable plants. These conditions no longer exist and the writer believes that for this and other reasons the penetration method of construction will gradually disappear. When, because of failure or increase in traffic, it becomes necessary to reconstruct a penetration road laid on a broken-stone foundation, practically all of the road must be removed and this is an expensive piece of work. This is not true of a bituminous road laid on a concrete foundation. The foundation can still be utilized and in most cases resurfacing is all that is necessary.

As between hot and cold mixtures the hot mixtures can be better graded and more thoroughly compressed by rolling, and are, therefore, somewhat better suited for fairly heavy traffic. For light traffic, the cold mixture will in many instances give equally good results and will often be very much cheaper and will, therefore, always have a wide field of usefulness. Cold mixtures would appear to be ideal for use by road patrols in the upkeep of bituminous road surfaces constructed of large aggregates, and are much superior to hasty mixtures of stone and bituminous binder often imperfectly made on the spot with inadequate appliances by more or less inexperienced workmen.

The so-called Topeka mixture is intermediate between the sheet asphalt and the coarse aggregate mixtures. As ordinarily made, it consists of a standard sheet asphalt