

age conditions. The heavier the traffic, the stronger must the foundation be. In cold climates, where the ground freezes to considerable depth in winter, the spring thaws produce a very unstable condition of the subsoil, and in such cases the foundation must be stronger than is required in climates where there is little or no frost. A well-drained sandy soil is much less affected by these temperature changes than is a heavy, clayey soil.

A number of different types of foundations have been successfully employed, such as old macadam; broken stone, rolled dry or cemented together with some form of bituminous cement; old cobblestone, Belgian block or granite sett pavements; old brick or asphalt block pavements; bituminous concrete; natural cement and Portland cement concrete. Where the traffic is light, as on country roads which are not main arteries from or between large cities, and in some residential streets, old macadam roads have proved to be suitable foundations for bituminous surface mixtures.

In some cases, notably the Thames Embankment in London, a foundation of this kind, covered with an asphalt pavement, has successfully carried very heavy traffic, but the layer of stone has been built up during many years and is very thick. Under severe conditions the use of macadam as a foundation is to be deprecated, and more failures than successes have resulted from it.

Many roads are classified as macadam which contain no base course of large stone, and are in reality old dirt roads, which have never been properly drained and on which fine stone has been dumped and consolidated by traffic. Before using any macadam road as a foundation, its history, and more particularly its condition in the spring of the year, should be investigated. A sufficient number of test-holes should be put down to determine the character and depth of the stone and provision made for proper under and side-drainage. It will usually be necessary to rebuild the road in a number of places, and in most instances the crown must be reduced. Wherever possible this should be done by filling up the depression and building up the shoulders. Traffic will compact a road far better than will a roller, and a road surface which has been scarified and rolled will not be as hard and firm as one which has been compacted by years of traffic. Where depressions are to be filled the roadbed should be cleaned and slightly loosened to ensure proper binding of the new stone, which should be of the same size as would be employed in building up the corresponding portion of a new macadam road. It should be thoroughly wetted and rolled with a 10-ton road roller, with the addition of sufficient screenings, until vehicles passing over it do not cause displacement.

Unless this work is thoroughly and conscientiously done the foundation will not be of uniform strength throughout and settlements will occur where the new stone was put. If it is necessary to scarify the road surface, this should be done to the minimum possible depth, after which the surface should be built up exactly as if constructing a new macadam road and rolled until the utmost compaction is obtained. Wherever possible traffic should then be turned upon the road for a few months to develop any weak spots in it and to secure still better compaction.

Old pavements of brick, granite, etc., should not be used as a base if it is first necessary to re-set them. In their original condition they are satisfactory if the traffic is not too heavy. Relaid blocks, until bedded by

traffic, are not rigid and have a tendency to rock, and asphalt pavements laid on such foundations in New York City have rapidly disintegrated wherever they were exposed to heavy traffic.

Concrete foundations vary according to conditions from 4 to 9 inches in depth, and in every case before laying them the subsoil should be thoroughly compacted. In certain localities in the north-western portion of the United States and Canada very heavy clay soils are found which in winter frequently develop cracks 4 to 5 inches in width and heave very badly. In such cases cross-trenches should be dug every 25 or 30 feet and filled with coarse broken stone and connected with longitudinal trenches at the side of the street similarly filled and draining to catch-basins. Concrete should not be laid directly on such a soil. Sand or gravel should first be spread upon it to such a depth that when rolled it will form a layer 3 to 4 inches in thickness, and the concrete should be placed on this.

The mineral aggregate constitutes from 75 to 90 per cent. of the pavement and takes practically all the wear resulting from traffic. It must, therefore, be selected with great care. It must be hard enough to carry the traffic; it must have clean grains or particles, and these grains or particles must be graded from coarse to fine, so as to make a pavement of the maximum density with the smallest-sized voids obtainable and with sufficient inherent stability to resist displacement under the shoving action of traffic. The surfaces of the grains or particles must be of such a character that the bituminous cement will adhere satisfactorily to them. Sand, gravel, broken stone or slag, or combinations of them, are the materials used in the type of pavements under discussion.

Sand should be clean-grained, hard and moderately sharp. The grains should be chiefly quartz, and should have rough, pitted surfaces. Where necessary the proper grading of the different-sized grains must be obtained by mixing several sands, or in certain cases by the addition of unweathered crusher screenings. When using the ordinary type of bituminous mixing plants the presence of clay is undesirable, either as a coating to the grains or disseminated throughout the mass. For medium or heavy traffic pavements all particles retained on a 10-mesh screen should be discarded. For light traffic 3 to 5 per cent. of 8-mesh particles can be incorporated in the pavement with advantage, or broken stone of the sizes and in the amounts described under "Topeka Mixture." Sands containing a large amount of flinty grains should be avoided.

Gravel should be clean-grained, hard and free from adhering clayey particles. It is lacking in stability owing to its roundness, and is usually considerably improved by passing it through a crusher. Gravel with a rough, pitted surface is to be preferred and gravel containing a large percentage of flinty particles is to be avoided. It is unsuitable for the construction of pavements carrying heavy traffic and inferior in all respects to crushed stone.

Broken stone should be freshly crushed, preferably in cubical-shaped particles. The size and hardness required depend upon the traffic which the pavement is to carry. Dense, hard limestone will carry medium and light traffic satisfactorily. Where the traffic, even though comparatively light in volume, is composed of heavy, iron-tired units, a dense, hard trap is required. Trap is now commonly used in the manufacture of asphalt block, although in the past a large number of asphalt blocks made from limestone gave excellent service under light