Unsuitable mineral aggregate	30%
Improper manipulation at mixing plant	25%
Poor workmanship on street	15%
Bad weather conditions	15%
Bitumen of improper consistency	10%
Bitumen unsuitable for paving	5%
	100%

In spite of its importance, it is only recently that general attention has been given to the physical testing of aggregates for bituminous pavements. Even to-day, most specifications are extremely vague and indefinite as to the quality of aggregate materials. The specifications of the United States Bureau of Public Roads, of several state highway departments and of a few cities have recognized the value of such tests, and have made their requirements as definite as the present state of our knowledge of physical testing permits. Hundreds of specifications are being prepared every year in which even the data available at present are not recognized. The only definite test commonly specified is the mechanical analysis as determined by laboratory sieves. Aside from this test, the acceptance of aggregate materials is ordinarily based upon visual examination and personal opinion, both of which have their value, but some more definite standards are needed, especially in these days when many inferior materials are being used, often under the supervision of men of limited experience.

In this article only the aggregate materials commonly used in mixed method pavements will be discussed. The essential properties of sand, filler and the usual coarse aggregates will be described briefly.

Sands for Bituminous Pavements

Sand is the water-worn detritus of crystalline rocks, and is largely composed of quartz, although calcareous and feldspathic sands are known. It is the writer's opinion, and the experience of others seem to bear this out, that for paving purposes satisfactory results are in general obtained only from quartz sands.

Sands may be classified, as to source, as beach, river and bank sands. A great variety of sands are found in each class, but in general the sands of greatest value are secured from rivers and banks, although many sands from the beaches of the Great Lakes have been used satisfactorily. Sea-beach sands are sometimes used, but as a class are not so satisfactory as the other sands mentioned.

Before discussing the physical properties which are necessary in a sand, it may be stated that very little real quantitative data regarding the physical properties of sands for bituminous pavements are available. This is a fruitful field for research and is well worth the time of qualified investigators. Prof. Abrams and others have ably investigated the properties of concrete sands, and if our knowledge of bituminous pavements is to be advanced, it is essential that similar investigation be made as to essential properties of sands for use in bituminous pavements. This is a complicated field of research which offers many practical difficulties, but nevertheless the problems which need solution can and will be solved.

Investigating Properties of Sands

The writer is glad to report that certain investigations have been under way in his laboratories for some time, and that progress is being made. In due time results will be secured which will be of value. In the meantime, we can best secure satisfactory results by availing ourselves of the information which has been accumulated through experience and observation. Although this information is largely empirical, it serves as a useful guide.

Both theory and experience have shown that sands having angular grains are best suited for bituminous pavements. Rounded grains do not have as many points of contact as angular grains, and, therefore, a mixture in which such grains are used is not stable and is more readily displaced by traffic than a mixture containing angular grains. This applies to sand used in both fine and coarse aggregate pavements.

In order that a film of bitumen of sufficient thickness may adhere to each sand grain, the surface of the grain should be somewaht rough or pitted. Sands with smooth and polished grains are frequently encountered, but their use should be avoided, because the individual grains are sometimes so thinly coated with bitumen that a proper bond between the different particles of the mineral aggregate cannot be secured.

The sand grains should be hard and tough, so that the individual grain will not readily wear away under the abrasion of traffic nor fracture under impact. Of course, the small size of the sand grains and the cushioning action of the bituminous cement so largely reduces the danger of fracture that toughness is a much less important factor than in the case of aggregate of larger size, such as gravel and crushed stone. Several failures have been attributed to the use of sands with soft grains.

Hardness and Toughness

As yet no satisfactory means of ascertaining the hardness and toughness of sands have been devised. There is, however, a need for such tests, and in connection with the investigations previously mentioned the writer has developed certain methods for making these tests. Before arriving at any definite conclusion as to the value of these tests, it will be necessary that many check tests of several hundred different sands be made.

The amount and character of the impurities found in a sand largely determine its value. Clay, loam, mica and organic matter are common impurities, and in sufficient amount each one is a most important factor in determining the quality of a mixture.

Clay is found either finely divided and evenly distributed through the sand or in the form of small clay balls. If only a small percentage of clay is present in a finely divided state, and the clay itself is not plastic, little harm will be done; in fact a large percentage of the clay will be removed by the fan on the heating drum of the asphalt plant. However, if the clay is plastic and present to the extent of more than 5%, the sand grains will be coated with a hardened film of clay after passing through the drum. This film will prevent the bitumen from adhering to the actual surface of the sand grains. The film of bituminous cement is easily broken away from the sand grains, permitting water and traffic to disintegrate the pavement.

Clay, Mica and Organic Matter

Clay balls, when present in any appreciable quantity are a source of even greater danger than evenly distributed clay, and engineers should take a decided stand against the use of sands containing such material, because disintegration is quite certain. The clay balls at the surface of the pavement are removed by water and traffic. This allows water to gradually work down into the pavement, softening the clay balls scattered throughout the mass. Eventually this results in serious disintegration of the pavement surface. This condition is of more common occurence than is often realized.

In certain localities where the sands have been formed by disintegration of granites and gneisses, mica is almost a universal constituent of the sands. If present in any appreciable amount, trouble may be experienced, since the mica grains cannot be satisfactorily coated with bitumen and will not resist traffic. In practice the writer has ordinarily rejected sands containing over 3% of mica, as estimated with the microscope.

Organic matter, usually in the form of roots, twigs and leaves, is found in many sands. When the hot sand is screened through an 8-mesh screen, as in the case of sheet asphalt, the greater portion of such material will be removed, but when the type of pavement requires the use of a larger size screen, the roots and twigs will pass through into the mixture. Such material in the mixture is a source of weakness, and either the sand containing it should not be used or else it should be screened out.

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