ESSENTIAL PHYSICAL PROPERTIES OF SAND, GRAVEL, SLAG AND BROKEN STONE FOR USE IN BITUMINOUS PAVEMENTS.*

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IN discussing the various physical properties of mineral aggregates it must be borne in mind that it is impossible to fix universally applicable definite values for them, as these will vary with the type of pavement and the kind and density of the traffic to which it is subjected. In order to understand fully the extent to which these considerations affect the selection of the mineral aggregate to be employed and modify any standards set for their essential physical properties, it is necessary to have clearly in mind the different types of bituminous pavement and of traffic and to discuss briefly a few points illustrative of their mutual relationship.

The types of pavement considered in this connection are: (1) Sheet asphalt, binder, surface; (2) bituminous concrete; (3) bituminous macadam; (4) asphalt block; (5) oiled macadam; (6) gravel.

Broken stone or gravel is used in all of these types, but in the case of sheet asphalt their use is restricted to the binder course in which they are not directly subjected to wear. In all the other types the broken stone or gravel forms part of the wearing surface. Obviously in the binder course neither of them would be required to possess the same degree of wear-resisting quality as when used in the surface.

The kind of traffic may be classified as: Iron-tired, chiefly horse-drawn; rubber-tired, chiefly self-propelled; mixed, both horse-drawn and self-propelled; and without entering into a detailed segregation, the traffic itself may be classified as: Light, medium, heavy.

Stone and gravel which would crush under heavily loaded iron-tired traffic would carry the same weight without fracture if rubber tires were used. The same distinction would apply in the case of heavy traffic as compared with light traffic.

A certain amount of crushing, thus increasing the proportion of fine material in the mineral aggregate, is desirable in certain types of pavement, such as tarred slag, when sufficient quantities of a soft bituminous binder are used with it which will readily cost the freshly fractured surfaces at ordinary atmospheric temperatures.

Where the bitumen is present in insufficient quantity or where it requires temperatures higher than atmospheric ones to make it adhere satisfactorily to the particles, the reverse is true.

Having before us this very wide range of conditions which must be met, we next come to a consideration of the physical properties themselves which are ordinarily regarded as essential. These are: Shape, character of surface, wear-resisting quality, size, cleanliness.

Shape.—Owing to the fact that all bituminous cements soften materially under heat and therefore lack stability in hot weather, it is desirable and necessary to obtain as great a degree of stability as possible in the particles whether they be coarse or fine. Gravel, with its rounded particles, has much less stability than broken stone. For this reason it is often passed through the crusher before using it. Stone which is crushed so that the particles are chiefly cubical in shape is to be preferred to stone that is crushed so that slivers predominate. These slivers do not compress as easily as do cubical particles to form a compact mass with a minimum of voids and are much more liable to fracture under the stress and weight of traffic. When the particles are small, their lack of weight and size render them more subject to displacement and angularity and consequent interlocking of the particles is very essential. At first sight this would appear to be much more important in the case of sand than in the case of stone. The larger the particle, however, the greater the leverage with which it may act under a force tending to displacement, hence there is not so great a difference between the relative importance of angularity in sand and stone. In fact, in certain cases it is more important with stone than with sand. In the binder course in sheet asphalt pavements, which is intended to increase the stability of the sand wearing surface and key it to the concrete and retard its movement upon the surface of the concrete, sharpness of stone is essential. For this reason gravel makes a very inferior binder and should not be used where it is possible to obtain stone. When used, it should be cracked by passing it through a crusher. Not only do rounded particles move on each other with greater ease than angular particles, but in masses they have fewer points of contact.

Character of Stone.—As our consideration of the materials under discussion is limited to their employment in bituminous pavements, it is necessary for us to consider the surfaces of them chiefly in connection with their ability to receive and retain a coating of sufficient thickness of the bituminous cementing material. Certain types of surfaces are much more desirable from this standpoint than are others. Broadly speaking, a rough, pitted and somewhat absorbent surface is the best. Smooth, glossy surfaces do not readily retain a thick coating of bitumen and require a relatively high heat to insure properly coating them. At a high heat the bitumen becomes very liquid and readily runs off of them, which results in a coating of undesirable thinness. Even when the temperature at which they are coated is no higher than that employed with rough surfaces, their smoothness permits the bitumen to drain off more readily. This is particularly the case with flint particles and sands containing them, when coated with bitumen and examined under a glass, invariably show the minimum thickness of coating on the flint particles sharply contrasting with the surrounding rougher surfaced quartz particles which have retained a coating of normal thickness. As compared with a non-absorbent surface, an absorbent one *per se* is to be desired. Unfortunately, most particles which have absorbent surfaces are lacking in resistance to wear and therefore, notwithstanding their superiority from the standpoint of coating them with bitumen, are not suitable for heavy traffic, more especially of the iron-tired variety. Where the bituminous cement used is lacking in cementing value an absorbent surface is especially necessary.

The speaker knows of a number of roads in which distinctly inferior bituminous cement was used which gave excellent satisfaction under medium and light traffic due to the fact that the mineral aggregate was a porous limestone. The same bituminous cement with hard non-absorbent rock failed utterly when used in similar types of construction on roads carrying an equivalent traffic.

The outer surface of the particles must be firmly adherent to and form a permanent part of the particles themselves and must show no tendency to scale off when heated. Certain sands, upon heating, appear to form loosely adherent scales upon the surface of their particles which are not removed by attrition in the mixer but which, under the stress of traffic and atmospheric changes in temperature, become loose and detach themselves, carrying the coating of bitumen with them. Pavements laid with this type of sand have been known to disintegrate

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