

Determination of fine aggregate angularity in relation with the resistance to rutting of hot-mix asphalt

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Abstract

Rutting in asphalt pavements continues to create problems for pavement agencies. One factor that has been identified in determining asphalt pavement rutting susceptibility is the fine aggregate angularity (FAA) in the asphalt aggregate mix. The aim of this study is to investigate the angularity of fine aggregate produced in Turkey and to draw the attention of design engineers to this subject. To examine the relative effect of angularity of fine aggregate on the passing time through an orifice, material was obtained from 30 different sources which represent a wide range of materials used in Turkey. This collection offered a variety of geometric irregularities. The aggregates included 4 natural sands and 26 crushed aggregates. ASTM C128 “Specific Gravity Test of Fine Aggregate” and AFNOR P18-564 “Determination of Flow Rate of Fine Aggregate” which has been adopted by AFNOR were performed on each sample. Rutting tests were then performed on four different aggregate samples which had different FAA values and which were crushed by different crusher types. Test results bring to light that factors like the mineralogical properties of the fine aggregate and the crusher type must be considered in determining the angularity of fine aggregate. Also rutting test results showed that higher FAA values increased resistance to rutting of hot-mix asphalt.

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1. Introduction

The weight and volume of mineral aggregates used in asphaltic mixtures are respectively, at the rate of 90–95% of mixture weight, 75–85% of mixture volume. Physical and mineralogical properties of mineral aggregates on which the load bearing capacity of a pavement depends affects directly the properties of a mixture, the workability of a fresh mixture and the performance of a pavement. The more asphaltic mixtures are workable, the more they are compactable. Researches show that easily compactable asphaltic mixtures can rut easily and quickly under traffic. In contrast, mixtures with low workability prove to be less prone to rutting under the

same conditions. Because of this reason, in recent years highway engineers have preferred less workable asphaltic mixtures. Angularity of aggregates particularly that of fine aggregate is a primary factor affecting the workability of asphaltic mixtures [1].

Aggregates may be of natural, processed or synthetic origin. The majority of aggregates used in road construction are obtained from naturally occurring deposits and processed quarry rock. Natural aggregates such as sand and gravel are obtained from transported deposits, river deposits, alluvial fans and glacial outwash. Processed aggregates are obtained by crushing and screening quarried rock, oversize gravel and boulders.

The suitability of aggregates to be used in asphaltic mixtures depends on their physical and mineralogical properties. The physical properties of aggregates are gradation, particle shape, surface texture, durability, cleanliness, toughness, and absorption. These properties

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primarily control the performance of mixtures [2]. The successful quantification of aggregate geometric irregularities is essential for understanding their effects on pavement performance and for selecting aggregates to produce pavements of adequate quality. Thus, the quantification of shape, angularity and surface texture is important as high-quality pavements are needed to meet increases in traffic volume and load [3]. Fine aggregate angularity (FAA) has been identified specifically a factor in determining asphalt pavement rutting susceptibility [4].

In the eighties, design methods in the USA (Superpave) and in France (Gyratory Shear Press) showed that FAA is important for resistance to rutting. The recent studies of the Strategic Highway Research Program (SHRP) identified FAA as one of the important aggregate properties contributing to the stability and permanent deformation resistance of hot-mix asphalt (HMA) [5]. Therefore, FAA is critical for the resistance to rutting of flexible pavements. Rutting observed in wearing and binder courses of asphalt pavements continues to be a major problem for highway engineers. Because of this reason, new specifications were prepared for FAA properties. However, FAA requirements have become controversial. Considerable discussion has occurred at various national technical meetings regarding the FAA test and the specification values [6].

2. Shape and surface texture of aggregates

The shape of three-dimensional particles is rather difficult to describe, therefore it is convenient to define certain geometrical characteristics of such bodies.

Roundness measures the relative sharpness or angularity of the edges and corners of a particle. The strength and abrasion resistance of the main rock controls roundness. In the case of crushed aggregate, the particle shape depends on the nature of the main material, also on the type of crusher and its reduction ratio. A classification used in the USA is as follows:

- Well-rounded: No original faces left.
- Rounded: Faces almost gone.
- Subrounded: Considerable wear, faces reduced in area.
- Subangular: Some wear but faces untouched.
- Angular: Little evidence of wear [1,7].

Angular aggregate shape is desirable in asphaltic mixtures. The shape of fine aggregate particles influences mix properties such as stability, workability, bitumen content, etc. Angular particles require more bitumen. Neville [7] stated that mixtures with high FAA values have better interlocking of aggregates thus these mixtures result in better performance. However, an objective method of measuring and expressing shape is not yet available despite attempts using measurement of the

projected surface area and other geometrical approximations.

The classification of the surface texture is based on the degree to which the particle surfaces are rough, smooth or polished. Surface texture depends on the hardness, grain size and pore characteristic of the parent material, as well as on the degree to which forces acting on the particle surface have smoothed or roughened it.

There is no recognized method of measuring surface roughness. The shape and surface texture of aggregates influence considerably the strength of HMA, the full role of shape and surface texture of aggregates in the development of HMA strength is not known, but possibly a rougher particle texture results in a larger adhesive force between the particles and the asphalt cement mix. Likewise, larger surface area of angular aggregate means that a larger adhesive force can be developed.

2.1. Influence of shape and surface texture on stability

Angular and rough textured aggregates have much greater particle-to-particle contact than rounded and smooth textured aggregate. Thus, when high resistance to shearing forces is required, rough, angular-shaped aggregates are used. This influence of particle contact is present not only in the coarse aggregate, but also in rough, angular fine aggregates. As an example, when highly stable asphaltic aggregate mixtures are needed, it is specified that both the coarse aggregate and the fine aggregate must be angular and rough surface textured crushed stone. Flaky and elongated aggregates are not desirable in asphalt applications, as they tend to break easily under stress.

2.2. Influence of shape and surface texture on workability

The ease of movement of one aggregate particle relative to another is related to the number of contact point between the aggregate particles. Thus rounded, smooth textured aggregate has a much better workability than rough angular aggregate. There is a noticeable increase in the ease of mixing a binder with gravel over mixing a binder with crushed stone.

2.3. Influence of shape and surface texture on amount of asphalt cement required

For the same weight of aggregate, an angular rough surface textured particle has a greater surface area than a rounded smooth surface textured particle. The greater the aggregate surface roughness, the greater the asphalt cement demand to fill surface voids. Also, the more aggregate angularity, the greater the asphalt

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