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Original Research Paper

An empirical method for estimating surface area of aggregates in hot mix asphalt

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ABSTRACT

Bitumen requirement in hot mix asphalt (HMA) is directly dependent on the surface area of the aggregates in the mix, which in turn has effect on the asphalt film thickness and the flow characteristics. The surface area of aggregate blend in HMA is calculated using the specific surface area factors assigned to percentage passing through some specific standard sieve sizes and the imaging techniques. The first process is less capital intensive, but purely manual and labour intensive and prone to human errors. Imaging techniques though eliminating the human errors, still have limited use due to capital intensiveness and requirement of well-established laboratories with qualified technicians. Most of the developing countries like India are shortage of well-equipped laboratories and qualified technicians. To overcome these difficulties, the present mathematical model has been developed to estimate the surface area of aggregate blend of HMA from physical properties of aggregates evaluated using simple laboratory equipment. This model has been validated compared with the existing established methods of calculations and can be used as one of the tools in different developing and under developed countries for proper design of HMA.

1. Introduction

Flexible pavement accounts for major percentages of the roads all over the world with the hot mix asphalt (HMA) as its base and surface course. The bituminous course up to 350 mm thick may be used in heavy traffic, making it the as the most expensive component of the road project costing up to two thirds of the total cost. The surface area of the aggregates blended in HMA can directly affect the asphalt film thickness and the flow characteristics (Anirudh et al., 2014; Arasan et al., 2010a, b; Naidu and Adiseshu, 2013; Ramli et al., 2013). Estimation of the surface area of aggregates in HMA is difficult due to their irregular shapes and the roughness of surface texture (Wang and Lai, 2009). The surface area which is one of the vital inputs in the design of HMA primarily derived based on the

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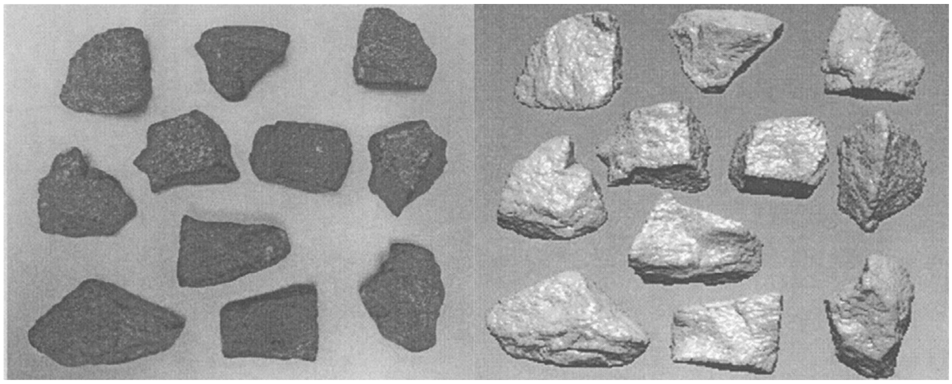

Fig. 1 – Picture of the aggregate particles.

centrifuge kerosene equivalent (CKE) (Asphalt Institute, 2007). Asphalt Institutes Manual Series MS-2 standardized the surface area factor (SAF) for a specified set of sieve sizes. Subsequently, fractional dimensional method was developed and a major improvement was achieved on surface area measurement through 3D laser imaging techniques to improve the accuracy (Arasan et al., 2010a, b). However, these techniques are either time consuming, limited accuracy, prone to subjectivity and human error or expensive. The costly 3D laser imaging equipment is not even available in all research laboratories of developing countries like India. Even the laboratories in remote areas of developing and under developed countries do not have the standard Marshall design equipment, which makes mix design of HMA difficult for field engineers. To overcome these difficulties, a simple mathematical model based on the physical properties of aggregates has been developed in the present paper for estimating surface area of the aggregates used in HMA and validated compared with other important existing methods used worldwide.

2. Background

HMA is a heterogeneous mix of materials consisting of aggregates, mineral fillers, bitumen, additives and air voids. Aggregates constitute the major portion of the HMA, primarily responsible for strength. HMA is designed to be durable under different types of loading and environmental conditions. Its durability mostly depends on (i) the type and quantity of bitumen, (ii) gradation, quality and quantity of aggregates, (iii) quantity of mineral fillers and voids (Anochie-Boateng et al., 2011; Anochie-Boateng and Maina, 2013; Anirudh et al., 2014; Arasan et al., 2010a, b; Bhasin and Dallas, 2006; Naidu and Adiseshu, 2013; Ramli et al., 2013). The physical properties of aggregates, i.e., angularity, form and texture at a macro scale are co-related with the distress mode, such as rutting in HMA. The physical and chemical properties of aggregates at a macro and micro scale also influence the performance of the HMA. Therefore, for estimating strength of the HMA, evaluation of the surface area of aggregate blend used in HMA in an accurate manner (Anochie-Boateng et al., 2011; Anochie-Boateng and Maina, 2013) is of vital importance. But evaluating the surface area of aggregates in a mix or even a single aggregate is difficult due to their irregular shapes, and the roughness of surface texture of aggregate particles (Fig. 1). This picture gives a rough assessment difficulty in measuring the surface area of aggregates.

A detailed and systematic review of literatures enumerating the work done by researchers on the surface area calculation of the aggregates used in HMA to ascertain the virtual film thickness for quantifying bitumen are described below.

Francis Hveem was among the first in the 1930's developed a mix design method for calculating the optimum bitumen content (OBC) for California Department of Transport. Here, film thickness was considered as an important factor for designing HMA and assumed that each aggregate particle needed to be covered with same optimum film thickness. This paves way for calculating the surface area of the aggregate blend was used in HMA (Asphalt Institute, 2007). The research thereafter could not swap Asphalt Institutes Manual Series MS-2 based on SAF for a specified set of sieve sizes widely used for deriving the surface area of aggregates blend used in HMA prior to 2003. Radovskiy (2003) analysed the formula used for calculating the film thickness in HMA and observed that obtaining film thickness by dividing the effective volume of asphalt to surface area calculated using specific surface area factor needs revision and stressed for revisiting

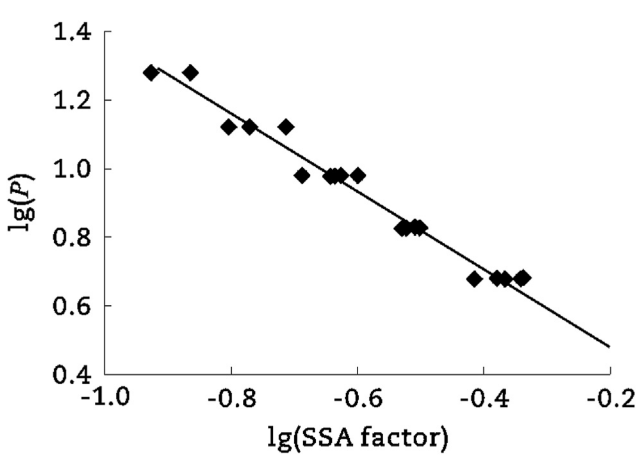

Fig. 2 – Graph between lg (SSA factor) and lg (P).