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A laboratory compaction approach to characterize asphalt pavement surface friction performance

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ABSTRACT

The main objective of the current study is to investigate whether surfaces produced by a standardized roller compaction method, using several compaction modes, could be used to simulate the frictional properties of the as-constructed pavement surfaces of a new, full-scale hot mix asphalt (HMA) road test section. Laboratory and field friction measurements were compared. The frictional characteristics of asphalt mixtures with different aggregate sizes, mix gradations and binder contents were investigated. Results indicated that the laboratory roller compaction method closely simulates, from a frictional point of view, the field construction processes. Thus, this methodology may be integrated into the existing mix design practices to assess asphalt mix frictional characteristics and to optimize the mix design accounting for both structural and functional requirements.

1. Introduction

Engineers involved with asphalt mix design attempt to account for several key mixture parameters, including stability, durability, fatigue resistance and permanent deformation. The above mentioned parameters characterize the asphalt mix and control the asphalt pavement structural performance. However, the asphalt pavement should provide as well road safety. Pavement surface frictional characteristics play an important role in road safety and thus the incorporation of the skid resistance evaluation in the asphalt mix design practices is of extreme importance.

Skid resistance describes the contribution of the road surface to the development of friction at the tire-pavement interface. It is a relationship between the vertical force and the horizontal force developed as a tire slides along the pavement surface. The friction force between the tire and the pavement surface is an essential part of the vehicle-pavement interaction. It allows the vehicle the ability to accelerate, maneuver, corner and stop safely as well as plays a great role in reducing wet pavement skid accidents [1]. Low levels of friction at the interface between the pavement and the car tires are known to account for vehicle accidents [2]. Depending on the rotational speed of the wheel and the characteristics of the road surface, after the maximum friction level is reached, the wheel may start skidding. A direct consequence of skidding is a dramatic loss of breaking power and steering capability of the vehicle which leads to property damage and may result into human casualties.

Currently, the design of asphalt mix accounting for skid resistance is rather empirical, based on previous experience gained from typical textures achieved in the field from dense, gap or open graded aggregate gradation and selection of high polish resistant aggregates. The major disadvantage of this approach is that the designer cannot evaluate the effect of changing the mix components in skid resistance before the mix is placed in the field. Consequently, a reliable test method is needed to fabricate laboratory asphalt specimens with frictional properties that represent field pavement surface performance just after construction.

The current research focuses on the investigation of utilizing the steel roller compaction method [3], which is a well proven standardized international method, for sample preparation in order to characterize the asphalt pavement surface friction performance. The evaluation of asphalt mixtures frictional characteristics with different aggregate sizes, mix gradations and binder contents is the initial objective of the current study. The main objective is to investigate whether the surfaces resulting from laboratory roller compaction, adopting several compaction modes, could be used to predict the frictional properties of the pavement surfaces just after construction on the basis of a new full scale HMA test section.

2. Background

2.1. Factors affecting skid resistance

Various factors affect the frictional characteristics of a tire-pavement surface system. These factors can be grouped into four

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categories; pavement surface characteristics, vehicle operational parameters, tire properties, and environmental factors. Among these categories the microtexture and macrotexture of asphalt mixture surface are key components of the tire-pavement surface interaction [4]. The microtexture and macrotexture of the surface and its friction are integrally related. Additionally, the characteristics of the construction materials and construction techniques influence pavement texture [5].

Macrotexture refers to the larger irregularities in the road surface (coarse-scale texture) that are associated with voids between aggregate particles. The magnitude of this component will depend on the size, shape, and distribution of coarse aggregates used in pavement construction, the Nominal Maximum Aggregates Size (NMAS), as well as the particular construction techniques used in the placement of the pavement surface layer. Adequate macrotexture is important for the quick dispersion of water accumulated on the surface of the pavement to prevent hydroplaning [6]. Additionally, it aids for the development of the hysteresis component of friction that is related to energy loss as the tire deforms around macro asperities and consequently increases pavement friction [7].

Microtexture refers to irregularities in the surfaces of the aggregate particles (fine-scale texture) that are measured at the micron scale of harshness and are known to be mainly a function of aggregate particle mineralogy [8]. These irregularities make the stone particles smooth or harsh when touched. The magnitude of microtexture depends on initial roughness of the aggregate surface and the ability of the aggregate to retain this roughness against the polishing action of traffic and environmental factors [9]. Microtexture plays a significant role in the wet road/tire contact. The size of micro asperities plays a key role in overcoming the thin water film. Existence of the microtexture is essential for squeezing the thin water film present in the contact area and generating friction forces. Moreover, the role of microtexture is to penetrate into thin water film present on the surface of the pavement so that the intimate tire/pavement contact is maintained. In general, microtexture contributes to friction at all speeds, but dominates at low speeds (about 50 km/h). Macrotexture generally controls friction at high speeds [1]. Overall, pavement texture can be used to indirectly determine surface friction. However using macrotexture alone cannot define the frictional properties of a pavement.

2.2. *Assessment of asphalt mix friction performance*

Previous work has demonstrated that aggregates play a key role in asphalt mix friction performance. Laboratory experiments showed that aggregate gap width had important effect on frictional resistance of several aggregate types [10]. However, there is a need for pavement engineers to examine this effect in the asphalt pavement mix design process to ensure that adequate skid resistance will be achieved in actual construction. The relation between the mineralogical composition of various aggregates and their capacity to generate adequate friction between the road surface and the tire after the polishing action of traffic was investigated from [8]. A new aggregate hardness parameter was introduced that gives a good indication of the ability of an aggregate to retain its microtexture and consequently its friction properties. Results from another study showed that the simulated road friction evolution curve, based on the Wehner/Schulze polishing test method, is similar to laboratory aggregate friction after two years [11]. However, the assessment of road polishing cannot be done only from the results of aggregate tests and should be complemented with the initial road friction information.

Research has been launched to develop a laboratory polishing device and testing procedure to accelerate polishing and evaluate the surface friction characteristics of hot mix asphalt (HMA) laboratory samples [12,13]. Moreover, evaluation of various aggregates blends to optimize the combination of micro- and macrotexture and achieve a satisfactory level of friction was also commenced. However, this approach needs to be verified with field polishing results. Other laboratory studies investigated the relationship between mix components properties and friction. A statistical model was developed to predict mix friction based on gradation and aggregates resistance to polishing [14]. The British Pendulum Number (BPN) value of aggregates was recognized to affect the mix skid resistance and thus the proposed model will help selecting the appropriate aggregate type for the desired mixture friction. A relationship between the initial field friction and mix properties (asphalt content, fineness modulus, bulk density and percent of aggregate passing the 4.75 mm sieve) was also proposed. A good correlation between macrotexture (measured using the sand patch method) of field and gyratory compacted specimens was further concluded [15]. However, poor correlation was observed between the British Pendulum Numbers recorded on unpolished field specimens versus gyratory specimens. The results suggested that the gyratory compactor orients the aggregate particles in a different manner than field compaction equipment. All previous work mainly aimed to characterize friction performance of aggregates and asphalt mix in the laboratory. While HMA friction properties can be laboratory evaluated it is anticipated that these represent field asphalt pavement surface friction characteristics. Consequently, a generally accepted standardized laboratory test method needs to be disposed that could address the pavement surface frictional characteristics.

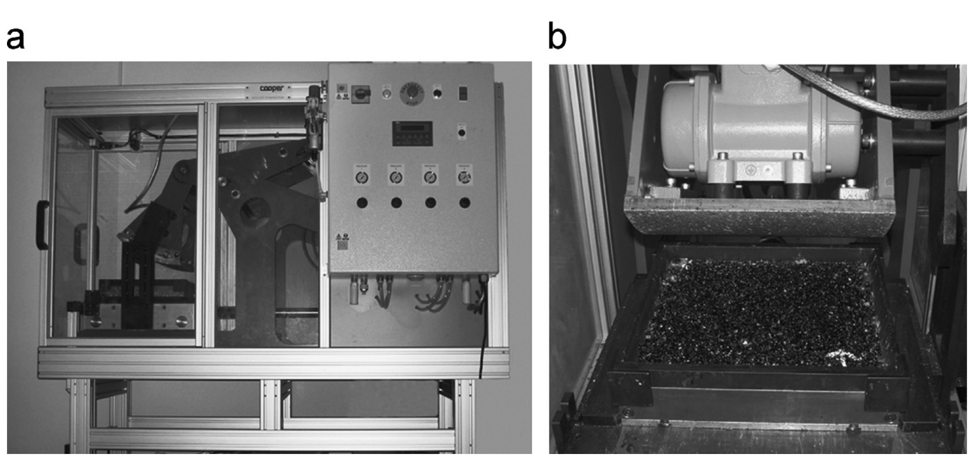

Fig. 1. Roller Compactor (left) and vibration assembly (right).