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Evaluation of Bond Between Bituminous Pavement Layers

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ABSTRACT

The vehicle ownership rate has been escalating round the world and to accommodate this increasing traffic load the modern trend of designing multi-layered bituminous pavement comes into play. Insufficient pavement interface bonding may lead to major pavement overlay distresses and eventually reduces the pavement service life. A tack coat is usually sprayed in between the bituminous pavement layers for effective stress distribution across pavement layer under heavy traffic loads. This paper presents the experimental results obtained through laboratory and field studies to recommend the effective tack coat materials and optimum application rate. A simple interface direct shear test was performed on 150 mm diameter cylindrical laboratory prepared specimens using two conventionally used tack coat materials in India namely, CMS-2 and CRS-1 sprayed at the interface between Bituminous Concrete (BC) and Dense Bituminous Macadam (DBM) at application rates varying at 0.20 kg/m2, 0.25 kg/m2 and 0.30 kg/m2.The test results indicated that CRS-1 as tack coat provides higher interface bond strength value compared to CMS-2. Similarly, irrespective of the types of emulsions used as tack coat, the optimum rate of application is found to be 0.25 kg/m2 as recommended in MORT&H's specifications. Also the test results obtained from the laboratory prepared specimens were compared with the results obtained from field cored specimens and found higher shear strength value of laboratory prepared specimens compared to field core specimens.

INTRODUCTION

The interface bonding between the layers is vital to the pavement integrity as the stresses generated from the heavy traffic loads need to be evenly distributed to each underlying bituminous layer to reduce the structural damage to pavements. Major pavement overlay distresses that have been linked to the poor interface bonding between pavement layers include slippage failure, premature fatigue, top down cracking, potholes andsurface layer delaminating [3]. One such result is the formation of cracks in the shape of a crescent as shownin Figure 1.1.

A tack coat is applied at the interface between the bituminous layers which acts as an adhesive or glue so thatcombined pavement layers perform as a monolithic structure rather than individual sections. Although hotbituminous binder, cutback bitumen or bituminous emulsions are commonly used as a tack coat materials, theuse of bituminous emulsions as a tack coat material is escalating instead of cutback asphalt or hot bituminousbinder because of their lower application temperature and environmental concerns related to the volatile.The modern flexible pavement is generally designed and constructed in several layers for effective stress distribution across pavement layers under the heavy traffic loads. The interlayer bonding of the multi-layered pavement system plays an important role to achieve long term performance of pavement. Adequate bond between the layers must be ensured so that multiple layers perform as a monolithic structure. To achieve good bond strength, a tack coat is usually sprayed in between the bituminous pavement layers. As a result, the applied stresses are evenly distributed in the pavement system and subsequently, reduce structural damage to the pavements. It has been observed that poor bonding between pavement layers contributes to major pavement overlay distresses. One of the most common distresses due to poor bonding between pavement layers is a slippage failure, which usually occurs where heavy vehicles are often accelerating, decelerating, or turning.The primary objective of this study is to fabricate a few simple testing devices for the evaluation of the bond strength offered by the tack coats at the interface between bituminous pavement layers in the laboratory scale by performing several laboratory tests with different tack coat application rates. The ideal design will be that the standard setup which produces consistent results comparable to others. A secondary goal of this study is to provide helpful information for the selection of the best type of tack coat materials and optimum application rate. An extensive laboratory testing programmed was devised and the results analyzed to critically assess the possible application of these materials in ground improvement. In this work we study on the bonding between the pavement layers of bituminous for evaluation of bond between bituminous pavement layers. We study on the basis of results obtained during the analyzing of various testes which are carried out in the transportation engineering lab. Numerous studies have been performed investigating adhesive properties of the interface between layers. These studies have typically developed a unique test method or instrument for analysis of the interface bond strength. Literature on bond strength clearly indicates that shear force is mainly responsible for interface bond failure.

LITERATURE REVIEW

The interlayer bonding between asphalt layers has a strong influence on the distribution of stresses and strains in the pavements subjected to traffic loads. Lack of or insufficient bond between the asphalt layers increases pavement deflections resulting in greater tensile stresses and strains created at the bottom of the respective layers. Un-favorable load conditions when accompanied with bad condition of the pavement structure may result in premature distresses (e.g. deformations, bulging, side shifting or cracking) which can decrease the service life of the pavement. A measure commonly used to ensure the desired bonding between the asphalt layers is application of bituminous tack coat sprayed on the contact surface. For successful tack coat performance it is of critical importance to identify and understand the factors which are relevant to the tack coat design and application. Leather shear test developed at the end of 1970 is one of typical method used to evaluate tack coat performance. Among the different factors affecting the interlayer bond strength the primary factors influencing the interlayer bond strength are the type of tack coat and the degree of compaction of the layers of asphalt, in particular of the upper (overlying) layer. The influence of the tack coat type on the bond strength has been examined and reported in many scientific articles and technical reports. The effect of the proper degree of compaction has been reported in various publications. The effect of good quality of compaction of asphalt layers on the bond performance was also examined on cores cut out from the existing pavements.The recent research confirmed the reported findings, i.e. a strong influence of the compaction technique and effort on the interlayer bonding of the asphalt layers. In some cases the maximum shear strength was attained by good compaction on its own, i.e. without any tack coat applied between the layers. It was also found that, the type of emulsion used for tack coat has a strong influence on the bond strength. some tests were carried out on cores cut out from the new constructed pavements of selected main roads in Poland. Specimens were tested by the relevant road administration laboratories. Literature on bond strength clearly reveals that shear force is mainly responsible for interface bond failure. Thatis why most of the research studies on the interface bond strength deal with tack coat direct shear tests. The mostpopular approach has been to employ a vertical shear force on a 150 mm double layered cylindrical specimenalong the interface at a constant deformation rate of 50.8 mm/min until complete separation of the specimen. While Santagata et.al. designed a device known as Ancona Shear Testing Research and Analysis(ASTRA) where a horizontal load was applied along the interface of double-layered cylindrical specimens of100 mm diameter at a constant displacement rate of 2.5 mm/min until failure; in the meantime, a constant normal load was applied on top of the specimen This paper aims primarily to fabricate a simple shear testing setup to save the time and cost aspects andthen using the same in existing Marshall Stability Apparatus for evaluating the interlayer bond strength between bituminous layers by performing laboratory tests. A secondary goal of this paper is to provide helpful information for the selection of the best type of tack coat materials and optimum application rate.

BASIC CONCEPTS OFEVALUATION OF BOND BETWEEN BITUMINOUS PAVEMENT LAYERS

The specimens prepared in the laboratory were made of asphalt mixtures compacted in two layers. The lower layer was made of AC22P asphalt concrete obtained by mixing granite aggregate with 4% (by weight) of plain bitumen type 35/50.The upper layer was made of AC20W asphalt concrete obtained by mixing granite aggregate with 4,2% (by weight) of plain bitumen type 35/50. The mixtures were designed according to the requirements of PN-EN 13108-1 and NA.

The two mixes were produced in the selected supplier's asphalt plant. The particle size distribution curves of the two mixes are presented in Particle size distribution curves of aggregate mixture used to produce the tested asphalt concretes Trial section was constructed using different asphalt concrete mix design. Their recipes were presented in report. Forthe purpose of this study only the bond strength between the wearing and binder course was examined. In field specimens cut out from selected main roads in Poland, the wearing course was made either from asphalt concrete or stone mastic asphalt and binder and base courses were made from asphalt concrete. Bond strength was examined for wearing/binder course interface

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Tack coat was examined in four different configurations: no tack coat, no tack coat but hot-to-hot placing or hot-to-cold placing, tack coat made from two different types of bitumen emulsions. Type 1 of the bitumen emulsion was produced from 160/200 plain bitumen. It was the standard material used for asphalt paving works in Poland till 2006. Type 2of the bitumen emulsion was produced from 70/100 plain bitumen It has been recommended as tack coat material since the introduction of PN-EN 13808 standard. Both laboratory and field specimens included the tack coat obtained by spraying the surface of lower asphalt layer with bitumen emulsion at a rate of 0.3–0.4 kg/m3.

This versatile digital loading frame features a microprocessor controlled drive system with stepper motor enabling the operator to easily set any test speed by digital switches. The machine is fitted with a port so it can be remotely controlled by a personal computer

EXPERIMENTAL INVESTIGATIONS

For preparation of cylindrical samples composed of Dense Bituminous Macadam (DBM) and Bituminous Concrete, aggregates were as per grading of Manual for Construction and Supervisions of Bituminous Works of Ministry of Road Transport and Highways. Coarse aggregates consisted of stone chips collected from a local source, up to 4.75 mm IS sieve size.

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Standard tests were conducted to determine their physical properties as summarized**.** Fine aggregates, consisting of stone crusher dusts were collected from a local crusher with fractions passing 4.75 mm and retained on 0.075 mm IS sieve. Its specific gravity was found to be 2.62. Portland slag cement (Grade 43) collected from local market passing 0.075 mm IS sieve was used as filler material. Its specific gravity was found to be 3.0

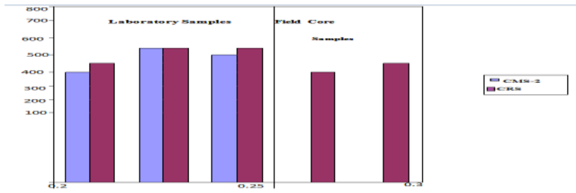
The 'Aggregate crushing value' gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. It is the percentage by weight of the crushed (or finer) material obtained when the test aggregates are subjected to a specified load under standardized conditions, and is a numerical index of the strength of the aggregate used in road construction. Aggregates with lower crushing value icate a lower crushed fraction under load and would give a longer service life to the road and hence a more economical performance. Weaker aggregates if used would get crushed under traffic loads, would produce smaller pieces not coated with binder and these would be easily displaced or loosened out resulting in loss of the surface/layer. In short the aggregates used in road construction must be strong enough to withstand crushing under roller and traffic

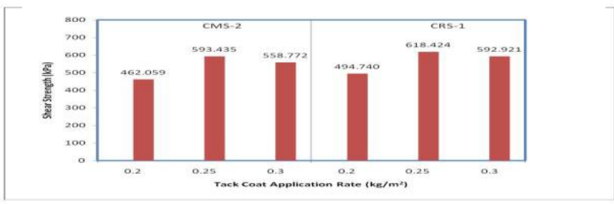
.The particle is considered as elongated if its length is more than 1.8 times the mean sieve size of the size fraction to which the particle belongs. Similarly, the particle is considered as flaky if its thickness is less than 0.6 times the mean sieve size of the size fraction. Elongated and flaky particles have a large surface area relative to its small volume, hence it decreases the workability of concrete mix. The flaky particles can affect the durability of concrete as they tend to be oriented in one plane, with water and voids forming underneath. The presence of flaky or elongated particles in excess of 10-15% of the weight of coarse aggregate is undesirable. The test is carried on aggregate sizes between 63 mm and 6.3 mm

.

The ductility test gives a measure of adhesive property of bitumen and its ability to stretch. In flexible pavement design, it is necessary that binder should form a thin ductile film around aggregates so that physical interlocking of the aggregates is improved. Binder material having insufficient ductility gets cracked when subjected to repeated traffic loads and it provides pervious pavement surface Ductility of a bituminous material is measured by the distance in centimeters to which it will elongate before breaking when two ends of standard briquette specimen of material are pulled apart at a specified speed and specified temperature.

ANALYSIS OF TEST RESULTS AND DISCUSSIONS





The base layer of a road lays the foundation for the upper pavement structure. It must offer excellent bearing capacity, be capable of withstanding a broad range of different climatic conditions, and remain functional over several decades. What materials are used for the construction of base layers? What properties do they need to possess Paving a hydraulically bound base layer. Precisely metered quantities of cement slurry are added via hose connections from the slurry mixer to the cold recycler.The base course serves as a foundation for the paving. Depending on the stresses to be expected, the road comprises various layers of different thickness in order to withstand the most diverse weather conditions and remain serviceable for many decades

Roads are exposed to particularly high stresses when the water contained in the pavement structure begins to freeze. Water expands when freezing, which can lead to frost damage that will sooner or later have an impact also on the road surface. This is prevented by a so-called frost blanket which usually consists of a mixture of gravel and sand, supplemented by crushed mineral aggregate. When compacted, these layers of frost-resistant materials conduct water away from the upper pavement layers, reducing tensions very effectively at the same time.

When the mineral aggregate mixture is bound with cement or lime, the resulting base layer is called a hydraulically bound base layer. Mineral aggregate mixtures used for this type of base layer consist of uncrushed gravel or coarse aggregate, chippings, and crushed or natural sand. Ever more frequently, these mixes also contain a percentage of recycled construction materials. Paving a hydraulically bound base layer. Precisely metered quantities of cement slurry are added via hose connections from the slurry mixer to the cold recycler.

For offset slip forming, material is normally transferred to the filling hopper from a concrete mixer truck. This material is transferred to the offset slip form mounted on the side of the paver by either a pivot able conveyor belt or a pivot able screw conveyor. The slip form produces the monolithic profile as the offset paver moves forward. The range of possible shapes and sizes is immense, from such common shapes as the New Jersey profile to customized solutions.

CONCLUSIONS

In this laboratory study was conducted to evaluate the bond strength provided by the tack coat laid at the interface between the Bituminous Concrete (BC) and Dense Bituminous Macadam (DBM). Also cylindrical core specimens were extracted from field to compare the results obtained from field with the results obtained from laboratory specimens. A laboratory study was conducted to evaluate the bond strength between the Bituminous Concrete (BC) and Dense Bituminous Macadam (DBM) layers with tack coat sprayed at the interface. For this purpose three simple shear testing models were fabricated and experiments were conducted using the same in a Marshall Stability Apparatus The following conclusions can be drawn from the study.A tack coat in form of bituminous emulsion is normally used between two bituminous layers, so that the two layers act in unison to take the traffic loads. Failures have been observed in the field because of deficiency of tack coat, either in form of quality or quantity, or both. As there is no standard method to address this issue, an attempt has been made in this study to develop a simple testing arrangement to be used in a conventional Marshall test apparatus to determine directly the interlayer bond strength between two layers. Specimens made of DBM in lower part and BC in upper part, have also been prepared as per Marshall procedure with few exceptions. The following conclusions are drawn from the results of the tests conducted at 25˚C.

- The optimum rate of application of emulsion as tack coat is found to be 0.25 Kg/m^2 irrespective of the two types of emulsion tried.
- Cationic Rapid Setting emulsion CRS-1 offers higher bond strength compared to Cationic Medium Setting emulsion CMS-2.
- Hence, it may be recommended within the limited scope of study that before laying a BC layer over DBM surface, CRS-1 emulsion applied at 0.25 Kg/m^2 may be preferred.
- Interface bonding is weaker at lower application rate because of the insufficient tack coat available to withstand the heavy shear stress. Also, shear strength decreases when the application rate is beyond the optimum as the excess tack coat material causes slippage at the interface. The test results concluded the application rate of 0.25 kg/m^2 as the optimum one for both types of tack coat.
- The specimens prepared using CRS-1 as a tack coat material exhibited slightly higher bond strength at all application rates compared to CMS-2.
- Laboratory specimens presented significantly higher shear strength compared to field core specimens.

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