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STUDY THE STRIPPING AND STABILITY OF AGGREGATE

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ABSTRACT

The stripping value of aggregate is defined as the ratio of uncovered area observed visually to the total area of aggregates, expressed as percentage. Proper adhesion between aggregate and bitumen is one of the principal fundamental properties for good performance of bituminous pavement. This adhesion can be reduced by presence of water which may be caused by de-bonding of bitumen from aggregate. The phenomenon is known as 'stripping". Bituminous roads are greatly susceptible to moisture damage. Nowadays proper drainage facilities are lacking on the roads which is one of the main reasons for road damage due to stripping. Adequate drainage must be provided for prevention of damage of roads due to stripping as complete failure of the pavement can take place.

Stripping is a complex problem comprising many variables, including the type and use of mix, aggregate and bitumen characteristics, environment, traffic, construction practice and use of anti-stripping additives.

Contact of water with bituminous pavement is one of the main factors for stripping. The moisture affects physical properties and mechanical behavior of bitumen paving mixtures as aggregates that have a dry surface adhere better to bitumen and have a higher stripping resistance than wet aggregate. The water can be in the form of ground water, surface water or rain water. Presence of water on the road, if not properly managed, may cause deterioration of road more rapidly as it reduce the potency of bond between bitumen and aggregate which provides strength to the mix and ultimately leads to failure of pavement. For prevention of such damage, adequate drainage must be provided.

The physical and chemical characteristics of aggregates have a significant effect on the bonding between aggregate and bitumen. In addition, aggregate surface texture. aggregate porosity and pore pressure are also known to affect stripping. A deficiency in properties of aggregates reduced the strength of bond and leads bitumen-aggregate mixture towards stripping. Stripping may further cause rutting, raveling, bleeding, cracking and formation of potholes and culminate with complete failure of pavement.

Hence, to prevent pavement from these failure, we need to thoroughly investigate various factors which affect the stripping of aggregates. This study presents various influencing factors, their effect and possible remedies to the problem. The stability test provides the performance prediction measure for the Marshall Mix design method. The stability portion of the test measure the maximum load supported by the test specimen. Load is applied to the specimen till failure, and maximum load is designed as stability.

The indirect tensile strength test is used to determine the tensile properties of bituminous mixture which can be further related to the cracking properties of the pavement. Low temperature cracking, fatigue and rutting are three distress mechanisms. The resistance of bituminous mixture to fatigue cracking is depending upon its tensile properties, notably its tensile strength and extensibility characteristics. The layers of flexible pavement structure are subjected to continuous flexing as a result of the traffic loads that they carry. resulting in tensile stresses and strains at the bottom of the bituminous layers of the pavements. The magnitude of strain is dependent on the overall stiffness of the pavement. Indirect tensile strength test is an indicator of strength and adherence against fatigue, temperature cracking and rutting.

Keywords: bituminous pavement, adequate drainage, stripping, potholes and culminate

1. INTRODUCTION

Stripping is one of the main causes due to which distress in bituminous layers occur. Moisture presence results in weakening or eventual loss of adhesive bond of bitumen from aggregate. Now a days, the roads are lacking in respect of proper drainage facilities. which is one of the main reasons for road damage due to stripping. Stripping can cause complete or partial failure of the pavement. Inadequacy in quality of aggregates and adhesion property of bitumen affects the quality of life of road, and if stripping is prevented, it will lead to reduction in quantity of resources and increase in pavement design life which in turn will lead to sustainable development. A brief overview of the stripping phenomenon of bituminous mixtures and research in the field over the past years has been presented in this study. The main objective of the paper is to study on stripping and stability characteristics of aggregates of Haryana due to the variation in various environmental factors.

The aggregates which are used in the study are taken from two places i.e. Tosham and Yamuna Nagar and then stripping value using these aggregates are studied. The field factors which are used to simulate the field conditions are temperature, contact period of water with bitumen and traffic effect. This work presents the lab test results which show the stripping value increases with increase in contact period, temperature and applied pressure on the aggregate at the time of test. After applying the pressure on aggregate with increase in temperature of water bath up to 60°C and contact period of water with bitumen for 5 days it has been observed that stripping value is increased with increase in immersion time. This study also shows that aggregates from Tosham shows more stripping value as compared to aggregates from Yamuna Nagar. The indirect tensile strength test results conducted on bituminous concrete samples indicated that tensile strength ratio increased with the use of modified bitumen that is CRMB-55 in place of VG-30.

2. OBJECTIVES OF THE STUDY

The study under consideration aims to identify the factors causing stripping and stability value of aggregate. It investigates the factors influencing stripping and stability of the mix including traffic and other environmental factors such as temperature, alternate wetting and drying and the pH value of water. The main objectives of the study are:

1. To evaluate the stripping and stability (indirect tensile strength) characteristics of aggregates of Haryana under standard test conditions.
2. To vary the standard test conditions of temperature and immersion time to simulate the field conditions and to evaluate the stripping under these varying conditions.
3. To evaluate stripping under the application of external pressure in the lab to simulate the effect of traffic load and tyre friction on the coated aggregate.
4. To study the effect of grade of bitumen on stripping of aggregate and indirect tensile strength value of bituminous mix.
5. To study the effect of additive on stripping value of aggregates.

3. LITERATURE REVIEW

Covington et al (1977) demonstrated that asphalt-aggregate adhesion is strongly influence by the PH of water, which changes with the temperature. The pH cause shift in angle of contact and significantly affect the wetting properties of bitumen. Weak acids affect some aggregate mineral like alkali feldspars. Adhesion affects capillarity while cohesion affects surface tension. Since most aggregate surface have electrostatic charges, water molecule attach to them with stronger forces than bitumen polar to satisfied unbalance surface charges. Calcareous aggregate give free calcium ions forming strong water resistant bonds with bitumen. Siliceous aggregates (with $SiO2$) form weak bonds with bitumen, which are hydrolytically unstable.

Tarrer et al (1991) reported that stripping in practice usually begins at the bottoms of the bitumen layer, where moisture content is highest and works its way up. A brief description of each of the suggested mechanism of stripping follows

Detachment

Detachment is the separation of a binder film from an aggregate surface by a thin layer of water to the aggregate surface through a crack in the bitumen film. Where stripping by detachment has occurred, the bitumen film can be strip cleanly from the aggregate, specify a complete loss of adhesion.

Displacement

Displacement is caused due to penetration of water from the aggregate surface results break in bitumen film. The break can be caused by incomplete coating of the aggregate initially or by film break.

Spontaneous Emulsification

It is observed that the spontaneous emulsification occurs whenever bitumen films are submersed in water but that the rate of emulsion formation depend upon the nature of the asphalt and the presence of additives.

Pore pressure

Pore pressure has been suggested as a mechanism of stripping in high void mixes where water may circulate freely through interconnected voids. Further traffic may induce high excess pore pressure in the trapped water causing stripping of the bitumen from aggregate.

Hydraulic scouring

Hydraulic scouring is a mechanism of stripping that is applicable only to surface courses. Stripping due to hydraulic scouring results from the action of vehicle tires on a saturated pavement.

Charles Mackean (1994) developed a moisture conditioning procedure to evaluate the effect of stripping on tensile strength of bitumen mixtures using the indirect tensile test. The test has been identified by AASTHO T283and ASTM D 4687.The tensile strength ratio (TSR) is calculated by dividing the maximum load applied to the conditioned sample by the maximum load applied to the dry sample. The average TSR value of the three replicates in one test is reported.

Kandhal et al (1998) reported in their study Some aggregate properties that are guess to affect the quality of the adhesive bond in a bitumen -aggregate mixture are: mineralogy (chemical composition), surface texture, absorption, surface age, surface coating, and particle shape. Aggregates are generally classified as hydrophilic. "water loving" or hydrophobic, "water hating". Hydrophilic aggregates have usually high silica content and an acidic surface. They have a greater affinity of water than bitumen and are consider being more susceptible to stripping. Hydrophobic aggregates have usually high carbonate content and a basic surface. They have a greater affinity for bitumen than water and are generally considered more resistance to stripping.

Bagampaddeet al (2006) investigated the impact of bitumen and aggregate composition on stripping in bituminous mixture using four bitumen and four aggregates.

It was found that mixture made with lower penetration grade bitumen exhibit higher tensile strength in dry and wet condition.

Yildirim et al (2007) shows that polymer modified bitumen shows greater resistance to fatigue, thermal cracking, rutting, stripping, and temperature susceptibility than neat binders and exhibited increased viscosity and elastic recovery.

P.K. Jain and J B Gupta (2007) reported in their study that indirect tensile strength under specific conditions of moisture soaking and immersion correlate with stripping area of aggregates to an extent of 90-100%. They suggested the addition of dehydrogenated tallow di methyl amine in bitumen to prevent stripping in presence of detrimental Salt ion.

Erollskender and AtkonAksoy (2009) reported in their study that moisture damage resistance increased with lime stone filler replacement substituted for basalt filler. AASTHOT 283 was found to be distinctive in terms of filler effect evaluation. With the adding of hydrated lime, the damage ratio for both basalt filler and lime stone filler increased and also indirect tensile strength increased. Hydrated lime relatively increases stripping resistance.

Moghadas Nejad et al (2012) reported in their study that the addition of Zycosoil in mixture containing lime stone and granite causes tensile strength ratio to increase 3% and 14% respectively. Due to stiffness and greater angularity of granite aggregates, mixture containing granite has more fatigue life. Because of formation of hydrophobic nano layer on aggregates, use of Zycosoil in the mixture containing lime stone granite aggregates lead to increase of fatigue life of 6% and 25% respectively.

Y. Liu et al (2014) determined that Bituminous mixtures containing limestone aggregates have better moisture resistance than granite aggregates based on results from loose bitumen coated moisture sensitivity tests. For unmodified mixtures, stiffer binder (40/60) provides better moisture resistance compared with softer binder (160/220), based on loose bitumen coated moisture sensitivity tests.

TESTS TO DETERMINE STRIPPING

Test As Per Indian Standard

"Method of test for determination of stripping value of road aggregates (IS: 6241-1971)" is the

Standard describing the stripping test for the coarse aggregate.

Procedure of testing the value of stripping is given below.

Test Procedure

The step wise procedure for preparation of sample and its testing under standard conditions is as per "Method of Test for Determination of Stripping Value of Road Aggregates (IS: 6241-1971) code which is as follows:-

Take 200g of aggregate passing 20mm IS sieve and retained on 12.5mm sieve. Dry, clean and mix aggregate with 5% bitumen binder by weight of aggregate, bitumen binder is heated to 160°C (110°C in the case of tar binder). The aggregate are also to be heated prior to mixing to a temperature of 150°C and 100°C, when these are to be mixed with bitumen and tar respectively.

The mixture is transferred to a 500 ml beaker after complete coating and allowed to cool at room temperature for about 2 hours. Distilled water is then added in the beaker to immerse the coated aggregate. The beaker is covered and kept in a water bath maintained at 40°C, taking care that the level of water in the water-bath comes up to at least half the height of the beaker. After the expiry of 24 hours the beaker is taken out, cooled at room temp. The extent of stripping is estimated visually while the specimen is still under water. The permissible value of stripping is 5 percent.

Test Under Varying Condition

In this study, testing is performed on the aggregate-bitumen sample by undertaking various field conditions in to consideration. Most of the time it is envisioned that the laboratory test condition and field condition vary a large extent leads to stripping of aggregates on the road even when laboratory tests indicates nil stripping value. It is mainly because of difference of temperature, contact time of water with coated aggregates, pH value of water, alternate wetting and drying conditions, traffic, vehicle load and tyre friction in the field which are different from the lab conditions. To determine the effect of these variables on stripping, experiment have been carried out in the highway engineering lab national institute of technology Kurukshetra. The effect of traffic load and tyre friction has been simulated by applying light pressure with small tyres by the observer.

INDIRECT TENSILE STRENGTH TEST

The IDT strength of bituminous mixtures is conducted by loading a cylindrical specimen across its vertical diametric Plane at a specified rate of deformation and test temperature The peak load at failure is recorded and used to calculate the IDT strength of the specimen.

The values of IDT strength may be used to evaluate the relative quality of bituminous mixtures in conjunction with laboratory mix design testing and for estimating the potential for rutting or cracking. The results can also be used to determine the potential for field pavement moisture damage when results are obtained on both moisture- conditioned and unconditioned specimens.

The tensile characteristics of bitumen mixture are evaluated by loading the Marshall specimen along a diametric plane with a compressive load at a constant rate acting parallel to and along the vertical diametrical plane of the specimen through two opposite loading strips. This loading configuration develops a relatively uniform tensile stress perpendicular to the direction of applied load and along the vertical diametrical plane, ultimately causing the specimen tested to fail by splitting along the vertical diameter. A 13 mm wide strip loading is used for 101 mm diameter specimen to provide a uniform loading with which produce a nearly uniform stress distribution. A loading rate of 51mm/minute is adopted. Tensile failure occurs in the sample rather than the compressive failure. The compressive load indirectly creates a tensile load in the horizontal direction of the sample.

The peak load is recorded and is divided by appropriate geometrical factors to obtain the split tensile strength using the following equation:

$St=2000p/\pi Dt.$ ... (3.1)

St-indirect tensile strength, kPa

P= maximum load. N

T-specimen height immediately before test, mm

D= specimen diameter, mm

Equation 3.1 is used to calculate indirect tensile strength and is used extensively in the section 4.4.

Bituminous mix made from certain materials may be sensitive to the presence of water in the finished pavement. Water will cause the binder to not adhere to the aggregate. Since the binder is the "glue" that holds the pavement together, rapid failure of the pavement can be expected if the Binder cannot adhere to the aggregate. This is often referred to as stripping. To help prevent stripping, additives such as hydrated lime or liquid anti- stripping chemicals may be required AASHTO T 283 is a test method that can be used to determine if the materials may be subject to stripping and also to measure the effectiveness of additives. The test is performed by compacting specimens to an air void level of six to eight percent. Three specimen are selected as a control and tested without moisture conditioning, and three more specimens are selected to be conditioned by saturating with water undergoing a freeze cycle, and Subsequently having a warm-water soaking cycle. The specimens are then tested for indirect Tensile strength by loading the specimens at a constant rate and measuring the force required to break the specimen. The tensile strength of the conditioned specimens is compared to the control specimen to determine the Tensile Strength Ratio (TSR).

Fig.1 Indirect tensile strength testing machine

TENSILE STRENGTH RATIO (TSR)

Moisture damage in bituminous mixes refers to the loss of serviceability due to the presence of moisture. The extent of moisture damage is called the moisture susceptibility. The ITS test is a performance test which is often used to evaluate the moisture susceptibility of a bituminous mixture. Tensile strength ratio (TSR) is measure of water sensitivity. It is the ratio of the tensile strength of water conditioned specimen, (ITS wet, 60°C, and 24 h) to the tensile strength of unconditioned specimen (ITS dry) which is expressed as a percentage. A higher TSR value typically indicates that the mixture will perform well with a good resistance to moisture damage. The higher the TSR value, the lesser will be the strength reduction by the water soaking condition, or the more water- resistant it will be.

SAMPLE PREPARATION FOR INDIRECT TENSILE STRENGTH TEST

Approximately 1200gm of aggregates and filler is heated to a temperature of 175-190°C. Bitumen is heated to a temperature of 121 - 125°C with the percentage of bitumen 5.4% by weight of the mineral aggregates. The heated aggregates and bitumen are thoroughly mixed at a temperature of 154 160°C. The mix is placed in a preheated mold and compacted by a rammer with 75 blows on either side at temperature of 138°C to 149°C. Three or four specimens may be prepared using each type of bitumen content. The compacted specimen are cooled to room temperature in the molds and then removed from the mold using a specimen extractor. The diameter and mean height of the specimen are measured and then they are weighed in air and also suspended in water. The specimens are kept immersed in water in a thermostatically controlled water bath at 60°C for 24 hour. The specimens are taken out and placed in the air bath at the temperature of 25°C and tested to determine the conditioned indirect tensile strength test.

4. CONCLUSIONS

The main conclusions drawn from the study are:

1. Stripping of aggregates is caused on the roads when they are subjected to inundated conditions due to poor drainage of roads. The test conditions to determine stripping value in the Lab do not properly simulate the field conditions. The difference in the lab and field conditions leads to stripping in the field many a times whereas lab test results indicate no stripping.
2. Two types of aggregate are considered for the purpose of stripping test of aggregates, Yamuna Nagar and Tosham quarry of Haryana. It is observed that the aggregates from Tosham quarry show more stripping as compared to aggregates of Yamuna Nagar. The aggregates of Yamuna Nagar quarry are considered for the purpose of indirect tensile strength test.
3. The lab tests indicate that stripping increases with increase in contact time of water with coated aggregate and test temperature.
4. CRMB-55 grade bitumen shows higher resistance to stripping than VG-10 grade bitumen.
5. To simulate the effect of traffic load and tyre friction on aggregates, slight pressure was applied with small tyre while visualizing the stripping of aggregates. It is observed that the stripping increases with application of external pressure on the coated aggregates.
6. Altered temperature cycle and wetting drying cycle increase the stripping of aggregates.
7. Acidic or alkaline nature of contact water also affects the stripping.
8. Stripping of aggregates is also depending upon types of aggregates.

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