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Influence of Coarse Aggregate Shape Factors on Bituminous Mixtures

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ABSTRACT :

The research represents a laboratory study of the factors effecting the aggregate shape in HMA. The shape of the aggregates particles is not only the factor of aggregate characteristics which effect on the HMA. Other specifications such as aggregate surface texture and aggregate gradation may also effect the HMA. The aggregate shapes are considered for the study of research was cubical, disk and blade shapes. Two aggregate surface textures used in the mix which are smooth and rough particles. The aggregate gradations that are used in the mixtures were high, medium and low gradation. Shape of the aggregate was determined by two methods. The first method was the surface measurement of coarse aggregate, while the second method was particle shape index. Marshal tests and indirect tensile test were performed to investigate the different in behaviors of different samples with different specifications considered in this study taking into account that the control mix contains crushed gravel, rough aggregate particles with disk shape, medium gradation of the aggregate and 4% of limestone powder content as mineral filler. The results showed in that using of cubical aggregate shape increased each of bulk density, Marshall Stiffness, Marshall Stability, Marshall Quotient, Stiffness Modulus and Indirect Tensile Strength of the mix than the disk and blade shapes while decreased each of flow and air voids. The results also showed that medium gradation of aggregate had good results than the other gradations. By using the rough particles the values of the ITS and stiffness modulus were higher than that using smooth particles.

Keywords: HMA, Aggregate, Aggregate shape, Gradation and Mineral filler.

INTRODUCTION

Many ambitious roads construction plans and activities are primarily involve bituminous pavements with hot mix technology. Hot mix technology which is a very conventional method for road construction, which has structurally satisfied the performance and requirements over many years. The procedure generally follows by the hot mix technology are : Heating of binder, aggregate, mixing, tack

coating, laying of the mix followed by the compaction process everything done at high temperature in a range of 120ºC to 160ºC temperature. Though the performance wise this has been the most suitable for pavement structures, but if their high use, have several drawbacks like environmental degradation, high energy consumption, increase in carbon footprint, low output for mix production, low laying work in rains and cold weather, limited construction period in a year, oxidative hardening of binder, health and safety hazard to Besides this in some North and North Eastern parts of India like Jammu and Kashmir, Manipur, Assam, Meghalaya, Arunachal Pradesh and others, rural road projects involving several lakhs and Due to topographical and weather constraints, it is difficult to work with hot mix technology in such hilly regions, heavy rainfall and forest zones. So, it is desirable to find out suitable alternative hot mix technology.

Advantages

• It improves skid resistance, reduces noise when compared to conventional alternative pavement surfaces.

• SMA also shows improved resistance to fatigue effects and cracking at low temperatures, also increases durability, and reduces permeability and sensitivity to moisture.

• SMA provides excellent resistance to rutting due to slow, heavy and high volume traffic, and resistance to deformation at high pavement temperatures.

• SMA has a rough texture which gives good friction properties after the upper surface film of the binder is removed by the traffic. Higher strength, durability, reduced moisture permeability and longevity of SMA (over conventional mixes)

Aggregates are the major material in construction of pavement. Conventional road aggregates in India are natural aggregates obtained from crushing of rocks. In Hot Mix Asphalt (HMA), aggregates are combined with the asphalt binding medium to form a compound material. By weight, the aggregate generally accounts for between 92 - 96 percent of HMA. They are comprised of the majority of pavement volume. Therefore, knowledge of aggregate properties is important in designing of a high quality pavement. Natural aggregates are generally extracted from the larger rock formations through the open excavation (quarry). Usually the rock are blasted and dug from the quarry walls then it reduced its size using a series of screens and crushers. Some quarries may also have capable of washing the finished aggregate.

Manufactured rock typically consists of industrial by-products such as slag (by-product of the metallurgical processing – typically produced from processing steel, tin and copper) or specialty rock that is produced to have a particular physical characteristic not found in the natural rock (such as the low density of lightweight aggregate).

INFLUENCE OF AGGREGATE PROPERTIES ON HMA PERFORMANCE

Aggregate particles can define in terms of the three independent shape properties: shape (or form), angularity, and surface texture (Barrett, 1980). These three aggregate shape properties are fully characterized particles based on their geometry. This form of property characterizes aggregate particles based on ratios of their particle dimensions. The angularity property measurement describes particles based on the variations at the edges of particle. This measurement defines particles in a range between rounded to angular. This property describes the surface roughness of the particle at a small scale, which is not influenced by changes in shape or angularity. These three properties are independent of each other: an increase or decrease in one of these properties does not necessarily influence the other two properties (Rousan, 2004).

SIGNIFICANCE OF AGGREGATE SHAPE ON BITUMINOUS MIXER

Rounded aggregates

The rounded aggregates are completely shaped by the attrition and available at the seashore in the form of seashore gravel. Rounded aggregates result the minimum percentage of voids (32 – 33%) hence gives more workability. They are not considered for the high strength concrete because of poor interlocking behavior and weak bond strength in between the rounded aggregates.

IRREGULAR AGGREGATES

The irregular or partially rounded aggregates are partly shaped by attrition and these are available in the form of pit sands and gravel. Irregular aggregates may result in the increase of voids when compared to rounded aggregates i.e.,35- 37% of voids. These will give lesser workability when compared to the rounded aggregates. The bond strength is slightly greater than rounded aggregates but not as required for high strength concrete.

Angular Aggregates

The angular aggregates consist of well defined edges formed at the intersection of roughly planar surfaces and these are obtained from crushing of the rocks. Angular aggregates result maximum percentage of voids (38-45%) hence gives less workability. They give 10-20% more

compressive strength due to development of the stronger aggregate-mortar bond. So, these are usally used in high strength concrete manufacturing.

Flaky Aggregates

Whereas the aggregate thickness is small when compared to the width and length of that aggregate is said to be flaky aggregate. Or in the other words, when the least dimension of the aggregate is less than the 60% of its mean dimension then it is said to be flaky aggregate

Literature Review

Transportation research circular entitled "Asphalt Emulsion Technology" (TRB, 2006) has provided detailed information regarding bitumen emulsion. An emulsion is a dispersion of the small droplets of the one liquid in another liquid. Emulsions are made by any two immiscible liquids, but in most of the emulsions one of the phases is water. Bitumen emulsion is a liquid product in which the substantial amount of bitumen is suspended in a finely divided form in water in presence of emulsifiers. The bitumen droplets are range from 0.1 to 20 micron in diameter. Standard bitumen emulsions is a brown liquid and contain 40% to 75% bitumen, 0.1% to 2.5% emulsifier, 25% to 60% water plus some minor components.

Elliot, Ford, Ghanim and Tu5 conducted an investigation to evaluate the effect of variations in the gradation of aggregates on the properties of asphalt concrete mixtures. The primary objectives were to determine the effect of gradation variation on (1) creep behavior as a measure of rutting resistance, (2) split tensile strength as an indicator of fatigue resistance potential, (3) Marshall Mix properties as a measure of mix acceptability and (4) resilient modulus as a design parameter.

EFFECTS OF AGGREGATE PROPERTIES ON HMA MIXTURES

Much research has been conducted concerning the effects of aggregate properties and characteristics on the quality and performance of HMA mixtures. A review of this research has been conducted and summarized into general categories that best relates aggregate properties to the performance of HMA mixtures. The literature review has been divided into the following areas

1) laboratory evaluations
2) field investigations

Laboratory evaluations

Elliot, Ford, Ghanim and Tu (6) conducted an investigation to evaluate the effect of variations in aggregate gradation on the

properties of HMA mixtures. The primary objectives were to determine the effect of gradation variation on (1) creep behavior as a measure of rutting resistance, (2) split tensile strength as an indicator of mix properties as a measure of mix acceptability and (4) resilient modulus as a design parameter. The authors evaluated five aggregate gradations of crushed limestone that simulated typical Arkansas State Highway and Transportation Department (AHTD) HMA mixtures. These gradations represented the extreme variations (based on field extractions) encountered on AHTD paving projects. The aggregate blends included the standard 3/4 in. maximum aggregate AHTD gradation (mid band), a coarse gradation (standard blend minus maximum variations for each sieve), a fine gradation (standard blend plus maximum variations for each sieve), and The poorly-graded gradations varied from the coarse gradation values to the fine gradation values (coarse-fine) and from the fine gradation values to the coarse gradation values (fine-coarse) and crossed From this investigation, the authors concluded the following:

1. Variations in gradation have the greatest effect when the gradation changes the general shape of the gradation curve (poorly-graded or cross-over gradations).

2. Creep stiffness is lowest for poorly-graded, cross-over gradations.

3. Coarse gradation produced the lowest tensile strengths.

METHODOLOGIES

MATERIALS AND METHODS

AGGREGATE

Aggregates influence, to a great extent in load transfer capability of pavements. Hence it is essential to teste the aggregate before using for construction. Not only that aggregates should be strong and durable, they should also possess proper form and size to make the pavement act monolithically. Aggregates are tested for strength, toughness, hardness, Shape and water absorption. Natural aggregates are generally obtained by extracted from larger rock formation through an open excavation (quarry). Extracted rock is typically reduced to series of usable sizes by mechanical crushing. Manufactured aggregate is often a bye product of other Manufacturing industries.

BITUMEN BINDER

The Bitumen binder component of a Bitumen pavement typically makes up about 5 to 6 percent of the total Bitumen mixture and coats and binds the aggregate particles

together. Bitumen The properties of binders are often improved or enhanced by using additives or modifiers to improve adhesion (stripping resistance), flow, oxidation characteristics, and elasticity. Modifiers include oil, filler, powders, fibers, wax, solvents emulsifiers, wetting agents, as well as other proprietary additives (AASTHO, 1993).

Quantification of aggregates

Mineral aggregates

Generally aggregate represents coarse and fine aggregates. There are various types of mineral aggregates which form the bituminous mixes. Aggregates play a very crucial role, which provides strength to SMA mixtures with 70-80 percent coarse aggregate content out of the total stone content. The aggregates that are used to manufacture bituminous mixes are obtained from various natural resources such as mines or glacial deposits.

Due to the high quantity of coarse aggregate in mixes forms a skeleton type structure and provides stone on stone contact which gives high resistance and high shear strength for rutting. Various types of artificial or manmade wasters are used as natural aggregates used in making the mixes example as slag, a byproduct of steel industries. Here Slag and RAP are used in partial replacement of stone aggregate for all coarse aggregate grades from 19-2.36mm.

Conclusion

Higher Marshall Stability values were obtained from the mixes prepared with cubical shape aggregates i.e. 16.77kN. It is observed that stability increases with increase in proportion of cubical aggregates up to 20%. Cubical particles exhibit interlock and internal friction, which results in higher mechanical stability than the flat, thin, and elongated particles. The parameters such as stability, flow and voids filled with bitumen increases with increase in proportion of cubical aggregates for DBM mixes. The parameters such as air voids and voids in mineral aggregate increases with increase in proportion of blade type of aggregates in DBM mixes, because the same type of particles will not replace the gaps between the bitumen mixes.Mixes prepared with replacement of 20% cubical, blade, rod and disk aggregates shown higher stability values.The stability of mix with different type of aggregates is shown good results, against satisfying the minimum requirement of 9kN.Cubical shape aggregates attains the maximum percentage VMA, and blade shape aggregates attains the lower values

because of the aggregates tend to break down excessively during compaction.

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