Influence of coarse aggregate shape factors on bituminous mixtures

A SAITEJA[1] BHUKYA PAVANI[2] YASA RAVALI[3] TURSA LAHARIKA[4] PUTTA PAVANI[5]

[1]Assistant Professor Department of Civil Engineering, Anu Bose Institute of Technology, K.S.P.Road, Paloncha, Khammam Dist, 507115

[2, 3, 4, 5]Scholar, Department of civil engineering, Anu Bose Institute of Technology, K.S.P.Road, Paloncha, Khammam Dist, 507115

ABSTRACT

Aggregates are the principal material in pavement construction. Conventional road aggregates in India are natural aggregates obtained by crushing rocks. The physical properties of coarse aggregate are more significant in new generation bituminous mixtures. Aggregate characteristics such as particle size, shape, and texture influence the performance and serviceability of hot mix asphalt pavement. The shape of aggregate particle has significant influence on performance of the Bitumen pavement. Particle shape can be described as cubical, blade, disk and rod .The strength serviceability requirements of Bitumen mixes such as stability, flow, voids in mineral aggregate (VMA), voids filled with bitumen (VFB) and air voids are highly depend on the physical properties of aggregate. Dense bituminous macadam (DBM) mixes were analyzed with different proportions (10%, 20%, 30%, 40%, 50%) of different shape of aggregates were studied. Mixes with cubical and rod shape aggregates has been showed good results on stability. The parameters such as air voids and voids in mineral aggregate increases with increase in proportion of blade type of aggregates in DBM mixes. The particle index value of coarse aggregate significantly affected the engineering properties of Hot mix asphalt (HMA) mix. The particle shape determined how aggregate packed into a dense configuration and also determined the internal resistance of a mix. Mixes prepared by replacing 20% aggregates shown higher stability values. Cubical particles exhibit interlock and internal friction, and hence results in greater mechanical stability than the blade, rod, and disk shape aggregates. Particle shape parameter values obtained were higher for cubical shape aggregates and lower for blade shape aggregates.

Key Words: coarse aggregate, aggregate shape, hot mix asphalt

1. Introduction

Aggregates are the principal material in pavement. Conventional road aggregates in India are natural aggregates obtained by crushing of rocks. In Hot Mix Asphalt (HMA), aggregates are combined with an asphalt binding medium to form a compound material. By weight, aggregate generally accounts for between 92 and 96 percent of HMA. They comprise the majority of pavement volume. Therefore, knowledge of aggregate properties is crucial in designing a high quality pavement.

Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Usually the rock is blasted or dug from the quarry walls then reduced in size using a series of screens and crushers. Some quarries are also 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 natural rock (such as the low density of lightweight aggregate).

HMA Pavement

HMA pavements are classified as "flexible" pavements because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of material. Each layer receives the loads from the above layer, spreads them out, then passes on these loads to the next layer below. Thus, the further down in the pavement structure a particular layer is, the less load (in terms of force per area) it must carry. Other pavements that are surfaced with asphalt materials, such as bituminous surface treatments are also classified as flexible pavements.

In flexible pavements, material layers are usually arranged in order of descending load bearing capacity with the highest load bearing capacity material (and most expensive) on the top and the lowest load bearing capacity material (and least expensive) on the bottom. This section describes the typical flexible pavement structure consisting of:

1. Surface course. This is the top layer and the layer that comes in contact with traffic. It may be composed of one or several different HMA sub layers.

2. Base course. This is the layer directly below the surface course and generally consists of aggregate (either stabilized or un stabilized) or HMA.

3. Sub base course. This is the layer (or layers) under the base layer. A sub base is not always needed.

2. Materials Used

Aggregate

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

Bitumen Binder

The Bitumen binder component of an Bitumen pavement typically makes up about 5 to 6 percent of the total Bitumen mixture, and coats and binds the aggregate particles together. Bitumen cement is used in hot mix asphalt. Liquid asphalt, which is asphalt cement dispersed in water with the aid of an emulsifying agent or solvent, is used as the binder in surface treatments and cold mix asphalt pavements. 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).

3. Methods used

Particle Shape Parameters

The shape of a rock particle can be expressed in terms of overall shape, roundness or large scale smoothness, and surface texture. These properties are the geometrically independent properties of a particle shape although there might be a natural correlation between them due to the common physical factors. In this study, a total of four shape properties (angularity, convexity ratio, roughness, and elongation ratio) were calculated to seek for possible correlations with the compressive strength.

Particle Index of Coarse Aggregate

The combined effects of particle shape and surface texture of aggregates were determined in accordance with ASTM Test Method for Index of Aggregate Particle Shape and Texture (D 3398). The equipment required for this test consists of basically a cylindrical steel mould 152mm (6 in.) in diameter by 178 mm (7 in.) high, and steel rod 16mm (5/8 in.) in diameter by 610 mm (24 in.) long with the tamping end rounded to a hemispherical tip. A clean, washed, oven-dried, single-size aggregate fraction was used for this test. The mould was filled in three equal layers, with each layer compacted with 10 well-distributed blows of the tamping rod. Each tamp consisted of a drop with the tamping rod from 51 mm (2in.) above the surface of the layer being compacted. This procedure was repeated using the same material but applying 50 blows on each of the three layers. The weight of the contents of the mould in each case was determined and the corresponding percentage of voids was calculated using the bulk specific gravity of each aggregate fraction. The particle index (PI) is derived using the following equation

$$PI = 1.25\ V10 - 0.25\ V50 - 32.0$$

Where V10 = percent voids in the aggregate compacted with 10 blows per layer,

V50 = percent voids in the aggregate compacted with 50 blows per layer.

Calculated voids

$$V10 = [1-(M_{10}/sv)]\ X\ 100$$

$$V50 = [1-(M_{50}/sv)]\ X\ 100$$

Where M10 = Average mass of the aggregate in the mold compacted at 10 drops Per layer-„g"

M50 = Average mass of the aggregate in the mold compacted at 50 drops Per layer -„g"

S = Bulk-dry specific gravity of the aggregate size fraction

V = Volume of the cylindrical mold „mL"

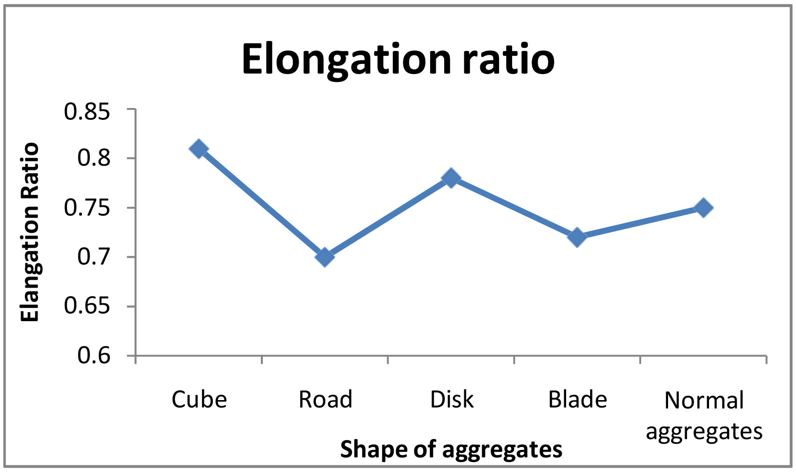
Significance and Use

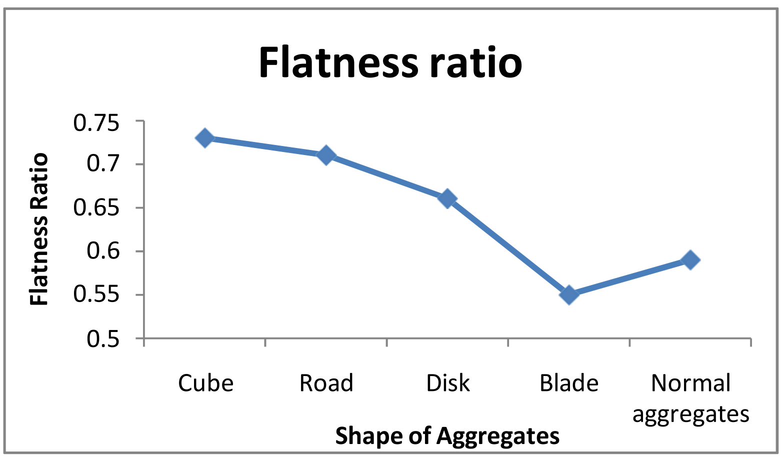
This test method provides an index value to the relative particle shape and texture characteristics of aggregates. This value is a quantitative measure of the aggregate shape and texture characteristics that may affect the performance of road and paving mixtures. This test method has been successfully used to indicate the effects of these characteristics on the compaction and strength characteristics of soil-aggregate and asphalt concrete mixtures.

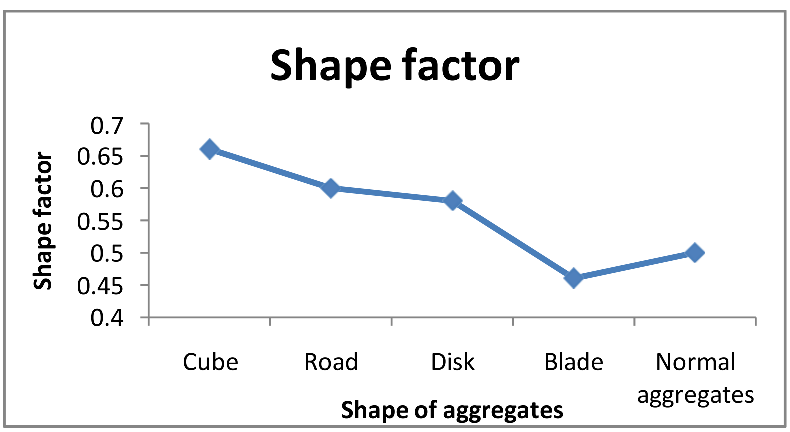
Marshall Test

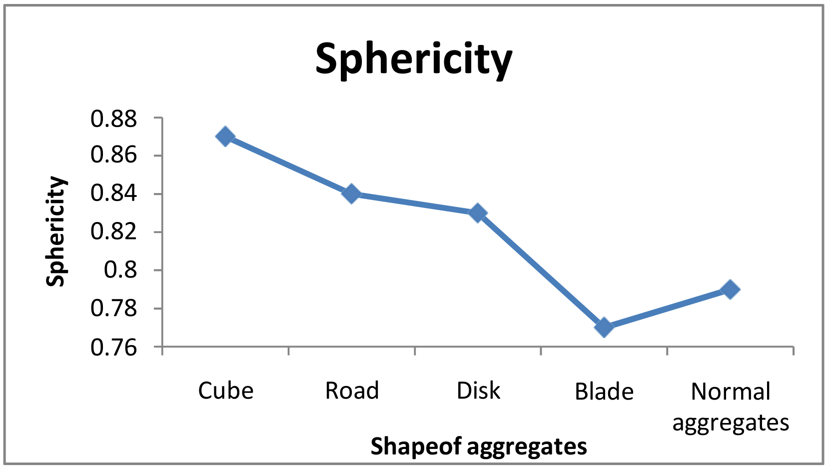
The principle of the Marshall stability is the resistance to plastic flow of cylindrical specimens of a bituminous mixture loaded on the lateral surface. It is the load carrying capacity of the mix at 600C and is measured in KN. The desirable mix properties include stability, density, durability, flexibility, resistance to skidding and workability during construction.

4. Experimental results





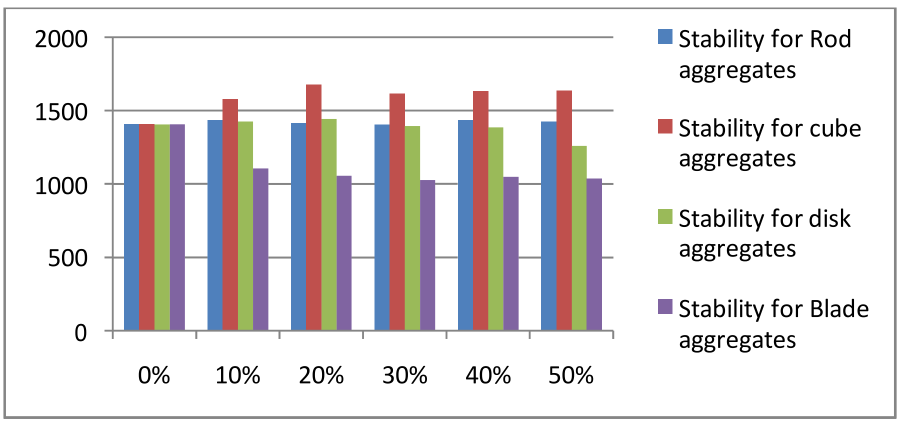




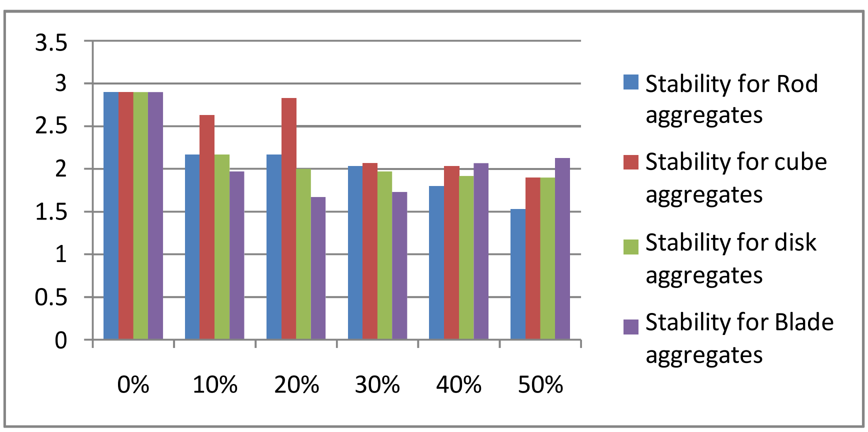
Marshall Design Values

The Marshall test is a routine test that enables one to determine strength indexes such as stability and flow for the design of a HMA Mixtures. Other Mixtures design criteria such as Density, air voids, Voids filled with bitumen (VFB) & voids mineral aggregate (VMA) are also Obtained from this test. Below table list to mixture Characteristics of Different aggregate shapes.

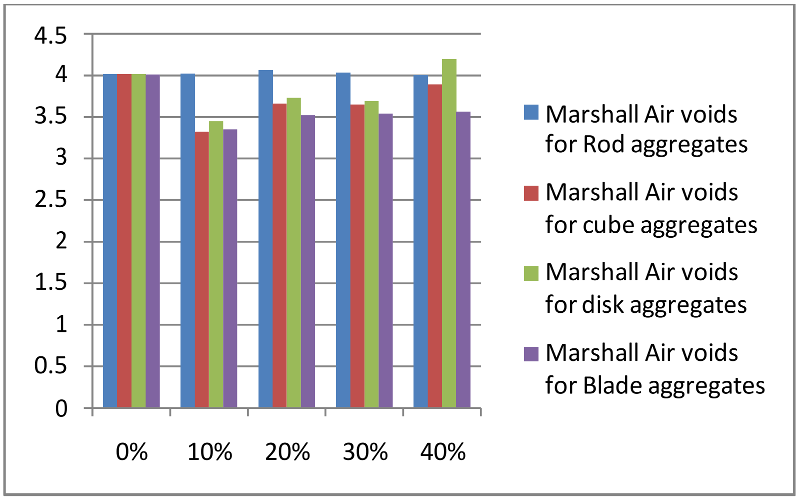
Comparison of Marshall Stability



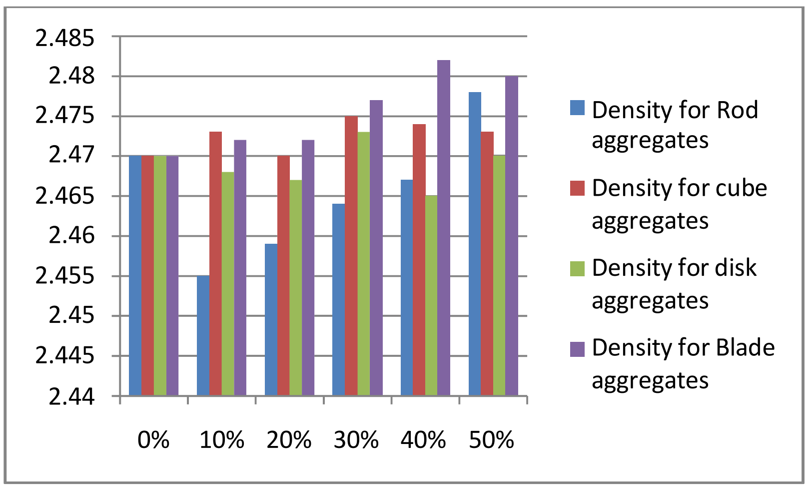
Comparison of Marshall flow



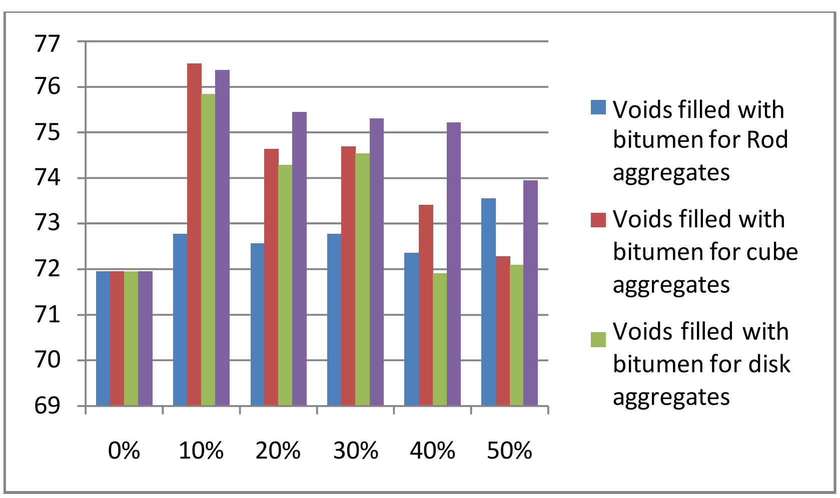
Comparison of Marshall Air voids



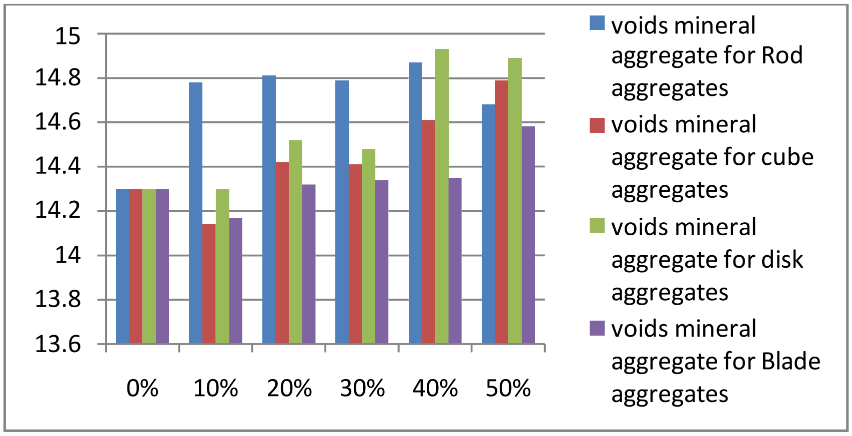
Comparison of Marshall Density



Comparison of Voids filled with bitumen



Comparison of voids mineral aggregate



Conclusions

Following conclusions are drawn from this study

1. 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.
2. The parameters such as stability, flow and voids filled with bitumen increases with increase in proportion of cubical aggregates for DBM mixes.
3. 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.
4. Mixes prepared with replacement of 20% cubical, blade, rod and disk aggregates shown higher stability values.
5. The stability of mix with different type of aggregates is shown good results, against satisfying the minimum requirement of 9kN.
6. 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.
7. Particle shape parameter, higher sphericity value obtained for cubical shape aggregates and lower value for blade shape aggregate, because the sphericity value higher indicates the roundness of the aggregate. Obtained particle index values satisfying the minimum requirement for cubical particles i.e more than 18

References

[1]. ASTM :D3398-00,Standarad test method for index of aggregate particle shape and texture.
[2]. Boutilier, O.D. (1967) A study of the relation between the particle index of the aggregate and the properties of bituminous aggregate mixtures. Proceedings of Association of Asphalt Paving Technologists, 36, 157-179.
[3]. Brown, E.R., McRae, J.L, and Crawley, A.B. (1989) Effect of aggregate on performance of bituminous concrete. ASTM STP 1016, Philadelphia, 34-63.
[4]. D. Sakthibalan (2007) Influence of Aggregate Flakiness on Dense Bituminous macadam & Semi Dense Bituminous Concrete Mixes.

[5]. Fletcher, T., Chandan, C., Masad, E., Sivakumar, K. (2002), "Measurement of Aggregate Texture and Its Influence on HMA Permanent Deformation," Journal of Testing and Evaluation, American Society for Testing and Materials, ASTM, Vol. 30, No. 6, 524-531.

[6]. Huber, G.A., and Heiman, G.H. (1987) Effect of asphalt concrete parameters on rutting performance: a field investigation. Proceedings of Association of Asphalt Paving Technologists, 56, 33-61.

[7]. Jian-Shiuh Chen, K.Y. Lin and M.K. Chang (2004) Influence of coarse aggregate shape on the strength of asphalt concrete mixtures, Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 1062 – 1075

[8]. Kalcheff, I.V., and Tunnicliff, D.G. (1982) Effects of crushed stone aggregate size and shape on properties of asphalt concrete. Proceedings of Association of Asphalt Paving Technologists, 51, 453-483

[9]. Kandhal, P.S., Khatri, M.A., and Motter, J.B. (1992) Evaluation of particle shape and texture of mineral aggregates and their blends. Journal of Association of Asphalt Paving Technologists, 61, 217-240.

[10]. Krutz, N.C., and Sebaaly, P.E. (1993) Effect of aggregate gradation on permanent deformation of asphaltic concrete. Proceedings of Association of Asphalt Paving Technologists, 62, 450-473.

[11]. Masad, E., Little, D., Tashman, L., Saadeh, S., Al-Rousan, T., and Sukhwani, R. (2003). "Evaluation of aggregate characteristics af fecting HMA concrete performance."