As per UGC guidelines an electronic bar code is provided to secure your paper

International Journal for Modern Trends in Science and Technology
Volume 10, Issue 08, pages 12-22.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol10issue08.html
DOI: https://doi.org/10.46501/IJMTST1008002

Influence of Coarse Aggregates Shape on Bituminous Mixtures

Bonangi Prasanth[1], Dr. M Madhuri[2], Sridhari Putrevu[3]

[1]PG Scholar, Department of Civil Engineering, Sanketika Institute of Technology and Management, Vizag, India.
[2]Assistant Professor, Department of Civil Engineering, Sanketika Institute of Technology and Management, Vizag, India.
[3]Research Scholar, Andhra University Visakhapatnam

To Cite this Article
Bonangi Prasanth, Dr. M Madhuri and Sridhari Putrevu, Influence of Coarse Aggregates Shape on Bituminous Mixtures, International Journal for Modern Trends in Science and Technology, 2024, 10(08), pages. 12-22. https://doi.org/10.46501/IJMTST1008002

Article Info
Received: 15 July 2024; Accepted: 30 July 2024; Published: 01 August 2024.

ABSTRACT

Since the early days of modern bituminous paving, highway engineers have noted that the shape of the mineral aggregate affects the strength of bituminous-aggregate mixtures in which it is used. I t was noted that sharply angular and roughly textured aggregates generally produced bituminous mixes with more stability^ than round, smooth-faced materials. Considering the types and control of the early bituminous pavings, any increase in stability was greath' desired, and angular crushed stone was used whenever possible. 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.

1.INTRODUCTION

Bituminous Mixture

A bituminous mixture is made up of a binding material that encases each mineral particle of an aggregate, regardless of its grading. They traditionally come in two types: cold bituminous mixtures and hot bituminous mixtures. Cold mixtures are those that can be manufactured with a cold or hot bituminous binder and a composition of aggregates, generally cold. These mixtures can be handled and spread at room temperature. Many of these products are storable. Hot bituminous mixtures, on the other hand, are made with a binder that needs to be heated. The mixture temperature in this case must be above ambient temperature when applied or laid on site. One type of binder commonly used in bituminous mixtures are hydrocarbon binders. It is a high viscosity type of binding agent, produced from natural hydrocarbons, which varies in consistency depending on the temperature (thermoplastic character) and offers good adherence to aggregates. As for aggregates, which come from fragmented rock, their chemical and surface activity against water and bituminous binders depends on their composition and grading. Bituminous pavements/surfaces are a mixture of mineral aggregates, mineral filler, and a bituminous material or binder. This mixture is used as the top portion of a flexible pavement structure to provide a resilient, waterproof, load-distributing medium that protects the base course from the detrimental effects of water and the abrasive action of traffic.

Bituminous Materials

A bituminous material is the adhesive agent or binder in a bituminous mixture. This material or binder provides two functions:

- It binds the aggregate together, holds it in place, and prevents displacement.
- It provides a waterproof cover for the base and keeps surface water from seeping into and weakening the base material.

The binder's functions require it to be a waterproof substance having the ability to bind aggregate particles together. All bituminous materials possess these qualities due to being mainly composed of bitumen a black solid that provides the black color, cementing ability, and waterproofing properties. Bituminous materials are classified into two main groups asphalts and tars. They are available in several forms suitable for different procedures of mixing or application under wide variations in temperature. Some bituminous materials are solid or semisolid at room temperature. Other grades are a relatively viscous (thick) liquid at room temperature. Mixing bituminous materials with solvents or water produces cutbacks or emulsions that are liquid at atmospheric temperatures. Such liquid asphalts and tars are used for cold mixes or are applied as sprays in building pavements.

In general, bituminous mixtures must be manufactured according to the properties required for the application they are to be used for, which can be extremely diverse. There are a series of properties that can be strengthened to a greater or lesser extent, taking into account the mixture's composition, the materials, the dosing and the product's manufacturing conditions.

These properties include:

- **Stability**: the ability to support loads and resist the stresses to which it will be subjected, while retaining a certain series of deformation values.
- **Resistance to plastic deformation**: bituminous mixtures feature a viscoelastic behaviour, leading to a series of deformations when low speed and high temperature loads are applied to it. The material's required rheology for the specific project in which it is to be applied, a concept that was introduced in our article on thixotropy, must be taken into account at the manufacturing stage.
- **Fatigue resistance**: bituminous mixtures are elastic at low temperature and at high speeds, but load repetition produces progressive wear due to material fatigue which results in an increase in deformation and cracking.
- **Slip resistance**: when this type of product is manufactured to be applied on pavement or road wearing courses, for example, it must provide adequate slip resistance for a given number of years.
- **Impermeability**: as in the case of slippage, bituminous mixtures used on top layers must protect the infrastructure against water infiltration action. Sometimes, impermeability can also be ensured with the lower layers, for example when

using a porous mixture that removes surface water by infiltration.

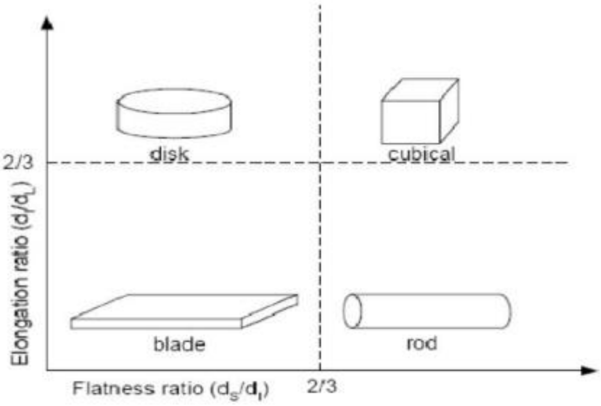
- **Durability**: sun, air, water or ice as well as vehicle oils or fuels affect the durability of the mixture used, for example on the wearing courses.

Bituminous mixture manufacturing process

Hot bituminous mixtures are manufactured with asphalt bitumen's at a higher or lower temperature, depending on the viscosity of the binder used. The aggregates that go into the mix are also heated so that they do not lower the binder's temperature when they are added to the mix. Bituminous binders provide efficient and flexible bonds, for example in road construction, thanks to their viscoelastic properties, as mentioned above. Since binder behaviour varies depending on ambient temperature, the mix should be manufactured using the binder that best adapts to the temperature range to which the mix is to be subjected once it has been applied to the pavement. There is also a number of products that modify asphaltic bitumen's and are obtained by dispersing polymers or rubber, among other materials, in the mix. These modified products can improve the binder's properties when exposed to high or low temperatures.

Aggregates

Aggregates influence greatly in the load transfer capacity of pavements. Therefore it is important that they should be tested before the construction. Aggregate should not only be strong and durable but they should also have proper shape and texture and also proper size in order to be get used in the mix. Many testes are also done on aggregates such as for water absorption, strength toughness and shape. The coarse aggregate was sieved and partitioned into four size fractions, namely 25 to 20mm, 20 to 12.5mm, 12.5 to 7.5mm and 7.5 to 4.75mm. Below figure shows the different types of aggregate shape particles used in this study



i. Rounded Aggregates

They are the natural aggregates available on the seashore in the form of gravel. They results in the minimum percentage of void ratio (30%-40%) and gives more workability of the bituminous mix. Due to their rounded shapes they are very poor in interlocking behavior which results in weak bond in the mix and thus gives less strength. Hence they are not preferred in high strength mix.

ii. Irregular Aggregates

They are shaped by attrition but are not fully rounded, these consists of small stones and gravel, and offer reduced workability to rounded aggregate. They will develop strength slightly lower than angular aggregates the irregular shapes are formed between the aggregates. The bondage between the aggregates is very low due to friction between the aggregates is very low due to its irregular shape and it develop low workability of concrete

iii. Elongated Aggregates

In elongates aggregates, the length of the aggregates is higher than its width. It is having low compression strength and recommended for concrete. If we use the elongated aggregate in concrete, the voids ratio will become high compared to the other aggregates.

iv. Flaky Aggregates

The flaky aggregates are having a very light thickness, and it can easily crack. Due to its lower workability, it is not used in mix and it also gets broken da to its minor thickness. The flaky and elongated aggregates are having less thickness. They gives less compressive strength to the mix and is not used. 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)

Influence Of Aggregate Properties On Hma Performance

Aggregate particles can be defined in terms of three independent shape properties: shape (or form), angularity, and surface texture (Barrett, 1980). These three aggregate shape properties fully characterize particles based on their geometry. The form property characterizes aggregate particles based on ratios of particle dimensions. The angularity property measurement describes particles based on the variations at the edges of particles. This measurement defines particles in a range from rounded to angular. The final property is surface texture. This property describes the surface roughness of a particle at a small scale, which is not influenced by changes in form 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). A schematic diagram illustrating the differences between these three aggregate shape properties.

Significance Of Aggregate Shape On Bituminous Mixes

Aggregate shape properties are known to influence Bitumen pavement performance. Angularity and texture govern the frictional properties and dilation of the aggregate structure. Aggregate texture plays a major role in influencing the adhesive bond between the aggregate and the binder, while aggregate form influences the anisotropic response of Bitumen mixes Aggregate characteristics such as particle size, shape, and texture influence the performance and service ability of hot-mix asphalt pavement (Brown et al. 1989, Kandhal et al. 1992). Flat and elongated particles tend to break during mixing, compaction, and under traffic. Therefore, aggregate shape is one of the important properties that must be considered in the mix design of asphalt pavements to avoid premature pavement failure. The shape of aggregate particle has a significant influence on the performance of the bituminous pavement. Particle shape can be described as cubical, flat, elongated and round. The presence of flaky aggregates is considered as undesirable in bituminous mixtures because of their tendency to break down during construction and subsequent traffic operations. The voids present in a compacted mix depend on the shape of aggregates. Blade shape aggregates.

2. LITERATURE REVIEW

J. R. Benson (1) is of the opinion that for bituminous mixtures "when optimum quantities and consistencies of bitumen are used, the flexibility will vary with aggregate structure. If the aggregate structure is weak, a low resistance to deformation will ensue, while too great a stability in the aggregate structure may result in brittleness and low resistance to impact." Benson further states, "In uniformly graded aggregates, particles are of uniformly decreasing size, coarse to fine to dust. Such aggregate structures have fairly uniform stress distribution. This type of grading is of special importance in the utilization of smooth, round aggregate such as alluvial sand and gravel. Careful grading control can yield high stability from aggregates possessing little stability.

Steele (2) classes gradings for bituminous mixtures as (a) open-graded, including materials ranging from a specified maximum to a specified minimum size, provided that such minimum size shall be retained, with specified tolerances, on a No. 4 sieve; (b) intermediate gradings including certain aggregate combinations with a substantial percentage passing the No. 4 sieve but with insufficient minus No. 10 material to qualify for the dense-graded classification; and (c) dense-graded having any specified maximum size with a continuous, and reasonably uniform, representation of particle sizes down to and including dust. Steele believes that a wide range of gradings is suitable for use in producing dense-graded mixtures.

Reagal (3), from his experience in Missouri, found a tendency for bituminous surfaces to rub and shove when constructed from aggregates having "humps" in their gradation curves. In comparison, McNaughton believes that "there is a fairly wide band of tolerance through which the grading curve can shift without changing appreciably the fundamental characteristics of the mix as regards bitumen requirements, density and stability. I do not.. . say that mixtures of maximum density are necessary or even desirable.

Hveem and Vallerga (4), in discussing relationships between density and stability of bituminous mixtures, comment as follows: "Therefore, recognizing that interparticle friction is the major property that cçntributes to stability, it must be recognized that this property is largely independent of the contact area between particles. In paving mixtures this accounts for the fact that aggregate gradation has little predictable influence and adequate stability may be developed in mixtures composed of a wide variety of particle size combinations." Gradation is an important factor in controlling the degradation of bituminous mixtures.

Moavenzadeh and Goetz (5) concluded from a study of degradation: "Gradation of the mixture is the most important factor controlling degradation. As the gradation becomes denser, degradation decreases. . . . from a degradation point of view, dense graded mixtures offer the best use of local aggregates with high Los Angeles values." McLeod (8), in summarizing important fundamentals to be considered in the selection of aggregates, writes as follows with regard to aggregate size and gradation.

Krutz and Sebaaly (1993) (6) found a direct correlation between the rutting potential of HMA mixtures and the shape and texture of coarse aggregate particles. Li and Kett (1967) concluded in their study that flat and elongated particles could be permitted in a mixture without adverse effect on its strength. Some mixes with flaky aggregates have been found to exhibit higher fatigue life than mixes with non flaky aggregates.

Oduroh et al. (2000) (7) showed that the percentage of crushed coarse particles had a significant effect on laboratory permanent deformation properties. As the percentage of crushed coarse particles decreased, the rutting potential of the HMA mixtures increased. **Huber and Heiman (1987) (8)** found that crushed aggregate containing 19% flat and elongated particles did not adversely affect the volumetric properties of HMA mixtures.

3.EXPERIMENTAL INVESTIGATION

Aggregates

Aggregate shapes influence the serviceability and performance of the pavement to a great extent. Therefore, it is important to select proper shape and size of aggregate in order to increase the functionality of pavement and to increase the service life of pavements. In this research it is known that different particle shapes constitute different properties when tested. Flat and elongated particles tends to break during mixing, compacting and under the influence of traffic loads. Cubical particles showed great resistance to breakage under heavy loads. Blade shaped particles large void ratio which may later get filled and can deform the pavement surface, when subjects to repeated traffic loads. And also due to these voices the workability of the mix reduced. Hence the study of effect of blade shaped aggregates is essential and important. Lower the percentage of blade shaped aggregates, greater will be the workability and greater will be the stability of the pavement. Kurtz and sebaaly (1992) found a direct correlation between the potential of pavement mixes and the shape and texture of the coarse aggregate particles. Li and kett (1967) founded in their study that flat and elongated particles could be permitted in a mixture without adverse effect on its strength.

Aggregates influence greatly in the load transfer capacity of pavements. Therefore, it is important that they should be tested before the construction. Aggregate should not only be strong and durable but they should also have proper shape and texture and also proper size in order to be get used in the mix. Many testes are also done on aggregates such as for water absorption, strength toughness and shape. The coarse aggregate was sieved and partitioned into four size fractions namely 25 to 20mm, 20 to 12.5mm, 12.5 to 7.5mm and 7.5 to 4.75mm. Below figure shows the different types of aggregate shape particles used in this study

Rounded Aggregates

Rounded aggregates

They are the natural aggregates available on the seashore in the form of gravel. They results in the minimum percentage of void ratio (30%-40%) and gives more workability of the bituminous mix. Due to their rounded shapes they are very poor in interlocking behaviour which results in weak bond in the mix and thus gives less strength. Hence they are not preferred in high strength mix.

Irregular Aggregates

They are shaped by attrition but are not fully rounded, these consists of small stones and gravel, and offer reduced workability to rounded aggregate. They will develop strength slightly lower than angular aggregates the irregular shapes are formed between the aggregates. The bondage between the aggregates is very low due to friction between the aggregates is very low due to its irregular shape and it develop low workability of concrete

Irregular aggregates

A. Elongated Aggregates

In elongates aggregates, the length of the aggregates is higher than its width. It is having low compression strength and recommended for concrete. If we use the elongated aggregate in concrete, the voids ratio will become high compared to the other aggregates.

Elongated aggregates

B. Flaky Aggregates

The flaky aggregates are having a very light thickness, and it can easily crack. Due to its lower workability, it is not used in mix and it also gets broken da to its minor thickness. The flaky and elongated aggregates are having less thickness. They gives less compressive strength to the mix and is not used.

Flaky aggregates

Shape of Aggregates

Aggregates which happen to fall in a particular size range may have rounded, cubical, angular, flaky or elongated particles. It is evident that the flaky and elongated particles will have less strength and durability when compared with cubical, angular or rounded particles of the same aggregate. Hence too flaky and too much elongated aggregates should be avoided as far as possible. Visual examination is the most common method of judging aggregate shape and this method is adopted for this study.

Shape Tests The particles shape of the aggregate mass is determined by the percentage of flaky and elongated particles in it. Aggregates which are flaky or elongated are detrimental to higher workability and stability of mixes. The flakiness index is defined as the percentage by weight of aggregate particles whose least dimension is less than 0.6 times their mean size. Test procedure had been standardized in India (IS: 2386 part –I) The elongation index of an aggregate is defined as the percentage by weight of particles whose greatest dimension (length) is 1.8 times their mean dimension. This test is applicable to aggregates larger than 6.3 mm. This test is also specified in (IS: 2386 Part-1). However there are no recognized limits for the elongation index. The coarse size fraction of DBM was evaluated for the influence of aggregate shape on engineering properties of HMA mix. Aggregate shape analysis was carried out through the use of the Zingg diagram on the basis of the particle longest diameter (dL), the intermediate diameter (dl), ad the shortest diameter (dS). From figure we can observe to stretch the particle in one direction and keep other dimension constant value then it will convert to other shape. The elongation ratio and the flatness ratio were used to define the aggregate shape as shown in Figure 3.4. The former is the ratio of dl to dL, and the latter is the ratio as dS to dl. Four different aggregate shapes were selected as follows: dist, blade, road, and cube. As both ratios are equal to or larger than 2/3, the cubical aggregate was selected for the HMA mix in order to contrast it with the mixes consisting of other shapes. The disk-shaped aggregate is flaky and oblate, the rod-shaped is elongated, and the blade-shaped is both flaky and elongated.

Aggregate shape analysis

It was carried out in terms of elongation ratio, flatness ratio, shape factor, and sphericity by direct methods. The shape parameters can be determined from the following equations. The mean value for each aggregate size is listed in below.

i. Elongation Index

Elongation index of aggregate is the percentage by weight of particles in it, whose least dimension is greater than 1.8 times mean dimension.

ii. Flakiness index

Flakiness index of aggregate is the percentage by weight of particles in it, whose least dimension is less than 0.6 times mean dimension. Length gauge Sieves(63mm,50mm,40mm,31.5mm,25mm,20mm,16mm ,2.5mm,10mm) were used for conducting the experiment in the laboratory as follows.

iii. Shape factor

The shape index (EN 933-4:1999) is a method for determining the elongation of coarse aggregate grains. The test is performed on aggregate with grain size ranging from 4 mm and up to 63 mm. Particle length is described as the maximum dimension of a particle as defined by the greatest distance apart of two parallel planes tangential to the particle surface. Particle thickness is described as the minimum dimension of a particle as defined by the least distance apart of two parallel planes tangential to the particle surface A special made particle slide gauge is used for determination of the category for each aggregate grain. This is made with the use of two openings or slots, one to measure the length and another opening that is 1/3 of the opening for the length. In this way it is easy to find if the length is more or less than 3 times the thickness. According to the result for each particle the sample is divides into the two categories; cubical and non cubical, where the non cubical is the particles where the thickness is less than 1/3 of the length. The shape index is calculated as the ratio between the mass of non-cubical particles and the total mass of particles tested.

Aggregate shape analysis

Shape	Elongation ratio	Flatness ratio	Shape factor
Cube	0.81	0.73	0.66
Rod	0.70	0.71	0.60
Disk	0.78	0.66	0.58
Blade	0.72	0.55	0.46
Normal aggregates	0.75	0.59	0.50

Bitumen Binder mix

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).

Marshall stability

The Marshall stability and flow test provides the performance prediction measure for the Marshall mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute. Load is applied to the specimen till failure, and the maximum load is designated as stability. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) as a result of the loading. The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load is recorded. The important steps involved in marshal mix design are summarized next.

Bituminous mixes are used in the surface coarse of road and airfield pavement, some type of Bitumen mixes are also used in base and/or binder course of flexible pavements. The desriable Bitumen mix properties include (i) stability (ii) density (iii) durability (iv) flexibility (v) resistance to skidding and (vi) workability during contruction. Stability is defined as resisitance of the paving mix to deformation under load is thus a stress level which causes strain depending upon anticipated field condition. Density is directly realted to voids in the compacted mixtures. Stability and density in general are related terms. Durabillity is defined as the resistance of the mix against weathering which causes hardenging and this depends upon loss of volatiles and oxidation. Generally, the stability test is applicable to hot-mix design using Bitumen and aggregate with maximum size of 25 mm. There are two major features of marshall method of designing mixes namely, (i) density-voids analysis (ii) stability-flow test. The marshall stability mix is defined as a maximum load carried by a compacted specimen at a standard test temperature at 60 oC. The flow value is the deformation the marshall test specimen undergoes during the loading upto the maximum load, in 0.25 mm units. The proposed steps for the design of bituminous mixes are given below.

a) Select grading to be used.
b) Select aggregates to be employed in the mix.
c) Determine the proportoin of each aggregate required to produce the design grading.
d) Determine the specific gravity of the aggregate combination and Bitumen.
e) Determine the specific gravity of each compacted specimen.
f) Make stability tests on the specimen.
g) Calculate the percentage of voids,VMA and the percentage voids filled with asphalt in each specimen.
h) Select optimum Bitumen content from the data obtained.
i) Check the values of Marshall stability, flow, voids in total mix and voids filled with Bitumen obtained at the optimum Bitumen content.

Sample Preparation

Mixture Designs were performed using the Marshall method by preparing and compacting samples with Bitumen content varied in 0.5% increments according to ASTM Test Method for Resistance to Plastic Flow of bituminous Mixtures Using Marshall Apparatus. Grade 60/70 Bitumen binder. Specimens were compacted with 75 blows on each side. Three samples were made for each Bitumen content. The optimum Bitumen content was chosen as the Bitumen content that produced 4% air voids. Further, two types of void were calculated for the compacted samples: the void in mineral aggregate (VMA), and the void space in coarse aggregate (VCA). The VCA"s were calculated in a way similar to the VMA"s by replacing percent of aggregate in the mix with percent of coarse aggregate in the calculation.

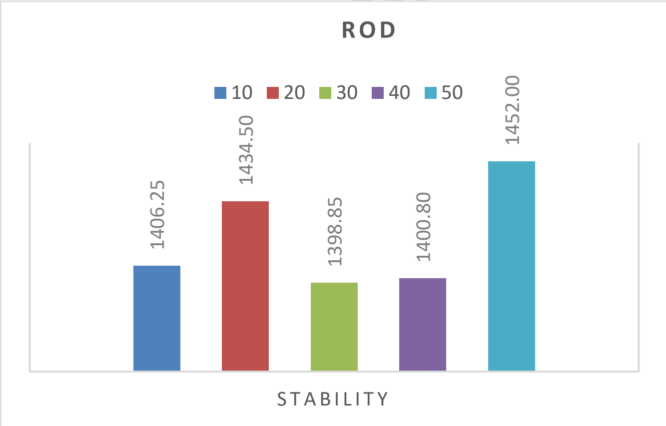
In this study, the behavior of DBM mixes was studied with aggregate having different shapes and different proportions (10%, 20%, 30%,40%, and 50%). Since the aim of this study is to quantify the effects of the different shape of the aggregates. The following properties were investigated in this study by conducting Marshall Tests. Stability, flow Percent of air voids (Va), Voids in Mineral Aggregate (VMA), Percent Voids Filled with Bitumen (VFB).

4.RESULTS AND DISCUSSIONS

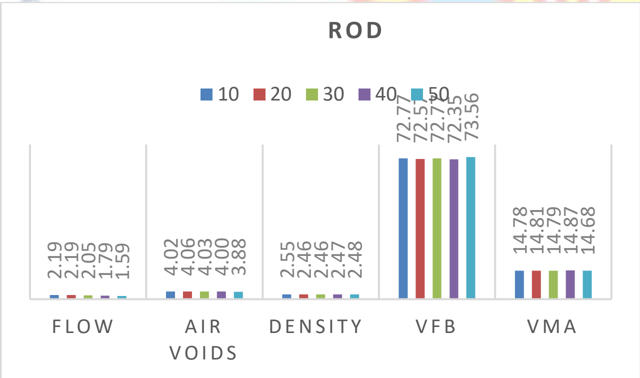
MARSHALL STABILITY TEST RESULTS

Rod shaped aggregates results

ROD					
Size	10	20	30	40	50
Stability	1406.25	1434.50	1398.85	1400.80	1452.00
Flow	2.19	2.19	2.05	1.79	1.59
Air voids	4.02	4.06	4.03	4.00	3.88
Density	2.55	2.46	2.46	2.47	2.48
VFB	72.77	72.57	72.77	72.35	73.56
VMA	14.78	14.81	14.79	14.87	14.68



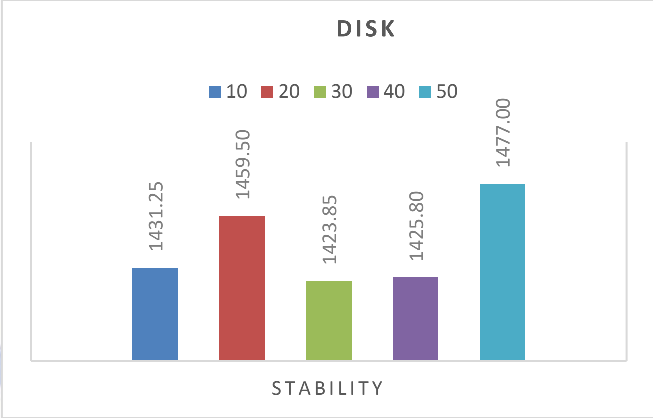
Rod shaped aggregates results (stability)



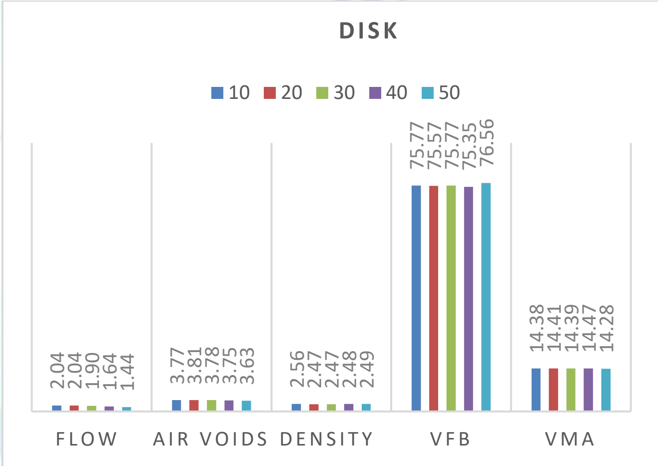
Rod shaped aggregates results

Disk shaped aggregates results

DISK					
Size	10	20	30	40	50
Stability	1431.25	1459.50	1423.85	1425.80	1477.00
Flow	2.04	2.04	1.90	1.64	1.44
Air voids	3.77	3.81	3.78	3.75	3.63
Density	2.56	2.47	2.47	2.48	2.49
VFB	75.77	75.57	75.77	75.35	76.56
VMA	14.38	14.41	14.39	14.47	14.28



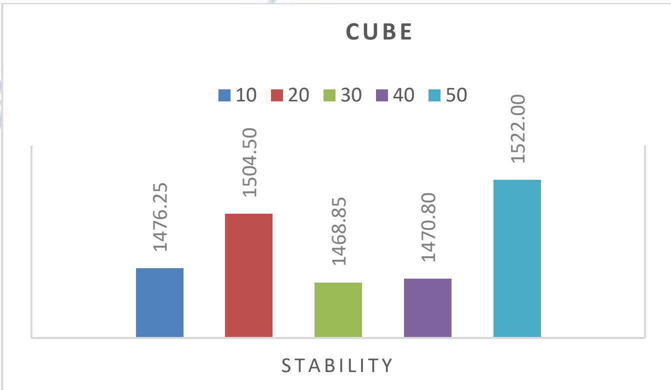
Disk shaped aggregates results (stability)



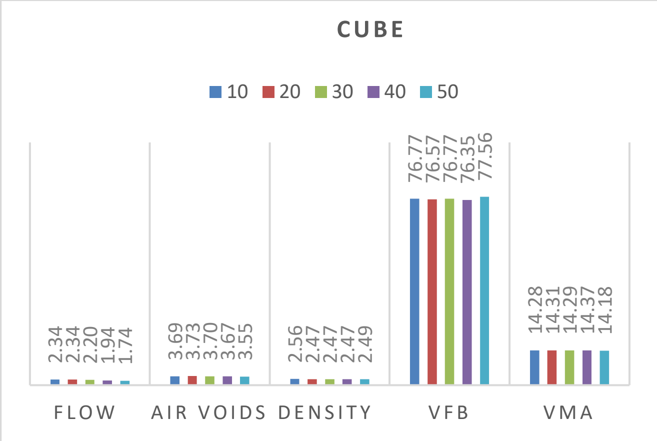
Disk shaped aggregates results

Cube shaped aggregates results

CUBE					
Size	10	20	30	40	50
Stability	1476.25	1504.50	1468.85	1470.80	1522.00
Flow	2.34	2.34	2.2	1.94	1.74
Air voids	3.69	3.73	3.7	3.67	3.55
Density	2.562	2.471	2.476	2.479	2.49
VFB	76.77	76.57	76.77	76.35	77.56
VMA	14.28	14.31	14.29	14.37	14.18



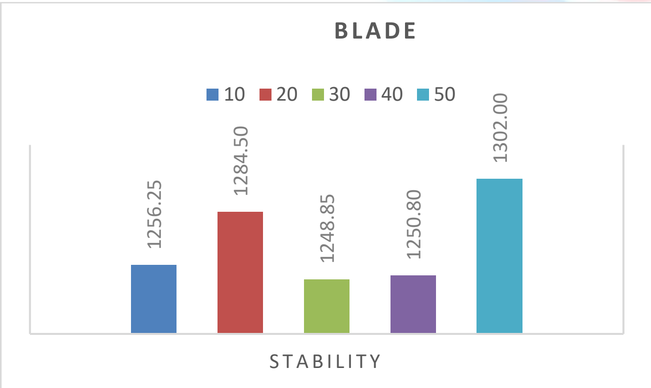
Cube shaped aggregates results (stability)



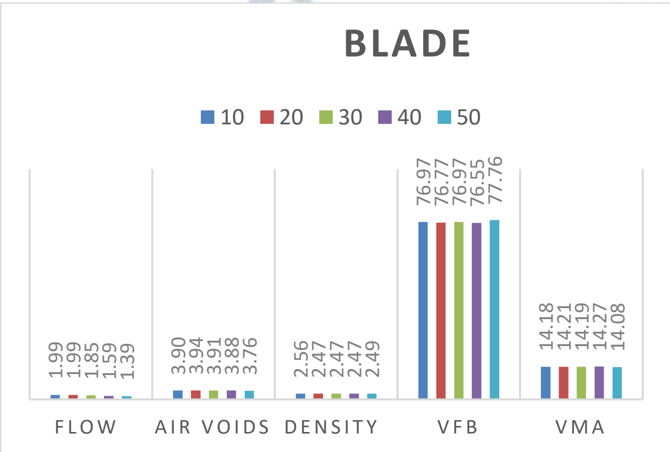
Cube shaped aggregates results

Blade shaped aggregates results

BLADE					
Size	10	20	30	40	50
Stability	1256.25	1284.5	1248.85	1250.8	1302
Flow	1.99	1.99	1.85	1.59	1.39
Air voids	3.9	3.94	3.91	3.88	3.76
Density	2.561	2.47	2.475	2.478	2.489
VFB	76.97	76.77	76.97	76.55	77.76
VMA	14.18	14.21	14.19	14.27	14.08



Blade shaped aggregates results (stability)



Blade shaped aggregates results

5. CONCLUSIONS

- 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. 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.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] ASTM :D3398-00,Standarad test method for index of aggregate particle shape and texture1

[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."
[12] MORT&H ,Section 500(Revision 2004.
[13] ASTM :D3398-00,Standarad test method for index of aggregate particle shape and texture
[14] 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
[15] 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.
[16] D. Sakthibalan (2007) Influence of Aggregate Flakiness on Dense Bituminous macadam & Semi Dense Bituminous Concrete.
[17] 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.
[18] 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.
[19] D. Sakthibalan (2007) Influence of Aggregate Flakiness on Dense Bituminous macadam & Semi Dense Bituminous Concrete Mixes.
[20] 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.
[21] 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.