INFLUENCE OF SHAPE OF AGGREGATE ON PROPERTIES OF BITUMEN MIX

A thesis submitted in partial fulfilment of the requirement for the award of the degree of

MASTER OF TECHNOLOGY

In

CIVIL Engineering

(SPECIALIZATION IN TRANSPORTATION ENGINEERING)

By

GULAM-E-MURTAZA

(110009238)

Under the supervision of

MR.SUPRIYA MARIK

DEPARTMENT OF CIVIL ENGINEERING

LOVELY PROFESSIONAL UNIVERSITY PHAGWARA, PUNJAB

DECLARATION

I hereby declare that the dissertation entitled, **Influence of shape of aggregate on properties of bitumen mix.** submitted for Master's Degree is entirely my original work and all the ideas and reference have been duly acknowledged. It does not contain any work for the award of any other degree or diploma.

Date: 29/4/15 **GULAM-E-MURTAZA**

REG.NO:11009238

CERTIFICATE

This is to certify that the project work entitled "Influence of shape of aggregate on properties of bitumen mix" being submitted by Mr GULAM-E-MURTAZA (REG NO: 11009238), has been carried out under my supervision and has not been submitted to any other institute or university for award of any degree.

Mr SUPRIYA MARIK
Assistant Professor,
Department of Civil Engineering,
Lovely Professional University,
. Punjab-144411, India.

Mrs MADEEP KAUR
H.O.D,
Department of Civil Engineering
Lovely Professional University
Punjab-144411, India.

ACKNOWLEDGEMENT

I feel overwhelmed in presenting out the project report for which I worked with great enthusiasm and exuberance. I have bogged down into this project and done a great deal of literature survey for the same. Indeed it would not have been possible without the joint venture of my colleagues and ma guide **Mr Supriy Marik**, Asst. professor in civil engineering, for the able guidance and valuable suggestions, extreme help and support in preparing ma thesis.

I am thankful to the H.O.D of civil engineering **Mrs Mandeep kaur**, for providing me with the facilities needed for the completion of my project

I am thankful to all laboratory assistants of Civil Engineering department for extending the laboratory facilities all the time and helping me with advices and experience.

Finally I am thankful to all the teaching and non–teaching staff of Civil Engineering and to my friends for their direct and indirect help provided to me in completing the project.

Also, I would like to express my love and gratitude to my beloved parents for their understanding and endless love, through the duration of my studies.

Place: LPU GULAM-E-MURTAZA

Date: 29/4/15

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 physical properties of coarse aggregates are more significant in new generation bituminous mixtures. The strength and serviceability requirements of bituminous mixture such as Stability, Flow, Voids in Mineral Aggregate (VMA), Voids Filled with Bitumen (VFB), Air Voids (Va) and Tensile Strength Ratio (TSR) highly depend on the physical properties of aggregates. Flakiness is an important physical property of mineral aggregates which affects the quality of bituminous mixes

In this study three shapes of aggregate were analysed and the effect on various properties of bitumen mix were observed. The experimental investigation were carried out on aggregates to check the various physical properties of aggregate, tests such as, aggregate impact load test, aggregate crushing value, specific gravity & shape test were done .

The gradation of aggregate was done as per MORT&H specification and Marshall Test was done on different shapes of aggregate and comparison was made between the different bitumen binder content and, results of stability, flow, air voids, VMA, VFB using different shapes of aggregate.

In this study the different shapes of aggregate that were analysed are cubical, rounded and blade respectively.

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LIST OF ABBREVIATION

1. HMA: HOT MIX ASPHALT.
2. AGG: - AGGREGATE.
3. AIV: - AGGREGATE IMPACT VALUE.
4. ACV: - AGGREGATE CRUSHING VALUE.
5. FI: FLAKINESS INDEX.
6. EI: ELONGATION INDEX.
7. MORT&H:-MINISTRY OF ROAD TRANSPORT & HIGHWAY.
8. VG: VISCOSCITY GRADE.
9. Gb: BULK DENSITY.
10. Gt: THEORETICAL SPECIFIC GRAVITY.
11. Vv: AIR VOIDS.
12. VMA: VOIDS IN MINERAL AGGREGATE.
13. VFB: VOIDS FILLED WITH BITUMEN.

CHAPTER 1

INTRODUCTION

1.1 General

Aggregate shape has a noteworthy influence on the performance of the bituminous pavement. Particle shape can be described as flat, cubical, elongated and round. Also presence of flaky and elongated aggregates in a bitumen mix is not desirable as they can break during traffic operations which can result in the failure of the road pavement. The voids that are present in a compacted bitumen mix usually depend upon the shape and size of course aggregates used for construction of flexible pavements. Extremely flaky or elongated aggregates have more voids present in them thus they tend to decrease the workability of the bitumen mix. Hence it was caressed that the study on the effect of the shape and size of aggregates on bituminous mixtures is pertinent and important.

Course aggregates are the chief and main materials that are found in a bitumen pavement construction. Conservative or traditional Indian road aggregates that are used for construction are natural aggregates that are originated form rocks by crushing of rocks. In bitumen mixes, aggregates are generally mixed with bitumen binder or binding medium so that compound material is formed. It has been seen that by weight, aggregates contributes usually between 90 to 95 per cent of HMA or bitumen mix. That implies they comprise the bulk or max. of pavement volume. Therefore it becomes necessary for an engineer to have proper information of aggregate properties in designing or constructing a high quality bitumen pavement surface.

Research has revealed that aggregate characteristics such as, shape, texture and particle size effect the performance and service ability of bitumen pavement (by Brown 1989, Kandal in 1992, Kim in 1992). Flat and elongated particles usually have tendency to break during various operations such as mixing, compaction, or under various traffic operating conditions. Hence, aggregate shape is one of the significant properties that must be considered in the mix design of bitumen pavements to avoid early pavement failure. As aggregates make up between 84% to 91% of the total volume or 94% to 95% of the total mass of bitumen mix, the quality of the aggregate considerably effects bitumen pavement performance. Aggregate geometry usually consists of three independent personalities such as form, surface texture and angularity or roundness. Aggregate angularity can be defined as the measurement of the sharpness of the corners of a particle, has been known as a serious property of bituminous mixtures and is one of the prime aggregate properties described in the bitumen pavement specifications. Furthermore, angularity is frequently mentioned as having the potential to effect aggregate and bitumen mixture performance through significant interfaces with other mixture and material properties. Hence the effects of aggregate angularity on bitumen mix design characteristics and mixture performance should be suitably established based on scientific meticulousness.

Bitumen mix are used as surface layers in a pavement structure so as to dispense stresses caused due to traffic load and also to protect the underlying layers from the adverse effects of water. Thus, to sufficiently perform both of these functions over the bitumen pavement design life, the mixture must also survive the effects of air and water, resist permanent deformation, and resist cracking caused by the loading and other environmental effects. Bitumen mix can be produced by liquefying the asphalt and by applying heat for mixing with aggregate. Both the asphalt binder and aggregate are heated so as to achieve fluidity to wool the aggregate and to dry the aggregate (by Elizabeth Chong in 2007). Numerous construction of pavement will require different kind of mixture to outfit to the desirable strength of bitumen pavement. There are various methods for designing a bitumen mix, such as a Marshall Method and hveem method.

Aggregate is important material that is commonly used in the bitumen pavement construction together with asphalt in bitumen mix as well. Overall, aggregates can contribute to the chief effects of the road problems in forthcoming such as surface defect, cracks, and others as these materials constitute approximately 85 to 90% of bitumen mix by weight and made up principally of coarse aggregate. Hence, to evade these conditions to occur on the actual situation, aggregates in bitumen mix are determined by evaluating in term of surface texture, gradation, toughness, soundness, particle shape and others to ensure these material is in good quality condition to use in term of durability and workability.

Bitumen mix design is the method of determining suitable proportion of the materials that can give long lasting performance paving mixture throughout its service life. This is a mixture of binder, aggregate, and air in different comparative proportions that determine the physical properties of bitumen mix and how the mix is going to perform as a completed bitumen pavement.

1.2 Effect of properties of aggregate on performance of bitumen mix.

Aggregate particles can be precisely defined in terms of three self-governing shape properties such as shape or also known as form, surface texture and angularity. The following three aggregate shape properties entirely describe particles based on their geometry. The form is defined as aggregate particles that are based on particle dimensions ratio. The angularity property is defined as measurement that describes particles based on the deviations at the edges of aggregate particles. Thus the above measurement defines the particles in a range from angular to round.

The final or last property is the surface texture of aggregate. This property describes the particle surface roughness at a small scale, and it is not prejudiced by changes in shape or angularity of the particle. These three properties are independent of each other also an increase or decrease in one of these properties does not necessarily influence the properties of other. (by Rousan in 2004). A diagram illustrating the differences between these three aggregate shape properties is shown in Fig 1

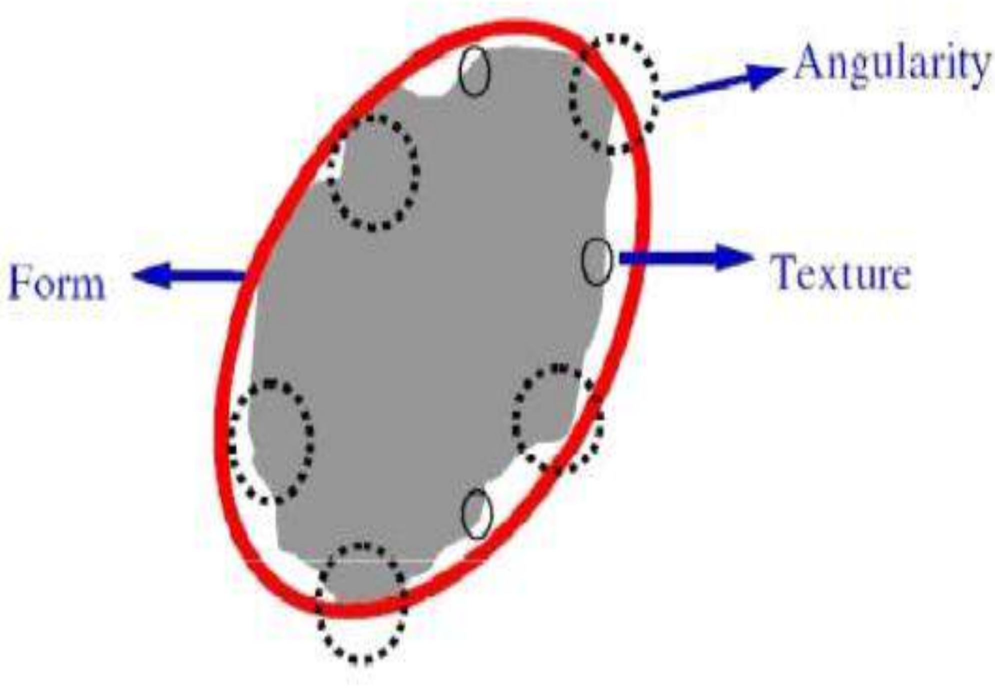


Fig 1: Aggregate shape Components form, angularity, and texture

(Source: Masad et al., 2003)

1.3 <u>Particle Size, Shape, and Texture.</u>

1.3.1 Particle Shapes: The shape of aggregate particles can be classified as rounded or sub rounded, angular and sub angular. Depending upon the desired properties of product each shape of aggregates has its own advantage and disadvantage.

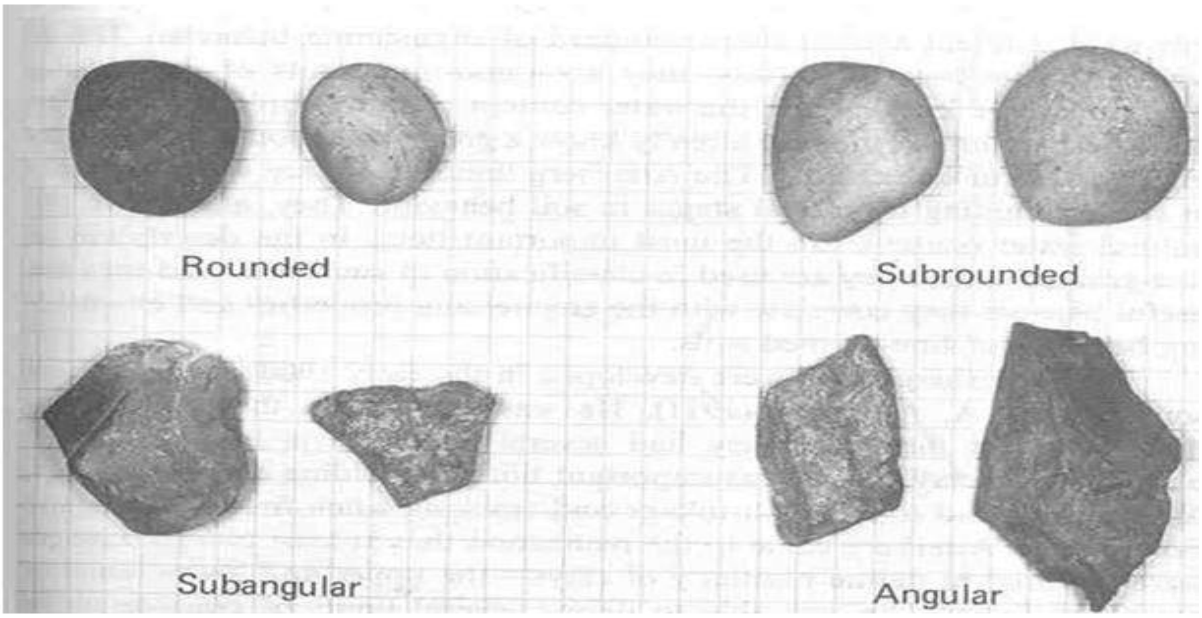


Fig 2: Different shapes of aggregates

(source: Google)

1.3.2 Surface Texture: surface texture can be defined as how it feels when the aggregate is rubbed between the fingers that is whether its smooth or rough.

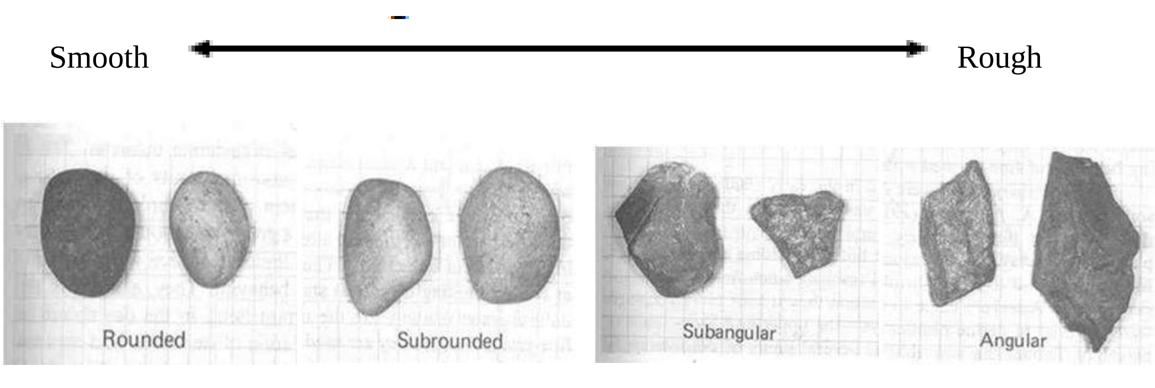


Fig 3: Surface texture of different shapes of aggregates

(source: Google)

1.3.3 Particle Size: Size of particle can be classified as

- **Boulder (**12 inches or more).
- **Cobble** (3 – 12 inches).
- **Gravel** (0.2-3inches).

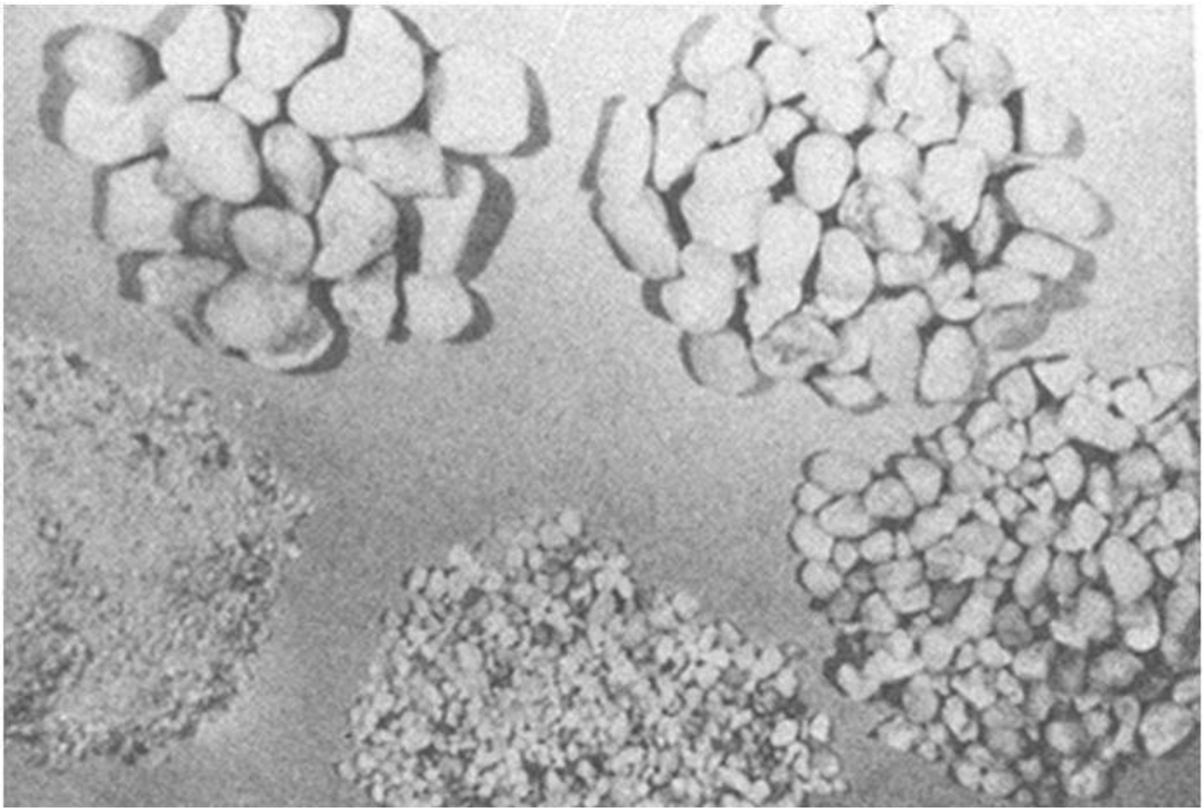


Fig 4: Different size of aggregates

(Source: CAL1 Section 2 rev3)

1.3.4 Effects of Particle Shape and Surface Texture:

- Strength of aggregate particles depends on shape and texture of aggregate.
- Particle shape and surface texture effects the bond with cement mix material.
- Property to sliding of one aggregate particle over another.
- Angular shaped particles with rough surface texture are able to create very strong and stable matrix but are difficult to compact because angular particles with rough surface can interlock and resist compactive effort.

- Rounded shaped particles with smooth surface texture have the advantage that it will get compacted readily, but the disadvantage is that they are unstable under heavy loads due to lack of bonding between particles and slide against each other.
- Also flat, long, needle-shaped particles are not recommended as they tend to break easily instead it's better to use cubical or sphere shaped aggregates.
- Rough and fractured faces aggregates allow better bonding with bitumen or cement concrete than rounded aggregates or smooth faced aggregates.

1.3.5 Gradation:

- Particle size distribution is how most of the aggregates are specified and is determined based on their intended use.
- Gradation is measured by sieve analysis

1.3.6 Gradation distribution:

- **Well-Graded distribution:** In this the particles are evenly distributed over a wide range. Smaller particles fill open spaces between larger particles.
- **Uniformly or Poorly Graded distribution:** In this type of gradation open space exists between particles and majority of aggregate particles are approximately of the same size.

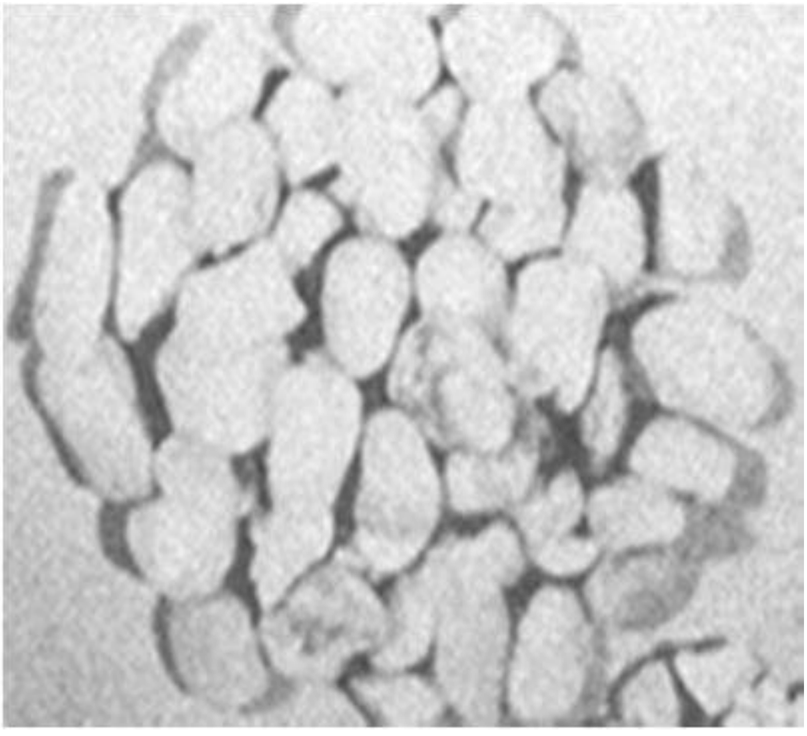


Fig 5: uniformly or poorly graded distribution

(Source: CAL1 Section 2 rev3)

- **Dense Graded distribution:** Due to good interlocking between particles the resistance to shear failure increases and its more economical in concrete and asphalt mixes because of the reason that less binder is required.

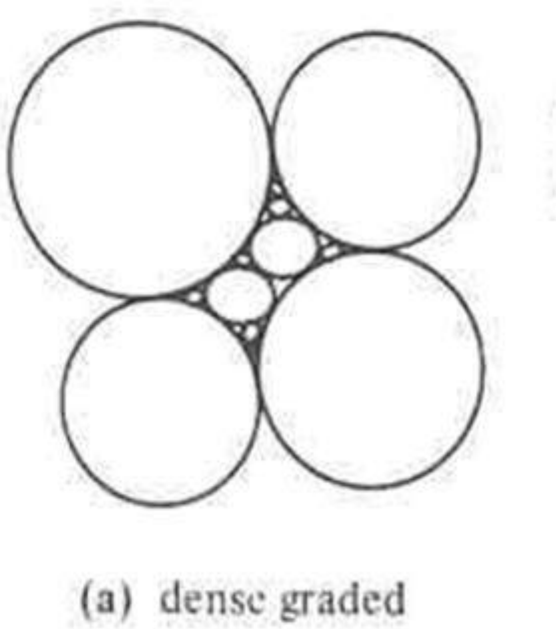


Fig 6: Dense Graded distribution

(Source: CAL1 Section 2 rev3)

- **Open Graded distribution:** in this there is large void spaces between aggregate particles that enable good drainage capability but they are unstable.

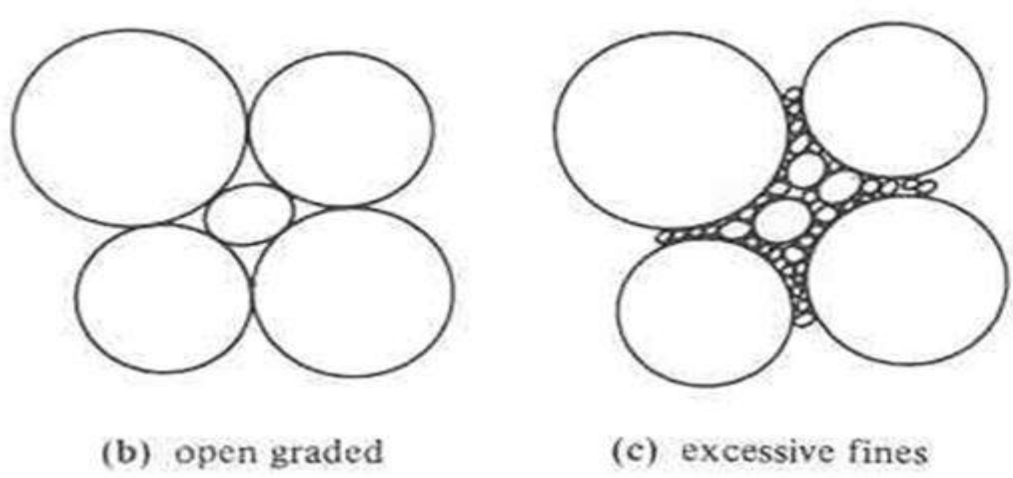


Fig 7: Open Graded distribution

(Source: CAL1 Section 2 rev3)

1.4 Desirable properties of aggregate:

1.4.1 Strength: Aggregates that are used in top layer are subjected to stress action due to wheel load, wear and tear and crushing. So for a high quality pavement surface, the aggregate should have high resistance to crushing and resistance to withstand the stress due to traffic operations.

1.4.2 Hardness: Aggregates should be hard enough to resist the action due to abrasion caused due to moving traffic. Usually abrasive action is severe when steel tyres vehicles move over the exposed aggregates.

1.4.3 Toughness: It can be defined as resistance of aggregate to impact. Aggregates that are used in the pavement should be tough enough to resist the effect due to jumping of the steel tyre vehicles from one particle to another at different levels causing severe impact on the aggregates.

1.4.4 Shape of aggregates: aggregates which happen to fall in a particular range may have rounded cubical, angular, flaky or elongated particles. It has been found that flaky and elongated particles possess less strength and durability when compared with cubical, angular particles.

1.4.5 Adhesion with bitumen: Aggregates that are used should have less affinity with water as compared with bitumen otherwise this will lead to stripping of bitumen. That is the coating on the aggregate will be stripped off in the presence of water.

1.4.6 Durability: It’s also knows as soundness and is defined as property of aggregate to withstand adverse action of weather. As aggregates are subjected to chemical and physical action of rain and ground water, so aggregates should be durable to withstand the weathering action.

1.5 Types and Causes of Failure in Base course of HMA Pavements:

- **Inadequate stability or strength:** poor mix proportion or inadequate thicknesses are the main reasons for the lack of strength and stability in HMA pavements. Also due to use of soft aggregates or improper quality control during the construction results in poor stability.

- **Loss of binding action:** Due to the internal movement of aggregates in base course or sub base course under repeated stress application, the composite structure of the layers gets disturbed. This results in loosening of total mass and formation of alligator carks on the bitumen surfacing of flexible pavement. There is also loss of binding action resulting in low stability and poor load transmitting property of the pavement layer. Excessive permanent deformation is thus caused in the sub base or base course layer.

- **Loss of base course material:** this type of failure is only possible when either the base course is not covered with surface course or wearing or if the surface course is completely worn out. Usually due to fast movement of cars causes this type of failure.

- **Inadequate wearing course:** Absence of wearing course or inadequate thickness and stability of wearing course exposes the base course and due to climatic effect, frost action and movement of traffic damages the base course.

1.5.1 Types and Causes of Rutting:

Rutting develops in the wheel path in the HMA pavements under channelized traffic. This type of failure is mainly caused by permanent deformation of materials present in the pavement structure under repeated load conditions. Mainly permanent deformation in HMA pavements results due to two processes

- Densification: A consolidation or depression appears under wheel load. It is caused due to poor compaction during construction of HMA pavement or due to inadequate mix design.
- Plastic Flow: A consolidation or depression followed by upheaval in the HMA layer on either side of the depression or consolidation. A mixture that has got plastic flow is generally caused due to the presence of unstable tender mixture.

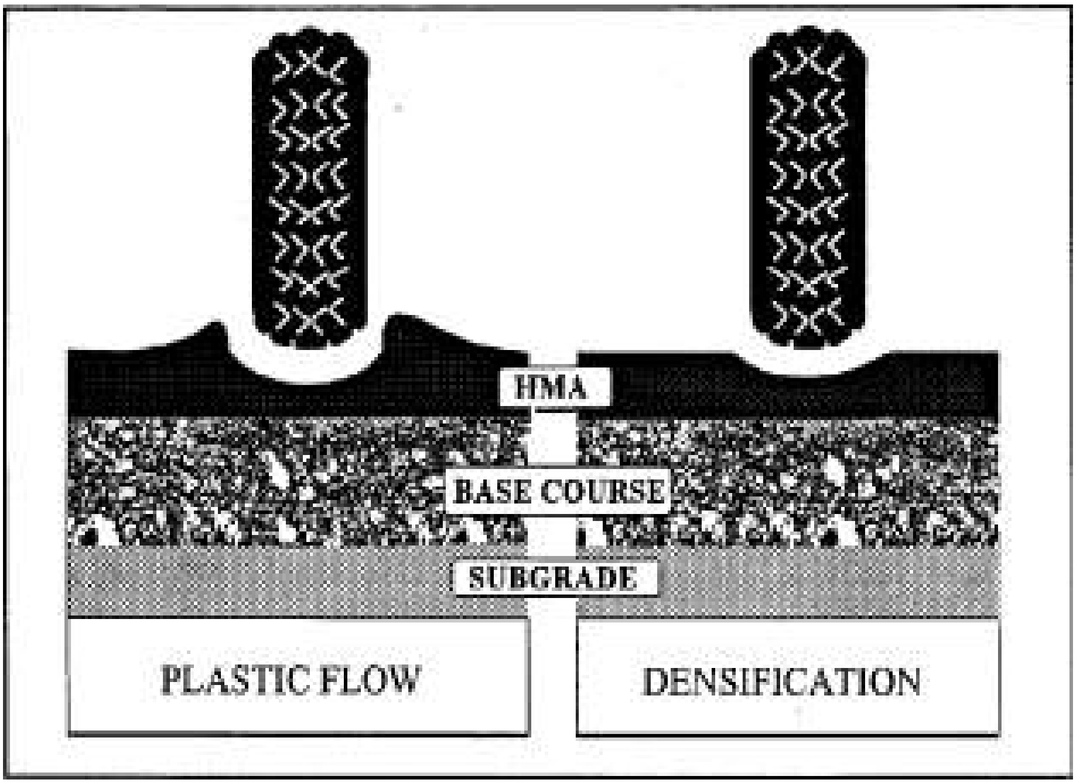


Fig 8: Difference between plastic flow and densification

(Source: Google)

1.6 Need of study

- Shape property of aggregate are well-known to influence Bitumen pavement performance.
- Angularity and texture oversee the properties such as frictional and dilation of the structure of aggregate. Texture of aggregate plays a main or important role in influencing the adhesive bonding between the binder and aggregate, meanwhile anisotropic response influences the aggregate form of Bitumen mixes.
- Shape of aggregate is considered to be one of the significant properties considered in the mix design of bitumen pavements so that to avoid the early failure of pavement.
- By replacing the smooth aggregates with cubical aggregates how much will it affect or increase the stability.

1.7 Objective of study

- To determine the various properties of the aggregate with respect to the different shapes such as (Round, cubical and blade) by conducting various tests such as impact test, crushing value test, sieve analysis, shape test.
- To determine and compare the Stability, Flow and other related properties of bitumen mixes by conducting Marshall Stability Test on different shapes of aggregates.
- Comparing the stability results of different shapes of aggregates.
- Finding the effect of shape of aggregate on bitumen mix. And which shape has got maximum and minimum stability.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

Aggregate geometry consists of three self-governing characteristics such as form, angularity or roundness of aggregate and surface texture. Aggregate angularity can be defined as the measurement of the sharpness of the corners of a particle. Thus, a rounded particle can be categorized as a particle which has low angularity and a non-rounded particle can be classified as a particle with high angularity.

Aggregate shape properties are known to influence bitumen mix performance. Aggregate texture plays a major role in inducing the adhesive bond between the aggregate and the binder, whereas aggregate form influences the response of bitumen mixes. Angularity and texture governs the frictional properties and dilation of the aggregate structure.

Performance of bitumen mixtures is prejudiced by the aggregate properties, such as aggregate gradation, aggregate shape including (angularity , surface texture or roughness). In HMA mix, various studies have related the gradation, shape, and surface texture of aggregate to durability, workability,, tensile strength, rutting susceptibility etc. . In respect of the importance of properties of aggregate on performance of bitumen pavement, flat and elongated particles should be limited in bitumen mixes.

However, there is deficiency of consistency between the specifications of aggregate and the capability to measure the preferred properties of aggregates. The common test method for calculating the angularity of aggregate and surface texture is indirect measures. Proper selection and evaluation of aggregate properties will remain necessary to yield high-quality HMA mixtures, predominantly as traffic loads increase .Quantification of aggregate properties with rational, objective characterization methods are appropriate. Visual examination is the best method for judging shape of aggregate, the chief objective of this study is to reconnoitre the use of different shape of aggregate in HMA mixes and performance of the bitumen mix calculated in terms of Marshall stability test result.

Morphological characteristics of aggregate are very complex and cannot be characterized sufficiently by conducting a single test. Thus, conflicting results have been stated on how aggregate shape influences the quality of bitumen mixtures. For example

- **Lievneh and Shklaarsky in 1964** determined that by replacing uncrushed coarse aggregate with crushed coarse aggregate does not improve the properties of asphalt mixes.
- **Sinhaa and Stephens in 1978** presented the data on the influence of shape of aggregate, and recommended that the blends of regular aggregates, flat aggregates, and rod like aggregates to attain optimum strength.
- **Kalcheef and Tuniclif in 1982** debated the effect of aggregate crushing, aggregate size, and particle shape. They highlighted that use of asphalt can be reduced by increasing the size of crushed aggregate that are to be used in a mix.

Thus these contradictory statements result mainly due to the lack of study on effect of aggregate shape on mechanical properties of a HMA mix.

2.2 Findings:

- **Huber and Heaiman in 1987** found that crushed aggregate contained 19% flat and elongated particles did not badly affect the volumetric properties of HMA mixtures.

- **Kruts and Sebaly in 1993** found a direct correlation between the shape and texture of coarse aggregate particles and the rutting potential of HMA mixtures.

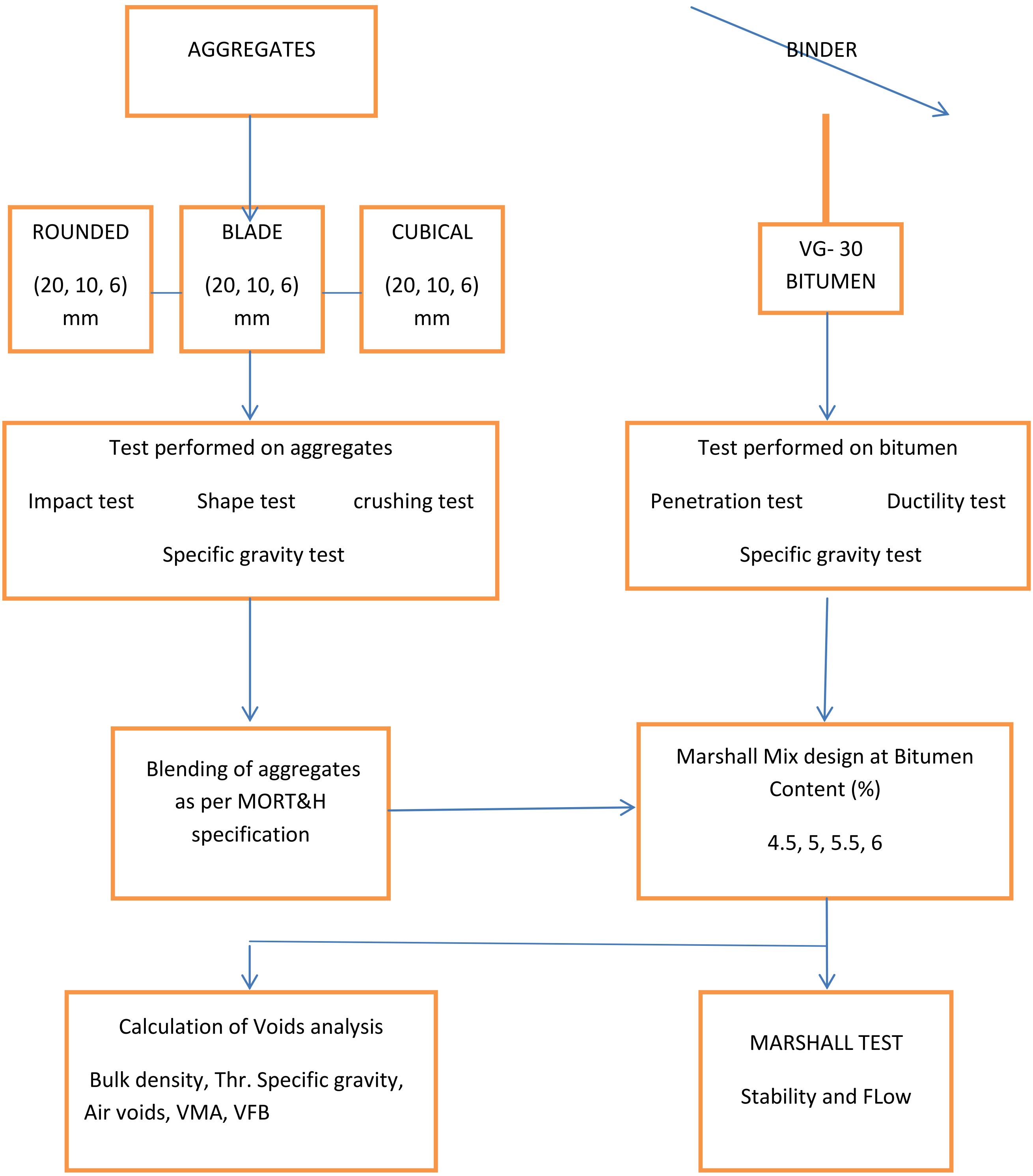
- **Oduroh in 2000** presented that the percentage of crushed coarse particles had a noteworthy effect on permanent deformation properties in laboratory. There is increase in the rutting potential of the bitumen mix when there is decrease in percentage of crushed coarse particles.

- **Kett and lee in 1967** found that flat and elongated particles can be permitted in a bitumen mixture without confrontational effect on its strength. Mixes with flaky aggregates have been found to exhibit higher fatigue life than mixes with non-flaky aggregates.

- **Elliot, Ford, Ghanim and Tu** evaluated the effect of variation in aggregate gradation on the properties of HMA mixes. They evaluated five aggregate gradation of crushed limestone HMA mixes. In their study they concluded that when the gradation changes the general shape of gradation curve it has the greatest effect on variation in gradation. In poorly graded and in cross gradation the creep stiffness is minimum. And tensile strength is lowest in coarse gradation. Marshall Stability is also affected due to gradation variation, fine gradation has highest stability and the fine coarse poorly graded gradation produced the minimum stability.
- **Crawford and Marker** concluded that the particle shape and the amount of material passing the sieve No. 4 were the major factors affecting the tenderness of asphalt concrete mix. In their study they found that most tender pavement have an excess of middle sized sand particle in aggregate gradation. They also concluded that rounded, uncrushed materials passing sieve no 4 increases.
- **Brown and Welke** determined the relation between asphalt mixture properties and maximum aggregate size. They concluded that there is no connection between stability and rutting resistance. Relationship between stability and maximum size of aggregate is poor. Very less effect or change in indirect tensile strength as maximum size aggregate changed. Creep test showed that increased size of aggregate is more resistant to permanent deformation and resilient modulus indicates good correlation with maximum aggregate size.
- **Herrin and Goetz** determined the effect of shape of aggregate on the stability of asphalt concrete mix. They used crushed and uncrushed gravel, crushed limestone for coarse aggregate and sand and crushed limestone sand for fine aggregates. Their major finding was that strength of asphalt mix was more affected by change in fine aggregate shape rather than change in coarse aggregate shape.
- **Wedding and Gaynor** determined the effect of shape of particle in dense graded asphalt concrete mix. From their study they concluded that crushed particles produce higher stability values than uncrushed or rounded aggregates. Use of crushed gravel sand instead of natural sand increased the stability as much as adding 25 per cent crushed coarse aggregates. Also increase in amount of crushed particles decreased the unit weight and increases voids in mineral aggregates and optimum bitumen content.

WORK PROGRAM

3.1 Flow Chart:



3.2 Methodology

Test on aggregates were performed such as:

- Sieve analysis.
- Impact test.
- Crushing value test.
- Shape test: elongation and flakiness index.
- Specific gravity test.

Test on Bitumen binder were performed such as:

- Penetration test.
- Ductility test.

For stability and flow determination:

- Marshall Stability test.

3.3 Materials used:

- **Coarse aggregates:** In this study I used three shapes of coarse aggregates (rounded, cubical, and blade), of size 20mm, 10mm, 6mm.
- **Fine aggregates:**
- **Filler:**
- **Binder:** Bitumen binder of grade VG 30 was used as binder in the study.

Table 1: IS 73: 2006 specification of VG 30 bitumen

Characteristics	Paving Grade VG 30
Penetration at 25 C	**50 - 70**
Softening point (C)	**40 - 55**
Ductility (cm)	**40**
Specific gravity	**>.99**

CHAPTER 4

EXPERMANTAL SETUP

4 Experimental Tests:

4.1 Sieve Analysis:

- **SUMMARY OF TEST**

  A known amount of material aggregate is placed upon the top sieve placed according to the size of sieve usually larger to smaller and then shaken by mechanical means for some time. After shaking the material through the nested sieves, the material retained on each of the sieves is weighed.

Fig 9: Set of Sieve

(Source: Transport lab LPU)

4.2 <u>Impact Value Test:</u>

- **SUMMARY OF TEST**

  Impact value of an aggregate can be defined as the percentage loss of weight of particles passing 2.36 mm sieve after application of 15 blows of standard hammer fall of hammer is 38cm. The aggregate impact value gives a comparative measure of the aggregate resistance to sudden shocks or impact which in some aggregate differs from their resistance to a slowly applied compressive load. The aggregate impact value should not exceed 30% for aggregates that has to be used as wearing course.

Fig 10: Aggregate Impact testing machine

(Source: Transport lab LPU)

4.3 Shape Tests

- **Flakiness Index**

SUMMARY OF TEST

Sample of aggregate are allowed to pass through a specified set of sieves. Weight of retained aggregate on each sieve is measured and determined as the percentage of retained aggregate. Each of the particles fractions of aggregate is tried to passing through the slot of the thickness gauge. The weight of aggregates passing on each gauge is measured. Flakiness index is the total weight of the material passing the various thickness gauges expressed as a percentage of the total weight of the sample gauged. The flakiness index value of the aggregate recommended for the road construction should be below 30 %.

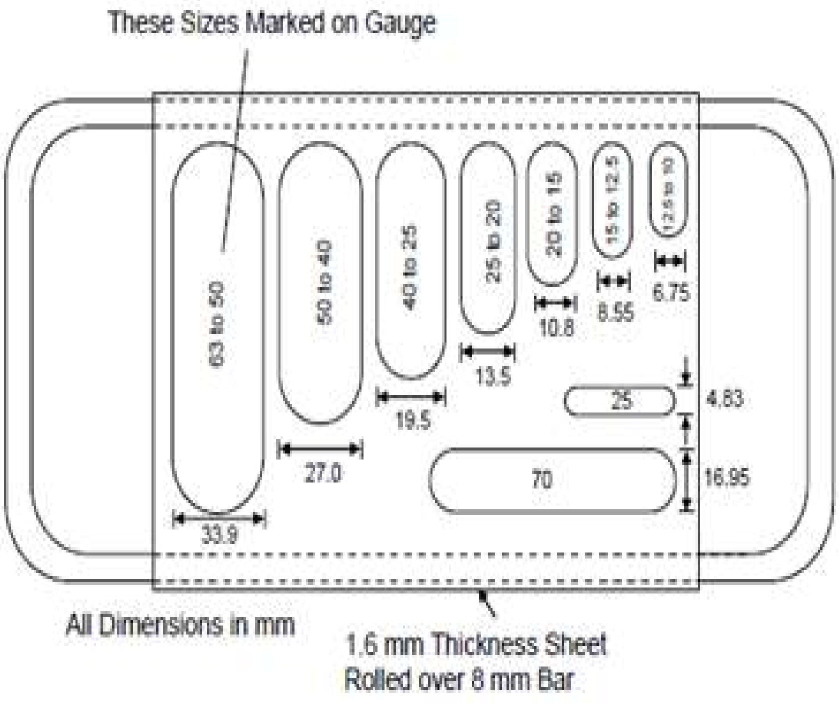


Fig 11: Thickness gauge

(Source: IS: 2386 (Part I) – 1963)

- **<u>Elongation Index</u>**

Summary of test

Sample is sieved through set of sieves. A minimum of 200 pieces from each fraction are taken and weighed, In order to separate the elongated material, each fraction is then gauged individually for length in a length gauge. From each sieve the pieces of aggregate which are not able to pass through the specified gauge length are elongated particles these particles are separately collected to find the total weight of aggregates retained on the length gauge from each fraction. The total amount of elongated material retained by the length gauge is weighed.

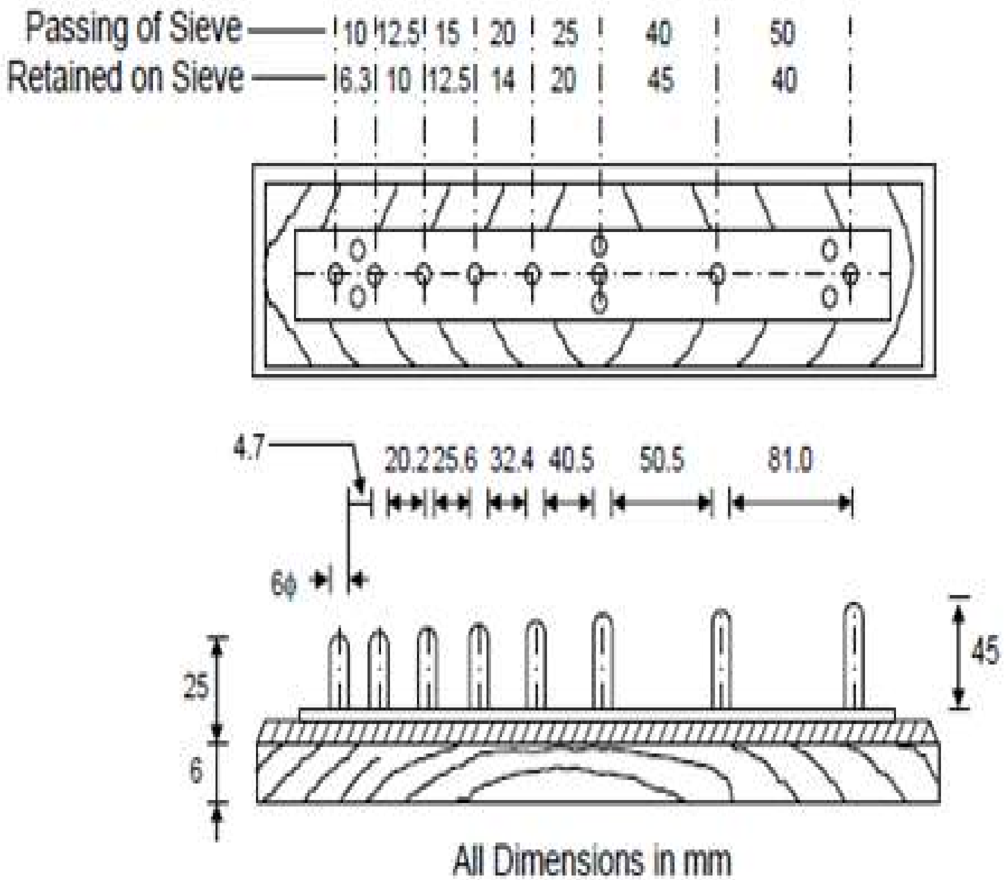


Fig 12: Length gauge

(Source: IS: 2386 (Part I) – 1963)

4.4 <u>Crushing Value Test</u>

- **Summary of Test**

Sample of aggregate passing the 12.5 mm and retained on the 10 mm sieve is sieved out .The cylindrical measure is filled with aggregate in three equal layers, with each layer being tamped 25 times with tamping rod.. The surface of the aggregate is levelled and the plunger is inserted. Now the apparatus is placed in the compressive testing machine and load is applied 400KN in 10min at the uniform rate of 40 KN per min. after the specified load is applied, the sample is removed from the cylinder and placed in a suitable pan and sieved on a 2.36 mm sieve. The fraction passing the sieve is weighed. Aggregate crushing value should not exceed 30% for use in pavement design.

Fig 13: Compression testing machine

(Source: Transport lab LPU)

4.5 Specific gravity test:

- **Summary:**

  Specific gravity of aggregate is used to determine the quality and strength of aggregate. Sample of aggregate is taken in wire basket and immersed in water then sample is weighted in water and buoyant weight is found. The aggregates are then surface dried and weight. After then put in an oven for 24 hours and then dry weight is determined. Specific gravity is calculated as the ratio of dry weight of aggregate to weight of equal volume of water.

Fig 14: specific gravity test

(Source: Transport lab LPU)

4.6 <u>Penetration Test:</u>

- **Summary of Test**

  Penetration test is used to determine the hardness or softness of the bitumen by measuring the depth in tenth of millimetre a standard loaded needle will penetrate vertically for a period of 5 seconds. Penetration value varies from 20 – 225 for different bitumen grades used in pavements.

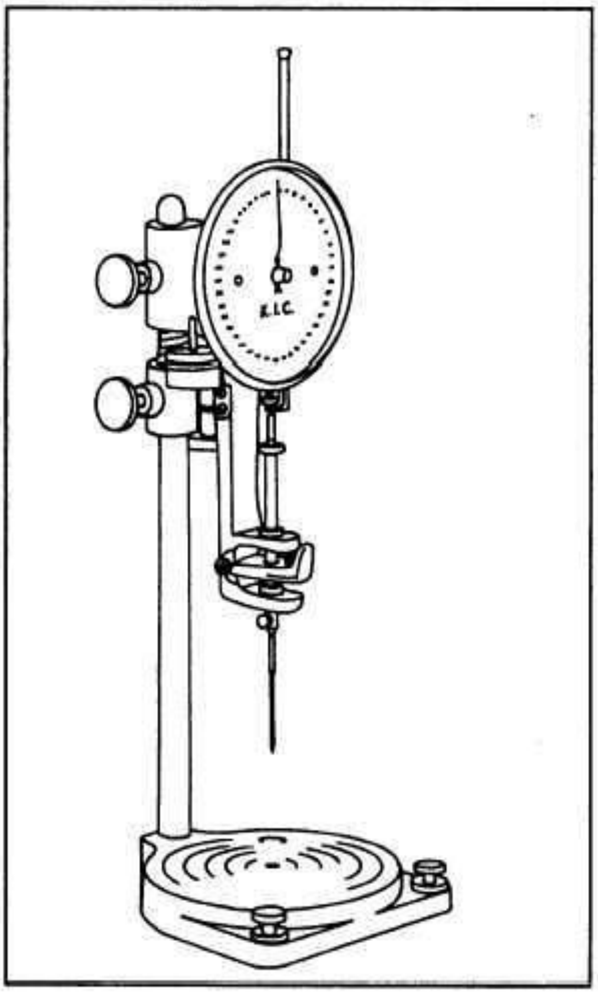


Fig 15: Penetrometer

(Source: Google)

4.7 <u>Ductility Test</u>:

- **Summary of Test**

Ductility test is carried out to measure the adhesive property of bitumen and its ability to stretch. The ductility is expressed as the distance travelled by the specimen in cm to which a standard briquette of bitumen can be starched before the tread breaks. The rate of pull is 50mm per min and the test is conducted at room temperature (27 C). ductility value varies from 5 – 100 for different bitumen grades. A min. value of 75 cm has been specified by ISI for 45 grade bitumen.

Fig 16: Ductility Test

(Source: Transport lab LPU)

4.8 <u>Marshall Stability Test:</u>

Summary of test

The principle of the Marshall Stability test is the resistance to plastic flow of cylindrical specimens of a bituminous mixture that is loaded on the lateral surface. Also it is the load carrying capacity of the bitumen mix at 60 C measured in KN. The various desirable mix properties include stability of mix, durability of pavement, workability and skid resistance.

Fig 17: Marshall Stability Tester

(Source: Transport lab LPU)

4.9 Density/Specific gravity and void analysis of Marshall Method:

- **Density or specific gravity of the mix (Gb):**

  Weight of specimen in air = W1 gm.

  Volume of compacted specimen (can be determined either by measuring mean dimension or by weighing in air and water and finding the volume of water displaced) =V (cm3).

  Bulk density of mix (Gb) = W/V (gm. /cm3).

- **Void Analysis:**

  Volume of voids in mix (Vv %) = 100(Gt – Gb) / Gt.

  Volume of bitumen (Vb %) = Gb x W4/G4.

  Volume of voids in mineral aggregate (VMA %) = Vv + Vb.

  Volume of voids filled with bitumen (VFB %) = 100Vb/VMA.

- **Theoretical Density or Specific Gravity of the Bitumen Specimen (Gt):**

$$Gt = \frac{100}{W1/G1 + W2/G2 + W3/G3 + W4/G4}$$

  Where

  W1 = % by weight of coarse aggregate in total mix.

  W2 = % by weight of fine aggregate.

  W3 = % by weight of filler.

  W4 = % by weight of bitumen binder.

  G1 = Specific gravity of coarse aggregate.

G2 = Specific gravity of fine aggregate.

G3 = Specific gravity of filler.

G4 = specific gravity of bitumen binder.

Chapter 5

RESULTS AND DISCUSSIONS

5.1 Impact value of different shapes of aggregate:

Table 2 Impact value of different shapes of aggregate

SHAPE	IMPACT VALUE (%)	MORT&H Limits
Rounded	16.77	Max 27 %
Blade	24.61	
Cubical	10.71	

5.2 Crushing value of different shapes of aggregate:

Table 3 Crushing value of different shapes of aggregate

SHAPE	CRUSHING VALUE (%)	MORT&H Limits
Rounded	25	Max 30 %
Blade	30	
Cubical	20	

5.3 Flakiness and Elongation index of different shapes of aggregate

Table 4 Elongation and Flakiness Index

SHAPE	Elongation Index (%)	Flakiness Index (%)	MORT&H Limit

Rounded	12.23	15.65	Max 30 %
Blade	15.27	21.22	
Cubical	7.25	8.31	

5.4 <u>Specific gravity test:</u>

Table 5 Specific gravity values of aggregates.

Description	Test value	Specified limits
Round aggregates	2.83	For aggregates 2.6 – 2.9
Blade aggregates	2.69	
Cubical aggregates	2.60	

5.5 <u>various test results of VG-30 bitumen binder</u>:

Table 6 Penetration, ductility and specific gravity values

Description	Test value	Specified limits
Penetration	62	50-70
Ductility	42	40
Specific gravity	1.011	>.99

- **Impact value:** From the above table we can observe that cubical aggregate got min value and blade got max this implies that cubical aggregate are hard stones and have high resistance to impact during traffic operations. Blade has more air voids that is why they are weak in impact.
- **Crushing value:** All three shapes fulfilled the MORT&H limit of CVA, cubical got min. value that specifics they are strong and blade are weak as they tend to break down during traffic operations.
- **Shape test:** Blade aggregate got higher values that imply they are elongated and flaky which is not desirable for road construction as they are under the specified limit so they can be used but will affect the stability of the bitumen mix.
- **Specific gravity:** Specific gravity of aggregate is considered to a measure of quality or strength of the material. Stones having low specific gravity values are generally

weaker than those having higher values. From the above table it was seen that cubical aggregate have higher value that is 2.89 whereas round has lower value of 2.60. That means cubical shaped aggregate will have more strength and thus will increase the stability.

5.6 MORT&H (Ministry of Road Transport and Highway) LIMIT:

- For rounded aggregate:

Table 7 Percentage passing of rounded aggregates

SIZE OF AGGREGATE(Individual Gradation)					
Sieve size(mm)	20mm	10mm	6mm	sand	cement
37.5	100	100	100	100	100
19.5	36.78	100	100	100	100
13.2	16.83	96.24	98.5	100	100
9.5	6.76	38	95.6	100	100
4.75	0.89	2.53	35	100	100
2.36	0.65	1.07	21.2	78	100
.300	-	0.90	1.62	38	100
.075	-	0.75	1.57	10	25.5

Table 7A Blending of rounded aggregate by hit and trail method

BLENDING BY HIT AND TRIAL METHOD							
Sieve size(mm)	20(mm)	10(mm)	6(mm)	sand	cement	Combined gradation	Specified limits
	29%	20%	20%	28%	3%	100%	
37.5	29	20	20	28	3	100	100%
19.5	10.66	20	20	28	3	86.8	(71-95)%
13.2	4.88	19.25	19.7	28	3	78.5	(56-80)%
9.5	1.96	11.02	19.12	28	3	61.1	(40-65)%
4.75	.258	.506	7	28	3	38.16	(38-54)%

2.36	.181	.214	4.24	21.84	3	31.35	(28-42)%
.300	-	.18	.324	10.64	3	13.30	(7-21)%
.075	-	.15	.314	2.8	.765	3.64	(2-8)%

- For blade aggregate:

Table 8 Percentage passing of blade aggregate

SIZE OF AGGREGATE(Individual Gradation)					
Sieve size(mm)	20mm	10mm	6mm	sand	cement
37.5	100	100	100	100	100
19.5	40	100	100	100	100
13.2	11	92	100	100	100
9.5	4	28	98	100	100
4.75	.9	9	35	100	100
2.36	.2	4	28	85	100
.300	.06	.5	10	32	100
.075	-	-	.4	12	25.5

Table 8A Blending of blade aggregate by hit and trail method

BLENDING BY HIT AND TRIAL METHOD							
Sieve size(mm)	20(mm)	10(mm)	6(mm)	sand	cement	Combined gradation	Specified limits
	22%	24%	28%	23%	3%	100%	
37.5	22	24	28	23	3	100	100%
19.5	8.8	24	28	23	3	86.8	(71-95)%
13.2	2.42	22.08	28	23	3	78.5	(56-80)%
9.5	.88	6.78	27.44	23	3	61.1	(40-65)%
4.75	.198	2.16	9.8	23	3	38.16	(38-54)%
2.36	.044	.96	7.84	19.55	3	31.40	(28-42)%

.300	.0132	.12	2.8	7.36	3	13.30	(7-21)%
.075	-	-	.112	2.76	.765	3.637	(2-8)%

- **For cubical aggregates:**

Table 9 Percentage passing of cubical aggregate

SIZE OF AGGREGATE(Individual Gradation)					
Sieve size(mm)	20mm	10mm	6mm	sand	cement
37.5	100	100	100	100	100
19.5	38	100	100	100	100
13.2	12	88	100	100	100
9.5	5	30	100	100	100
4.75	.8	10	40	100	100
2.36	.2	3	25	80	100
.300	.03	.7	10	38	100
.075	-	-	.3	12	25.5

Table 9A Blending of cubical aggregate by hit and trail method

BLENDING BY HIT AND TRIAL METHOD							
Sieve size(mm)	20(mm)	10(mm)	6(mm)	sand	cement	Combined gradation	Specified limits
	20%	25%	30%	22%	3%	100%	
37.5	20	25	30	22	3	100	100%
19.5	7.6	25	30	22	3	87.6	(71-95)%
13.2	2.4	22	30	22	3	79.4	(56-80)%
9.5	1	7.5	30	22	3	63.5	(40-65)%
4.75	.16	2.5	12	22	3	39.66	(38-54)%

2.36	.04	.75	7.5	17.6	3	28.89	(28-42)%
.300	.0006	.175	3	8.36	3	14.54	(7-21)%
.075	-	-	.09	2.64	.765	3.50	(2-8)%

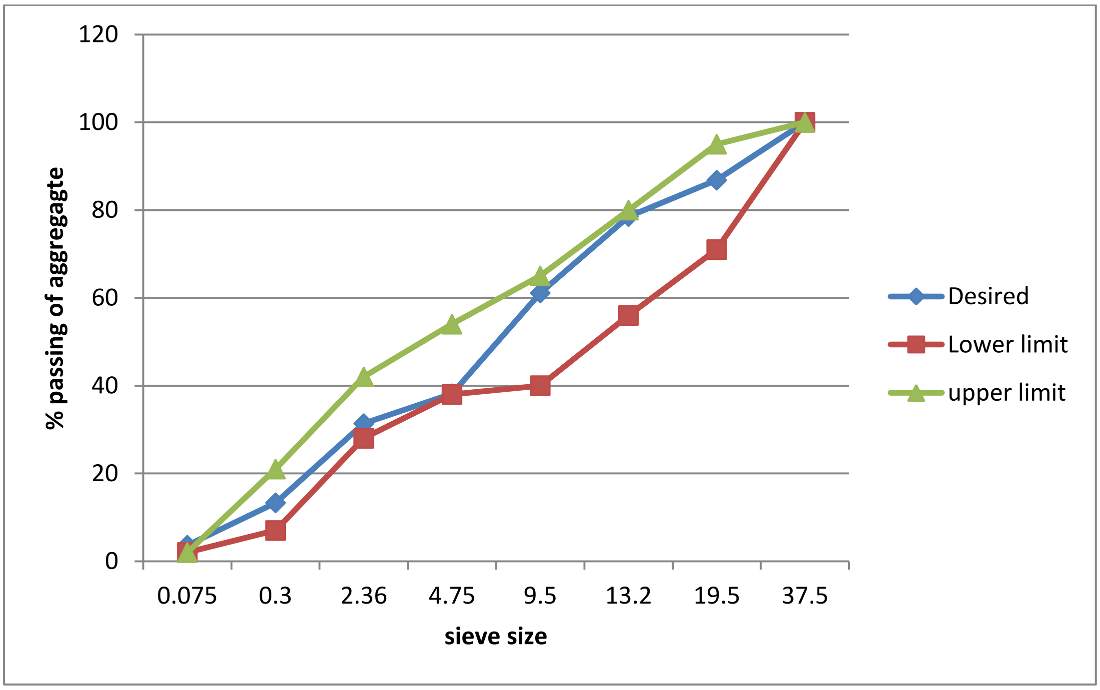


Fig 18: Comparison of Desired gradation of round aggregate with MORT&H s' lower and upper limits.

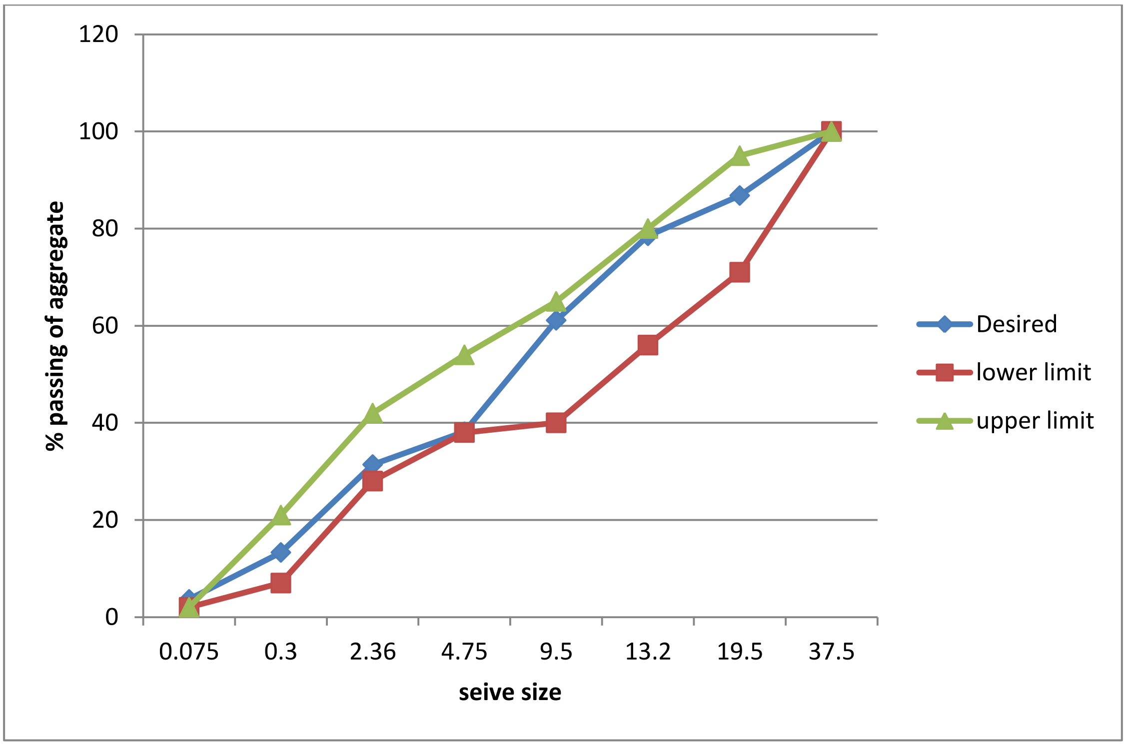


Fig 19: Comparison of Desired gradation of blade aggregate with MORT&H s' lower and upper limits.

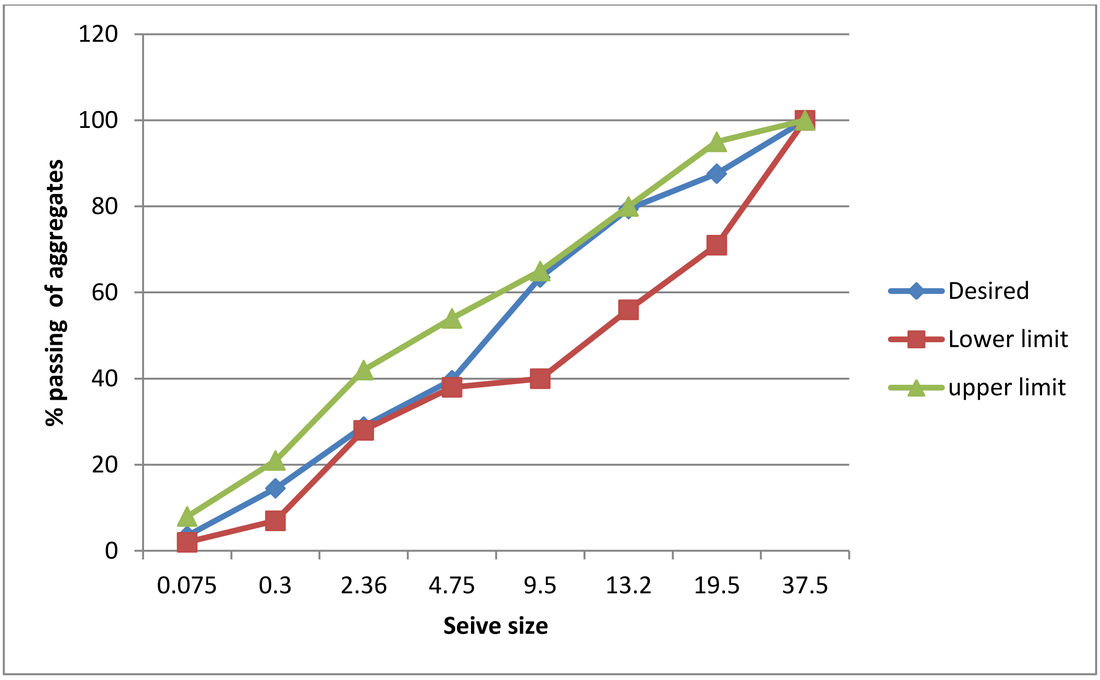


Fig 20: Comparison of Desired gradation of cubical aggregate with MORT&H s' lower and upper limits.

- The main purpose of blending was to find out gradation is within the specified limits stated by MORT&H. The blending has been done for different size of aggregate (20mm, 10mm, and 6mm) and is found within the allowed limits. From the above graphs it's clear that all the shapes are within the specified gradation limit. The upper and lower limits specified by MORT&H are shown in table and the desired gradation should lie between these limits.

5.7 Determination of Bulk Density/ Specific gravity and Theoretical specific gravity:

Table 10: Determination of theoretical specific gravity and bulk density.

Shapes	Bitumen Content (%)	Weight		Bulk density/ specific gravity	Theoretical Specific gravity
		In Air	In Water	(Gb)	(Gt)
Rounded Aggregate	4.5	1212.50	680.50	2.28	2.411
	5	1224.12	685.40	2.27	2.382
	5.5	1228.65	688.2	2.26	2.35
	6	1232.49	679.34	2.23	2.327
Blade Aggregate	4.5	1230.25	688.15	2.26	2.402
	5	1232.25	688.75	2.26	2.38
	5.5	1238.21	690.20	2.25	2.35
	6	1235.10	686.5	2.251	2.32
Cubical Aggregate	4.5	1227.5	715.45	2.397	2.496
	5	1231.5	713.15	2.378	2.466
	5.5	1235.42	710.35	2.352	2.437
	6	1230.10	701.15	2.325	2.408

5.8 Results of Marshall Test:

- **For Round shaped aggregate:**

Table 11: Stability, Flow, Vv, VMA, and VFB values for round shape

Bitumen content (%)	4.5	5	5.5	6
Stability (kg)	985	1085	1007	965
Flow	3	3.4	4.9	6.1
Air voids (Vv) %	5.43	4.7	3.82	3.80
VMA (%)	15.57	15.88	16.01	17.03

VFB (%)	65.09	70.44	75.11	77

- **For Blade shaped aggregate:**

Table 12: Stability, Flow, Vv, VMA, and VFB values for blade shape

Bitumen content (%)	4.5	5	5.5	6
Stability (kg)	1021	1180	1050	979
Flow	2.6	3.2	4.3	5.9
Air voids (Vv) %	5.91	5.04	4.25	3.70
VMA (%)	15.9	16.21	16.84	16.95
VFB (%)	62.93	68.95	74.22	76.15

- **For Cubical shaped aggregate:**

Table 13: Stability, Flow, Vv, VMA, and VFB values for cubical shape

Bitumen content (%)	4.5	5	5.5	6
Stability (kg)	1180	1320	1240	1102
Flow	2.5	3.1	4.12	5.5
Air voids (Vv)	3.96	3.56	3.48	3.44
VMA	13.87	14.31	15.10	15.89
VFB	70.29	72.29	76.40	78.56

- **Stability:** The stability increases with increase in bitumen content initially after that decreases with further increase in bitumen content. Among the three shapes cubical shape got the maximum value of stability this can be because of the reason that cubical shapes aggregate has more interlocking with each other and the texture is rough which holds the bitumen and increases the stability. Round shapes aggregate has less interlocking and have smooth surface texture that is the reason they have less stability while blade also got low stability values the reason behind it is that mix prepared with blade shaped aggregate have more voids that tends to decrease their stability. The min Stability value specified by MORT&H is 900 kg.

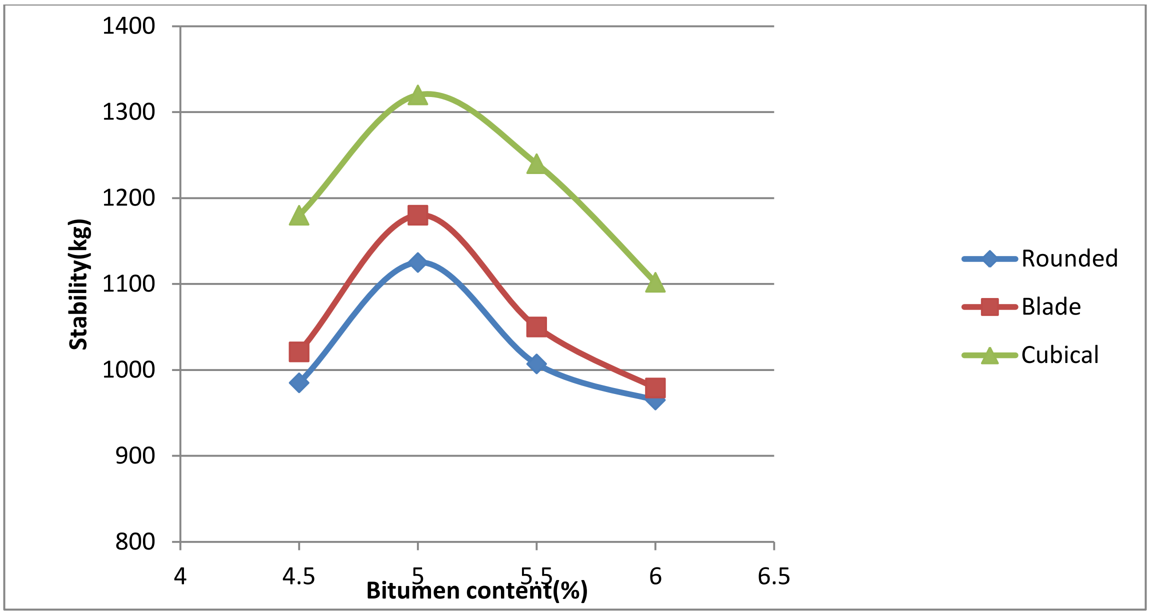


Fig 21: Bitumen content vs stability for different shapes of aggregates

- **Flow:** It is measured as the deformation in 0.25 mm units between no load and maximum load carried by the test specimen while doing the stability test.

  From the graph it can be observed that with increase in bitumen content there is increase in flow value. Mix with cubical aggregate have low flow values and that with blade and rounded shaped aggregate have higher value of flow this is because of the reason that blade aggregate have more air voids and tend to break while rounded have smooth surface texture and air void. The value should lie between 2 to 4 as per MORT&H specification.

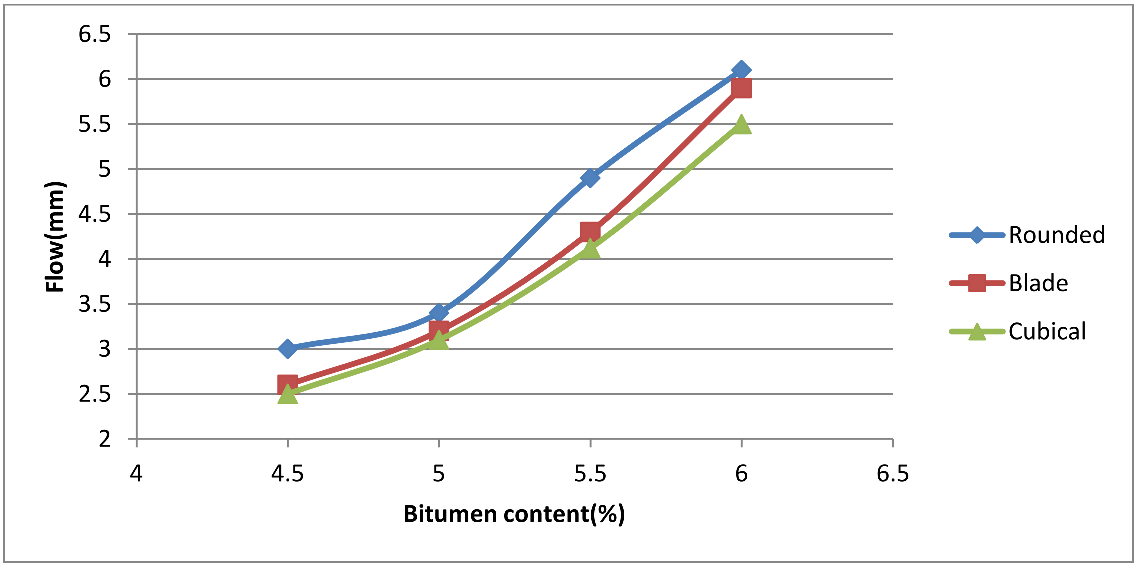


Fig 22: Bitumen content vs Flow for different shapes of aggregate

- **Air voids:** For densification of the bitumen mix under varying traffic condition or loads air voids are necessary and also for the prevention of bleeding of bitumen mix in hot climatic condition. Cubical shape got the min. value of air void while as blade and rounded got higher values. As rounded aggregate have less adhesion with bitumen due to smooth surface that is the reason the flow values are higher. From the graph it can been seen that the percentage of air void decreases with increase in bitumen content and cubical shaped aggregate have less void than other shapes. MORT&H specifies the values from 3 to 6.

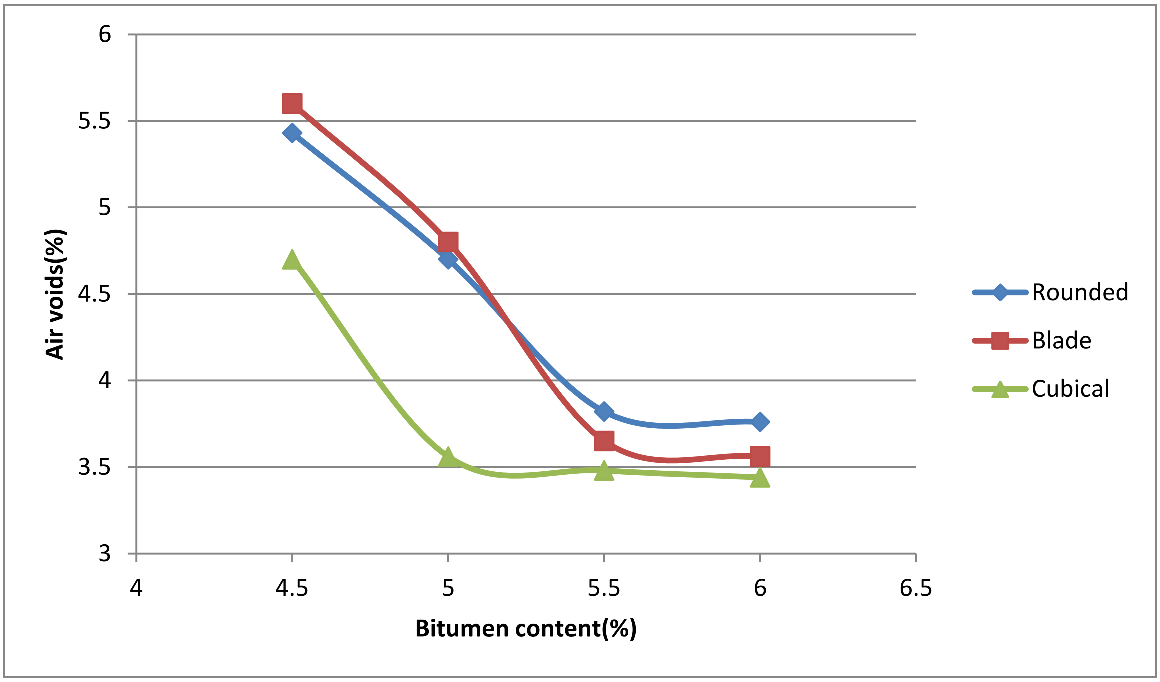


Fig 23: Bitumen content vs Air voids for different shapes of aggregate

- **Voids in mineral aggregates (VMA):** With increase in bitumen content it was found that there is increase in VMA. As per MORT&H specification the value for VMA should be from 12 to 15. Cubical aggregate have min value of VMA this is because they have less air voids and the interlocking is more between the aggregate. As blade aggregate are weak and tends to break during traffic operation so the VMA value is more in blade.

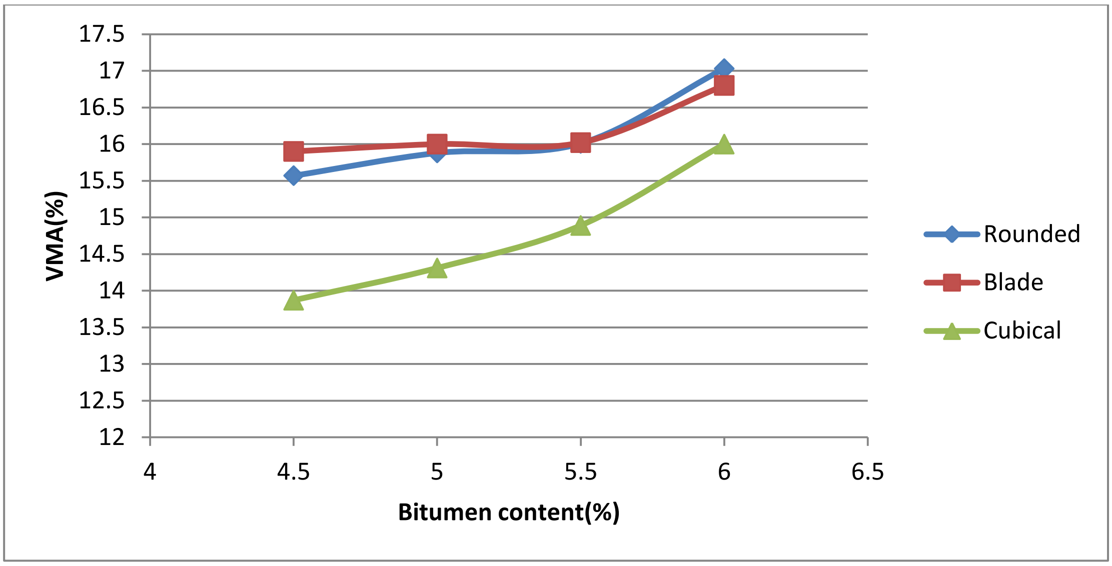


Fig 24: Bitumen content vs VMA for different shapes of aggregate

- **Voids filled with bitumen:** There are some amounts of voids present in aggregates and it is expected that these voids are filled by bitumen. As per MORT&H specification bitumen should fill up to 65 – 75 per cent of these voids. And from the graph it can be seen that with the increase in bitumen content VFB also increases.

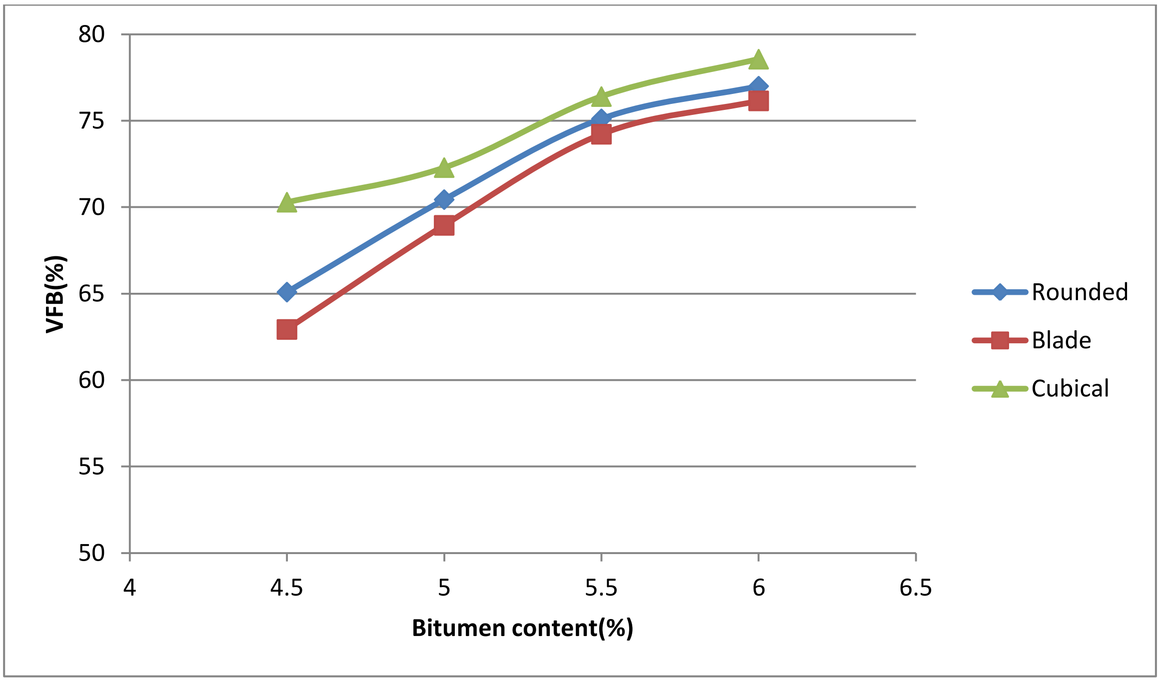


Fig 25: Bitumen content vs VFB for different shapes of aggregate

Chapter 6

CONCLUSIONS

This study was made to find out the influence of coarse aggregates shapes on the properties of bitumen mix. In this study three different shapes were analysed (Rounded, Blade, and cubical), and from the various test results and analysis following conclusions are drawn from this study:

- From the above experimental studies it was observed that mix prepared with cubical shaped aggregate got higher stability values of 1320 kg at 5% bitumen content. As cubical particles have higher interlocking and internal friction that is the reason behind higher stability.
- Optimum bitumen content is 5% as the stability is maximum and at 4% air voids.
- Mix prepared with rounded aggregates got lower stability value of 1085 kg at 5% bitumen content , this is because of the reason that rounded particles have very less interlocking property also the surface texture is smooth that affects the property of adhesion with bitumen and decreases the stability.
- Mix prepared with blade shaped aggregate also got lower stability value of 1180 kg at 5% bitumen content but higher than rounded aggregate. Blade particles have interlocking and are rough in texture but mixes with blade aggregate have more air voids present that is the reason the stability is low.
- As per MORT&Hs' specification the min value of stability should be 900 kg. From the above results we can conclude that all the shapes fulfil the requirement with cubical shape attaining maximum stability.
- The flows values were found more in mixes with blade and rounded shapes aggregate this can be because blade aggregate tends to break during compaction and rounded aggregate have smooth surface texture and low interlocking and the flow values increases with increase in bitumen content.

6.1 **Future Scope**:

- Replacement of natural aggregate with Different percentage of cubical, rounded, and blade shaped aggregate.
- Effect of different shapes of aggregate with SBR modified bitumen.
- As this study is limited in the areas of testing the effect of aggregate shape on rutting, fatigue and other properties of bitumen mix.
- Effect of shape of aggregate on durability of cement concrete.

Chapter 7

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