EFFECT OF FILLERS ON BITUMINOUS PAVING MIXES

A PROJECT SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Civil Engineering

By

SATYAJEET PRADHAN(10401006)
PRAGNA NANDO ROY(10401027)

DEPARTMENT OF CIVIL ENGINEERING
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UNDER THE PROFOUND GUIDANCE
OF
Prof. M.Panda & Prof. J.K.Pani

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NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA

CERTIFICATE

This is to certify that the Project Report entitled "**EFFECT OF FILLERS ON BITUMINOUS PAVING MIXES**" submitted by **Mr. Pragna Nando Roy** and **Mr. Satyajeet Pradhan** in partial fulfillment of the requirements for the award of Bachelor Of Technology Degree in **Civil Engineering** at National Institute Of Technology, Rourkela (Deemed University) is an authentic work carried out by them under our supervision and guidance.

To the best of our knowledge, the matter embodied in this Project Report has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Date: Prof. M.Panda

Prof.J.K.Pani
Dept. of Civil Engg.
National Institute of Technology
Rourkela-769008

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PRAGNA NANDO ROY
Roll No. 10401027

SATYAJEET PRADHAN
Roll No. 10401006

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ABSTRACT

Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment; as well as reliable performance of the in-service highway can be achieved. Two things are of major considerations in this regard – pavement design and the mix design. Our project emphasizes on the mix design considerations. A good design of bituminous mix is expected to result in a mix which is adequately strong, durable and resistive to fatigue and permanent deformation and at the same time environment friendly and economical. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions of material combinations and finalizes the best one. This often involves a balance between mutually conflicting parameters. Bitumen mix design is a delicate balancing act among the proportions of various aggregate sizes and bitumen content. For a given aggregate gradation, the optimum bitumen content is estimated by satisfying a number of mix design parameters.

Fillers play an important role in engineering properties of bituminous paving mixes. Conventionally stone dust, cement and lime are used as fillers. An attempt has been made in this investigation to assess the influence of non-conventional and cheap fillers such as brick dust and fly ash in bitumen paving mixes. It has been observed as a result of this project that bituminous mixes with these non-conventional fillers result in satisfactory Marshall Properties though requiring a bit higher bitumen content, thus substantiating the need for its use. The fillers used in this investigation are likely to partly solve the solid waste disposal of the environment.

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Chapter 1

INTRODUCTION

INTRODUCTION

1.1 General

Highway construction activities have taken a big leap in the developing countries since last decade. Construction of highway involves huge outlay of investment.

Basically, highway pavements can be categorized into two groups, flexible and rigid. Flexible pavements are those which are surfaced with bituminous (or asphalt) materials. These can be either in the form of pavement surface treatments (such as a bituminous surface treatment (BST) generally found on lower volume roads) or, HMA surface courses (generally used on higher volume roads such as the Interstate highway network). These types of pavements are called "flexible" since the total pavement structure "bends" or "deflects" due to traffic loads. A flexible pavement structure is generally composed of several layers of materials which can accommodate this "flexing". On the other hand, rigid pavements are composed of a PCC surface course. Such pavements are substantially "stiffer" than flexible pavements due to the high modulus of elasticity of the PCC material. Flexible pavements being economical are extensively used as far as possible. A precise engineering design of a flexible pavement may save considerable investment; as well as reliable performance of the in-service highway pavement can be achieved.

In recent years, many countries have experienced an increase in truck tire pressures, axle loads, and traffic volumes. Tire pressure and axle load increases mean that the bituminous layer near the pavement surface is exposed to higher stresses. High density of traffic in terms of commercial vehicles, overloading of trucks and significant variations in daily and seasonal temperature of pavements have been responsible for development of distress symptoms like raveling, undulations, rutting, cracking, bleeding, shoving and potholing of bituminous surfaces. Suitable material combinations and modified bituminous binders have been found to result longer life for wearing courses depending upon the percentage of filler and type of fillers used

1.2 Objectives of bituminous paving mix design

The overall objective of the design of bitumen pavement mixtures is to determine an economical blend of stone aggregate, sand and fillers such as fly ash and brick dust that yields a mix having

- Sufficient bitumen to ensure a durable pavement.
- Sufficient mix stability to satisfy the demands of traffic without distortion or displacement.
- Sufficient void in total compaction mix to allow for a slight amount of additional compaction and traffic loading without flushing bleeding and lost of stability yet low enough to keep out harmful air and moisture.
- Sufficient workability to permit sufficient placement of the mix without segregation.

1.3 Functions of different highway materials

- **Coarse aggregate :**

  The coarse aggregate should have good crashing strength, abrasion value, impact value. Its function is to bear stresses coming from wheels. It has a resist wear due to abrasive action of traffic.

- **Fine aggregate :**

  It shall be fraction passing 600 microns and retained on 75 microns sieve consisting of crushed stone or natural sand. Its function is to fill up the voids of the coarse aggregate.

- **Fillers:**

  The fillers should be inert materials which pass 75 micron sieve. Fillers may be limestone dust, cement, stone dust, brick dust, fly ash or pond ash and its function is to fill up the voids.

Bitumen:

It is used as a binding material as well as water proofing material.

1.3.1 Aggregate for bitumen mixes:

The mineral aggregates most widely used in bitumen mixes or crushed stone, slag, crushed or uncrushed gravel, sands and mineral fillers. Since mineral aggregates constitutes of approximately 88% to 96% by weight and approximately 80% by volume of the total mix. Their influence upon the final characteristics of bituminous mixes is very great.

1.3.2 Desirable aggregate characteristic:

The choice of an aggregate for use in bitumen construction depends upon the aggregates availability, their cost and the type of construction in which they are to be used. However gradation of construction type, on ideal aggregate for use in bitumen constructions should have the following characteristics:

- Gradation and size appropriate to type of constructions
- Strength and toughness
- Cubical shape
- Low porosity
- Proper surface texture
- Hydrophobic characteristic

a. Gradation and size:

One of the most important aspects of an aggregate affecting the stability and working properties of a mix is the gradation. Maximum aggregate size also has a great effect upon workability and density of bituminous mixtures. It is also observed that use of a maximum aggregate greater than 1 micron in graded mixture often results in harsh or non-workable bituminous mixtures that tend to segregate in the handing operation. This result in pavement surface that have an objectionable surface voids which may lead to raveling.

The dense graded mix used in this project includes appropriate amount of all sizes from coarse to fine including the dust of the materials. Dense graded mixes tend to have large number of points of contact between individual aggregate pieces resulting in high frictional resistances. The increase of contact points of compacted with poorly graded materials also results in a great area

of load transfer from one aggregate to another. This decreases the possibility of crushing of the individual aggregate piece by point loading.

The gradation aggregates used in this project are as per IRC grading 2 as given in the following table (MORTH: Specifications for Road and Bridge works 2003):

Table No: 2.1.1 IRC Grading 2 for bituminous concrete mixes

Grading	2
Nominal aggregate size	13mm
Layer thickness	30-45mm
I.S sieve	Cumulative percent by weight of total aggregate passing
19 13.2 9.5 4.75 2.36 1.18 0.6 0.3 0.15 0.075	100 79-100 70-88 53-71 42-58 34-48 26-38 18-28 12-20 4-10
Bitumen content by mass of total mix Bitumen Grade (penetration)	5.0-7.0 65

b. Strength & Toughness

The aggregate in bituminous mixtures supplies most of the mechanical stability. It supports the load imposed by the traffic and at the same time distributes this loads to a sub-base at a reduced intensity. The aggregate used in bituminous mixes tend to break or

degrade by the loads imposed upon them during construction and later by the action of traffic. Degradation may take place by compression failure from a concentrated load at points of contact between aggregate particles and by abrasion action by the individual pieces move with respect to others. The amount of the gradation is affected by both magnitude of the applied loads and the resistance of crushing and abrasion aggregates.

c. Particle shape

Irregular angular pieces when compacted tend to interlock and this possesses a mechanical resistance to displacement. This interlock is best obtained by cubicle particles. The stability of open type mixes where the coarse aggregates is in only contact at few points is almost entirely due to effects of mechanical interlock regardless of the grading of the aggregates for those mixes containing fine and coarse aggregates , the angularity of fine aggregate is more important to mixture stability than angularity of the coarse aggregate . Addition of the crushed fine aggregate is as low as 25% based on total fine aggregate.

1.4 Scope of project

In order to achieve the desirable engineering properties of bituminous paving mixes mainly in form of Marshall test results it has been planned to carry out the project in the following phased manner.

- **IRC** grading 2 with stone aggregates from 19 mm to 600 micron, granulated blast furnace slag from 600 micron to 75 micron and fly ash/ brick dust constitute the aggregate grading.
- **Bitumen** 80/100 has been used as an alternative to 60/70 as used in case of normal paving mixes.
- **Bitumen content** has been varied depending on the type of filler till changes in the trend of Marshall Properties are observed.
- **Mixing and Compaction** temperature of bitumen has been decided based on viscosity tests on 80/100 bitumen at various temperatures.
- **Marshall Properties** of the resulting mixes are compared with the minimum requirements suggested by IRC.

Chapter 2

LITERATURE SURVEY

2. REVIEW OF LITERATURE

2.1 Evolution of mix design concepts

During 1900's, the bituminous paving technique was first used on rural roads – so as to handle rapid removal of fine particles in the form of dust, from Water Bound Macadam, which was caused due to rapid growth of automobiles [Roberts et al. 2002]. At initial stage, heavy oils were used as dust palliative. An eye estimation process, called pat test, was used to estimate the requisite quantity of the heavy oil in the mix. By this process, the mixture was patted like a pancake shape, and pressed against a brown paper. Depending on the extent of stain it made on the paper, the appropriateness of the quantity was adjudged [Roberts et al. 2002]. The first formal mix design method was Hubbard field method, which was originally developed on sand-bitumen mixture. Mixes with large aggregates could not be handled in Hubbard field method. This was one of the limitations of this procedure. Fransis Hveem, a project engineer of California Department of Highways, developed the Hveem stabilometer (1927). Hveem did not have any prior experience on judging the just right mix from its colour, and therefore decided to measure various mix parameters to find out the optimum quantity of bitumen .Hveem used the surface area calculation concept (which already existed at that time for cement concrete mix design), to estimate the quantity of bitumen required [Hveem 1942]. Moisture susceptibility and sand equivalent tests were added to the Hveem test in 1946 and 1954 respectively [Roberts et al. 2002]. Bruce Marshall developed the Marshall testing machine just before the World War-II. It was adopted in the US Army Corpes of Engineers in 1930's and subsequently modified in 1940's and 50's.

2.2Role of mix volumetric parameters

Bitumen holds the aggregates in position, and the load is taken by the aggregate mass through the contact points. If all the voids are filled by bitumen, then the load is rather transmitted by hydrostatic pressure through bitumen, and strength of the mix therefore reduces. That is why

stability of the mix starts reducing when bitumen content is increased further beyond certain value.

During summer season, bitumen melts and occupies the void space between the aggregates and if void is unavailable, bleeding is caused. Thus, some amount of void is necessary to provide by design in a bituminous mix, even after the final stage of compaction. However excess void will make the mix weak from its elastic modulus and fatigue life considerations. The chances of oxidative hardening of bitumen are more, where, the mix has more voids.

Evaluation and selection of aggregate gradation to achieve minimum VMA is the most difficult and time-consuming step in the mix design process .VMA specification has always been a big issue in mix design specifications. The recommendation of minimum VMA is sometimes questioned by the researchers, and is said not to be equitable across different gradations. It is seen that the bitumen film thickness, rather than the VMA, may be related to durability of the mix.

2.3 Various mix design approaches

There is no unified approach towards bituminous mix design, rather there are a number of approaches, and each has some merits are demerits. Table-1 summarizes [RILEM 17 1998] some of the important bituminous mix design approaches:

Table No 2.2.1 Various mix design approaches [RILEM 17 -1998]

Mix design method	Description
Recipe method	Recipe based on experience of traditional mixes of known composition. This is experience based approach, which has shown good performance over long period of time, and under given site, traffic and weather conditions.
Empirical mix design method	In empirical mix design method, optimization of several variables are done by mechanical empirical test, taking into account some specifications as limits which evolved through prior experience. Variables considered in this approach may not be used as direct measures of performance.
Analytical method	The analytical method does not consider preparation of any physical specimen. Composition is determined exclusively through analytical computations.
Volumetric method	In volumetric method, proportional volume of air voids, binder and aggregates are analyzed in a mixture, which is compacted in the laboratory by some procedure close to field compaction process.
Performance related approach	In performance related mix design, the specimens that meet volumetric criteria are compacted and tested with simulation and/or fundamental tests to estimate their properties that are related to pavement performance.
Performance based approach	Performance based approach is something which is based on the performance of the complete system. Laboratory instrumentation tends to simplify the situation, yet it is indeed difficult to simulate field conditions. Superpave mix design recommends use of Supepave shear tester, indirect tensile tester for evaluation of laboratory of the bituminous mix. These tests are basically accelerated performance tests of bituminous mixes.

Various countries have adopted various mix design approaches, which have been evolved through individual experiences. Most of the time these do not follow a particular approach as enlisted in Table-1, rather use a combined approach. Some of these mix design approaches followed in various specifications may be summarized in Table-2 [RILEM 17 1998].

Table-2.2.2 Mix design approaches adopted in various specifications/ organizations [RILEM 17-1998]

Specification/ organization	Country	Category
NARC'96-I-III	Australia	Recipe/ Volumetric/ Performance related
ASTO/ PANK'95	Finland	Recipe/ Volumetric/ Performance related
AFNOR	France	Recipe/ Volumetric/ Performance related
DIN	Germany	Recipe/ Empirical
CROW	The Netherlands	Volumetric/ Performance related
BS 594 / 598	UK	Recipe/ Empirical
Asphalt Institute	USA	Empirical/ Volumetric
SHRP Superpave	USA	Volumetric/ Performance related / Performance based

2.4 Recent trends

As obvious from the above discussion, the recent emphasis on bituminous mix design is on performance related and performance based approaches. The requirement of a good mix design has changed from time to time. Table-3 gives some idea of how the mix design requirements have changed from past to present.

Table No 2.2.3 Requirements of bituminous mix design

Past	Present
Stability Durability Economy	Stiffness Permanent deformation Fatigue Temperature susceptibility Low temperature cracking Moisture susceptibility Freeze-thaw Permeability Economical Environment friendly Workability Economy

Some of the above requirements are sometimes mutually conflicting. For, example, the higher is the bitumen content; the better is the fatigue life, provided all the other parameters are kept unchanged. But with the increase of bitumen content, the resistance to rutting may decrease.

Increase in bitumen content not accompanied by adequate amount of air voids will result in the fall of stability of the mix, the chances of bleeding will increase. The only way to increase bitumen content keeping sufficient air voids (VA) is by maximizing VMA and suitably gradation can be designed. Heavy duty bituminous pavements are composed of bituminous binder course and wearing course, for example, Dense Bituminous Macadam (DBM) and BC [MORT&H 2003], as per Indian specification. Same grades of bitumen are generally used for construction of these layers. Generally same grades of bitumen are used for construction of these layers. Stiffer grade of bitumen has higher value of stiffness, and it causes lesser stains to the pavement layers and also it is expected to show lesser rutting. On the other hand, higher fatigue life as observed for bituminous mixes with softer grade of bitumen indicates greater longevity of the pavement against fracture. It can be shown computationally that if a pavement is constructed with softer grade of bitumen at the lower layer, and harder grade at the top layer, the pavement is expected to last longer, than a pavement constructed with same grades for both the layers – this technique is known as rich-bottom pavement construction in other countries.

2.5 Results of Marshall tests on mixes with conventional aggregates and fillers

A large number of experimental investigations have been carried out so far with normal aggregate grading containing stone chips, sand and cement/lime/stone dust as filler. A few of them have been listed below.

Table No: 2.2.4 Results with cement and lime as filler (ref *Das and Pandey)*

Filler	Design Value of optimum bitumen content in %	Stability value (kg)	Flow value from graph	% Vv
Cement	5.13	1090.26	4.7	3.0
Lime	5.38	1170.00	3.7	4.7

2.6 Bitumen

2.6.1 Bitumen as a binder

Bitumen materials have been known and used in building and road construction since ancient times. They were used as a mortar and waterproofing agent as early as 3800 B.C. Early bitumen was of natural origin, found in pools and bitumen lakes. Many of these pools and lakes exist today and prehistoric flora and fauna, in addition to supplying bitumen over many centuries. The bitumen lake on island of Trinidad and the Bermudez deposit in Venezuela are the largest and the best known producers of natural bitumen. Prior to the development of the processes for producing bitumen from crude petroleum these sources supplied the early paving industry of the United States.

In various states of the world bitumen is also found in porous rocks such as sandstone and lime stones. This bitumen-impregnated rock has been of limited commercial value because of the range of bitumen content. Crushed-rock bitumen are used, however, for floors and bridge and sidewalk surfacing in France as early as 1802 and in Philadelphia as early as 1838. Gilsonite is another form of natural bitumen and is related to rock bitumen. It is a form of bitumen occurring in rock crevices or veins are hard, brittle and relatively pure, and therefore, they are of commercial interest. The Unita River basin of Utah is the principal source of gilsonite in the United States.

The construction of road and street pavements with bitumen began in 1870, when a street in Newark, New Jersey, was paved with rock bitumen imported from France. In 1876 Pennsylvania Avenue in Washington, D.C was paved, partially with rock bitumen mixed with aggregates. The Trinidad bitumen pavement was successful and wide acceptance and use of this paving medium resulted, so that by 1903 some 42 million square yards of pavements have been placed throughout the United States.

Of the bitumen consume worldwide the distribution of bitumen in different construction industries is as follows:

Table No: 2.2.5 Utilization of bitumen in various construction industries

Highways, airport and other paving	70%
Roof material	20%
Miscellaneous such as waterproofing, pipe coating, and auto undercoating	10%

The distribution shows the importance of bitumen in paving work that is job-engineered construction material.

Bitumen is refined to meet specifications for paving purposes is called bitumen cement, abbreviated A.C. At normal temperature it exists as semisolid, with the degree of solidity measured by a penetration test. It is heated until liquefied before being blended with aggregates in paving mixtures.

Various tests have been developed for use in the control of the products in the bitumen family. The ones that have been found significant in predicting the suitability of bitumen for some given application, basically these tests are used to measure consistency, ability of mixing and placing, durability, the ability to remain effective in hostile environments
and rate of hardening , significant to construction operations and serviceability.

Penetration The consistency of bitumen cement is measured by the penetration test.
A weighted needle (100 g) is allowed to bear on the surface of a dish of bitumen of standard test temperature (770 F) for a given length of time (5 sec). The depth of penetration of needle into the bitumen is termed as the penetration of the bitumen and is measured in units of 0.1mm.The needle penetrates farther into soft bitumen than into the harder grades, and thus the lower the penetration, the harder the bitumen. This test is the basis upon which most bitumen cements are classified into standard penetration ranges.

Softening point The consistency of bitumen cement can also be measured by determining its softening point. A sample of bitumen loaded with a steel ball is confined on a brass ring suspended in a beaker of water. As the water is heated at a given rate, the bitumen softens and eventually drops, along with the ball, through the ring. At the moment the bitumen and the steel ball touch the bottom of the beaker, the temperature of the water is recorded; this temperature is designated as the softening point of the bitumen.

The softening point can be used in conjunction with the penetration test to furnish a general indication of the relative temperature susceptibility of two or more bitumen of the same

penetration. For example, of two bitumen having the same penetration value, the one with the higher softening point is less temperature susceptible than the one that softens less rapidly as its temperature is raised.

2.6.2 Bitumen mixtures-applications.

Applications

Bitumen materials find wide usage in the construction industry. The wide use of bitumen as a cementing agent in pavements is the most common of is applications.

Bitumen products are used to produce flexible pavements for highways and airports. The term "flexible" is used to distinguish these pavements from those made with Portland cement, which are classified as rigid pavements , that is having beam strength. This classification is important because it provides the key to the design approach which must be used for successful flexible pavement structures.

The flexible pavement classification may be further broken down into high and low types, the type usually depending on whether a solid or liquid bitumen product is used. The low types of pavements are made with cutback, or emulsion, liquid products and are very widely used throughout the country. Descriptive terminology has been developed in various sections of this country to the extent that one pavement type may have several names. However, the general process followed in construction is similar for most lo-type pavements and can be described as one in which the aggregate and the bitumen product are usually applied to the roadbed separately and there mixed or allowed to mix, forming the pavement.

The high type of bitumen pavements is made with bitumen cements of some selected penetration grade. They are used when high wheel loads and high volumes of traffic occur and are therefore, often designed for a particular installation.

2.6.3Theory of bituminous concrete mix design

High types of flexible pavement are constructed by combining bitumen cement, often in the penetration grade of 80 to 100, with aggregates that are usually divided into three

groups , based on size. The three groups are coarse aggregates, fine aggregates and mineral filler. Each of the constituent part mentioned has a particular function in the bitumen mixture, and mix proportioning or design is the process of ensuring that no function is neglected. Before these individual functions are examined, however, the criteria for pavement success and failure should be considered so that design objectives can be established

A successful flexible pavement must have several particular properties. First, it must be stable that is resistant to pavement displacement under load. Deformation of bitumen pavement can occur in three ways, two unsatisfactory and one desirable. Plastic deformation of pavements results in ruts and ridges which represents a type of pavement failure and which is to be avoided if possible. Compressive deformation of the pavement results in a dimensional change in the pavement, and with this change come a loss of resiliency and usually a degree of roughness. This deformation is less serious that the one just described, but it too leads to pavement failure .The desirable type of deformation is an elastic one, which actually is beneficial to flexible pavements and is necessary for their long life.

The pavement should be durable and offer protection to the subgrade. Bitumen cement is not impervious to the effects of weathering, and so the design must minimize weather susceptibility. A durable pavement does not crack or ravel will probably also protect the roadbed. It must be remembered that flexible pavements transmit loads to subgrade without significant bridging action, and so a dry firm base is absolutely essential.

Rapidly movement vehicles depend on the tire-pavement friction factor for control and safety. The texture of pavement surface must be such that an adequate skid resistance is developed or unsafe conditions result. The design procedure should be used to select the bitumen material and aggregate combination which provides a skid resistant roadway.

Design procedure which yield paving mixtures embodying all these properties are not available. Sound pavements are constructed where materials and methods are selected by using time-tested tests and specifications and engineering judgments along with a a so called design method.

The final requirement for any pavement is economy. Economy, again, cannot be measured directly, since true economy only begins with construction cost and is not fully determinable until the full useful life of pavement has been recorded. If, however, the requirements for a stable

, durable and safe pavement are met with a reasonable safety factor, then the best interests for economy have probably been served as well.

With these requirements in mind, the functions of the constituent parts can be examined with consideration to how each part contributes to the now-established objectives or requirements. The function of the aggregate is to carry the load imposed on the pavement which is accomplished by frictional resistance and interlocking between the individual pieces of aggregates. The carrying capacity of the bitumen pavement is then related to the surface texture (particularly that of fine aggregate) and the density, or "compactness," of the aggregate. Surface texture varies with different aggregates, and while a rough texture is desired, this may not be available in some localities. Dense mixtures are obtained by using aggregates that are artificially or naturally "well graded.' This means that fine aggregates serve to fill in voids in the coarser aggregate. In addition to affecting density and therefore strength characteristics, the grading also influences workability. When an excess of coarse aggregate is used, the mix becomes harsh and hard to work. When an excess of mineral filler is used, the mixes become gummy and difficult to manage.

The bitumen cement in the flexible pavement is used to bind the aggregate particles together and to waterproof the pavement. Obtaining the proper bitumen content is extremely important and bears a significant influence on all the items marking a successful pavement. A chief objective of any design method is to arrive at the best bitumen content for a particular combination of aggregates.

2.6.4 Aggregates for bituminous concrete.

The bitumen cementing agent has given name to a second principal type of concrete, bitumen concrete, and very often the family of bitumen products get first consideration is
a study of this material. As was the case with Portland cement concrete, however, aggregates comprise a very large percentage of the total bitumen concrete as used and are highly significant to the performance of the mixture. Aggregates normally constitute 90 percent or more by weight, and as was pointed out in the previous chapter, they influence the element of strength in a very direct way. Other elements of quality bitumen concrete such as durability and workability are also influenced by the aggregates used, though in a less direct fashion.

The general requirements for aggregates for bitumen mixtures are that the must be clean, hard, tough, strong and durable, and most important thy must be properly graded. The first general requirements can be met by using materials passed through certain standard test among which are the following.

Soundness Test - The soundness test is an indication of durability under weathering. Cycles of immersion and drying in a saturated solution of sodium or magnesium sulfate are commonly specified, but rapid freeze-thaw cycles can be used in some cases.

Specific-gravity determination- Specific gravity is used to calculate voids in the compacted bituminous mix and to adjust quantities in mixture.

Wear test- These tests are used to measure the abrasion resistance of mineral aggregate. The Los Angeles abrasion machine is most widely used to determine abrasion resistance but the Deval machine can also be used.

Gradation

The element of strength is very dependent on aggregate gradation and so this matter deserves special attention.

Bitumen concretes are most often produced by using a dense-graded aggregate with close tolerance which, by experience, yields dense, tight mats with maximum strength. A dense-graded aggregate is one formed by blending several size fractions selected so that fines fill the voids around coarser particles through a particular size range.

Surface characteristics

The surface characteristics of bitumen concrete aggregates also deserve some special comment. This is true because of the importance of aggregate frictional resistance in developing pavement stability and also because of the nature of the aggregate-bitumen bond.

Particles with rough surface texture and angular surfaces tend to make more stable bitumen concretes. As the bitumen cement content is increased, the importance of the aggregate surface as a stability factor decreases. Cohesive strength and inertial resistance may partially compensate in these cases, especially in resisting dynamic loads.

Bitumen cements must bond well with the mineral aggregates if the resulting concrete is to be strong and durable. If the bitumen does not bond well, it may ‘strip’ from the aggregate and failure will occur. Quartzite and other siliceous aggregate often do not have a strong affinity for bitumen and are classed as hydrophilic, having greater affinity for water than bitumen. Calcareous aggregates such as limestone and dolomites usually develop a strong bond with bitumen cement are termed hydrophobic.

2.7 Aggregate blending procedures

Aggregate blending the process of mechanically combining two or more separate aggregates, is necessary because it is difficult, if not impossible to find a single natural or artificial source that can provide the dense gradings required for modern bituminous concretes . While improved grading is a major reason for blending, it is not the only

One, since aggregates may be blended because of limited supplies or because of economic considerations. The best blend is that one which has the lowest cost of these meeting the gradation specification.

1. Trial and error blending

2. Mathematical methods

3. Graphical methods

Chapter 3

EXPERIMENTAL INVESTIGATIONS

3.1 TESTS OF MATERIALS USED IN PAVING MIXES

3.1.1 BITUMEN

- **Penetration** is the consistency test used to designate grades of bitumen. It is the distance in tenths of millimeter that a standard needle will penetrate the sample under specified conditions of time, temperature and load on the needle. The test was performed by taking bitumen in a container and softened then the temperature was maintained at 25^0C the dial was set so that the needle was just in contact with the surface of the bitumen. The initial reading was taken. Then the needle was released for 5 seconds and the final reading was taken the difference between the two readings gave the penetration value.

The conducted test was as follows:

Table No 2.3.1 Results of penetration test of Bitumen 80/100

Sample	Reading-1	Reading -2	Reading-3	Average	Final Averaged
1	104	84	81	89.67	
2	89	84	70	81.60	85.33

- **Softening point test** may be classed as a consistency test in that it measures the temperature at which the bituminous materials reach a given consistency as determined by the test conditions while it is applicable to semi-solid materials and is useful in characterizing bitumen.

The test was performed by forming a sample in a brass ring, cooling it in a melting ice bath and then placing the sample within the ring in a 5^0C water bath. After placing a steel ball on a sample surface, the water bath temperature was raised at the rate of 5^0C per minute. The temperature at which the sample sagged under the weight of the steel ball and touches the bottom of the container surface 2.5 cm below the sample was the softening point temperature.

Table No 2.3.2 Results of Softening Point test

Specimen no(80/100)	Softening point(^{0}C)	Average
1	48	
2	46	47

- **Specific gravity** of bitumen is defined as the ratio of mass of a given volume of substance to the mass of an equal volume of water temperature of both being 27^0C. The bitumen was taken in a pycnometer having weight 25gm the water raised in pycnometer was observed 24.27 gm from which the specific gravity of bitumen was found. Grade 80/100 = 1.03.

- **Viscosity test** was conducted in BROOKFIELD VISCOMETER. The test is conducted mainly for determination of mixing and compaction temperature for bitumen with fly-ash and brick-dust as fillers. The following readings we got in the laboratory.

BITUMEN 80/100

Table No 2.3.3 Viscosity test results for bitumen 80/100

Temperature ^{0}c	**Speed(rpm)**	**Torque (%)**	**Viscosity(cp)**
120	2	10.3	2575
	2.5	7.5	1575
	3	9.7	1617
	4	9.5	1188
	5	12.1	1210
	6	13	1083
130	2	5.8	1450
	2.5	4.2	840
	3	5.3	883.3
	4	5.2	650
	5	5.8	580
	6	7	583.3
	10	11.5	575
	12	13.6	566.7
140	2	3.7	925
	2.5	3.5	700
	3	2.6	433.3
	4	3.9	487.5
	5	3.7	370
	6	4.4	366.7
	10	7	350
	12	8.5	358.3

	20	13.7	342.5
150	2	2.6	650
	2.5	1.9	380
	3	2.0	333.3
	4	3.1	387.5
	5	8.3	330
	6	3.1	258.3
	10	5.3	265
	12	5.2	216.7
	20	9.1	227.5
	30	12.8	215
160	2	2	500
	2.5	2.1	420
	3	2.5	416.7
	4	2.5	312.5
	5	2.4	240
	6	2.7	225
	10	3.7	185
	12	4.4	183.3
	20	5.9	147.5
	30	8.7	145
	50	14.6	146
	60	17.2	143.3
170	2	1.6	400
	2.5	2	400
	3	2.1	350
	4	2	250
	5	2.2	220
	6	2.3	191.7
	10	2.9	145
	12	3	135
	20	4.4	110
	30	6.1	101.7
	40	8.1	101.3
	50	9.8	98
	60	11.7	97.5
180	2	2.2	225
	2.5	2.7	440
	3	3.9	416.7
	4	1.7	212.5
	5	2.2	220

	6	2.1	175
	10	2.5	125
	12	2.9	120.8
	20	4.4	110
	30	4.4	76.7
	50	7.5	74
	60	8.5	70.8
	100	14.1	70.5

3.1.2 AGGREGATES

- **Elongation index** of an aggregate is percentage by weight of particles whose greatest dimension of length is greater than one and four fifth or 1.8 times than mean dimension. The elongation test is not applicable for sizes smaller than 6.3mm.Taking 200 sample of each sieve range as specified below, the result of our computed elongation index are as follows. If 'm' g of aggregates retained out of total amount of 'M' then elongation=(m/M)x100

Table No: 2.3.4 Elongation test results

Sieve size(mm)	Passing(gm)	Retained(gm)
6.3-9.5	165.2	169.2
9.5-13.2	670.4	13.2
13.2-19	382.8	540
>19	1194	456.4
Total	Passing = 2412.40g	Retained = 1308.8g

Elongation = T. retained x 100/T.weight=1308.8 x 100/3721.2 = 35.17%

- **Flakiness index** of aggregates is the percentage by weight of aggregates whose least dimension is less than three fourth or 0.6 times than mean dimensions. The test is applicable to size greater than 6.3mm.The results are as follows:

If 'm' g of aggregates passed out of M g of total aggregates then

Flakiness index = (m-M) x 100

Table No: 2.3.5 Flakiness test results

Sieve size(mm)	Passing(gm)	Retained(gm)
6.3-9.5	30	284.4
9.5-13.2	184.4	635.6
13.2-19	177.2	725.2
Total	Passing = 909.6	Retained = 2697.6g

Flakiness index = 909.6 x 100/ 3607.2 = 25.21%

- **Specific gravity** of an aggregate is to measure the quality or strength of the material. Stone having low specific gravity values are generally weaker than those having higher values

The sample was weighed in water and the buoyant weight was found 1.259kg

Specific Gravity = 2.64

Table No:2.3.6 Aggregate test results

Parameters	Value
Specific gravity	2.64
Impact Strength (%)	20.2
Abrasion Strength (%)	19.5
Water Absorption (%)	3.06
Crushing strength (%)	19.12

The specific gravities of GBFS, fly ash and brick dust were found to be 2.3, 2.63, and 2.72

3.2 BITUMEN CONCRETE MIX DESIGN

Marshall method of mix design has been adopted in this project. Accordingly aggregates with the grading 2 of IRC and bitumen 80/100 having properties as described in the preceding paragraphs have been used.

The objective of bituminous paving mix design is to develop an economical blend of aggregates and bitumen. In the developing of this blend the designer needs to consider both the first cost and the life cycle cost of the project. Considering only the first cost may result in a higher life cycle cost.

Historically bitumen mix design has been accomplished using either the Marshall or the Hveem design method. The most common method was the Marshall. It had been used in about 75% of the DOTs throughout the US and by the FAA for the design of airfields. In 1995 the Superpave mix design procedure was introduced into use. It builds on the knowledge from Marshall and Hveem procedures. The primary differences between the three procedures are the machine used to compact the specimens and strength tests used to evaluate the mixes. The current plan is to implement the Superpave procedures throughout the US for the design and quality control of HMA highway projects early in the next century. It appears that the Marshall method will continue to be used for airfield design for many years and that the Hveem procedure will continue to be used in California.

The HMA mixture that is placed on the roadway must meet certain requirements.

- The mix must have sufficient bitumen to ensure a durable, compacted pavement by thoroughly coating, bonding and waterproofing the aggregate.
- Enough stability to satisfy the demands of traffic without displacement or distortion (rutting).
- Sufficient voids to allow a slight amount of added compaction under traffic loading without bleeding and loss of stability. However, the volume of voids should be low enough to keep out harmful air and moisture. To accomplish this mixes are usually designed by 4% VTM in the lab and compacted to less than 7% VTM in the field.
- Enough workability to permit placement and proper compaction without segregation.

Fig 3.3.1 shows a setup of the Marshall test apparatus where it is designed to apply loads to test specimens through semicircular testing heads at a constant rate of 50mm per minute. It is equipped with a calibrated proving ring for determining the applied testing load, a Marshall stability testing head for use in testing specimen, and a Marshall flow meter for determining the amount of strain at maximum load for test.

Fig No: 3.3.1 Marshall Apparatus Setup

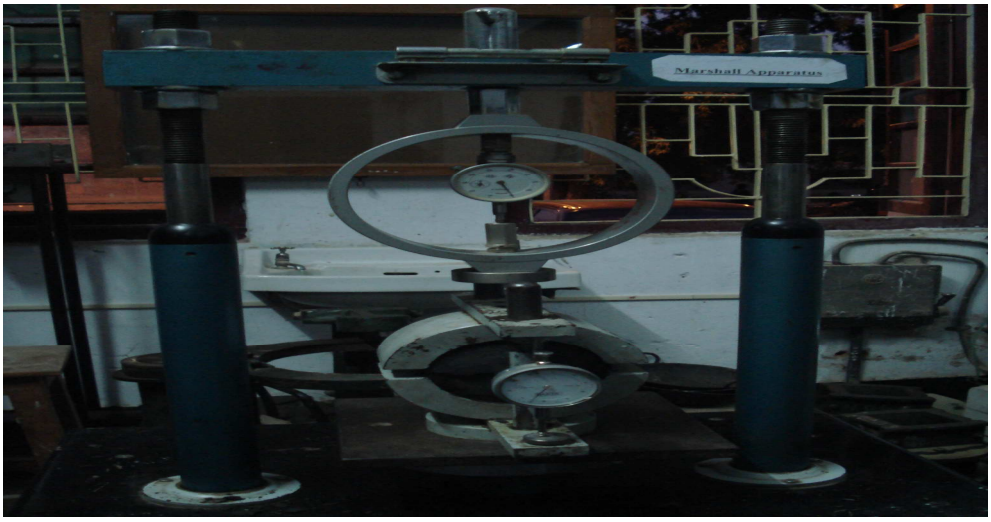


Fig No: 3.3.2 shows a water bath where Marshall Specimens are kept immersed for about 30 minutes at 60 degree centigrade just before the conduct of the test.

The tank has a perforated false bottom or equipped with a shelf for suspending specimens at least 5cms above the bottom of both.

Before the sample was tested for stability and flow tests, then inner surface of testing head was cleaned thoroughly. Guide rods were lubricated with a thin film of oil so that the upper head would slide down without bending. A proving ring was used to measure applied load. It was checked that dial indicator was firmly fixed and zeroed for “no load” position.

With testing apparatus in readiness, the test specimen was removed from water bath .The test specimen was placed in a lower testing head centre; then upper testing head was fitted in position and the centered completely assembly in loading device. Flow meter was placed over marked guide rod.

Testing load was applied to specimen at a constant rate of deformation 51mm/min,until the failure occurred the point of failure is defined by maximum load required to reduce failure of the specimen at 60 C should be recorded as of Marshall “stability” value.
While stability test was in progress the flow meter was held firmly in position to decrease; reading was taken and recorded. This reading was the flow value for specimen.

Fig No 3.3.3: Specimens containing brick dust as filler

The flow value was measured from flow meter. The reading of the flow value corresponding to the optimum load for the given specimen was taken. Taking reading from the flow meter was difficult as the speed of the flow meter was very fast. So the reading taken corresponding o the optimum load was difficult.

Stability was calculated by multiplying (100/36) to the observed division to convert it into kilogram force. Flow was determined by multiplying the flow value with 0.01 to convert it into millimeters.

For preparation of a Marshall Specimen in total 1200gm of ingredients was taken. The proportions of ingredients by weight for varying percentage of bitumen were taken as per Tables from 2.3.7 to 2.3.9 as given below.

Table No. 2.3.7 Calculation of quantity of aggregates (having fly ash as filler)

Sieves (mm)	Material	5% Bitumen	5.5% Bitumen	6% Bitumen	6.5% Bitumen
19		125	125	124	124
13.2		114	113	113	113
9.5	Stone chips (19-2.36)	194	193	192	191
4.75		137	136	135	134
2.36		102.5	102	101.5	101
1.18	Slag (2.36-0.3)	102.5	102	101.5	101
0.6		102.5	102	101.5	101
0.3		80	79.5	79	78.5
0.15	Fly ash (0.3-passing 0.075)	102.5	102	101.5	101
0.075		80	79.5	79	78.5
Passing 0.075					
Total Aggregate		1140	1134	1128	1122
Bitumen		60	66	72	78

Table No: 2.3.8 Calculation of Quantity of Aggregates (Having Brick Dust As Filler)

Sieves (mm)	Material	5% Bitumen	5.5% Bitumen	6% Bitumen	6.5% Bitumen	7%	8%
19		125	125	124	124	123	121
13.2		114	113	113	113	112	110
9.5	Stone chips (19-2.36)	194	193	192	191	190	188
4.75		137	136	135	134	134	132
2.36		102.5	102	101.5	101	100	100
1.18	Slag (2.36-0.3)	102.5	102	101.5	101	100	100
0.6		102.5	102	101.5	101	100	100
0.3		80	79.5	79	78.5	78	76.5
0.15	BRICK DUST (0.3-passing 0.075)	102.5	102	101.5	101	101	100
0.075		80	79.5	79	78.5	78	76.5
Passing 0.075							
Total Aggregate		1140	1134	1128	1122	1112	1104
Bitumen		60	66	72	78	88	96

Table No: 2.3.9 Calculation of quantity of bitumen

Bitumen (%)	Quantity of bitumen required
4.5	1200-1146=54
5.0	1200-2240=60
5.5	1200-1134=66
6.0	1200-1128=72

CHAPTER 4

TEST RESULTS AND DISCUSSION

4.1 BRIEF PROCEDURE OF MARSHALL TEST

- 1200gm aggregate are weighted and heated up to 154-160 degree C.
- Bitumen is heated 175 -190 degree C.
- Aggregates & Bitumen are mixed thoroughly until a uniform grey colour is obtained.
- Marshall mould dia 100mm & 64mm ht compacted with 75 blows on each face.
- Mould is taken out kept under normal laboratory temp for 12 hours.
- It is immersed in water bath kept at a const temp 60 degrees for 30 minutes

- Load is applied vertically at the rate of 50mm per minute.
- The maximum load at sample fails is recorded as the Marshall Stability value.
- Corresponding vertical strain is termed as the flow value.

4.2 CALCULATION OF AIR VOIDS AND VMA

After completion of stability and flow test a density and void analysis was made for each series of test specimen.

1. Bulk specific gravity values corresponding to given bitumen content was determined. The erroneous results were not entered.
2. The unit weight for bitumen content was determined by multiplying the bulk specific gravity value by 1gm/cm^3.
3. The percentage of air voids was calculated for

$V_v = ((G_t - G_m) / G_m) * 100$

G_m = Bulk Density

G_t = Theoretical specific gravity of mixture

$G_t = 1000/ (W_1/G_1+W_2/G_2+W_3/G_3+W_4/G_4)$

Where

W_1 = Percentage by weight of coarse aggregates in total mix

W_2 = Percentage by weight of fine aggregates in total mix

W_3 = Percentage by weight of filler in total mix

W_4 = Percentage by weight of bitumen in total mix

G_1 = Apparent specific gravity of coarse aggregate

G_2= Apparent specific gravity of fine aggregate

G_3= Apparent specific gravity of filler

G_4= Apparent specific gravity of bitumen

The percent voids in mineral aggregate (VMA) corresponding to given % of bitumen and various fillers was determined using formula given below.

$VMA = V_v + V_b$

V_v = Volume of air voids;

V_b = Volume of bitumen = $G_m*(W_4/G_4)$

G_m = Bulk Density

W_4 = Percent by weight of bitumen in total mix

4.3 MARSHALL TEST RESULTS:

The results of the Marshall test of individual specimens and average Marshall properties of specimens prepared with fly ash as filler for varying bitumen contents have been presented in tables 2.4.1 and 2.4.2 respectively.

Table No 2.4.1 Results of Marshall test (specimens with fly ash)

Bitumen (80/100) (%)	Sample no:	Wt in air	Wt in water	Flow value (mm)	Stability Value(kg)	G_t	Unit wt(g/cc)	% air voids	VMA
5	1	1176	608.2	1.7	2080	2.25	2.07	8.69	18.74
	2	1182	618.1	1.9	2000		2.1	7.14	17.33
	3	1066	548.2	1.9	2220		2.06	9.2	19.2
	4	1172	611.5	2.2	1305		2.09	7.65	17.79
5.5	1	1182	623.3	2.4	2140	2.23	2.10	6.2	17.41
	2	1170	614.5	2.1	1910		2.09	6.69	17.85
	3	1174	616.5	2.7	2570		2.09	6.69	17.85
	4	1142	599.1	2.4	2380		2.08	7.21	18.31
6	1	1198	628.6	2.7	2000	2.19	2.10	4.28	16.51
	2	1164	612.5	3.1	2800		2.11	3.79	16.08
	3	1174	616.1	2.5	2500		2.10	4.28	16.51
	4	1182	619.5	2.9	2550		2.10	4.28	16.51
6.5	1	1098	570.4	3.3	2190	2.17	2.08	4.32	17.44
	2	1084	570.1	3.4	1970		2.10	3.33	16.58
	3	1082	564.1	3.8	2400		2.05	5.85	18.78

Table No 2.4.2 Average Marshall Properties of samples with fly ash

Bitumen % / Marshall Properties	5	5.5	6	6.5
Stability (kN)	18.64	22.07	23.53	21.39
Flow value (mm)	1.95	2.4	2.8	3.50
Unit wt (g/cc)	2.08	2.09	2.10	2.07
% air void	8.17	6.69	4.18	4.5
VMA (%)	18.27	17.88	16.41	17.6

The results of the Marshall test of individual specimens and average Marshall properties of specimens prepared with fly ash as filler for varying bitumen contents have been presented in Tables 2.4.3 and 2.4.4.

Table No 2.4.3 Test results of Marshall Specimens (with brick dust as filler)

Bitumen (80/100) %	Sample (no)	Wt in air	Wt in water	Flow value (mm)	Stability Value (kg)	G_t	Unit Wt(g/cc)	% air voids	VMA
4.5	1	1194	661	1.8	1660	2.45	2.24	9.4	19.2
	2	1150	645	1.4	2016		2.27	7.9	17.78
	3	1180	651	1.6	1527		2.23	9.8	19.5
	4	1215	672	2.6	1558		2.24	9.4	19.15
5	1	1201	652	2.2	1581	2.44	2.24	8.9	19.6
	2	1201	659	2.6	1821		2.28	7.0	18.03
	3	1203	648	2.2	1788		2.29	6.6	17.72
	4	1200	653	2.5	1619		2.26	7.9	18.87

6	1	1204	656	3.6	1958	2.41	2.27	6.2	19.4
	2	1203	654	2.8	1833		2.26	6.6	19.76
	3	1189	653	3.2	1805		2.28	5.7	18.98
6.5	1	1204	679	3.1	1938	2.40	2.29	4.8	19.2
	2	1190	666	4.0	1896		2.27	5.7	19.98
	3	1183	665	3.9	2144		2.28	5.2	19.54
	4	1196	676	3.9	1889		2.3	4.3	18.77
7	1	1217	688	3.9	2267	2.39	2.3	3.9	19.48
	2	1201	679	4.8	2035		2.3	3.9	19.48
	3	1179	659	4.3	2189		2.27	5.3	20.68
	4	1191	681	5.3	2033		2.33	2.5	18.33
8	1	1203	707	5.4	1972	2.38	2.33	2.14	20.18
	2	1191	679	5.2	1888		2.33	2.14	20.18
	3	1216	715	5.3	1805		2.33	2.14	20.18
	4	1188	695	5.1	1895		2.31	3.03	20.9

Table No 2.4.4 Average Marshall Properties of samples with Brick dust as filler

Bitumen %	4.5	5	6	6.5	7	8
Marshall Properties						
Stability (KN)	15.69	16.67	18.35	19.42	20.6	17.66
Flow value (mm)	1.8	2.4	3.2	3.73	4.57	5.3
Unit wt (g/cc)	2.245	2.27	2.27	2.29	2.3	2.33
% air voids	9.13	7.6	6.2	5	3.9	2.4
VMA(%)	19.1	18.35	19.35	19.8	19.5	20.4

4.4 Discussion of test results

4.4.1 Fly ash and Brick dust specimen Marshall Curves

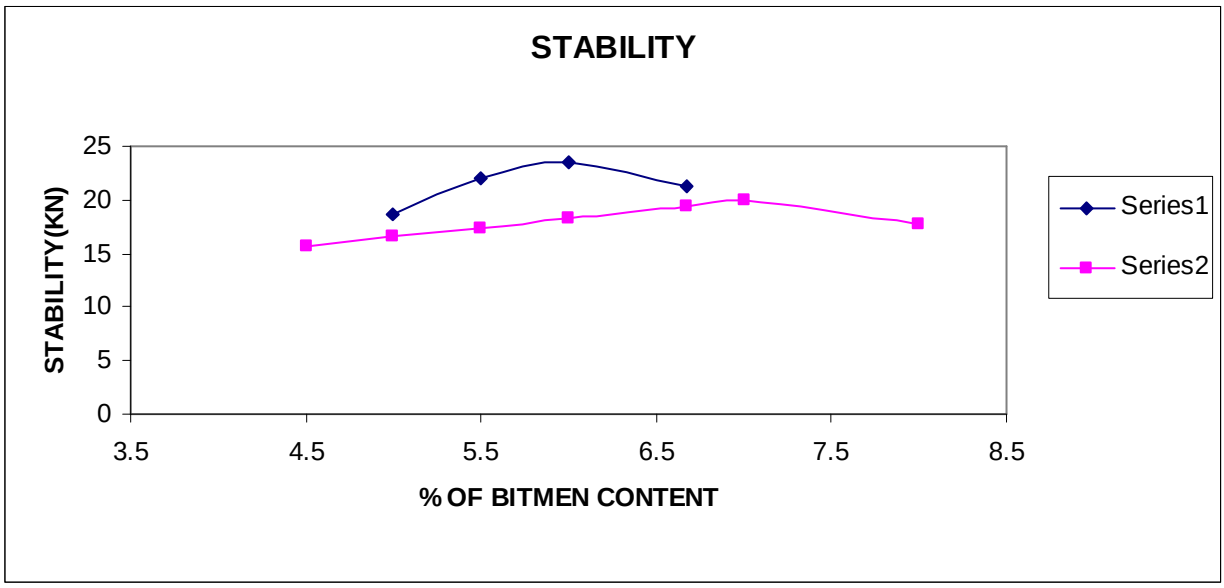
The results of Marshall Tests of specimens prepared with fly ash given Tables 2.4.1 and 2.4.2 and specimens prepared with brick dust as filler given in Table 2.4.3 and 2.4.4 have been presented graphically for comparison in Figures 3.4.1 to 3.4. 5.

4.4.1.1 Marshall Stability

Fig.3.4.1 shows the variation of Marshall Stability with bitumen content where it is seen that as usual the stability value increases with bitumen content initially and then decreases. Maximum stability value of 23.2 kN is observed at 6% bitumen content in case of fly ash as a filler but in case of brick dust a maximum stability value of 20.58 kN is obtained at 7% bitumen content in case of brick dust as a filler. A lower value of stability in case of brick dust specimen in comparison with fly ash may be attributed due to higher bitumen content.

Fig: 3.4.1 Marshall Test Curves for Stability (fly ash and brick dust)

(Series 1 – fly ash: Series 2 – brick dust)

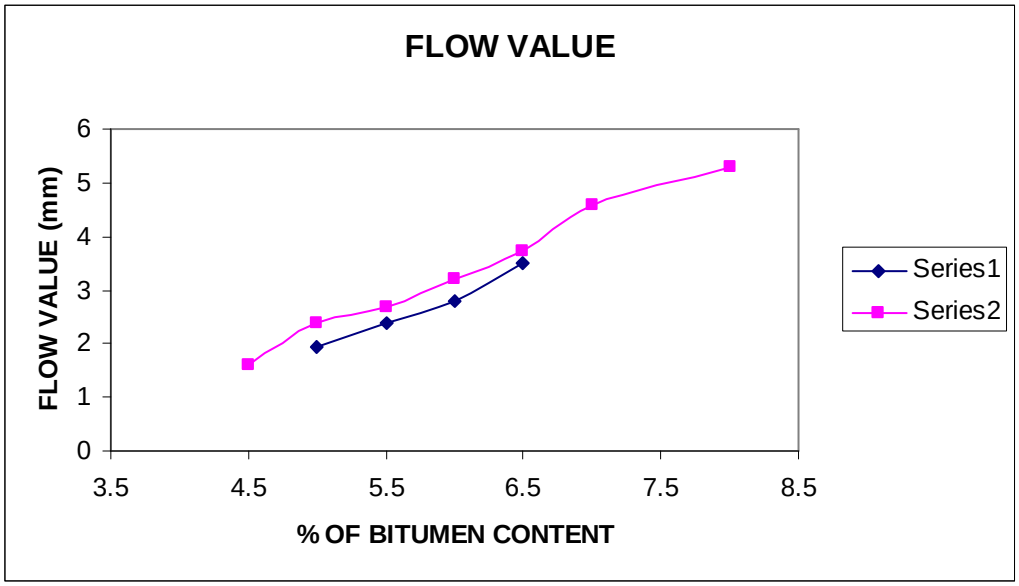


4.4.1.2 Marshall Flow value (mm)

Fig 3.4.2 shows the variation of Marshall flow value with % of bitumen content where it is seen that usually an increasing trend is followed with increase in bitumen content and on comparing fly as and brick dust results graphically it can be seen that brick dust specimens are found to display a higher flow value in comparison with fly ash specimen , from here we can speculate

that this might be due to a higher bonding in specimens with fly ash as filler in comparison with specimens having brick dust as filler material.

Fig 3.4.2 Marshall test curves for Flow value (fly ash and brick dust)
(Series 1 – fly ash: Series 2 – brick dust)

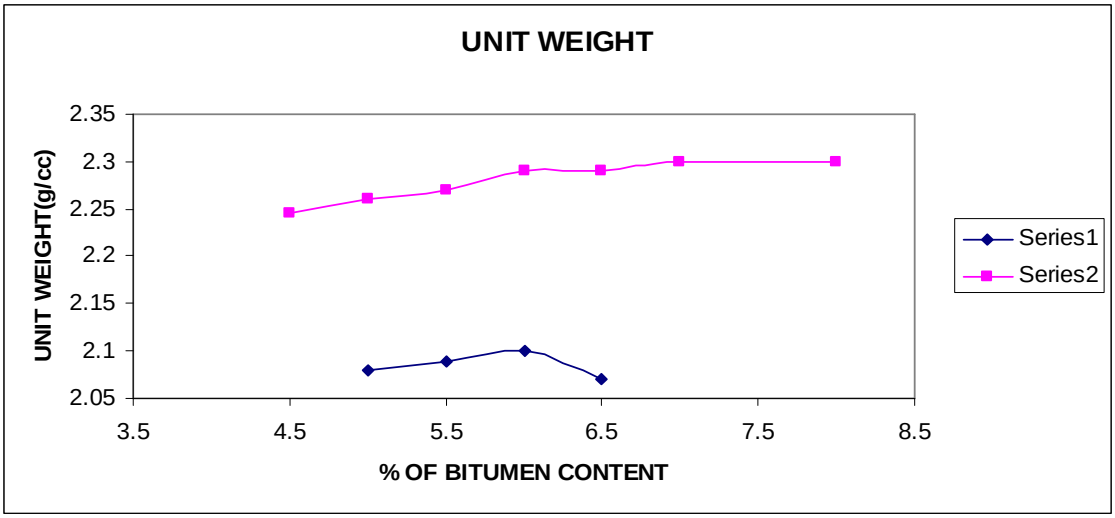


4.4.1.3 Marshall Unit weight curves (g/cc)

Fig 3.4.3 displays the graphical representation of unit weights for variation in % of bitumen content for Marshall Specimens having fly ash and brick dust as fillers. In this figure brick dust specimens are found to display a higher unit weight in comparison with fly ash as filler due to lesser no of air voids in case of specimens having brick dust as filler, this may be due to brick dust acting as a filler material having better ability to fill up air voids than fly ash. In fly ash specimens maximum unit weight obtained is 2.10 g/cc at 6% bitumen content whereas in case of brick dust specimens it is 2.33 g/cc at 8% bitumen content showing an increasing trend in brick dust specimens which might tend to reduce at higher percentage of bitumen content.

Fig 3.4.3 Marshall test curves for Unit Weight (g/cc) (fly ash and brick dust)

(Series 1 – fly ash: Series 2 – brick dust)

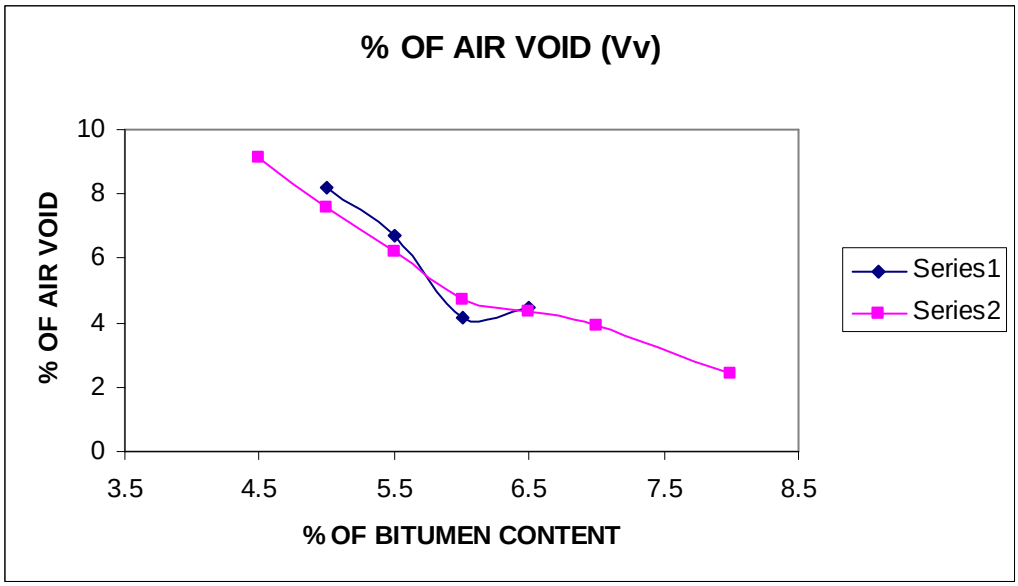


4.4.1.4 Marshall air voids (%) curve (fly ash and brick dust)

Fig 3.4.4 shows the variation of air voids with variation in percentage of bitumen content with the minimum percentage of 4.13 % air voids being obtained at 6% bitumen content, however the curve obtained in brick dust specimen is found to have a decreasing trend displaying a greater bonding between brick dust and bitumen thus showing a decreasing trend in case of air voids with increase in bitumen content.

Fig 3.4.4 Marshall test curves for Air void (%)(fly ash and brick dust)

(Series 1 – fly ash: Series 2 – brick dust)

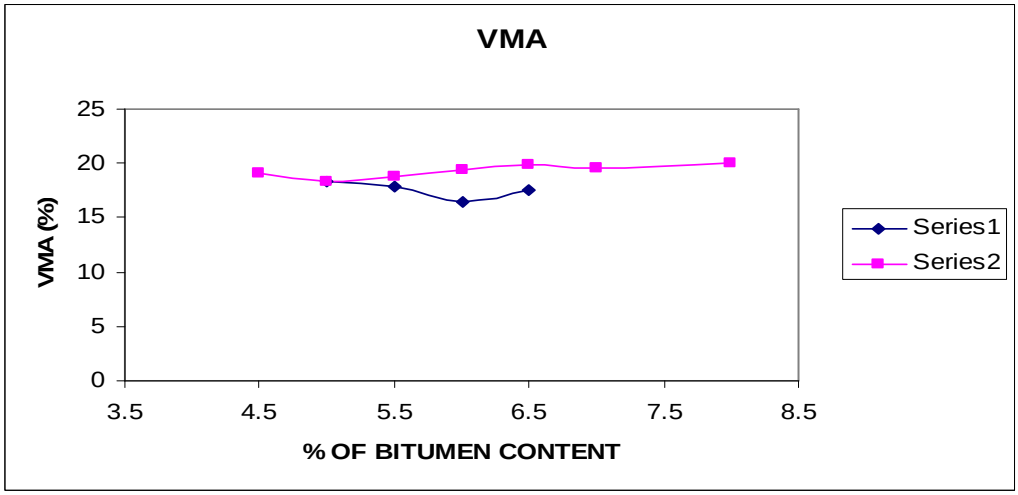


4.4.1.5 Marshall's VMA (%) curve (fly ash and brick dust)

In fig 3.4.5 Brick dust specimens are found to be displaying higher values of VMA than fly ash specimens but in fig 3.4.4 they are found to display lesser amount of air voids thus leading to the conclusion that brick dust absorbs higher amount of bitumen in comparison with fly ash specimens.

Fig 3.4.5Marshall test curves for VMA (%)(fly ash and brick dust)

(Series 1 – fly ash: Series 2 – brick dust)



4.4.2Comparison with Conventional Mixes

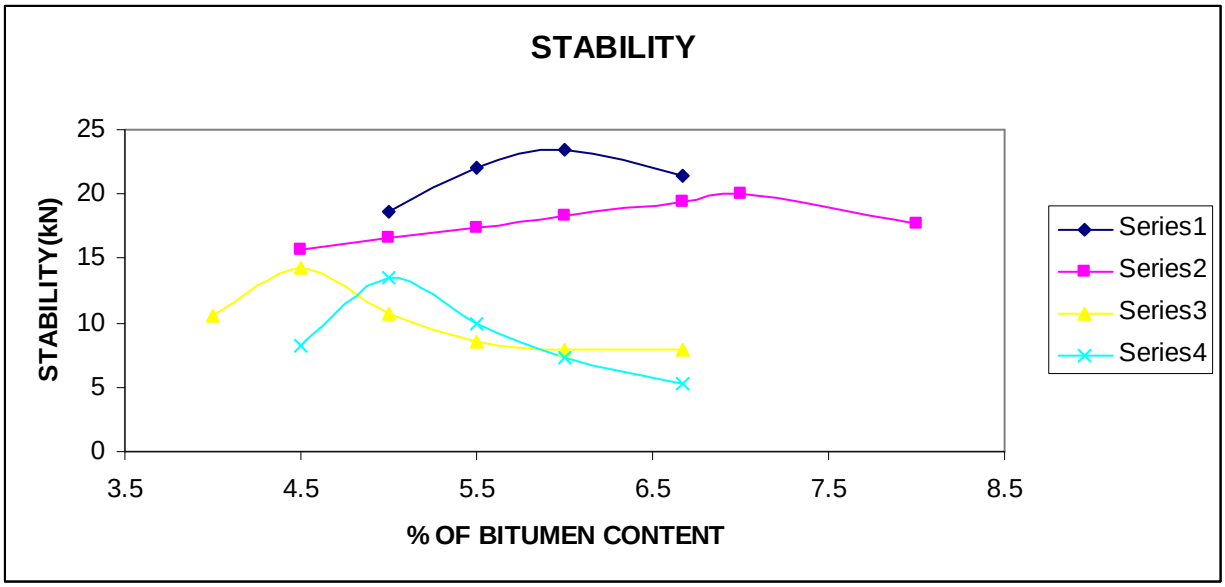
Fig 3.4.6 to 3.4.10 represents a graphical represents a graphical comparison of Marshall Properties between conventional fillers such as cement and lime (ref. Das and Pandey) and non-conventional fillers fly ash and brick dust

4.4.2.1 Marshall stability curves

Fig No 3.4.6 Graphical comparison of Marshall Stability value

Series 1- fly ash; Series 2- brick dust

Series 3 – cement; Series 4 - lime



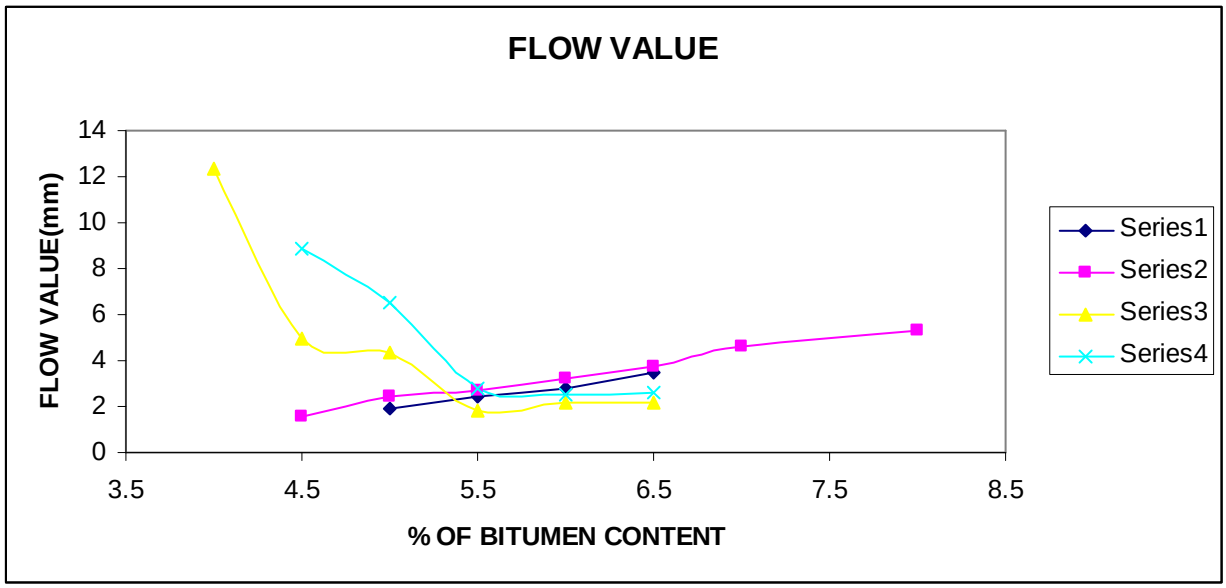
In fig no 3.4.6 we find that non conventional fillers such as fly ash and brick dust are found to have given a higher stability value at slightly higher bitumen content in comparison with conventional fillers cement and lime this might be due to higher bitumen content.

4.4.2.2 Marshall flow value curves

Fig No 3.4.7 Graphical comparison of Marshall Flow value

Series 1- fly ash; Series 2- brick dust

Series 3 – cement; Series 4 - lime



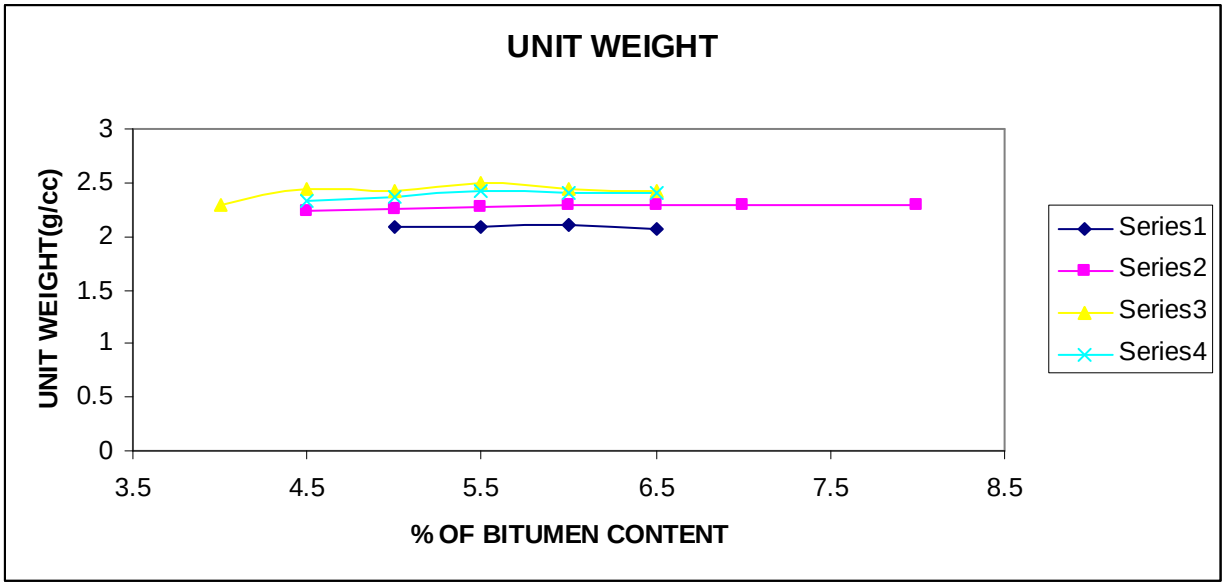
In fig no 3.4.7 both fly ash and brick dust are found to have given lower flow value in comparison with cement and lime. From this lower deformation values it can be concluded that fly ash and brick dust specimens might be having higher value of modulus of elasticity.

4.4.2.3 Marshall Unit weight curves

Fig No 3.4.8 Graphical comparison of Marshall Unit weight

Series 1- fly ash; Series 2- brick dust

Series 3 – cement; Series 4 - lime



In fig 3.4.8 we find that fly ash and brick dust specimens have lower value of unit weight in comparison with cement and lime. It might be due to higher number of air voids in fly ash and brick dust specimens in comparison with cement and lime.

4.4.2.4 Marshall air void(%) curves

Fig No 3.4.9 Graphical comparison of air voids

Series 1- fly ash; Series 2- brick dust

Series 3 – cement; Series 4 - lime

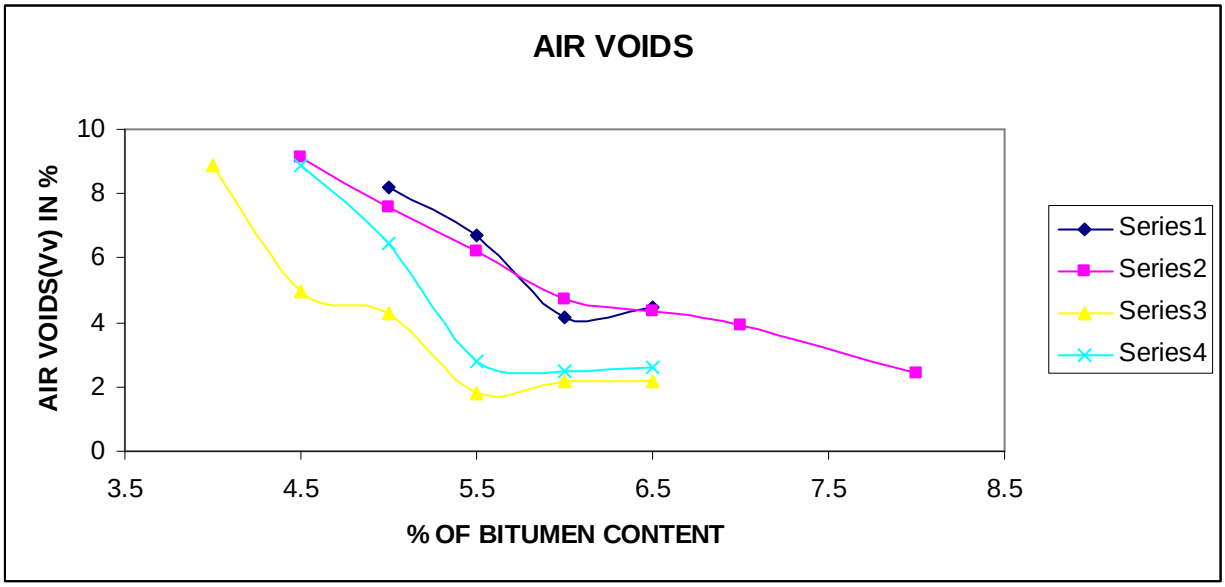


Fig 3.4.9 shows that fly ash and brick dust specimens display a higher number of air voids in comparison with cement and lime dust still then these non conventional fillers are found to have given satisfactory results.

4.4.2.5 Marshall VMA(%) curves

Fig No 3.4.10 Graphical comparison of VMA

Series 1- fly ash; Series 2- brick dust

Series 3 – cement; Series 4 - lime

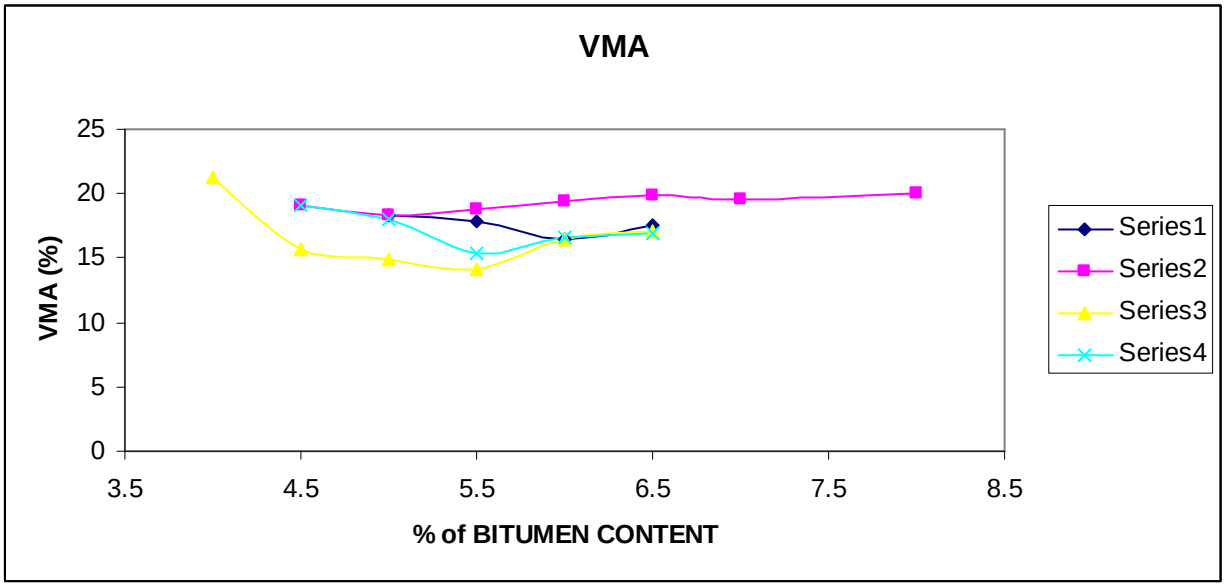


Fig 3.4.10 represents the VMA % curves showing that brick dust specimens showing almost a constant trend in VMA whereas its varying in case of fly ash, moreover they are found to display higher VMA in comparison with cement and lime dust specimens.

Criteria for satisfactory paving mix

Optimum bitumen content is determined by IRC code having specifications

- Stability should be greater than 840kg
- Flow value should be within the range of 2mmto 5mm
- % of Air voids should be 3-5% .The stability value, flow value and % air voids for the design optimum bitumen contents for different fillers are within the specified value.

Table No. 2.4.3 Comparison of results against various parameters for optimum bitumen content

Filler type	Max. Stability value	Max. Unit weight	4% of air voids	% VMA	Average value
Fly ash	6%	6%	6%	6%	6%
Brick dust	7%	7%	7%	7%	7%
Cement	4.5%	5.75%	4.75%	5.5%	5.13%
Lime	5.0%	5.5%	5.5%	5.5%	5.38%

In table no 2.4.3 it is found that brick dust and fly ash are found to require higher percentage of bitumen content in comparison with conventional fillers such as cement and lime

Table No. 2.4.4 Comparison of Marshall properties of various fillers

Parameters	Fly ash	Brick dust	Cement	Lime
Optimum Bitumen Content, %	6	7	5.13	5.38
Stability (kN)	21.58	19.23	10.69	11.48
Flow value (mm)	4.57	2.8	4.7	3.7
Unit wt (gm/cc)	2.3	2.1	2.42	2.41
% of air void	3.9	4.18	3.0	4.7
VMA(%)	19.5	16.41	14.8	15.6

CHAPTER 5

CONCLUSIONS

CONCLUSIONS

1. Bituminous mixes containing fly ash and brick dust as fillers are found to have Marshall properties almost nearly same as those of conventional fillers such as cement and lime.
2. Bituminous mixes containing fly ash as filler displayed maximum stability at 6% content of bitumen having an increasing trend up to 6% and then gradually decreasing, the unit weight/ bulk density also displayed a similar trend with flow value being satisfactory at 6% content of bitumen.
3. Bituminous mixes containing brick dust as filler showed maximum stability at 7% content of bitumen displaying an ascending trend up till 7% and then decreasing, the flow value showed an increasing trend and similar was the trend shown by unit weight/bulk density, the percentage of air voids obtained were seen to be decreasing with increase in bitumen content thus from here we can see that at 7% bitumen content we are obtaining satisfactory results.
4. These mixes were seen to display higher air voids than required for normal mixes.
5. Higher bitumen content is required in order to satisfy the design criteria and to get usual trends.

6. From the above discussion it is evident that with further tests fly ash and brick dust generated as waste materials can be utilized effectively in the making of bitumen concrete mixes for paving purposes.
7. Further modification in design mixes can result in utilization of fly ash and brick dust as fillers in bituminous pavement thus partially solving the disposal of industrial and construction wastes respectively.
8. Though cement and stone dust being conventional fillers however fly ash and brick dust can be utilized in their place effectively thus solving the waste material disposal substantially resulting in utilization of industrial space being consumed in disposal of industrial wastes
9. The cost effectiveness of these non conventional filler specimens can be realized after performing a cost analysis of these non conventional materials against the conventional specimens resulting in reduction of the construction costs considerably.
10. It is evident that with further tests fly ash and brick dust generated as waste materials can be utilized effectively in the making of bitumen concrete mixes for paving purposes.

FUTURE SCOPE:

- Pavement mixes with brick dust and fly ash as fillers using modified binders such as CRMB (60).
- Indirect tensile test of bituminous mixes can give us an idea about the tensile strength of the bituminous mixes.
- Repeated load testing can give us an overview about the fatigue failure resistance of the specimen.

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