UTILISATION OF SUGARCANE BAGASSE ASH IN BITUMEN

A Thesis Submitted

In partial fulfillment of the requirement

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MASTER OF TECHNOLOGY

In

Transportation Engineering

By

SAUMITRA YADAV

(University roll no. 1160467003)

Under the Guidance of

Prof. D. S. RAY

Department of Civil Engineering

BBD UNIVERSITY

BABU BANARASI DAS UNIVERSITY

LUCKNOW

2018 – 19

CERTIFICATE

This is to certify thesis entitled "**UTILISATION OF SUGARCANE BAGASSE ASH IN BITUMEN"** which has being carried out by Mr. SAUMITRA YADAV (Roll No. 1160467003) for partial fulfillment of requirement for the award of **MASTER OF TECHNOLOGY** (TRANSPORTATION ENGINEERING) of Babu Banarasi Das University, Lucknow, is a record of his work carried out by him under the guidance and supervision. The result embodied in this thesis has not been submitted elsewhere for award of any other degree or diploma.

D. S. RAY

(Professor)

(Project Guide)

Department of civil Engineering

BBD University, Lucknow

DECLARATION

I, hereby declare that the work which is being presented in the **M.Tech** Thesis Report entitled **"UTILISATION OF SUGARCANE BAGASSE ASH IN BITUMEN",** in fulfillment of the requirements for the award of the MASTER OF TECHNOLOGY in **Transportation Engineering (Civil Engineering)** and submitted to the Department of Civil Engineering of Babu Banarasi Das University, Lucknow (U.P.) is an authentic record of our own work carried out during the period from August 2016 to June 2019 under the guidelines of **Prof. D.S. Ray, Department Of Civil Engineering**. The matter presented in this thesis has not been submitted by me for the award of any other degree elsewhere.

Mr. SAUMITRA YADAV

(Roll No. 1160467003)

ABSTRACT

This study investigates the Utilization of industrial and agricultural waste products in the industry ,which has been the focus of research for economic, environmental and technical reasons. Sugarcane bagasse is fibrous waste product of the sugar refining industry and Sugarcane bagasse has high concentration of silica in it approximately 72%. which is very fruitful for increasing the strength of pavement. Huge quantity of ash which is a waste product available at very negligible rate. It causes chronic lung condition pulmonary fibrosis more specifically referred to as Bagasse. The aim of this research is to make economical construction of pavement &to maintain environmental balance &avoid problem of Ash disposal.

In this study, different content of bagasse ash 2 wt.%, 4wt.% & 6wt.% have been added to the Bitumen to modify the physical, mechanical & rheological properties of warm mix Asphalt(WMA).Various quality control test have been carried out to characterize the modified bitumen. The Rheological investigations showed that the complex modulus of base bitumen increases by increasing the percentage bagasse ash from 2to 6wt%.Result of investigations on Bitumen demonstrated the fact that by increasing bagasse ash content the quality of bitumen has been improved and resilient modulus of Bitumen has increased.

Key Words: Waste Sugarcane bagasse ash , Bitumen, coarse aggregate, fine aggregate.

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SAUMITRA YADAV

(1160467003)

TABLE OF CONTENT

Page No.

LIST OF TABLE

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 GENERAL

As we know that the roads are the life-line of every nation. A country's road network should be efficient in order to maximize economic and social benefits. Roads are an integral part of the transport system. They play a significant role in achieving national development and contributing to the overall performance and social functioning of the community. It is acknowledged that roads enhance mobility, taking people out of isolation and therefore poverty. Roads play a very important role in the socio-economic development of the country. The road transport industry is the backbone of strong economies and dynamic societies. The road transport industry is indeed instrumental in interconnecting all businesses to all major world markets, driving trade, creating employment, ensuring a better distribution of wealth and uniting mankind. It plays a crucial role in the daily economic and social life of industrialized and developing countries alike. An important part of the road transport industry's story is sustainable progress. Due to the above mentioned advantages, the road transport has become very popular and its share is constantly increasing. It is therefore legitimate and indispensable to safeguard an industry that is vital to economic growth, social development, prosperity and ultimately peace and which plays a crucial role in everyone's life in industrialized and developing countries alike by meeting the demand for the sustainable mobility of both people and goods.

But very less has been achieved in this sector because in the road transport sector energy planning has a special significance as transport is the second largest consumer of energy. As we know that due to limited availability of natural resources and rapid urbanization, there is a shortfall of conventional building construction materials. Thus the funds required for the construction of roads also increase. These financial constraints hamper the development of a developing nation like India. Also energy consumed for the production of conventional building construction materials pollutes the air, water and land. The growth of transport not only leads to pressure on limited availability of non- renewable energy resources but also gives rise to broader environmental issues. Moreover, the various processes for the production and processing of cement, bitumen, fine and coarse aggregate require a lot of energy and production of harmful gaseous and chemical wastes into the environment. As the demand for transport services rise, it leads to increased use of scarce land resources and contributes to the atmospheric pollution in a big way. The massive constructions release enormous amount of pollutants to the atmosphere and studies reveal that the pollutants from the construction industry are more harmful than the pollutants from any other segment. But on the other hand, there is a large production of agricultural wastes such as rice husk ash, wheat straw ash, hazel nutshell, fly ash, cork and sugarcane bagasse ash. Agriculture industry is the largest industry in India as more than 70% of Indian population is dependent on it. It is observed that in India more than 600 MT wastes have been generated from agricultural wastes-(2010).

Sugarcane is largely produced in the states of Punjab, Haryana, Uttar Pradesh and Tamil Nadu. The state of Uttar Pradesh is called the “Sugar Bowl” of India. A large number of sugarcane processing industries are located in these areas. But a large quantity of wastes called as bagasse is produced from these sugarcane processing industries as shown in figure 1.1.

Fig. 1.1: Sugarcane

As production of sugar cane is more than 1500 million tons in the world and in India about 10 million tons of sugarcane bagasse ash is treated as a waste material. These roads can be constructed in those areas where there is availability of sugarcane bagasse. In Uttar Pradesh and Haryana, there is a large scale cultivation of sugarcane and thus the sugarcane bagasse can be easily procured to be used in the construction of low volume traffic roads.

The fibrous residue (about 40–45%) of sugarcane after crushing and extraction of its juice is known as ‘‘bagasse”. The bagasse is reused as fuel in boilers for heat generation which leaves behind 8–10% of ash, known as Sugar Cane Bagasse Ash (SCBA) which is treated as waste and unutilized. Sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicelluloses and 25% of lignin. The use of sugarcane bagasse as bio fuel or burning in open fields has posed a great environmental threat of polluting air, water, etc. Even after strict restrictions by the government of these above said states, there is no end to field fires as people only want to get rid-off these bulky and huge wastes. During rains these wastes begin producing highly offensive gases, thereby again causing nuisance. The smoke produced also causes invisibility. It can therefore be advantageous to use it in the construction of pavements to mitigate the disposal problem as well as to minimize the use of natural aggregate (sand) and binding material (cement, bitumen), so as to construct the low volume economic road pavements.

Fig. 1.2 Sugar Cane Bagasse Ash

1.2 BACKGROUDG STUDY

Road transport plays an important role in the development of the India economy as it accounts for over 80% of passenger and goods movement in India (Analysis, 2015). India depends on the agriculture for its economy, and thus an efficient road infrastructure is a prerequisite for its socio-economic development. A well-developed road network will facilitate the transportation and marketing of farm produce, while bad roads impede the movement of commodities and services from producers to consumers and farm produce from rural area to urban centers. Poor road network increases the cost of farm inputs, impede access to the market consequently raising the cost of living. They also constrain access to essential services such as healthcare, education and emergency responses in the event of disasters.

The majority of road network in India constitute unpaved roads as opposed to paved road surfaces. To improve the road network, more and more roads need to be constructed to paved surface standards. There are three main types of paving used in India as follows:

- Flexible paving made using bituminous mix.
- Rigid paving made of concrete surfacing.
- Paving block surface made with pre-cast road paving blocks.

Road networks mostly apply to flexible paving because it is cheaper and easier to construct although it has generally shorter life span compared to rigid and paving block. One of the main components of flexible road surface construction is bitumen. It is important to use bitumen with higher mechanical properties in order to achieve a sound and durable road surface by improving the physical properties of bitumen. This project aims to achieve that broad objective. Discussion in this study will be limited to flexible pavement surface.

The term bituminous materials are generally taken to include all materials consisting of aggregates bound with bitumen. Initially roads were being constructed using the principles developed by Macadam water bound graded aggregates. Under the action of pneumatic tyres and high speed vehicles, lots of dust was generated and the need to come up with tar as surface dressing binder was necessary. The benefit of using tar as a binder was quickly outweighed by the benefits of bitumen and also the fact that tar is carcinogenic in nature making it unacceptable binder in road construction. Bitumen was found to be less temperature susceptible than tar. At high temperatures bitumen is stiffer than its own equivalent grade of bitumen making it more resistant to deformation. While at low temperature bitumen is softer than tar making it less brittle and more resistant to cracking.

Deterioration of bituminous roads has prompted civil engineers to keep investigating on better binder until a strong one is obtained. There are two areas that can improve the serviceability of a road surface. Either by applying a thicker bituminous mixture which increases the construction cost or using a bituminous mixture with modified characteristics.

Their Brundtland Commission, they defined sustainable development as that development that meets the needs of the current generation without compromising the ability of future generations to meet their own needs. In line with this, the researchers have focused their studies on the utilization of industrial and agricultural waste produce by combining them with virgin engineering materials. This helps in strengthening the materials, minimize on environmental pollution, economic gain as well as save on natural extraction of that particular virgin engineering materials.

This study has addressed modification of bitumen by replacing a certain percentage of bitumen with the same amount of additives. The additives that were used in the modification of bitumen were waste sugar cane ash. It will establish the effect of WSCA on bitumen, bituminous material, any cost saving and suggest the optimum percentage of bitumen that can be replaced WSCA for the improvement of binder.

Agricultural waste material such as rice husk ash, wheat straw ash, hazel nutshell and sugarcane bagasse ash (referred here as Waste Sugar Cane Ash) has been used in the in preparation of concrete blocks due to their pozzalanic properties (Ganesan K, Rajagopal K, 2007). The stability of bitumen was found to improve when cement, fly ash and stone dust were added to paving bitumen (Mohi, Din, & Marik, 2015). Based on this, WSCA having similar characteristics with rice husk ash and wheat straw ash can be used as a bitumen modifier.

In India, construction of bituminous road is carried out commonly using bitumen grade 80/100. This bitumen grade is softer and is more susceptible to temperatures changes as compared to bitumen grade 60/70. Their penetration parameters can be lowered by the additional of additive limiting them to be grade 60/70. Use of these waste products would have the double benefit of solving the environmental problem and improve the bitumen quality.

1.3 PROBLEM STATEMENT

The state of road network in Kenya is poor with most road unpaved and many paved roads going for long periods without maintenance. The need for maintenance increases as a road ages. The road surface becomes fragile and less resilient in carrying the loading. This leads to defects which consequently allow water to percolate to the underlying layers causing effectual road failure. Road failures lead to traffic jams for long hours, loss of man hours for drivers and passengers as well as increased air pollution from gas emissions.

Use of modified bitumen would result in road pavements with longer design life. Using locally available admixtures to modify bitumen would give an additional benefit to the local economy in the long run. When such a material is a waste or a by-product, the benefits are even higher as this helps to maintain the environment and provide a beneficial use of the waste. WSCA is readily available as by-product by the numerous sugar factories in India.

1.3.1 OVERALL OBJECTIVE

The main objective of this study is to evaluate the performance of bitumen and bituminous mixture, modified with waste sugar cane ash for road wearing course.

1.3.2 SPECIFIC OBJECTIVES

The specific objectives of this research study are listed below: -

- To evaluate the performance of conventional bitumen modified with shredded waste sugar cane ash and determine the optimum mix proportions of the and ash in the modification for road wearing course.
- To evaluate the stability, flow value and volumetric properties of bituminous mix with and without additional of shredded Waste sugar cane ash and the blend of the two waste.
- To analyze the cost impact on the use of modified bitumen over the convention one.

1.4 JUSTIFICATION OF THE STUDY

Bitumen is among the oldest engineering materials and has been used for thousands of years in various ways; as adhesive, sealant, preservatives, waterproofing agent and pavement binder. Initially bitumen was used in its natural occurrence as there were no refineries, but in the early 1900s, developed countries like USA began to refine bitumen. Since then, the world consumption of bitumen has increased rapidly, most of which is used in road construction. A joint publication done by Asphalt Institute and Euro bitumen in 2011, stated that the world consumption of bitumen by that time was approximately 102 million tons per year and 85% of which was used in pavement construction.

Road industry has developed rapidly all over the world in the last few decades, especially in developing countries as witnessed in Kenya. Following this rapid development and higher traffic volume, there is great need for bitumen for new road construction and maintenance of the existing ones.

In the vision 2030 document under infrastructure, the Government of India aims at providing a cost-effective world-class infrastructure facilities and services in support of the economy. Due to this, the demand for bitumen in India has gone higher to cater for its growing infrastructure that has been expanding by the year. In order to obtain bitumen with enhanced quality, there is need to use modified bitumen. This will extend the service life of the road surface by improving the performance of bituminous mixture. This is also important as it will provide a disposal route for waste sugar cane ash.

Successful modification of bitumen as envisaged in this study would have a beneficial impact on the economy and the environment. The economy would improve by saving on road construction and maintenance cost, establishment of bitumen modification companies, beneficial usage of waste products, and job creation. The environment would benefit by providing an environmentally friendly disposal route for waste sugar cane ash. Modification of bitumen will also reduce in the extraction of bitumen taking care of the future generation.

1.5 SCOPE AND LIMITATIONS OF STUDY

The study focused on the modification of bitumen using Waste Sugar Cane Ash. The penetration test, ductility test, softening point test, and specific gravity tests were carried out to determine the quality of the modified bitumen. Marshall Stability test was used in determining the volumetric properties, stability and flow of the briquette. The following were the limitation of the study:-

- This study was limited to the bitumen used on the wearing course alone. The investigator has assumed that the other pavement layers like sub-grade, sub-base and base courses have been done to road designer’s satisfaction and they can adequately support the wearing course.
- The waste sugar cane ash used in this study was from Mumias Sugar Company.
- The WSCA were limited to particle sizes passing through sieve 2.36 mm.

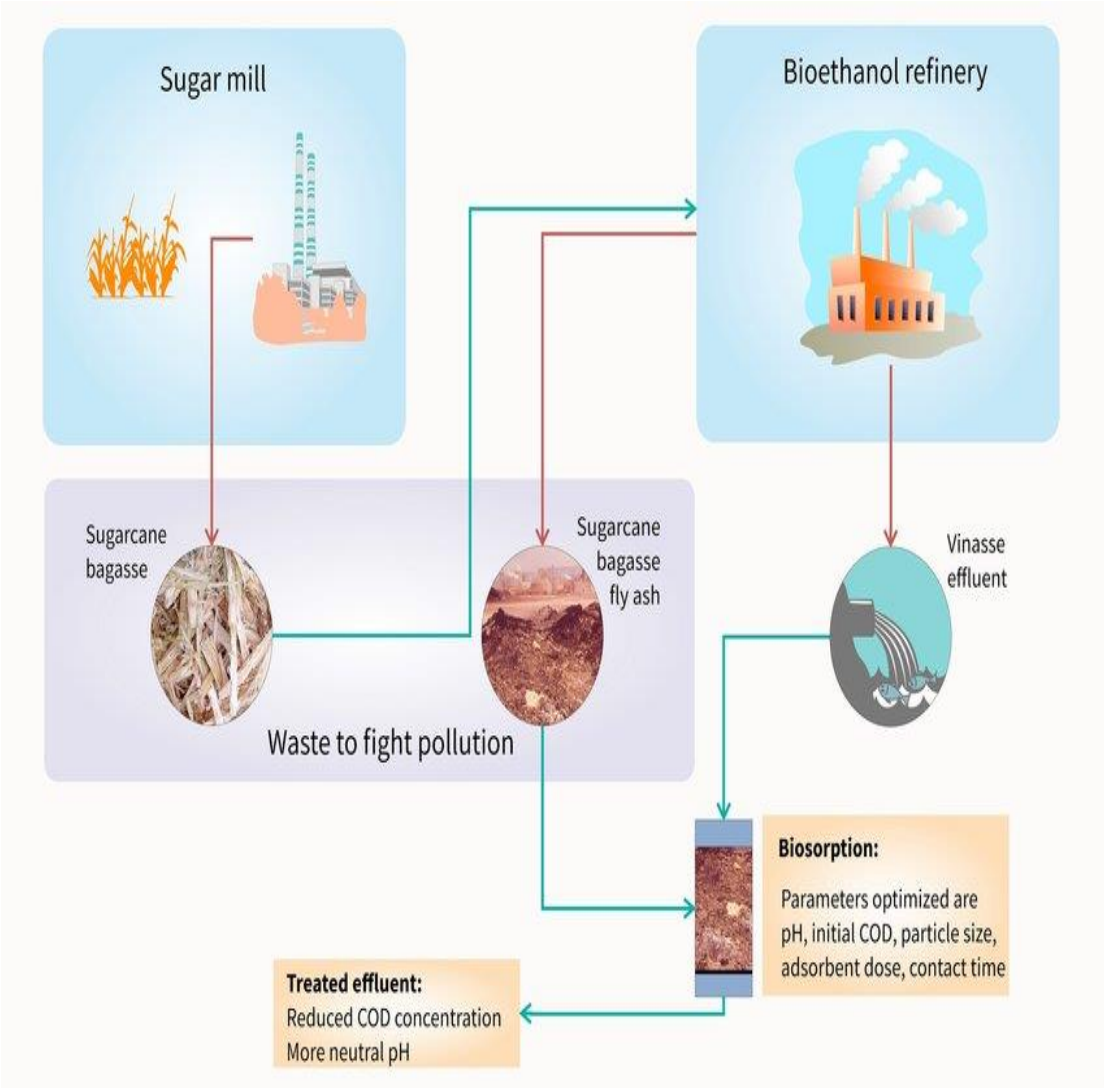


Fig. 1.3 Manufacturing Process of Sugarcane

CHAPTER 2

LITERATURE REWIEW

2.1 STDUIES ON WASTE BAGASSE ASH FOR PAVEMENT CONSTRUCTION

2.1.1 Wang et al. (2011) Effect of coal properties and operation conditions on flow behavior of coal slag in entrained flow gasifier: a brief review

Integrated gasification combined cycle (IGCC) is a potentially promising clean technology with an inherent advantage of low emissions, since the process removes contaminants before combustion instead of from flue gas after combustion, as in a conventional coal steam plant. In addition, IGCC has potential for cost-effective carbon dioxide capture. Availability and high capital costs are the main challenges to making IGCC technology more competitive and fully commercial. Experiences from demonstrated IGCC plants show that, in the gasification system, low availability is largely due to slag buildup in the gasifier and fouling in the syngas cooler downstream of the gasification system. In the entrained flow gasifiers used in IGCC plants, the majority of mineral matter transforms to liquid slag on the wall of the gasifier and flows out the bottom. However, a small fraction of the mineral matter (as fly ash) is entrained with the raw syngas out of the gasifier to downstream processing. This molten/sticky fly ash could cause fouling of the syngas cooler. Therefore, it is preferable to minimize the quantity of fly ash and maximize slag. In addition, the hot raw syngas is cooled to convert any entrained molten fly slag to hardened solid fly ash prior to entering the syngas cooler. To improve gasification availability through better design and operation of the gasification process, better understanding of slag behavior and characteristics of the slagging process are needed. Slagging behavior is affected by char/ash properties, gas compositions in the gasifier, the gasifier wall structure, fluid dynamics, and plant operating conditions (mainly temperature and oxygen/carbon ratio). The viscosity of the slag is used to characterize the behavior of the slag flow and is the dominating factor to determine the probability that ash particles will stick. Slag viscosity strongly depends on the temperature and chemical composition of the slag. Because coal has varying ash content and composition, different operating conditions are required to maintain the slag flow and limit problems downstream. This report briefly introduces the IGCC process, the gasification process, and the main types and operating conditions of entrained flow gasifiers used in IGCC plants. This report also discusses the effects of coal ash and slag properties on slag flow and its qualities required for the entrained flow gasifier. Finally this report will identify the key operating conditions affecting slag flow behaviors, including temperature, oxygen/coal ratio, and flux agents.

2.1.2 Tekle et al. (2012) Application of sugarcane bagasse ash as a partial cement replacement

Sugarcane bagasse ash is a byproduct of sugar factories found after burning sugarcane bagasse which itself is found after the extraction of all economical sugar from sugarcane. The disposal of this material is already causing environmental problems around the sugar factories. On the other hand, the boost in construction activities in the country created shortage in most of concrete making materials especially cement, resulting in an increase in price. This study examined the potential use of sugarcane bagasse ash as a partial cement replacement material. In this study, bagasse ash sample was collected from Wonji sugar factory and its chemical properties were investigated. The bagasse ash was then ground until the particles passing the 63μm sieve size reach about 85% and the specific surface area about 4716 cm2/gm. Ordinary Portland cement and Portland Pozzolana cement were replaced by ground bagasse ash at different percentage ratios. Normal consistency and setting time of the pastes containing Ordinary Portland cement and bagasse ash from 5% to 30% replacement were investigated. The compressive strengths of different mortars with bagasse ash addition were also investigated.

2.1.3 Tijore et al. (2013) Utilization of Sugarcane Bagasse Ash in Concrete IJSRD - International Journal for Scientific Research & Development| Vol. 1, Issue 9

Abstract—Utilization of industrial and agricultural waste products in the industry has been the focus of research for economic, environmental, and technical reasons. Sugar-cane bagasse is a fibrous waste-product of the sugar refining industry, along with ethanol vapour. This waste-product is already causing serious environmental pollution which calls for urgent ways of handling the waste. In this paper, Bagasse ash has been chemically and physically characterized, in order to evaluate the possibility of their use in the industry. X-ray diffractometry determination of composition and presence of crystalline material, scanning electron microscopy/EDAX examination of morphology of particles, as well as physical properties and refractoriness of bagasse ash has been studied.

2.1.4 Kulkarni et al. (2013) Bagasse Ash as an Effective Replacement in Fly Ash Bricks International Journal of Engineering Trends and Technology (IJETT) – Volume 4 Issue 10

Utilization of industrial and agricultural waste products in the industry has been the focus of research for economic, environmental, and technical reasons. Sugar-cane bagasse is a fibrous waste-product of the sugar refining industry, along with ethanol vapor. Huge quantity of ash which is a waste product, available at very negligible rate. It causes the chronic lung condition pulmonary fibrosis more specifically referred to as bagassios. In this paper, Bagasse ash can be utilized by replacing it with fly ash and lime in fly ash bricks. Trial bricks of size (230x100x75) mm were tested with different proportions of 0%, 10%, 20%, 30%, 40%, 50% and 60% with replacement of fly ash and 0%, 5%, 10%, 15% and 20% with replacement of lime. These bricks were tested in Compression test and Water absorption test as per Indian Standards. The aim of this research was to make economical and green bricks to maintain environmental balance, and avoid problem of ash disposal.

2.1.5 Prakash et al. (2014) PERCENTAGE REPLACEMENT OF BITUMEN WITH SUGARCANE WASTE MOLASSES IAEME Volume 5, Issue 7, pp. 188-197

Bitumen the residue left over from petroleum distillation is throughout the world the most significant bonding agent used for road way construction. Crude petroleum is a fossil mineral resources and fuel source that will be used up within next 50years. Increasing energy costs and the strong worldwide demand for petroleum has encouraged the development of alternative binders to modify or replace asphalt binders. The benefits of using alternative binders are that they can save the natural resources and reduce energy consumption, while maintaining, and in some cases improving pavement performance. Because of urgent need of infrastructure, rehabilitation and maintenance, the introduction and application of such sustainable and environmental friendly materials like sugar cane waste molasses are required. And today the demand lies around 200 million tons.

2.1.6 Kharade et al. (2014) WASTE PRODUCT 'BAGASSE ASH' FROM SUGAR INDUSTRY CAN BE USED AS STABILIZING MATERIAL FOR EXPANSIVE SOILS International Journal of Research in Engineering and Technology

Soil is a base of structure, which actually supports the structure from beneath and distributes the load effectively. If the stability of the soil is not adequate then failure of structure occurs in form of settlement, cracks etc. Expansive soil also known as black cotton soil is more responsible for such situations and this is due to presence of montmorillonite mineral in it, which has ability to undergo large swelling and shrinkage. To overcome this, properties of soil must be improved by artificial means known as 'Soil Stabilization'. It is a technique which improvises one or more soil properties by mechanical, cementing and chemical use. Many research has been conducted for stabilization of soil by using cementing, chemical materials e.g. Fly ash, cement, Calcium chloride, Sodium chloride etc. Toady world is facing serious problem of disposal of agricultural waste. Western Maharashtra is popular for production of sugar cane in large quantity. Sugar factories produces waste after extraction of sugar cane in machines that waste when burnt, the resultant ash is known as ‘Bagasse Ash’. It is a fibrous material with presence of silica (SiO_2) and can be used to improve the existing properties of black cotton soil. In this study laboratory experiments were conducted on black cotton soil with partial replacement by Bagasse Ash (3%, 6%, 9% and 12%). This paper highlights significant increase in properties of black cotton soil obtained at 6% replacement of Bagasse Ash without any chemical or cementing material.

2.1.7 Maung et al. (2015) PREPARATION AND CHARACTERIZATION OF BAGASSE ASH International Journal of Technical Research and Applications e-ISSN: 2320-8163, www.ijtra.com Volume 3, Issue 1), PP. 84-87

The bagasse was packed in the air tight and placed inside electric control furnace and burnt at a temperature of 1200˚C for 3h and 6h to obtain bagasse ash. After firing, it was characterized by X-ray diffraction (XRD). Bio-char disk (pellet) was formed by following appropriate amount of silica gel, PVA and DIW. They were annealed at 110˚C for 3h to be binder burnt-out. They were annealed at 600˚C for 1h to be more rigid. The bagasse ash ceramics were annealed at 1200˚C for 1h, 2h and 3h. Microstructural properties of bagasse ash ceramics were characterized by scanning electron microscope (SEM). Physical properties such as firing shrinkage and density of all Bio-char ceramics were determined.

2.1.8 Norsuraya et al. (2016) Sugarcane Bagasse as a Renewable Source of Silica to Synthesize Santa Barbara Amorphous-15 (SBA-15 4th International Conference on Process Engineering and Advanced Materials

Sugarcane bagasse is an agricultural waste that is potentially used as natural silica resources. Natural silica claimed to be safe in handling, cheap and can be generate from cheap resource. In this study, Santa Barbara Amorphous-15 (SBA-15) was synthesized using sodium silicate that is extracted from Sugarcane bagasse ash (SCBA). Post treatment method using hydrochloric acid (HCl) was introduced during the silica extraction process to improve its purity. The result indicated that the amount of SiO_2

present in the raw sugarcane bagasse ash was 53.10% while the silica composition in acid treatment sample was 88.13%. The FTIR pattern of extracted sodium silicate shows a similar spectrum with the commercial pattern of sodium silicate. While the Inductive Coupled Plasma (ICP) result shown that the concentration of silica in extracted sodium silicate was 4873 ppm. Then the extracted sodium silicate produce was used as a silica precursor in the synthesis of mesoporous silica, Santa Barbara Amorphous-15 (SBA15). The formation of SBA-15 was characterized using X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM). The result indicated that the synthesis SBA-15 have present peaks 100, 110 and 200 which represent the hexagonal mesoporous material associated with p6mm symmetry.

2.1.9 Najar A et al. (2017) Experimental Investigation on the Use of Bagasse Ash in the Construction of Low Volume Traffic Roads International Journal for Research in Applied Science & Engineering Technology (IJRASET)

The road transport industry is indeed instrumental in interconnecting all businesses to all major world markets, driving trade, creating employment, ensuring a better distribution of wealth and uniting mankind. The road transport industry's story is sustainable progress. Transport investments within cities and across cities are essential for economic growth, job creation and poverty reduction. Over the last ten years (2002-03 to 2011-12) road transport sector gross domestic production grew at an annual average rate close to 10 per cent compared to an overall annual gross domestic production of 6 per cent. An efficient road transport system is a pre-requisite for sustained economic development. It is not only the key infrastructural input for the growth process but also plays a significant role in promoting national integration, which is particularly important in India. In the road transport sector energy planning has a special significance because transport is the second largest consumer of energy. The growth of transport not only leads to pressure on limited availability of non- renewable energy but also gives rise to broader environmental issues. As the demand for transport services rise, it leads to increased use of scarce land resources and contributes to the atmospheric pollution in a big way. There is also a large production of agricultural wastes as agricultural industry is one of the largest industries in India as more than 70%

of Indian population is dependent on agriculture. On the other hand, accumulation of unmanaged agro-waste, especially from the developing countries has an increased environmental concern. Therefore, development of new technologies to recycle and convert waste materials into reusable materials is important for the protection of the environment and sustainable development of the society. Many agricultural waste materials are already used in concrete as replacement alternatives for cement, fine aggregate, coarse aggregate and reinforcing materials. Moreover, the various processes for the production and processing of cement, bitumen, fine and coarse aggregate requires a lot of energy and production of harmful gaseous and chemical wastes into the environment. Thus in view of the above problems, an attempt is made to study, to reduce the pollution from cement and other materials used in the construction process with a view to create and develop greener methods of construction by using bagasse ash in the construction of low volume traffic roads by the partial replacement of certain constituent materials. These roads can be constructed in those areas where there is availability of sugarcane bagasse. In Uttar Pradesh and Haryana, there is a large scale cultivation of sugarcane and thus the sugarcane bagasse can be easily procured to be used in the construction of low volume traffic roads.

2.1.10 MISHRA et al. (2019) EFFECT OF WASTE POLYTHENE USE IN DIFFERENT MODIFIER BITUMEN IN FLEXIBLE PAVEMENT IJARIT (Volume 5, Issue 3)

The use of waste polythene is increasing week by week. The waste polythene pollutes the environment, especially where there is no garbage collection and disposal system. A large amount of plastic collected from the tourist trekking regions and housing area are discarded or burned which releases harmful gases into the environment. The waste polythene collected from domestic and industrial sectors can be used in the production of plastics coated aggregate. Waste polythene, mainly used for packing and carrying any food. It’s made up of Polyethylene, Polypropylene, and polystyrene. Their softening point varies between 110 degree Celsius to 140 degree Celsius and if the wastes polythene is heated within this temperature range then they do not produce any toxic gases but the softened waste polythene have tendency to form a film like structure over the aggregate, when it is sprayed over the hot aggregate at 160 degree Celsius to 170 degree Celsius. The Plastics Coated Aggregates (PCA) is a better raw material for the construction of flexible pavement. PCA was mixed with hot bitumen of different types and the mixes were used for road construction.

2.2 CLASSIFICATION OF BITUMEN

2.2.1 Behavioral Characteristics of bitumen

Bitumen can be defined as a civil engineering construction material manufactured by extracting the lighter fractions such as liquid petroleum gas, petrol and diesel from heavy crude oil during refining process and is commonly referred to as refined bitumen (Bejjenki, 2015). One of the characteristics and advantages of bitumen as an engineering construction and maintenance material is its great versatility. Bitumen can be liquefied by applying heat, dissolved in solvents, emulsified and modified. Bitumen is used as a binder in road construction by mixing it with graded aggregates to form bituminous mixture which is later laid on the road surface as a wearing course. The main function of the wearing course is to spread traffic and environmental loading applied on the road surface to the other unbound road layers, protect the other road layers from adverse environmental effects and give road users a smooth ride.

For bitumen to be usable in road construction, it must be fluid enough to coat all aggregates and stiff enough when load is applied to it to resist deformation (Bejjenki, 2015). Bitumen has various properties that determine its performance and this includes adhesion, elasticity, plasticity, viscoelasticity, and temperature susceptibility.

Adhesion is the process in which dissimilar particles or surfaces are held together by varying forces and or interlocking forces (Raquel Moraes, Raul Velasquez, 2010). This quality of bitumen is expected to hold the aggregates together at all weather condition enabling the aggregates to carry the traffic and environmental loading applied to it. However, in the presence of water, the adhesion may be affected. It is therefore necessary to dry the aggregate well before coating them with bitumen and use nonporous aggregates when constructing the road.

Elastic behaviour of bitumen can be seen when the binder is able to recovers most or all of its initial shape when the load that caused the deformation is removed (Raquel Moraes, Raul Velasquez, 2010). This implies that the binder is able to deform when a load is applied to it and recover to its original shape when that particular load has been removed. This property of the binder is commonly used to determine the fatigue resistance or its ability of the binder to absorb large stresses with minimum cracking or deforming (Rossmann Sanral, Sabita .T.M. Gilbert, J.A. Grobler, 2002). It is an important property of the binder as it enables the road surface to deform upon loading and gain its original shape once the load. If bituminous surfaces are able to retain their elasticity, the durability of the same is enhanced.

Also, bitumen is a viscoelastic material in nature. Its rheological properties are very sensitive to temperature and rate of loading (Ali, Mashaan, & Karim, 2013). At higher temperatures there is more flow, while at lower temperatures the bitumen tends to be stiff and elastic, while at intermediate temperatures, it tends to be visco-elastic (C.A. Emeritus, 2002). Temperature susceptibility of the binder being used in a paving mixture is crucial as it indicates the proper temperature at which to mix the binder with aggregate, and compact it on the road surface (Rossmann Sanral, Sabita .T.M. Gilbert, J.A. Grobler, 2002). When the binder is subjected to a temperature above its softening point and is loaded, rutting occurs, and if it is subjected to a temperature below its fragility point, cracking may occur.

The above mentioned properties of bitumen are greatly affected by adverse weather conditions once the bituminous mixture has been laid on the road surface. Bitumen can be modified to enhance their physical properties making it a better binder. From previous research, modified bitumen improves the performances of bituminous mixture and substantially increases the service life of a highway. Once admixtures are added to the conventional bitumen as a modifier, they alter various bitumen properties, making it more stable and stiffer at high temperatures and more flexible at low temperatures (Al-Mansob et al., 2014).

Table shows the bitumen properties for conventional bitumen grade 60/70 and grade 80/100 as derived from the different standard manuals. When the bitumen was modified, parameters like penetration grade, softening point, and ductility were tested.

Any binder sample whose penetration value was not with 60-70mm was discarded and briquette prepared using the adopted samples.

Table 2.1: Bitumen Standard Properties

Properties	Grade 60/70	Grade 80/100	Test Method
Penetration at 250° C	60/70	80/100	**IS:1203-1978**
Softening point (R&B) °C	52/60	42/52	**IS:1205-1978**
Ductility @270°C, cm	100	100	**IS:1208-1979**
Specific gravity of bitumen	1.00/1.05	1.01/1.06	**IS:1202-1980**

2.2.2 Modified Bitumen

Investigations have revealed that properties of bitumen and bituminous mixes can be improved, by improving bitumen physical properties without changing its chemical nature (Al-Mansob et al., 2014). In the past, Conventional bitumen used to be modified using agents like polymer, crumb rubber, sulphur, magnesium and polyphosphoric acid (Tam & Tam, 2006). Also cement or lime could be incorporated in bitumen to enhance its adhesive property thus improving the binder strength and its resistance to water damage (C.A. Emeritus, 2002). When approximately 1-2% of lime or cement by mass of aggregate was added to the bitumen, a chemical reaction took place resulting in formation of compounds that were absorbed by negatively charged aggregate surface and this improved adhesion and rendered the aggregates less vulnerable to stripping (B.L Gupta, 2010).

Plastic bags due to their binding properties when molten can be mixed with bitumen to enhance its binding property making it a good modifier (Verma, 2008). Due to its higher softening point, shredded waste plastics bags generally increases the softening point of modified bitumen (Vasudevan, A. Ramalinga Chandra Sekar, B. Sunkarakannan, 2011). Flexibility of the road surface is retained during the cold weather enabling it to withstand repeated loading on warm weather condition resulting in its long life. If cracks development was minimized, the rate of water seepage through the pavement surface is greatly reduced eliminating the effect of water to the underlying layers. In the long run, the serviceability of the road surface is maintained. The environment is improvement by finding a disposal route for plastic bags and job creation (Shirish N. Nemade, 2014). The strength of bituminous mix is improved (Kadam, 2014).

The SWPB particles sizes were limited to only those particles that were retained in sieve size 2.36mm (Verma, 2008). Based on ASTM 2002, where particles size of crumb rubber used in modification of bitumen were limited to particle sizes retained in sieve size 1.18mm and passing through sieve size 4.75mm. In line with, the waste particle sizes to be used in this study will be limited to particle sizes passing through sieve 2.36mm. This will assist in blending the binder homogeneously.

Though SWPB had been used in the past for the modification of bitumen in other countries, the same has not be done locally. This study will aim at testing the locally generated SWPB and further compare its results with those obtained when WSCA is used as a modifier.

These among many other studies, clearly indicate that modified bitumen has been used in the construction of bituminous roads to improve road performance by enhancing bitumen mechanical properties. The studies carried out are not exhaustive and more studies can be done depending on the additives being used in line with sustainable development. According to (Gro Harlem Brundtland, Mansour Khalid, Susanna Agnelli, 1987) in their Brundtland Commission, they defined sustainable development as that development that meets the needs of the current generation without compromising the ability of future generations to meet their own needs. When bitumen is modified, their properties are improved; the rate of extraction will be minimized thus taking care of the future generation.

2.2.3 The bitumen Test

Bitumen is subjected to various tests before it is used as a binder in road construction to determine its suitability as a binding material. The tests include penetration test and this is the measure of hardness or softness of bitumen by measuring the depth a standard loaded needle penetrate vertically in five seconds (Ehinola, Felode, & Jonathan, 2012). Higher penetration values indicate softer consistency while lower values indicate hard consistency. Modification of bitumen tends to lower the value of penetration index. This implies that, soft bitumen can be modified and used as harder binder in a hotter climatic condition.

Secondly, the ring and ball softening point test is a test conducted to determine the consistency of bitumen by measuring the equi-viscous temperature at the beginning of the fluidity range of bitumen (Lesueur, 2009). Generally, higher softening point indicates lower temperature susceptibility and is preferable in hot climates. (Whiteoak D., 1990).

Thirdly, ductility is the distance in centimeters, to which a standard sample of bitumen will be elongated without breaking (Whiteoak D., 1990). This property of bitumen enables it to withstand deformation once a load is applied on its surface. The bituminous surface elongates once subjected to a loading without cracking and consequently protecting the underlying layers to environmental conditions.

The specific gravity of bitumen is the ratio of mass of given volume of bitumen to the mass of equal volume of water at 27o C and it varies between 0.97 to 1.02 (1202-1978, n.d.). It is measured using either pycnometer or by preparing a cube specimen of bitumen in solid or semi-solid state.

Finally, the Marshall Stability was used to determine the volumetric properties of bituminous mixture to produce a mix with desired properties (Roberts F.L, Kandhal. P.S, Brown. E.Ray, Lee. D, 1991). These volumetric properties include bulk density, voids in mineral aggregates (VMA), voids filled with bitumen (VFB), flow and Stability value.

2.3 THE ROAD WEARING COURSE MATERIALS

This is the layer in direct contact with traffic loading. It is meant to take the brunt of traffic wear and can be removed and replaced as it gets worn away. The road surface is made up of a mixture of various selected aggregates bound together with bituminous binder, known as Hot Bituminous Mixture (HBM) (Rogers, 2003). The aggregates act as the skeleton while the bitumen provides the muscles to hold it together (Syamsul Arifin, Mary Selintung, 2015). The skeleton must carry the weight while the muscles must be strong enough to hold the skeleton in place but still be flexible enough; this is known as mix design. Mix design is the proportion of the aggregates to be used and the amount of bitumen to be added. These proportions are established by testing various combinations in the laboratory until one is found that meets the desired requirement through Marshall Stability.

A bituminous mixture derives its strength from the cohesion resistance of the binder and the grain interlock and frictional resistance of the aggregate (Aziz et al., 2006). The cohesion resistance is only fully available if a good bond exists between the binder and the aggregates.

2.3.1 Aggregates and their suitability in road construction

Aggregates constitute a large portion of the materials used in the construction of the road surface. The physical and chemical characteristics of the aggregate play a significant factor in determining the strength of the bitumen and aggregate bond. The aggregates are tested for engineering properties to assess their suitability as road construction materials. Various tests on aggregates have been formulated keeping in view the following quality parameters.

2.3.1.1 Strength

The aggregates which are in direct contact with the traffic load need to be the strongest, compared to those of the subsequent layers (Chakroborty & Das, 2003). A study carried out by (Shagoti, 2015) showed that there is a direct relationship between strength of the aggregates and laboratory permanent deformation properties of bituminous mixture. When the percentage of the crushed particles increases, the rutting of the mixture goes high. When the aggregates are weak, the integrity of the pavement structure will be adversely affected as the aggregates will crush under traffic loading.

The strength of coarse aggregates is measured by aggregate crushing test (ACV). The aggregates crushing test gives a relative measure of the resistance of aggregates to crushing to compressive stress under a gradually applied load (Mathew, 2007). From (Note, 2002), the ACV should not exceed 25%.

2.3.1.2 Hardness

The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving vehicles causing them to undergo continuous wear and tear under the wheels of the vehicles (Chakroborty & Das, 2003). Hard aggregates are better as they have the ability to resist the abrasive effects of traffic over a long time compared to flaky and soft aggregates. The hardness of aggregates is determined by carrying out the Los Angeles Abrasion test (LAA). The LAA test is a measure of degradation of mineral aggregates of standard grading resulting from abrasion, impact and grinding in a rotating steel drum containing a specified numbers of steel spheres (IS 2386 part- IV, 1963). The LAA value should not exceed 25% (Note, 2002).

2.3.1.3 Shape of aggregates

Particles shape and size has a noticeable effect upon the physical properties of bituminous mixture affecting its serviceability (Roberts F.L, Kandhal. P.S, Brown. E.Ray, Lee. D, 1991). Flat and elongated particles tend to break during mixing, compaction, and under traffic making aggregate shape an important factor to be considered to avoid premature pavement failure. There is a direct relationship between rutting of the bituminous mixture and the shape of coarse aggregate particles (N.C Krutz, 1993).

The flakiness index of an aggregate in a sample is found by separating the flaky particles and expressing their mass as a percentage of the mass of the sample. From road note 19 manuals, the flakiness index should not exceed 30% and the test is applicable to aggregates larger than 6.3mm.

2.3.1.4 Adhesion with bitumen

The affinity to water by bituminous pavements construction aggregates should be as minimum as possible. The porosity of aggregates various from one material to the other, and this is determined by the amount of liquid absorbed when aggregates is soaked in water. The intent of this test is to eliminate the use of porous, absorptive aggregates to eliminate stripping of bitumen and eliminate excessive absorption of binder by the aggregates (.P & Adiseshu, 2013). From (Note, 2002), water absorption should be determined and its value should not exceed 2% for the aggregates to qualifier as a road construction material.

2.3.1.5 Durability

Durable or sound aggregates should resist the disintegrating actions caused by repeated cycles of wetting and drying, or change in temperature and this resistance is determined by sulphate soundness testing in the laboratory (Egesi & Tse, 2012). This is accomplished by repeated immersion of weighed aggregate sample in saturated solutions of sodium sulphate followed by oven drying, to dehydrate the salt precipitated in permeable pores spaces for a period of five days. Normally, the aggregates are subjected to the physical and chemical action in the environment demanding that the aggregates used in the construction be sound enough to withstand the weathering action (Clark et al., n.d.). From the (Note, 2002), the Sodium Sulphate Soundness Test (SSS) should be conducted and its value should not exceed 12% for the aggregate to be classified as a durable material (Note, 2002).

2.3.1.6 Freedom from deleterious particles

Aggregates used in road construction should be free from adherent silt size and clay size material as its strength is compromised. It is important to use coarse aggregates as they consume less bitumen compared to fine ones and tend to withstand heavier load (B.L Gupta, 2010).

2.3.1.7 Specific gravity

The specific gravity of aggregates indicates the strength or quality of the material. A higher specific gravity value generally implies a stronger aggregate and vice versa and the values ranges between 2.5 to 2.9 ((1963), n.d.).

2.3.1.8 Aggregate Impact Value (AIV)

Traffic loading on the road surface due to movement of vehicles causes aggregate to break into smaller pieces. This breakage alters the aggregates gradation, widening the gap between properties of the laboratory designed mix and field produced mix finally causing construction and performance problems (Wu, Parker, & Kandhal, 1998). The aggregates should therefore have sufficient toughness to resist breakages due to vehicle impact. This breakage characteristic is measured by impact value test (AIV) and should not exceed 30% (Note, 2002).

2.3.1.9 Sieve Analysis

The purpose of sieve analysis is for determining the percentages of various sizes of minerals aggregates to use to get a mix of maximum density (Chakroborty & Das, 2003). The particle size distribution of aggregates is usually determined and specified by passing aggregates through various sieve sizes and that reveals the size makeup of aggregates from the largest to the smallest. For hot bituminous mixture design and analysis, an aggregates sieve analysis uses the following standard sieve sizes: 37.5 mm, 25.0 mm, 19.0 mm, 12.5 mm, 9.5 mm, 4.75 mm, 2.36 mm, 1.18mm, 0.60mm, 0.30 mm, 0.15mm, and 0.075 mm among others (Clark et al., n.d.).

The strength and the performance of a bituminous mixture are dependent to a greater extent on the composition of aggregates used. Aggregates used in bituminous paving mixture as coarse, fine and as mineral filler (AL-Saffar, 2013). The main purpose of coarse aggregates is in contributing to the stability of a bituminous paving mixture due to the interlocking and frictional resistance to the adjacent particles, while fines and mineral fillers, fills the voids between the course aggregates (Clark et al., n.d.). Good aggregates selection through gradation is important as this assist in achieving high bulk density, high physical stability, and low permeability (Mamlouk & Zaniewski, 2011).

The results of an aggregate sieving analysis in bituminous mixture technology are usually presented as weight percent passing (Clark et al., n.d.). In this study, three types of aggregates were passed through different sizes of sieves. They included aggregates size 10/14, 6/10 and 0/6 representing coarse aggregates, fine and mineral fillers respectively, all from Aristocrat quarry in Mlolongo.

It is important to note that a good bituminous pavement requires good bitumen, aggregates and equipment and also requires knowledge, skill, and workmanship. Part of this knowledge and skill is the ability to blend aggregates to meet a specific mix, known as the job-mix formula achieved through trial and error methods (Mathew, 2007). The aggregates proportion is varied by varying their percentages and a graph is drawn to determine the kind of blend to be used in preparing the bituminous mixture.

2.4 RE - CYCLING OF WASTE SUGAR CANE BAGASSE ASH

Plenty of sugarcane bagasse ash which is produced in Kenya today by approximately seventy industries spread out throughout the country and most of these waste are used for shopping, packaging and as trash can liners (Eunice Muchane and Grace Muchane (2006), n.d.). Over twenty-four million bagasse are used monthly in Kenya, half of which end up in the solid waste main stream (Ong’unya Raphael Odhiambo, Aurah Cathrine Musalagani & Ruth, 2014). The expansion of sugar can production and consumption is having a major impact, both visibly and invisibly on the social-physical environment in Kenya (M.M. Ikiara, A.M. Karanja, 2004). Due to ease of accessibility and affordability of sugar cane bagasse ash, the waste generated increases by the day contributing to the blockage of sewer, landfills and adding to the expanding amount of solid waste creating a menace in the environment.

The need to tackle this menace has been high with companies mushrooming in this country engaging in waste bagasse recycling. Some of these companies include Nairobi Plastics, Central Glass, Kamongo Waste Paper, Madhu Paper, and Premier Rolling Mills among others (Verma, 2008). Despite the effort by these private organizations, rampant littering is still experienced and additional methods should be introduced to reduce the pollution of the environment by sugar cane bagasse.

2.5 WASTE SUGAR CANE ASH (WSCA)

Researchers have focused their studies on the utilization of industrial and agricultural waste produced by industrial processes focusing on economic, environmental, and technical reasons so as to minimize their effect on the environment. Waste material such as rice husk ash, wheat straw ash, hazel nutshell and sugarcane bagasse ash (referred here as Waste Sugar Cane Ash) are used as construction material for the development of concrete due to their pozzalanic properties (Ganesan K, Rajagopal K, 2007). Sugarcane is a major crop grown in many countries in the world for the production of sugar through processing it in sugar mills that generates millions of tonnes of sugar cane ash as a waste material.

About 40-45% of fibrous residue is obtained after extraction of all economical sugar from sugarcane, and later reused as fuel in boilers for heat generation leaving behind approximately 8 -10 % of ash as waste (H. Otuoze, Y.Amartey, B. Sada, H.Ahmed, 2012). The WSCA has no other economic value and can only be dumped in the open field and this poses a serious threat of polluting air and water bodies and landfills (R, B, & Pradeep T, 2012).

In Kenya, Mumias Sugar Company have boilers that have a capacity of burning 70 tonnes of bagasse per hour with a weekly ash output of approximately 120 tonnes when running at full capacity (Mwero et al, 2011). This waste product is non-biodegradable solid material currently being disposed as soil fertilizer though this is not environmentally sustainable (Schettino & Holanda, 2015). Water has to be added to the ash to avoid wind blowing it around thus causing environmental hazard. This calls for urgent ways of handling the waste as it is becoming a menace.

Srinivasan and (Srinivasan & Sathiya, 2010) carried a study on partial replacement of cement with Sugar Cane Baggase Ash (SCBA) and concluded that SCBA improves the quality of construction material such as concrete blocks, mortar, and soil cement interlocking block and thus reducing their production cost. Also the compressive strength of blocks is improved ((Dhengare, Raut, Bandwal, & Khangan, 2015), (Anand & Mishra, 2016) and workability of fresh concrete was improved (Anand & Mishra, 2016).

Typical fillers are fine powder in nature with particle size of less than 75µm and they include industrial waste such as fly ash or natural occurring products like cement, stone dust or calcium carbonate. Filler modify a material by the manner in which it gets distributed in a liquid and how it interacts with the liquid phase of the mixture (Mohi et al., 2015). This interaction creates a chemical bond or physical interaction leading to a reinforced material strength.

Ishfaq and Supriya (2015) carried out a study on the influence of fillers on paving grade bitumen using cement, fly ash and stone dust. The stability value of bitumen was found to improve with cement giving the highest stability value. This could be attributed to the fact that, the fillers tend to fill the voids in the aggregates and also improved the resistance of pavement to permanent deformation. Konstantin et al (2013) investigated on the effect of fly ash on bituminous mixture and concluded that fly ash improved the rheological properties of bitumen, its ageing resistance and consequently increasing the longevity of a pavement.

WSCA has pozzolanic properties comparable to Ordinary Portland Cement (OPC) and can have particles size comparable to filler material making it suitable as an additive in bituminous mixtures. The Utilization of WSCA as bitumen modifier may improve the properties of bitumen and minimize the negative environmental effects with its disposal.

2.6 SUMMARY OF GAPS IN REVIEWED LITERATURE

From the literature review, it has emerged that the modification of bitumen has been studied for a number of years since 1970s though they have concentrated mostly on bitumen modification using polymers (Zhu et al, 2014). While scholars in developed countries like India, USA, and Arabian Countries have researched on modified bitumen, none or very little has been carried out locally.

During the review of the literature, it is apparent that there are no studies which has been conducted in the area of bitumen modification using Waste Sugar Cane Ash. Bitumen has been modified mostly by the use of polymers such as plastomers (for example, polyethylene (PE), polypropylene (PP), ethylene-vinyl acetate (EVA), ethylene-butyl acrylate (EBA)) and thermoplastic elastomers (for example, styrenebutadiene- styrene (SBS), styrene-isoprene-styrene (SIS), and styreneethylene/butylene-styrene (SEBS) (Polacco et al, 2005; Shirish et al, 2014; Tapase et al, 2014; and Tariq et al, 2014). Due to the successes achieved by binder modified by polymer, researchers has paid little interest on the modification of bitumen by other additives. Other additives that have been used to modify bitumen include sulphur, magnesium and crumb rubber among others (Vivian and Tam, 2006).

This research is intended to address that gap by introducing WSCA as a bitumen modifier. SWPB that has been used widely in other countries as a bitumen modifier, will be used to generate results that will be comparable to WSCA. Unlike Verma, 2008 whose study concentrated on modification of bitumen using SWPB whose particles sizes used were retained in sieve 2.36mm. The particle sizes will be limited to only those that will pass through sieve 2.36mm for both SWPB and WSCA. It will assist the investigator have the same comparable particle sizes for both SWPB and WSCA.

The modified bitumen together with tested aggregates were used to prepare briquette and determine their volumetric properties. This is the first study that has focused on the use of WSCA and a blend of WSCA and SWPB as a modifier of conventional bitumen.

CHAPTER 3

MATERIALS AND METHODS

3.1 INTRODUCTION

In this chapter, the details of research work and the procedure of how this study was carried out is explained. Before proceeding to the procedures of laboratory tests, desktop study was carried out to explore the background information of the study. The aim of the research was to assess the physical properties of modified bitumen binder in Hot Bituminous Mixture (HBM) design. Tests were conducted according to the required specifications, laboratory test procedures and information on the materials used. The sample mix tested involved three types of modified bitumen with shredded waste plastic bags, waste sugar cane ash and a blend of the two wastes. The standard bitumen tests were used to determine the properties of modified bitumen while Marshall Stability was used to determine the volumetric properties of the bituminous mixture.

3.2 Research Design

The study was conducted based on laboratory tests as a main procedure to obtain data sets and results. All the tests were conducted using the facilities available in the University of Babu Banarasi Das and Ministry of Roads bituminous laboratory. The laboratory tests were divided into several stages beginning with sieving of WSCA to remove any unburned materials and any material retained in sieve 2.36 mm respectively, testing of conventional bitumen, modified bitumen and aggregate preparation. Sieving analysis was carried out to separate aggregate into different sizes. Marshall Stability test method was used to determine the strength of the mix, determine the optimum bitumen content, and other parameters.

3.3 Material Collection

The binder used in this study was grade VG 30 and was bought from the BBD Campus. Aggregates were well blended and were purchased from Local Market. The waste sugarcane bagasse ash was obtained from Rauza Mill which is 63 Km. apart from Lucknow and Rauza Mill is situated in Faizabad.

Fig. 3.1 Rauzagaon Chini Mill

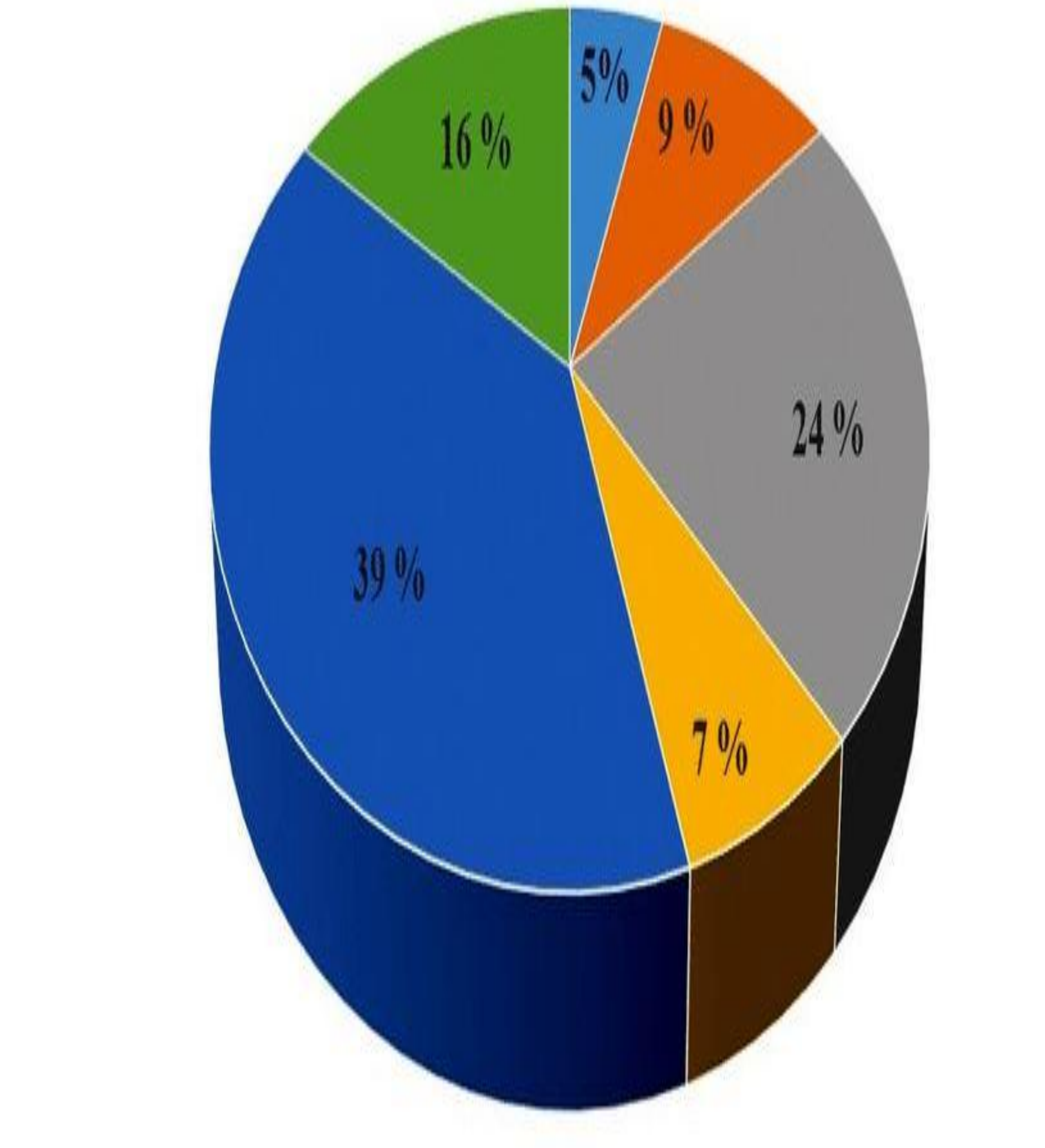


Fig. 3.2 Production of Bagasse in India

3.3.1 Waste Sugar Cane Ash

Figure 3.3 is a flow chart representing modification of bitumen with WSCA.

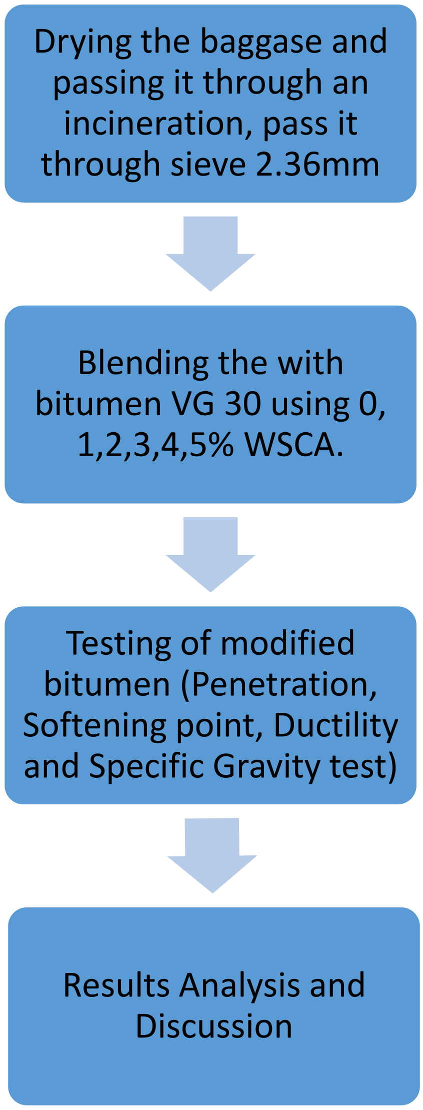


Fig. 3.3 Flow Chart of Modification of bitumen with WSCA

Fig. 3.4 Sugar Cane Bagasse

Fig. 3.5 Sugar Cane Bagasse Ash

Fig. 3.6 Production of Bagasse Ash

Particle size distribution of SCBA

The SCBA particles that are dumped in an open area shows larger diameter size. Since raw SCBA has a larger particle size and ha high porosity thus results lower compressive strength when mixed with mortar. The original SCBA can be reduced to 56.5% smaller by grinding.

The observations made are:-

- The temperature at which SCBA burnt is responsible for particle size of SCBA.
- SCBA particles can be available at any required particle size based on grinding time.
- SCBA specific surface is increased rapidly with respect to grinding then burning the SCBA.

3.4 Material Testing

3.4.1 Sieve Analyses

Single size aggregate size 10/14 and 6/10 were oven dried and their weight taken, while single size aggregate 0/6 were first cleansed to remove all the dust and then oven dried and their weight taken.

A representative sample of the above aggregate was passed through a series of sieves stacked progressively from the top to the bottom as shown in Plate 3.1 and the entire nest agitated. The material whose diameter was smaller than the mesh opening passed through the sieves. After the aggregate reached the bottom pan, the amount of material retained in each sieve was weighed. The results of mechanical analysis were presented by semi-logarithmic plots known as particle-size distribution curves.

3.5 Bitumen's

3.5.1 Overview

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost. Bituminous materials consists of bitumen which is a black or dark colored solid or viscous cementitious substances consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar.

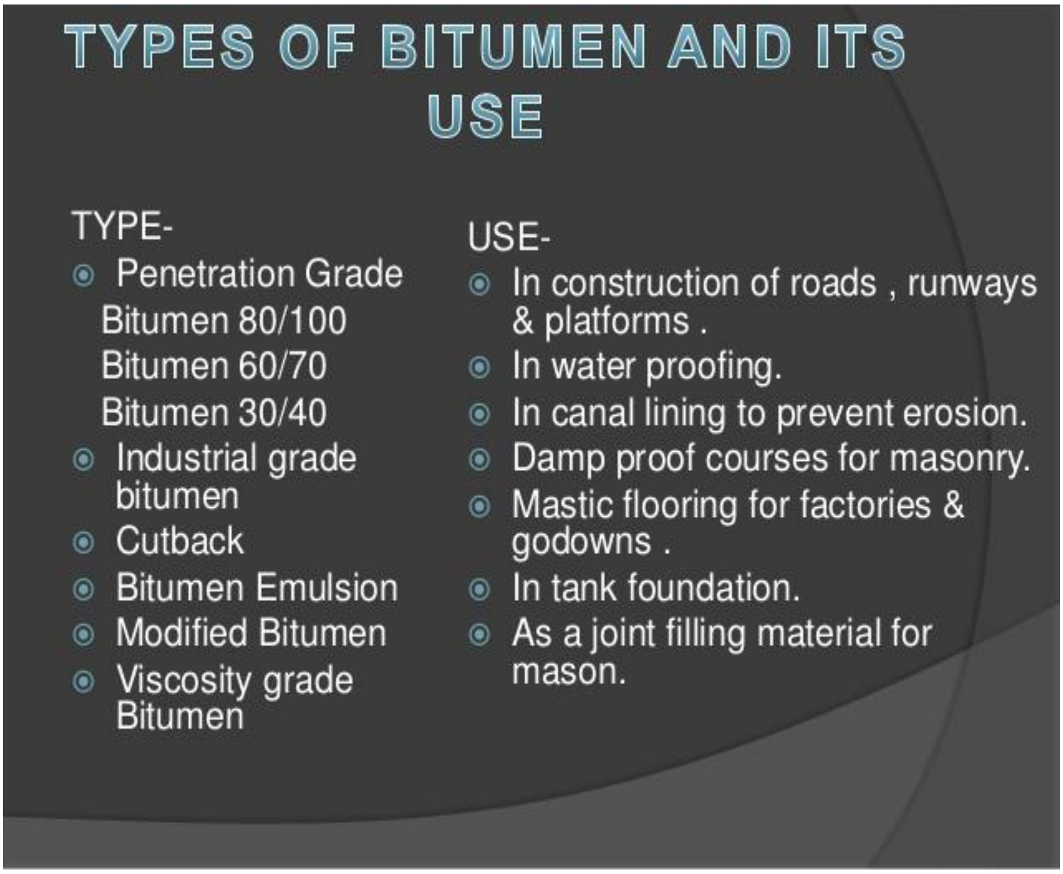


Fig. 3.7 Types of Bitumen

3.5.2 Production of Bitumen

Bitumen is the residue or by-product when the crude petrolium is refined. A wide variety of refinery processes, such as the straight distillation process, solvent extraction process etc. may be used to produce bitumen of different consistency and other desirable properties. Depending on the sources and characteristics of the crude oils and on the properties of bitumen required, more than one processing method may be employed.

3.5.3 Vacuum steam distillation of petroleum oils

In the vacuum-steam distillation process the crude oil is heated and is introduced into a large cylindrical still. Steam is introduced into the still to aid in the vapourisation of the more volatile constituents of the petroleum and to minimise decomposition of the distillates and residues. The volatile constituents are collected, condensed, and the various fractions stored for further refining, if needed. The residues from this distillation are then fed into a vacuum distillation unit, where residue pressure and steam will further separate out heavier gas oils. The bottom fraction from this unit is the vacuum-steam-refined asphalt cement. The consistency of asphalt cement from this process can be controlled by the amount of heavy gas oil removed. Normally, asphalt produced by this process is softer. As the asphalt cools down to room temperature, it becomes a semi solid viscous material.

3.5.4 Different forms of bitumen

3.5.4.1 Cutback bitumen

Normal practice is to heat bitumen to reduce its viscosity. In some situations preference is given to use liquid binders such as cutback bitumen. In cutback bitumen suitable solvent is used to lower the viscosity of the bitumen. From the environmental point of view also cutback bitumen is preferred. The solvent from the bituminous material will evaporate and the bitumen will bind the aggregate. Cutback bitumen is used for cold weather bituminous road construction and maintenance. The distillates used for preparation of cutback bitumen are naphtha, kerosene, diesel oil, and furnace oil. There are different types of cutback bitumen like rapid curing (RC), medium curing (MC), and slow curing (SC). RC is recommended for surface dressing and patchwork. MC is recommended for premix with less quantity of fine aggregates. SC is used for premix with appreciable quantity of fine aggregates.

Fig. 3.8 Cutback bitumen

3.5.4.2 Bitumen Emulsion

Bitumen emulsion is a liquid product in which bitumen is suspended in a finely divided condition in an aqueous medium and stabilized by suitable material. Normally cationic type emulsions are used in India. The bitumen content in the emulsion is around 60% and the remaining is water. When the emulsion is applied on the road it breaks down resulting in release of water and the mix starts to set. The time of setting depends upon the grade of bitumen. The viscosity of bituminous emulsions can be measured as per IS: 8887-1995. Three types of bituminous emulsions are available, which are Rapid setting (RS), Medium setting (MS), and Slow setting (SC). Bitumen emulsions are ideal binders for hill road construction. Where heating of bitumen or aggregates are difficult. Rapid setting emulsions are used for surface dressing work. Medium setting emulsions are preferred for premix jobs and patch repairs work. Slow setting emulsions are preferred in rainy season.

Fig. 3.9 Bitumen Emulsion

3.5.4.3 Bituminous primers

In bituminous primer the distillate is absorbed by the road surface on which it is spread. The absorption therefore depends on the porosity of the surface. Bitumen primers are useful on the stabilized surfaces and water bound macadam base courses. Bituminous primers are generally prepared on road sites by mixing penetration bitumen with petroleum distillate.

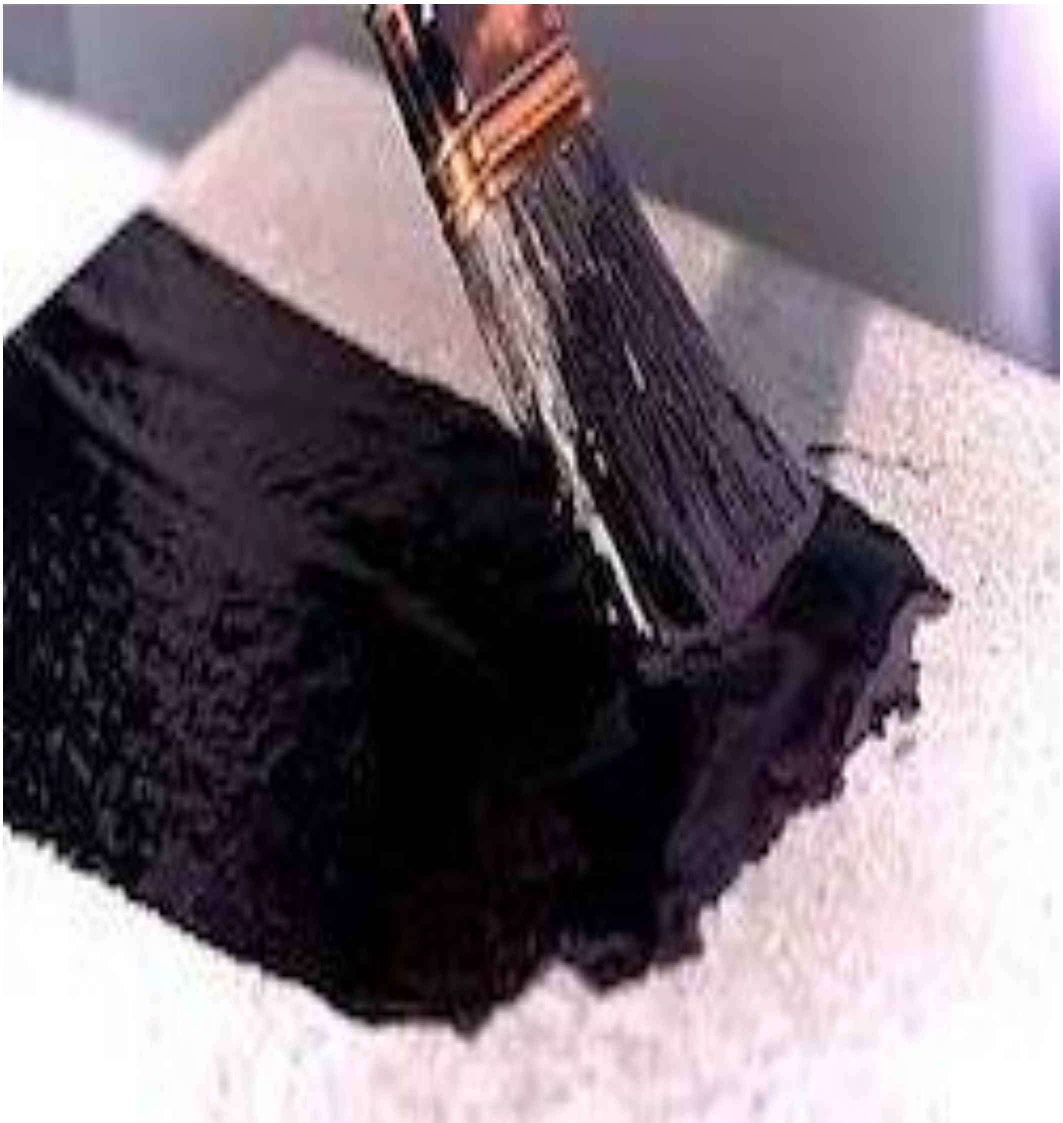


Fig. 3.10 Bituminous primers

3.6 Bitumen Tests

3.6.1 Modified bitumen

Standard bitumen tests were used to evaluate the quality of modified bitumen and bituminous mixtures. Conventional bitumen was mixed with shredded waste plastic bags, waste sugar cane ash and the blend of the two to form the modified bitumen.

The modified bitumen samples were prepared by adding 1, 2, 3, 4, 5 and 6, 7.5, 10 and 12.5% by weight of the bitumen to different portions of bitumen. The SWPB proportions were added to the hot molten bitumen of temperature around 170 – 180^{0}C by constantly stirring until the mixture was homogeneous and was set aside to cool down.

Based on the above proportions, the waste sugar cane ash was added to conventional bitumen in proportions of 1, 2, 2.5, 3, 4 and 5%.

More bitumen modified samples were prepared by mixing the two waste in different proportions and later mixing them with conventional bitumen. 2.5% WSCA and 1.5% SWPB, 1.5% WSCA and 2.0% SWPB and 2.0% WSCA and 1.0% SWPB by weight of bitumen were added slowly to the molten bitumen until a homogeneous mixture was attained. It is important to note that replacement method was used. For every percent additional of waste, the bitumen quantity was reduced by the same percentage. Additional of less waste to the bitumen implied a soft blend while higher percentages resulted in a stiffer blend.

The modified bitumen was subjected to a series of standard laboratory tests to determine its physical properties and the results were tabulated. The test that were carried out included: -

- Penetration test
- Ductility test
- Softening point test
- Specific gravity test
- **3.5.1.1 Penetration test**

It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds. BIS had standardized the equipment and test procedure. The penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and locking in any position. The bitumen is softened to a pouring consistency, stirred thoroughly and poured into containers at a depth at least 15 mm in excess of the expected penetration. The test should be conducted at a specified temperature of 25^{0}C. It may be noted that penetration value is largely influenced by any inaccuracy with regards to pouring temperature, size of the needle, weight placed on the needle and the test temperature. A grade of VG30 bitumen means the penetration value is in the range 60 to 70 at standard test conditions. In hot climates, a lower penetration grade is preferred. The Figure shows a schematic Penetration Test setup.

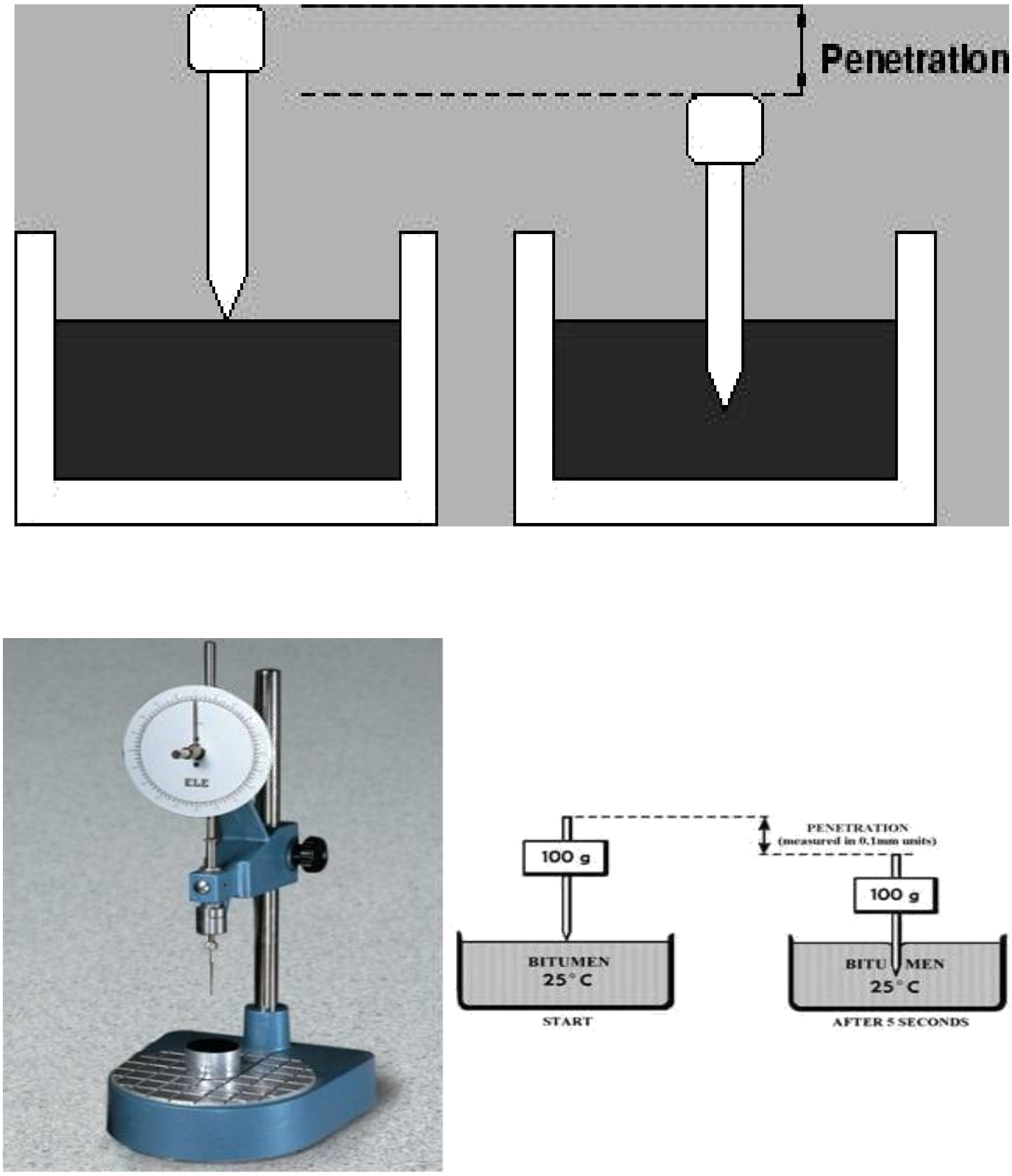


Fig. 3.11 Penetration test

3.5.1.2 Ductility test

Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured in the mould assembly placed on a plate. These samples with moulds are cooled in the air and then in water bath at 27^0C temperature. The excess bitumen is cut and the surface is leveled using a hot knife. Then the mould with assembly containing sample is kept in water bath of the ductility machine for about 90 minutes. The sides of the moulds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of breaking of thread is the ductility value which is reported in cm. The ductility value gets affected by factors such as pouring temperature, test temperature, rate of pulling etc. A minimum ductility value of 75 cm has been specified by the BIS. Figure shows ductility moulds to be filled with bitumen.

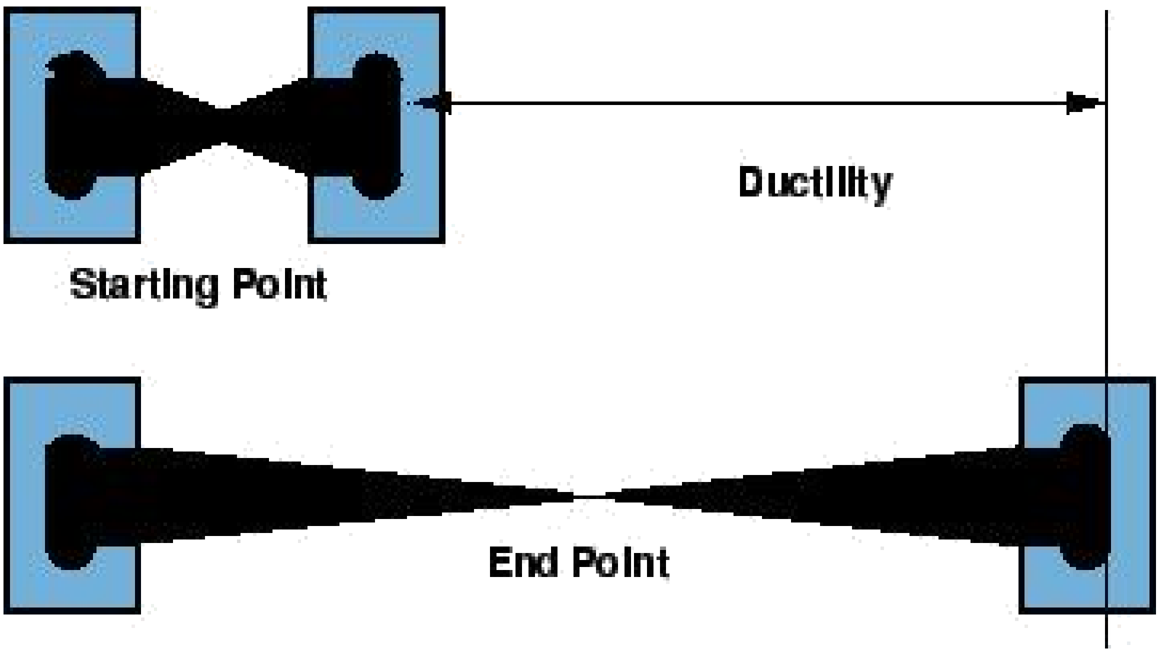


Fig. 3.12 Ductility test

3.5.1.3 Softening point test

Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test. The test is conducted by using Ring and Ball apparatus. A brass ring containing test sample of bitumen is suspended in liquid like water or glycerin at a given temperature. A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5^0C per minute. Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below. Generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates. Figure shows Softening Point test setup.

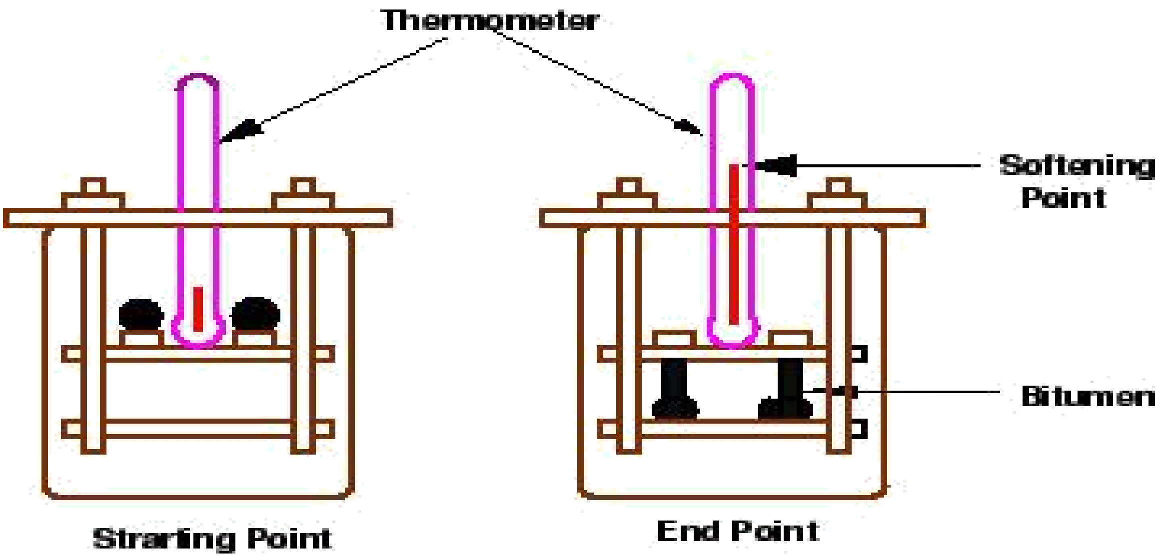


Fig. 3.13 Softening point test

3.5.1.4 Specific gravity test

In paving jobs, to classify a binder, density property is of great use. In most cases bitumen is weighed, but when used with aggregates, the bitumen is converted to volume using density values. The density of bitumen is greatly influenced by its chemical composition. Increase in aromatic type mineral impurities cause an increase in specific gravity.

The specific gravity of bitumen is defined as the ratio of mass of given volume of bitumen of known content to the mass of equal volume of water at 27^0C. The specific gravity can be measured using either pycnometer or preparing a cube specimen of bitumen in semi solid or solid state. The specific gravity of bitumen varies from 0.97 to 1.02.

3.5.1.5 Viscosity test

Viscosity denotes the fluid property of bituminous material and it is a measure of resistance to flow. At the application temperature, this characteristic greatly influences the strength of resulting paving mixes. Low or high viscosity during compaction or mixing has been observed to result in lower stability values. At high viscosity, it resist the comp active effort and thereby resulting mix is heterogeneous, hence low stability values. And at low viscosity instead of providing a uniform film over aggregates, it will lubricate the aggregate particles. Orifice type viscometers are used to indirectly find the viscosity of liquid binders like cutbacks and emulsions. The viscosity expressed in seconds is the time taken by the 50 ml bitumen material to pass through the orifice of a cup, under standard test conditions and specified temperature. Viscosity of a cutback can be measured with either 4.0 mm orifice at 25^0C or 10 mm orifice at 25 or 40^0C.

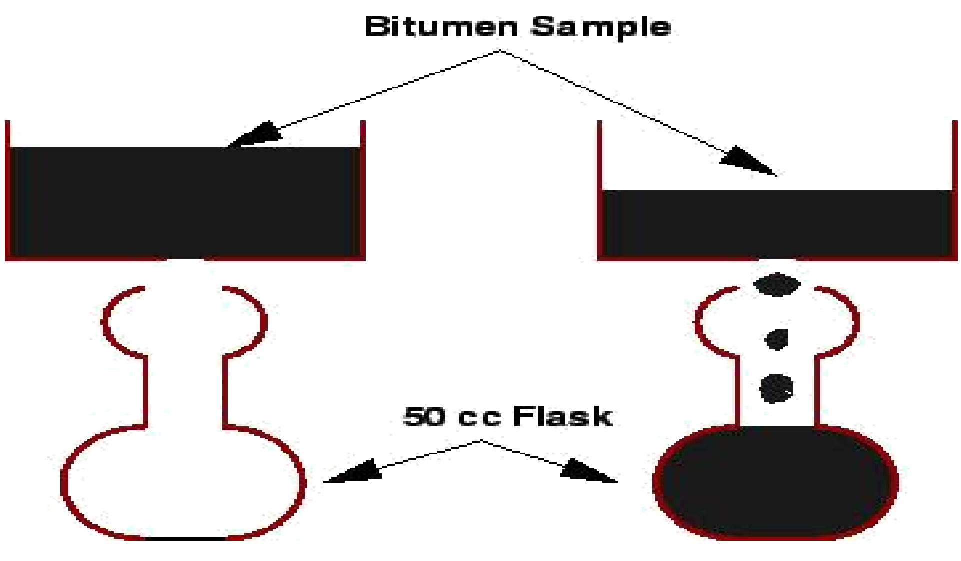


Fig. 3.14 Viscosity test

3.5.1.6 Flash and fire point test

At high temperatures depending upon the grades of bitumen materials leave out volatiles. And these volatiles catches fire which is very hazardous and therefore it is essential to qualify this temperature for each bitumen grade. BIS defined the flash point as the temperature at which the vapour of bitumen momentarily catches fire in the form of flash under specified test conditions. The fire point is defined as the lowest temperature under specified test conditions at which the bituminous material gets ignited and burns.

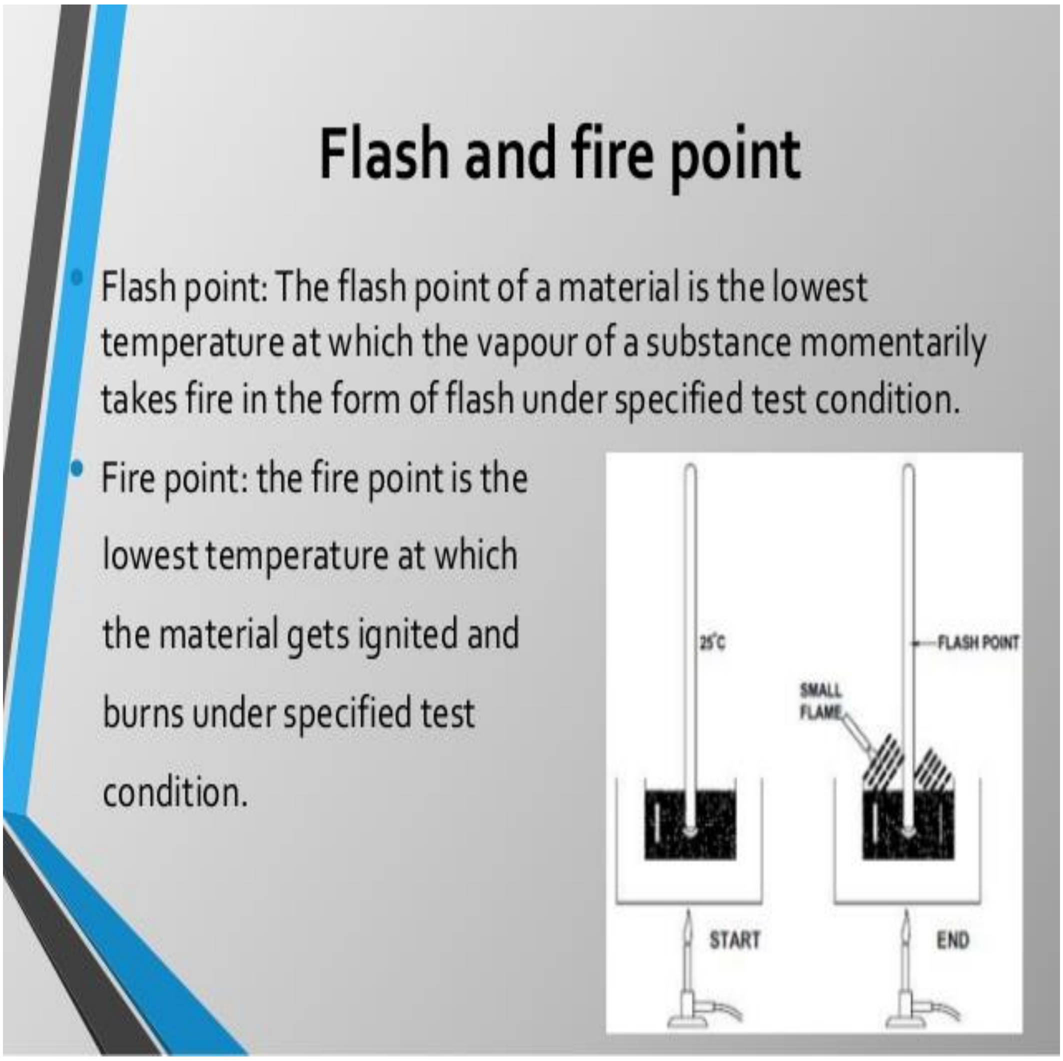


Fig. 3.15 Flash and fire point test

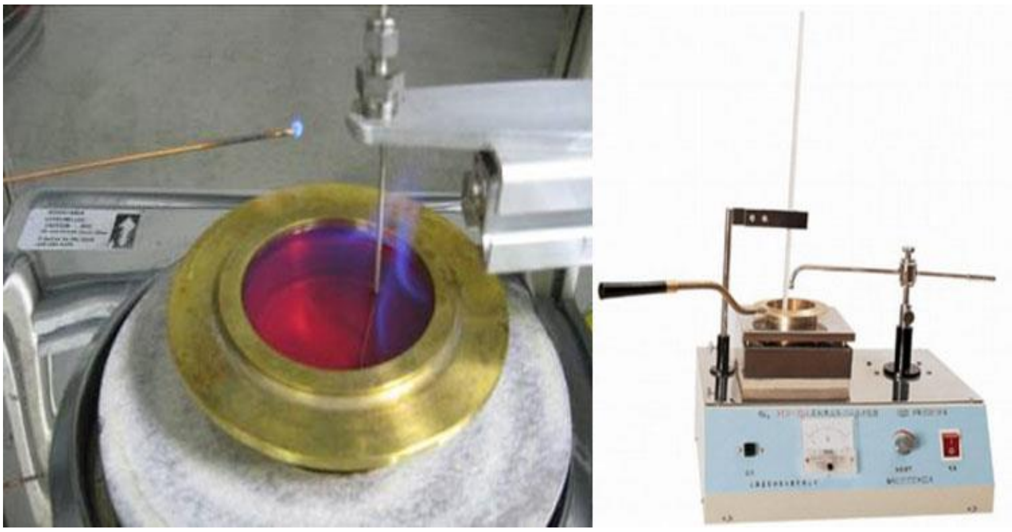


Fig. 3.16 Flash and fire point test

3.5.1.7 Float test

Normally the consistency of bituminous material can be measured either by penetration test or viscosity test. But for certain range of consistencies, these tests are not applicable and Float test is used. The apparatus consists of an aluminum float and a brass collar filled with bitumen to be tested. The specimen in the mould is cooled to a temperature of 5 C and screwed in to float. The total test assembly is floated in the water bath at 50 C and the time required for water to pass its way through the specimen plug is noted in seconds and is expressed as the float value.

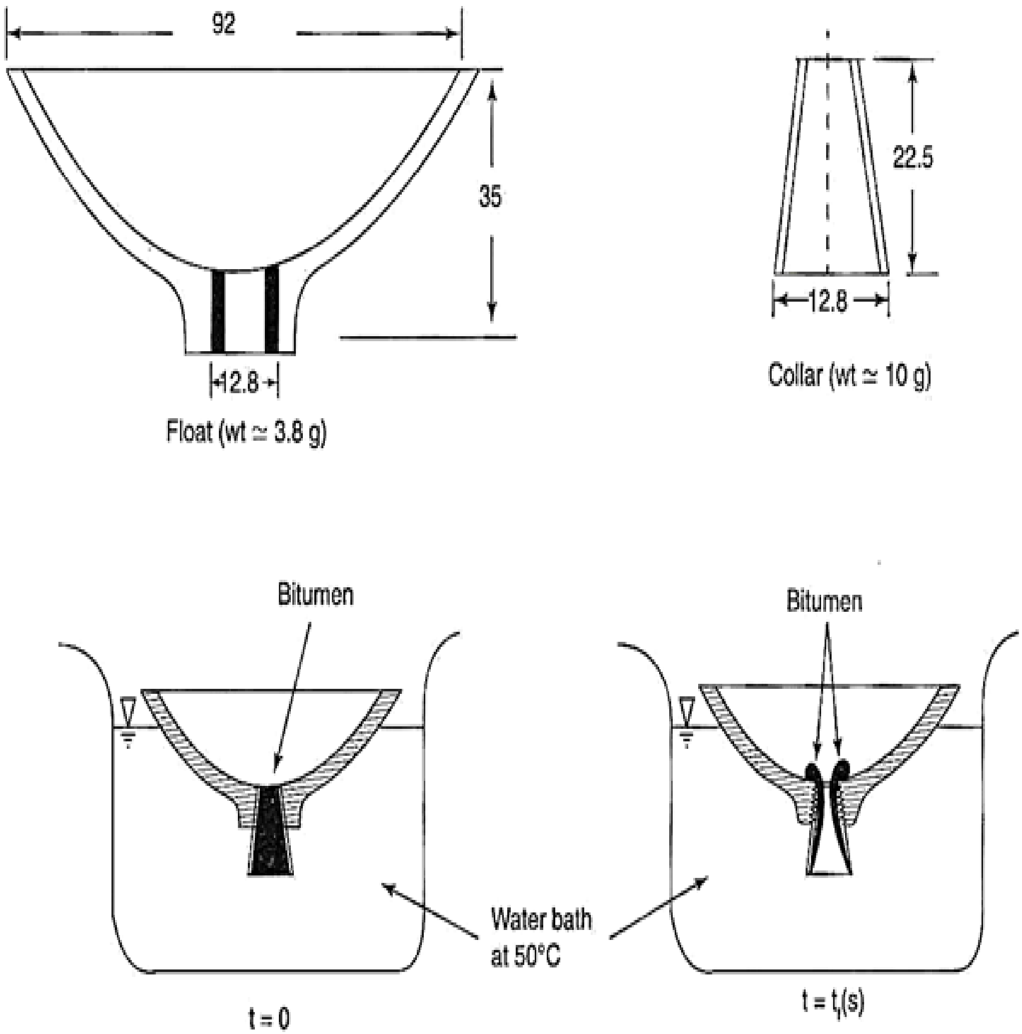


Fig. 3.17 Float test

3.5.1.8 Water content test

It is desirable that the bitumen contains minimum water content to prevent foaming of the bitumen when it is heated above the boiling point of water. The water in a bitumen is determined by mixing known weight of specimen in a pure petroleum distillate free from water, heating and distilling of the water. The weight of the water condensed and collected is expressed as percentage by weight of the original sample. The allowable maximum water content should not be more than 0.2% by weight.

3.5.1.9 Loss on heating test

When the bitumen is heated it loses the volatility and gets hardened. About 50gm of the sample is weighed and heated to a temperature of 163 C for 5hours in a specified oven designed for this test. The sample specimen is weighed again after the heating period and loss in weight is expressed as percentage by weight of the original sample. Bitumen used in pavement mixes should not indicate more than 1% loss in weight, but for bitumen having penetration values 150-200 up to 2% loss in weight is allowed.

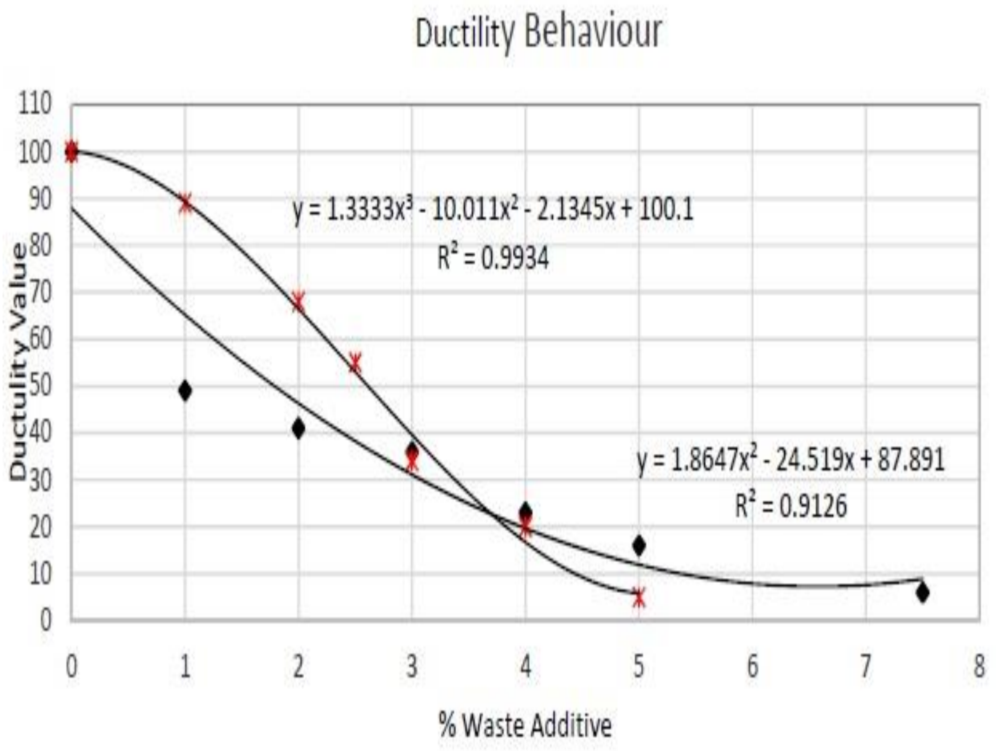
3.5.1.5 Marshall stability test

The Marshall Stability value of bituminous mixture was estimated as per ASTM D 1559. Approximately 1200g of aggregates was put together as per the determined percentages in the sieve analysis graph and heated to a temperature of 160-170˚C. Aggregates were heated to a temperature of 160˚C with the first trial percentage of bitumen (4.5% by weight of the mineral aggregates). The heated aggregates and bitumen were thoroughly mixed. The mix was placed in a preheated mold and compacted by a hammer having a weight of 4.5 kg and a free fall of 45.7 cm giving 75 blows on either side at a temperature of 160˚C to prepare the laboratory specimens of compacted thickness 63.5+/-3 mm. The briquette prepared are displayed as per Plate 3.5. The height of the samples was measured and specimens were immersed in a water bath. Three samples were prepared for each binder percentage added. The sample weight was taken both in air and in water to determine the bulk density of the sample.

Later, the load was applied to the specimen at a deformation rate of 50.8 mm/minute using Marshall Stability assembly. The load was increased until it reached a maximum when the load just began to decrease, the loading was stopped and the maximum load was recorded. Flow value was noted as the deformation of the sample at the maximum load. Measured stability values were corrected by multiplying each measured stability value by an appropriated correlation factors as given.

After the completion of the stability and flow test, bulk gravity and voids analysis was determined for each test specimen to determine the percentage air voids in mineral aggregate and the percentage air voids in the compacted mix and voids filled with bitumen. Values which were obviously erratic were discarded before averaging.

Volumetric parameters such as bulk specific gravity, stability, flow, percentage voids in minerals aggregates (VMA) and Voids filled with binder (VFB) were determined. Graphs were plotted using the obtained parameters separately against the bitumen content and a smooth curve drawn through the plotted values.



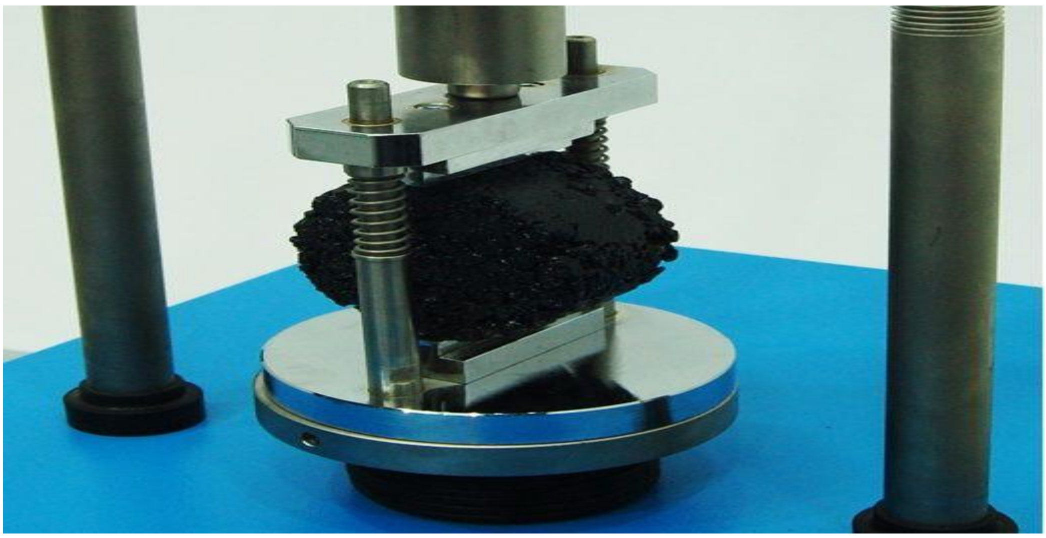


Fig. 3.18 Marshall Stability test

3.6 AGGREGATE TEST

There are various types of mineral aggregates used to manufacture bituminous mixes can be obtained from different natural sources such as glacial deposits or mines and can be used with or without further processing. The aggregates can be further processed and finished to achieve good performance characteristics. Industrial by-products such as steel slag, blast furnace slag, fly ash etc. sometimes used by replacing natural aggregates to enhance the performance characteristics of the mix. Aggregate contributes up to 90-95 % of the mixture weight and contributes to most of the load bearing & strength characteristics of the mixture. Hence, the quality and physical properties of the aggregates should be controlled to ensure a good pavement. Aggregates are of 3 types:

3.6.1 COARSE AGGREGATE

The aggregates retained on 4.75 mm sieve are called as coarse aggregates. Coarse aggregate should be screened crushed rock, angular in shape, free from dust particles, clay, and vegetation’s and organic matters which offer compressive and shear strength and shows good interlocking properties. In present study, stone chips are used as coarse aggregate with specific gravity 2.75.

Fig. 3.19 COARSE AGGREGATE

3.6.2 FINE AGGREGATE

Fine aggregate should be clean screened quarry dusts and should be free from clay, loam, vegetation or organic matter. Fine aggregates, consisting of stone crusher dusts were collected from a local crusher with fractions passing 4.75 mm and retained on 0.075 mm IS sieve. It fills the voids in the coarse aggregate and stiffens the binder. In this study, fine stones and slag are used as fine aggregate whose specific gravity has been found to be 2.6 and 2.45.

Fig. 3.20 FINE AGGREGATE

3.6.3 FILLER

Aggregate passing through 0.075 mm IS sieve is called as filler. It fills the voids, stiffens the binder and offers permeability. In this study, stone are used as filler whose specific gravity has been found to be 2.7 and 2.3.

For preparation of bituminous mixes (DBM) aggregates as per MORTH grading as given in Table 3.1 respectively, a particular type of binder and polyethylene, Polypropylene in required quantities were mixes as per Marshall Procedure. The specific gravity of aggregate are given in Table-3.2.

Table 3.1 Specific gravity of aggregates

Types of aggregates	Specific gravity
Coarse	2.75
Fine	2.6
Filler	2.7

Table 3.2 Gradation of Aggregates for DBM

Sieve size (mm)	Percentage passing	Spec. Limit of % Passing
40	100	100
25	97.8	85-100
20	73.78	71-95
12.5	61.7	58-82
10	55	52-72
4.75	37	35-50
2.36	35	28-43
0.6	20	15-27
0.3	18	7-21
0.15	10	5-15
0.075	4	2-8

3.7 Test Procedure of Marshall Stability Test

The apparatus for the Marshall Stability test consists of the following:

- Specimen mould assembly comprising mould cylinders 10.16cm diameter by 6.35cm height, base plate and extension collars.

- Specimen extractor for extracting the compacted specimen from the mould. A suitable bar is required to transfer load from the extension collar to the upper proving ring attachment while extracting the specimen.

- Compaction hammer having a flat circular tamping face 4.5kg sliding weight constructed to provide a free fall of 45 cm.

- Compaction pedestal consisting of a 20×20×45 cm wooden block capped with 30×30×2.5 cm MS plate to hold the mould assembly in position during compaction. Mould holder is provided consisting of spring tension device designed to hold compaction mould in place on compaction pedestal.

- Breaking head: this consists of upper and lower cylindrical segments or test heads having an inside radius curvature of 5 cm. the longer segment is mounted on a base having two perpendicular guide rods which facilitate insertion in the holes of upper test segment.

- Loading Machine: It is provided with a gear system to lift the upward direction. Pre-calibrated proving ring of 5 tones capacity is fixed on the upper end of the machine, specimen contained in the test head is placed in between the base and the proving ring.

  The load jack produces a uniform vertical moment of 5 cm per minute. Machine is capable of reversing its moment downward also. This facilitates adequate space for placing test head system after one specimen has been tested.

- Flow meter consist of guide, sieve and gauge. The activating pin of the gauge slides inside the guide sleeve with a slight amount of frictional resistance. Least count of 0.025 mm is adequate.

The flow value refers to the total vertical upward movement from the initial position at zero load to value at maximum load. The dial gauge of the flow meter should be able to measure accurately the total vertical moment upward.

In addition to above the following general equipment's are also required:

- Oven or hot plate
- Water bath
- Thermometers of range up to 200^0C with sensitivity of 2.5^0C and
- Miscellaneous equipment's like containers, mixing and handling tools etc.

3.7.1 Preparation of Test Specimen

- 1200 grams of aggregates blended in the desired proportions is measured and heated in the oven to the mixing temperature.
- Bitumen is added at the mixing temperature to produce viscosity of 170 ± centi-stokes at various percentages.
- The materials are mixed in a heated pan with heated mixing tools.
- The mixture is returned to the oven and reheated to the compacting temperature (to produce viscosity of 280±30 centi-stokes).
- The mixture is then placed in a heated Marshall mould with a collar and base and the mixture is spaded around the sides of the mould. A filter paper is placed under the sample and on top of the sample.
- The mould is placed in the Marshall Compaction pedestal.

- The material is compacted with 50 blows of the hammer (or as specified), and the sample is inverted and compacted in the other face with same number of blows.

- After compaction, the mould is inverted. With collar on the bottom, the base is removed and the sample is extracted by pushing it out the extractor.

- The sample is allowed to stand for the few hours to cool.

- The mass of the sample in air and when submerged is used to measure the density.

Test Procedure:

- Specimens are heated to 60 ±1oC either in a water bath for 30-40 minutes or in an oven for minimum of 2 hours.
- The specimens are removed from the water bath or oven and place in lower segment of the breaking head. The upper segment of the breaking head of the specimen is placed in position and the complete assembly is placed in position on the testing machine.
- The flow meter is placed over one of the post and is adjusted to read zero.
- Load is applied at a rate of 50 mm per minute until the maximum load reading is obtained.
- The maximum load reading in Newton is observed. At the same instant the flow as recorded on the flow meter in units of mm was also noted.

CHAPTER 4

RESULTS ANALYSIS AND DISCUSSION

4.1 Introduction

The chapter discusses the laboratory results for modified bitumen using shredded waste plastic bags, waste sugar cane ash and Marshall Stability test for hot bituminous mixture prepared using the modified binder. The tests were tabulated, necessary graphs drawn and test comparison carried out. The tests determining suitability of aggregates were also summarized in here.

4.2 Sieve Analysis and Aggregates Mix Design Result

The particle size distribution of all the three types of aggregates was determined through sieving analysis. The cumulative percent passing of the aggregate was found by subtracting the percent retained from one hundred percent. The results for each type of aggregate were then plotted on a different graph with cumulative percent passing on the y-axis and logarithmic sieve size on the x-axis. The results were used to determine compliance of the particle size distribution with applicable specification requirements.

the results for a sieve analysis of aggregates alongside the calculations of percent retained, cumulative percent retained, and percent passing for each aggregate particles are calculated as per the formula: -

$$\%\,Retained = \frac{W\ sieve}{W\ total}$$

Where, W_{sieve} is the weight of aggregate in the sieve

W_{total} is the total weight of the aggregate

$$\%\,Cummulative\ Passing = 100\ \% - \%\,Cummulative\ Retained$$

$$\%\,Passing = \frac{W\ below}{W\ total} \times 100$$

Where, W_{below} - The total mass of the aggregate within the sieves below the current sieve

W_{total} - The total mass of all of the aggregate in the sample.

Sieve Analysis for Aggregates size 6/10

Weight for the Sample = 615.6 gm

Table 4.1: Sieve Analysis for Aggregates size 6/10

Sieve sizes (mm)	Weight retained (g)	Percent Retained	Weight	Percent Passing
20	0	0		100
14	0	0		100
10	28.6	4.6		95.4
6.3	319	51.8		43.6
4	268	43.6		0
2	0	0		0
1	0	0		0
0.425	0	0		0

Sieve Analysis for Aggregates size 10/14

Weight for the Sample = 924.6 gm

Table 4.2: Sieve Analysis for Aggregates size 10/14

Sieve size (mm)	Weight retained (g)	Percent Retained	Percent Passing
20	0	0	100
14	142.8	15.5	84.6
10	684.8	74.1	10.4
6.3	96.4	10.4	0
4	0	0	0
2	0	0	0
1	0	0	0

Sieve Analysis for Aggregates Size 0/6

Weight for the Sample = 817.4 gm

Table 4.3: Sieve Analysis for Aggregates Size 0/6

Sieve sizes (mm)	Weight retained (g)	Percent Weight Retained	Percent Passing
20	0	0	100
14	0	0	100
10	0	0	100
6.3	4.9	0.6	99.4
4	89.1	10.9	88.5
2	143.9	17.6	70.9
1	0	26.4	44.5
0.425	0	16.8	27.7
0.3		5.5	22.2
0.15		5.6	16.6
0.075		2.9	13.7
Less than 0.075		13.7	0

A mix design was carried out through trial and error method to determine the proportions of different aggregates and how they should be mixed together for a strong blend. The mix proportions determined were 55% quarry dust (0/6), 23% size 6/10 aggregates and 22% size 10/14 aggregates and the results are as attached in the appendices one. From the trial and error method carried out, these aggregates have sufficient dust and no more fines to be added to it.

While actual grading of the aggregates is determined by combining the three single aggregates by weight using the above percentages against 1100g. Then sieving analysis is carried out on the combined aggregates and a graph is drawn to ensure the combined curves passes through the standard maximum and the minimum curve as per Figure.

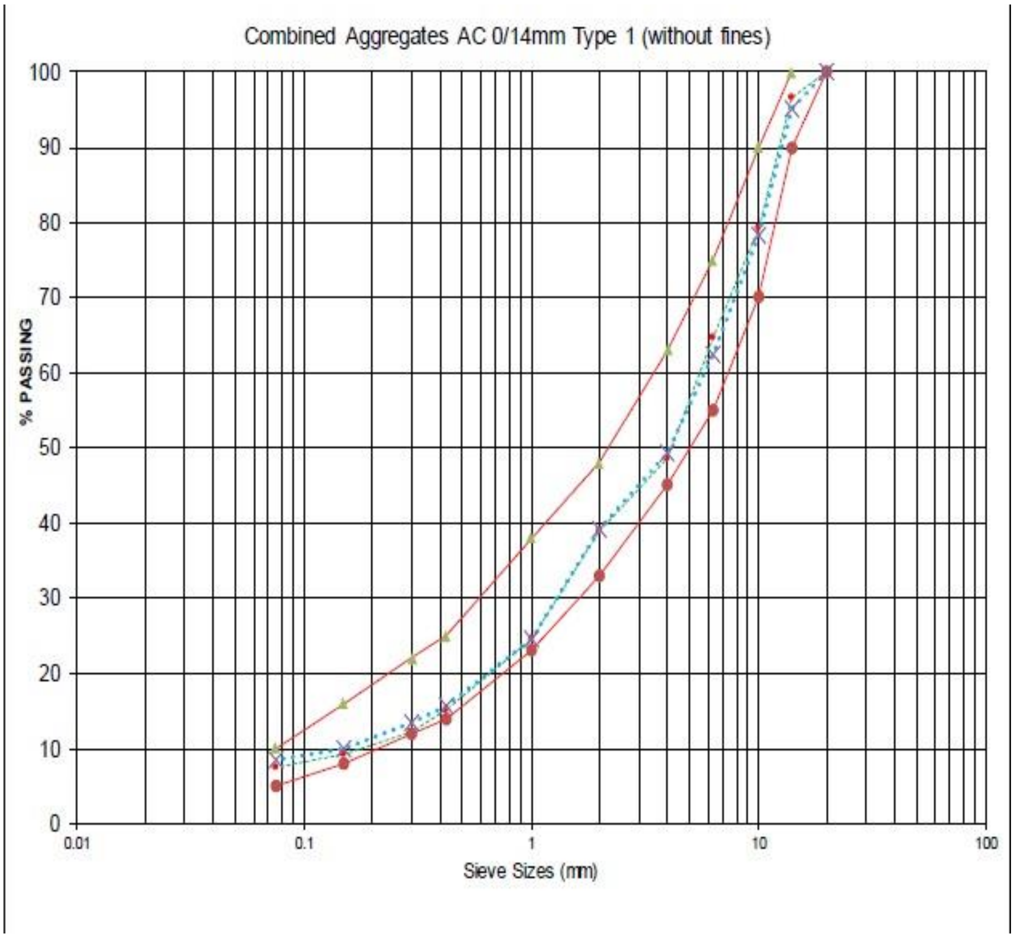


Fig.4.1: Graph of percentage passing of aggregates Vs sieve size (mm)

A particle size distribution analysis was a necessary classification test for aggregates in that it presents the relative portions of different sizes of aggregates. Proper mixing of aggregates is important before being mixed with hot bitumen as it ensures that the right sizes of voids are maintained for adequate covering of aggregates by the binder. Adequate voids in mineral aggregate (VMA) during mix design and in the field, helps in establishing sufficient film thickness without excessive binder bleeding or flushing (Robert, 1991)

The gradation of the aggregates used in this project gave a coarse blend that is economical as it consumes less binder. These aggregates are suitable as road construction material and will not interfere with performance of hot bituminous mixture.

4.3 Aggregates Test Results

The aggregates used in this study were subjected to various aggregates tests to determine their suitability as road construction material. The laboratory results for the various tests are summarized in the Table.

Table 4.4: Summary of the Aggregates Test Results

Property of aggregate	Type of Test	Standard	Value	Limitation
Crushing Strength	Aggregate Crushing Value	IS:2386(Part 4)	20.60%	30%
Hardness	Los Angeles Abrasion test	IS:2386(Part 5)	17.10%	35%
Toughness	Aggregate Impact Value	IS:2386(Part 4)	10.10%	30%
Durability	Soundness test	IS:2386(Part 5)	2%	12%
Shape Factor	Flakiness index	IS:2386(Part 1)	9.70%	
Specific Gravity & Porosity	Specific gravity	IS:2386(Part 3)	2.737	
Adhesion of Bitumen	Water absorption	IS 6241-1971	0.691	2%

From the test results tabulated above, it is clear that the aggregates used in this study were within the recommended parameters and thus good for road construction. The purpose of these tests is to ensure the results achieved at the end of the study are not influenced by the aggregates in a negative way.

4.4 Bitumen

Conventional bitumen used in this research was grade 60/70 as is commonly used in construction of bituminous roads in India. The conventional bitumen was taken through the standard bituminous test like penetration test, ductility test, ring and ball softening point test, specific gravity and its results are tabulated in Table to ascertain of its properties and compare them with the manufacturer's standard specification. The importance of the procedure is to ensure the bitumen being modified is pure with no additives. This will assist in establishing the effect of the modifiers on the bitumen. The results were presented.

4.5 Evaluations of mechanical properties of modified binder

A standard briquette weighs 1200gm, consisting of 80gm bitumen and 1120gm aggregates. The research concentrated in modifying the 80gm of bitumen by replacing the weight of the binder by the percentage weight of the additive.

The results of bitumen modified with waste sugar cane Ash (WSCA). In each sample of bitumen, a certain percentage of bitumen was replaced by the same percentage of WSCA and the sample taken through the standard bitumen test. The bitumen could only be replaced with 5% WSCA beyond which the blend became too stiff to be worked on. This could be due to pozzolanic nature of WSCA making it to absorb bitumen when blending and fill the molecular spaces in bitumen, thus making it stiff. Also the amount of bitumen decreases as the mount of modifier increases thus increasing the stiffness of the modified binder.

Table 4.5: Bitumen Modified with WSCA

% Wgt of WSCA	% Wgt of Bitumen	Penetration Value (mm)	Softening point Value (°C)	Ductility Value	Specific gravity value
0	0	87	53	100	1.01
1	99	78	53	89	1.02
2	98	67	55	68	1.04
2.5	97.5	62	56.6	55	1.05
3	97	58	57.3	34	1.07
4	96	45	58.2	28	1.08
5	95	30	59.8	20	1.09
6	94	Very Stiff			

The different percentages of the WSCA used in modifying bitumen were comparable to percentages of SWPB used in modifying bitumen and the consistency of modified binder and the maximum additives used was 6% due to workability.

4.5.1 Penetration Value

The Penetration Value of the convectional and modified binders are presented in Figure. They decreased with increase of Waste Sugar Cane Ash in the bitumen. The penetration value of binder modified with WSCA decreased from 87 to 30mm with increase of the additive from 0 to 5%.

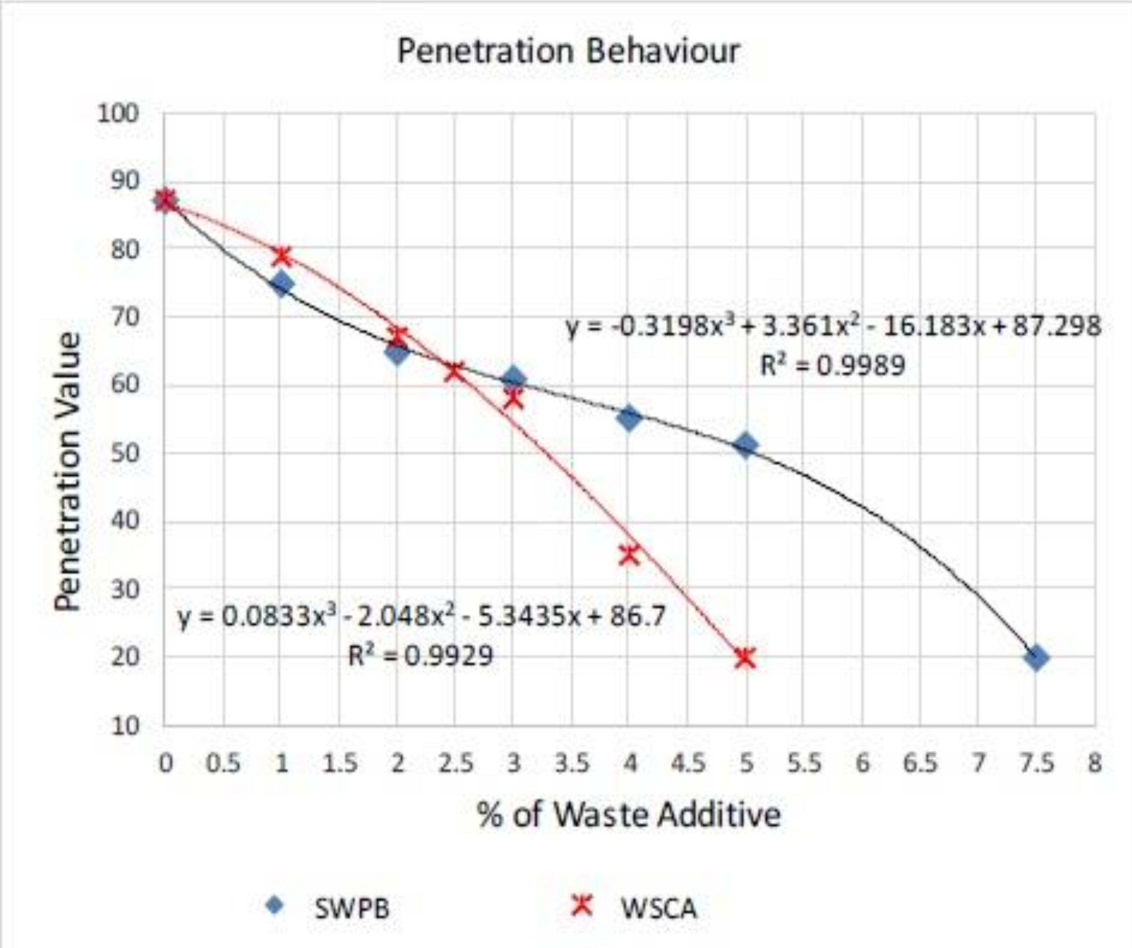


Fig 4.2. Penetration Vs Percent Waste Additive

The R2 is 0.9989 (99.89%) and 0.9929 (99.29%) for WSCA respectively, thus the line drawn is the best line of fit. There was a sudden drop in the penetration value when 1and 2% of WSCA was added to the bitumen then a gentle drop upon to 5% of the additive then another sudden drop. WSCA curve gave a gentle drop of penetration value. Polynomial equation indicated against each line will assist the investigator predict the behaviour of the penetration value with percentage increase of the waste additive.

Binder modified with WSCA were slightly softer than binder modified with WSCA up to 2.25% additive where stiffness increases. This could be due to the increase of impurities in the bitumen hindering the needle from penetrating further into the bitumen. WSCA due to its pozzolanic nature, will absorb bitumen and due to its fineness, mix with bitumen molecules much faster hindering the penetration needle from going further into the binder.

The performance of bitumen can be predicted by its penetration value as it represents its quantitative measure of bitumen in response to temperature. Therefore, bitumen with high penetration value can be referred to as soft and be used for cold climates while those with low values treated as hard are used for warm climates (Nurul et al, 2016). When the binder is soft, it will resist cracking at low temperature but undergo deformation under loading at high temperatures and vice versa (Tasdemir, 2009). The waste additive has a great effect on reducing the penetration value by increasing the stiffness of the modified binder. Lowering the penetration values of the binder makes it less susceptible to increase in temperature. The resistance of the binder to deformation is improved.

4.5.2 Softening Point

The relationship between softening point value of the bitumen and the additive is represented in Figure. The polynomial equation indicated against each line will assist the investigator predict the change in value of softening point with increase in waste material. The softening point value of the binder increases with increase of WSCA. The softening point value of binder modified with WSCA ranged between 55 to 66.6^{0}C, while that of binder modified with WSCA ranged between 53 to 57.3^{0}C with increase of the additives. Figure clearly indicates that the binder modified with WSCA has a higher softening point value than that of binder modified with WSCA.

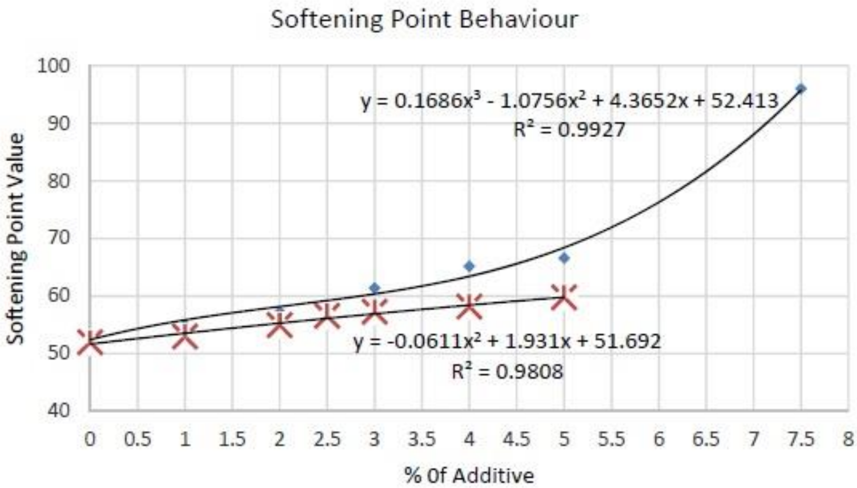


Fig. 4.3: Softening Point

Both additives increase the softening point of the binder and this phenomenon indicates that the resistance of the binder to the effect of heat is increased and reduces its tendency to soften in hot weather. The main idea of replacing bitumen with waste additive is to modify it so as to increase the resistance of the bituminous mixture to permanent deformation at high road temperature and still retaining the properties of the bitumen or bituminous mixture at other temperature (Poorna and Mohamed, 2014). The modified binder is less susceptible to temperature changes.

4.5.3 Ductility Value

The relationship between the ductility value of the bitumen and modifying additive is represented in Figure. The polynomial equation indicated against each line will assist the investigator predict the change in value of ductility index with percentage increase in the waste material.

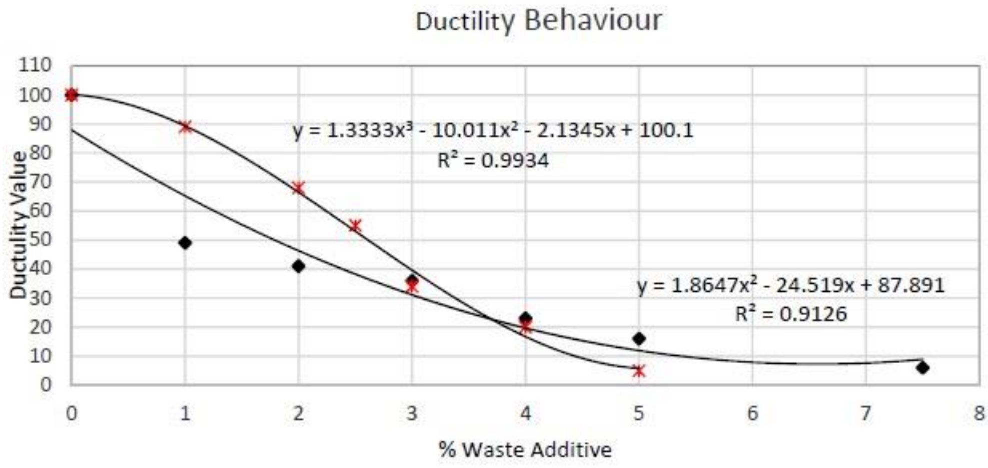


Fig. 4.4: Ductility Vs Percentage Waste Additive

The ductility value decreases with the increase of both SWPB and WSCA. It is very clear that ductility of the binder modified with SWPB decreases between 100 and 16mm, while that modified with WSCA decreases between 100 and 5mm with increase with both additives. The decrease in the ductility value could be due to the interlocking of waste molecules with bitumen. The binder modified with WSCA will stretch more than the one prepared using SWPB up to 3% of waste additive due to the interlocking nature of its molecules. Binder modified with WSCA.

This decrease in ductility value of the binder enables it to stretch less under loading and recovers quickly when the loading has been removed leading to reduction in deformation.

4.5.4 Specific Gravity

The relationship between specific gravity of modified binder and the percentage of waste material added to the bitumen is represented in Figure. The polynomial equation indicated against each line will assist the investigator predict the change in value of specific gravity with percentage increase of the waste material.

The Specific Gravity of the binder modified with SWPB decreased up to a certain level and then increased with increase with SWPB content while that modified with WSCA increased with increase with WSCA content. According to ASTM standards, the specific gravity of polythene material ranges between 0.910-0.960g/cm3 while that WSCA was estimated to be 1.2g/cm3 (Chennakesava and Prabath, 2015). This could be the reason why the values of specific gravity of the binder modified using WSCA are higher than binder modified using SWPB.

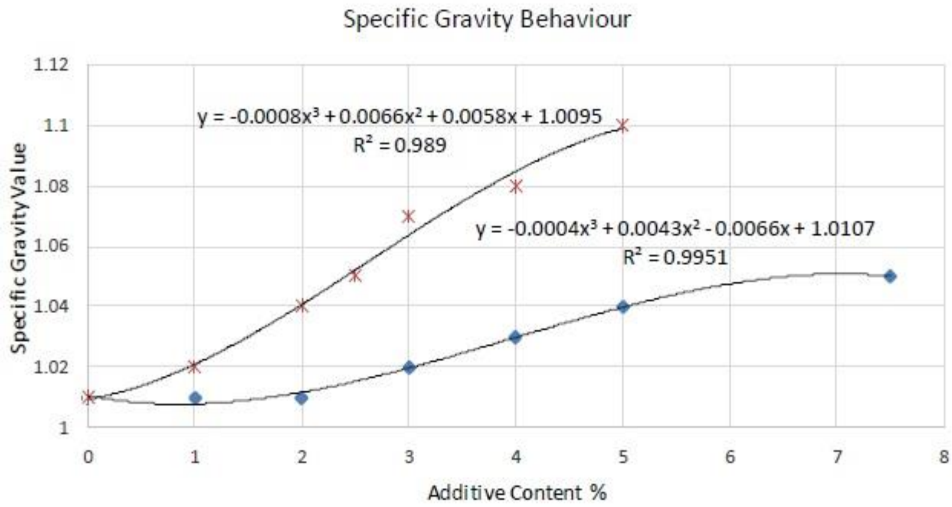


Fig. 4.5: Specific Gravity Vs Percentage of Additive

4.6 Marshall Stability Test

Marshall Stability tests were conducted on the different briquette and volumetric parameters like flow value, bulk density, voids filled with bitumen (VFB) and voids filled with mineral aggregates (VMA) were analysed and the results were attached. The results were converted to standard units using correction ratios and the results posted.

4.6.1 Bulk Density

Figure is for bulk density calculated from various briquette prepared using different binders.

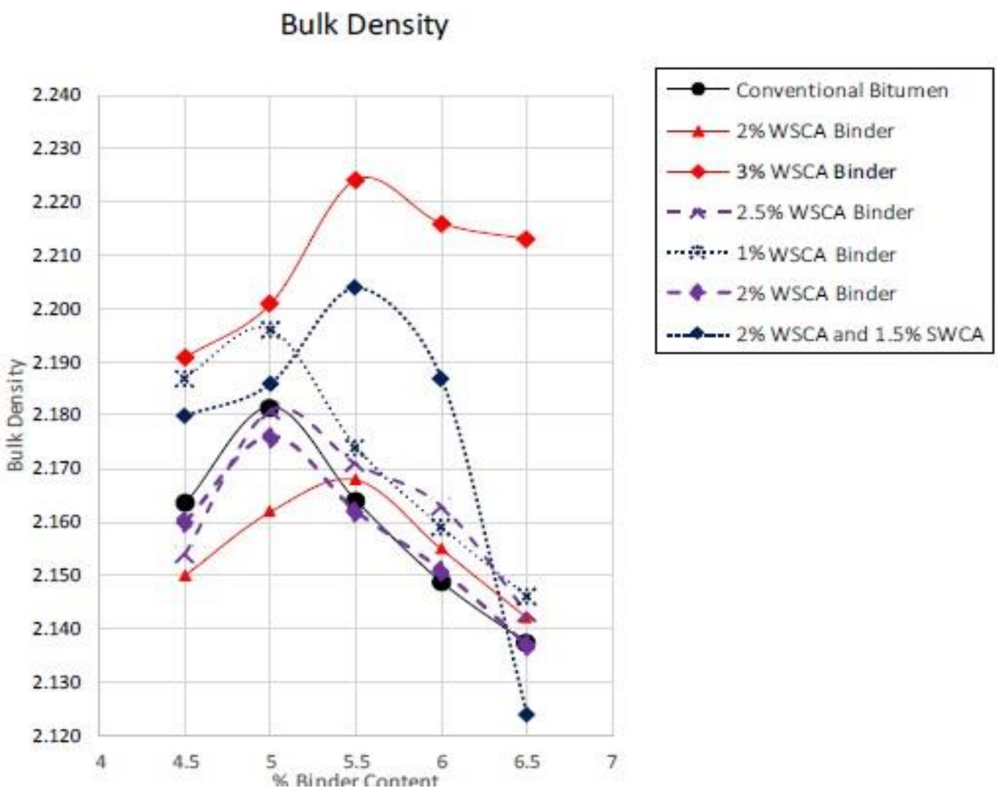


Fig. 4.6: Bulk Density Vs Percentage Binder Content

Binders modified using 3% SWPB, a blend of 1% SWPB and 2% WSCA, and a blend of 2% SWPB and 1.5% WSCA yielded highest bulk density value compared to conventional bitumen. While binder modified using 2.5% WSCA, 2% WSCA and 2% SWPB yielded binder with less bulk density value compared to conventional bitumen.

The bulk density of conventional bitumen was affected by additional of waste material by raising it to a certain point then lowering it as the total percentage of the additive increased. This point could be referred to as optimum binder content. The design curves indicated that the optimum binder content was higher when 3% SWPB and a blend of 2% SWPB and 1.5% WSCA were used to modify bitumen which was 5.5% binder content and is higher than that of conventional bitumen and other binders. This could be due to the fact that WSCA being comparable to Portland cement enhances adhesion of bitumen with aggregates.

4.6.2 Marshall Stability and Flow Value

Figure represents the effect of shredded waste plastic bags and waste sugar cane ash on the bituminous mixtures. As the additive content increased, the stability value initially increased, reaching a maximum value and then started decreasing.

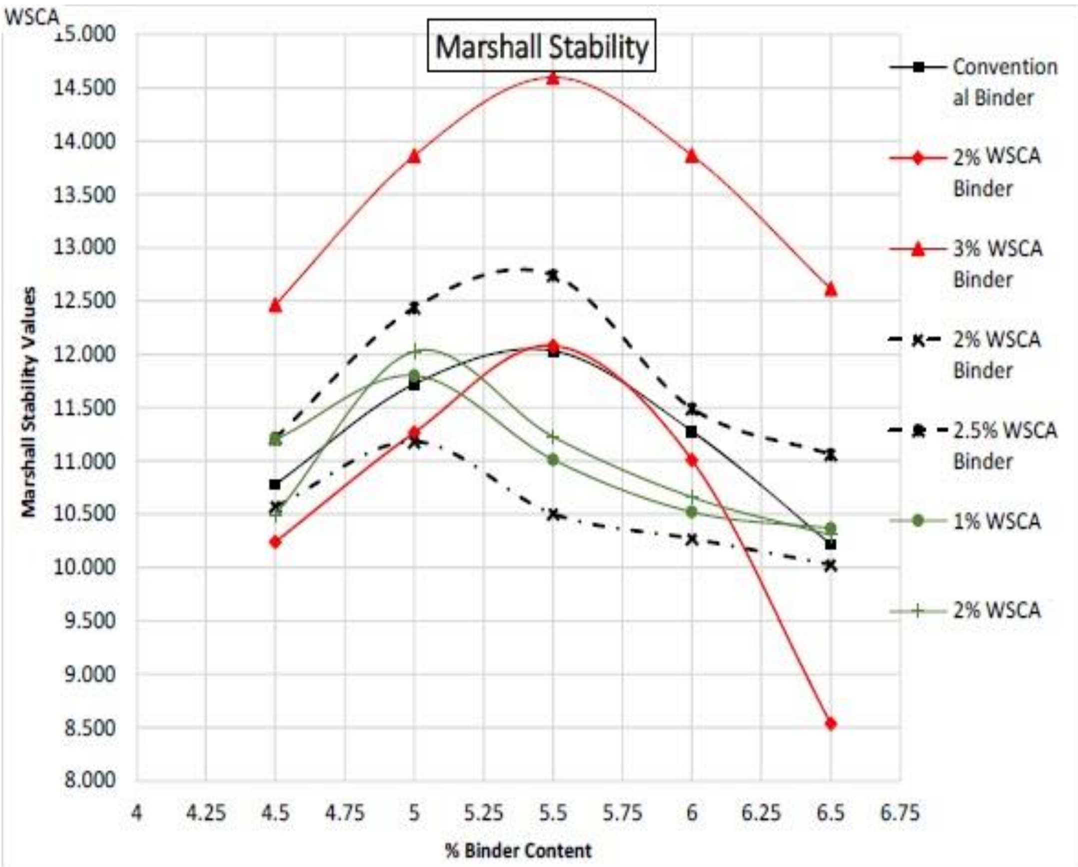


Fig. 4.7: Marshall Stability Vs Percentage Binder Content

Briquette prepared using modified binder of 3% SWPB and 2.5% WSCA yielded the highest Stability value. Additional of 3% SWPB to the bitumen raised the Marshall Stability value of controlled mix to 14,400N from 11,300N which was equivalent to 27.33 while 2.5% WSCA raised it to 12,600 that is equivalent to 11.5% increase in binder strength. This could be attributed to specific gravity of plastic bags that is less than that of bitumen and is less than one. It enables the binder to penetrate between the aggregates increasing the bond between the binder and the aggregates thus increasing the stability. The optimum binder content was 5.5%, beyond which the stability decreases. This could be caused by too much binder in the mix reducing the interlocking between the binder and the aggregates. From the design graphs, the binder modified with 3% SWPB gave the highest stability value and thus the highest bituminous strength.

Samples prepared using 2.5% waste sugar cane ash gave a higher stability conventional mix but less than that of 3% SWPB. The stability value increased by 11.5% from 11,300N. This could be attributed to the adhesive properties between WSCA and bitumen holding the aggregates more strongly compared to when conventional bitumen is used. The highest strength is obtained at the optimum binder content (OBC) of 5% beyond which the strength of the bituminous mixture start decreasing. This could be attributed to the increase of fines in the mixture due to higher percentage of WSCA absorbing part of the bitumen and interfering with the gradation of aggregates. If all the voids are filled by bitumen, then the load is transmitted by hydrostatic pressure through the binder instead of through contact points of aggregates and the strength of the mix therefore decreases.

It is clear from the Figure the blend of the two waste increases the Marshall Stability value of the conventional mix. Blend of 2% SWPB and 1.5% WSCA increased the bituminous mix strength to 12,030N while 1% SWPB and 2% WSCA increased the bituminous mix strength to 11,080N. The higher the percentage of the additive to the bitumen, the better the strength of the bituminous mix.

Figure portrays the relationship between the flow value and bitumen content. The flow value of the binder increased with the increase in binder content. The Marshal Flow value was also altered by the additional waste material to conventional bitumen.

The flow value increased when WSCA was added to the mix indicating improvement in the resistance to permanent deformation of bituminous mixes. The flow value of the sample prepared using 2 and 3% SWPB, and the blend of the additive was lower than that of conventional binder while the flow value of sample prepared using 2 and 2.5% WSCA is higher.

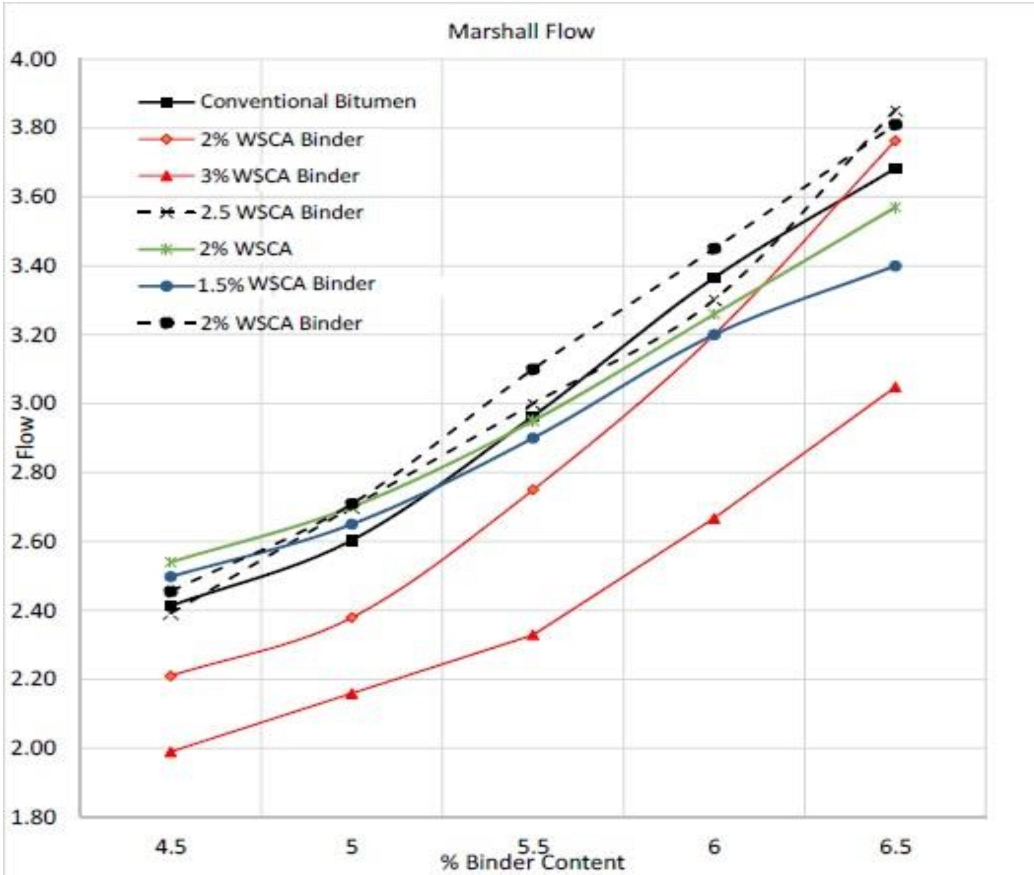


Fig. 4.8: Flow Value Vs Percent Binder Content

4.6.3 Voids in Mineral Aggregates and Voids filled with Bitumen

The total volume of void spaces that exist between the aggregates particles in a compacted bituminous mixture plus those filled with bitumen are referred to as voids in mineral aggregates (Roberts et al, 1991). These are the spaces available to accommodate binder once bitumen and aggregates are mixed together and it is expressed as a percentage of the total volume of the mix.

From the Figure, the design curve for conventional bitumen, 2% SWPB, 3% SWPB, 2% WSCA and 1% SWPB plus 2% WSCA exhibit the same characteristics of Voids in Mineral Aggregates (VMA) while that of 2% WSCA, 2% SWPB and 1.5% SWCA binder has lower values. The VMA value with lower binder content is high, then reduces to a certain point, then start increasing. VMA is inversely proportional to Marshall Stability value of the briquette. When VMA is too low, there is not enough room in the mixture to add sufficient binder to coat the individual particles leading to stripping of aggregates and while it is too higher there will be overfilling of the voids leading to bleeding of the pavement. Adequate VMA is important as it ensure the pavement is durable.

Void filled with bitumen (VFB) is the percentage of VMA containing bituminous binder in the briquette. It refers to the voids that exist between the aggregates particles in the compacted mixture that are filled with binder. The relationship between the VFB and binder content is illustrated by design curves.

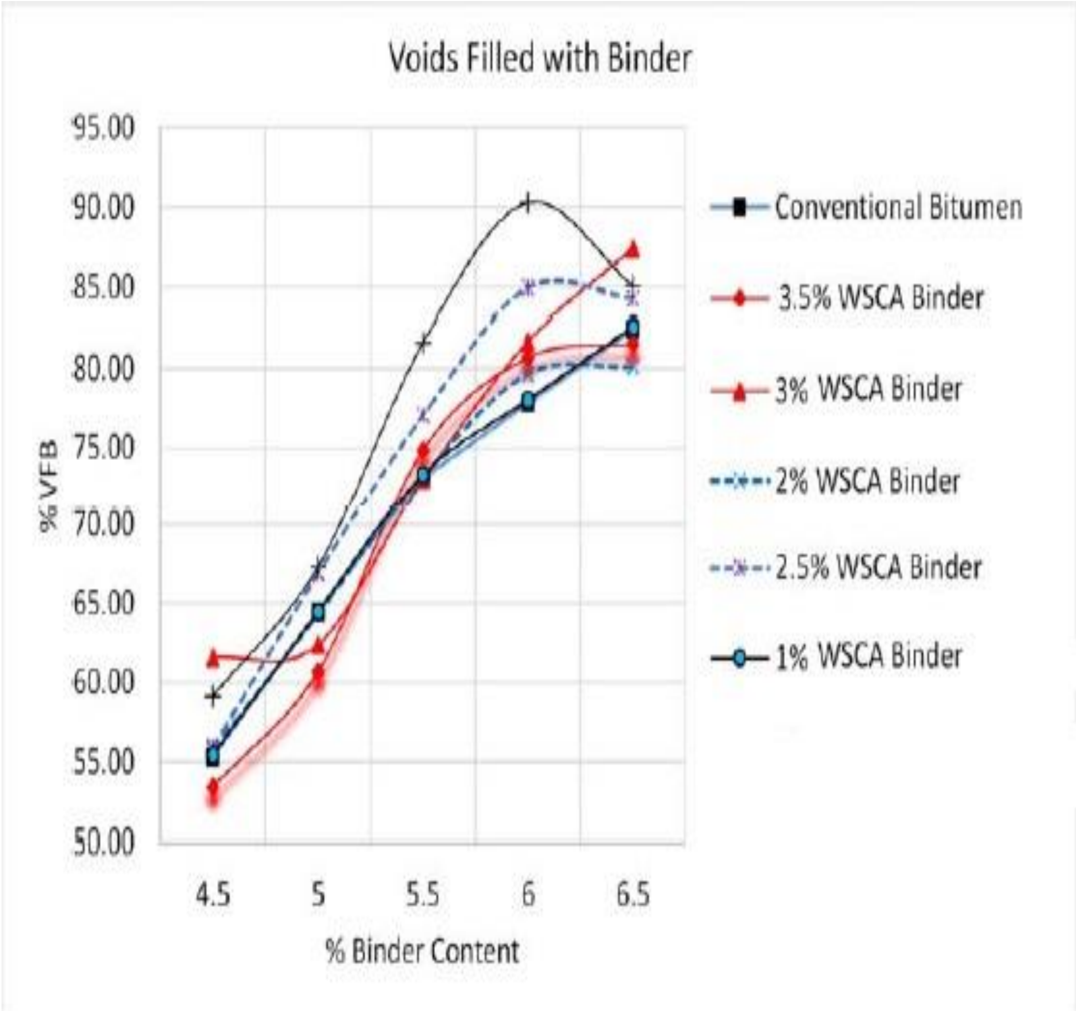


Fig. 4.9: VFB Vs Percent Binder Content

Generally, VFB increases with increase with binder content. The binder modified with SWPB has a higher VFB value than both conventional bitumen and binder modified with WSCA. This could be due to the fact that SWPB has a lower specific gravity enabling it to coat aggregates faster than the other two binders. At OPC of 5.5%, the VFB for all the mix are higher than that of conventional mix. This is facilitated by the ease at which the binder is able to penetrate between the aggregates spaces.

The main effect of VFB is to limit maximum levels of VMA and subsequently maximum levels of binder content. VFB also restricts the allowable air void content for asphalt mixtures that are near the minimum VMA criteria. The VFB is inversely related to the air voids. As the percentage of air voids approaches zero, the VFB approaches a hundred though the binder is expected to fill up between 67 and 75 percent of these voids (Ganapati and Adiseshu, 2014).

Void in the mix (VIM) is the total volume of the small air pockets between the coated aggregates particles throughout the compacted paving mixture. The amount of voids in the mix is very important and closely related to stability, durability and permeability of the bituminous mixture. Insufficient air voids content can lead to flushing, in which excess bitumen squeezes out the mix to the surface. Excessive of air voids content in the mix provides passageways through the mix for water and air, damaging the pavement layer (Roberts, 1991).

The relationship between VIM and binder content is illustrated in Figure. The percentage of VIM decreases exponentially with increase with binder content. VIM is highest in samples prepared using binder modified with SWPB. However, the VIM of all samples prepared using different binder content are located within the specification range of 3 to 5% (John, 2002) which support the use of these additive.

VMA and VFB are widely accepted that these volumetric properties are useful in predicting hot mix bituminous pavement performance. Excessive air or inadequate VMA brings about durability problem leading to rutting of the bituminous surface.

4.7 Cost Analysis for surfacing for 1Km stretch using modified bitumen

Cost Estimation of waste Sugar Cane Bagasse Ash for Pavement construction:-

- **Making 1Km. Normal bitumen road:-**

  Total Wt. of mix (as per data book) = 450 tones

  Wt. of bitumen (as per data book) = 5% of total wt. of mix

  = 23 tones

  Wt. of aggregate = 450 – 23 = 427 tones

  Cost of bitumen for 1 Kg. is 56 Rs/-.

  1 kg. = 56 Rs/-

1 tone = 56 x 1000 = 56,000 Rs/-

23 tones = 23 x 56,000 = 12,88,000 Rs/-

Total Cost of bitumen for 1 Km. road is 12,88,000 Rs/-

- **Making 1Km. of Pavement Using Waste Bagasse Ash in Bitumen:-**

Total Wt. of mix (as per data book) = 450 tones

Wt. of bitumen (as per data book) = 5% of total wt. of mix

= 23 tones

Adding waste Bagasse Ash (according to test) = 11% of bitumen = 2.53 tones

Sr. No.	Particulars	Approx. Rate (Rs./Kg)
1	Waste Sugar Cane Bagasse	8
2	Collection of Bagasse Ash	3
3	Transportation	2
4	Cleaning	2
5	Labor Charger	3
6	Machinery Charges including electricity / Maintenance	2
	Total	20

Cost of waste Sugar Cane Ash for 1Kg. is 20 Rs/-

1 Kg. = 20 Rs/-

1 tones = 20 x 1000 = 20,000 Rs/-

2.53 tones = 20,000 x 2.53 = 52,000 Rs/-

Total cost of waste Sugar Cane Bagasse Ash for 1 Km. road is 76,000 Rs/-

- **Required bitumen in waste Sugar Cane Bagasse Ash road:-**

Required bitumen in waste polythene road = (Wt. of bitumen) –

(Adding Sugar Cane Bagasse Ash)

= (23 tones) – (2.53 tones)

= 20.47 ≅ 21 tones

Cost of 21 tones bitumen = 21 x 52,000

= 11,00,000 Rs/-

Saving cost of bitumen in 1 Km. of waste Sugar Cane Bagasse Ash road

= 12,88,000 – 11,00,000

= **1,88,000 Rs/-**

Total saving cost in bitumen is 14% to 15%.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following are conclusions that could be drawn based on the results of this research.

1. The mechanical properties of conventional bitumen were altered when shredded waste plastic bags, waste sugar cane ash and the blend of both waste materials when added to it as a modifier. The penetration value of binder decreased from 87 to 20mm while ductility value decreased from 100 to 3cm with increase in percentage of waste replacement. The Softening point of the binder increased from 52 to 96^0C with increase with waste addition. This alteration of the mechanical properties of the bitumen aids in improving the road surface performance by increasing its resistance to wear and tear and deformation.

   The modified bitumen with 2 & 3% SWPB, 2 & 2.5% WSCA, the blend of 2% SWPB & 1% WSCA and a blend of SWPB & 2% WSCA were narrowed down to as the best binders as their penetration values were within those of bitumen 60/70. Though the parameters of binder modified with 2.5% WSCA by weight of bitumen were all within the standard specification of bitumen grade 60/70 apart from its ductility value of 55cm that is lower than the recommended ductility of 100cm, it can be treated as the optimum mix.

2. There was a considerable increase in Marshall Stability value ranging from 11450N to 14400N and reduction in flow value varying from 3.4 to 2.3mm depending on the binder used. With increase in Marshall Stability and reduction in flow, the formation of rutting, potholing and cracks will be greatly reduced. This improves the performance of the road surface by reducing the formation of rutting, potholing and cracking.

   The binder modified with 3% SWPB and 2.5% WSCA gave the highest stability value. However, the WSCA produced the better results at optimum mix of 2.5%

SWPB and 97.5% bitumen by weight compared to optimum mix blend of SWPB and WSCA binder due to its higher ductility value and low flow value. The improvement of bituminous mix of WSCA gives the best results.

3. There would be a slight cost benefit of approximately KES. 53,108/= and KES 44,256/= when SWPB and WSCA are used to modify bitumen respectively. This is in additional to many environmental benefits.

5.2 Recommendations

5.2.1 Recommendations

I. Bitumen and bituminous mixture modified with SWPB and with WSCA withstood more loading, stretch less under loading and was less susceptible to temperature changes as compared to conventional binder. It is thus recommended that these materials be developed for use as bitumen and bituminous mixture modifier for road wearing course.

II. The blending of SWPB and WSCA as a modifier yielded better mechanical properties for the binder than conventional binder. However, improvement was proportionately lower than when each of the modifier was used individually. It is thus recommended that the blend may not be used for modification.

5.2.2 Recommendations of Areas for Further Research

I. The study limited its research on the modification of bitumen for the construction of the wearing course. It is recommended that further study to be carried out to determine the suitability of modifying bitumen with WSCA for the other layers of the road.

II. This study concentrated on modification of bitumen using waste particle size passing through sieve 2.36mm. Further research should be carried out to investigate the behaviour of bitumen and bituminous mixture when modified with particle sizes greater than 2.36mm.

REFERENCES

1) Ajay Goyal et al;"Properties and reactivity of sugarcane bagasse ash" Transe of JSIDRE NO. 261 pp11 - 19(2009).

2) Abhishek Bejjenki (2015). Performance of Bituminous Mixes with Modified binders. International Journal of Civil Engineering 2 (3)

3) Airey G. D. (2004). Styrene butadiene styrene polymer modification of road bitumen. Journal of Materials Science, 39(3), 951–959.

4) Amit P. Gawande (2013). Economics and Viability of Plastic Road: A ReviewDepartment of Chemical Engineering, College of Engineering and Technology, Akola (M.S.) India, Journal of Current Chemical and Pharmaceutical Science: 3(4), 231-242.

5) Ankur Anand & A.K. Mishra (2016). Comparative study of concrete strength by partially replacing cement with sugarcane bagasse ash and Fly Ash. International Journal of Science, Engineering and Technology Research, 5(4), 1063-1069.

6) Asim Hassan Ali, Nuha S. Mashaan, & Mohamed Rehan Karim (2013). Investigations of Physical and Rheological Properties of Aged Rubberised Bitumen. Corporation Advances in Materials Science and Engineering,

7) Biruk Hailu et al," application of sugar cane bagasse ash as a partial cement replacement material"

8) Chennakesava Rao M. S & N. V. N. Prabath (2015). Green Concrete using Agro Industrial Waste (Sugarcane Bagasse ASH). International Journal of Soft Computing and Engineering 5(1) 86-92.

9) Emeritus C.A. & O'flaherty. A.M. (2002). Highway location, design, construction and maintenance of road pavement.

10) Eunice Muchane & Grace Muchane (2006). Solid Waste Management in Nairobi andthe town of Limuru, in Kenya. Unpublished Environmental

EngineeringThesis, Tampere Polytechnic University for Applied Sciences, Finland.14.

11) Fwa T. F. (2006). *The Handbook of Highway Engineering*. London, CRC Press, 7-23.

12) Gupta B.L & Gupta Amit (2010). *Highway and Bridge Engineering.* (3rd Ed). New Delhi

13) Ganapati Naidu & P.S. Adiseshu (2014). Influence of Coarse Aggregate Shape Factors

14) Bituminous Mixture. *International Journal of Engineering Research*, 1(4) 2013-2024

15) Ganesan K., Rajagopal K.&Thangavel K. (2007). Evaluation of Bagasse Ash as Supplementary Cementitious Material. *Cement and Concrete Composites. 29*, 515–524.

16) Gro Harlem Brundtland, Mansour Khalid, Susanna Agnelli, Saleh A. Al-Athel et al(1987). *Our Common Future: Report of the World Commission on Environment and Development*. Oxford: University Press.

17) Ikiara M.M., A.M. Karanja, & T.C. Davis (2004). *Collection, Transportation and Disposal of Urban Solid Waste in Nairobi, in Baud, I., Post, J. and Furedy, C. (Eds.) Solid Waste Management and Recycling: Actors, Partnerships and Policies in Hyderabad, India and Nairobi, Kenya*. Netherlands- KluwerAcademic Publishers.

18) IS: 2386 (Part IV) (1963). Methods of Test for Aggregates for Concrete-Part 4 Mechanical Properties. Bureau of Indian Standards, India.

19) IS: 1202-1978. Methods for Testing Tar and Bituminous Materials, Determination of Specific Gravity. Bureau of Indian Standards, India.

20) IS: 1203 -1978. Methods for Testing Tar and Bituminous Materials, Determination of Penetration. Bureau of Indian Standards, India.

21) IS: 1205-1978. Methods for Testing Tar and Bituminous Materials, Determination of Softening Point. Bureau of Indian Standards, India.

22) IS: 1208-1978. Methods for Testing Tar and Bituminous. Materials, Determination of Ductility. Bureau of Indian Standards, India.

23) Ishfaq Mohi UD Din & Supriya Marik (2015). Influence of Fillers on Paving Grade Bitumen. *International Journal of Innovative Research in Science, ngineering and Technology,* 4 (12) 12549-12554.

24) John Hodges (2002). *A Guide to The Design of Hot Mix Asphalt in Tropical and Sub- Tropical Countries. Overseas Road Note 19, Road Manual*. Old Wokinghm Road: TRL Ltd,

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

26) Kenya Public Policy Research & Analysis (2001). Roads Infrastructure Policies in Kenya Historical Trends and Current Challenges. *KIPPRA Working Paper No.1*. Nairobi: Infrastructure and Economic Services Division.

27) Konstantin S., Ismael F., Justin D. B, & Ahmed F., (2013). Application of fly Ash in Asphalt Concrete: From Challenges to opportunities. *World of Coal Ash Conference, Session: Cement & Concrete VI,* 20.

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

29) Lavanya M., Sugumaran B., & Pradeep T. (2012). An Experimental Study on the Compressive Strength of Concrete by Partial Replacement of Cement with Sugarcane Bagasse Ash. *International Journal of Engineering Inventions, 1*(11), 2319-6491.

30) Lesueur D. (2009). The Colloidal Structure of Bitumen: Consequences on the Rheology and on the Mechanisms of Bitumen Modification. *Advances in Colloid and Interface Science,145*, 42–82.

31) Mamlouk & J.P. Zaniewski (1999). *Materials for Civil and Construction Engineers.* California: Addison-Wesley.

32) Morgan. P & A. Mulder (1995). The shell Bitumen Industrial handbook.

33) Mwero J. N. Abuodha, S. O. Mumenya, S. W., Rading, G. O. & Kavishe, F. P. L. (2011). Sugarcane Waste Fiber Ash: Composition, Particle Size Distribution and Pozzolanic Properties. ICASTOR Journal of Engineering, 4 (2), 137- 144.

34) Myrian Aparecida S. Schettino, José Nilson & F. Holanda (2015). Characterization of sugarcane bagasse ash waste for Its Use in Ceramic Floor Tile. Procedia Materials Science 8, 190 – 196.

35) Neil J. Pedersen, Sandra Rosenbloom, Robert E. & Skinners Jr (2011). A Manual for Design of Hot Mix Asphalt with Commentary. National Cooperative Highway Research Programme Report 673.

36) Nathem A.H & AL-Saffar (2013). The Effects of Filler Type and Content on Hot Asphalt Concrete Mixtures Properties. Al-Rafidain Engineering, 21(6).

37) National Environmental Management Association (2014). Another Chance to Manage Plastic Waste. Waste Amendment Act 26.

38) Ndukauba Egesi & Akaha.C. (2012). Engineering-Geological Evaluation of Rock Materials from Bansara, Bamenda Massif Southeastern Nigeria, as Aggregates for Pavement Construction. Geosciences, 2(5), 107-111.

39) Nurul Asyiqin Binti Ahmad & Ramad Hansyah Putra jaya (2016). The Use of Plastic Waste in Bituminous Mixture for the Road Pavement. Malaysia: Universiti Teknologi Malaysia.

40) Nyangaga F. (2007). International Seminar on Roads Financing and Investment Road Fund management: Best Practices, Nairobi.

Utilization of Sugarcane Bagasse Ash in Bitumen

Saumitra Yadav
PG Student
Department of Civil Engineering
BBD University, Lucknow, INDIA

D. S. Ray
Professor (HOD CIVIL, BBDNITM)
Department of Civil Engineering
BBD University, Lucknow, INDIA

***Abstract* - This paper summarizes the ongoing researches about the experimental investigation on the use of bagasse ash in the construction of low volume traffic roads. The main focus of this research was to improve the transport industry so as to result in greater economy and mobility of goods and services by developing economic roads and also to utilize the various agro-wastes in the construction industry to result in suitable waste management for environmental susceptibility and eco-conservation. in this case sugarcane bagasse ash(an agro-waste) is being utilized for the Construction of low volume traffic roads(village roads, city street roads and other arterial roads).**

Key Words: Sugarcane bagasse ash, Coarse and Fine aggregate, Water bound Maccadam and Wet Mix Maccadam.

1. INTRODUCTION

Sugarcane is major crop grown in over 110 countries and its total production is over 1500 million tons.Sugarcane production in India is over 300 million tones per year.The processing of it in sugar mill generates about 10 million tones of SCBA as a waste material.one ton of sugarcane can generate approximate 26% of bagasse and 0.62% of residual ash.The residue after combustion present a chemical composition dominates by silicon dioxide.The SCBA contains high amounts of unburnt matter,silicon,aluminium and calcium oxide.The main parameter responsible for this improvement was higher silica content. Bagasse ash contains amorphous silica and display good pozzolanic property.Bagasse is often used as a primary fuel source for sugar mills;when burned in quantity,it produces sufficient heat energy to supply all the needs of a typical needs of a sugar mill.The dumping of these industrial wastes in open land poses a serious threat to the society by polluting the air and waste bodies.This also adds the no availability of land for public use.SCBA was tested in various part of the world and found the ash can improve the compressive strength of the material.

As we know that the roads are the life-line of every nation. A country’s road network should be efficient in order to maximize economic and social benefits. Roads are an integral part of the transport system. They play a significant role in achieving national development and contributing to the overall performance and social functioning of the community. It is acknowledged that roads enhance mobility, taking people out of isolation and therefore poverty. Roads play a very important role in the socio-economic development of the country. The road transport industry is the backbone of strong economies and dynamic societies.

The road transport industry is indeed instrumental in interconnecting all businesses to all major world markets, driving trade, creating employment, ensuring a better distribution of wealth and uniting mankind. It plays a crucial role in the daily economic and social life of industrialized and developing countries alike. An important part of the road transport industry’s story is sustainable progress.

The massive constructions release enormous amount of pollutants to the atmosphere and studies reveal that the pollutants from the construction industry are more harmful than the pollutants from any other segment. But on the other hand, there is a large production of agricultural wastes such as rice husk ash, wheat straw ash, hazel nutshell, fly ash, cork and sugarcane bagasse ash. Agriculture industry is the largest industry in India as more than 70% of Indian population is dependent on it. It is observed that in India more than 600 MT wastes have been generated from agricultural wastes-(2010).

Sugarcane is largely produced in the states of Punjab, Haryana, Uttar Pradesh and Tamil Nadu. The state of Uttar Pradesh is called the “Sugar Bowl” of India. A large number of sugarcane processing industries are located in these areas. But a large quantity of wastes called as bagasse is produced from these sugarcane processing industries.

As production of sugar cane is more than 1500 million tons in the world and in India about 10 million tons of sugarcane bagasse ash is treated as a waste material.

These roads can be constructed in those areas where there is availability of sugarcane bagasse. In Uttar Pradesh and Haryana, there is a large scale cultivation of sugarcane and thus the sugarcane bagasse can be easily procured to be used in the construction of low volume traffic roads.

The fibrous residue (about 40–45%) of sugarcane after crushing and extraction of its juice is known as ‘‘bagasse”. The bagasse is reused as fuel in boilers for heat generation which leaves behind 8–10% of ash, known as Sugar Cane Bagasse Ash (SCBA) which is treated as waste and unutilized. Sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicelluloses and 25% of lignin. The use of sugarcane bagasse as bio fuel or burning in open fields has posed a great environmental threat of polluting air, water, etc. Even after strict restrictions by the government of these above said states, there is no end to field fires as people only want to get rid-off these bulky and huge wastes. During rains these wastes begin producing highly offensive gases, thereby again causing nuisance. The smoke produced also causes invisibility. It can therefore be advantageous to use it in the construction of pavements to mitigate the disposal problem as well as to minimize the use of natural aggregate (sand) and binding material (cement, bitumen), so as to construct the low volume economic road pavements.

CHEMICAL PROPERTIES OF BAGASSE

Sr. No.	Chemical Compound	Percentge
1	Nitrogen	0.2- 0.3%
2	P2O5	1.5 -2%
3	K_2+Na_2	5-10 %
4	CaO	1-2%
5	Mgo	0.07%
6	Sio_2	85-90%
7	Heavy metals	NA
8	Fe	2-4%

1.1 Objectives and Scope of Study

The main objectives of the proposed experimental study is as discussed below-

- To study the physical properties of SCBA modified concrete.
- To arrive at a mix design review for modified concrete using IS code method.
- To study the workability of a fresh sample of this concrete.
- To study the different strengths of hardened concrete such as compressive strength of concrete samples at 7 and 14 days.
- To compare the workability and various strengths for different percentage substitutions of cement and sand with sugarcane bagasse ash.
- Economical design of low volume traffic road pavement tiles
  of different shapes and sizes by using SCBA.

2. MATERIALS USED

Waste Sugarcane Baggase Ash

Bagasse is a cellulose fiber remaining after the extraction of the sugar-bearing juice from sugarcane.Bagasse ash is one of the biomass source and valuable byproducts in sugar milling that often uses bagasse as a primary fuel source to supply all the needs of energy to move the plants. Burinf bagasse as a energy source yields its ash,considered as a waste causing disposal problems.It is well known that bagasse ash is an alternative source of energy with high silica content.The extracted silica from this study can be added value of silica source for many application of bagasse ash.

3. EXPERIMENTAL

Raw Material Preparation.

Sugarcane bagasse ,from local market and bagasse ash from sugarcane bagasse burnt in factory boilers,main raw materials,were used in this study.Before any treatment ,the sugarcane bagasse was dried,resized with refiner 2850 rpm &screened thriugh a sieve of 20 mesh size for 2 hours to eliminate the larger bagasse size.Then the pretreatment step with 1M&3M hydrochloric acid of those samples at 100 degree C for 2 hours was carried out.The samples were washed with distlled water until neutral condition was achieved.The samples were then dried in oven.The acid treatment helped to dealuminate the bagasse ash &to remove iron to certain extent for adjustig raw material quality.Afer acid treatment sugarcane bagasse&bagasse ash were treated in furnace under different temperatures at 600C,700C&800C ,different heating time 0f 1hour,2hour,3hour .The highly silica content from processing conditions was analyed.

4. MIXTURE PROPORTION AND SAMPLE PREPARATION.

Silica modified bitumen is prepared by adding Waste sugarcane bagasse ash in bitumen.The main purpose of this addition of bagasse ash in bitumen is to increase the strength of bitumen as baggase ash inherits ample amount of silica in it.Bagasse ash is added into the molten bitumen in the proportion of 10%,20%,30%,and 40% respectively and we further performed different kinds of bitumen tests over these samples.we found that the best result is attained at the addition of 40%of ash in Bitumen,which actually improves and enhances the property of Bitumen.

5. METHODOLODY

The evaluation of Bagasse ash for use as a replacement of Bitumen begins with the penetration test in which we add ample amount of bagasse ash in the bitumen in the proportion of 10%,20%,30% and 40% respectively.After the addition of bagasse ash in bitumen,the properties of bitumen is monitored and recorded for further analysis and the best attained data is appreciated.

6. CONCLUSION

Following conclusions have been drawn based on the present study:

- Sugarcane bagasse ash modified bitumen performed better when compared to ordinary bitumen up to 30% for baggase ash replacement and 10% of sand replacement in ordinary bitumen.
- Increase of strength in pavement is mainly due to presence of high amount of silica in sugarcane bagasse ash.
- These pavements are unaffected by the spillage of oil from vehicles and are ideal for bus stops, bus depots and parking areas.
- As far as the costs are concerned, it is estimated that the amount required per kilometre length of flexible pavement is Rs.90,10,000 and the cost of interlocking bagasse ash pavement is Rs.68,93,000 per kilometre. The construction of road using bagasse ash seems to be more cost effective than the conventional flexible pavement by 23.50%.
- Baggase ash pavement does not need in-situ curing and so can be opened to traffic soon after completion of construction.
- The design life of bagasse ash pavement is high when compared to conventional flexible pavement and also the maintenance of bagasse ash pavement is easy when compared to flexible pavement.
- The occurrence of damage is less in bagasse ashpavement and it is easy to remove and rectify the road with less amount. The digging and reinstatement of trenches for repairs to utilities is easier in the case of baggase ash pavement.
- Since there is ample amount of silica present in it, they are of a very high quality, thus avoiding the difficulties encountered in quality control in the field.
- Silica modified bitumen pavements restrict the speed of vehicles to about 60 km per hour, which is an advantage in city streets and intersections. The block pavements are ideal for intersections where speeds have to be restricted and cornering stresses are high.
- Unlike Rigid pavements, baggase ash modified bitumen pavement does not exhibit very deterioratory effect due to thermal expansion and contraction, and are free from the cracking phenomenon.
- Apart from these things, bagasse ash is a readily available waste material and is also an eco-friendly material. The design life of bagasse ash paver blocks road is 20 years, whereas design life of flexible pavement is only 10 years. So utilization of the waste material sugarcane bagasse ash is advantageous as a replacement of cement or fine aggregate in the preparation of concrete paver blocks.

7. REFERENCES

[1] Fotovat,F.,Kazemian,H.,and Kazemeini M.,Synthesis of Na-A and faujasitic zeolite from high silicon fly ash,M aterials Research Bulletin,pp.1-23.2007

[2] Ojha,K., Pradhan,N. C. and Samanta,A.N.,zeolite from fly ash;synthesis and characterization,bulletein of materials science ,vol27

[3] Guidelines for the Design of Flexible Pavement, New Delhi: The Indian Roads Congress. IRC: 37-2012.

[4] 4.Pandey A, Soccol CR, Nigam P and Soccol VT, "Biotechnological potential of agro-industrial residues. I: sugarcane bagasse", Bioresource Technology. 2000; 74(1):69-80.

[5] 5. Trejo-Hernandez MR, Ortiz A, Okoh AI, Morales D, and Quintero R "Biodegradation of heavy crude oil Maya using spent compost and sugar cane bagasse wastes". Chemosphere. 2007; 68(5):848-55.

[6] 6. Mulinari DR, Voorwald HJC, Cioffi MOH, Silva MLCPD, Cruz TGD, and Saron C. "Sugarcane bagasse cellulose/HDPE composites obtained by extrusion". Composites Science and Technology. 2009; 69(2):214-9.

[7] Almeida, F.C.R, Sales, A Moretti, J.P. Mendes and P.C.D, 2015. "Sugarcane bagasse ash sand (SBAS)": Brazilian agro-industrial by-product for use in mortar Construction, Building Material. 82, 31–38.

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