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An Experimental Study on Bituminous Mix Design using Different Percentage of Crumb Rubber to Improve the Strength of Pavement

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ABSTRACT

Production of rubber bitumen by blending of bitumen with crumb rubber from crumb tires is not just a waste treating method, but a possible solution for improving the durability of asphalt pavements compared to roads made of conventional bitumen. The following advantages are usually emphasised: improved durability, longer life time, lower life cycle / maintenance cost, increased permanent deformation resistance, traffic noise reduction effect. MOL together with University of Pannonia developed a new, patented production method (HU226481), which is capable to produce chemically stabilised rubber bitumen (CSRB). Asphalt tests have proved that the performance of CSRB is comparable to high quality polymer modified bitumen. Experience attracts attention to the fact that appearance of a binder of such quality is required in the future since it significantly supports sustainability and quality of road network. In 2010 MOL won a HuF 128 million research grant, partly supported by the EU and Hun-gary. Main parts of the supported project are • Implementation of new technology in Zala Refinery (prototype plant) • R&D work for finalisation of technology • Test road construction and evaluation of the road quality • Marketing support of product sales.

Solid waste management has gained a lot of attention to the research community now-a- days. Out of the various solid waste, accumulated waste tires, has become a problem of interest because of its non- biodegradable nature. Road network is important to the economic development, social integration and trade of a country. Inadequate transportation facilities could have an effect on socio-economic and cultural development of a country.

Stone Matrix Asphalt having good stability, strength and maintenance of the smooth surface of the road & other structures. Stone Matrix Asphalt mix is prepared by blending of course and fine aggregates.

Study on road in india indicated increased the volume of traffic as a result huge development of road is required. The SMA mixture is used to restrain the distresses and provide better durability in the bituminous pavements. Aggregate gradation was taken as per MORTH specification for SMA mix.

Study resulted that optimum bitumen content for samples prepared by mix of 5% crumb rubber (Tyre waste). Mixing of crumb rubber with 5% waste in SMA mix was observed cost effective & economical. Here maximum stability obtained is 12.72 kN This value as compared to other fibers is a little higher. Study of test result resulted higher stability, strength & durability of roads.

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KEYWORDS: *BC, SMA, Marshal Stability, VMA, VFA, Crumb Rubber, CSRB*

1. INTRODUCTION

Bitumen, also known as asphalt, is a substance that forms through the distillation of crude oil. It has waterproofing and adhesive properties. Bitumen production through distillation removes lighter crude oil components, such as gasoline and diesel, leaving the "heavier" bitumen behind. The producer often refines it several times to improve its grade. Bitumen can also occur in nature: Deposits of naturally occurring bitumen form at the bottom of ancient lakes, where prehistoric organisms have since decayed and have been subjected to heat and pressure.

Bitumen is generally for industry use. Bitumen was first used for its natural adhesive and waterproofing characteristics, but it was also used as a medicine. It was used to bind building materials together, as well as to line the bottoms of ships. Ancient civilizations traded the material. Herodotus, a fifth-century BC Greek historian, claimed that the walls of ancient Babylon contained bitumen.

CRUMB RUBBER

Crumb rubber quality without fluctuation is one of the most important requirements for rubber bitumen production process and is a constant product quality. During crumb rubber production waste tyres are shredded, fabric and steel used as reinforcement material are removed. Tyres should be clear before shredding because im-purities (sand, clay, gravel in the tread, etc.) are not allowed. From rubber bitumen production point of view most valuable component of tyres (and crumb rubber) is polyisoprene (natural rubber). Crumb rubber derived from passenger tyre contains 10-20% of it; this amount is around 35-45% in case of truck tyres. Further components of crumb rubbers are synthetic rubber (15-45%), carbon black (25-30%), plasticizers (5-15%) and inorganic additives (5-15%) as measured according to ASTM D297-93 standard.

STONE MATRIX ASPHALT

Stone Matrix Asphalt (SMA) is a gap-graded mixture, have a better stone to stone contact which gives better strength to the mixture.

In this examination work total utilized according to the MORTH determination which was taken from an equivalent part. The examples are made with total with various degree, filler (concrete) and fastener (bitumen 60/70). Strands are utilized as stabilizer and are utilized to diminish the channel down and to expand the quality and dependability of the SMA Blend. The trial of the SMA Blend tests is done in Marshall Mechanical assembly. Stone Network Black-top (SMA) is a hole reviewed blend, portrayed by high coarse totals, high black-top substance.

- High convergence of coarse total expands stone-to-contact and interlocking in theblend which gives quality and the rich mortar folio gives toughness. It gives a higher impervious to rutting and gives adequate erosion to asphalt surface even it is presented to rehashed loads.
- In correlation with thick evaluated blends, SMA has higher extent of coarse total, lower extent of moderate size total and higher extent of mineral filler. Stone Lattice Black- top blend test are tried in Marshall Contraption
- Resistance to mileage, more prominent solidarity to perform well during overwhelming burdens. All the exploration work done before by utilizing Sisal Strands. Sisal Strands are broadly utilized in SMA in Europe and USA. These filaments are protected. The strands improve the administration properties of the blend by shaping micromesh in the black-top blend to counteract the channel down of the black-top in order to build the strength and solidness of the blend. Here we have attempted to utilize sisal fiber which is more monetary than cellulose strands, doing same work as cellulose fiber.

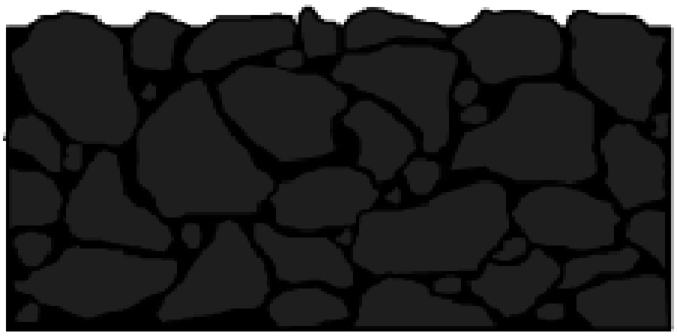

Fig.1.1 Gap Graded Mix Structure

Flexible pavements designing are preferred always over all other rigid pavements for road construction. Stone matrix asphalt mix sample were tested in Marshall Apparatus. SMA Mix is desired to have quality of resistance to wear & tear, greater strength for better performs during heavy loads.

World is starting at now focusing on substitute material sources that are condition pleasant and biodegradable in nature. In view of the growing common concerns, bio composite delivered out of standard fiber and polymeric tar. The composite materials could be named as those materials which are incorporated by at least two materials having various properties. All things considered, composites materials have solid burden conveying strengthening material imbedded in flimsier cross section materials. The essential constituent of composites have a relentless stage which is the huge a bit of the composite is called lattice. Grid are all things considered increasingly bendable and less hard and these are commonly either inorganic or regular. Discretionary constituent of composites have pliable called fortification and they are embedded in the lattice. The constituents of composite materials have their property anyway when they are united together, they give a mix of properties that a particular can't have the ability to give. For the most part, composite materials are organized based on network materials as:

A. Ceramic Lattice Composites
B. Polymer Framework Composites
C. Metal Framework Composites

1.1. Stone Matrix Asphalt (SMA)

Stone framework black-top (SMA), at times called stone mastic black-top, is a hole reviewed HMA initially created in Europe to boost rutting opposition and solidness in substantial rush hour gridlock Street. This high bitumen content likewise improves adaptability. Expansion of a little amount of cellulose or mineral fiber avoids seepage of bitumen during vehicle and arrangement. There are no exact plan rules for SMA blends. The fundamental highlights, which are the coarse total skeleton and mastic organization, and the resulting surface and blend solidness, are generally dictated by the determination of total reviewing and the sort and extent of filler and folio. SMA improved trench obstruction and solidness. It has great weakness and ductile strength.SMA is solely utilized for surface seminars on high volume streets. Materials utilized for SMA are Hole evaluated total, adjusted black-top fastener, fiber filler. Other SMA advantages incorporate wet climate rubbing (because of a coarser surface), lower tire clamor (because of a coarser surface) and less extreme intelligent breaking. Mineral fillers and added substances are utilized to limit black-top cover channel down during development, increment the measure of black-top folio utilized in the blend and to improve blend strength.

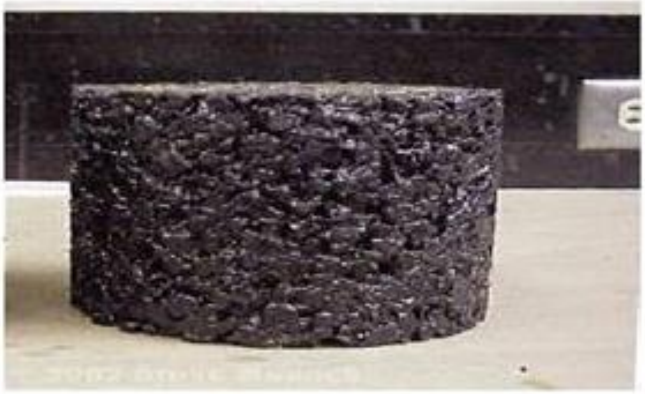
Fig.1.2 SMA Lab Sample


Fig.1.3 SMA Surface

1 Open-Graded Mixes

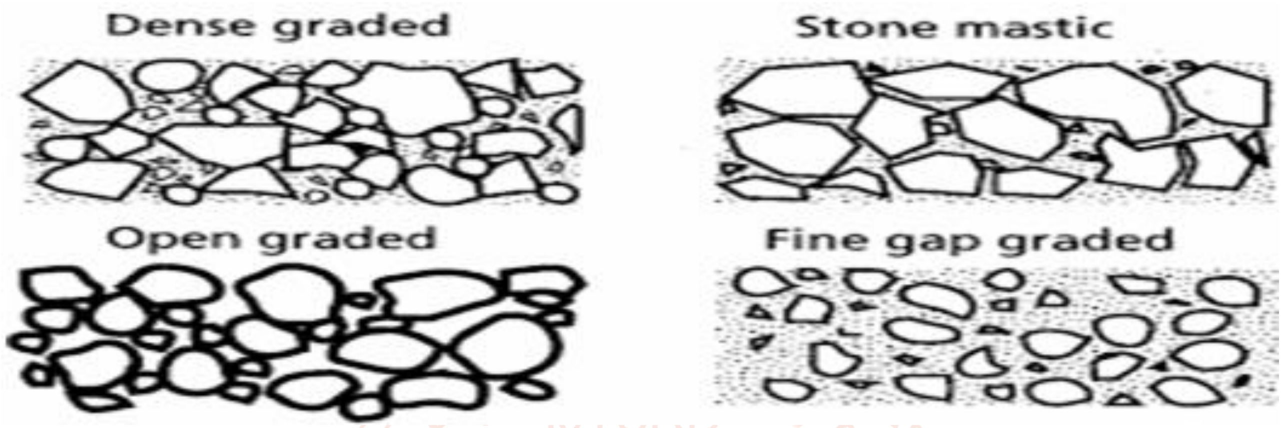

Fig.1.4 Different Graded Mixes

Unlike dense-graded mixes and SMA, an open-graded HMA mixture is designed to be water permeable.

Material used aggregate (crushed stone or gravel and manufactured sands), asphalt binder (with modifiers). OGFC is more expensive per ton than dense-graded HMA, but the unit weight of the mix when in-place is lower, which partially offsets the higher per-ton cost. The open gradation creates pores in the mix, which are essential to the mix's proper function. Anything that tends to clog these pores, such as low-speed traffic, excessive dirt on the roadway can degrade performance.


Fig.1.5 OGFC Surface


Fig .1.6 OGFC Lab Samples

1.1.1. Dense-Graded Mixes

This type of bituminous concrete is a well-graded HMA has good proportion of all constituents are also called Dense bituminous macadam. When properly designed and constructed, a dense- graded mix is relatively impermeable. Dense-graded mixes are generally referred to by their nominal maximum aggregate size and can further be classified as fine-graded or course- graded. Fine-graded mixes have more fine and sand sized particles than coarse-graded mixes.

Table 1.1 Details associated to SMA and bituminous mix

Properties	SMA	BC
Definition	SMA isa gap graded mix which consists of high amount of coarse aggregate firmly bonded together by a strong asphalt matrix Consisting of fine aggregate, filler, bitumen and stabilizing additives.	BC consists of well graded coarse and fine aggregate, filler and bitumen.
Mass of Coarse Aggregate Content, (%)	75 – 80	50-60
Mass of Fine Aggregate (%)	20 – 25	40 - 50
Mass of Filler content, (%)	9 – 13	6 – 10
Binder Type	60/70, PMB- 40	60/70 and modified binders
Minimum binder content by weight of mix, (%)	>6.5	5 - 6
Stabilizing Additives by weight of mix,(%)	0.3 – 0.5	--------
Air Voids (%)	3—4	3--6
Layer Thickness, mm	25-75	30-65

1.2. THESIS ORGANIZATION

The aim of this thesis is to design dense bituminous mix by using modified SMA and possessing enhanced properties. The present work has five chapters.

Chapter 1 Includes the general information with related to this research work, scope of the study and thesis organization.

Chapter 2 Presents literature review and important findings on similar work, problem identification and objective.

Chapter 3 Presents methodology and experimental.

Chapter 4 Presents results and discussion showing the results obtained from the experiments over samples prepared.

Chapter 5 Concludes the dissertation work and future scope of work.

Chapter 6 Contains references of this dissertation work

OBJECTIVES OF THE RESEARCH WORK

- To analyze the cost of bituminous pavement and also reduce the total construction cost.
- To study the strength of SMA by partial replacement of coarse aggregate with 5%,10% and 15% crumb Tyer waste by weight of aggregate.
- Preparation of Marshall Specimens and getting optimum mix content with the help of Marshall Test data and to study the Thermo-economic feasibility of rubber Tyre crumbs for its use as 60/70 grade of bitumen.
- To conduct techno-economic study of the desire material feasibility.
- To utilize the crumb tyre rubber as it is a waste.

2. LITERATURE REVIEW

General

This chapter presents a brief review of literature on the topics related to bitumen additives, modified stone matrix asphalt mixtures particularly using fibers, waste crumb and engineering/rheological characteristics of bitumen and mixtures. This chapter presents the characteristics of SMA with fibers to justify research aim and sets the background for the proposed work.

Modified Bitumen

1. **Aslamet al [2001]** built up an altered system for development of adaptable asphalts. In adaptable asphalt development plastic covered total indicated better restricting property. It has less wetting property and voids. the plastic waste-mixed bitumen demonstrate that the expansion of plastic waste to bitumen builds softening point, Abatements entrance esteem and malleability, expands streak point and fire point, increment Marshall steadiness esteem and enhance hostile to stripping properties. The procedure has its own restrictions. The readiness of such adjusted bitumen needs high power stirrer with thermostatic offices to keep up the temperature between160-1800C. Any expansion in the temperature could influence the properties of bitumen. The best possible stockpiling of such polymer-mixed bitumen is imperative. It ought to be put away in a cooler and it is additionally alluded that it is steady for 6 hrs at a temperature of 1800C.

2. **Bangalore Process et al [2003]** think about with respect to plastic streets introduced. A 25 km plastic street was laid in Bangalore as a piece of xyz consider. The plastic street indicated prevalent smoothness, consistency and less rutting when contrasted with a sans plastics street laid in the meantime, which started creating "crocodile breaks" before long. The procedure was additionally endorsed in 2003 by the CRRI (Focal Street Exploration Foundation Delhi). Street life enhances through enhanced cheapness and thickness of the bituminous blend, in this way restricting the stones all the more immovably together and enhancing the water-opposition of the blend to rain and so forth. For a similar reason, the temperature of the blend both at the plant and at the purpose of lying should be 20°C higher than typical. Various examinations including utilization of plastic to improve rheological qualities can be found in writing. In this sub-segment, survey a portion of the vital works important to this examination.

3. **Mohamed Rehan Karim al. (2004)** Optimization of polymer and asphalt content in polymer modified asphalt mixture is the aim of road engineers and designers. The purpose of this study is to characterize Stone Mastic Asphalt (SMA) mixture's properties containing waste polyethylene terephthalate (PET) which is a type of polymer material. Response Surface Methodology (RSM) was designated as a new method to measure mixture properties at different PET content and asphalt binder value. To fabricate the mixture fresh 80/100 penetration grade asphalt binder with different percentages (5–7% by weight of aggregate particles) was utilized. Different amounts of PET were used from 0% to 1% by weight of aggregate particles. Marshall Stability and Flow test was performed on the mixtures.

Specific gravity and volumetric properties of mixtures were obtained. RSM was used to analyze Marshall and volumetric properties of unmodified and PET modified asphalt mixtures. Models were produced to fit the experimental results. As shown in this study suggested models were successfully fitted to the experimental results. Based on the results achieved amounts of 5.88% of asphalt content and 0.18% of PET were found to be the optimal values.

4. **Bradelyet.al. (2004)** studied Utilization of waste fibers in stone matrix asphalt mixtures. They used carpet, tire and polyester fibers to improve the strength and stability of mixture compared to cellulose fiber. They found no difference in moisture susceptibility and permanent deformation in SMA mix containing waste fibers as compared to SMA mix containing cellulose or mineral fiber.[4]

5. **Kamaraj C., G. Kumar, G. Sharma, P.K. Jain and K.V. Babu (2004)** carried laboratory study using natural rubber powder with 80/100 bitumen in SMA by wet process as well as dense graded bituminous mix with cellulose fiber and stone dust and lime stone as filler and found its suitability as SMA mix through various tests.[5]

6. **Punith V.S., Sridhar R., Bose Sunil, Kumar K.K., Veeraragavan A (2004)** dida comparative study of SMA with asphalt concrete mix utilizing reclaimed polythene in the form of LDPE carry bags as stabilizing agent (3 mm size and 0.4%) .The test results indicated that the mix properties of both SMA and AC mixture are getting enhanced by the addition of reclaimed polythene as stabilizer showing better rut resistance, resistance to moisture damage, rutting, creep andaging.

7. **Muniandy R., Huat, B.B.K. (2006)** used Cellulose oil palm fiber (COPF) and found fiber- modified binder showed improved rheological properties when cellulose fibers were preblended in PG64-22 binder with fiber proportions of 0.2%,0.4%,0.6%,0.8% and 1.0% by weight of aggregates. It showed that the PG64-22 binder can be modified and raised to PG70- 22 grade. The Cellulose oil palm fiber (COPF) was found to improve the diameteral fatigue performance of SMA deign mix. The fatigue life increased to a maximum at a fiber content of about 0.6%, whilst the tensile stress and stiffness also showed a similar trend in performance. The initial strains of the mix were lowest at a fiber content of0.6%.[10]

8. **Kumar Pawan, Chandra Satish and Bose Sunil (2007)** tried to use an indigenous fiber in SMA Mix by taking low viscosity binder coated jute fiber instead of the traditionally used fibers and compared the result with the imported cellulose fiber, using 60/70 grade bitumen and found optimum fiber percentage as 0.3% of the mixture. Jute fiber showed equivalent results to imported patented fibers as indicated by Marshall stability test, permanent deformation test and fatigue life test. Aging index of the mix prepared with jute fiber showed better result than patented fiber.[12]

9. **Chui-Te Chiu, Li-Cheng Lu, al [2007],** used asphalt rubber (AR),produced by blending ground tire rubber (GTR) (i) 30% of a coarse GTR with a maximum size of #20 sieve and (ii)20% of a fine with a maximum size of #30 sieve with an asphalt, as a binder for SMA and found AR-SMA mixtures were not significantly different from conventional SMA in terms of moisture susceptibility and showed better rutting resistance than that of conventional dense graded mixture.[11]

10. **YongjieXue, Haobo Hou, Shujing Zhu, JinZhaal [2008],** used municipal solid waste incinerator (MSWI) fly ash as a partial replacement of fine aggregate or mineral filler and BOF Slag as part of coarse aggregate with polyester fiber of 6.35 mm in length obtained from recycled raw materials, PG76-22 binder in the SMA mix and performed Marshall and super pave method of design and found it's suitability for use in the SMA mix.[15]

11. **Asim Hassan Ali al [2013],** anticipate asphalt upsets there are different arrangements, for example, receiving new blend plans or usage of black-top added substances. The essential point of this examination was to explore the impact of including crumb tire elastic as an added substance to SMA blend execution properties. This examination explored the fundamental parts of altered black-top blends so as to all the more likely comprehend the impact of CRM modifiers on volumetric, mechanical, and firmness properties of SMA blend. In this investigation, virgin bitumen 80/100 entrance evaluation was utilized, altered with crumb elastic (CRM) at five distinctive alteration levels, in particular, 6%, 12%, 16%, and 20%, individually, by weight of the bitumen. The fitting measure of the additional CRM was seen as 12% by weight of bitumen. This rate brings about the most extreme degree of security. The flexible modulus (Mr) of changed SMA tests including various rates of CRM was clearly higher in examination with that of unmodified examples

12. **Vasudevanet. al [2014],** displayed an examination on the preparation of plastics waste – bitumen blend and its properties to find the propriety of the blend for road advancement, was finished. A changed system was delivered and the stone absolute was secured with fluid plastics and the plastics waste secured complete (PCA) was used as the rough material for versatile improvement. PCA exhibited better confining property. It had less wetting property. Its voids were generously less. The model exhibited higher Marshall Strength regard. The lanes laid using PCA are performing honorably. A point by point considered is shown.

13. **Vasudevan, et al. [2015]** in like manner watched that the polymer blended bitumen has better properties regarding Mellowing point, Passage point, Adaptability, Stripping Quality and Marshall Security regard. Along these lines the blend can be used for laying versatile black-top. In this examination both dry and wet methods were used to prepare balanced bituminous mixes. In the wet technique, the blending was finished by direct mixing the annihilated polymer with hot bitumen at 160 deg. C. In the dry method, a novel framework was used to use more elevated level of waste plastics in road advancement and using this methodology a substitute procedure was used. In this method, the waste polymer was incorporated the hot aggregate (170deg.C). The polymer was secured over the aggregate. Here the spreading was straightforward. The hot absolute was secured with polymer reliably. By then the Bitumen was incorporated. The mixing of bitumen with polymer was happening at the outside of the aggregate. The temperature was around 155 – 163 C. Both the polymer and bitumen were in the liquid state.

14. Shaik. Dilkusha al [2015] Advancement of balanced out Stone Lattice Black-top (SMA) blends for improved asphalt execution has been the focal point of research all over India for as long as couple of decades. India, being a horticultural economy delivers genuinely gigantic amount of regular strands. This paper centers around the impact of added substances like coir, sisal, banana strands (normal filaments), on the compressive quality of SMA blends. A starter examination is directed to portray the materials. Compressive quality tests are led to contemplate the protection from squashing to withstand the worries because of traffic loads. Every balanced out blend demonstrate the most extreme estimation of compressive quality at 0.3% fiber content. SMA with coir fiber shows higher compressive quality demonstrating its higher smashing obstruction. The records of held quality for all blends fulfill the constraining estimation of 75%. In any case, for control blend, it is just about 60%, which substantiate the need of added substances in SMA blends.

15. Naveen Kumar R et al [2016] in the present examination, an endeavor has been made to contemplate the building properties of blends of stone lattice black-top made with customary bitumen 60/70 with a nonconventional characteristic fiber, in particular sisal fiber. The covers in various extents are utilized for readiness of blends with a chose total evaluating to discover OBC. The ideal folio substance is dictated by keeping the recommended air voids content in the blend. The fiber is added to OBC and two other bitumen focuses nearest to it. For this, different Marshall tests of SMA blends with and without filaments with changing fastener focus are readied. Marshall properties, for example, soundness, stream esteem, thickness, air voids are utilized to survey the ideal fastener substance and ideal fiber content for changed SMA blends. From there on, the channel down attributes for adjusted and unmodified SMA Blend have been examined. It is seen that lone 0.28% expansion of sisal fiber fundamentally improves the Marshall properties of SMA blends. Expansion of ostensible 0.28% fiber impressively improves the channel down qualities of the SMA blends with customary bitumen, which would some way or another have not had the option to meet the recommended criteria.

16. Yadav et al [2017] deals with the improvement of changed clasp definitions from plastomer and elastomer compose waste with an intend to constrain non-biodegradable the post client polymer waste and furthermore environmental hazard, to meet this objective ten exceptional models have been gotten from a couple of sorts of waste to cover particular arrangements of polymeric waste from the family unit, mechanical and likewise restorative waste. Changed spread definitions were from the start depicted by the relevant checks (code of preparing) to deciding their suitability for above said application. The physical properties of changed spreads are inside beyond what many would consider possible. Marshall Adequacy, underhanded unbending nature and creep modulus lead have been evaluated and discussed in this assessment to exhibit their twofold favorable circumstances like waste minimization and propriety of such latches to be used for Durable Road.

17. Shaik. Dilkusha al [2018] Street system is critical to the monetary advancement, social coordination and exchange of a nation. Deficient transportation offices could affect financial and social improvement of a nation. In India, increment in the volume of traffic and huge stacking conditions requires an enormous advancement for better, sturdy, and increasingly compelling streets that averts or decreases the misery of bituminous black-top. In Indian interstates, the wearing coat is laid by thick evaluated bituminous blends; consequently the significant misery is because of dampness actuated harms. The SMA blend is utilized to control the bothers and give better sturdiness in the bituminous asphalts.

18. Hoang-Long Nguyen's al [2018] The fundamental target of this investigation is to create and analyze crossover Man-made reasoning (computer based intelligence) approaches, to be specific Versatile System based Fluffy Induction Framework (ANFIS) enhanced by Hereditary Calculation (GAANFIS) and Molecule Swarm Improvement (PSOANFIS) and Bolster Vector Machine (SVM) for anticipating the Marshall Steadiness (MS) of Stone Lattice Black-top (SMA) materials. Other significant properties of the SMA, specifically Marshall Stream (MF) and Marshall Remainder (MQ) were likewise anticipated utilizing the best model found. With that objective, the SMA tests were manufactured in a neighborhood research center and used to produce datasets for the displaying. The considered information parameters were coarse and fine totals, bitumen substance and cellulose. The anticipated targets were Marshall Parameters, for example, MS, MF and MQ. Models execution appraisal was assessed on account of criteria, for example, Root Mean Squared Mistake (RMSE), Mean Supreme Blunder (MAE) and connection coefficient (R). A Monte Carlo approach with 1000 reproductions was utilized to conclude the measurable outcomes to evaluate the presentation of the three proposed computer based intelligence models. The outcomes demonstrated that the SVM is the best indicator with respect to the united factual criteria and likelihood thickness elements of RMSE, MAE and R. The consequences of this investigation speak to a commitment towards the determination of a reasonable man-made intelligence way to deal with rapidly and precisely decide the Marshall Parameters of SMA blends.

19. Abdulnaser Al-Sabaeei al [2018] Compaction is one of the most significant parameters that influence the properties and execution of black-top blend. The point of this examination was to explore the impacts of TCR on the gyratory compaction of stone mastic black-top (SMA) blend. Tests for execution tests were readied utilizing Superpave blend plan technique. A 40 work TCR powder was differed from 0 to 2.5% by weight of the all out blend with 0.5% augmentation. A few examinations including the volumetric properties of SMA, flexible modulus and Marshall Properties, steadiness and stream were tried for both control and rubber treated blends. The outcomes demonstrated that as the measure of TCR expanded the quantity of gyrations required expanded and the channel down of the cover diminished. The rubber treated examples indicated better dependability, strong modulus and channel down obstruction than the control tests.

20. Shaik. Dilkusha al [2018] Street system is critical to the financial improvement, social reconciliation and exchange of a nation. Insufficient transportation offices could affect financial and social advancement of a nation. In India, increment in the volume of traffic and huge stacking conditions requires a gigantic advancement for better, solid, and progressively viable streets that counteracts or decreases the trouble of bituminous black-top. In Indian roadways, the wearing coat is laid by thick reviewed bituminous blends; subsequently the significant misery is because of dampness actuated harms. The SMA blend is utilized to limit the upsets and give better strength in the bituminous asphalts.

21. PHoang-Long Nguyen's al [2019] The main objective of this study is to develop and compare hybrid Artificial Intelligence (AI) approaches, namely Adaptive Network-based Fuzzy Inference System (ANFIS) optimized by Genetic Algorithm (GAANFIS) and Particle Swarm Optimization (PSOANFIS) and Support Vector Machine (SVM) for predicting the Marshall Stability (MS) of Stone Matrix Asphalt (SMA) materials. Other important properties of the SMA, namely Marshall Flow (MF) and Marshall Quotient (MQ) were also predicted using the best model found. With that goal, the SMA samples were fabricated in a local laboratory and used to generate datasets for the modeling. The considered input parameters were coarse and fine aggregates, bitumen content and cellulose. The predicted targets were Marshall Parameters such as MS, MF and MQ.

22. Shiva Kumar Govindarajual [2019] In this study, banana fiber (BF) and pelletized fiber (VP) are used as stabilizing additives to prepare SMA mixtures with conventional viscosity-graded (VG) 30 bitumen. Mixtures were prepared with different levels BF and VP content, and another mixture without any stabilizers was also prepared using polymer-modified bitumen (PMB). Superpave mix design, drain down, fatigue, rutting, workability, and moisture-induced damage properties were evaluated. Results indicated that addition of natural and pelletized fiber controls binder drain down and improves resistance to rutting, fatigue, and moisture-induced damage of SMA mixture. Further, polymer-modified SMA mixtures take less energy for densification compared to SMA mixtures with natural and pelletized fiber. Results also showed that even though polymer-modified SMA mixtures performed better, SMA mixtures with pelletized fiber provided comparable results.

Problem identification

The growth in various types of industries together with population growth has resulted in enormous increase in economic activities world-wide.

- Various developments have caused tremendous increase in the movement of people and goods, causing much stress on roads.
- The eco-Friendly and reliable development for construction consists the use of non- conventional and different waste materials and recycling of waste material and decreasing the use of natural resources.
- The construction industry is the area where the safe use of crumb tyre rubber are possible.
- When it is introduced in SMA as a replacement material, it reduces space problem and also reduces the cost of pavement.
- It is very much desirable that life of roads be long and requires minimal maintenance.
- The growth in various types of industries together with population growth has resulted in enormous increase in economic activities world-wide.

3. METHODOLOGY

MATERIALS USED

A. Bitumen as binder(60/70)
B. Coarse And Fine Aggregate
C. Waste Crumb rubber

Coarse And Fine Aggregate

The aggregates are crushed by using jaw crusher to get different size of aggregates varying from 16mm to 75micron. Quality of aggregates was check through various tests as per MoRTH specification given below.

Test conducted for aggregates

A. Impact Value Test (IS 2386 -Part1)

Table 4.1 Determination of Impact Value of Aggregate

SI No.	Wt. Of oven dried sample (in gm) A	Wt. of aggregate retained through 2.36mm IS sieve (in gm)	Wt. of passing aggregate (in gm) B	Impact Value	Avg. Impact Value
1	356	303	52	14.64	14.71
2	359	300	54	15.25	
3	354	307	51	14.24	

According to MORTH the aggregate impact value should be < 18%

B. Crushing Value (IS 2386 -Part1)

The standard aggregate crushing test shall be made on aggregate passing a 12.5-mm IS Sieve and retained on a 10-mm IS Sieve.

Ratio of the weight of fines formed to the total sample weight in each test shall be expressed as a percentage, the result being recorded to the first decimal place:

Aggregate crushing value = (B/A) x 100

Where

B = weight of fraction passing the appropriate sieve, and A = weight of surface-dry sample.

Table 4.2 Determination of Crushing Value of Aggregate

Wt. Of oven dried sample (in gm) A	Wt. of aggregate retained through 2.36mm IS Sieve (in gm)	Wt. of passing aggregate (in gm) B	Crushing Value
3086	2634	452	14.64

C. Los Angel's Abrasion Value (IS 2386 -Part1)

The test sample and the abrasive charge shall be placed in the Los Angeles abrasion testing machine and the machine rotated at a speed of 20 to 33 rev/min. The machine shall be rotated for 500 revolutions.

Difference between the original weight and the final weight of the test sample shall be expressed as a percentage of the original weight of the test sample. This value shall be reported as the percentage of wear/abrasion value.

Table 4.3 Determination of Los Angel's Abrasion Value

Wt. Of oven dried sample (in gm) A	Wt. of aggregate retained through 2.36mm IS sieve (in gm)	Wt. of passing aggregate (in gm) B	Abrasion Value
10000	8502	1498	14.98

As per MoRTH Los Angle's Abrasion value should be < 25%

D. Flakiness and Elongation Index (IS 2386 -Part1)

The elongation index is the total weight of the material retained on the various length gauges, expressed as a percentage of the total weight of the sample gauged.

The flakiness index is the total weight of the material passing the various thickness gauges or sieves, expressed as a percentage of the total weight of the sample gauged.

Table 4.4 Determination of Flakiness and Elongation Index

Size In mm	Wt. of sample taken in gm.	Aggregate passing in the gauge in gm.	Flakiness index	Average flakiness index	Aggregate retained in the elongation gauge in gm.	Elongation index	Average elongation index
25-20	392	60	15.36	18.83	130	33.16	21.5
20-16	734	135	18.39		131	17.84	
16-12.5	547	91	16.6		103	18.8	
12.5-10	280	78	27.2		54	19.28	
10-6.3	90	15	16.6		38	18.4	

According to MORTH the Flakiness and elongation index value should be <30

The gradation of aggregate was taken as per MORTH specification given below in table1.

Table 4. 5: Gradation of Aggregates

Total weight of sample taken= 1200gm

Sieve size in mm	% passing		%retained adopted	amount of aggregate taken in this binder content in gm						
	Intermediate	Adopted		4%	4.50%	5%	5.50%	6%	6.50%	7%
				1152	1146	1140	1134	1128	1122	1116
16	100	100								
13.2	90-100	94	6	69.12	68.76	68.4	68.04	67.68	67.32	66.96
9.5	54-70	62	32	368.6	366.72	364.8	362.9	360.96	359.04	357.12
4.75	26-39	34	28	322.6	320.88	319.2	317.5	315.84	314.16	312.48
2.36	21-28	24	10	115.2	114.6	114	113.4	112.8	112.2	111.6
1.18	17-25	21	3	34.56	34.38	34.2	34.02	33.84	33.66	33.48
0.6	15-22	18	3	34.56	34.38	34.2	34.02	33.84	33.66	33.48
0.3	13-19	16	2	23.04	22.92	22.8	22.68	22.56	22.44	22.32
0.15	09-15	12	4	46.08	45.84	45.6	45.36	45.12	44.88	44.64
0.075	08-13	10	2	23.04	22.92	22.8	22.68	22.56	22.44	22.32
Filler	0	0	10	115.2	114.6	114	113.4	112.8	112.2	111.6

BITUMEN

Bitumen is act as a binder in SMA Mix. Different grade of bitumen are used in different mix like hot-mix or gap-graded mix or dense-graded mix. For preparation of SMA Mix we used 60/70 bitumen in this research work.

FILLER

Filler is used in SMA mix for better binding of materials. Rock dust, slag dust, hydrated lime, hydraulic cement, fly ash, mineral filler and cement are used as filler in SMA mix, also we can use the fine aggregate below 75micron as filler, but here we use cement as filler which makes a better bond with aggregate and bitumen.

CRUMB TYRE:

- Tyre may be divided into two types – car and truck tyres. Car tyres are different from truck tyres with regard to constituent materials (e.g. natural and synthetic rubber).

- Usually three main categories of discarded tyre rubber have been considered such as chipped, crumb and ground rubber. Chipped or shredded rubber is used to replace the gravel. To produce this rubber, in first stage the rubber has length of 300 – 430 mm long and width of 100 -230 mm wide. In the second stage its dimension changes to 100 -150 mm by cutting. If the shredding is further continued particles of about 13 – 76 mm in dimension are produced.

Fig 4.2 Sample crumb tyre chips

EXPERIMENTALPROCEDURE

Methodology Adopted

Research facility tests were directed on the regular bitumen (60/70) and changed bitumen tests. Singular properties (Infiltration, Softening Point, Flexibility, Flash and fire, and Specific Gravity) of the example were resolved. Utilizing the Marshal Blend outline portrayal of customary bituminous blend (60/70) for thick bituminous blend (DBC) were completed and examination was made for traditional bitumen blend properties with changed bitumen. Subsequent to deciding elements to be considered for demonstrating adjusted bitumen in bituminous blend, a point by point anticipates the exploratory program (test arrangement and arrangements of tests) was created. Following tests were conducted:

A. Penetration test
B. Ductility test
C. Softening point test
D. Specific gravity test
E. Flash and fire point test
F. Marshal stability test

The above recorded tests were led on the accompanying customary/changed bituminous examples, given in Table - 60/70 Review bitumen, Bitumen and CRMB. The subtle elements of the materials utilized and the planning of the examples are given in the ensuing segments. The test method is portrayed in next area.

Penetration Test

It measures the hardness or non-abrasiveness of bitumen by estimating the profundity in tenths of a millimeter to which a standard stacked needle will enter vertically in 5 seconds. The penetrometer comprises of a needle gathering with an aggregate weight of 100g and a gadget for discharging and securing any position. The bitumen is mellowed to a pouring consistency, mixed completely and filled holders at a profundity no less than 15 mm in overabundance of the normal entrance. The test ought to be directed at a predefined temperature of 25 C. It might be noticed that infiltration esteem is generally affected by any error with respect to pouring temperature, size of the needle, weight put on the needle and the test temperature. A review of 60/70 bitumen implies the infiltration esteem is in the range 60 to 70 at standard test conditions. In hot atmospheres, a lower infiltration review is favored.

Ductility Test

Ductility is the property of bitumen that licenses it to experience incredible twisting or stretching. Flexibility is characterized as the separation in cm, to which a standard example or briquette of the material will be stretched without breaking. Measurement of the briquette in this manner shaped is precisely 1 cm square. The bitumen test is warmed and poured in the shape get together put on a plate. These examples with molds are cooled noticeable all around and afterward in water shower at 27 C temperatures. The abundance bitumen is cut and the surface is leveled utilizing a hot blade. At that point the form with get together containing test is kept in water shower of the pliability machine for around a hour and a half. The sides of the molds are expelled, the clasps are snared on the machine and the machine is worked. The separation up to the point of breaking of string is the flexibility esteem which is accounted for in cm. The malleability esteem gets influenced by variables, for example, pouring temperature, test temperature, rate of pulling and so forth. A base malleability estimation of 75 cm has been determined by the BIS.

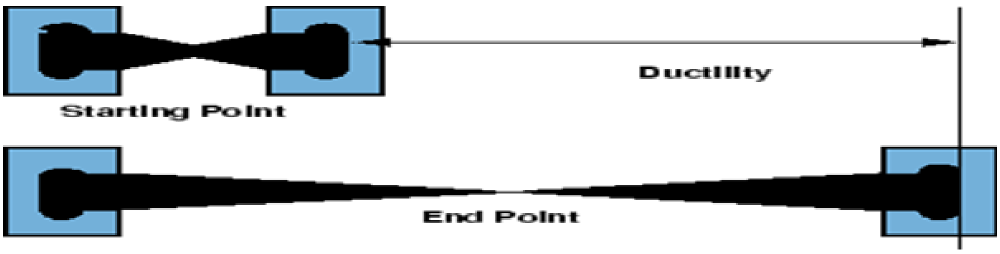

Figure 4.4: Ductility Test

Flash and Fire Point Test

Flash Point – Flash Point – The glimmer purpose of a material is the least temperature at which the use of test fire makes the vapors from the material quickly burst into flames as a blaze under indicated states of the test.

Fire Point – The fire point is the most minimal temperature at which the utilization of test fire makes the material light and consumes in any event for 5 seconds under determined states of the test.

Specific Gravity Test

The specific gravity of bitumen is characterized as the proportion of mass of given volume of bitumen of known substance to the mass of equivalent volume of water at 27 C. The particular gravity can be estimated utilizing either pycnometer or setting up a 3D shape example of bitumen in semi strong or strong state. The particular gravity of bitumen shifts from 0.97 to 1.02.

Sieve analysis

Sieve analysis was done and aggregates of appropriate sizes were collected and stored in place with sizes as per MoRTH gradation. Weight of one sample is 1200 gms here. The distribution of aggregates was taken as per table.

Sample preparation

For sample preparation some steps given below are taken:

Weighing of sample

Here 6 samples with binder content 4, 4.5, 5, 5.5, 6, 6.5 and 7 Percentage of each were prepared.

Heating of aggregates

After weighing of aggregates, aggregates with of all gradation are mixed with each other to make one sample of weight 1200gms. All samples were heated in oven at a temperature of 130^0 centigrade for 24hrs so that fiber is not burnt. Overheating of sample was avoided.

Heating of bitumen

60/70 bitumen was heated with a high temperature to liquefy. So that it will mix with all aggregates.

Mixing of components

All components (aggregate, filler and bitumen) are mixed to make a homogeneous SMA mix sample.

Fig 4.6 Heating of bitumen

Fig 4.7 Mixing of Aggregate

Filling in the marshall mould

For preparation of samples the mixture prepared was put in moulds. A standard mould is a cylindrical mould made of iron having a diameter of 100 mm. mould was also heated before use so that before hammering mixture may not be cold. A typical mould is shown in fig below:

Compaction

After putting in mould hammering was performed. For hammering a standard hammer was used. Usually hammering was done by giving 50 or 75 blows to each side of specimen. In this research each sample was given 50 blows each on both faces. For hammering first of all mould was attached to a fixed arrangement to make sure that mould is not staggered during hammering. This is the procedure of compaction.

Finalizing the sample

After hammering the sample was taken out of mould. Name sticks representing sample's binder content and sample number are glued to sample to recognize it later on. Then the sample was left in open to cool down to room temperature.

EXPERIMENTS PERFORMED

When the sample is prepared it was supposed to go under Marshall Test. The test was performed as per ASTM D 6927 – 06. This test gives the results of flow and stability number. To get that first of all dry weight of samples is taken and recorded. Weight of sample in water is also desirable. Because sample has voids so water may enter in voids. To prevent that wax was coated around the sample.

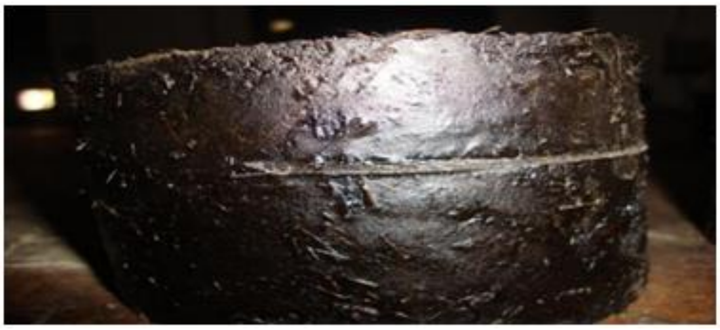

Fig 4.8 Wax coated sample

The figure above shows a wax coated sample. After wax coating the weight of waxed sample is taken. Now weight of sample in water is also recorded. After weighing the sample is put in water bath before testing upto a maximum of ½ hours. In water bath temperature of 60^0 C is maintained throughout. If sample is heated more than that wax may come out. So overheating is avoided. Only 6 samples may be put in Water bath.

Once the sample is heated up to 60^0 C for half hours it is ready for Marshall Test.

Marshall Test

A. Tests on Mixes

Presented below are the different tests conducted on the bituminous mixes with variations of binder type and quantity, and fiber concentration in the mix.

Marshall Mix design is a standard laboratory method, which is adopted worldwide for determining and reporting the strength and flow characteristics of bituminous paving mixes. In India, it is a very popular method of characterization of bituminous mixes. This test has also been used by many researchers to test bituminous mixes. This test method is widely accepted because of its simplicity and low of cost. Considering various advantages of the Marshall method it was decided to use this method to determine the Optimum Binder Content (OBC) of the mixes and also study various Marshall Characteristics such as Marshall Stability, flow value, unit weight, air voidsetc.

Fig. shows the Marshall sample and Marshall Apparatus with a loaded Marshall specimen. The Marshall properties such as stability, flow value, unit weight and air voids were studied to obtain the optimum binder contents (OBC). The mix volumetric of the Marshall samples such as unit weight, air voids were calculated by using the procedure reported by Das and Chakroborty (2003). For constraint of time each and every test on all types of mixes cannot be completed. Hence it was decided to carry out the next set of experiments such as drain down test, static indirect tensile test and moisture susceptibility tests on the mixes prepared at their OBC.

Fig. 4.9 Marshall testing machine

Fig. 4.10 Marshall Samples

Fig.4.11 SMA mix samples after Marshall Stability Test

Drain- down test

There are several methods to evaluate the drain-down characteristics of bituminous mixtures. The drain down method suggested by MORTH (2001) was adopted in this study. The drainage baskets fabricated locally according to the specifications given by MORTH (2001) is shown in Figure 4.12. The loose un-compacted mixes were then transferred to the drainage baskets and kept in a pre-heated oven maintained at 150°C for three hours. Pre- weighed plates were kept below the drainage baskets to collect the drained out binder drippings. From the drain down test the binder drainage has been calculated from the equation: Drain down equation is

$$d = \frac{W2 - W1}{1200 + X}$$

Where

W1 = initial weight of the plate

W2 = final weight of the plate and drained binder

X = initial weight of crumb rubber in the mix

For a particular binder three mixes were prepared at its optimum binder content and the drain down was reported as an average of the three. Figure 3.3 shows the drainage of 60/70 bitumen.

Fig. 4.12 Drainage of 60/70 bitumen sample

4. RESULT AND DISCUSSION

INTRODUCTION

In this chapter Result and Observation of test carried out in previous chapter is presented, analyzed and discuss. First section is deals with parameter used for analysis. Second section deals with calculation of Optimum binder Content (OBC). Third section deals with calculation of Optimum binder Content (OBC).

PARAMETERS USED

Based on volume considered in evaluating specific gravity of an aggregate, some definitions of specific gravity are proposed. As per Das A. and Chakroborty P. (2010); the definitionsand other formulae used in calculations hereafter are as follows:

$$G_{se} = \frac{P_{mm} - P_b}{\left(\frac{P_{mm}}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)}$$

Where:

G_{se} = Effective specific gravity of aggregate

P_{mm} = total loose mixture = 100%

P_b = asphalt, percent by total weight of mixture

G_{mm} = maximum specific gravity of paving mixture (no air voids), **(KT-39)**

G_b = specific gravity of asphalt

If mix composition is determined as percent by weight of the total mixture:

$$VMA = 100 - \frac{G_{mb}\ P_s}{G_{sb}}$$

Where:

VMA = voids in mineral aggregate (percent of bulk vol.)

G_{sb} = bulk specific gravity of aggregate.

G_{mb} = bulk specific gravity of compacted mixture. **(KT-15)**

P_s = aggregate, percent by total dry weight of mixture.

$$G_{mm} = \frac{P_{mm}}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

Where:

G_{mm} = maximum specific gravity of paving mixture (no air voids)

P_{mm} = total loose mixture = 100%

P_s = aggregate, percent by total weight of mixture ($P_1 + P_2 + P_3 + P_n$)

P_b = asphalt, percent by total weight of mixture.

G_{se} = effective specific gravity of aggregate.

G_b = specific gravity of asphalt.

$$VFA = \left(\frac{VMA - P_a}{VMA}\right)100$$

Where:

VMA = voids in mineral aggregate, percent of bulk vol.

P_{be} = effective asphalt content.

G_b = specific gravity of asphalt.

G_{mb} = bulk specific gravity of compacted mixture.

Observations and Tabulation

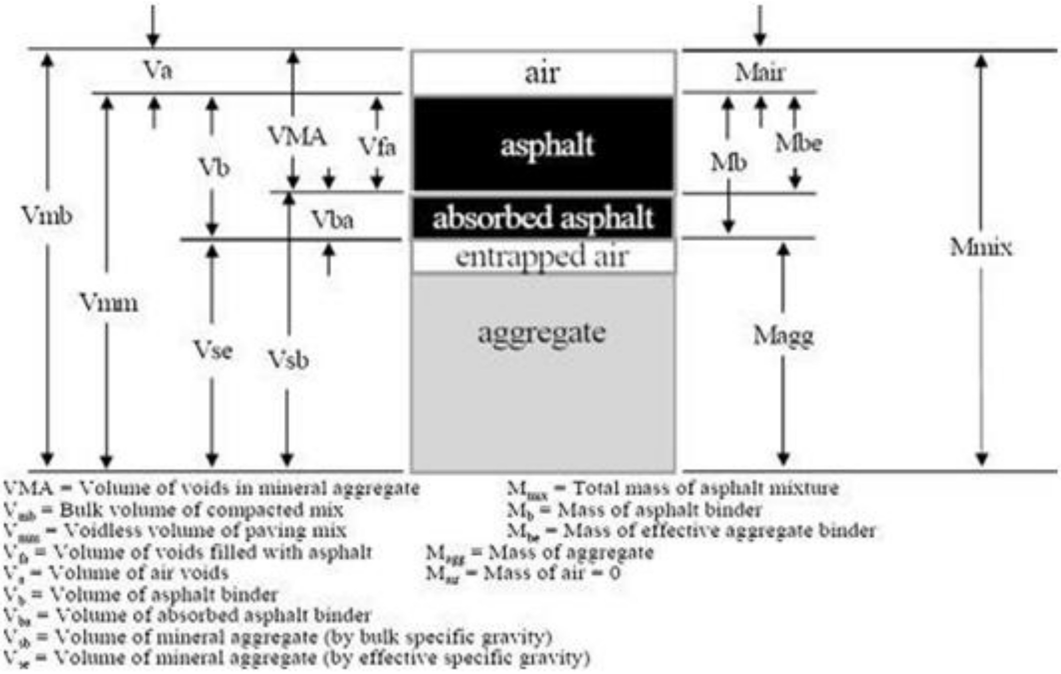

Fig. 5.1 Phase Diagram of bituminous mix

Weights of samples

Once the sample is prepared its dry weight, weight after wax coating and weight in water is taken. By these values bulk volume of the sample is calculated and hereafter $G_{mb}$is calculated by formula 5 given above. For calculation of bulk volume, volume of paraffin is deduced from total volume. Specific gravity of wax is taken as 0.9 g/cc and for water it is taken as 1 g/cc for calculation. Data obtained in this case is tabulated below:

Here W_{pca} = wt. of wax coated sample inair.
W_{pcw} = wt. of paraffin coated sample in water. W_s = wt. of sample in air B_{vs} = bulk volume of sample
G_{mb} = bulk specific gravity of the mix
For every percentage average specific gravity is calculated.

Marshall Test Values

For every sample Marshall Test data is recorded and tabulated in following table: Here stability number is in kN and flow is in mm.

STABILITY

Table 5.1 Stability vs. crumb rubber Content with 5.5% bitumen binder

S. NO.	Mix	CRUMB RUBBER (%)	3-3 SAMPLES STABILITY (KN)
1.	**M-1**	**0**	10.7 10.6 10.8 **Av=10.7**
2.	**M-2**	**5**	12.9 12.7 12.6 **Av=12.7**
3.	**M-3**	**10**	11.9 12.0 11.8 **Av=11.9**
4.	**M-4**	**15**	11.5 11.5 11.7 **Av=11.5**

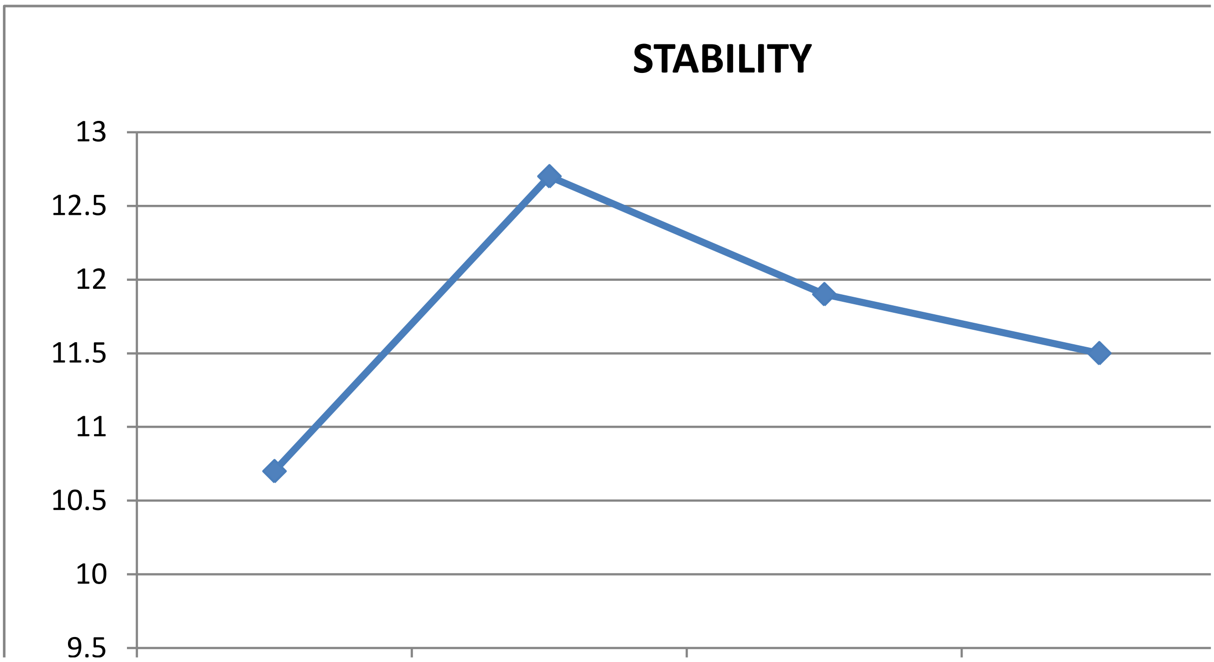

Fig 5.2 Stability vs. crumb rubber Content

FLOW VALUE

Table 5.2 Flow vs. crumb rubber Content with 5.5% bitumen binder

S. NO.	Mix	CRUMB RUBBER (%)	3-3 SAMPLES STABILITY(KN)
1.	**M-1**	**0**	3.88 3.48 3.69 **Av=3.71**
2.	**M-2**	**5**	3.55 3.22 3.34 **Av=3.42**
3.	**M-3**	**10**	2.89 2.65 2.77 **Av=2.75**
4.	**M-4**	**15**	2.56 2.36 2.58 **Av=2.53**

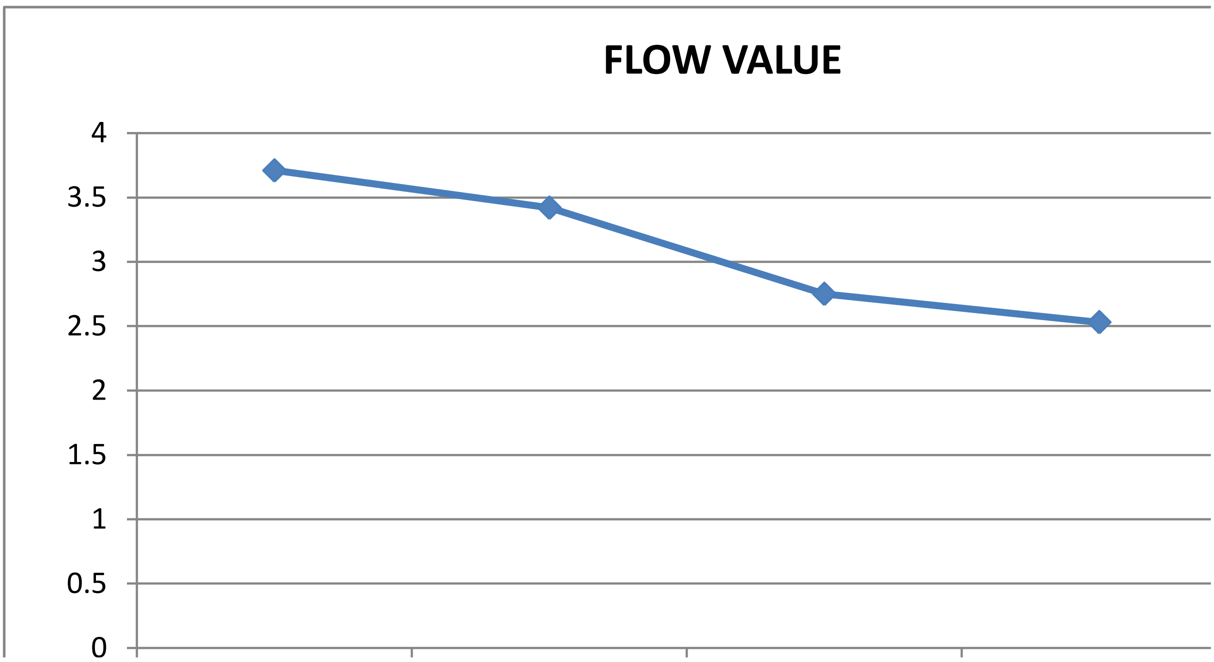

Fig 5.3 Flow vs. crumb rubber Content

VMA

Table 5.3 VMA vs. crumb rubber Content with 5.5% bitumen binder

S. NO.	Mix	CRUMB RUBBER (%)	3-3 SAMPLES STABILITY(KN)
1.	**M-1**	**0**	18.7 18.6 18.8 **Av=18.7**
2.	**M-2**	**5**	19.9 19.7 19.6 **Av=19.7**
3.	**M-3**	**10**	18.9 18.0 18.8 **Av=18.9**
4.	**M-4**	**15**	18.5 18.5 18.7 **Av=18.5**

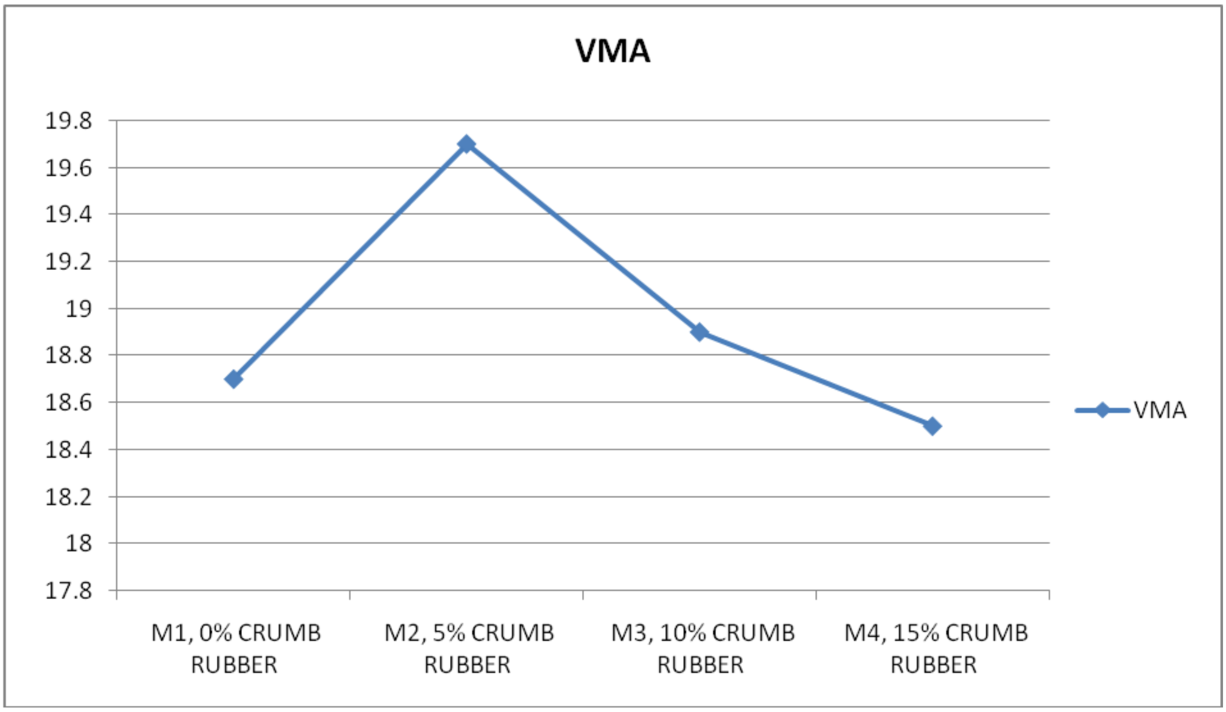

Fig 5.4 VMA vs. crumb rubber Content

VFB

Table 5.4 VFB vs. crumb rubber Content with 5.5% bitumen binder

S. NO.	Mix	CRUMB RUBBER (%)	3-3 SAMPLES STABILITY(KN)
1.	**M-1**	**0**	78.7 78.9 78.2 **Av=78.6**
2.	**M-2**	**5**	78.9 78.7 78.6 **Av=78.7**
3.	**M-3**	**10**	79.9 79.0 79.8 **Av=79.9**
4.	**M-4**	**15**	78.5 78.2 78.8 **Av=78.5**

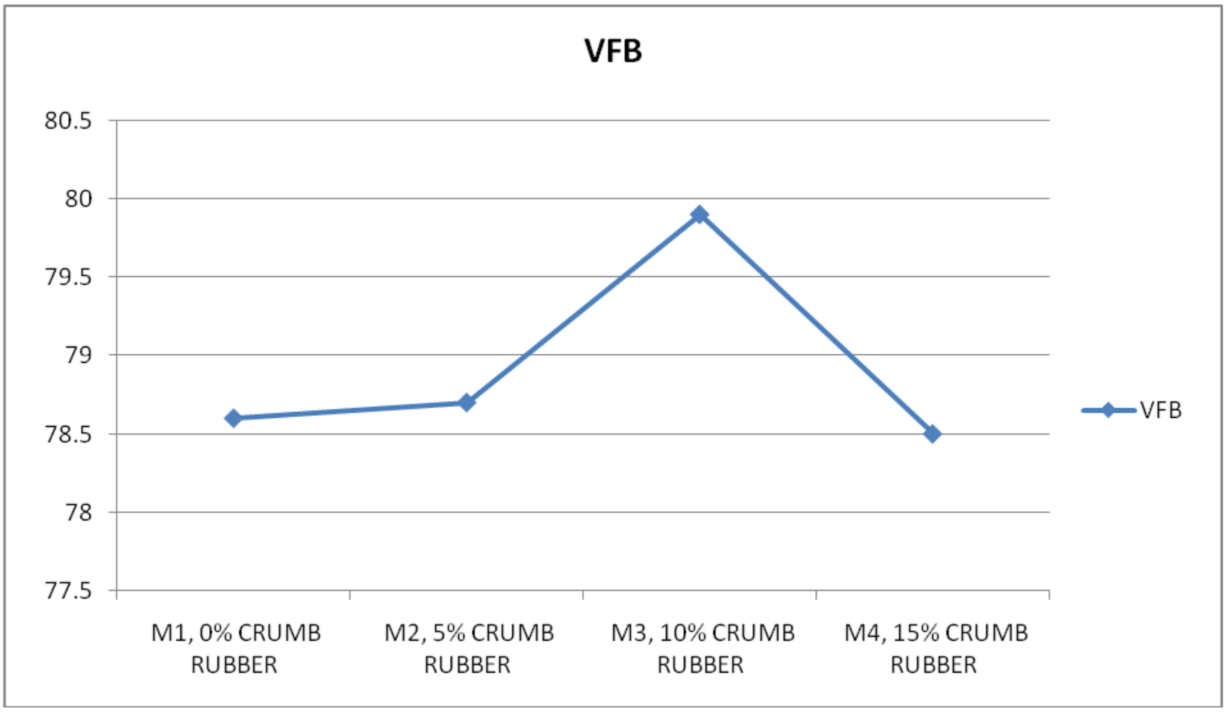

Fig 5.5 VFB vs. crumb rubber Content

Graphs obtained

Stability vs. bitumen content

Values of stability and bitumen content are plotted against bitumen in x-axis and stability in y-axis.

Table 5.5 Stability vs. bitumen content

Binder Content	Stability value without crumb rubber	Stability value with crumb rubber
4	10.62	12.13
4.5	10.89	12.32
5	11.3	12.52
5.5	11.50	12.72
6.5	8.04	8.55

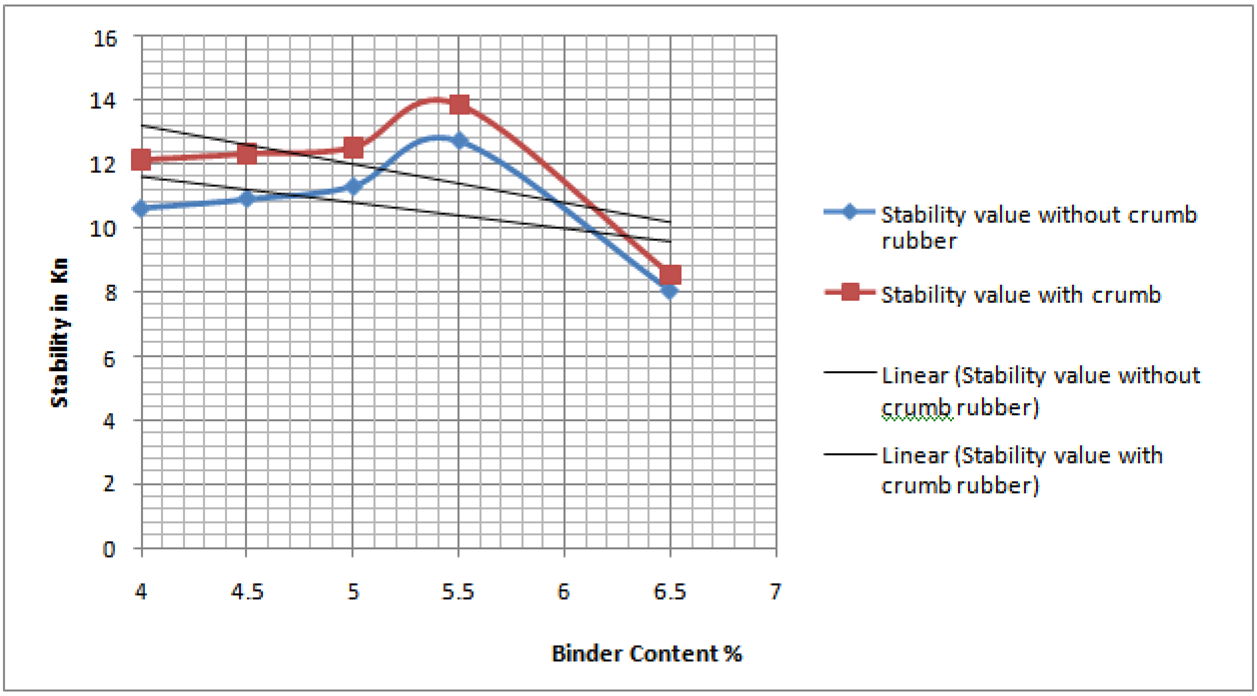

Fig 5.6 Stability vs. Bitumen Content

Flow value vs. bitumen content

Values of flow values in mm and bitumen content in bitumen in %ge are plotted against bitumen in x-axis and Flow in y-axis.

Table 5.6 Flow vs. bitumen content

Binder content	Flow value without crumb rubber	Flow value with crumb rubber
4	2.40	2.40
5	2.42	2.32
5.5	2.56	3.42
6	2.70	2.73
6.5	2.85	2.90

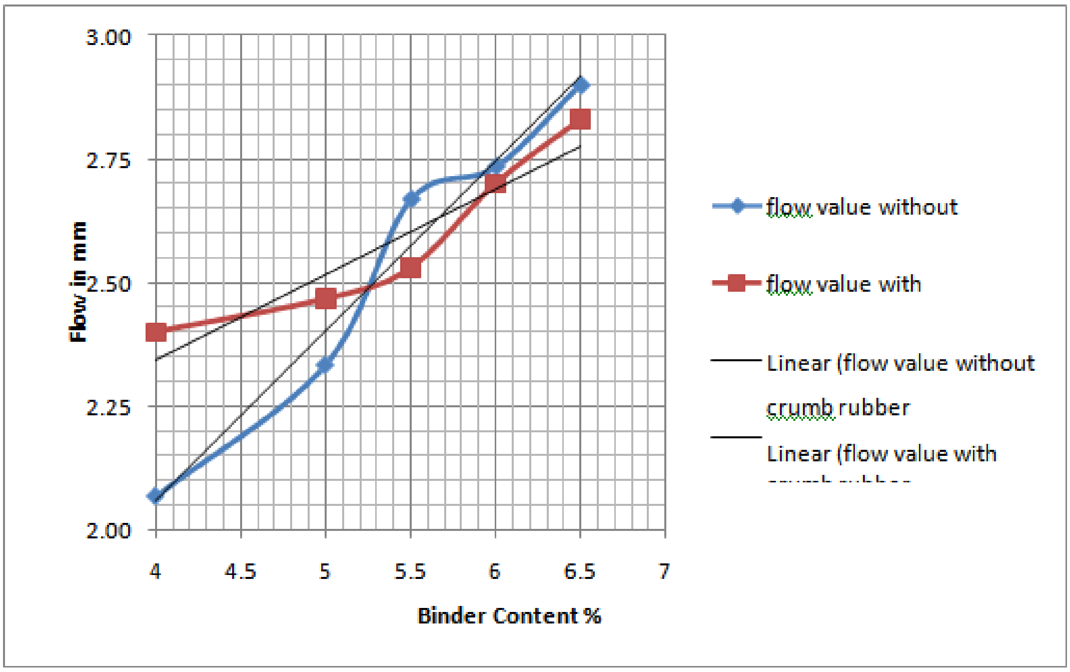

Fig. 5.7 Flow vs. bitumen content

VMA vs. bitumen content

Values of VMA values in %ge and bitumen content in bitumen in %ge are plotted against bitumen in x-axis and VMA in y-axis.

Table 5.7 VMA vs. bitumen content

Binder Content	VMA
4.0	15.23
4.5	14.08
5.0	14.65
5.5	19.70
6.5	15.30

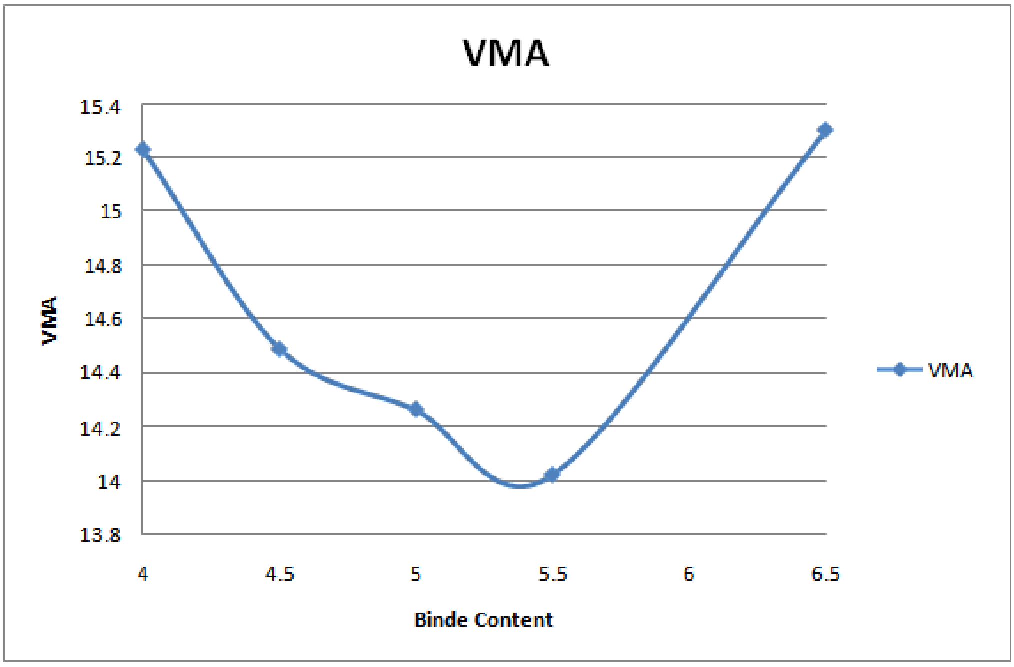

Fig. 5.8 VMA vs. bitumen content

VFB vs. bitumen content

Values of VFB values in %ge and bitumen content in bitumen in %ge are plotted against bitumen in x-axis and VFB in y-axis.

Table 5.8 VFB vs. bitumen content

Binder content	VFB
4.0	53.95
5.0	67.81
5.5	78.70
6.0	82.53
6.5	93.40

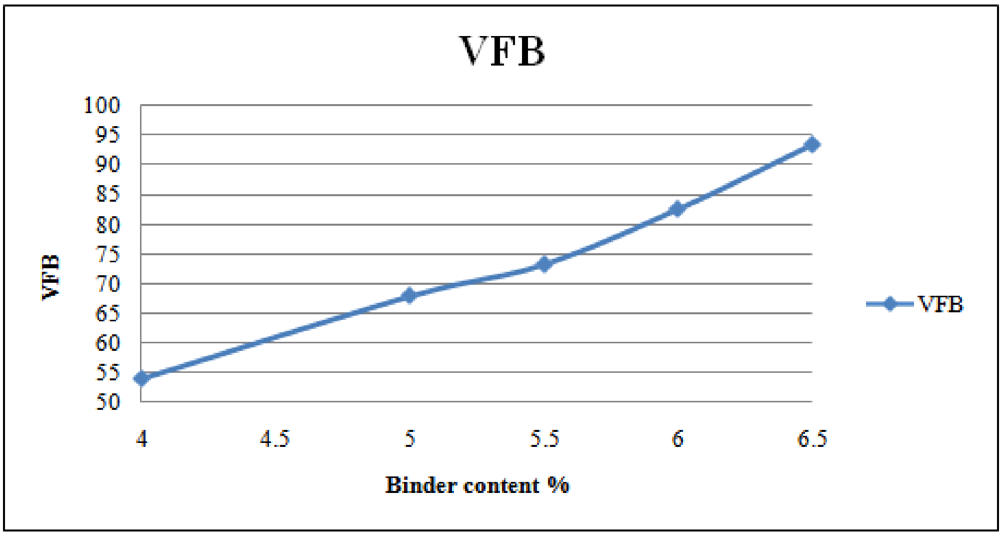

Fig. 5.9 VFB vs. bitumen content

VA vs. bitumen content

Values of VA values in %ge and bitumen content in bitumen in %ge are plotted against bitumen in x-axis and VA in y-axis.

Table 5.9 VA vs. bitumen content

Binder content	VA
4.0	7.04
5.0	4.54
5.5	3.98
6.0	2.59
6.5	1.21

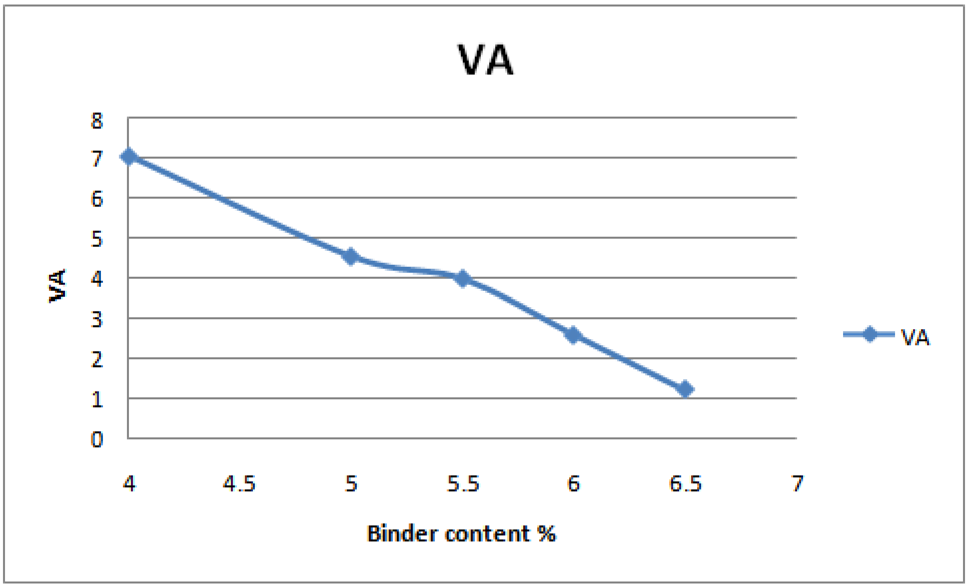

Fig. 5.10 VA vs. bitumen content

DETERMINATION OF MIX DESIGN PARAMETER

From the curves, at 4 % air voids, the mix properties are as follows

SMA With crumb rubber content

Requirements of SMA according to IRC SP-79-2008 IS given in table 5.2

Table 5.10 IRC SP 79-2008 Specification mix design requirements of SMA & Mix properties at 4% air void

Property	Specification	Result obtained with 5% Crumb Tire
Minimum binder content by weight of mix, (%)	>6.5	5.5%
Stability (kN)	8 Minimum	12.72
Flow (mm)	2 – 4	3.42
VMA (%)	17 Minimum	19.70
VFA (%)	75 – 80	78.70
Binder Type	60/70 grade binders	60/70 and modified binders

Here OBC is 5.5% with 5% Crumb tyre.

Marshall Stability

It can be observed that with increase binder content stability value increases up to certain binder content and there after it decreases. Similarly by addition of Crumb tyre stability value also increases up to certain limits and further addition of Crumb tyre stability value starts decreasing. May be this is due to excess amount of Crumb tyre which is not able to mix in asphalt matrix properly.

OPTIMUM BINDER CONTENT

Optimum Binder Content is found out by taking average value of following three bitumen content found from above graph i.e.

A. Bitumen content correspond to maximum stability
B. Bitumen content corresponding to the Air void.

SMA with 5% Crumb tyre waste & OBC is 5.5% were found. Hence for SMA OBC is found as 5.5%.

5. CONCLUSIONS

General Conclusion

Based on the results and discussion of experimental investigation carried out on mixes SMA following conclusion are drawn.

- It is found that by addition of 5% crumb rubber to SMA mix, the OBC value is 5.5%
- By addition of 5% crumb rubber to SMA, Stability value increases significantly, further addition to it stability decreases.
- From the graph of stability vs. bitumen it is learnt that optimum binder content for samples prepared by use of 5% tyre Crumb is found to be 5.5 %. For SMA mixes value of optimum binder content is quite high that makes it very costly. So we can say here that use of tire crumb would result into sufficient cost effective and money saving measure.
- Here maximum stability obtained is 12.72 kN This value as compared to other substitutes is little higher.
- Theoretically VMA should remain constant for a given aggregate gradation with respect to binder content. Practically it is observed that at low bitumen content, VMA slowly decreases then increases after a pause.
- The initial fall in VMA is due to re-orientation of aggregates in presence of bitumen. In present case it is seen that VMA increases as binder increases. This may be explained by argument that due to thicker bitumen film, the aggregates move apart slightly resulting in increase of VMA.
- With increase in bitumen content, VA of Marshall sample decreases, as bitumen replaces the air voids in the mix and subsequently, VFB increases with increase in bitumen content.

Future scope of work

- In future performance of crumb rubber with other grades of bitumen can also be tested.
- Use of crumb rubber may also be tested not only for SMA but also for different other HMA.
- Indirect tensile test of SMA mix can give us an idea about tensile strength of mix.
- Repeated load testing can be studied on SMA Mix.

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