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A COMPARATIVE STUDY OF MARSHALL PARAMETERS BY USING DIFFERENT FILLER MATERIALS

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Abstract: *Bituminous concrete (BC) is most commonly used all over the world in construction projects like road surfacing (flexible pavements), parking lots, airports etc. BC mainly consists of asphalt or bitumen (used as a binder) and mineral aggregates which are mixed together in desired proportions and laid down in layers and then compacted. The volumetric properties we're examining include aspects like air voids, voids in mineral aggregate (VMA), and voids filled with asphalt (VFA). These properties are majorly responsible for surface failures like rutting, cracking, path holes etc. and in determining the durability and overall quality of asphalt pavements. The fillers has the following roles in bituminous concrete like filling voids, improving rutting resistance performance, mitigation of thermal cracking. To overcome all the failures the filler materials are added to bituminous concrete where all the properties like impermeability, stability, strength, flow value and bond between aggregate and bitumen will be increased.This project summarizes the careful consideration of marshal mix design and testing of bituminous concrete samples which emphasizes the effectiveness of different fillers (like Steel slag, granite powder, stone dust, etc.) materials in properties of bitumen concrete.Marshall parameters serve as crucial indicators of asphalt mixture performance and durability. The research investigates the influence of various filler materials on key Marshall parameters such as stability, flow, air voids, and voids in mineral aggregates (VMA). Through a systematic examination of these parameters, the study aims to discern the optimal filler material composition for enhancing the overall quality and longevity of asphalt pavements. By analyzing and comparing the performance of different filler materials, this study seeks to provide valuable insights for the construction industry, facilitating informed decision-making in asphalt mixture design and pavement engineering. Also it gives an idea of suitable filler material for different Marshall parameters of bituminous concrete.*

Key words: Marshall stability, fillers, Bituminous concrete, Volumetric properties

1. BACKGROUND OF THE STUDY

Marshall mix design holds significant importance in the realm of bituminous concrete for several critical reasons. Firstly, it serves as a pivotal tool for optimizing the proportions of various components within the asphalt mixture, including aggregates, binders, and fillers. Through systematic experimentation and analysis, engineers can determine the ideal combination that yields the desired performance characteristics, such as strength, durability, and resistance to deformation. .This customization capability is essential as different road projects often necessitate tailored asphalt mixtures to meet specific requirements dictated by factors like traffic volume, climate conditions, and expected lifespan. Furthermore, Marshall mix design plays a crucial role in ensuring the performance and longevity of asphalt pavements. By subjecting mixtures to Marshall testing, which evaluates parameters like stability, flow, air voids, and density, engineers can assess their ability to withstand traffic loads and environmental stressors, such as temperature fluctuations and moisture exposure. This comprehensive evaluation enables the selection of mix designs that exhibit superior performance over their intended service life, thus enhancing the reliability and durability of roadway infrastructure. Additionally, Marshall mix design facilitates effective quality control and assurance throughout the construction process. By adhering to standardized testing procedures and specifications, construction teams can verify that asphalt mixes meet required performance standards. This consistency in quality control not only ensures the reliability of the constructed pavement but also minimizes the need for costly repairs and maintenance down the line. Moreover, Marshall mix design contributes to cost efficiency in roadway construction and maintenance. By developing asphalt mixtures with optimized proportions, engineers can minimize life cycle costs associated with pavement upkeep. Selecting materials and proportions that maximize performance and durability ultimately reduces the frequency and extent of maintenance activities, resulting in long-term cost savings. In summary, Marshall mix design serves as a cornerstone in bituminous concrete, providing a systematic approach to optimizing mixture proportions, ensuring performance and durability, facilitating quality control, and contributing to cost efficiency in roadway construction and maintenance. Its application enables engineers to create asphalt pavements that meet specific project requirements while delivering long-lasting, high-performance infrastructure.One of the most significant production issues that businesses have focused on during the last decades is quality that includes not only the quality of products but also the quality of services and processes. As markets become more and more competitive, quality becomes a key ingredient for business success, as customers get more and more aware of its significance and ask from every company to assure the fulfillment of their needs.

Improper mix design in asphalt pavement can lead to several significant problems that impact the performance, longevity, and safety of roadways:

Premature Pavement Failure: Inadequate mix design can result in asphalt pavements that lack sufficient strength and durability to withstand traffic loads and environmental stresses. This can lead to premature pavement failures such as rutting, cracking, andpotholing, necessitating costly repairs and premature resurfacing.

Reduced Durability: Poor mix design can compromise the durability of asphalt pavements, making them more susceptible to damage from factors such as heavy traffic, temperature fluctuations, and moisture infiltration. This can result in accelerated deterioration, requiring frequent maintenance interventions and reducing the overall lifespan of the pavement.

Safety Hazards: Asphalt pavements with improper mix designs may exhibit surface irregularities, unevenness, and distresses such as depressions and upheavals, posing safety hazards to motorists, cyclists, and pedestrians. These defects increase the risk of accidents, especially during adverse weather conditions, leading to potential injuries and liabilities.

Increased Maintenance Costs: Pavements with inadequate mix designs often require more frequent and extensive maintenance interventions to address performance deficiencies and structural failures. This translates into higher maintenance costs for agencies responsible for roadway upkeep, as resources are expended on patching, sealing, and rehabilitation efforts.

Negative Environmental Impact: Inefficient mix designs may contribute to increased material consumption, energy consumption, and greenhouse gas emissions associated with asphalt production and transportation. Additionally, the need for frequent repairs and resurfacing due to pavement failures further exacerbates the environmental footprint of roadway maintenance activities.

2. OBJECTIVES OF THE STUDY:

The main objective of this study is to identify the best and economical filler material in bituminous concrete by performing Marshall mix design.

Specific objectives

1. To find OBC (optimum bitumen content) of bituminous concrete by using different fillers materials
2. To find out the best filler material for different volumetric properties of bituminous concrete by comparison of test results.

3. METHODOLOGY OF THE STUDY

The methodology employed in studying the partial replacement of bitumen with fillers involves a systematic approach to assess the material properties and performance of modified asphalt mixtures. Researchers typically begin by selecting appropriate filler materials, considering factors such as particle size, shape, and chemical composition. Laboratory experiments are then conducted to investigate the rheological behaviour, mechanical properties, and durability of the asphalt mixes containing varying percentages of fillers. Common tests include dynamic shear rheometer (DSR) analysis to evaluate the stiffness and rutting resistance, bending beam rheometer (BBR) tests to assess low-temperature cracking resistance, and fatigue testing to gauge the material's endurance under repeated loading. Furthermore, researchers often employ microscopy techniques to examine the micro structure and filler distribution within the asphalt matrix. Additionally, computational modelling may be utilized to predict the performance of modified asphalt mixes under different loading and environmental conditions. Overall, the methodology in this field is aimed at comprehensively evaluating the effects of filler incorporation on asphalt mixture properties and optimizing mix design parameters to achieve desired performance characteristics

4. LITERATURE REVIEW

The literature review on the partial replacement of bitumen with fillers reveals a diverse array of studies focusing on the optimization of asphalt mixtures to enhance their mechanical properties and durability while mitigating environmental impacts. Researchers have explored various types of fillers including mineral, waste, and synthetic materials, examining their effects on the theologicalbehaviour, fatigue resistance, rutting performance, and moisture susceptibility of asphalt mixes. Studies highlight the potential benefits of filler incorporation such as improved stability, stiffness, and resistance to aging, as well as reduced asphalt content and cost. However, challenges such as achieving optimal filler-bitumen interactions, maintaining adequate work ability, and addressing potential compatibility issues have also been identified. Overall, the literature underscores the importance of further research to elucidate the mechanisms governing filler-bitumen interactions and to develop standardized methodologies for evaluating the performance of modified asphalt mixtures in different climatic and traffic conditions.Among the multiple definitions of quality that can be found in literature, the most comprehensive one is the following: ‘‘Quality is meeting or exceeding the needs and expectations of customers.’’ This means that quality is more than a product that simply works properly. It may also include the concepts of performance, appearance, availability, timely and proper delivery, reliability, maintainability, cost-effectiveness and low price. Quality Management (QM) includes all activities ensuring that products and services fit their purpose and meet the predetermined specifications.

P. Jitsangiam (2023) An evaluation of the suitability of SUPERPAVE and Marshall asphalt mix designs as they relate to Thailand's climatic conditions. This research aims to develop the mix design concept for asphalt concrete mixed with recycled plastic. The assumptions of this proposed mix design were for the volumetric calculations to obtain the volumetric parameters corresponding to the Marshall mix design procedure**.** This study aims to evaluate whether the SUPERPAVE mix design procedure can be reliably implemented under Thailand pavement conditions. A map of the Performance Grade (PG) asphaltbinders was generated to cover the study area, namely the North part of Thailand, according to the SUPERPAVE asphalt classification with the highest and lowest temperature ranges that the asphalt might be subjected to. Using local materials, and considering loading and environmental conditions, a comparative study of the performance of two mixes, designed using SUPERPAVE and Marshall Mix design procedures, was carried out.The SUPERPAVE mixes proved superior to the Marshall Mixes. However, the asphalt binder commonly used in Thailand is not suitable for Thailand pavement conditions, based on the PG grade asphalt classification system.

Tapas Kumar Roy (2019) Experimental evaluation of rice husk ash and fly ash as alternative fillers in hot mix asphalt. This research evaluated the effect of RHA and FA-F as a substitute to conventionally used HL filler in various proportions on the performance behavior of bituminous mixture and mastic. Primarily, the dense graded bituminous macadam (DBM) mix specimens were made in the laboratory with varying proportions ranging from 2% to 8% of HL, RHA and FA by following design mixes according to the Marshall method and compared the results with control mix as prepared by utilising 2% HL. The performances of the said mixes were studied through the Marshall quotient, indirect tensile strength and tensile strength ratio. Results of investigation show better performance of HMA with the addition of RHA and FA and also proved to be economical as the optimum bitumen content is reduced by 7.5% from that of control mix when added at 4% filler ratio. Further, RHA shows a greater affinity to the bitumen attributing the highest stiffening effect of the bituminous mastic droplets compared to that of other used fillers with good compatibility at the micro level by satisfying the essential criterion.

Namir G. Ahmed Alkawaaz (2019) Experimental evaluation of durability characteristics for reclaimed local asphalt pavement mixtures. The optimum asphalt content of the HMA is highly dependent on the aggregate characteristics such as gradation and absorption. In the Superpave mix design, the optimum asphalt content is found to be 4.42% for (R1) TRZ gradation and 4.54% for (R9) ARZ gradation. Demand for HMA recycling was driven by increased cost of asphalt, the lack of quality aggregates, and the need to preserve the environment. Reclaimed Asphalt Pavement (RAP) material is produced when deteriorated pavement is milled, crushed, fractionated, and stockpiled for use as an additional component in asphalt mixture. In addition to previous considerations, RAP can also increase the durability of the produced HMA mixtures which is proved by this study. For the laboratory investigations, natural aggregate from AlNibaay, (40-50) grade asphalt from Daurah refinery, and four different percentages of (RAP) material were used. Laboratory testing program was conducted on asphalt concrete mixes with 5, 10, and 15 percent of RAP and compared with the control mix which contains 0 percent of RAP. The mechanical criteria for durability performance in this research is retained Marshall Stability. The durability potential of a given mixture was assessed by testing the mixture after immersion in water bath at 25˚C for 1, 2, 4, 7, and 14 days. Experimental results indicate that the durability potential was increased by 10.4, 15.7, and 20.2% for 5, 10, and 15 % RAP content respectively. The optimum binder content (OBC) decreased with increased RAP percent in HMA mixtures. The test results indicate that the amount of new binder that needs to be added to the RAP mixture can be reduced without significant effects on the quality of the produced mix.

Athira R Prasad (2019) Experimental investigation on partially replacement of bitumen with waste materials for flexible pavement construction. We have conducted the experiments on the physical properties of bitumen mix by varying from 10 to 60% of waste plastic (PET), waste rubber, both plastic and rubber equally combined respectively. According to this research we found that 30% is the optimum percentage of waste stuff can be restored. In addition, the use of these waste substance will play a significant role in reducing the use of non-renewable resources, in constructing sustainable pavements and leads to decrease in cost of construction up to 38.5%, 40% and 39.3% when waste (plastic, rubber, plastic & rubber respectively) restored when compare to ordinary bitumen. Keywords :-(Flexible Pavement, Environmentally Friendly, Marshall Stability, Plastic, Tires, Waste)

Tapas Kumar Roy (2019) Effect of using fly ash as alternative filler in hot mix asphalt. This study investigates the effect of using fly ash (FA) in asphalt mixture as replacement of common filler. In view of the same, samples were prepared for different bitumen content (3.5−6.5% at 0.5% increments) by using 2% hydrated lime (HL) in control mix as well as varying percentage of FA ranging from 2 to 8% as alternative filler in modified mixes. The optimum bitumen content (OBC) was then determined for all the mix by Marshall mix design. Experimental results indicated higher stability value with lower OBC for the mixture having 4% FA as optimum filler content in comparison with conventional mix and standard specification. So this study discuss the feasibility of using FA as alternative filler instead of HL in asphalt concrete mix by satisfying the standard specification.The potential use of fly ash, collected from local thermal power plant, in hot mix asphalt was investigated through Marshall mix design. From the analysis of the laboratory test data, the following conclusions can be made-According to obtained Marshall parameters, the addition of FA up to 4% in DBM mix, by replacing conventional mineral filler like HL shows a 7.5% reduction in OBC compared to the control mix, which may provide a considerable economy of bitumen in resulting mixture.So, the replacement of HL by FA in HMA not only satisfies all the standard specification of MORTH but also gives better strength with lesser deformation compared to that of the conventional mix.

Sahil Arora (2017) Use of waste plastic in bituminous concrete. From the research work it was found that Marshall Characteristics improves after adding waste plastic in mix. Optimum bitumen content of BC comes out at 6% after adding waste plastic to the mix the optimum plastic content comes out at 7%, after that the value of stability decreases. The various properties of bituminous concrete with or without plastic were checked. As per IRC 111-2009, the quantity of the bitumen in

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BC was from 5.2% to 6.8%. The waste plastic is added in various percentages (5% to 9%) in all samples to replace the bitumen with these percentages in BC. Then the Marshall Test for flow and stability with all void analysis are done on all samples.

Khimta, A. and Arora, S., (2016) Experimental study on the suitability of using polyvinyl chloride (PVC) plastics wastes in the production of Bituminous mix for pavements Construction. Experimental results indicate higher stability value with lower OBC for the mix having 4% FA as optimum filler content in comparison with conventional mix & standard specification. This research assesses the use of ABS waste plastic in production of bituminous mix for flexible pavement. In particular, the research focused first in determination of the softening temperature of ABS waste plastics and characterizing aggregates bitumen and binder according to their physical properties. Furthermore, the bituminous mix containing ABS plastic waste was prepared using the Marshall Mix design and analysis for its Marshall properties was done and finally some Marshall specimens were prepared and tested to evaluate their indirect tensile strength as a measure of Optimum performance of the mix and durability. Summarily, the results of bituminous mix having ABS plastics showed better pavement performance results in terms of ITS than the conventional mix. The better results therefore mean better performing, durable, economically cheap and environmentally friendly road pavements can be constructed when ABS is used as a bituminous mix.

Athira R Prasad (2016) Bituminous modification with waste plastic and crumb rubber. Thus According to the study, the use of plastic at 6% by weight of bitumen improve its properties. The use of waste materials like plastics and rubber in road construction is being increasingly encouraged so as to reduce environmental impact. Plastics and rubbers are one of them. . The plastic waste quantity in municipal solid waste is increasing due to increase in population and changes in life style. .Similarly most tires, especially those fitted to motor vehicles, are manufactured from synthetic rubber. Disposal of both is a serious problem. At the same time, continuous increase in number of vehicles emphasizes on need of roads with better quality and engineering design. This waste plastic and rubber can be used to partially replace the conventional material which is bitumen to improve desired mechanical characteristics for particular road mix.In the present study, a comparison is carried out between use of waste plastic like PET bottles and crumb rubber (3%, 4.5%,6%,7.5%,9%by weight of bitumen) in bitumen concrete mixes to analyse which has better ability to modify bitumen so as to use it for road construction.

Agarwal et al. (2012) studied that the pavement system can lead to moisture damage, modulus reduction, and loss of strength. The drainage design criteria used in the past have been based on the assumption that both the flow of water through pavements and the drainage of pavement layers can be represented with saturated flow assumptions. Full saturation of pavement systems can occur only under specific circumstances, when positive total heads are present. Detrimental effects can be reduced by preventing water from entering the pavement by providing drainage to remove infiltration. Building the pavement strong enough to resist the combined effect of load and water can reduce detrimental effects. Pavement service life can be increased by 50% if infiltrated water can be drained without delay. Similarly, pavement systems incorporating good drainage can be expected to have a design life of two to three times that of undrained pavement sections. This paper gives an analysis of drainage related performance of flexible pavements.

5. RESULTS AND DISCUSSIONS

Aggregate, Bitumen and filler materials are collected at different fields and subjected to various tests according to IS code.

Table 1. Preliminary results on Aggregates

Properties	IS code	Mean Value	Max. Value
Impact value	IS 2386 Part 4	27%	30%
Crushing value	IS 2386 Part 4	28.18%	30%
Specific gravity	IS 2386 Part 3	2.82	2.5-3.0
Losangles abrasion	IS 2386 Part 4	25.9%	30%

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Table Preliminary test on bitumen

Properties	Test Method	Result	Maximum values
flash point (°c)	IS:1209-1978	332.5	min 220°c
fire point (°c)	IS:1209-1978	340	min 220°c
ductility (cm)	IS:1208-1978	100	50-75
softening point (°c)	IS:1205-1978	53.25	45-48°c

Marshall stability Results

The following below table shows Marshall Stability values conducted as per Marshall procedure. we conducted the test with three samples for each percentage of bitumen from 4.5% to 6% with 0.5% increments. Corresponding correction factors are applied as per the volume of samples.

Table Marshall Stability Test values

Type of filler material	Bitumen grade (%)	Marshall stability value (KN)			Mean of Marshall stability	volume of sample	cor n fa
		Sample 1	Sample 2	Sample 3			
Steel slag	4.5	14.00	15.10	14.90	14.67	500.20	
	5.0	16.99	19.59	15.80	17.46	499.82	
	5.5	17.64	20.78	19.57	19.33	500.64	
	6	18.82	19.35	19.12	19.10	506.35	
Granite powder	4.5	16.00	19.15	16.11	17.09	502.27	
	5	20.75	21.15	22.54	21.48	502.27	
	5.5	20.07	19.45	23.14	20.89	499.82	
	6	18.90	14.89	14.86	16.22	508.80	
	4.5	23.45	23.82	24.52	23.93	502.27	

Mean of Marshall stability at 4.5%= (14.00+15.10+14.90)/3=14.67 Kn

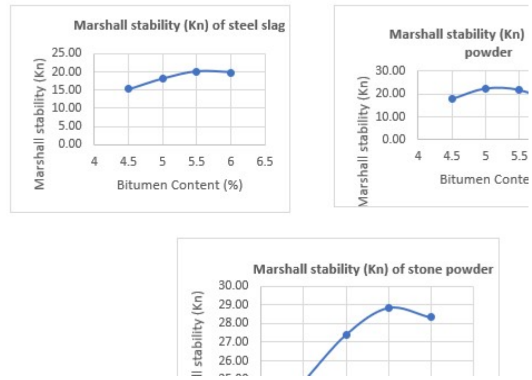

Fig. Marshall stability Test Graphs

Marshall flow Results

The following below table shows Marshall flow values conducted as per Marshall procedure. we conducted the test with three samples for each percentage of bitumen from 4.5% to 6% with 0.5% increments. Corresponding correction factors are applied as per the volume of samples.

Mean of Marshall flow at 4.5%= (3.42+3.54+3.60)/3=3.52mm

Table Marshall flow Test values

Type of filler material	Bitumen grade (%)	Flow value (mm)		
		Sample 1	Sample 2	Sample 3
Steel slag	4.5	3.42	3.54	3.60
	5.0	3.50	3.62	3.90
	5.5	3.80	3.75	3.84
	6	4.25	3.92	3.90
Granite powder	4.5	3.20	3.50	3.80
	5	3.70	3.56	3.60
	5.5	2.12	4.63	4.25
	6	3.20	3.30	4.55
	4.5	1.28	2.68	2.50

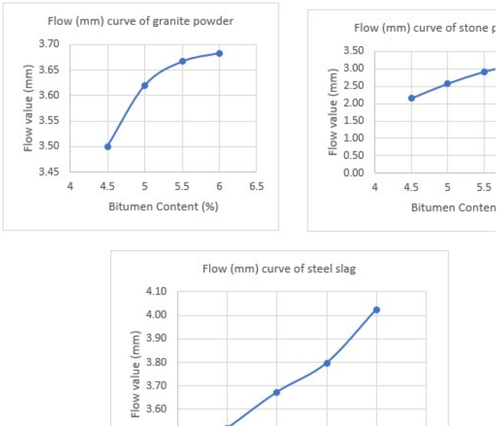

Fig. Marshall flow Test Graphs

Table Results of Volumetric properties of Bituminous mix

Type of filler material	Bitumen grade (%)	Va	OBC	Vb	VM
Steel slag	4.5	4.92	4.83	12.11	17.
	5.0	4.64		13.45	18.1
	5.5	4.23		14.80	19.
	6	3.93		16.15	20.
Granite powder	4.5	4.73	4.66	12.00	16.7
	5	4.31		13.33	17.6
	5.5	3.97		14.67	18.6
	6	3.06		16.00	19.
	4.5	4.82		12.03	16.

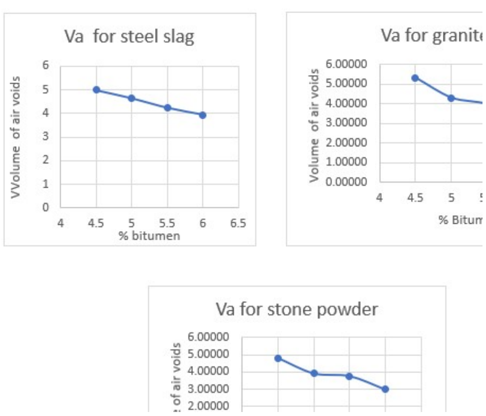

Fig. Air Voids of Bituminous mix Test Graphs

The volume of air voids curve, commonly referred to curve, is a graphical representation used in asphalt mix design to optimize the proportion of voids within an asphalt mixture. This curve illustrates the relationship between the percentage of air voids in the compacted asphalt mixture and the asphalt binder content.

OBC (optimum bitumen content) is calculated as average values of that satisfy the set of requirements stability, Bulk unit weight, and volume of air voids. OBC is obtained as 5.5% by weight of sample**.**

6. CONCLUSIONS

The partial replacement of bitumen with stone powder, granite powder, and steel slag represents a valuable innovation in asphalt engineering, offering a sustainable, cost-effective, and durable solution for road construction and maintenance. Embracing these advancements can contribute to the development of more resilient and eco-friendly transportation infrastructure in the years to come

- The optimum bitumen content for steel slag, granite powder and stone powder are 4.83%, 4.66% and 5.5% by weight respectively.
- The maximum stability for steel slag, granite powder and stone powder are 20.10 KN, 22.34 KN and 28.87 KN respectively.
- Out of all the filler materials used, it was found from the experimental results that stone powder gives the best stability value of 28.87 KN
- The minimum Flow values for steel slag, granite powder and stone powder are 3.52 mm,3.50mm and 2.15mm respectively.
- Out of all the filler materials used, it was found from the experimental results that stone powder gives the best flow value of 2.15mm.
- The volume of air voids for steel slag, granite powder and stone powder are 3.93%, 3.06% and 3.77% respectively.
- Out of all the filler materials used, it was found from the experimental results that stone powder gives the optimum volume of air voids value of 3.77% considering both primary and secondary compaction.
- It is evident from the experimental results that Marshall parameters improves after adding various filler material in mix.

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- IS : 2386 (Part IV) This standard covers the following tests for aggregates for concrete : a) Determination of Aggregate Impact Value b) Determination of Aggregate Abrasion Value, c) Determination of Crushing Strength**.**