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# Investigation of SMARC Mixes and Marshall Characteristics and Moisture Susceptibility Attribute for Flexible Pavements

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**ABSTRACT:** In this investigation of SMARC mixes, the Marshall characteristics, drain down properties, tensile strength property attributes, fatigue property attributes, and moisture susceptibility attribute have all been examined. In this investigation, three distinct types of binders, including one that had been modified, as well as a natural fibre, were put through their paces. Resistance to rutting and creep behaviour are two characteristics that might be the subject of more research. Mixtures created using SMARC may also be evaluated using a variety of natural and synthetic fibres. Due to the fact that there is only one here, it is easy to compare numerous gradations that have been presented by various agencies. Because the coconut fibre that was used in this study was very affordable, a cost-benefit analysis could be carried out to estimate the effect that it would have on the expenses of constructing buildings. It is possible to construct trial stretches and monitor their performances on a regular basis in order to further ensure that this new material will be successful. In addition, it has been observed that the addition of fibre to mixtures, regardless of the kind of binder that is used, leads in a significant increase in the tensile strength of the mixture. This is the case regardless of the type of binder that is employed. According to the findings of the study, it is feasible to utilise any of the SMARC mixes that were made with three different kinds of binders in the wearing courses of flexible pavements.

**KEYWORDS:** SMARC, tensile strength, Marshall characteristics, pavements, Bituminous Mixtures

## I. INTRODUCTION

Traditionally, bitumen-bound aggregates are utilised in the building and maintenance of flexible pavements all over the globe. This kind of pavement is quite widespread in the paving business because of its ability to withstand heavy traffic loads when properly planned and installed. However, dense graded aggregates may not always be accessible on the site. SMARC, a bituminous mix mostly composed of gap-graded aggregates, may be used in these types of conditions.For studded tyre damage, Zichner of Straubag-Bau AG's Central Laboratory developed SMARC in 1960s Germany.

Even after the usage of studded tyres was made illegal, the use of SMARC continued due to the material's exceptional resilience to deformation under the stress of heavy traffic at high temperatures. Coarse aggregate makes up 70–80 percent of gap-graded SMARC, while binder accounts for 6-7 percent, filler ranges from 8–13 percent, and fibre or modifier makes up the remaining 1 percent (0.3-0.5 percent). This creates a "architectural skeleton" that allows for more stone-on-stone contact and results in higher rusting resistance.

Even in densely graded mixes, there is aggregate-to-aggregate contact; however, it is confined to a SMARCller portion of the fine aggregate particles, which do not provide the same shear resistance as coarse aggregates. SMARC traffic loads are handled by coarse aggregate particles rather than fine asphalt-mortar particles, according to Brown and Manglorkar (1993). The blend is more durable because of the greater binder concentration. During manufacture, transit, and laying, fibres or modifiers retain the binder in the mixture and prevent the binder from drying out.

For high-volume roads, SMARC has shown to be more cost-effective than thick graded mixtures. The performance of SMARC mixes is influenced by a variety of parameters, according to Brown (1992), such as changes in the binder supply and grade as well as the kind of aggregate used, ambient conditions, manufacturing processes, and so on.

An analysis of these characteristics is necessary in order to determine the SMARC's performance over the long run and to provide information for future changes to be made to accommodate a variety of environmental variables. In their definition, the FHWA's SMARC Technical Working Group refers to "a gap graded aggregate hot mix asphalt" as "a stable stone-on-stone skeleton, kept together by a rich blend of binder, filler, and stabilising additives." This is what they mean when they say "a gap graded aggregate hot mix asphalt."

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**Comparison to Traditional Bituminous Mixtures**

SMARC pavements are superior in terms of strength, durability, and lifetime than conventional asphalt pavements. SMARC is superior than traditional mixes in a number of ways. Improved skid and noise resistance, reduced permeability and sensitivity to moisture are some of the advantages of SMARC over conventional alternative pavement surfaces.Additionally, it offers improved resiliency in the face of the rutting that may occur as a result of slow, heavy, and high-volume traffic. It has properties that are advantageous at low temperatures and has a high level of resistance to plastic deformation even when subjected to heavy traffic loads combined with high tyre pressures.

After the traffic has removed the binder's surface coating, the rough roughness of SMARC's surface offers excellent friction. SMARC has a longer life expectancy than traditional thick graded mixes, according to Kamaraj et al. (2004). In addition, it is anticipated that it will cost around 20 to 25 percent more than the conventional thick graded mixes; however, the increased longevity of the road may make this additional expense justifiable.SMARC has been shown to be superior than HMA blends because of these benefits.

**Marshall test**

A number of Marshall attributes, including Marshall stability, flow, and unit weight, as well as SMARC mix air void content, have been investigated. Binder content (OBC) and fibre content (OFC) were calculated using these factors to arrive at the ideal mixture composition. When fibre is used in a specific blend, the OBC percentage lowers, which is contrary to the typical trend of increasing Marshall stability values with fibre additions of up to 5%. Their OBC and OFC were used for the following round of trials.

**Drain down test**

SMARC mixtures are subjected to a drain down test to determine the binder's drain down percentage. The results of drainage tests performed on SMARC mixes that included three distinct types of binder showed that none of the binders drained down in any of the mixes that contained fibre.Fiber enhances the performance of 80/100 and 60/70 bitumen mixes.

**Tensile evaluation using a static indirect load**

For the purpose of determining the tensile strength of SMARC mixtures at their OBC and OFC sites. The findings show that adding fibre increased the mixture's tensile strength. Using this procedure, the tensile strength of SMARC mixtures is also being tested since repeating a load test may be time-consuming. Results show that the tensile strength falls as the test temperature rises.

**Indirect tensile test subjected to repeated loads**

The fatigue properties of pavement materials, in addition to their elastic modulus and Poisson's ratio values dynamically circumstances are all essential variables in the construction of a pavement.In order to evaluate the fatigue life properties of SMARC mixtures, This has been done using a laboratory-fabricated repeating load indirect tensile testing set up. For a total of three distinct temperature ranges ranging from 25 degrees Celsius to 35 degrees Celsius, several load tests were performed.

## II. EXPERIMENTAL INVESTIGATIONS

Experiments that were carried out as part of this inquiry are outlined in this chapter. There are two sections to this chapter. In the first section, experiments with materials (aggregates, bitumen, and fibre) are discussed, while in the second section, testing on bituminous mixtures are discussed.

**Tests on Materials Cast-off**

**Aggregates**

SMARC mixes were made by mixing NCHRP-graded aggregates (as shown in Table 3.1), a specific binder, and the requisite amounts of fibre according to the Marshall technique.

Coarse Aggregates

Stone chips up to an IS sieve size of 4.75 mm were used as coarse aggregates. They were subjected to standard testing to assess their physical characteristics, which are reported in Table 3.2.

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Fine Aggregates

Fine aggregate was obtained from a nearby stone crusher by using sieves with a mesh size of 0.075 mm IS, and the fractions that were larger than 4.75 mm were retained on the sieve. This substance's specific gravity was found to be 2.65 upon further investigation.

## III. TEST RESULTS ANALYSIS AND DISCUSSION

In the chapter before this one, the specifics of the tests that were conducted on various SMARC mixtures are described in further detail. The findings and observations made during the tests that were carried out are summarised, examined, and spoken about in this chapter. This chapter is broken down into five different parts. The findings of the Marshall experiments conducted on SMARC mixtures are discussed in the first half of this article. In the next part, we will go over the findings of the drain down test that was performed on SMARC mixtures. The outcomes of the static and repeated load indirect tensile tests are discussed in the third and fourth parts of this report, respectively. The findings of the test to determine the moisture susceptibility are presented in the last section.In this experiment, SMARC mixes with and without coconut fibre were prepared using three different types of binders: As was mentioned before, the experiment was conducted using both mixes. More information on these SMARC mixtures and their testing may be found on this page.
The findings and observations of the experiments undertaken are reported, examined, and discussed in this chapter. Five parts make up this chapter. The findings of Marshall experiments on SMARC mixtures are provided in the first part. This section discusses the results of drain down tests performed on SMARC mixtures. This section concludes with a look at the test findings for moisture susceptibility.

### Marshall Properties

**The effect on Marshall characteristics of the kind of binder used, the amount of binder used, and the fibre content**It was shown that Marshall characteristics are affected by the amount of binder and fibre in a combination. This research employed three different kinds of binders to perform a comparison analysis: ordinary and CRMB 60 binder. The findings are presented in the next section.

### Marshall Stability

As can be seen in Figures 1, the Marshall stability values of the three binder types at 0%, 0.3%, 0.5%, and 0.7% fibre concentrations vary depending on the amount of binder present. Binder weight percentages ranged from 3% to 7% in the final blend. After a particular binder content has been reached, the stability value begins to decline, as expected for a bituminous mixture. Binder hardness (in terms of penetration value) has been shown to enhance the stability value in general. For example, samples made have the lowest stability whereas samples prepared have the best stability values for a certain fibre concentration. Higher viscosity binders allow for greater interlocking between aggregates that have larger void packing. Stiffer binder may also be noticed to need greater binder content to achieve the maximum stability value. Binders with a lower draindown effect need more filler in their voids, which may be owing to the binder's greater viscosity.

After 0.5 percent fibre, the stability value begins to decline as the fibre content rises. That's because at a larger proportion of fibre, it's impossible to homogeneously blend fibre components and this leads in fibre aggregation.

A heterogeneous mixture has an effect on the bonding between the aggregates and the binder as well as the which results in According to these numbers, the highest value for stability that can be achieved without having any fibres in the mixture is even bigger than the maximum value that can be achieved with 0.7% fibre in the mixture. This structure is shared by all three varieties of binders.

It is shown in Table 1 that various binders have varying maximum stability values at different fibre percentages and their related binder needs. Using the 80/100 bitumen blend as an example, the maximum stability value is attained at a 4 percent binder concentration, whereas the maximum stability value is obtained at a 4.5 percent binder content for blends with 0.5 percent fibre and 0.7 percent fibre.

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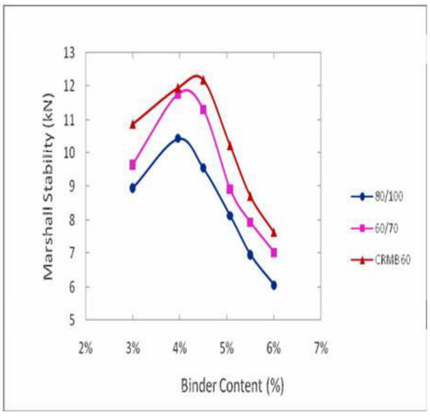
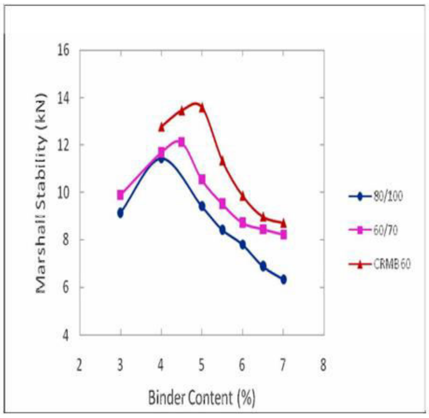
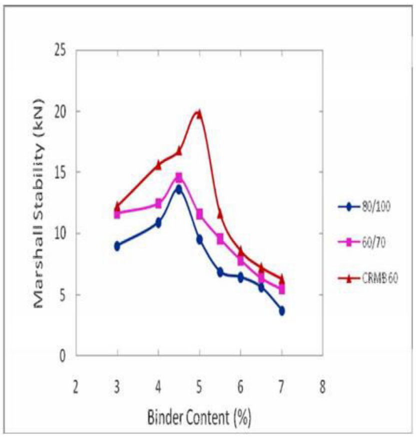


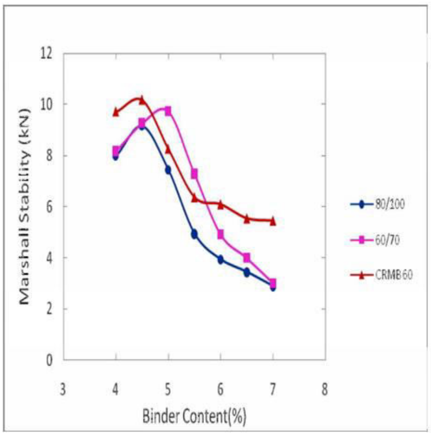

(i) 0% Fiber




(ii) 0.3% Fiber

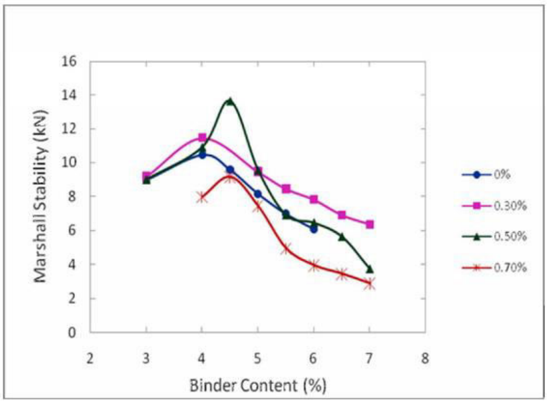



(iii) 0.5% Fiber




(iv) 0.7% Fiber

**Fig. 1:** Variation of Marshall stability value with binder content for different binder




(i) 80 /100 Bitumen

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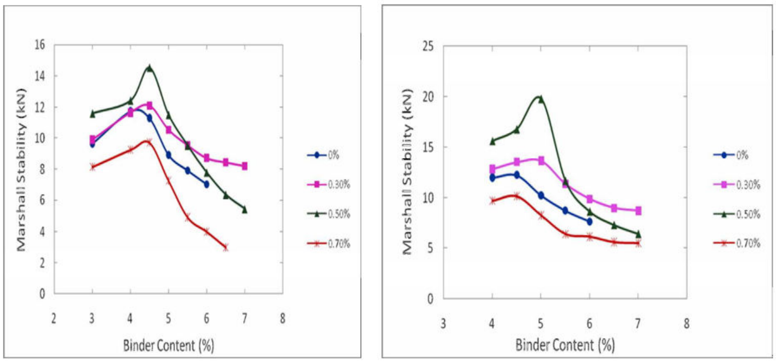


(ii) 60/70 Bitumen (iii) CRMB 60 Binder

**Fig. 2:** Variation of Marshall stability value with binder content for different fiber concentrations in the mix

**Table 1: Maximum Marshall stability values and their corresponding binder content**

| Fiber Content (%) / Binder Type | 0% | | 0.3% | | 0.5% | | 0.7 % | |
|---|---|---|---|---|---|---|---|---|
| | Max. Stability (kN) | Binder Content (%) | Max. Stability (kN) | Binder Content (%) | Max. Stability (kN) | Binder Content (%) | Max. Stability (kN) | Binder Content ( % ) |
| 80/100 Bit. | 10.42 | 4% | 11.43 | 4% | 13.61 | 4.5% | 9.16 | 4.5 % |
| 60/70 Bit. | 11.75 | 4% | 12.09 | 4.5% | 14.52 | 4.5% | 9.71 | 5 % |
| CRMB 60 | 12.19 | 4.5% | 13.61 | 5% | 19.78 | 5% | 10.16 | 4.5 % |

## IV. CONCLUSIONS

The following conclusions are formed from the findings and comments of experiments on various SMARC mixtures.

### Marshall Properties

#### *i) Marshall Stability*

Variations show that binder stiffness has a direct effect on stability, with stiffer binders providing more stability. More binder is needed for optimal stability with a stiffer binder, but that extra binder is worth it. A higher fibre content in the mix (i.e., more than 0.5 percent) enhances the stability value, while additional fibre content.

#### *ii) Flow Value*

The flow value falls as the stiffness of the binder increases, but the flow value rises as the binder content rises. The flow value reduces even more when fibre is introduced to the mix, compared to a regular SMARC mix without fibre. In contrast, a larger percentage of fibres in the mix improves flowability.

#### *iii) Unit Weight*

Up to a particular binder level, the weight of the unit rises, but thereafter drops. After, the unit weight decreases and the stiffness of the binder in the mix increases. Fiber content affects the unit weight as well. Its unit weight rises when 0.3 percent of fibre is added to the mix, but additional fibre addition reduces.

#### *iv) Air Voids*

Binder content minimises the number of air spaces in the mix. The amount of fibre in the mix also affects the amount of fibre in the final product. In the combination, the 0.3 percent fibre content is found to have the lowest air spaces.

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### *v) Optimum Binder Content*

According to the Marshall test findings, the optimal binder content (OBC) of the SMARC mixes is seen to rise, based on the Marshall test results. The optimal binder level of the mixture is reduced when coconut fibre is added.

### *vi) Optimum Fiber Content*

According to the findings of the Marshall tests, the optimal quantity of binder for each of the blends is 0.3 percent, at which point they all display the highest quality characteristics. Therefore, 0.3 percent of the mix should be comprised of the optimum fibre content (OFC) for all SMARC mixes.

**Drain down Characteristics**

When it comes to drain down, mixtures with or without fibre that use CRMB 60 modified binder perform the best. Drainage of binder is too low in mixtures using CRMB 60 binder and no fibre. When fibre is added to 80/100 and 60/70 bitumen mixtures, there is a tiny proportion of drain down, but when no fibre is present, there is no drain down of the binder.

**Tensile Strength**

The tensile strength of 60/70 bitumen mixes is greater than that of 80/100 bitumen mixes at a certain test temperature. Using CRMB 60 binders at low temperatures results in poorer tensile strength than using unmodified binders at higher temperatures, however this is reversed at higher temperatures. In comparison to blends without fibre, the tensile strength of blends with fibre is greater.

**Repeated load Indirect Tensile Test**

### *i) Poisson's Ratio*

Poisson's ratio is impacted not just by the kind of binder used, but also by the temperature of the mixture. The Poisson's ratio in any mixture will increase as the temperature is raised.

### *ii) Resilient Modulus of elasticity*

Based on the binder, fibre content, and test temperature, the Resilient Modulus of Elasticity (RME) value might vary widely. With a rise in temperature, the resilience modulus drops for a certain mixture. Resilient modulus of the SMARC mixes with fibre is significantly greater than the same without fibre.

### *iii) Fatigue Life*

Fibre concentration, test temperature, and binder type all have a role in the fatigue life of SMARC mixtures. Testing at higher temperatures reduces fatigue life for a certain combination. Mixes with fibre have a longer fatigue life than mixes without fibre.Using this formula, the link between fatigue life (Nf) and stress difference () may be found:

$$N_f = K_2' \left(\frac{1}{\Delta\sigma}\right)^{n_2}$$

**Moisture Susceptibility Tests**

(1) The tensile strength ratio (TSR) of SMARC blends without fibre is less than 80% when using unmodified binders, however it is more than 80% using CRMB 60 binder. All forms of binders enhance the TSR value of mixtures containing fibres by more than 80%, the permitted maximum.
(ii) In the immersion stability test, mixtures with CRMB 60 binder preserve a higher percentage of stability than those including 60/70 or 80/100 bitumen. When fibres are added to a mix, its stability value improves.
Thus, the inclusion of fibre to the mix results in good moisture susceptibility properties.

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**Scope for Future Work**

Marshall qualities, drain down properties, tensile strength property attributes fatigue property attributes moisture susceptibility attribute attributes have all been investigated in this examination of SMARC mixtures. This study tested three different kinds of binders, including one that was modified, as well as a natural fibre. The qualities that may be further studied include rutting resistance and creep behaviour. SMARC mixtures may also be tested with various synthetic and natural fibres. It's possible to compare different gradations proposed by various authorities since there is just one here. Due to the inexpensive cost of the coconut fibre utilised in this research, a cost-benefit analysis may be performed to determine its impact on building costs. As a further safeguard, trial stretches may be built and regular performances checked to assure the success of this new material.

**Concluding Remarks**

We picked coconut fibre since it is a cheap and readily accessible natural fibre. The Marshall characteristics of SMARC mixes may be significantly improved by a 0.3 percent fibre content, especially for mixes containing 80/100 bitumen. It has been discovered that adding fibres reduces the optimal binder content by a significant amount, which has serious implications for both economics and quality. Modified binder and fibre have been shown to enhance drain down and moisture susceptibility in the mix.

In addition, it has been noted that the incorporation of fibre into mixes, regardless of the kind of binder used, results in a considerable increase in the tensile strength of the mixture. According to the results of the research, it is possible to use any of the SMARC mixes that were generated with three distinct types of binders in the wearing courses of flexible pavements. The mixes were effective in all of the tests since the binders were of various types.

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