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EXPERIMENTAL STUDY ON USAGE OF COCONUT SHELL AND COCONUT FIBER IN FLEXIBLE PAVEMENTS

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Abstract: Flexible pavement systems play a crucial role in modern transportation infrastructure, demanding materials that enhance structural integrity and durability. This study explores the potential of utilizing coconut shell can improve the indirect tensile strength and static creep behavior while coconut fibre can increase the stability, skid resistance and resilient modulus as a sustainable alternative in flexible pavement construction. This investigation gives the use of the coconut shell 10mm size replacing with 10mm size coarse aggregate so that the usage of conventional aggregates should be reduced. And also coconut fibre cut into small pieces 5% replacing with filler .This paper explains the suitability of coarse aggregate replacing with coconut shell and also coconut fibre replacing with filler at different percentages.

Index Terms: **Coconut shell, coconut fibre, waste material, bituminous pavement**

I INTRODUCTION

An efficient road network is very important for country's development and socio economic development. Both for freight and people, road transportation is regarded to be one of the most cost-effective and favoured modes of transportation. Coconut shell (CS) and coconut fibre (CF) shown in figure 1are known as new waste materials that used in construction of pavement. The pavement construction continuously seeks sustainable and eco-friendly alternatives to traditional materials. In this context, the integration of coconut shell and coconut fiber as replacements for coarse aggregates and filler in flexible pavement construction has garnered attention. This introduction provides an overview of the rationale behind this innovative approach and its potential benefits.

The primary objective of this research is to investigate the feasibility and effectiveness of replacing traditional coarse aggregates with coconut shell and fibre in flexible pavement construction. Through comprehensive laboratory experiments and analysis using the Marshall Stability test, the study aims to assess the mechanical performance, durability, and sustainability aspects of coconut-based pavement mixtures. The successful implementation of coconut shell and fibre in pavement construction could yield several advantages, including reduced reliance on non-renewable resources, lower material costs, improved pavement durability, and enhanced environmental sustainability. Furthermore, it can contribute to the economic development of coconut-producing regions by creating additional value from waste materials.

Figure .1 Coconut shell and Coconut fibre

II CHARACTERSTICS OF COCONUT SHELL AND COCONUT FIBRE

2.1 COCONUT SHELL (CS):

The coconut shell contains 33.61% cellulose, 36.51% lignin, 29.27% pentosans and 0.61% ash. CS has low ash content but high volatile matter, 65-75%3. But coconut fibre has the lowest cellulose content, 36 - 43% but with twice amount of lignin (41- 45%) compared to jute and sisal which makes it has greater resistance and hardness. CF will act as stabilizing agent when added into the bituminous mix around 180°C. The water absorption of the CS is higher than normal aggregate, which is 24% compared to 0.5. CS is also more resistance against impact, crushing and abrasion compared to others conventional crushed granite aggregate. It can be used to mix with bituminous mixture directly for the experiment except water absorption test. This is because coconut shell has high water absorption capability and not suitable to use for mixing without treatment.

2.2 COCONUT FIBRE (CF):

Coconut fibre has many advantages when react with bituminous mixture as it can reduce bleeding of the binder and advancing the macro texture of the coating. It can help to reform the mechanical properties and improve surface drainage .Coconut fibre enable the use of discontinuous of grain size, which can increase the content of binder, hence the aggregates will coat with thicker film. This can reduce the oxidation of bituminous mixtures, moisture penetration and separation. Coconut fibre has outstanding moisture absorption because the irregular of crack in the cross section surface provides unique structure. This structure also results in better air permeability and moisture conductivity. In addition, the unique structure of the CF will improve the moisture susceptibility, viscoelasticity and rutting resistance as well as ameliorate low temperature anti-cracking properties, durability, material toughness, fatigue life and lowering reflective cracking of bituminous concrete mixtures and pavements.

III MATERIALS AND METHODS:

3.1 AGGREGATES

Aggregates is a collective term for the mineral materials such as sand, gravel and crushed stones that will be used with a binding medium to form compound materials. They should be strong and durable; and also possess proper shape and size. Aggregates are tested for strength, toughness, hardness, shape and impact. Aggregates can either be natural or manufactured. The size of aggregates used from 20mm – 4.75mm. The test results are computed as follows

Table 1 Test on Aggregates

Aggregates	Test	Experimental value	Standard value
Coarse aggregate	Impact strength	18.75	30
	Crushing strength	23.35	30
	Flakiness & Elongation index	15	35
	Specific gravity	2.78	3
	Water absorption	0.75	2
	Abrasion test	20	30
	Attrition test	4	10

3.2 BITUMEN BINDER

The bitumen acts as a binder of the aggregate that provides the structural strength and texture of the road surface. It makes up about 4 to 12 percent of the total bitumen mixture. It is available in various grades, for higher traffic roads, found to be suitable. A25 grade could be used in this research work. The properties of bitumen are analyzed by performing various tests.

Table 2 Test on bitumen

Test	Experimental values	Standard values
Specific gravity	1.01	0.97-1.02
Penetration	22	55-70

3.3 MIX DESIGN

Marshall Method of mix design has been adopted in this work. Accordingly aggregates with the grading 1 of IRC 29-1988 and bitumen having properties described in the tables have been used. The objective of bituminous paving mix design is to form an economical blend of aggregates and bitumen. Several trial aggregate-bitumen binder blends have been used, each of different binder content. By evaluating each trial blend's performance, optimum bitumen binder content is obtained. The first step in sample preparation is to estimate OBC. Trial blend bitumen contents are then determined from this estimate.

Marshall Stability is a method used to measure the resistance of bituminous mixtures to plastic deformation under a standard loading condition. The mix design for Marshall Stability typically involves determining the optimal proportion of aggregate bituminous binder, and other additives to achieve the desired strength and durability for the specific application. It considers factors like aggregate type, gradation, bituminous binder content, compaction temperature, and compaction effort to ensure the mixture meets performance requirements.

3.4 MARSHALL STABILITY TEST PROCEDURE

1. The coarse aggregate, fine aggregate and the filler material should be proportioned and mixed as per the dry mix design (1200gm).
2. The dry mix of aggregates and filler is heated to a temperature of 150°C to 170°C.
3. The compacted mould assembly and rammer are cleaned and kept preheated to a temperature of 100°C to 145°C.
4. The bitumen is heated to a temperature of 150°C to 165°C and the required quantity of the first trial percentage of bitumen is added to the heated aggregates and thoroughly mixed.
5. The mix is placed in the mould and compacted by a rammer with about 75 blows on each side.
6. The weight of rammer is 4.54 kg and height of fall is 45.7 cm.
7. The compacting temperature may be about 135°C to 155°C.
8. Sample is being extracted after 24hr using sample extractor
9. Compact the mixture using a Marshall compactor to achieve the desired specimen density.

IV RESULTS

Grading mix proportion of aggregates when 10mm size coarse aggregates replaced with 10mm size coconut shell and Grading mix proportion of aggregates when 5% coconut fibre replaced in filler is used expect that same as gradation for conventional mix of aggregates.

Table 3 Gradation proportion of Aggregates

Sieve size mm	Grading proportion of aggregate (%) and it's Weights									
	Bitumen content (4%)		Bitumen content (6%)		Bitumen content (8%)		Bitumen content (10%)		Bitumen content (12%)	
Bitumen content	%	Weight (gm)	%	Weight (gm)	%	Weight (gm)	%	Weight (gm)	%	Weight (gm)
	4	48	6	72	8	96	10	120	12	144
20	0	0	0	0	0	0	0	0	0	0
12.5	2	24	3.51	42.16	2.7	32.4	1.8	21.6	2.72	32.64
10	4.47	50.4	5.02	60.24	4.7	56.4	3.8	45.6	4.72	56.6
4.75	7.6	91.2	7.85	94.28	6.7	80.4	6.9	82.8	6.72	80.64
2.36	10	120	9.69	116.28	9.3	111.6	9.09	108	9.09	109
1.18	11	132	11.04	132.48	10	120	10.7	128.4	9.45	113.14
0.6	12.33	148	12.38	148.56	12.7	152.4	12.3	147.6	11.24	135.24
0.3	14.6	175.2	13.72	164.64	13.6	163.2	14	168	13.09	157.28
0.15	16	192	14.72	176.64	15.6	187.2	15.2	182.4	14.54	174.4
0.075	18	216	16.06	192.72	16.7	200.4	16.9	202.8	16.4	196.8

4.1 DETERMINATION OF OPTIMUM BITUMEN CONTENT:

In the present work for finding optimum bitumen content the conventional mix, when 10mm size coarse aggregates replaced with 10mm size coconut shell and 5% coconut fibre replaced with filler has been prepared by the help of as shown in table 4 and different samples are prepared at different bitumen content i.e., 4%, 6%, 8%, 10% and 12%. Further then, the Marshall stability test are done on these samples which give the value of Marshall Stability and flow value and maximum value of Marshall Stability give out the value of optimum bitumen content.

The results of Marshall Stability test at different percentages of bitumen for conventional mix and replacements are shown in table 4.

Table 4 Optimum bitumen content

Group	Sample name/(%) of bitumen	Marshall stability value(KN)	Flow value (mm)	Theoretical specific gravity(g/cm^{3})	Bulk specific gravity (g/cm^{3})	Air voids (%)	VMA (%)	VFB (%)
Coarse Aggregates (Group 1)	4	36.41	1.58	2.47	2.26	8.5	16.38	56.04
	6	51.50	1.96	2.43	2.37	2.47	16.5	84.84
	8	52.77	2	2.36	2.3	2.54	20.74	87.85
	10	53.81	2.5	2.3	2.28	0.87	23.44	95.98
	12	51.9	3	2.26	2.25	0.45	27.17	98.3
	4	26.79	1.1	2.47	2.34	4.96	14.52	63.77

Coconut shell (Group 2)	6	51.11	1.3	2.43	2.37	2.42	16.42	85.26
	8	53.97	1.83	2.36	2.33	1.27	19.72	93.55
	10	56.06	2.3	2.3	2.28	0.87	23.77	95.98
	12	51.38	3.3	2.26	2.25	0.45	27.17	98.3
Coconut fibre (Group 3)	4	49.09	0.8	2.47	2.36	4.66	14.08	66.33
	6	54.36	1.1	2.43	2.37	2.46	16.53	85.11
	8	50.88	1.44	2.36	2.32	1.69	20.06	91.57
	10	52.54	2.0	2.3	2.27	1.3	23.77	94.53
	12	50.00	2.33	2.26	2.2	0.45	27.17	98.2

From the table, it can be concluded that conventional mix possess maximum Marshall stability values while 10mm size coconut shell replaced with 10mm size coarse aggregates was achieved maximum load at 10% bitumen content . And also while coconut fibre is replacing with 5% filler maximum load was achieved at 6% bitumen content. Show better results of Marshall Stability as compared to other replacements values of coconut shell and coconut fibre.

Moreover, on comparing with conventional mix flow value, air voids and VFB do not show significant changes but all the values of Marshall Stability, flow value, air voids and VFB are all within limits.

The results are plotted on graphs and show variation with percentages of coconut shell and coconut fibre. The graph for Marshall Stability is shown in fig 2, graph for flow value is shown in fig 3, graph for Bulk specific gravity is shown in fig 4, graph for air voids is shown in fig 5 and graph for voids filled with bitumen (VFB) is shown in fig 6

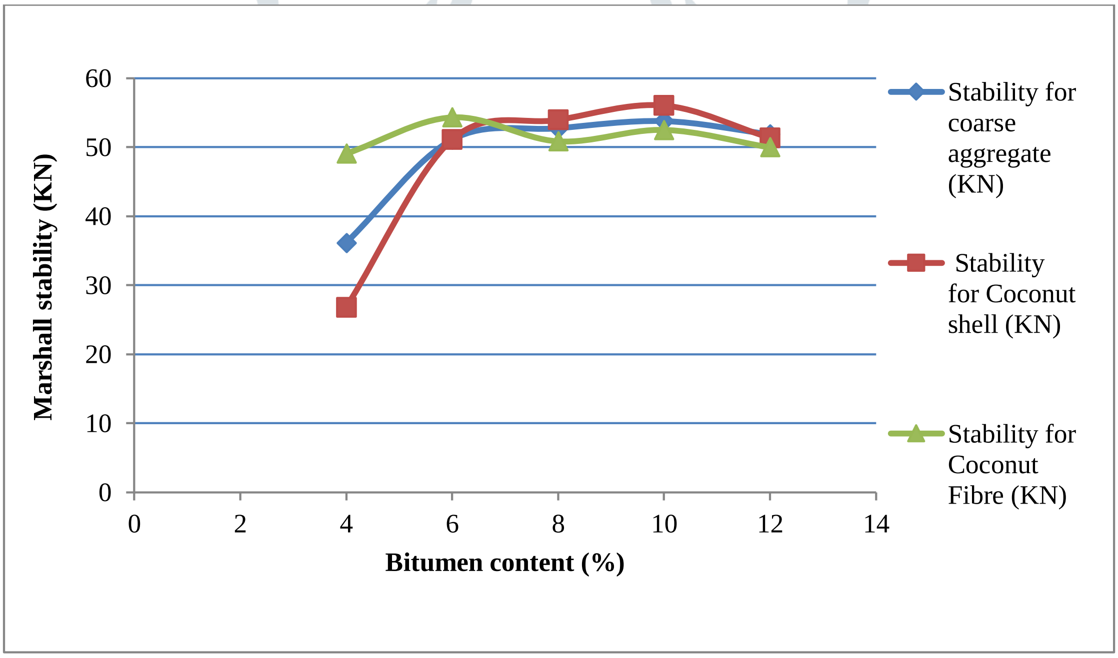

Figure 4.2 Graph plotted between Marshall Stability and bitumen content at different materials

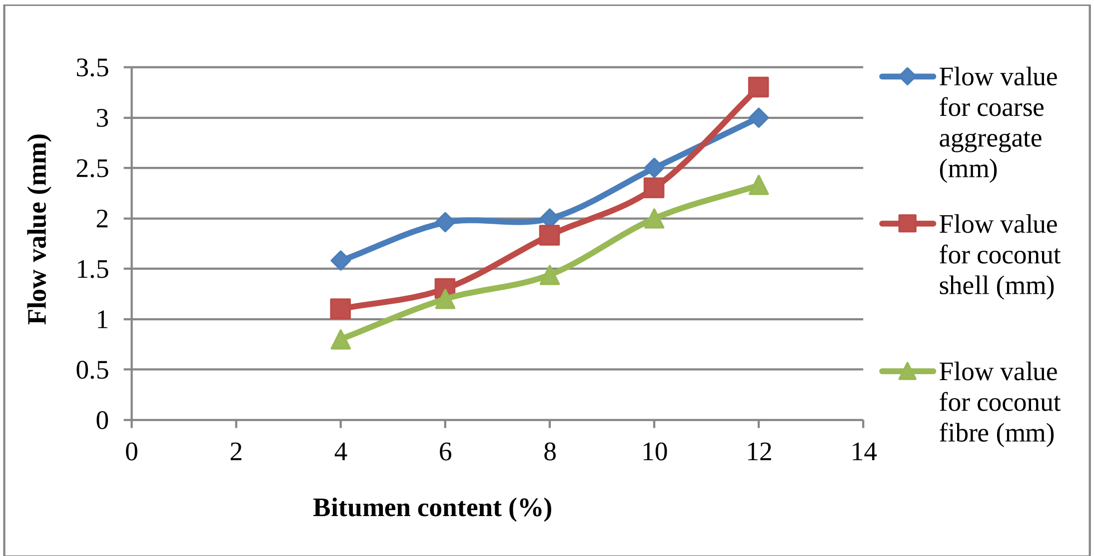

Figure 4.3 Graph plotted between Flow value and bitumen content at different materials

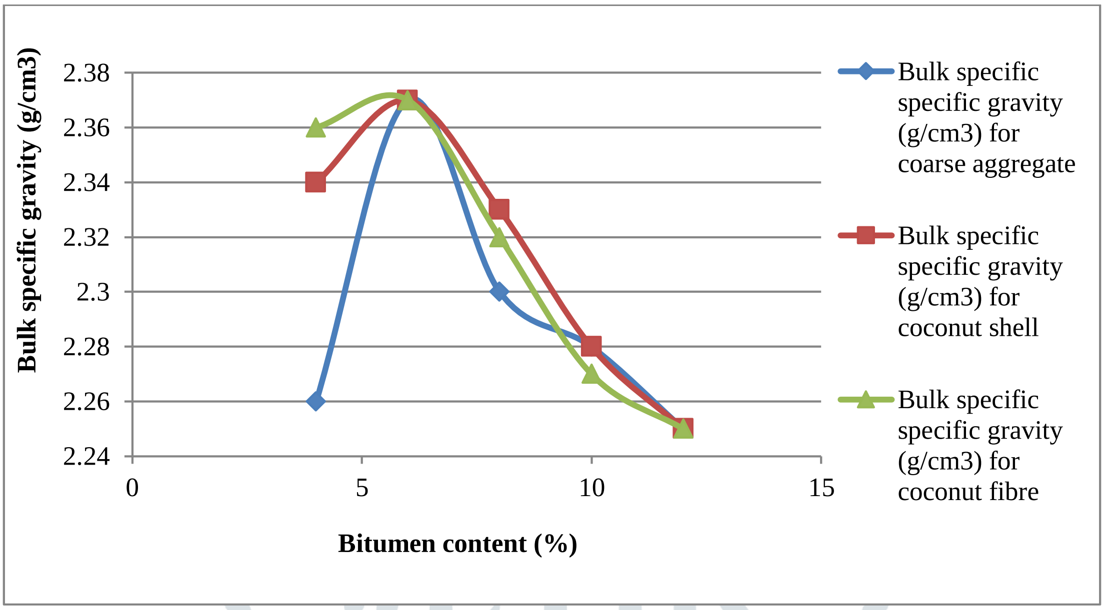

Figure 4.4 Graph plotted between Bulk specific gravity and bitumen content at different materials

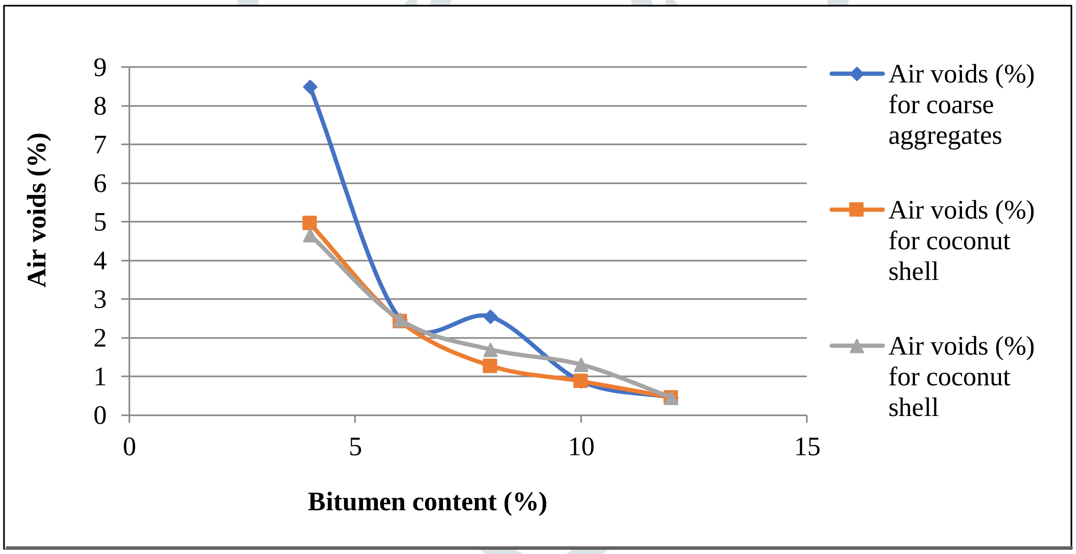

Figure 4.5 Graph plotted between Air voids and bitumen content at different materials

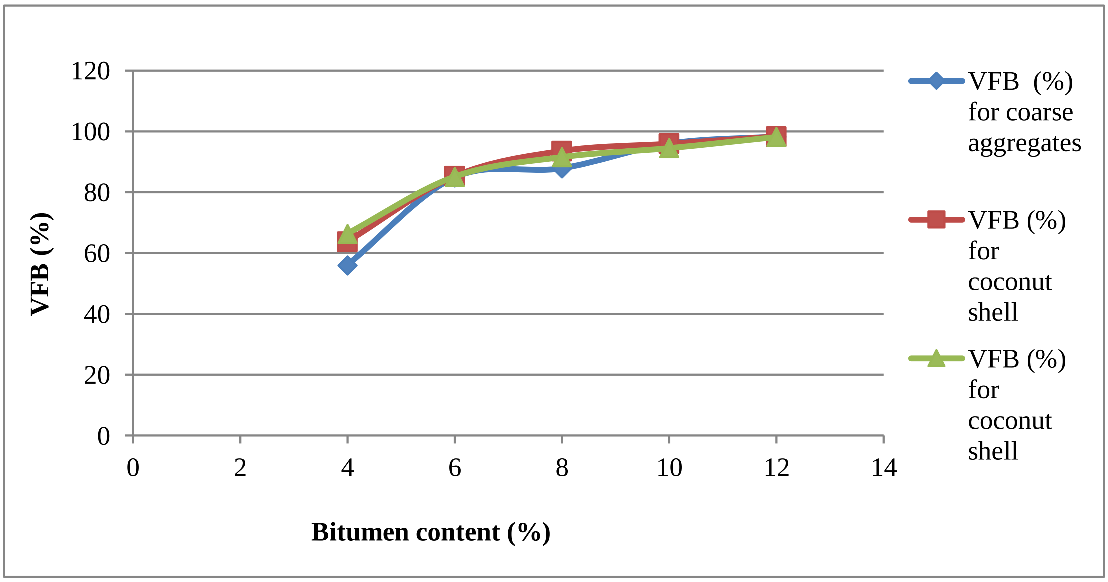

Figure 4.6 Graph plotted between VFB and bitumen content at different materials

V CONCLUSION

1. The aim of the study was to investigate the possibility of use of coconut shell and coconut fibre in bituminous concrete based on the laboratory study. In this study 10mm size coarse aggregate was replaced with 10mm size coconut shell and coconut fibre was replaced with 5% filler in flexible pavement. In the present study 10mm coconut shell, stone dust, coconut fibre and bitumen used in the study for the mix design as per mix design requirements in MORTH BC.
2. Greater strength was obtained when coconut shell replaced in place of coarse aggregate than when coarse aggregate was used value of 56.06 KN.
3. Although, CS and CF replacement at 10mm size coarse aggregate the highest value observed at 10% bitumen content value of 56.06 KN and 5% fibre replacement with filler the highest value observed at 6% bitumen content value of 54.36 KN gives the highest stability. And from Marshall Flow, all the specimens are also within the given range.
4. Based on the percent air voids present in the specimens, all the specimens were under the specified range. But the least voids were found in 12% bitumen content of CS and CF. It makes it more suitable as it prevents cracking, plastic flow and bitumen bleeding.
5. Areas for further research to address gaps in knowledge and improve the understanding of coconut-based materials in pavement engineering.
6. Final thoughts on the potential benefits and challenges of incorporating these sustainable materials into pavement construction practices.

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