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MECHANICAL PERFORMANCE OF BIO-BASED MODIFICATION OF ASPHALT CONCRETE MIX: A STUDY FOR ECO-FRIENDLY SUSTAINABLE DEVELOPMENT IN DEVELOPING COUNTRIES

processes

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ABSTRACT

Bio-based modification of bitumen can be used to replace the stiffening effect of asphalt pavement. It can help improve the efficiency of the asphalt projects for sustainable development. In this study, different percentages of bio-based waste cooking oil (WCO) have been used for modification of bitumen. Marshal stability analysis methodology was used to analyse the performance of modified asphalt concrete mixtures. The various characteristics of the modified asphalt mixtures were analyzed to determine the performance of modified asphalt. The results of the study revealed that the recycling process of waste bio-based oil maintained the performance of the asphalt mixtures compared to the control ones. Marshal Stability Analysis showed that stability value with the modification of 2% WCO in Bitumen increased from 29.363 to 31.855 but even at 6% modification value remained within acceptable limit. Flow value also remained within the range i.e., (2-4). This study will help for Eco-friendly sustainable development of road infrastructures and sustainable cities in developing countries.

INTRODUCTION

The rapid expansion of cities and the increasing number of vehicles on the road have created a growing demand for the construction and maintenance of pavements. Flexible pavement, which constitutes approximately 95% of the world's roadways, often relies on asphalt binder as a primary material. However, asphalt binder is derived from crude oil, a finite resource, and its cost has surged due to diminishing petroleum reserves. This has compelled authorities responsible for roads to explore alternative solutions. The global trend is now shifting towards creating more sustainable, cost-effective, and environmentally friendly infrastructure. To achieve this goal while reducing costs and energy consumption, the scientific community is actively exploring the utilization of bio-based resources for pavement construction, emphasizing renew-ability, sustainability, and localized production within the industry.

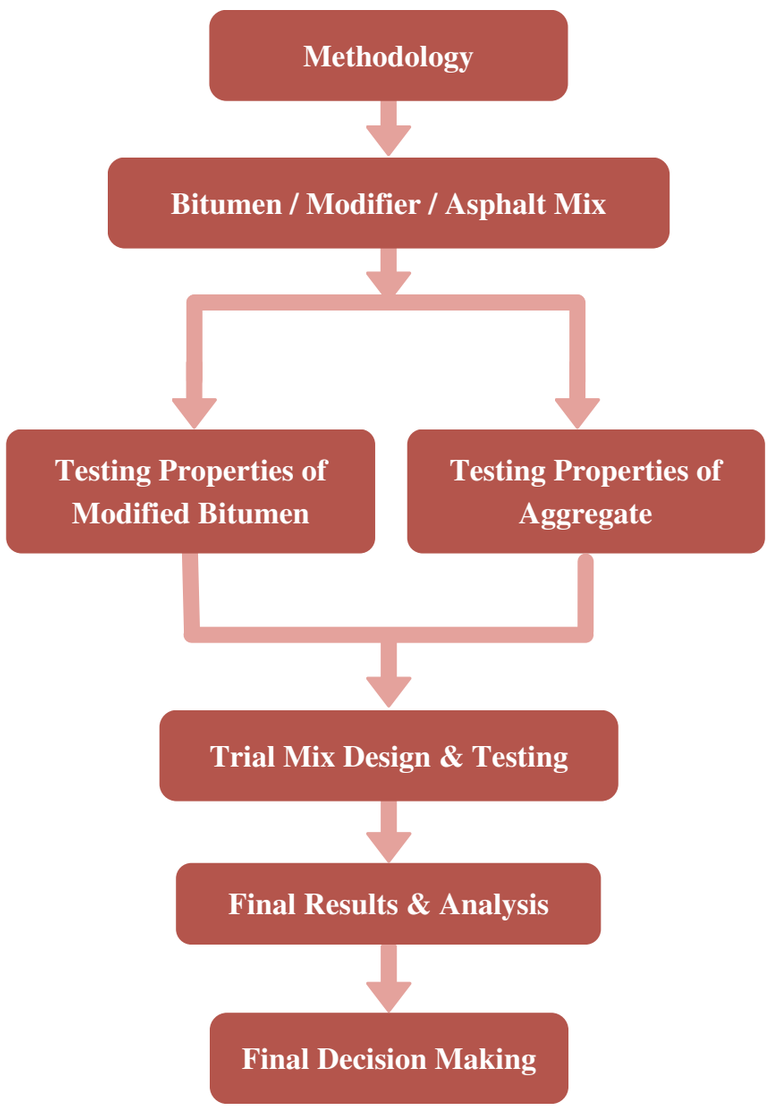
The research is aimed at exploring the use of WCO (Waste Cooking Oil) as a bitumen modifier in the creation of flexible pavements. The primary goal is to substitute a significant portion of the binder content with WCO, thereby encouraging sustainable resource utilization in the construction of durable bio-based pavements.

METHODOLOGY, RESULTS & ANALYSIS

THEME

The construction and rehabilitation of roads is related to the future of sustainable developments as part of Sustainable development Goals (SDGs). It is part of a global effort to measure the level of investment in infrastructures and sustainable cities by targeting goal no. 11 & 9 which are set to achieve this target as shown in Figure.

METHODOLOGY



RESULTS & ANALYSIS

The research project comprises two distinct stages. In the initial stage, a thorough analysis was conducted of all the fresh properties of both pure bitumen and WCO-modified bitumen. This comprehensive analysis was undertaken to facilitate a more meaningful comparative assessment of the outcomes. During the secondary stage, Marshal stability analysis was conducted on the WCO-modified mixture and subsequently compared it to the control specimens.

Performance Analysis of WCO - Modified Bitumen

The findings from the WCO-modified bitumen were displayed alongside the results of pure bitumen in following Table.

Table. Physical Properties of WCO-modified bitumen

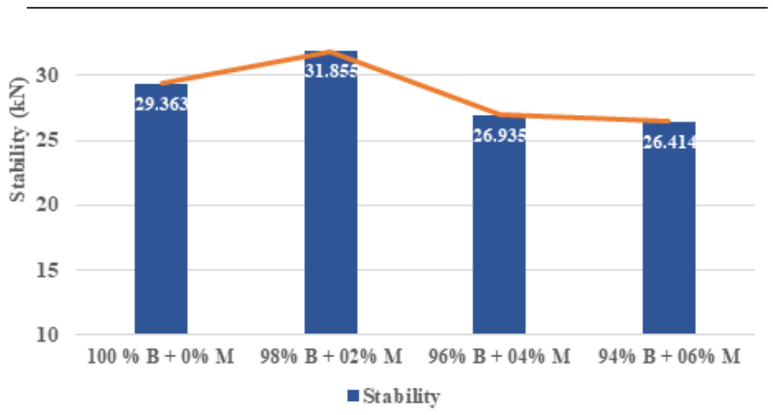
Sample	Composition	Penetration	Ductility	Softening Point
		(25 ˚C,100 g,5 s)	25 ˚C	˚C
Test Method		ASTM: D5-97	ASTM: D113	ASTM: D36
Units		0.1 mm	0.1 cm	1 ˚C
M 1	100 % B + 0 % M	69	> 150	46.4
M 2	98 % B + 02 % M	100	> 150	44.2
M 3	96 % B + 04 % M	130	> 150	43.3
M 4	94 % B + 06 % M	155	> 150	41.6
Standard	Pure Bitumen	60-70	> 75	40-55
Remarks		> 60 are ok	> 75 are ok	Within Limit

Marshal Stability Analysis of WCO - Modified Specimen

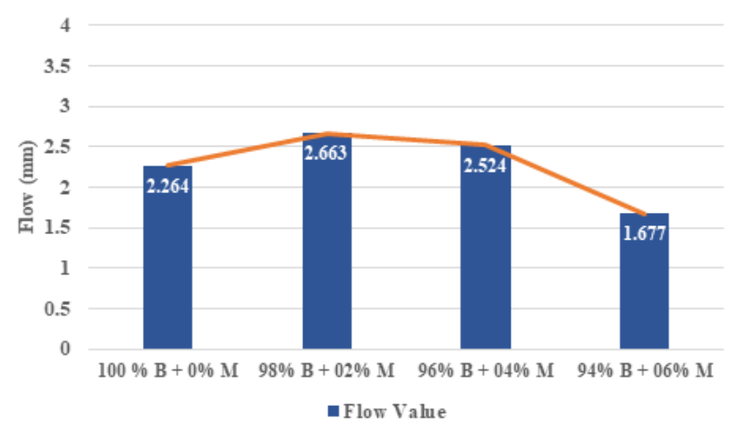
Marshal Stability Analysis is performed to analyze the performance of asphalt concrete mix. In this two major parameters stability and flow are evaluated. To summarize, the flow value generally exhibits a decreasing trend as the WCO percentage in the binder content increases, up to 2%.

Table. Marshal Stability and Flow Value Test Results

Sample	Composition	Marshal Stability	Marshal Flow
		(60 ˚C)	(60 ˚C)
Test Method		ASTM: D1559	ASTM: 1559
Units		kN	mm
M 1	100 % B + 0 % M	29.363	2.264
M 2	98 % B + 02 % M	31.855	2.663
M 3	96 % B + 04 % M	26.935	2.524
M 4	94 % B + 06 % M	26.414	1.677



Graphical Presentation of Marshal Stability Test



Graphical Presentation of Marshal Flow Value Test

CONCLUSION

Analyzing the test results presented in the study following can be concluded:

- An eco-friendly road network can be developed by using wastes in bitumen and applying them in road construction process.
- The penetration and softening point of bitumen mix change considerably after adding wastes, as they become significantly lower.
- We can decrease the cost of project by using the Waste Vegetable Oil as a modifier.
- Finally, the current study resulted in that all used percentages of WCO additive in combination with 2% WCO may be considered as optimum percentage depending on desired properties, better stability and climate conditions and is highly recommended to modify the asphalt binder.

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