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EXPERIMENTAL STUDY OF ASPHALT CONCRETE CONTAINING RECLAIMED ASPHALT PAVEMENT MIXTURES

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ABSTRACT

Asphalt pavement is made of coarse aggregates, sand, filler, and bitumen. It is a heterogeneous material. Bitumen is a material of the mix that holds the asphalt pavement mix together and gives it flexibility and the ability to heal. But over time, the environment (oxygen, UV light, moisture, etc.) causes bitumen to age and lose its volatile chemical compounds. This makes it brittle and prone to cracking, which can cause asphalt pavement to fail too soon. But the effects of bitumen ageing can be reversed. The bitumen rejuvenator can be used to reverse the effects of bitumen ageing by restoring the lost properties, such as chemical composition, physical properties, and rheological properties. Rejuvenating bitumen depends a lot on the type and amount of rejuvenator used. In industry, bitumen with a high penetration level (70/100 or higher) is often used to soften bitumen that has hardened over time. General types of rejuvenators include bio-based rejuvenators that are either pure or made from waste streams, chemically modified rejuvenators, and maltene-rich fractions made during the oil refining process. The recommended dosage ranges from 2% to 20% by weight of bitumen, depending on the type of rejuvenator and the properties of the old bitumen (e.g., ageing level)

INTRODUCTION

Asphalt pavement refers to any paved road surfaced with asphalt. Hot Mix Asphalt (HMA) is a combination of approximately 95% stone, sand, or gravel bound together by asphalt cement, a product of crude oil. Asphalt cement is heated aggregate, combined, and mixed with the aggregate at an HMA facility. The resulting Hot Mix Asphalt is loaded into trucks for transport to the paving site. The trucks dump the Hot Mix Asphalt into hoppers located at the front of paving machines. The asphalt is placed, and then compacted using a heavy roller, which is driven over the asphalt. Traffic is generally permitted on the pavement as soon as the pavement has cooled. Hot Mix Asphalt (HMA) is a hot mixture which involved heating, mixing and coating of aggregates and bitumen at the desired mixing temperature.

Moisture damage to asphalt pavements occurs when moisture enters the asphalt mixture and impairs its mechanical qualities, leading the pavement to perform poorly. Moisture damage can lead to serious pavement problems such as cracking and pumping. As a result, it has become an issue for most transportation agencies around the world, and both the research and engineering areas are focused on it.

RESEARCH METHODOLOGY

It's important to know everything about the elements that will be utilised in the mix design.

1. Coarse and fine aggregate
2. Bitumen as binder (60/70)
3. Fly ash and waste tyre
4. Filler

CHARACTERIZATION OF MATERIALS USED

COURSE AND FINE AGGREGATE

Asphalt as a flexible wearing course has a life expectancy of 15 to 20 years, and has to remain in place and continue to perform its role for this entire life span. The aggregates used in the asphalt mix must therefore be durable enough to tolerate the long-term loading while maintaining their physical, mechanical and chemical properties under various climatic conditions. This includes the wetting and drying cycles that occur during the life of the pavement and flexing of the pavement due to traffic and to sub-pavement movement. AS 2758.5 has a range of durability tests included that either singularly or in combination, provides some confidence of material integrity. The Standard notes that the three sets of tests nominated, represent those most commonly used in Australia. Of special note is the indication in the Standard that only one of the durability test methods is needed to classify aggregate durability in any works specification.

Based on their size, coarse and fine aggregates are the most commonly utilized in construction. IRC: SP: 79: 2008 and MORTH section 500 require that aggregates for Stone Matrix Asphalt be submitted to different aggregate tests, according to the table 500-36. Crushed aggregates of various sizes in good durable quality may be found on the local market. Table 1 shows the aggregate results of the tests.

Table 1 Physical Characteristics of Aggregates- Test Results

S. No	Aggregate Test	Method	Result	Requirement as per IRC:SP:79:2008
1	Aggregate Impact Value (%)	IS : 2386 (Part-IV)	16.19 %	< 18 %
2	Los Angeles Abrasion Value (%)	IS : 2386 (Part-IV)	13.60 %	< 25 %
3	Combined Flakiness and Elongation Index (%)	IS : 2386 (Part-I)	12.69 %	< 30 %
4	Water Absorption	IS : 2386 (Part-III)	0.91 %	< 2 %
5	Specific gravity Coarse Aggregate Fine aggregate	IS : 2386 (Part-III)	2.63 2.68	2.5-2.8

BITUMEN

Bitumen binds the SMA Mix together. Bitumen is mixed in a variety of ways, including hot-mix, gap-graded, and dense-graded mixes. In this study, we utilised 60/70 bitumen to make the SMA mix.

Bitumen has a number of applications but its use for construction and maintenance of roads either directly or through asphalt accounts for nearly 90% of all demand. Key bitumen types for road applications including paving grades, cutback bitumen, and bitumen emulsions. Hard, oxidized, and blown grades and mastic asphalt are used for paints, sealants, adhesives, enamels, waterproofing, electrical products, flooring materials, back carpet tiles, land and marine pipe coatings and numerous other non-road applications. Polymer-modified bitumen (PMB) is a recent innovation that is finding growing application in both paving and non-road applications. Although there are numerous non-road applications for bitumen, they consume small volumes and road paving is the primary application. As a result, infrastructure cuts have significantly impacted global bitumen demand.

Bitumen types regarding their application regarding their applications, bitumen can be divided into two groups: road construction or thin bitumen, and building bitumen and (roof insulator) or hard bitumen. About 90% of the produced bitumen is used in road construction activities and 10 % of it is used for insulation applications. In Iran, the main part of bitumen is used in the road construction activities and by the municipalities for coating the streets. Road construction bitumen is usually classified according to its penetration. The penetration rate of bitumen material represents its strength and hardness which is defined as the number of penetration unit (one tenth millimeter) of one vertical standard needle in one bitumen sample, in the certain time and weight on the needle and temperature. The penetration rate of bitumen is usually measured 25-degree centigrade with 100-gram weight and in 5 seconds. Road construction bitumen made in Iran are "60 to 70" and '85 to 100". The numbers represent the range of bitumen penetration rate. Bitumen is hydrocarbon substance which is black to dark brown and quite solvable in carbon-sulfur. It is solid in normal environment temperature but in increased temperature, it first becomes a paste and then liquid. It has two important properties, impenetrable against water and adhesiveness which makes it an important material for the application.

Bitumen is usually acquired from petroleum distillation. Such kind of bitumen is called petroleum asphalt or distillery bitumen. Petroleum bitumen is the product of two stages of petroleum distillation in a distillation tower. In the first stage of distillation, light materials such as gasoline and propane are separated from the raw oil. This process is done in the pressure close to atmospheric pressure. In second stage heavy compounds such as diesel oil and kerosene are extracted. This process is done at a pressure close to vacuum pressure. Finally, a mixture of solid bits called asphaltene remains which are floated in a grease-like fluid called Malton.

Table 2 lists the physical parameters of the bitumen utilised in the manufacture of the mix samples, which were sourced from the local market and graded at 60/70 for penetration.

Table 2 : Physical properties of bitumen

S.no.	Property	Result	Test procedure as per specification
1	Specific Gravity @ 27˚C	1	IS:1202 - 1978
2	Softening Point (˚C) (R&B Method)	50	IS:1205 - 1978
3	Penetration @ 25˚C,0.1 mm 100g, 5 sec	64	IS:1203 - 1978
4	Ductility @ 27˚C (cm)	72	IS:1208 - 1978
5	Flash Point (˚C) Fire Point (˚C)	240 270	IS:1209 – 1978
6	Viscosity at 60 ˚C (Poise)	1200	IS:1206 – 1978
7	Elastic recovery @ 15˚C (%	11	IRC: SP:53 – 2002

FLYASH AND WASTE TYRE AS STABILIZER

Exhaust gases carry fly ash from the combustion chamber, which is finely split residue from of the burning of pulverized coal. Coal-fired power stations and steam boilers emit fly ash as a byproduct. Combustion chambers in boilers are filled with crushed coal, which is then ignited by air forced into the combustion chamber. This produces heat and a molten mineral residue. Extraction of heat via boiler tubes cools the flue gas and hardens the molten waste, forming ash. Slag and ash are separated by ash particles that are larger and heavier, known as bottom ash or slag, while small ash particles known as fly ash stay suspended in the exhaust flow. Before the flue gas is exhausted, particle emission control equipment such as electrostatic precipitators or filter cloth bag houses remove fly ash. Portland cement concrete is the most typical application for fly ash as a pozzolana. Because of their siliceous or aluminous composition and the presence of water, pozzolanas react with calcium hydroxide to generate cementations compounds at room temperature. Fly ash seems to be a useful mineral filler for hot mix asphalt (HMA) applications because of its spherical form and particle size distribution, which enhances the flow ability of flow able fill and grout. Fly ash's consistency and availability in many regions make it an ideal filler for highway structures and other uses. Fly ash, bottom ash, and pond ash are really the three main forms of fly ash. Pond ash refers to fly ash and bottom ash that are carried and deposited in a pond.

Stabilizing substance is a slurry of shredded rubber powder. Crumb rubber was chosen as an addition to improve the engineering qualities of clay. Recycled rubber from automobile and truck scrap tires (CRP) is commonly referred to as crumb rubber powder (CRP). Steel and fluff are removed from the rubber during the cycling process, resulting in a granular consistency. Particle size can be further reduced using a mechanically assisted continuous process including a granulator or cracker mill.

FILLER

The characteristics of SMA mixes are greatly influenced by the use of mineral fillers. A quarry dust filler material is utilised in the construction. Purchased from a nearby market. Table 2 shows the sieve analysis findings.

The durability of the road pavement is related to the appropriate choice of materials. The technology of a particular layer, its function in pavement construction and traffic categories should be taken into account on the stage of design. All the component materials which are used for upper layers of pavement made of asphalt mixture must be of the highest quality. Bituminous mixtures are basically composed of aggregates of different sizes, filler and bitumen. Fillers (filler aggregate) consists of mineral grains most of which pass 63µm sieve (EN 13043). This component represents 3–14% of the total aggregate by weight in the whole mixture regardless the type of asphalt mixtures (Stone Mastic Asphalt, Asphalt Concrete). In the case of Mastic Asphalt content of filler is in the range 26-36%.

RESULTS AND DISCUSSION

MARSHALL TEST RESULTS AND DISCUSSIONS

There seem to be distinct chapters on mix design results and discussion for reference & fibre stabilized mixes.

MARSHALL TEST RESULTS OF MIX WITHOUT AND WITH FLY ASH

Following is an explanation of how bituminous concrete (BC) with various bitumen percentages, without or with fly ash, changes its Marshall properties.

Table 3 shows the Marshall Test findings for such bituminous mixtures with and without fly ash, including Marshall Stability and flow values and void parameters.

Table 3 Parameters of reference mix without and with fly ash

	Bitumen content %	Stability, KN	Flow, mm	V_V %	VFB %
Without fly ash	4	7.57	2.2	4.97	65.31
	5.5	8.16	2.5	2.32	83.73
	6	6.9	3.7	2.09	86.13
	6.5	5.76	4.5	1.19	92.74
	7	4.77	5.4	1.02	94.11
	4	8.14	2.68	5.04	68.42
	5.5	9.49	3.01	3.21	82.46
	6	7.27	4.19	2.24	89.68
	6.5	6.45	4.67	2.13	94.25
	7	5.49	5.75	1.14	95.36

MARSHALL STABILITY

When the binder content is increased to a particular level, the stability value begins to drop. That because as

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bitumen concentration rises, so does the binding between the aggregate and bitumen, though as the contact point between the aggregates becomes immobilized, the strength between them reduces. Because of this, the mixture is vulnerable to plastic deformation. As a result, the stability Values are likewise decreasing at an increasing rate. Figure 1 shows how Marshall Stability changes with the amount of binder in the mixture. Table 1 shows that the inclusion of fiber in the SMA mixes effectively increases the stability values, which will lead to an increase in the toughness of the mixture. This suggests that the fiber-based combination would outperform the control mixture in terms of performance.

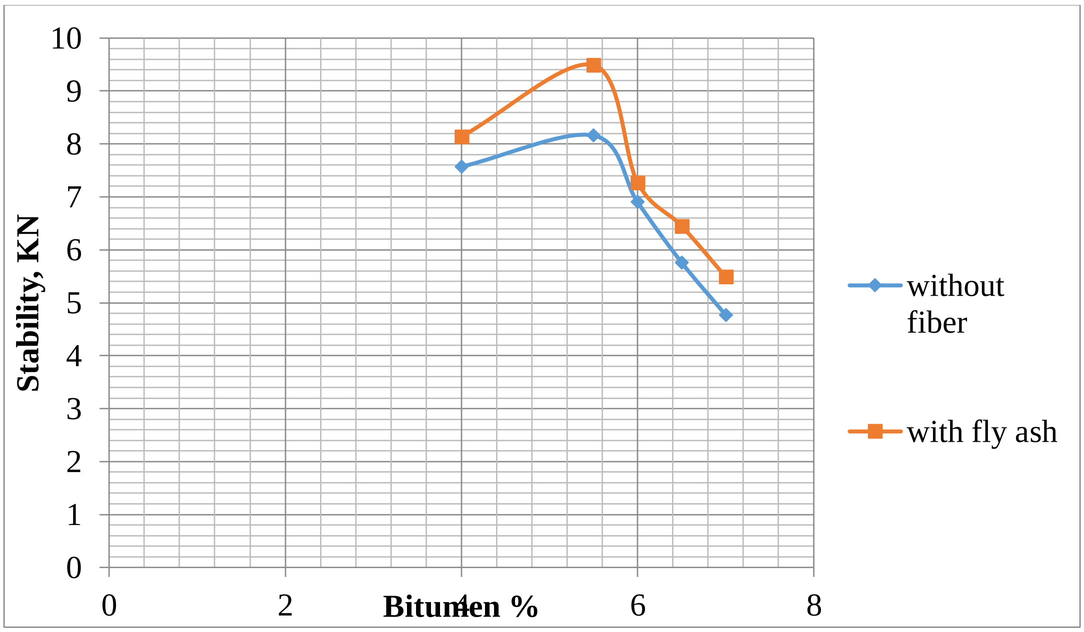

Fig. 1 Variation of stability for different bitumen % without and with fly ash

FLOW VALUE

Flow seems to be the specimen's deformation at its maximum load, which is the point of failure. Both mixes with or without fly ash show an increase in flow value with only an increase in bitumen content. At first, the rate of growth is moderate, but as the bitumen concentration rises, the pace accelerates. Mixtures containing fly ash have a higher initial flow value than someone who does not. This might be because the fly ash fills in the voids in the mixture at lower bitumen contents, enhancing homogeneity and providing the stability needed to resist deformation under load. This homogeneity is lost when bitumen concentration rises, and as a result, the binder property takes over, causing the fly ash to lump up and reduce stability while also increasing deformation under load.

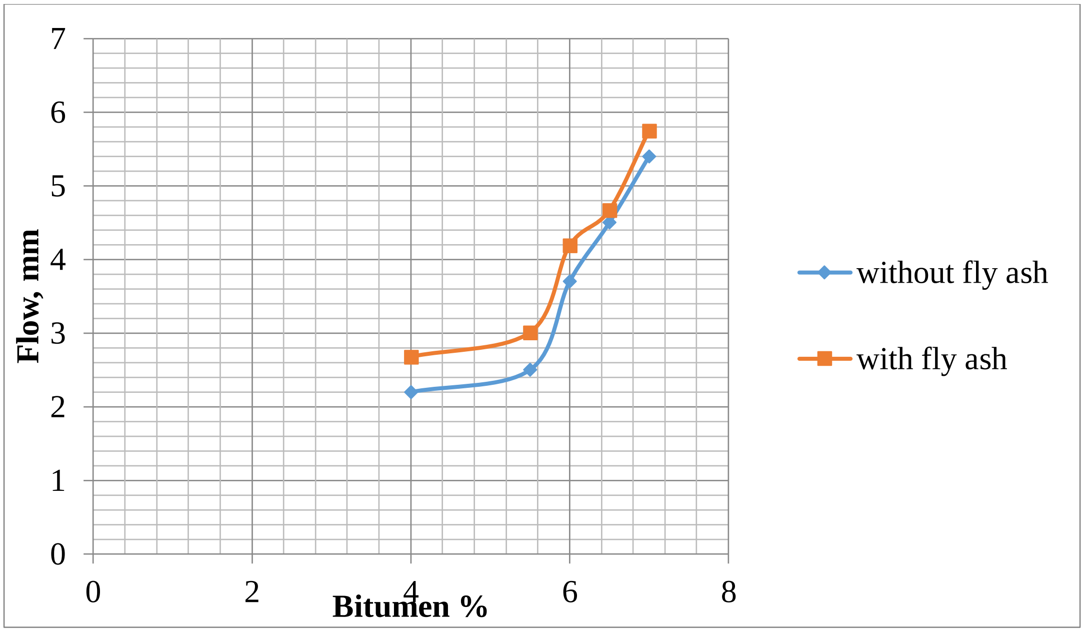

Fig. 2 Variation of flow for different bitumen % without and with fly ash

AIR VOID

The gap that exists between the aggregates is known as the "air void." Increases in bitumen reduce the vacuum. Bitumen bridges the chasm and improves the object's suitability. As the amount of bitumen in the mix increases, the air spaces reduce at a much faster rate. Bitumen and stabilisers work together to fill in the gaps. Air void diminishes as the binder content increases. Figure 2 shows the impact of binder content on air void variation.

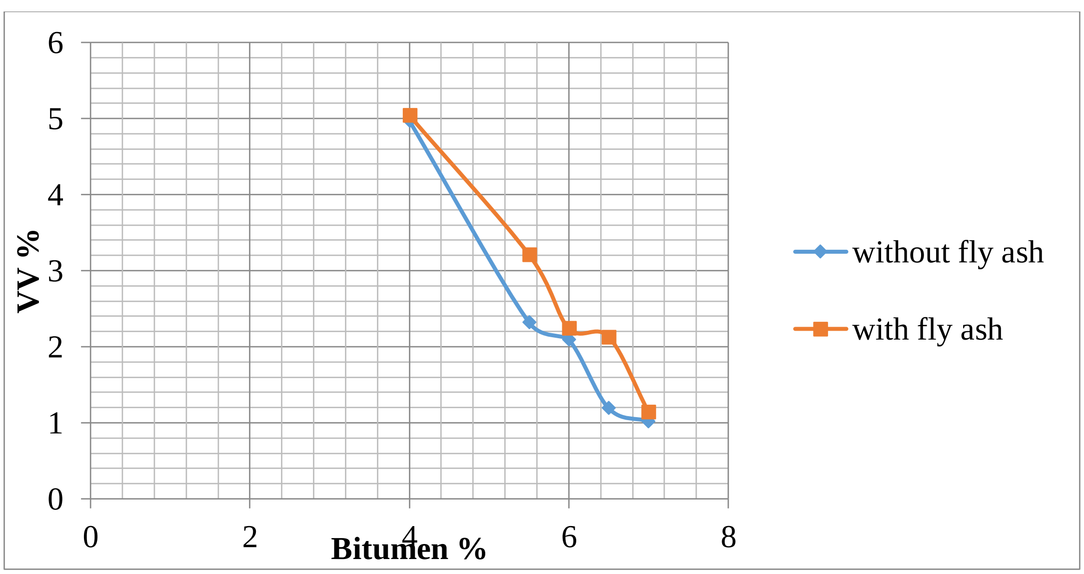

Fig. 3 Variation of Vv % for different bitumen without and with fly ash

It shows that bituminous mixes with fly ash added have a larger air void volume. This might be attributed to the fibers in the mixture having an influence on the process (lower Gmb correlates to higher air voids). These additives can be used since the air voids in the mixes are within the specified range of 3 to 5 percent (AASHTO T 312).

VOID FILLED WITH BITUMEN (VFB)

The Voids Filled Bitumen (VFB) is a percentage of VMA, which is how it is usually represented. The higher the bitumen concentration, the higher the VFB of a blend. Since the bitumen content in the mix grows, more and more bitumen is able to fill in the aggregates' empty spaces as well as the voids in the mix, leading to an increase in the total amount of bitumen within the voids (VFB) as a result.

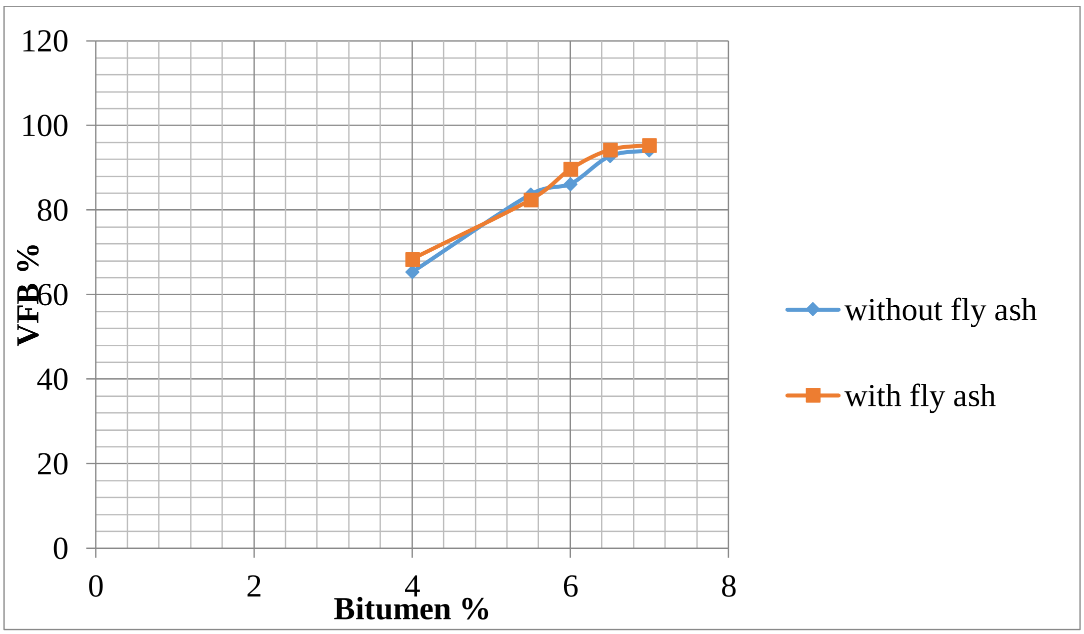

Fig. 4 Variation of VFB % without and with fly ash

OPTIMUM BITUMEN CONTENT (OBC) OF MIX WITH AND WITHOUT FLY ASH

Table 3 gives the various parameters for the reference mix which is the conventional bituminous mix without addition of fly ash. These values are plotted against the binder content and the binder content corresponding to the maximum stability, minimum flow, mean VV and mean VFB are taken and averaged. This gives the optimum binder content for the reference mix by the Marshall method. Table 3 gives the bitumen content corresponding to the optimum values.

For mix without fly ash

1. Binder content corresponding to maximum stability = 5.5 %
2. Binder content corresponding to maximum bulk specific gravity (Gm) = 4.5 %
3. Binder content corresponding to the median of designed limits of percent air voids (Vv) in the total mix (i.e. 4%) = 4.12 %

Optimum Bitumen content of mix = 5.5 + 4.5 + 4.12/3 = 4.7 %

For mix with fly ash

1. Binder content corresponding to maximum stability = 5.5 %
2. Binder content corresponding to maximum bulk specific gravity (Gm) = 4.5 %
3. Binder content corresponding to the median of designed limits of percent air voids (Vv) in the total mix (i.e. 4%) = 4.01 %

Optimum Bitumen content of mix = 5.5 + 4.5 + 4.12/3 = 4.67 %

The Marshall mix design specification chart shown in the table below is used to verify the stability, flow, and VFB values. Mixes with the a high stability and low flow value really aren't recommended since heavy moving loads can cause pavements to break.

The values of stability, flow, VV, and VFB that correlate to the bituminous mix's OBC may be gleaned from the graphs after the OBC has been determined. Table 4 shows the values for such reference mix.

Table 4 Mix properties of mix without and with fly ash

	OBC %	Stability in KN	Flow in mm	VV %	VFB %
Without fly ash	4.70	8.12	2.51	2.85	79.02
With fly ash	4.67	9.01	4.62	3.52	80.19

MARSHALL TEST RESULTS OF MIX WITHOUT AND WITH WASTE TYRE

Following is an explanation of how bituminous concrete (BC) with various bitumen percentages, both with and without waste tyres, changes in Marshall Properties.

Table 4 lists the findings of the Marshall Test, including the Marshall Stability and Flow values and the void parameters for bituminous mixtures with and without waste tyres.

Table 5 Parameters of reference mix with and without waste tyre

	Bitumen content %	Stability, KN	Flow, mm	V_V %	VFB %
Without waste tyre	4	7.68	2.13	4.95	65.02
	5.5	8.23	2.36	3.45	83.58
	6	6.97	2.83	3.04	86.42
	6.5	5.64	3.7	1.15	92.56
	7	4.43	4.68	1.13	94.18
	4	8.31	2.43	5.15	68.44
	5.5	8.64	3.06	4.23	82.48
	6	7.73	3.38	3.16	89.53
	6.5	5.46	3.82	2.18	94.28
	7	4.17	5.36	2.01	95.29

MARSHALL STABILITY

When the binder content is increased to a particular level, the stability value begins to drop. Its because as bitumen concentration rises, so does the binding between the aggregate and bitumen, though as the contact point here between aggregates becomes immobilized, the strength between them reduces. Because of this, the mixture is vulnerable to plastic deformation. As a result, the stability Values are likewise decreasing at an increasing rate. Figure 4 shows how Marshall Stability changes when binder content changes.

SMA mixes made with waste tyres have better stability characteristics, which means that the mixture toughness will indeed be improved as well. This suggests that the fiber-based combination would outperform the control mixture in terms of performance.

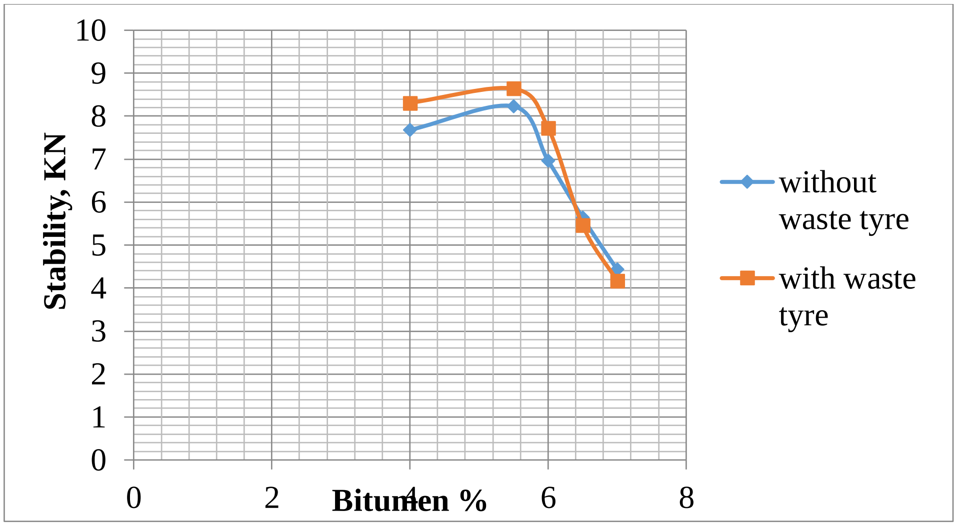

Fig. 5 Variation of stability for different bitumen % without and with waste tyre

CONCLUSION

Conclusions gathered from an examination into SMA/BC concrete are summarized in the following:

Samples of SMA was made with bitumen percentage varied between 4 and 5.5 percent, 6 and 6 and 5 percent, and 6.5 and 7 percent. In order to see how increasing its bitumen content affected the stability value, this experiment was conducted. Researchers can also use this plot to determine the ideal binder content for this combination. The graph shows that the stability value first rises, but subsequently declines as the amount of bitumen in the mixture increases. Due to the fact that when bitumen content rises, the aggregates' connection becomes stronger, yet hydrostatic pressure keeps the portion between the contact sites of aggregates immobilised as a result of the applied stress being imparted to them. Plastic deformation weakens the mix, resulting in a decrease in its structural integrity. Fly ash and waste tyre can be used in the same way as a binder, however the mix with fly ash and waste tyre has a greater stability value at the same binder concentration. Stabilizers like fly ash and waste tyres in the mix help to hold the binder together, since they not only fill up gaps in samples but also greatly restrict drain flow. Fly ash and waste tyres are also used to help homogenise the mixture.

In both mixes with and without fly ash and waste tyre, the flow value increases with the increase in bitumen content At first, the rate of growth is slow, but as the bitumen concentration rises, the pace accelerates. Because fly ash and waste tyre are added to the mix, the flow value is higher than it would be without them. According to the theory here, at lower levels of bitumen content, filling up the gaps with fly ash and waste rubber helps maintain consistency, which in turn helps to keep things stable under load. A lack of homogeneity is lost as bitumen concentration rises. This means that when fly ash and waste tyres are mixed together, they form lumps, reducing stability and increasing deformation when subjected to loads.

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