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Use of waste plastic and crumb rubber in construction of flexible pavement

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ABSTRACT

Generation of plastic waste and rubber waste is increasing day by day and the necessity to dispose of this waste in a proper way is arising. Nowadays pavements are subjected to various kinds of loading which affects the pavement performance condition that causes various distresses. Use of plastic and rubber in pavement design as an innovative technology not only strengthened the road construction but also increase the road life. In this study, different tests were conducted on aggregates, bitumen, and bituminous mixes. The effect of the addition of waste polyethylene in the form of locally available carry bags had been checked on aggregates as well as on bitumen. As per visual inspection, 5%, 7.5% and 10% plastic coating was made on aggregates and sample were checked for crushing, impact and abrasion values. Effect of addition of waste plastic and crumb rubber on bitumen had been studied by varying concentrations of polyethylene from 0% to 15% i.e. 0%, 5%, 7.5%, 10%, 12.5% and 15% in bitumen. Various tests such as penetration, ductility, softening point, flash and fire point, viscosity and loss on heating were performed on the samples. The optimum percentage was taken from these tests which had shown satisfactory results for all the tests performed. Later, that optimum percentage value was used for preparing bituminous mixes for testing pavement properties such as Marshall Stability, compressive strength, and indirect tensile strength. As per the test results, about 10% plastic waste with crumb rubber replacement in bitumen shows better results than conventional bitumen as well as 10% plastic coating to aggregates also improve the load-bearing capacity. The strength is found to be increased by 62% as compared to conventional mixes. By using plastic waste in flexible pavement design, the problem of plastic and waste rubber disposal gets solved as well as the performance of roads gets improved. Investigations can also be made on using other grades of bitumen and other substituents. Generation of plastic waste and rubber waste is increasing day by day and the necessity to dispose of this waste in a proper way is arising. Nowadays pavements are subjected to various kinds of loading which affects the pavement performance condition that causes various distresses. Use of plastic and rubber in pavement design as an innovative technology not only strengthened the road construction but also increase the road life. In this study, different tests were conducted on aggregates, bitumen, and bituminous mixes. The effect of the addition of waste polyethylene in the form of locally available carry bags had been checked on aggregates as well as on bitumen. As per visual inspection, 5%, 7.5% and 10% plastic coating was made on aggregates and sample were checked for crushing, impact and abrasion values. Effect of addition of waste plastic and crumb rubber on bitumen had been studied by varying concentrations of polyethylene from 0% to 15% i.e. 0%, 5%, 7.5%, 10%, 12.5% and 15% in bitumen. Various tests such as penetration, ductility, softening point, flash and fire point, viscosity and loss on heating were performed on the samples. The optimum percentage was taken from these tests which had shown satisfactory results for all the tests performed. Later, that optimum percentage value was used for preparing bituminous mixes for testing pavement properties such as Marshall Stability, compressive strength, and indirect tensile strength. As per the test results, about 10% plastic waste with crumb rubber replacement in bitumen shows better results than conventional bitumen as well as 10% plastic coating to aggregates also improve the load-bearing capacity. The strength is found to be increased by 62% as compared to conventional mixes. By using plastic waste in flexible pavement design, the problem of plastic and waste rubber disposal gets solved as well as the performance of roads gets improved. Investigations can also be made on using other grades of bitumen and other substituents.

Keywords— *Pavement, Bitumen, Waste plastic, Crumb rubber, Plastic coated aggregate*

1. INTRODUCTION

Plastic and rubber are everywhere in today's lifestyle. The main problem is what to do with waste. Use of plastic waste which is non-biodegradable is rapidly growing and researchers have found that the material can remain on earth for 4500 years unchanged and without degradation. Plastic and rubber are very versatile material. Due to the industrial revolution, and its large scale production they seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to

packaging, automobile, electronics, electrical, building construction, communication sectors has been virtually revolutionized by the applications of plastics and rubbers. Several studies carried out by Health Departments have proven the health hazard caused by improper disposal of plastic waste and rubber waste. The health hazard includes reproductive problems in human and animal, genital abnormalities etc. Although the waste plastic and rubber taking the face of the devil for the present and future generation, we can't avoid the use of plastic and rubber but we can reuse it. This threat of disposal of plastic and rubber will not solve itself and certain practical steps have to be initiated at the ground level. On the other hand, the road traffic is increasing with time hence there arises a need to increase the load bearing capacities of roads which can be made possible by utilizing the waste plastic and crumb rubber in flexible pavement design.

1.1 Necessity

Use of polyethylene in road construction is not new. Some aggregates are highly hydrophilic (water-loving). Like bitumen, polyethylene is hydrophobic (water-hating) in nature. So the addition of hydrophobic polymers by dry or wet mixing process to asphalt mix lead to improvement of strength, water repellent property of the mix. Polymer modification can be considered as one of the solutions to improvise the fatigue life, reduce the rutting & thermal cracking in the pavement. Creating a modified bituminous mixture by using recycled polymers (e.g., polyethylene) which enhances properties of HMA mixtures would not only produce a more durable pavement but also provide a beneficial way of disposal of a large number of recycled plastics. Crumb rubber obtained from the shredding of those scrap tire has been proven to enhance the properties of plain bitumen since the 1840's. It can be used as cheap and environment-friendly modification process to minimize the damage of pavement due to increase in service traffic density, axle loading and low maintenance services which deteriorated and subjected road structure to failure more rapidly.

- Stronger road with increased Marshall Stability value.
- Better resistance towards rainwater and water stagnation so no stripping and no potholes.
- Increase binding and better bonding of the mix thus reduction in pores in aggregate.
- No leaching of plastics.
- No effect of radiation like UV
- The load withstanding property increases. It helps to satisfy today's need for increased road transport.

2. LITERATURE REVIEW

The concept of using plastic and rubber in flexible pavement has been done several years ago in India. Plastic has played a very vital role in increasing the strength of bitumen as well as aggregate. Prof. C. E. G. Justo (2015) states that the addition of plastic in bitumen improves the stability, strength, life and other desirable properties of bitumen.[1] Similarly, Dr R. Vasudevan (2013) states that the polymer bitumen blend is a better binder compared to plain bitumen.[2]Dr. Khandekar S.D. *et al.* (2015)stated that the concept of utilization of waste plastic in the construction of pavement has shown better resistance to water which reduces the stripping of bitumen from aggregate and also made investigations over the use of waste plastic in road construction as an effective way to reutilize the plastic waste.[3] Nemade S. *et al.* (2013) studied the feasibility of the use of shredded waste plastics in semi-dense bituminous concrete with 60/70 penetration grade bitumen employing the dry process of mixing. On heating, the softened plastics, provide a thin coating on the aggregate. Marshall Stability and flow values, over 50 samples with varying percentage bitumen by weight of mix and percentage plastics by weight of binder were evaluated. There was a 10% saving in the bitumen content which leads to a saving in the national economy and also an eco-friendly method for the disposal of waste plastics. The stability value of the mix was increased by about 30%. There is also less ageing of bitumen and no bleeding. The plastic coated aggregates showed no stripping even after 96 hours of water immersion and hence avoid the use of anti-stripping agents in bituminous mixes. Water absorption was found to be less as compared to uncoated aggregates indicating its higher degree of water susceptibility.[4] Mohd Rasdan Ibrahim (2013) explains that Crumb rubber modification has been proven to enhance the properties of pure bitumen. Crumb rubber modifications of bitumen have been proven to improve characteristics of bituminous binder such as the viscosity, softening point, loss modulus, and storage modulus. This subsequently improves the rutting resistance, resilience, and improving fatigue cracking resistance of asphaltic mixes. In order to achieve a superior and balanced CRMB in term of high and low-temperature properties, factors such as the mixing time, temperature, characteristics, and source of the crumb rubber and bitumen type must be considered since these are the factors that govern the resulting performance of asphaltic mixes. Ageing mechanism of CRMB is also important to be considered in order that the resulting CRMB has a workable viscosity to be applied in the construction process. Finally, chemical modification of CRMB is a new area that has promising possibilities in the future to further enhance the properties of CRMB and at the same time eliminate rubber particle settling problem that is one of the limiting factors in the current application of crumb rubber modified bitumen [5].

3. RESEARCH METHODOLOGIES

The research methodology for the present study has adopted various tests to investigate the results on aggregate, bitumen and waste plastic with crumb rubber substituted bitumen and aggregate-bitumen-modified mix. The waste plastic and crumb rubber are mixed in equal proportion. The waste plastic has been collected from the neighborhood college area and crumb rubber is obtained from the tyre industry and used for testing. The various tests conducted on bitumen and modified bitumen was as follows:

Table 1: Tests on bitumen

S no.	Test	Apparatus used	Reference
1.	Penetration Test	Standard Penetrometer	IS : 1203-1978
2.	Ductility Test	Ductility Apparatus	IS: 1208-1978
3.	Softening Point	Ring Ball Apparatus	IS: 1205-1978
4.	Flash And Fire Point	Pensky-Martens Apparatus	IS : 1209-1978
5.	Viscosity Test	Orifice Viscometer	IS: 1206(Part I)-1978
6.	Loss On Heating	Oven	IS : 1212-1978

For checking whether the plastic coating can be used to enhance the strength of aggregates, the following tests were conducted on aggregates and plastic coated aggregates:

Table 2: Tests on aggregates

S no.	Test	Apparatus used	Reference
1.	Aggregate Impact Value	Impact Testing Machine	IS: 2386(Part IV)-1963
2.	Abrasion Value	Los Angeles Abrasion Testing Machine	IS: 2386(Part IV)-1963
3.	Crushing Value	Crushing Value Apparatus	IS: 2386(Part IV)-1963

The optimum percentage of plastic and crumb rubber substitution is found out from bitumen testing. Various bituminous mixes were prepared by using pure bitumen and plastic and crumb rubber substituted bitumen. These mix samples were tested for the following tests:

Table 3: Tests on aggregates

S no.	Test	Apparatus used	Reference
1.	Marshall Stability Test	Marshall Test Apparatus	IRC SP 53-1999 and ASTM D 1559-1979
2.	Compressive Strength Test	Universal Testing Machine	ASTM D 1074-09
3.	Indirect Tensile Strength Test	Universal Testing Machine	ASTM D 6931

4. RESULT AND DISCUSSION

4.1 Laboratory tests on Aggregates

The results of various tests conducted over aggregates are as follows:

Table 4: Results of tests on aggregates

S no.	Test	Result (%)				Standard Value
		Pure aggregate	5% Coat	7.5% Coat	10% Coat	
1.	Crushing Value	21.72	19.57	17.18	16.45	30 % Max
2.	Impact Value	13.46	12.50	10.90	8.92	30 % Max
3.	Abrasion Value	9.8	9	8.4	7.6	30 % Max

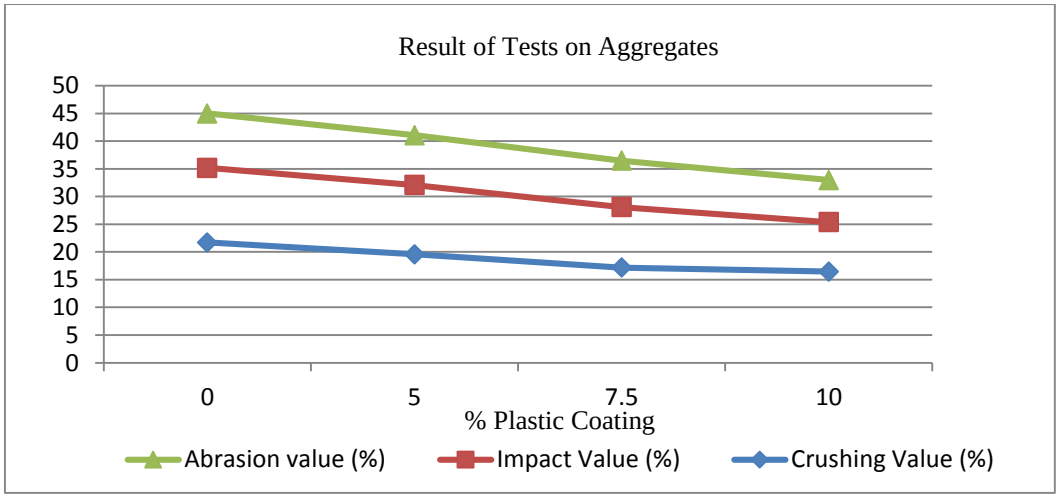

Fig. 1: Results of tests on aggregates

Comment: The strength of aggregates gets increased after coating with plastic which is beneficial in the pavement.

4.2 Laboratory tests on Bitumen

The results of various tests conducted on bitumen are as follows:

Table 5: Results of tests on bitumen

S no.		Result						
		Penetration (mm)	Ductility (cm)	Soft. Pt.(^{0}C)	Flash pt.(^{0}C)	Fire pt.(^{0}C)	Viscosity (sec)	Loss on Heating (%)
1.	Pure Bitumen	84	81	46	248	291	290	0.32
2.	5% Replacement	79	62	48	257	300	190	0.21
3.	7.5% Replacement	73	51	54	265	310	165	0.16
4.	10% Replacement	65	47	62	280	330	155	0.21
5.	12.5% Replacement	60	38	65	290	350	132	0.25
6.	15% Replacement	58	32	69	297	360	121	0.27
	Standard Values	60 Min	50 Min	40 Min	220 Min	290 Min	50 Min	1% Max

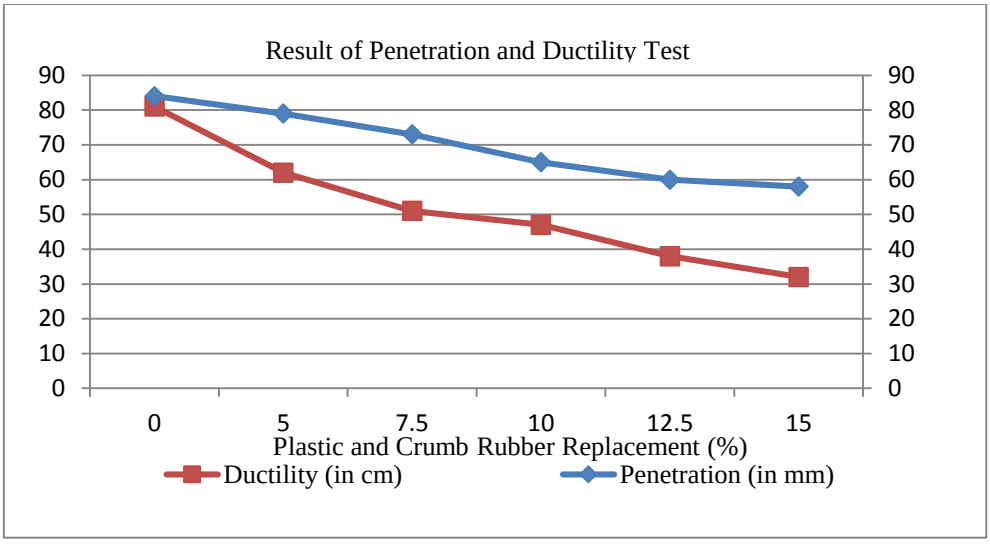

Fig. 2: Result of penetration and ductility test

Comment: After replacement of plastic and crumb rubber with bitumen, there is decrease in penetration & ductility value which indicates that the bitumen is getting harder with more plastic and rubber replacement.

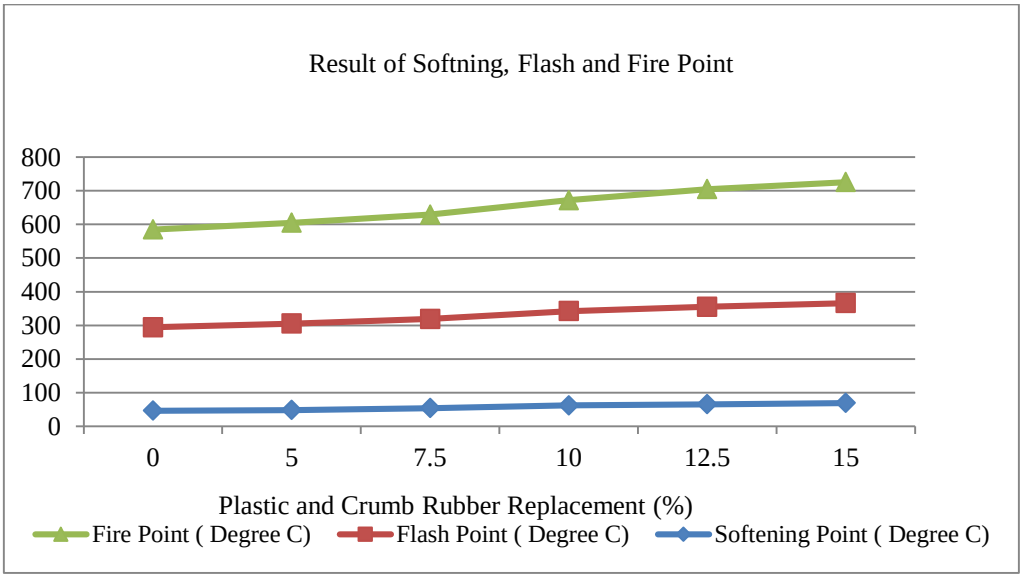

Fig. 3: Result of softening, flash and fire point

Comment: With an increase in plastic and crumb rubber percentage, there is an increase in flash, fire and softening point which indicates more susceptibility of bitumen in tropical regions.

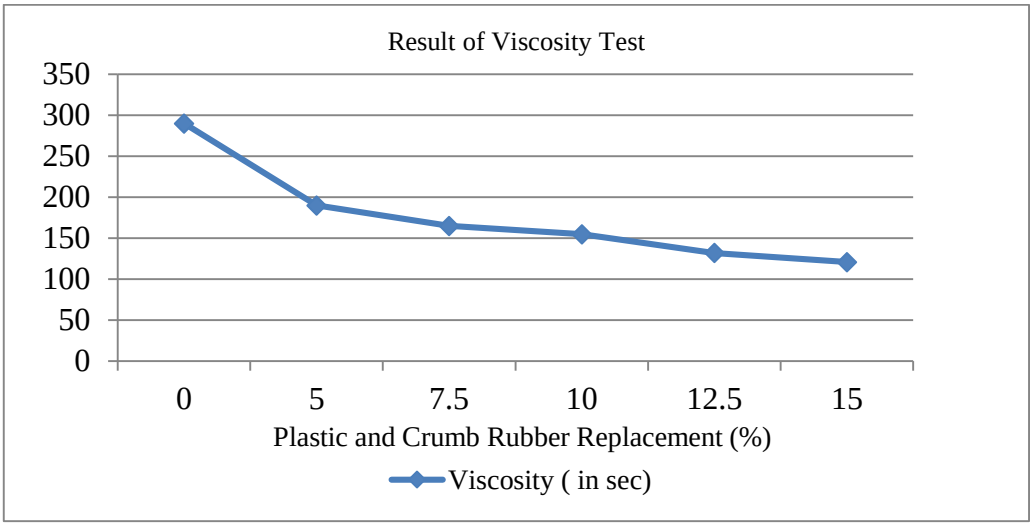

Fig. 4: Result of viscosity test

Comment: Reduction of viscosity is useful to lower the mixing and compaction temperature of the asphalt.

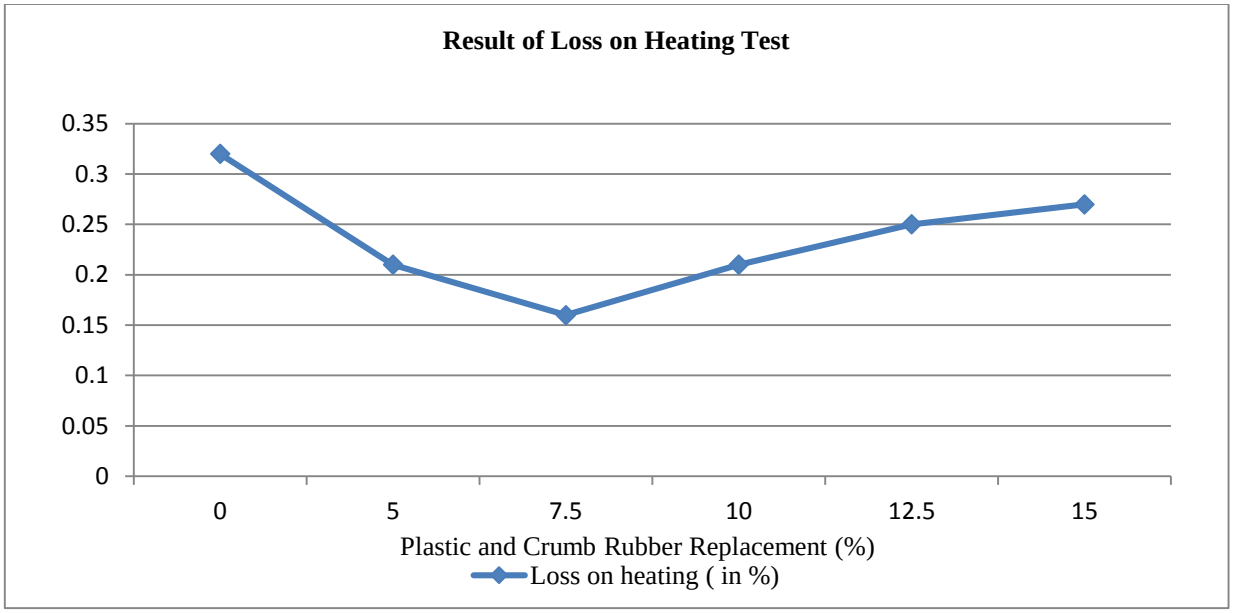

Fig. 5: Result of loss on heating test

Comment: Addition of plastic and crumb rubber shows a slight decrease in loss on heating.

4.3 Laboratory tests on bituminous mixes

The results of various tests conducted on bituminous mixes are as follows:

Table 6: Result of tests on bituminous mixes

S no.	Test	Specification	Result	Standard Value
1.	Marshal Stability Test (Stability)	Pure Bitumen	610 kg	Minimum 340 kg
		10% Replacement	990 kg	
2.	Marshal Stability Test (flow value)	Pure Bitumen	8.7 mm	Min 8 mm Max 17 mm
		10% Replacement	10.9 mm	
3.	Compressive strength of bitumen	Pure Bitumen	820 kg	Min 700 kg
		10% Replacement	1620 kg	
4.	Indirect tensile strength of bitumen	Pure Bitumen	340 kg	Min 330 kg
		10% Replacement	620 kg	

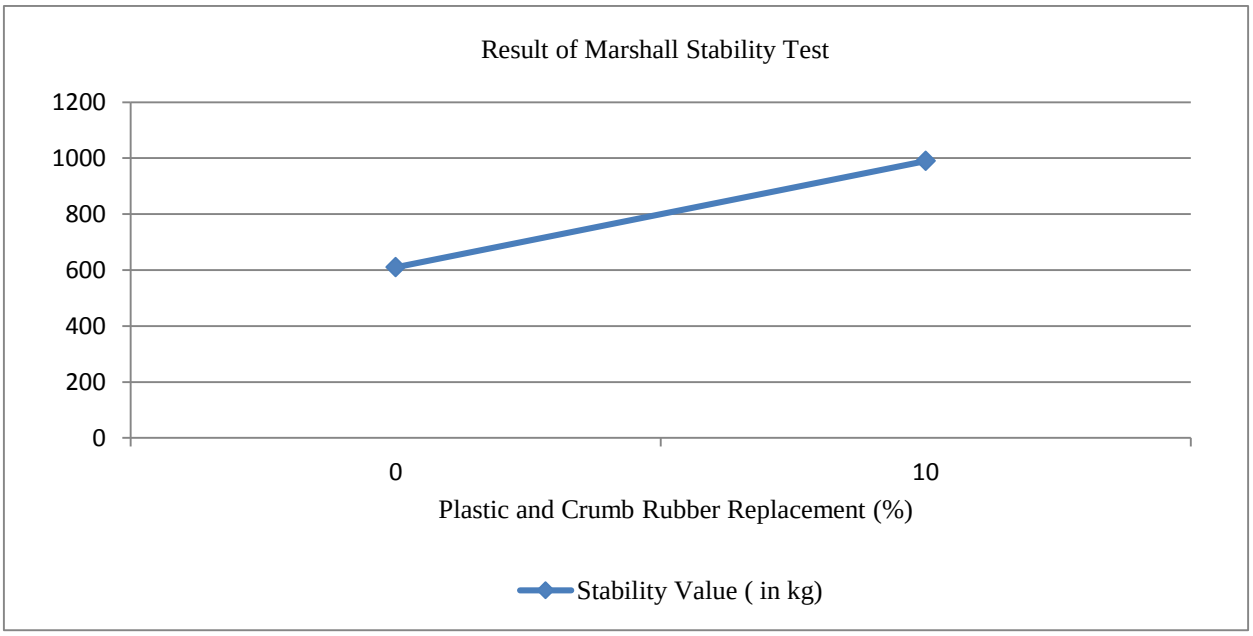

Fig. 6: Result of Marshall Stability test

Comment: Addition of plastic and crumb rubber shows increase in stability value which is useful to sustain large load.

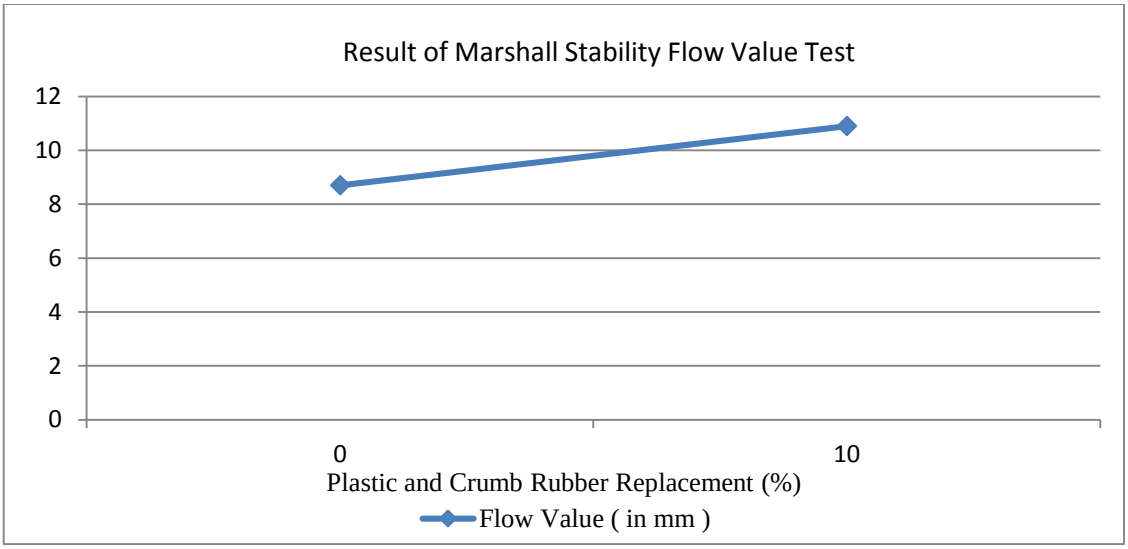

Fig. 7: Result of Marshall Stability flow value test

Comment: Replacement of plastic and crumb rubber shows an increase in flow value i.e. less resistance to deformation but change is very little which is in specified limit.

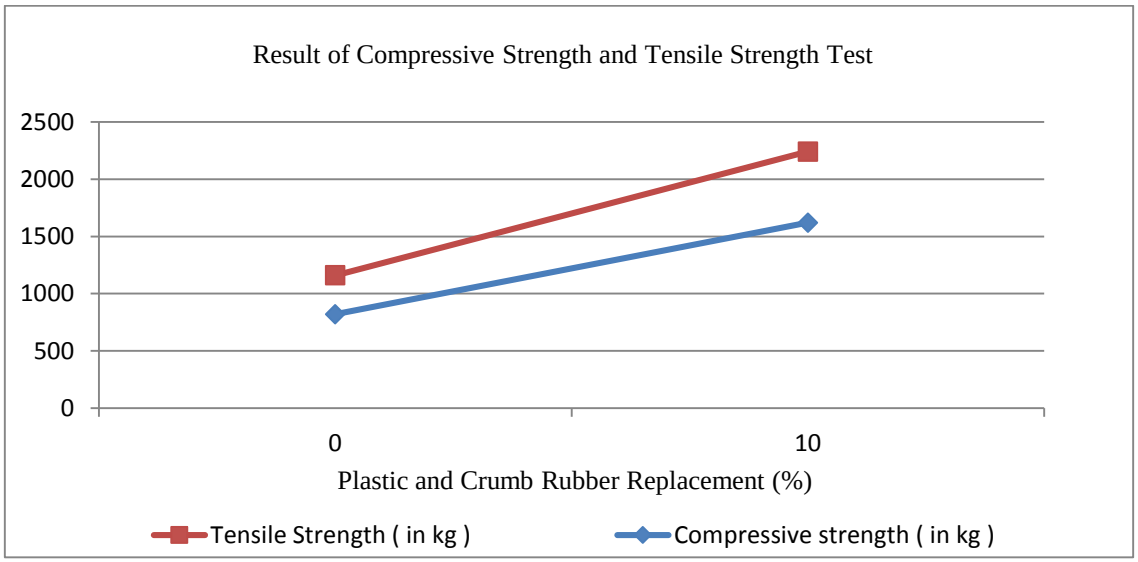

Fig. 8: Result of compressive strength and tensile strength test

Comment: Addition of plastic and crumb rubber shows increase in compressive and tensile strength.

5. CONCLUSION

Based upon the work carried out in the project, the following conclusions can be framed:

- 10% of plastic coating samples showed more strength than conventional bitumen.
- By studying the test results of the conventional bitumen and the waste plastic and crumb rubber modified bitumen it is concluded that the penetration value and the softening value of the conventional bitumen can be improved significantly.
- By studying the test results of the conventional bitumen and the waste plastic and crumb rubber modified bitumen it is concluded that the flash point and the fire point of the conventional bitumen can be improved significantly.
- Plastic and crumb rubber as a 10% replacement in bitumen can be used as an optimum percentage value for bituminous mix design and testing.
- 10% plastic and crumb rubber replacement in bitumen shows better results for pavement properties.
- Plastic with crumb rubber can be utilized as a partial blending material in design of flexible pavement.
- It can be used as a partial replacement in bitumen as well as coating over aggregate.

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