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EXPERIMENTAL STUDY ON THE IMPACT OF USING WASTE PLASTIC AND GLASS ON THE PROPERTIES OF ASPHALT PAVEMENT PRAVIN

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ABSTRACT

As the world continues to urbanize and modernize, more and more waste is being generated today. Landfill is not a long-term solution. Collecting plastic and glass waste from the houses is increasing exponentially. Glass cannot be decomposed, so it can only be disposed of in landfills or reprocessed to reuse as a new glass material, but on reprocessing it requires high energy to melt and reproduce a new material. Plastic waste is not easy to deal with. If it is taken to landfills to decompose, the soil will become infertile, which is detrimental to the environment. In many countries, waste glass is used in road construction instead of aggregates in hot asphalt mixes, to ensure sustainable management of waste glass. The further utilization of wastes in construction applications is likely to offer an environment friendly, sustainable solution. No matter what type of product we use, whether it is concrete, plastics, glass or wood, it will one day become waste. The best way to handle these wastes is to either recycle it or reuse it as raw materials, additives or modifier. Of all the wastes, plastic and glass are the most commonly used materials in our everyday life. Plastic and glass are not incinerated or decomposed. It is better to use this waste material in bituminous constructions to modify mechanical and physical behaviour of the mix. This waste mixed modified mix is better than conventional mix in terms of longevity and durability compared to conventional mix. It can be cost-effective, eco-friendly and can withstand temperature variations. In this study, we will look at the properties of the asphalt mix. We will look at the effect of the binder of the waste as well as the fine material of the crushed glass. We will compare the results of the different proportions of the binder and virgin bitumen with the suitable glass percentage of the mixture. We will also look at the percentage variation between the conventional and the modified mix. The shredded waste plastics were mixed with hot bitumen. A wet mixing process is used to prepare the mix. The HDPE modifier is combined with the binder to form a homogeneous binder for the mixture before the binder is added. The bituminous mixture has gradation equivalent to stone dust. Glass waste generated from glass liquor bottle is added to the mix. The particles are finer than the 4.75mm limit. Marshall Method is used to determine the optimal binder content, optimal plastic content and optimal glass cullet content for the mixture.

Keywords: Bituminous mixture, Plastic waste, HDPE, Glasphalt, Glass cullet, Marshall Stability Test, HDPE Modified Binder, optimum binder content, optimum plastic content.

1. INTRODUCTION

1.1 GENERAL

India's road network is over 5,472,144 kilometers (3,400,233 mi) as of 31 March 2015, the second largest road network in the world. The quantitative density of India's road network is 1.66 kilometers per square kilometer of land, and the density is higher than that of Japan (0.91) and the United States (0.67) and much higher than China's road network (0.46) and Brazil (0.18). or Russia (0.08), (Ministry of Road Transport and Highways).

However, Indian roads are a mix of modern highways and narrow unsurfaced roads in terms of quality and are being improved (Indian Transport Sector). As of 31 March 2015, 61.05% of Indian roads were asphalted (Ministry of Road Transport and Highways) and most of these roads are deteriorating day by day due to negative traffic load, bitumen aging and extreme weather conditions. However, the cost of improving such roads has increased due to lack of good quality binding materials as described in IRC 37 (India Roads Congress 2012).

It is estimated that around 70% of plastic packaging becomes plastic waste within a short period of time. Every year, approximately 5.6 million tonnes of plastic waste (TPA) is generated in the country, which is 15342 tonnes per day (TPD). About 10 million tonnes of LDPE carrier bags are produced every year in India, of which nearly 2 million tonnes are recycled. LDPE carrier bags are not easily biodegradable and remain relatively unchanged in the environment for a long time, causing environmental problems due to tipping as well as limited recycling options (Punith 2005). Today, disposal of landfills has become a crying need not only to reclaim their vast valuable space but also to reduce pollution and other hazards. Many researchers have tried to use waste materials in road construction. Aging of bitumen is one of the most important factors causing deterioration of asphalt pavements. Major aging-related defects are traffic and thermal cracking. The bituminous material used as mineral adhesives for paving structures and coatings is a thermoplastic viscoelastic material. Conventional tests have been used to characterize bitumen in India so far, but these tests are not satisfactory for the rheological characterization of bitumen and provide values indirectly (Praveen Kumar and Rashi Garg (2008).

With the world modernization and rapid economic growth, increased consumption and large amounts of waste materials such as plastic, glass, CRT, tires, industrial and construction wastes as well. These wastes cause problems to living human and are harmful to health.

Nowadays glass waste is generated. Also increasing day by day. According to data collected from a survey conducted in the city, rag pickers collected 2-3 tons of wasted wine glass bottles every day. Although these glass wastes are 100% recyclable, they require a lot of energy during the recycling process and due to their content form harmful gases when melted. So, therefore, to save energy and the environment, and as an alternative construction product, as a filler, this old glass can also be used in road construction in the base and surface layer. Based on previous studies, many researchers have found that it is a good alternative product to add and can be cost-effective.

1.2 ISSUES ON DISPOSAL OF PLASTIC WASTE

Indiscriminate littering and unorganized recycling/recycling and non-biodegradability of plastic waste raises several environmental problems such as below;

- Release of volatile emissions during polymerization process.
- Harmful gases like carbon monoxide, formaldehyde etc. are released during the manufacturing of the product.
- Land is becoming depopulated due to indiscriminate disposal of plastic waste.
- Burning plastic waste, including polyvinyl chloride (PVC), releases toxic emissions such as carbon monoxide, chlorine, hydrochloric acid, dioxin, furans, amines, nitrides, styrene, benzene, 1,3-butadiene, CCl_4 and acetaldehyde.
- Leaching of toxic metals such as lead and cadmium pigments into groundwater due to indiscriminate dumping of plastic waste on land.
- Multi-layer metallized bags and other single-use plastics cause disposal problems.
- Non-standard plastic carrier bags, thin packaging films etc. cause problems in collection, recycling and reuse.
- Unbearable and strewn plastic waste creates an unsightly appearance and chokes drainage.
- Soiled and mixed plastics waste interferes its beneficial utilization.
- Unhealthy operations of plastic waste and recycling industries in non-compliant areas release fugitive emissions.

2. LITERATURE REVIEW

Panda and Mazumdar (2002) utilized reclaimed polyethylene (PE) obtained from LDPE carry bags to modify bitumen properties. They studied the basic properties such as Marshall Stability, resilient modulus, fatigue life, and moisture susceptibility of mixes with 2.5% of PE and compared with those of asphalt cement. They concluded that at a particular temperature and stress level, polymer modification increases the resistance to moisture susceptibility, resilient modulus and fatigue life of mixes. [24]

Awwad and Shbeeb (2007) indicated that the modified mixture has a higher stability and VMA percentage compared to the non-modified mixtures and thus positively influence the rutting resistance of these mixtures. According to them modifying asphalt mixture with HDPE polyethylene enhances its properties far more than the improvements realized by utilizing LDPE polyethylene. [3]

P. Kumar and R. Garg (2011) concluded that the 60/70 modified binders have shown a higher rutting resistance value than the 80/100 modified binders at the same percentage of the modifier, the properties of bitumen can be enhanced by adding small amounts of the modifier. [30] Bindu and Beena (2010) studied how Waste plastic acts as a stabilizing additive in Stone Mastic Asphalt when the mixtures were subjected to performance tests including Marshall Stability, tensile strength, compressive strength tests and Tri-axial tests. There results indicated that flexible pavement with high performance and durability can be obtained with 10% shredded plastic. [7]

Ahmadinia et al. (2011) carried out an experimental research on the application of waste plastic bottles (Polyethylene Terephthalate (PET)) as an additive in bituminous mixture. Wheel tracking, moisture susceptibility, resilient modulus and drain down tests were carried out in their study on the mixtures that included various percentages of waste PET as 0%, 2%, 4%, 6%, 8% and 10% by weight of bitumen content. Their results show that the addition of waste PET into the mixture has a significant positive effect on the properties of SMA which could improve the mixture's resistance against permanent deformation (rutting), increase the stiffness of the mix, provide lower binder drain down and promotion of re-use and recycling of waste materials in a more environmentally and economical way. [1]

V.S. Punith and A.Veeraragavan (2011) modified the 80/100 paving grade asphalt cement using reclaimed polyethylene (PE) derived from low-density polyethylene carry bags (LDPE) and carried out the various tests on PE-modified binder with variation on blending temperature and blending time thus results of which indicated enhanced binder properties like improved storage stability, resistance to aging, degradation, and temperature susceptibility. It is observed that viscosity at a given temperature increases with the addition of PE in the binder. Dynamic shear rheometer test results revealed that PE-modified binders (when subjected to the same stress) experienced lower strains than the neat asphalt; in addition, tan δ values of PE-modified binders considerably decreased as the PE content was increased. It was found that 5% PE content in modified asphalt by weight is adequate in terms of enhanced binder properties. [34]

IRC 98 (2013) provides a guideline for the use of waste plastic in hot bituminous mixes (dry process) in wearing courses and suggested that the plastic shall be tested for impurity and melt flow value. It is also indicated that the waste plastic shall conform to the size passing 2.36 mm sieve and retained on 600 µ sieve and dust and other impurities shall not be more than 1%. [15]

Metin guru M. et al. (2014) derived two novel additive materials, namely Thin Liquid Polyol PET (TLPP) and Viscous Polyol PET (VPP), were chemically derived from waste PET bottles and used to modify the base asphalt separately for this aim. The effects of TLPP and VPP on the asphalt and hot mix asphalt (HMA) mixture properties were detected through conventional tests (Penetration, Softening Point, Ductility, Marshall Stability, Nicholson Stripping) and Superpave methods (Rotational Viscosity, Dynamic Shear Rheometer (DSR), Bending Beam Rheometer (BBR)). The additives improved both the asphalt and the asphalt mixture performance. [26]

Sandip Karmakar and Tapas Kumar Roy (2016) used modifying agents like plastic carry bag (PB), plastic milk pouch (PMP), plastic disposal tea cup (PC), mixed plastic (MP), tire rubber ash (TRA) and TRA+MP, mixed with 60/70 penetration grade bitumen and investigated the modified properties of the mix. The results of experiment indicate that addition of 1% by weight of mixed plastic (MP) to the hot 60/70 pen grade bitumen provides the enhancement in the temperature susceptibility resistant characteristics, viscous properties, and elastic recovery properties with good compatibility and cohesiveness at the micro level by satisfying the essential criterion of PMB 40. [31]

2.2 Effect of Waste Glass

Krishnan viswanathan (1996) concluded that addition up to 20 percent glass cullet does not have any noticeable effect on the optimum moisture content and the dry density of the mix. This makes glass cullet a viable material for use in flexible bases. The results from the triaxial tests indicate that there is no appreciable change in the corrected stress observed for samples with different amounts of glass cullet up to 20 percent. It is therefore safe to conclude that glass cullet up to 20 percent can be mixed with conventional granular material for use in structural fills without compromising the strength of the material. [21]

Nan Su , J.S. Chen (2002) investigated that glass contents of 0, 5, 10, and 15%, in terms of the total aggregate weight used in the mixture designs for casting series of 10 cm diameter by 6.35 cm disk specimens. Tests including Marshall stability value, dry/wet moisture damage, skid resistance, light reflection, water permeability, and compaction in accordance with the ASTM and AASHTO procedures and the test results reveal that glass waste is a viable material for asphalt concrete that has been widely used in pavement that offers profound engineering and economic advantages. [28] Nicholls and Lay (2002) reported on a recycled asphalt mixture with 30 % crushed glass. Compaction tests showed that glass-bitumen mixture performed about as well as the control asphalt mixture (standard mixture) and revealed no issues with workability or compaction. [29]

Hassan H. Jony et.al. (2011) indicated that the glass powder filler can improve Marshall stability values for all mixtures comparing to Portland cement or limestone powder fillers. The percentage of increase ranging from 6% to 36% depending on percentage of filler. The average value of Marshall flow is less than resulted from mixtures with ordinary Portland cement or limestone powder fillers. [14]

M. Ghasemi, S. M. Marandi (2013) investigated that by using recycled glass powder (RGP) in the asphalt mixture can improve Marshall Stability and mechanical properties. It could be also inferred that stiffness and thermal sensitivity improved. Moreover, Marshall Stability, tensile strength and stiffness modulus of asphalt mixtures increased with increase of RGP content. Optimal modification was attained with 3% SBR and 2% RGP. Application of RGP in asphalt mixtures may also have many environmental benefits and prevent accumulation of waste glass in the natural environment.

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3 METHODOLOGY

3.1 INTRODUCTION- In this chapter the material used, their physical properties, mix preparation and test on conventional and modified samples are discussed. This chapter only explains the types of material that we used their physical characteristic

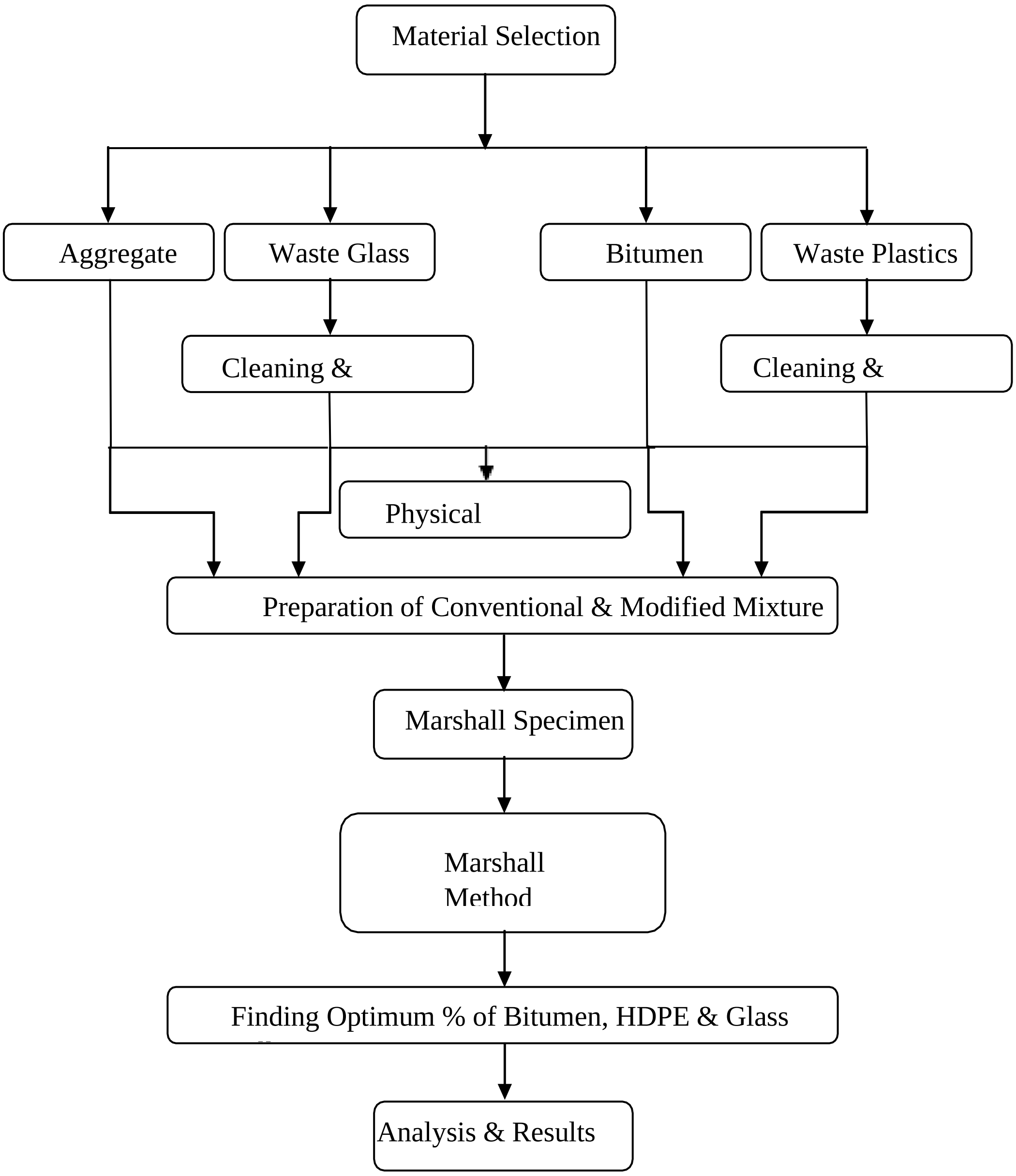

Figure 1 Flow Chart of Experimental Work

3.2 USED MATERIALS- To achieve the objective of the study following materials are used, which are locally available. Table 1 shows the type of material used in this study.

Table 1 Types of Material used

Sl. no.	Material		Specification
1.	Aggregate	Course	20mm, 10mm, 6mm
		Fine	Stone dust
2.	Filler		Cement
3.	Bitumen		VG30 / (60-70)
4.	Waste Plastic		HDPE
5.	Waste Glass		Liquor Bottles

3.3 AGGREGATES

For preparation of bituminous mixes normally coarse and fine aggregates are used. These aggregate are first collected from the source then investigated to check the physical characteristics, as per the norms on MORTH (5^{th} rev. 2013). Table 3.2 shows thephysical characteristic of these aggregates.

Table 2 Physical characteristics of coarse aggregate

Sl. no.	Test description		Property	Specification	Test Method
1.	Grain size analysis		leanliness(Dust)	Max.5% passing 0.075mm sieve	IS:2386 Part 1
2.	Combined flakiness and elongation index		Particle shape	Max. 30%	IS:2386 Part 1
3.	Aggregate impact value		Strength	Max. 24%	IS:2386 Part 4
4.	Coating & stripping ofbitumen aggregate		Stripping	inimum retainedcoating 95%	IS:6241
5.	Water absorption		Water absorption	Max.2%	IS:2386 Part 3
6.	Soundness	Sodium Sulphate	Durability	Max. 12%	IS:2386 Part 5
		Magnesium Sulphate		Max. 18%	

3.4 BITUEN

In this research, VG 30 is used as binder agent between aggregate and filler. All the specimens are prepared with VG 30 grade bitumen. Physical properties of this binding agent is conducted and all the rules are followed as per IS 73-2013. Table 3.3 shows the physical requirement for binder.

Table 3 Physical tests for Bitumen

S. no.	Description of Test	Grade of bitumen andits Acceptable Value	IS Test method
		VG30 or (60/70)	
1.	Penetration at 25^0C,100g,5s,0.1mm Min	45	IS:1203
2.	Softening point (R&B), ^{0}C , min	47	IS:1205
3.	Ductility at 25^0C, cm, min	40	IS:1208
4.	Specific gravity	-	-
5.	cosity by Tar viscometer at60^0C, sec.	-	IS:1206 Part-II

Figure 2 Bitumen (VG 30)

4 ANALYSIS OF RESULTS

4.1 INTRODUCTION-

This chapter presents the test results, analysis, rate of change in properties with changing blends, effect of different HDPE percentages on binders, and effect of broken glass on blends. Throughout this chapter, the properties of coarse and fine aggregates, the physical properties of virgin and modified asphalt, the Marshall stability of conventional and modified mixtures, and the percentage change in stability and binder physical properties , and their graphical representations are shown.

4.2 PHYSICAL PROPERTIES OF AGGREGATE-

Physical requirements for dense bituminous concrete materials for the construction of wear courses have been adopted following the guidelines proposed in the MORTH (2013) specification. Tests were independently performed on 20mm, 10mm and 6mm aggregate sizes and stone dust samples. Test results are shown in Tables 4.

Table 4 Physical properties of course aggregate

S. No.	Description of test		Property	Test method	articlesize	Test result observed
1	nbined Flakiness andElongation index		Particle Size	IS:2386 Part 1	20mm	23.2
					10mm	27.8
2	Aggregate Impact Value		Strength	IS:2386 Part 4	20mm	9.8
					10mm	10.3
3	Water Absorption		Water Absorption	IS:2386 Part 3	20mm	0.59%
					10mm	0.79%
4	Coating & Stripping of Bitumen Aggregate		Stripping	IS: 6241		97.50%
5	Soundness	Sodium Sulphate	Durability	IS: 2386 Part 5		1.42
		Magnesium Sulphate				1.65

Table 5 Physical properties of Stone dust

S. No.	escriptionof test	Property	Test Method	Test of fines	Test Resultobserved	MORTH Specification
1	Atterberg's Limits	Liquid limit, W_L	IS 2720 (Part-5) 1973	Stonedust	19	-
		Plastic limit, W_P			Non Plastic	-
		Plasticity Index, I_P			Does not exist	Maximum 4

4.3 PHYSICAL PROPERTIES OF VIRGIN BITUMEN-

Penetration, ductility, softening, flash point, viscosity and specific gravity tests have been performed on virgin VG30 (60/70) grade bitumen. the test result of these experiments are shown below :

4.4 Penetration Test-

As per IS-1203 specifications, penetration test was performed on bitumen and results are shown on table 6

Table 6 Penetration test result of virgin bitumen

PenetrationValue (0.1mm)	**Sample (1)**		**Sample (2)**	
	1	**2**	**1**	**2**
	56.5	58.3	57.4	56.5
	57.4		56.9	
	Average = 57.2			

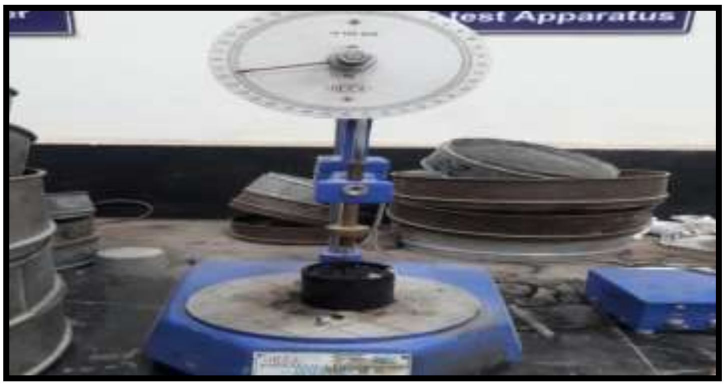

Figure 3 Penetration test

5 DISCUSSION AND CONCLUSION

5.1 DISCUSSION & CONCLUSION

In order to accomplish the purpose of this study, an experimental work was conducted on virgin binder, conventional binder, HDPE modified mixture and Glass modified mixture. In addition, the effect of HDPE on mixture with Glass cullet has been examined separately using Marshall Test method. The results are compared and the % change is determined where the volumetric properties change as the proportion of HDPE increases with the Glass cullet. Since HDPE is combined with VG30 binder, which also changes the physical properties of binder, after a certain percentage level of HDPE, the values cannot be acceptable. The analysis of the test results leads to the conclusion that the optimal dose of the HDPE plastic waste is in VG30 binder.:

- By mixing of HDPE into the VG30 bitumen, penetration value decreases up to 60% of 1% dose of HDPE, but up to 0.4% of HDPE the value can be accepted. Ductility also decreases with increase in HDPE by 74% of 1% HDPE content.
- Softening point increases by mixing of HDPE into bitumen which is good and suitable for high temperature region.
- Decrease in value of Penetration and Ductility shows the hardness and brittleness respectively; of the binder with HDPE mix, which shows the impermeable quality by the modified binder.
- Optimum dose of HDPE in VG30 bitumen is between 0.2 to 0.4%.
- Using Marshall Method of mix design the optimum binder content and optimum plastic has been determined which is 5.60% and 0.6% respectively.
- It has been observed that addition of HDPE waste plastic into the conventional mix can enhance the stability of mixture with lesser flow value in comparison with conventional mix, up to a certain dose of HDPE.
- The existence of waste plastic and waste glass cullet in bituminous binder course mixture is considered as an eco friendly material and sustainable management of these waste products in Pavement construction.
- Using glass waste into bituminous pavement mixture is a good initiate to save environment and nature and it is a sustainable management of this waste.
- Glass can be use in place of finer material in bituminous binder course.
- By incorporation of waste plastic and waste glass into the bituminous binder course the stability increase approx. 50% than conventional mix.
- Optimum dose of waste glass cullet is in the range of 2.5 to 7.5%.

5.2 RECOMMENDATIONS

Following recommendations are made from the investigation on incorporation of waste plastic and waste glass on bituminous mixture:

- This study used liquor glass bottles only, further studies are needed using other types of glass products.
- In this study only HDPE incorporated with waste glass other types of plastics need to be incorporated with this or other waste glass.
- Some strength characteristic studies need to be performed on these materials.
- In the present stud plastic is added to mix via wet mixing process and we further incorporated dry mixing process and should compare the results.

- In this study only VG30 grade bitumen was used, future more studies are needed with these materials using other VG grade bitumen.
- Some of the properties like tensile strength ratio, fatigue behavior, rutting resistance, dynamic and static tensile strength are need to investigate.

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