A COMPREHENSIVE REVIEW ON MODIFIED BITUMENOUS MIX USING HDPE AND GLASS POWDER

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A B S T R A C T
In this experimental study, plastic and glass waste are used as a partial replacement for Bitumen and aggregate in top bitumen layer. Numerous attempts have been made to reduce the rising rate of plastic and glass consumption. Despite the fact that plastic and glass are part of every aspect of our existence. Such solid waste disposal is loaded with financial difficulties and worries. Massive amounts of plastic and glass are released into the environment every day, polluting it. Therefore, it is essential to use plastic and glass as a replacement for engineering work. Today one of the most important engineering materials available on the market is plastic. The use of waste plastic as a source of energy is a part of the solution to ecological and environmental problems. Consequently, the utilization of plastic and glass waste, lower bitumen and aggregate costs, and bitumen layer constructions. In this experimental research, we used glass cullet and waste plastic. In some instances, plastic and glass are non-biodegradable material-is utilized to replace bituminous mix. Since it is not feasible to completely replace natural aggregate and bitumen with plastic and glass waste, only partial replacement is examined in the current dissertation work. In this study, behavior of modified bitumen in an asphalt pavement mixture was studied with different types of polymers. Your glass waste also causes problems for the environment during remelting and recycling. Crushed glass can be a useful substitute for aggregate in a bituminous mixture. This study was conducted to obtain test results on the use of VG30 grade bitumen and the optimal dosage of recycled HDPE polymers and crushed glass in the bitumen mixture. This study also discusses the wet mixing process of the mixture and the Marshall stability of the modified mixture, as well as the optimal dosage of glass mud and plastic waste.
Keywords: Hdpe Plastic waste Modified bitumen

1. Introduction

India's road network is over 6,671,144 kilometers (4,145,256 mi) as of 31 March 2020, 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 2020, 70.00% 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. With the world modernization and rapid economic growth, increased consumption and large amounts of waste material such as plastic, glass, CRT, tires, industrial and construction Wastes as well. These wastes cause problems to living human and are harmful to health.

1.2 WASTE PLASTIC- A PROBLEM

In 2016, India Today reports that more than 15,000 tons of plastic waste is generated every day in India, of which 6,000 tons are uncollected and strewn. It's quite possible that India has the highest recycling rate for polyethylene terephthalate, or PET, the plastic used in drinking water bottles and food containers. According to a 2013 estimate by the Central Pollution Control Board (CPCB), Indians throw away 15,342 tonnes of plastic waste every day, of which about 60% is recycled, the majority in the informal sector. Although India's recycling rate is significantly higher than the global average of 14%, there is still more than 6,100 tonnes of dirty plastic fill or stop polluting streams or underground supplies. Some types of plastic don't break down at all, but others can last up to 450 years, leaving a vexing problem to deal with. It is estimated that around 70% of plastic packaging becomes plastic waste in 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). On the other hand, due to rapid modernization of polymer technology, India consumed 159 million tonnes of plastic compared to 2005- 06. with an estimated production of 127 million tons.

1.3 ISSUES ON DISPOSAL OF PLASTIC WASTE

Indiscriminate littering and unorganized recycling/recycling and non-biodegradability of plastic waste raises several environmental problems such as release of volatile emissions during polymerization process, harmful gaseslike 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.

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1.4 TYPES OF PLASTIC WASTE

The main category of plastics includes;

A. Recyclable Plastics (Thermoplastics): PET, HDPE, LDPE, PP, PVC, PS, etc.

B. Non-Recyclable Plastics (Thermoset & others): Multilayer & Laminated Plastics,PUF, Bakelite, Polycarbonate, Melamine, Nylon etc. As per BIS Codification as notified in Rule 8 (b) of the Plastic Waste (Management and Handling) (Amendment) Rules, 2011, there are seven categories of plastics:

2. LITRATURE REVIEW

i. Obaid, H.A (2021) investigated Characteristics of warm mixed asphalt modified by waste polymer and nano-silica. warm mixture asphalt (WMA) contain Polypropylene polymer (PP) and Nano- silica particles (NS). Two kinds of WMA were used: unmodified WMA and modified WMA contain 3% PP and NS (2–5) % by total weight of asphalt.

ii. Torres, H.P.; Fernandes, S.R.; Loureiro, C.D.; Moura, C.F.; Silva, H.M.; Oliveira, J.R. (2020) investigated modified binders as rejuvenators in a recycled asphalt mixture with a high content of RAP material (50%) to maximize its properties.

iii. Ikeagwuani, C.C.; Nwonu, D.C. (2021) investigated Significant improvement in the expansive soil was found when a combination of 20% SDA, 10% QD and 8% OPC (A6 B2 C3) were blended with it. The CBR of the expansive soil that was combined with the optimum combination of additives increased significantly apparently due to the improved mechanical strength of the soil. The improved mechanical strength aroused from the micro-filler effect experienced between the reaction of the QD and the soil. Furthermore, cation exchange effect caused by the reaction between ionized potash in the SDA and the montmorillonite clay mineral also contributed to the significant improvement in the CBR.

iv. AASHTO-T283; American Association of State Highway and Transportation Officials (2022) standard method of test for resistance of compacted asphalt mixtures to moistureinduced damage.

v. Hasan, E.A.; Abed, Y.H.; Al-Haddad (2021) investigated that - Adhesion work of asphalt binders modified with different modifiers is higher than the pure asphalt binder. Maximum improvement in adhesion work due to the addition of 7% of SBS modifier with an increment rate of 9.577% in the Durah asphalt binder and 7.363% in Basrah asphalt binder with Dukan aggregate case.

vi. Y. ISSA (2016) investigated the effect of adding crushed glass to asphalt mix and found that crushed glass can be used in asphalt pavement with optimum replacement ratio of 10% by weight of total aggregates. The value of stability and MQ for 10% glass modified mixture was higher than the control mixture. Therefore, a significant improvement occurred in the Marshall properties of asphalt concrete mixtures using a crushed glass modifier.

vii. 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 .

viii. 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.

ix. Ahmadinia et al. (2011) carried out 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.

x. Ahmed Abbas Jasim (2014) investigated waste glass as secondary aggregate in asphalt mixture. The study covers firstly using glass as aggregates including two percentages of glass content (50 and 100 %) by weight of each sieve, and six sizes of glass (1/2, 3/8, No.4, No.8, No.50 and No.200). Secondly, using glass as additives including three percentages of glass content (1, 2 and 4 %) by weight of total mix, and two sizes of glass (No.50 and No.200) and concluded that Marshall Stability for glasphalt is higher than of the control mixture by (127 and 174) % when using glass size (No.8 and No.200) respectively as secondary aggregate in asphalt mixture.

xi. 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.

xii. G.H. Shafabakhsh, Y. Sajed (2014) studied dynamic properties of glasphalt, including fatigue life, stiffness modulus and creep compliance. The data showed that the dynamic properties of glass–asphalt concrete are improved in comparison with ordinary asphalt concrete.

xiii. M. Panda and M. 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.

xiv. 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.

3. EXPERIMENTAL PROGRAM

Experimental work was performed to investigate conventional and improved binders, and modified mixtures with HDPE plastic and broken glass in the mixture. After measuring physical properties of materials used such as aggregates, fillers, asphalt, plastic waste, and used glass, and performing sieve analysis of aggregates and glass fragments, aggregates are mixed. A combined grading analysis was performed following the guidelines suggested in Section 507.2.5, Category II, Table 500-17, Section 507, Pg. 507.2.5 for the blend fractions shown in Table 3.6. 189, MORTH spec (2013).

3.1 Preparation of Modified Binder

In this study, shredded HDPE plastic bags mixed with hot asphalt are used to create a modified binder. Mix the hand modifier (HDPE) with the asphalt and stir for 20 minutes. The mixing temperature is 170 °C (Punith et. al. 2011). The blended modified binder was tested according to IS 73-2013.

3.3 Preparation of Mixture

In the mixture preparation, the proportion of each type of aggregate is calculated. The mixing ratio of each aggregate is shown in Table 3.8. Each aggregate sample was blended separately for each proportion of conventional and modified blends. Agglomerates are dried and heated to 120°C before mixing. Fresh material heated at 160 °C and modified asphalt binder are mixed at 165°C. Add the required proportion of bitumen to the heated aggregate and mix thoroughly to form a homogeneous mixture. A standard Marshall mold was heated in a temperature-controlled oven, after which the hot mixture was poured into the mold and both sides of the mold were compressed with 75 Number of punches to test. The compressed sample is then removed from the mould and placed in a water bath at a temperature of 60 °C for 30 minutes.

3.3 Determination of Optimum Bitumen, HDPE and Glass content

Marshall Test Method

In this study, the Marshall stability test was used to determine the optimal asphalt, HDPE and glass contents. The Marshall Stability Test is an empirical method for measuringthe stability, deflection and volumetric properties of asphalt mixtures. This test method measures the resistance to plastic flow of 102 mm (4 inch) cylindrical bitumen pavement specimens loaded perpendicular to the cylinder axis on a Marshall machine. Marshall stability and flow values and densities; air voids, mineral aggregate voids, or asphalt-filled voids throughout the mixture, or both asphalt-filled, for laboratory mix design and evaluation of bituminous mixtures used for the degree of Marshall stability depends on the type and grade of aggregate and the type, grade and amount of asphalt (D6927-05). The sample is loaded diametrically at a strain rate of 50 mm/min. Here we present two key features of his mixed design of the Marshall method.

i. Stability, flow tests and
ii. Voids analysis

Marshall stability of a mixture is defined as the maximum load a sample can support at a standard test temperature of 60°C. Yield value is the deformation that a specimen undergoes when loaded to its maximum load. This is a very popular method to characterize asphalt mixtures in India due to its simplicity and low cost. In this study, Marshall properties such as stability, yield value, unit weight and air voids were examined to determine the optimum binder content (OBC) and optimum polyethylene content (OPC). Table 3.7 shows the requirements for the asphalt concrete layer.

Specification for Marshall Specimen

Sl. no.	Marshall parameters	Specification
1	Marshall stability at 60^0C, KN	9
2	Flow Value, mm	2-4
3	Compaction level (No. of blows)	75 on each face
4	Air void %	3-6
5	VMA %	-
6	VFB %	65-75

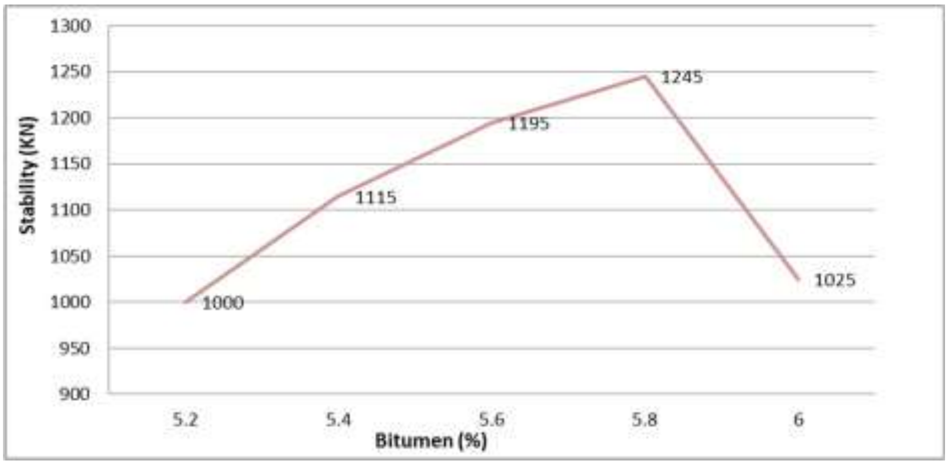
Marshall Stability tests were performed on the mixtures to determine the optimal binder content. Mixtures were made with 5, 5.2, 5.4, 5.6, and 5.8 D44 bitumen. Table 4.14 shows the results of Marshall Tests at various binder levels. Calculating the optimum binder content yielded a value of 5.66% of the asphalt content. A maximum stability of 1218 KN was obtained at the optimum binder content of 5.66%. Figure 4.6 shows Marshall Samples with different asphalt percentages.

Marshall Test result of conventional

Bitumen (% by weight of aggregate)	Stability (KN)	Flow value (mm)	Unit wt. (gm/cc)	Air Void (%)	VMA (%)	VFB (%)
5.2	1000	2.89	2.34	5.1	19.7	75.42
5.4	1115	3.5	2.37	4.3	19.2	79.75
5.6	1195	3.9	2.39	2.85	18.9	84.95
5.8	1245	4.12	2.4	1.7	18.2	85.82
6	1025	4.45	2.35	3.55	20.1	81.42
OBC (5.8%)	1245	3.772	2.37	3.5	19.22	81.472

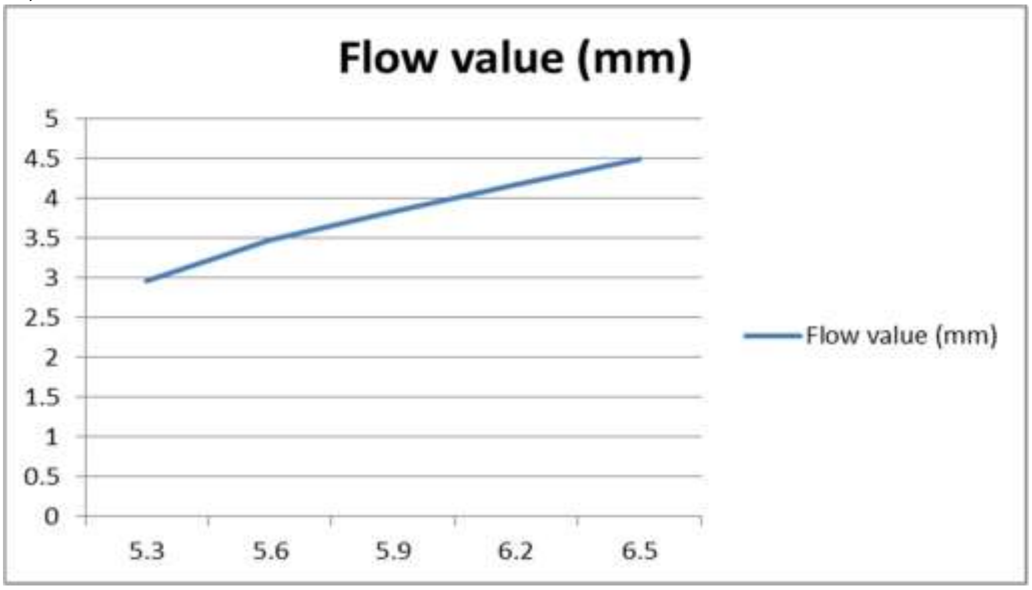
Marshall Stability

Figure shows the graph of Marshall Stability at different bitumen percentages. It was found from the test results that with increase in bitumen content stability also increases, but at 5.8% of bitumen content the stability was drop. From all the calculations at 5.8% optimum bitumen content stability was maximum i.e. 1245 KN.



Flow value

Figure shows the deformation on specimens with increase in bitumen %. With increase in bitumen concentration, flow value increases. At OBC % i.e. 5.80 flow value is 3.77 mm.



Determination of optimum plastic content of modified mix

To determine the optimum plastic content of the modified mixture, the mixture was prepared with an optimum binder content of 5.80% bitumen, and the HDPE content of the modified mixture was 0.2, 0.4, 0.6, 0.8, and 1.0% (by weight). is. of aggregate). Molds could not be made with binders containing 1% HDPE due to the low ductility values of the binders. Bonding between aggregate and binder is not possible due to poor binding properties. The molded sample broke when the compressed sample was ejected from the Marshall mold. A modified binder is produced and the aggregate is heated to 160 °C. The binder is then mixed over the hot aggregate and mixed evenly. Table 4.16 shows the Marshall test results for the HDPE modified blends and Figure 4.14 shows the HDPE modified Marshall samples

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OBC (%)	HDPE % (By wt. of Aggregate)	Stability (KN)	Flow (mm)	Unit wt. (gm/cc)	Air Void (%)	VMA (%)	VFB (%)
5.80	**0**	1210	3.90	2.402	2.39	18.69	87.0
	0.25	1405	2.38	2.358	3.95	20.18	82.5
	0.50	1625	3.23	2.375	3.15	19.45	83.95
	0.75	1670	3.52	2.410	2.14	18.85	87.75
	1.0	1205	3.95	2.342	3.74	20.10	81.25

Marshall Test results of HDPE modified mix

Determination of optimum glass content of plastic modified mix

In order to determine the optimal glass content on the bituminous admixture samples, the glass content was prepared at the OBC and the binder content of the OPC. The glass was then mixed on the hot total with a tolerance of 10 by 2.5-10 by 2.5 for each sample. The results of the Marshall Test of Glass mixed HDPE modified sample.

Marshall Test result of Glass mixed HDPE modified sample

OBC (%)	HDPE % (By wt. of Aggregate)	Stability (KN)	Flow (mm)	Unit wt. (gm/cc)	Air Void (%)	VMA (%)	VFB (%)
5.80	**0**	1210	3.90	2.402	2.39	18.69	87.0
	0.25	1405	2.38	2.358	3.95	20.18	82.5
	0.50	1625	3.23	2.375	3.15	19.45	83.95
	0.75	1670	3.52	2.410	2.14	18.85	87.75
	1.0	1205	3.95	2.342	3.74	20.10	81.25

Comparison between Conventional and HDPE modified mixture

Marshall Test Results for Conventional and Modified mixtures; comparing the results of the two mixtures we can see that the stability of the conventional mix increases by 30% with the addition of the modified HDPE binder and the deformation rate also decreases. Other volumetric parameters such as unit weight, air void percentage, VMA, and VFB are also modified in comparison to the conventional mix. The optimal dose of the HDPE binder (bituminous) is 0.6% (based wt.).

4. 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;

- **i.** 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.
- **ii.** Softening point increases by mixing of HDPE into bitumen which is good and suitable for high temperature region.
- **iii.** 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.
- **iv.** Optimum dose of HDPE in VG30 bitumen is between 0.2 to 0.4%.

v. Using Marshall Method of mix design, the optimum binder content and optimum plastic has been determined which is 5.80% and 0.6% respectively.

vi. 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.

vii. 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.

viii. 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.

ix. Glass can be use in place of finer material in bituminous binder course.

x. By incorporation of waste plastic and waste glass into the bituminous binder course the stability increases approx. 50% than conventional mix.

xi. Optimum dose of waste glass cullet is in the range of 2.5 to 7.5%.

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