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Use of Plastic Waste in Bituminous Pavement

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Abstract : The waste plastic and its disposal is a major threat to the environment, which results in pollution and global warming. The utilization of plastic waste in bituminous mixes enhances its properties and also its strength[1]. In addition it will also be a solution to plastic disposal & various defects in pavement viz., pot holes, corrugation, ruts, etc. the waste plastic used are poly-ethylene, poly-styrene, poly-propylene. The waste plastic is shredded & coated over aggregate & mixed with hot bitumen and resulted mix is used for pavement construction. This will not only strengthen the pavement and also increases its durability. The titanium-di-oxide is used as a smoke absorbent material, which will absorb the smoke from the vehicles. This innovative technology will be boon for Indian hot-humid climate. It's economical and eco-friendly. In this paper, we have discussed about the soil properties to be considered in design of pavement, pavement design, process of construction flexible and plastic-smoke absorbent pavement.
Keywords : plastic waste, flexible pavement, strength, eradication of pot holes.

1.0 Introduction

The major threat to the environment is the disposal of waste plastic. In a highway, the potholes and corrugation is the major problem[9]. Plastic pavement will be a better solution to the above stated problems. A material that contain one or more organic polymer of large molecular weight, solid in its finished state, can be shaped by its flow is called as "plastic". The durability of plastic is high and it degrades very slowly. And also plastic has high resistant to degradation. Plastic can be divided into two major categories- thermoses & thermoplastics[2,3]. Thermosets have high durability and strength because it solidifies irreversibly when heated, henceforth can be used primarily in construction application. Plastic is a non-degradable waste, causes green-house effect and global warming. The various experiments have been carried out whether the waste plastic can be reused productively. The various literature indicated that the waste plastic when added to hot aggregates will form a fine coat of plastic over the aggregate and such aggregates when mixed with binder is found to have higher strength, higher resistance and better performance over a period of time. Along with bitumen, use waste plastic increases its life and smoothness. It is economical and eco-friendly. Addition of plastic waste in construction of pavements reduces the plastic shrinkage and drying shrinkage. The use of waste plastic improves the abrasion & slip resistance of asphalt pavement[4]. In India, because of hot and extremely humid climate, plastic pavements of greatest advantage.

In order absorb the smoke from the vehicles; titanium di-oxide can be used. It also enhances the mechanical properties of the plastic, resulting in higher strength and high resistance.

2.0 Objective

The objectives of this project are:

- To carry out the soil test.
- To design the flexible pavement
- To design the asphalt pavement with aggregate- plastic- bitumen mix.
- To coat the aggregate with plastic and incorporate titanium di-oxide.
- To test the bitumen and the modified bitumen.

3.0 Scope of The Project

- To eradicate potholes
- To minimize the global warming , greenhouse gases and pollution.
- The lifespan of the roads can be increased.
- Eco-friendly in nature.

3.1 Plastics Roads - General Introduction

Plastic use in road construction is not new. It is already in use as PVC or HDPE pipe mat crossings built by cabling together PVC (polyvinyl chloride) or HDPE (high-density poly-ethylene) pipes to form plastic mats. The plastic roads include transition mats to ease the passage of tyres up to and down from the crossing. Both options help protect wetland haul roads from rutting by distributing the load across the surface. But the use of plastic-waste has been a concern for scientists and engineers for a quite long time[6]. Recent studies in this direction have shown some hope in terms of using plastic-waste in road construction i.e., Plastic roads. A Bangalore-based firm and a team of engineers from R. V. College of Engineering, Bangalore, have developed a way of using plastic waste for road construction. An initial study was conducted in 1997 by the team to test for strength and durability. Plastic roads mainly use plastic carry-bags, disposable cups and PET bottles that are collected from garbage dumps as an important ingredient of the construction material. When mixed with hot bitumen, plastics melt to form an oily coat over the aggregate and the mixture is laid on the road surface like a normal tar road.

3.1.1 Advantages

- Reduce the need of bitumen by around 10%.
- Develop a technology which is eco-friendly.
- Improvements in fatigue life of roads.
- Increase the strength and better performance of the road.
- Use higher percentage of plastic waste.
- The gases released during traffic conditions are absorbed by smoke absorbent.

3.1.2 Disadvantages

- Toxic present in the co-mingled plastic wastes would start leaching.
- But the presence of chlorine will definitely release HCL gas.

4.0 Literature Review

Dr.R.Vasudevan,(2007) - stated that the polymer bitumen blend is a better binder compared to plain bitumen. Blend has increased softening point and decreased Penetration value with a suitable ductility[7].

Zahra Niloofar Kalantar(2012) - Many researches on PMA mixture have been conducted for the past two decades. Although addition of virgin polymers to asphalt for the purpose of enhancing the properties of asphalt over a wide temperature range in paving applications was contemplated quite some time ago, recycled polymer added to asphalt have also shown almost the same result in improving the road pavement performance as compared to virgin polymers. This paper is a review of the use of polymers in asphalt pavement. In this study, a critical review on the history and benefits of using waste and virgin polymer in asphalt is presented

followed by a review of general studies on using polymers in asphalt in order to improve the properties of pavement[9]

Amit Gawande (2012) - The quantum of plastic waste in municipal solid waste (MSW) is increasing due to increase in population, urbanization, development activities and changes in life style which leading widespread littering on the landscape. Thus disposal of waste plastic is a menace and become a serious problem globally due to their non-biodegradability and un aesthetic view. Since these are not disposed scientifically & possibility to create ground and water pollution. This waste plastic partially replaced the conventional material to improve desired mechanical characteristics for particular road mix. In conventional road making process bitumen is used as binder. Such bitumen can be modified with waste plastic pieces and bitumen mix is made which can be used as a top layer coat of flexible pavement[11]. This waste plastic modified bitumen mix show better binding property, stability, density and more resistant to water.

Sunil J. Kulkarni (2015) - Minimization of waste material is important aspect of the modern growth and development initiatives[4]. Plastic is used in various domestic and industrial applications. Use of plastic bags and bottles is very common. The disposal of plastic waste is major problem due to non-biodegradable nature of plastic. The plastic can be used as feedstock for ethanol like products. It can be used for road construction and other construction related activities. The current review summarizes the research on use of waste plastic

Rishi Singh Chhabra (2014) - In the highway infrastructure, a large number of originates materials and technologies have been invented to determine their suitability for the design, construction and maintenance of these pavements. Plastics and rubbers are one of them. Also considering the environmental approach, due to excessive use of polythene in day to day business, the pollution to the environment is enormous. The use of plastic materials such as carry bags, cups, etc. is constantly increasing day by day[10]. Since the polythene are not biodegradable, the need of the current hour is to use the waste polythene in some beneficial purposes. The use of these materials as a road construction proves eco-friendly, economical and use of plastic gives strength in the sub-base course of the pavement.

5.0 Comparative Study

5.1 Central Mixing Plant (CMP)

The dry process can also be carried out using central mixing plant. The shredded plastic is added along with the aggregate in the conveyor belt. This is transferred into the hot cylinder. There aggregate is coated with plastic first andthen with the bitumen. The mixer so prepared is then loaded in the dipper lorry and transported for road laying. CMP helps to have better control of temperature and better mixing of this material thus helping to have a uniform coating. This is adopted in our project.

The comparative study is done by testing the normal aggregates & plastic coated aggregates, and the bitumen and modified bitumen (10% of bitumen replaced by plastic). The various tests that are carried out for the comparative study are

- Test on aggregates

  i. Aggregate crushing test
  ii. Los Angeles abrasion test
  iii. Impact test

- Test on bitumen

  i. Penetration test
  ii. Softening point test
  iii. Viscosity test
  iv. Marshall Stability test.

6.0 Tests on Aggregates

6.1 Aggregate Crushing Test

The strength of the coarse aggregate may be assessed by aggregate crushing test. The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied compressive load. To achieve a high quality of pavement, aggregates possessing high resistance to crushing or low aggregate crushing value re preferred.

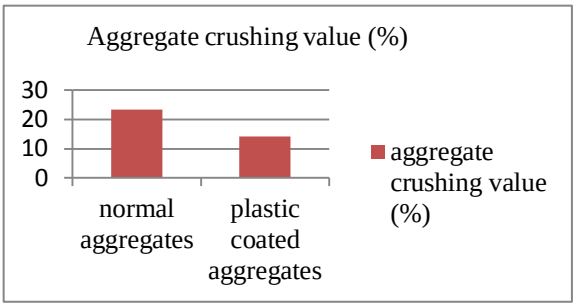

Figure 1 – Aggregate crushing value

6.2 Abrasion Tests

Due to the movements of traffic, the road stones used in the surface course are subjected to wearing action at the top. Hence road stones should be hard enough to resist the abrasion due to traffic. Abrasion tests are carried out to test the hardness property of stones and to decide whether they are suitable for the different road construction works. The abrasion test on aggregate may be carried out using any one of the following three tests

- Los Angeles abrasion test
- Deval abrasion test
- Dory abrasion test

However Los Angeles abrasion test is preferred as the test results have been correlated with pavement performance.

6.3 Los Angeles Abrasion Test

The principle of Los Angeles abrasion test is to find the percentage wear due to the relative rubbing action between the aggregate and steel balls used as abrasive charge. Pounding action of these balls also exists during the test and hence the resistance to wear and impact is evaluated by this test.

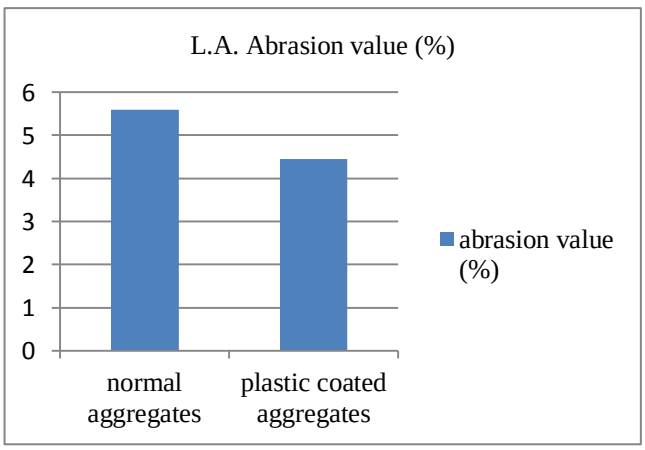

Figure 2 – Aggregate Los Angeles Abrasion value

6.4 Impact Test

The test is designed to evaluate the toughness of stone or the resistance of the aggregates to fracture under repeated impacts is called impact test. The aggregate impact test is commonly carried out to evaluate the resistance to impact of aggregates and has been standardised by ISI.

The aggregate impact value indicates a relative measure of aggregate to impact, which has a different effect than the resistance to gradually increasing compressive stress.

The aggregate impact value should not normally exceed 30% for aggregate to be used n wearing course of the pavements. The maximum permissible value is 35% for bituminous macadam and 40% for water bound macadam base course.

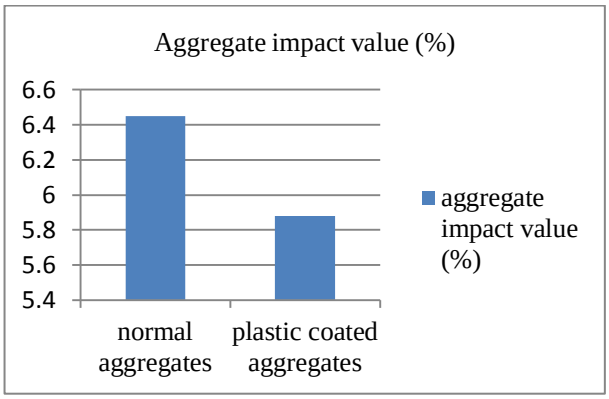

Figure 3 – Aggregate impact value

6.5 Tests on Bitumenpenetration Test

Penetration test is to determine the hardness of the bitumen. The penetration of a bitumen is the distance in tenths of millimetre, that a standard needle will penetrate into the bitumen under a load of 100gm applied for 5 seconds at 25℃. Penetration value indicates the softness of bitumen(higher the penetration ,softer is the bitumen).

Table 1 – test result of penetration value of bitumen vs Penetration Value (mm) modified Bitumen

S. No	Penetration Value (mm) Plain Bitumen	Penetration Value (mm) Modified Bitumen (10% Plastic Replaced)
1	79	67
2	63	49

6.6 Softening Point Test

The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test.Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of this test.

The test is conducted by ring and ball apparatus. A brass ring containing test sample of bitumen is suspended in liquid like water or glycerine at a given temperature. A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5℃/ minute. Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below. Generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates.

Table2– test result of softening point of bitumen and modified bitumen (bitumen replaced by plastic)

Sample No	Softening point(^{0}C) (plain bitumen)	Softening point(^{0}C) 10% bitumen replaced by plastic
1	69.2	80.7
2	70	81.2

6.7 Viscosity Test

Viscosity isdefined as the inverse of fluidity. Viscosity thus defines the fluid property of bituminous material. Viscosity is the general term for consistency and is the measure of resistance to flow. Many researchers believe that grading of bitumen should be by absolute viscosity units instead of the conventional penetration units.

The degree of fluidity of the binder at the application temperature greatly influences the strength characteristics

Figure 4 – Digital test result representation of viscosity.

6.8 Marshall Stability Test

Table 3 – Percentage of bitumen content

S. No	Bitumen content(%)	Modified bitumen(gm)
1	4.5	5.9
2	5.0	6.0
3	5.5	6.6
4	6	7.2

Table 4 – Test results of Marshall Stability test

S.No	Bitumen Content (%)	Weight of mix(g)	Weight in air(g)	Weight in water (g)	Stability of bitumen Stability of modified		Flow (mm)	Diame -ter (cm)	height (cm)
					Plain bitumen	Modified bitumen			
1	4.5	1255.5	1256.5	733	14.7	17.95	1.99	10	6.3
2	5	1253	1255.5	734	19.47	23.44	2.38	10	6.4
3	5.5	1257	1259	736	13.46	18.21	2.88	10	6.5
4	6	1268	1270	748	8.9	13.10	2.59	10	6.4

7.0 Summary

7.1 Result and Disussion

- The crushing value reduces from 23.32 to 14.22 for normal and plastic coated aggregate. The value was reduced by 40%. Lower the aggregate crushing value higher is the strength.
- The aggregate impact value of plastic coated aggregate was reduced by 9% than the normal aggregate. It's the higher toughness of plastic coated aggregates.
- Los Angeles abrasion value indicates the hardness of the aggregates. The abrasion value plastic coated aggregates were 21% less than the normal aggregates.
- The penetration value of bitumen is higher than the bitumen mixed with the plastic.
- The bitumen softens 10^{o}C less than the bitumen replaced with plastic.
- The stability of modified bitumen (10% bitumen replaced by plastic) is higher than the normal bitumen.

8.0 Conclusion

The plastic mixed with bitumen and aggregates is used for the better performance of the roads. The polymer coated on aggregates reduces the voids and moisture absorption. This results in the reduction of ruts and there is no pothole formation. The plastic pavement can withstand heavy traffic and are durable than flexible pavement. The use of plastic mix will reduce the bitumen content by 10% and increases the strength and performance of the road. This new technology is eco-friendly.

The use of smoke absorbent material (titanium di-oxide) by 10% of polymer content can reduce the vehicular pollution.

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