International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 4, Issue 5, May-2018

# Performance Evaluation of Bituminous Paving Mix with Waste Plastic

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***Abstract—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 unaesthetic 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 this paper the improved techniques which uses plastic waste for construction purpose and flexible pavements has reviewed. 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. This waste plastic modified bitumen mix***

***This work reports on the use of plastic waste and chemical additives in order to improve the performance of the volumetric and mechanical properties of bituminous mixtures. The selected recycled waste plastics were used as partial aggregate replacement in bituminous mix product.***

***Keywords— Abrasion test, Impact test, Water absorption test, Shape test, Penetration test, Softening test, Aggregate, Bitumen, Optimum bitumen content (OBC) & Optimum waste plastic content (OPC).***

## I. INTRODUCTION

Plastics are one of the supreme up start of the millennium and have surely proved their reputation to be true. There are a numerous ways that plastic is and will be used in the years to come. Waste plastics contribute to great environmental and social problems due to the loss of natural resources, environmental pollution, depletion of landfill space on the one hand and demands of environmentally-oriented society on the other hand. The plastic is lightweight, doesn't rot or rust, reusable, low cost, and conserves natural resources is the reason for which plastic has gained this much popularity. The total global production of plastics has grown from around 1.3 million tons (MT) in 1950 to 245 MT in 2006. Plastics continue to be a global success story with Europe and Switzerland major manufacturing region, producing about 25% of the total estimated worldwide plastics production of 245 million tons during 2006. An analysis of plastics consumption on a per capita basis shows that this has now grown to over 100 kg/y in North America and Western Europe, with the potential to grow to up to 130 kg/Year per capita by 2010.

The environmental issue arises due to the increasing percentage of waste plastic day by day.

- Lack of proper collection and management.
- The 'throw away culture' outcome in these bags searching their route in the drainage system of the city and thus choking the drainage.
- The littering also reduces rate of rain water percolation resulting in lowering water table levels.
- Plastics go into the water bodies which are already polluted due to many sources. Fish and other aquatic animals swallow plastic garbage mistaken as food items.
- Plastics become a nuisance because of their non-biodegradability.
- Animals eating carry bags sometimes die.
- Soil fertility deteriorates as plastic bags form part of manure and remain in soil for years.
- Polythene bags if burnt release highly toxic gases like phosgene, carbon monoxide, chlorine, sulphurdioxide, nitrogen Oxide beside deadly dioxins.
- Requires large are for disposal and there are further waste disposal impacts related to landfills and incineration.

**ORDER OF ROAD DEVELOPMENT**

A. Roman Roads

Roman started first time construction of roads in large scale. In 312 BC they constructed Appian Way of length over 580 km.

Main features of Roman roads are

- They were straight regardless of gradients.
- Total thickness was a high as 0.75 to 1.2 km.
- The wearing course consists of dressed large stone-blocks set in lime mortar.

B. Tresaguet Construction (1716-1796)

"Pierre Tresaguet" developed roads in France during 1764 A.D.

Main features are

- Thickness was of the order of 30 cm.
- Consideration was given to sub grade moisture and drainage of surface water.
- The top wearing surface was made up of smaller slope having a cross slope of 1 in 45 to the surface to provide surface drainage. Shoulder sloping was also provided of the order of1 in 20.

C. Metcalf. Construction (1717-1810)

"John Metcalf" was working in England and he followed the instruction of Robert Phillip.

D. Telford Construction (1757-1834)

Telford works started in early 19th century in England.

Main Features are

- Telford provides level sub grades of width 9 meters
- A binding layer of wearing course 4 cm thick was provided with cross slope of 1 in 45.
- Thickness of foundation stone varied from 17 cm to 22 cm at the center.

E. Macadam Construction (1756-1836)

The method of road construction to compare all the previous methods, to improve the road condition made by him 1815.This was the first method based on scientific thinking.

Main features are

- Macadam was the first person who suggests the heavy foundation stones are not at all required at the bottom layer. He provided stone of size less than 5 mm and thickness of 10 cm.
- The value to drainage system and compaction was shown to the prepared with cross slope of 1 in 36.
- The size of broken for the top layer was on the basis of stability.
- The pavement of surface was also given as cross slope of 1 in 36.

F. Water Bound Macadam (W.B.M.)

In this method the broken stone of the base course and surface course are bound by the stone dust in the presence of moisture content.

## II. PAVING MIX MATERIAL

- **Basalt**

Basalt is a dark-colour, fine-grained, igneous rock composed mainly of plagioclase and pyroxene minerals. It most commonly forms as an extrusive rock, such as a lava flow, but can also form in small intrusive bodies, such as an igneous dike or a thin sill. Basalt is used for a wide variety or purpose. It will change in shredded form for use as an aggregate in construction work. Crushed (shredded) basalt is used for road base, concrete aggregate in pavement aggregate. Basalt found in more under of the earth than other type of rocks. Basalt is very important rock. Stone dust is multipurpose material for road construction. Stone dust grain size 0 to 3.4mm or 0.8mm.Because stone dust contain vary fine mineral aggregate. It is also a great sub-base in laying paving block and slab and for jointing natural stone such as slate.

- **Bitumen 80/100 penetration paving bitumen grade**

The standard penetration grade for bitumen is 80/100 which is generally used as a Paving Grade Bitumen appropriate for construction of road and for the asphalt production pavements with better properties. This grade of Bitumen is mostly used in the manufacture of hot mix asphalt for bases and wearing courses. BITUMINA GROUP supplied Penetration Grade Bitumen which is petroleum grade bitumen, manufactured from fractional vacuum distillation of crude oil.

- **Plastic Consumption**

Plastic is material consisting of any of a wide range of synthetic or semi-synthetic organic compounds that are malleable and so can be moulded into solid objects. But still waste plastic currently plays a massive role in our daily lives due to increasing in population. Waste Plastic are utilized in virtually in all area of manufacturing for create new thing. Here some tabular data shows per year consumption of plastic in different countries, comparison, types of plastic, waste plastic in India and polymers respectively.

## III. OBJECTIVES

- Determine various physical properties of bitumen and Aggregate.
- Determine the effect of different plastic content with bitumen.
- Obtain the values for optimum bitumen content.
- Obtain the values for optimum plastic content.
- Compare the results of OBC and OPC, and also satisfied the MORTH 2001 recommended IS specification.

## IV. METHODOLOGY

From the literature review it is observed that the disposal of waste plastic is the major problem in India. The work from the literature review will work as a guideline for the recycling of waste plastic for road construction and other construction as better in quality. There are so many different processes for the reusing of the waste material. So in order to have an effective solution for construction industries bitumen with aggregate and a mix design of Bitumen can be tested to see the resulting values effecting and other strength based properties Steps of Working Method.

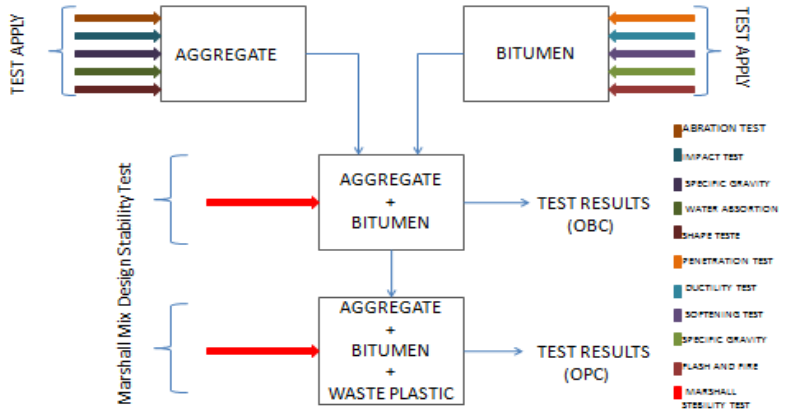


**Fig: 1**. Schematic approaches adopted for performing various test to determine the values for OBC and OPC

## V. EXPERIMENTAL TEST FOR PLAIN BITUMEN

PHYSICAL PROPERTIES OF AGGREGATE

- **Los Angeles Abrasion test (IS 2386 part IV-1963)**

The 'toughness' of aggregate is measured by Los Angeles abrasion test, and abrasion resistance such as degradation and disintegration, and crushing.

- **Impact test (IS 2386 Part-IV)**

Toughness is the property of a material to resist impact. Because of traffic loads the read stones are subjected to the pounding thing or impact & the possibility of stores breaking into little pieces. The road stones should therefore be hard enough to resist fracture under impact. A test designed to evaluate the toughness of stones i.e. the resistance of a stones to fracture under repeated impact may be called an impact test for road stones.

- **Specific gravity of course aggregate (IS 2386 Part-IV WSDOT 2009)**

The specific gravity of aggregate and absorption of course aggregate relatively Volume of water equal to the Volume of the aggregate to partials also referred to as the absolute volume of the aggregate.

- **Specific gravity of fine aggregate**

Specific gravity of fine aggregate is similar to the nature of course aggregate specific gravity test.

- **Specific gravity of filler material**

Filler material - fillers are particles added to material plastics, composite material, concrete to the lower the consumption of more expensive binder material or to better some properties of the mixture material. Take a specific gravity bottle & note down by add kerosene full bottle up to top of the bottle & take its weight.

- **Shape Test (IS 2386 Part –I)**

The jot shape of aggregate is finding by the percentage of elongated & flaky particle contained in it. In gravel case, it is determined by its angularity number. The construction of bituminous and cement concrete tyre the presence of flaky and elongated particles are considered undesirable as they may cause in heart weakness with possibility of breaking down under heavy road. When the shape of aggregate deviates. In case of elongated, flaky, angular, & aggregate, the voids content in an aggregate of any size of increases & hence & the grain size increase. The angularity number has considerable importance in the graduation requirements of various types of mixes such as bituminous concrete & soil aggregate mixes.

This shape test done by 3 content tests.

- Flakiness Index Test
- Elongation Index Test
- Angularity Number

- **Water absorption test**

In water absorption test, an oven is used to dry the specimen as per specified time & temperature and then employ in a dessicalator to cool. Immediately upon cooling the specimen are weighted. The material is then emerged in water at agreed upon condition after 230C for 24 hours or until equilibriums.

TABLE I
PHYSICAL REQUIREMENT FOR IS 2386 PART-I AND MORTH 2001 SPECIFICATION FOR FOLLOWING THE PHYSICAL AGGREGATE

| S.No. | Test | Specification | Results |
|---|---|---|---|
| 1 | Los angles abrasion test | < or equal 35% | 23. 42% |
| 2 | Aggregate impact test | < or equal 35% | 21.42 |
| 3 | Specific Gravity | | |
| | 1. Course aggregate | | 3.1 |
| | 2. Fine aggregate | Basalt 20% | 2.94 |
| | 3. Mineral filler material | | 2.89 |
| 4 | Shape test | | |
| | 1. Flakiness Index<br>2. Elongation Index | 40% | 24.09<br>14.46 |
| | FI+EI | 40% | 38.55% |
| | 3. Angularity Number | 0 - 11 | 7 |
| 5 | water absorption test | 2% | 1.81 |

PHYSICAL PROPERTIES OF BITUMEN

- **Penetration test (IS 1203 for Paving bitumen)**

A penetration test or pen test is an evaluate the security of an safety trying to exploits penetration test determine the hardness or softness consistency of bitumen by measuring depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds . The sample is maintained at 250C the penetrometer consist of a needle assembly of 100gm. 80/100 Reading means needle penetrates 80-100 of 1/10 of 1mm i.e. 8 to 10 mm at 250C. Penetration test is the most commonly adopted test on bitumen to grade the material in terms of its hardness. Based upon the environmental condition & construction types, bitumen of different penetration grades is used. 80/100 bitumen denotes that the penetration Value range 80/100. The Penetration Values of Various type of bitumen used in pavement construction in this county range between 20 & 225. Penetration grades are preferred & in cold region bitumen with higher penetration values are used. The penetration test is not indented to estimate the cost of soft material like or tar, which are usually graded by a viscosity test in an orifice viscometer.

- **Ductility Test (IS-1203)**

The value of ductility is the gap where it will elongate before crushing when a material from specimen is took at a specified spied and at particular fixed temperature.

- **Softening point test**

Softening point is the temperature at which the substance attains a particular degree of softening under specified conditions of test. The softening test under specified usually determined by ring and ball test. Steel ball 2 nos each 9.5 mm in diameter and weighting 3.5 grams. Brass ring 2 nos the ring shall be tampered and shall confirm of depth 6.4 of inside diameter at bottom 15.9 & inside diameter at top =17.5 water bath should be manual or mechanical to ensure uniform heat distribution at all-time throughout the water bath.

- **Flash & fire point test (IS-1209-1958)**

Flash point -The flash point of a material is the lowest temperature at which the vapour of substance momentarily takes fire in the form of a flash under specified condition of test.

Fire point – The lowest temperature point at where the material gets ignited and starts burn under the particular condition for test.

## VI. EXPERIMENTAL INVESTIGATION ON MIX DESIGN

MATERIALS USED

- Crushed basalt type of course aggregate 20mm.
- Crushed basalt type of fine aggregate 2.36 and down.
- 80/100 penetration grade bitumen.
- Basalt stone dust and cement as mineral filler.
- Waste plastic is in shredded form.

TABLE II
PLASTICS USED AND THEIR PROPERTIES

| Description | Products | Properties of Thermoplastic |
|---|---|---|
| PET | **Drinking water bottles** etc. | Flexible, High density ,Light Weight, Easy Soluble, |
| PP | **Bottle caps closures**, wrappers of detergent, biscuits vapour basket microwave etc. | Hard but still flexible, versatility |
| PVA | Wrapper of silver paper , **Dry Plastic** | Light Weighted, Easy Soluble |
| PS | Pots, egg packet, **bottle caps**, food traps, egg box, **disposal glass cup** | transparent, bright surface 90 % light permeability (with 400-800nm) |
| PVC | **mineral water bottles**, furniture, credit card, toys pipes folders, pen medical disposal etc. | Flexible, Clear elastic can be solvent, dense as compare to most plastic specific gravity around 1.4,good tensile strength |
| LDPE | **Carry bag**, socks milk pouch cosmetic detergent bottle | Soft, Flexible. |
| HDPE | Carry bag, **bottle cap** | Translucent to opaque, wax-like surface |

PROPERTIES OF THE MIX CONTENT

There are some properties of Mix Content that are 1.Theoretical specific gravity 2. Bulk density of the mix 3.Percentage air voids 4.Percentage of volume of bitumen 5. Percentage of voids in mixed aggregate 6.Percentage air voids filled with bitumen.

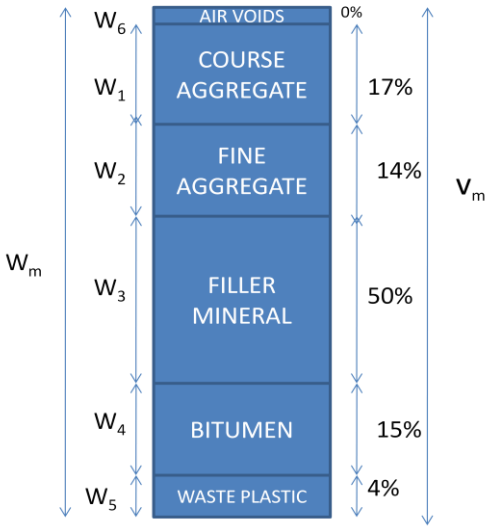


**Fig: 2**. Phase diagram of bituminous and waste plastic content mix

The Marshall Stability value, flow value and plastic content average value plastic are with the Marshall Stability mix design Criteria .Hence the optimum plastic content (OPC) for the mix design of average value. The average of density, Stability and flow value (mm) of plastic content. It is denoted by ($P_0$).

$P_0$= (6.5+6.6+4.6)/3 = 5.9

TABLE III
DENSITY AND VOIDS FOR THE PLASTIC CONTENTS

| S.No. | Plastic Content | Weight Of Sample(Gm) | | Bulk Density (Gb) | Theoretical Density (Gt) | Vv | Vb | VMA | VFB |
|---|---|---|---|---|---|---|---|---|---|
| | | Air | Water | | | | | | |
| 1 | 8% | 1260 | 690 | 2.21 | 2.3 | 3.47 | 25.61 | 29.08 | 88.06 |
| | | 1268 | 698 | 2.22 | | | | | |
| | | 1240 | 686 | 2.24 | | | | | |
| | | | | 2.22 | | | | | |
| 2 | 10% | 1206 | 678 | 2.28 | 2.3 | 1.3 | 26.19 | 27.49 | 95.27 |
| | | 1236 | 698 | 2.29 | | | | | |
| | | 1244 | 688 | 2.2 | | | | | |
| | | | | 2.23 | | | | | |
| 3 | 12% | 1250 | 692 | 2.24 | 2.3 | 2.17 | 25.96 | 28.13 | 92.28 |
| | | 1247 | 694 | 2.25 | | | | | |
| | | 1270 | 711 | 2.27 | | | | | |
| | | | | 2.25 | | | | | |
| | | | | | Final Result | 2.31 | 25.92 | 28.23 | 91.87 |

## VII. RESULT

The table given below showing the comparison of the average values of OBC and OPC.

TABLE IV
THE VARIOUS OBTAINED ARE AS TABLE COMPARISON BETWEEN OPC AND OBC MIX REQUIREMENT

| S. No. | Content | Optimum Bitumen Content | Optimum Plastic Content | Specified by MORTH 2001 Recommended IS Specification. |
|---|---|---|---|---|
| 1 | $V_v$ | 7.9 | 2.31 | Below 5 |
| 2 | $V_b$ | 26.22 | 25.92 | Range 20-26 |
| 3 | VMA | 34.19 | 28.13 | Maximum 30% |
| 4 | VFB | 76.83 | 92.02 | Range (90-100) |
| 5 | Stability | 22.6 | 30.1 | Indian Standard Graph (IS) |
| 6 | Flow Value | 4.3 | 4.6 | |
| 7 | Density | 2.31 | 2.33 | |
| 8 | OBC/OPC | 5.3 | 5.9 | |

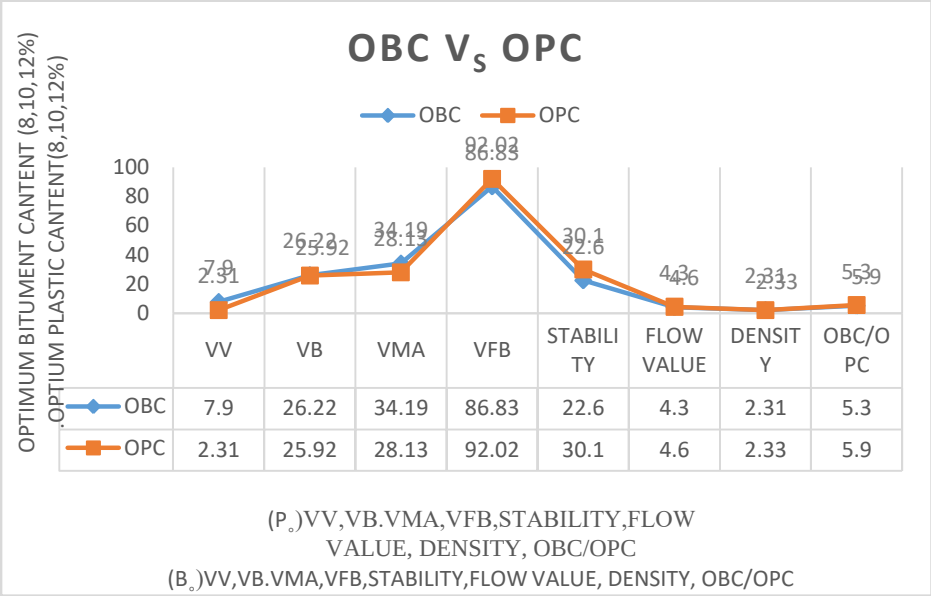


**Fig: 3**. Comparison between optimum bitumen content (OBC) & optimum waste plastic content (OPC)

By comparing the results between BC mix with waste plastic and plain BC mix, it has been found that the stability value of OPC(optimum plastic content) is 30.1 which is much higher than OBC, also satisfy the IS specification. The unit weight of BC mix with waste plastic and plain BC mix is according to the standard weight. The volume of voids for BC mix with waste plastic is lower than plain BC mix. Voids in mineral aggregate for BC mix with waste plastic are lower than plain BC mix. The voids filled with bitumen for BC mix with waste plastic are lower than that of the plain mix. The above results are within the limits specified by MORTH-2001 specifications.

## VIII. CONCLUSION

- OPC mix shows higher stability when it compared to OBC mix.
- As plastic cannot be decomposed, it can be used for constructing pavement as proved by test results.
- Using Plastic paving mix, the cost of scarce material and amount of energy required can be reduced.
- The aggregate with plastic coating bitumen mix and modified bitumen with plastic forms much Better Materials for the construction of flexible pavement because the mixture shows the higher Marshall Stability value.
- Hence the use of waste plastics for flexible pavement is one of the best Methods of easy disposal of waste plastics.
- Inter molecular bonding between bitumen & waste plastic enhances Strength & thus quality of road increases.
- In summer season the chances of melting of bitumen is decreases due to mixing the waste material in BC mix.
- As compare to the OBC mix construction the life will increases of OPC mix construction.

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