International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 7, July 2013)

Use of Waste Plastic and Waste Rubber in Aggregate and Bitumen for Road Materials

Dr. Abhaykumar S Wayal[1], Mudassir. D. Wagle[2]
[1]*Associate professor, Dept. of Civil and environmental Engineering, V.J.T.I, Mumbai*
[2]*M-Tech in Construction Management, civil, V.J.T.I, Mumbai,*

***Abstract*— Many roads agencies have been experiencing problem of premature failure of pavements like potholes, roughness, cracks and etc. which leads to poor performance of roads and its life. On the other hand, plastics, rubbers, etc. are increasing day by day. Waste like plastic bottles, polymers, cups, waste tyre's can be re-used by powdering or blending it with crusher's and can be coated over aggregate and bitumen by any heating process. In this study we have used polymer and crumbed rubber as a binder with respect to aggregate and bitumen. In bituminous roads, we use materials like aggregate (of various sizes), grit and bitumen. The various tests are conducted during this study on aggregates such as crushing value, impact value, abrasion value, and specific gravity and also on bitumen penetration value, ductility, softening point. The results are discussed in this paper.**

***Keywords*— Waste Plastic, Crumbed rubber, Aggregate, Bitumen.**

I. INTRODUCTION

Plastics, a versatile material and a friend to common man become a problem to the environment after its use. Disposal of a variety of plastic & rubber wastes in an eco-friendly way is the thrust area of today's research. The authors' innovative techniques to use the waste plastics and the tire waste for the construction of flexible pavement material which would give a better stability, durability, resistance and strength to the road as compared to the conventional material made road.

II. CHARACTERISTICS OF PLASTIC AND RUBBER COATED AGGREGATE

2.1 Moisture Absorption and Void Measurement

Hot stone aggregate (150^0c) is mixed with hot bitumen ($170\ ^0$c). The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity as per IS coding. The bitumen is chosen on the basis of its binding Property, Penetration value and visco-elastic property. The aggregate, when coated with plastics and rubber improved its quality with respect to voids, moisture absorption and soundness. The coating of plastic and rubber decreases the porosity and helps to improve the quality of the aggregate and its performance in the flexible pavement.

It is to be noted here that stones with < 2% porosity only allowed by the specification.

2.2 Soundness Test

Soundness test is intended to study the resistance of aggregate to weathering action. The weight loss is attributed to the poor quality of the aggregate. The plastic and rubber coated aggregate, did not show any weight loss, thus conforming the improvement in the quality of the aggregate.

2.3 Aggregate Impact Value

A study on the effect of plastic and rubber coating was extended to study on the aggregate impact value. Aggregate was coated with 1% & 2% plastics and rubber by weight (splitted in 0.5% & 1%) and then was submitted to Aggregate Impact Value test and the values were compared with values for non-coated aggregate. For each % of waste, the tests were conducted twice to get the better results.

TABLE I
Aggregate Impact Value

Percentage of Plastics (%)	Percentage of rubber (%)	Aggregate Impact value (%)	Conventional value (%)
0.5	0.5	9.23	12.63
0.5	0.5	8.73	12.16
1	1	8.73	12.14
1	1	8.10	12.63

It is clearly observed that the coating of plastics & rubbers improves Aggregate Impact Value. Coating of plastics & rubber over the stone aggregate improves the quality of the aggregate. Moreover a poor quality of aggregate can be made useful by coating with polymers & rubbers. This in turn helps to improve the quality of flexible pavement.

2.4 Aggregate crushing Value

A study on the effect of plastic and rubber coating was extended to study on the aggregate crushing value.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 7, July 2013)

Aggregate was coated with 1% & 2% plastics and rubber by weight (split in 0.5% & 1%) and then was submitted to aggregate crushing Value test and the values were compared with values for non-coated aggregate. For each % of waste, the tests were conducted twice to get the better result.

TABLE II
Aggregate crushing value

Percentage of Plastics (%)	Percentage of rubber (%)	Aggregate crushing value (%)	Conventional value (%)
0.5	0.5	11.41	23.66
0.5	0.5	12.27	22.37
1	1	11.30	23.70
1	1	11.32	23.86

2.5 Los Angel's Abrasion Test

The repeated movement of the vehicle with iron wheeled or rubber tire will produce some wear and tear over the surface of the pavement. This wear and tear percentage of an aggregate is determined with the help of los Angeles abrasion study. Under this study the percentage of wear and tear values of the 1% & 2% plastic & rubber coated aggregate is found to be in decreasing order with respect to the conventional values. This wear and tear percentage of an aggregate is determined with the help of Los Angeles abrasion study.

TABLE III
Los Angeles abrasion value

Percentage of Plastics (%)	Percentage of rubber (%)	Los Angeles value (%)	Conventional value (%)
0.5	0.5	14.64	17.51
0.5	0.5	14.72	17.42
1	1	13.77	17.46
1	1	13.85	17.43

When the Los Angeles abrasion value of plain aggregate value is compared with the Plastic and rubber coated aggregate the values are less for conventional aggregates as compared to polymer and rubber coated aggregates.

III. Characteristics Of Polymer And Crumbbed Rubber Modified Bitumen

An alternate use of plastic and rubber waste is also under study where plastics and rubber is mixed with bitumen and used for preparing the mix. The waste tires are made into powder by grinding into some special type of grinders. The powder is collected and it is used for modification of bitumen. The bitumen is heated to 120-140 degree Celsius and the powdered crumb rubber and plastic is added to the bitumen by its weight and stirred well with help of mechanical stirrer. The mix was used to study the basic properties of bitumen like softening point, penetration point and ductility. Here 10% & 20% plastics & crumbed rubber (split in 5% & 10%) is taken in proportion by weight. For each % of waste, the tests were conducted twice to get the better results.

3.1 Conventional Value

TABLE IV

Bitumen(gms)	Ductility (mm)	Softening point °C	Penetration (mm)
37	89	34	91
38	93	35	93
39	91	37.52	89
40	88	36	90

3.2 Polymer and Crumbed rubber modified value

TABLE V
Polymer and Crumbed rubber modified value

% plastics	% crumbed rubber	Ductility (mm)	Softening point °C	Penetration (mm)
5	5	62	48.5	70
5	5	60	47.5	68
10	10	58	45	59
10	10	56	42	54

Above values were compared with the conventional value & was found better. Thus by using waste plastics & waste rubbers can increase the durability & life of the road material substantially.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 7, July 2013)

IV. MARSHALL STABILITY TEST

4.1 Marshall Stability:

This test is carried out to determine the stability of bituminous mix i.e. resistance to plastic flow of cylindrical specimens of a bituminous mixture loaded on the lateral surface at 60 degree Celsius. Here we have designed the Dense Bituminous Macadam.

There are two major feature of Marshall Stability test to design the mix:

i) Density-void analysis,
ii) Stability-Flow analysis.

4.2 Combined Gradation

TABLE VI
Combined Gradation

Sieve analy-sis	Required gradation	M20 coarse 30%	M10 fine 50%	Grit 20%	Combined gradation
26.5	100	30	50	20	100
19	90-100	25	50	25	100
13.5	56-88	3.65	40	30	73.65
4.75	16-36	0.10	0.85	18.7	19.70
2.36	4-19	0	0.15	16.9	17.05
0.3	2-10	0	0.05	6.69	6.74
0.075	0-8	0	0	4.96	4.96

Preparing 3 gradations of each bitumen content for making the block and allowing for Marshall Stability.

In conventional mix design, 15 samples are prepared; each 3 samples have constant bitumen percentage from 3.5, 4.0, 4.5 & 5.0. Percentage is increased by 0.5% and so on till 5% bitumen content.

4.3 Marshall Apparatus:

a) Mould assembly (10cm dia, 15cm height) with base plate and collar extension.
b) Sample extractor,
c) Compaction pedestal and hammer,
d) Breaking head,
e) Loading machine @ 5cm per minute,
f) Flow meter with least count of 0.025mm

Fig No.1 Marshall Stability Apparatus

The test is applicable to hot mix designs using bitumen and aggregates up to a maximum size of 25mm. In this method, the resistance to plastic deformation of cylindrical specimen of. Bituminous mixture is measured when the same is loaded at periphery at 5 cm per min. This test procedure is used in designing and evaluating bituminous paving mixes.

Marshall Stability plays a very important role in the testing of road materials. Hence the values obtained by the Marshall Stability test shows the actual strength and load carrying capacity of the road materials.

4.4 Preparation of the conventional mix:

1) 1200 Gms of mix taken. Thickness should be 63.5mm.
2) Approximately 1200gms of aggregate and filler is heated at temperature 180-200 degree Celsius.
3) The compaction mould assembly and rammer is pre-heated at 100-145 degree Celsius.
4) Bitumen is heated at 130-140 degree Celsius and it is added in the aggregate ay the appropriate percentage.
5) 80/100 bitumen is heated at 160-180 degree Celsius.
6) In this way, preparing the other samples of the mix and allowing the block for the testing.

4.5 Preparation of the mix by adding Polymer & Crumbed Rubber:

1) 1200 Gms of mix taken. Thickness should be 63.5mm. TABLE VII values of conventional bituminous mix.
2) Approximately 1200 Gms of aggregate and filler is heated at temperature 180-200 degree Celsius.
3) The compaction mould assembly and rammer is pre-heated at 100-145 degree Celsius.
4) Bitumen is heated at 130-140 degree Celsius and it is added in the aggregate ay the appropriate percentage.
5) Similarly, polymer and crumbed rubber is added to the bitumen in the proportion of 8% i.e. 4% polymer and 4% crumbed rubber by weight of each bitumen content.
6) 80/100 bitumen is heated at 160-180 ^{o}c.
7) In this way, preparing the other samples of the mix and allowing the block for the testing.

Preparing 3 gradations of each bitumen content for making the block and allowing for Marshall Stability. In conventional mix design, 15 samples are prepared; each 3 samples have constant bitumen percentage. Percentage is increased by 0.5% and so on till 5% bitumen content.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 7, July 2013)

Marshall Stability test is carried out to determine the stability of bituminous mix i.e. resistance to plastic flow of cylindrical specimens of a bituminous mixture loaded on the lateral surface at 60 degree Celsius. Here we will design the Dense Bituminous Macadam.

Values of conventional bituminous mix. TABLE VIII values of polymer and crumbed rubber mix

TABLE NO VI shows the values of conventional bituminous mix.

TABLE NO VII shows the values of polymer and crumbed rubber modified bituminous mix.

Where,

Gmb = Density of the bitumen,

Gt = Maximum theoretical density of bitumen,

Vb = Volume of bitumen, cm^3

Av = air Voids, %

VMA = voids of mineral aggregates, %

VFB = voids filled by bitumen, %.

TABLE VII
Values of conventional bituminous mix.

% Bitumen	Sample Wt. gm	Marshall stability kg	Flow mm	Gmb gm/cm^3	Gt gm/cm^3	Vb %	AV %	VMA %	VFB %
3.5	1120	871.12	3.1	2.101	2.31	7.3	9.24	16.59	44.30
4.0	1122	940.75	3.0	2.114	2.30	8.4	8.12	16.58	50.99
4.5	1100	892.70	2.9	2.155	2.25	9.4	6.49	15.94	60.26
5.0	1167	882.90	3.0	2.252	2.23	9.6	5.35	14.97	68.94

TABLE VIII
values of polymer and crumbed rubber mix.

% Bitumen	Sample Wt. gm	Marshall stability kg	Flow mm	Gmb gm/cm^3	Gt gm/cm^3	Vb %	AV %	VMA %	VFB %
3.22	1046	689.71	3.0	2.120	2.49	6.5	18.9	25.44	25.51
3.68	1089	885.79	3.5	2.167	2.47	7.9	12.3	20.24	39.39
4.14	1106	1095.50	3.3	2.210	2.43	9.1	9.05	18.20	50.27
4.6	1120	1289.75	3.5	2.298	2.39	10	3.85	14.41	73.35

V. GRAPH

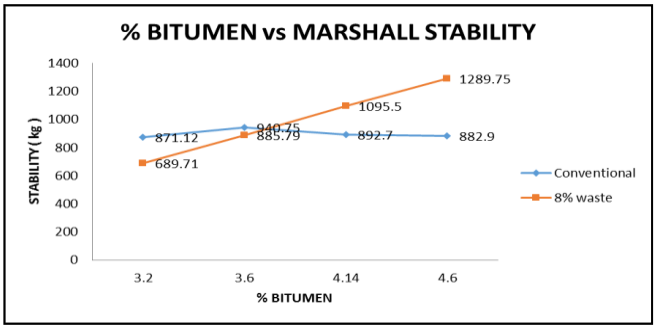

Fig No. 2 Graph of % Bitumen Vs Marshall Stability

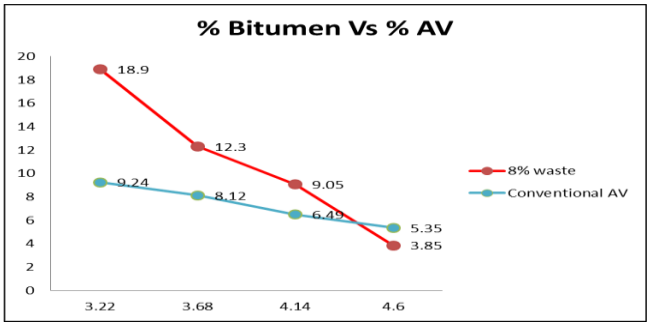

Fig No. 3 Graph of % Bitumen Vs % AV

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 7, July 2013)

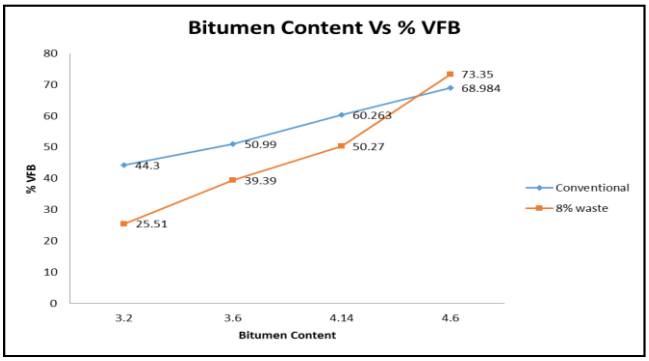

Fig No. 4 Graph Of % Bitumen Vs Vfb

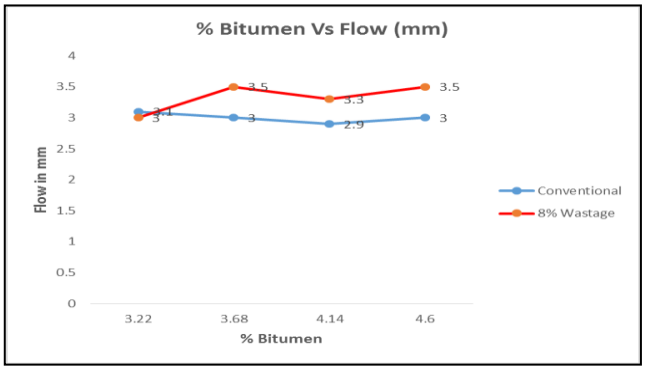

Fig No. 5 Graph of % Bitumen Vs Flow

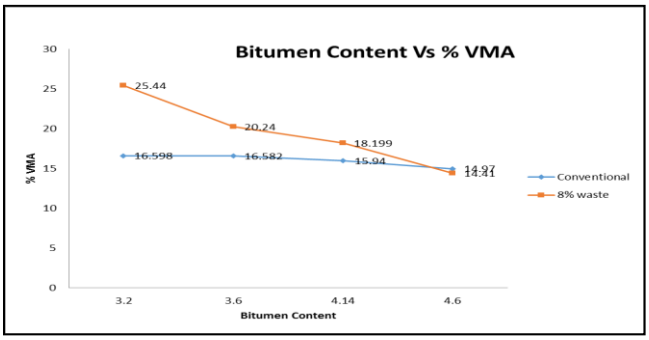

Fig No. 6 Graph of % Bitumen Vs VMA

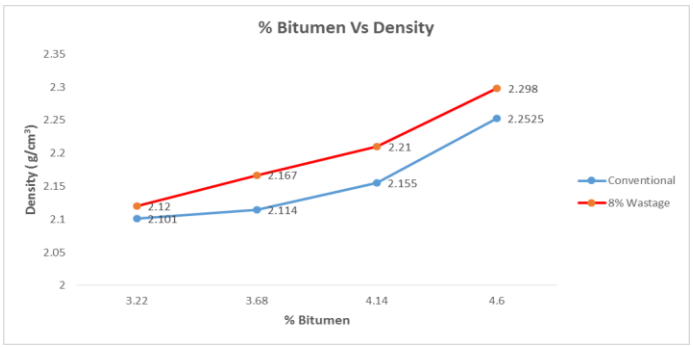

Fig No. 7 Graph of % Bitumen Vs Flow

VI. Field Applications

More than 1000kms length of Plastic tar road was laid by Tamil Nadu government during 2004-2006. Test road were laid at Mumbai, Pondicherry and Trivandrum. These roads are functioning well without pothole, raveling and rutting. The process requires only 30 seconds for mixing 10% of plastics and rubber. The plastic available in the nearby area can be used.

VII. Conclusion

As seen the above results and graphs, when 8% polymer and crumbed rubber is blended in the mix, the values of the Marshall tests viz.. Marshall Stability (kg), Flow (mm), Gmb (gm/^{cm3}), AV (%), VMA (%), VFB (%) goes on increasing as compared to the conventional mix. This shows and proves that by adding certain amount of waste in the bitumen, it gains strength and thus becomes more durable and tough. Stone aggregate is coated with the molten waste plastics & rubber powders. The coating of plastics & rubber reduces the porosity, absorption of moisture and improves soundness. Hence the use of waste plastics & rubber tyres in the form of powder for flexible pavement material is one of the best methods for easy disposal of wastes. The use of polymer & crumbed rubber coated aggregate is better than the use of conventional aggregates in many respects. As shown in the table, it is clearly shown that there is a huge difference in the values of the mix when compared with the conventional value. In India more than 3.3 million km of road is available. If they are constructed as plastic-rubber tar road, there will be less waste plastic & waste tyres available on the road. The process is eco-friendly.

REFERENCES

[1] "Mrs.Vidula Swami Et.al, "Use of waste plastics in construction of bituminous road", International journal of engineering and sciences and technology (IJEST), ISSN: 0975-5462, Vol.4, May 2012, 2351-2355

[2] "Aydin Kavak Et.al," In situ modification of road material using a special polymer" Scientific research and essays, ISSN: 1992-2248, Vol.5 (17), pp.2547-2555, 4th September, 2010.

[3] "Rokade S, " Use of waste plastics and waste rubber tires in flexible highway pavements", 2012 International conference on Future environments and Energy, IPCBEE Vol.28(2012), IACSIT Press, Singapore.

[4] "Gayle and King Et.al, "polymer modified Bitumen", Third International Road Federation, Middle East Regional Meeting, Riyadh, Saudi Arabia, February 1998.

[5] "Sinan Hinislioglu Et.al, "Use of High Density Waste Polyethylene as a bitumen modifier." Materials Letters 58(2004)267-271, Science Direct.

[6] "R. Vasudevan Et.al," Proceedings of the International Conference on Sustainable Solid Waste Management, 5 - 7 September 2007, Chennai, India. Pp.105-111

[7] "J.M.Mauskar, I.A.S., Chairman of Central Pollution Control Board"