Bituminous Mix Design Studies Using High Density Polyethylene on BC Layer

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***Abstract* - Disposal of waste materials including waste plastic bags has become a serious problem and waste plastics are burnt for apparent disposal which cause environmental pollution. Utilization of waste plastic bags in bituminous mixes has proved that these enhance the properties of mix in addition to solving disposal problems.. Plastic waste which is cleaned is cut into a size such that it passes through 2-3mm sieve using shredding machine. Plastic roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the roads with big potholes. In my research work I will do a thorough study on the methodology of using plastic waste in bituminous mixes and presented the various tests performed on aggregates and bitumen. Therefore it is necessary to utilize the wastes effectively with technical development in each field. Many by-products are being produced using the plastic wastes**

Keywords: High Density Polyethylene, Bitumen, Aggregates, Marshal Stability, Indirect Tensile Strength

1. INTRODUCTION

Materials that contain organic polymer additional than one and of molecular weight larger, solid in its state while manufacturing and processing into finished objects, can shaped by its flow, is called as 'Plastic'. Plastics durable and gets degrade slowly; the chemicals bonds which make plastic durable and long life make equally resilient to natural practice of deprivation. Plastics can divided in two major categories such as: thermoset and thermoplastics. A thermoset type plastic get hardens or "set" in irreversibly manner when heated. They were valuable their permanency and strength properties, hence therefore used mainly in automobiles and also in construction applications. These type plastics are namely polyethylenes, polypropylenes, polyamides, polyoxymethylenes, polytetrafluorethylenes, and polyethyleneterephthalates.

A thermoplastic type plastic moderates and softens while expose to temperature and heat then returns its original condition at standard room temperature. According to studies so far, plastics are stay unaffected and unchanged for as long as 4000+ years on the upper most surface layer of earth with increase in the total population and the increasing need to nutrition and other fundamentals, there been a rise in of waste produced. Plastics are in dissimilar forms found to 5%-10% in public solid wastes, which are toxic. It is a common sight in both town and village area to find empty plastic bags and other type of plastics material mess the roads as well drain

Recent days discarding of different unwanted produced by different Industries are great problem. These materials causes pollution in the nearest locality because of many of are non-biodegradable which easily can't be degraded. Materials such as soil, viz stone aggregates, viz sand, viz bitumen, etc. used for construction of roads. Natural materials getting exhaustible from nature, such quantity is getting slowly. Also, costs of extracting such good and quality of natural materials are getting increasing. Concerned about such things, the scientists and researchers are looking for alternative materials for construction of road, and industrial wastes products are category. If all such materials are suitably used in construction of roads, the pollution disposal harms may be partially reduced. In the absence other outlet, these solid waste will have occupied a number of acres and sections land round plants through the country. Keeping these things in mind the require for large bulk use of such solid wastes in country like India, it was thought expedient to test such materials and to develop provision improve to use these industrial wastes in construction of road in which higher financial returns may be promising. The possible use of such materials should be developed for construction of low volume roads in different parts of our nation. The necessary provisions should be expressed and determinations are to be made to maximize the use of solid wastes in different layer of pavement.

2. OBJECTIVES

Sufficient amount bitumen added in mix compacted mix effectually impervious and also will have acceptable dissipative and property such as elasticity. The mix design objects for determining the percentage proportion of binder, filler like sand, aggregates, and also aggregates such as coarser aggregates produce mix which is practical, strong, also durable, economical. The utilization of the mix design will produce bituminous blend by many components so as to have

1. To ensure and evaluate the modified characteristics of bitumen
2. To ensure sufficient strength to resist shear deformation under traffics at higher temperatures
3. To ensure sufficient air void in compacted to permit for additional compaction traffic
4. To evaluate performance of bituminous mixes when HDPE added
5. Enough resistance to low temperature to avoid shrinkage crack

3. PROPOSED METHODOLOGY

Materials used for the project is various sizes of aggregates, filler, bitumen as binder, high density polyethylene. The various tests performed on the material and their results will be as follows

(1) AGGREGATES: The aggregates are bound together either by bituminous materials or by cement. In a few cases, the rock dust itself when mixed with water forms slurry which acts as a binding medium. The aggregates may be classified into natural and artificial aggregates. The natural aggregates again are classified as coarse aggregates consisting of crushed rock aggregates or gravels and fine aggregates or sand. The blast furnace slag obtained as by-product from blast furnaces is the one extensively used as road

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construction material. Stone aggregate used for road work should be hard, tough, durable and hydrophobic for bituminous surface. Gravel should be well graded (6.4mm to 38mm) and should have a fineness modulus of not less than 5.75. Sand should be sharp, well graded, clean of all silts, clay and organic matter.

Tests conducted on the aggregates:

(a)Impact Value Test (BIS 2386 -Part1):, The aggregate impact value indicates a relative measure of resistance of aggregate to impact. The aggregate impact value should be less than 18%.Aggregate impact value = (B/A) x 100, Where B=weight of fraction passing 2.36-mm IS Sieve and A =weight of oven-dried sample.

(b) Crushing Test (BIS 2386 -Part1): This test value provides a relative measure of resistance to crushing under gradually applied crushing load. Aggregate crushing value = (B/A) x 100, Where B= weight of fraction passing the appropriate Sieve, and A = weight of surface-dry sample.

(c) Los Angel’s abrasion Test (BIS 2386 -Part1):
The test sample and the abrasive charge shall be placed in the Los Angeles abrasion testing machine and the machine rotated at a speed of 20 to33 rev/min. The machine shall be rotated for 500 revolutions. The difference between the original weight and the final weight of the test sample shall be expressed as a percentage of the original weight of the test sample and this value shall be reported as the percentage of wear/abrasion value. Los Angel’s abrasion value should be less than 25%

(d) Flakiness and Elongation Index (BIS 2386 -Part1):
The elongation index is the percentage by weight of the materials whose greatest dimension is greater than 1.8 times of their mean dimension. The flakiness index is the percentage by weight of the materials whose least dimension is less than 0.6 times of their mean dimension

(e)Specific Gravity:
The object of this experiment is to determine the specific gravity of coarse aggregate.The obtained specific gravity G= 2.62

(d) Water Absorption:
By the help of this experiment we will know how much water will coarse aggregate absorbs. Hence if the absorption is not in the limits the water content ratio should be altered. The physical properties of the mineral aggregates as obtained from testing of Impact value, crushing value, flakiness index, elongation index, Los Angeles abrasion value, Water absorption and Specific gravity test for the stone aggregates.

Table 1 Physical property of Coarse Aggregates:

Sl. No.	Tests	Results	MoRTH Specifications for BC layer
1	Specific gravity	2.65	-
2	Abrasion Value	32.0%	Max. 35%
3	Impact Value	21.21%	Max. 27%
4	Water Absorption	0.9%	Max. 2.0%
5	Flakiness Index	12.0%	Max. 15%
6	Elongation Index	13.26%	Max. 20%

(2) BITUMEN: Bitumen is used as binders in pavements constructions. Bitumen may be derived from the residue left by the refinery from naturally occurring asphalt. As per definition given by the American Society of Testing Materials bitumen has been defined as “Mixtures of hydrocarbons of natural or pyrogenous origin, or combination of both, frequently accompanied by their non-metallic derivatives, which may be gaseous, liquid, semi-solid or solid, and which are completely soluble in carbon disulphide.” Bitumen found in natural state known as asphalt contains large quantities of solid mineral matter. The grades of bitumen used for pavement construction is known as paving grades and that used for water proofing of structures is known as industrial grades. The grade of straight run bitumen is chosen depending upon the climatic conditions of the region in which surface dressing is to be constructed.

Tests conducted on the bitumen binder:

(a) Penetration test:
It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds

(b) Softening point test:
Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test. This test is conducted by using the Ring and Ball apparatus.

(c) Specific gravity test:
The specific gravity of bitumen is defined as the ratio of mass of given volume of bitumen of known content to the mass of equal volume of water at 27ºC. It can be measured using either pycnometer or preparing a cube specimen of

bitumen in semi-solid or solid state

(d) Flash and fire test:

The flash point of a material is the lowest temperature at which the application of test flame causes the vapours from the material to momentarily catch fire in the form of a flash under specified conditions of the test.

The fire point is the lowest temperature at which the application of test flame causes the material to ignite and burn at least for 5 seconds under specified conditions of the test.

(e) Viscosity:

Degree of fluidity at the application of temperature greatly influences the ability of bituminous material to spread, penetrate into the voids and also coat the aggregates and hence affects the strength characteristics of paving mixes.

Table 2 Properties of bituminous binder

Test description	Results	Standard values (MORTH
Penetration 25ºC(1/10mm)	65	50-70
Softening point ºC	48	> 47ºC
Ductility, cm	>75	-
Specific gravity	1.06	-
Viscosity	16 sec	
Flash point	179º C	
Fire point	185º C	

(3) FILLER: Filler is used in mixes for better binding of materials. Stone dust is used as filler for and dust is used as filler for DBM mix.

Mineral fillers have significant impact over the properties of DBM mixes:

- Mineral fillers tend to increase the stiffness of the asphalt and mortar matrix.
- Mineral fillers also affect the workability, aging characteristics and moisture resistance of mixtures.

(4) HIGH DENSITY POLYETHYLENE: High-density polyethylene (HDPE) or polyethylene high-density (PEHD) is a polyethylene thermoplastic made from petroleum. It is sometimes called "alkathene" or "polythene" when used for pipes. With a high strength-to-density ratio, HDPE is used in the production of plastic bottles, corrosion-resistant piping, geomembranes, and plastic lumber. HDPE is known for its large strength to density ratio The density of HDPE can range from 0.93 to 0.97 g/cm^3 or 970 kg/m^3. Although the density of HDPE is only marginally higher than that of low-density polyethylene, HDPE has little branching, giving it stronger intermolecular forces and tensile strength than LDPE. The difference in strength exceeds the difference in density, giving HDPE a higher specific strength. It is also harder and more opaque and can withstand somewhat higher temperatures (120 °C/ 248 °F for short periods). High-density polyethylene, unlike polypropylene, cannot withstand normally required autoclaving conditions. The lack of branching is ensured by an appropriate choice of catalyst (*e.g.*, Ziegler-Natta catalysts) and reaction conditions.

Figure 1 High Density Polyethylene

4. PREPARATION OF MIX

Sieve analysis was done and aggregates of appropriate sizes were collected and stored in place with sizes as per IRC gradation for DBM mix. The coarse aggregate, and the filler should be mixed according to specified proportion so as to fulfill the requirements. Samples were prepared for different binder content such as 4%, 4.5%, 5%, 5.5% and 6% in order to bet the optimum binder content (OBC). Aggregates and bitumen are heated together at mixing temperature of 160° C together and placed in the moulds and 75 blows are given on the both face of the mouls by using standard hammer

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Prepared moulds are cooled down for 24 hours and before testing kept in water bath maintain the water bath temperature as 60°C for 30 minutes. After keeping in the water bath the weight of samples are weighed in water as well in air weight are taken.

MARSHAL TEST:

1. The rods and inner surfaces of the test head segments prior to conducting the test are thoroughly cleaned.
2. Guide rods are lubricated so that the upper test head segment slides freely over them and excess water from the inside of the head segments is wiped off.
3. A sample from the water bath is removed and placed in the lower segment of the testing head. The upper segment of the testing head is placed on the sample and the complete assembly is paced in position in the loading machine.

4. Then the dial gauge is placed in position over one of the guide rods. The time elapsed from removal of the test specimens from the water bath to the final load determination should not exceed 30 s. The readings of dial gauge and proving ring are recorded. In this case 36 divisions of proving ring were equal to 100 kg.

Table 3 Adopted gradation

IS Sieve (mm)	Aggregate	Aggregate	Aggregate	Obtained Gradation	MoRTH Specification (Grading-II)
	A	.B	C		
	20 down	12.5 down	4.75 down		
	16	32	44		
19	100	100	100	100	100
13.2	34.9	91.95	100	84.17	79-100
9.5	10.95	72.03	100	74.17	70-88
14.75	0	18.78	99.01	59.17	53-71
2.36		8.78	77.63	45	42-58
1.18		5.83	61.04	34.16	34-48
0.6		4.15	48.78	25.41	26-38
0.3		2.55	29.55	18.32	18-28
0.15		1.55	18.69	12.4	12-20
0.175		0.38	7.19	6.6	4-10

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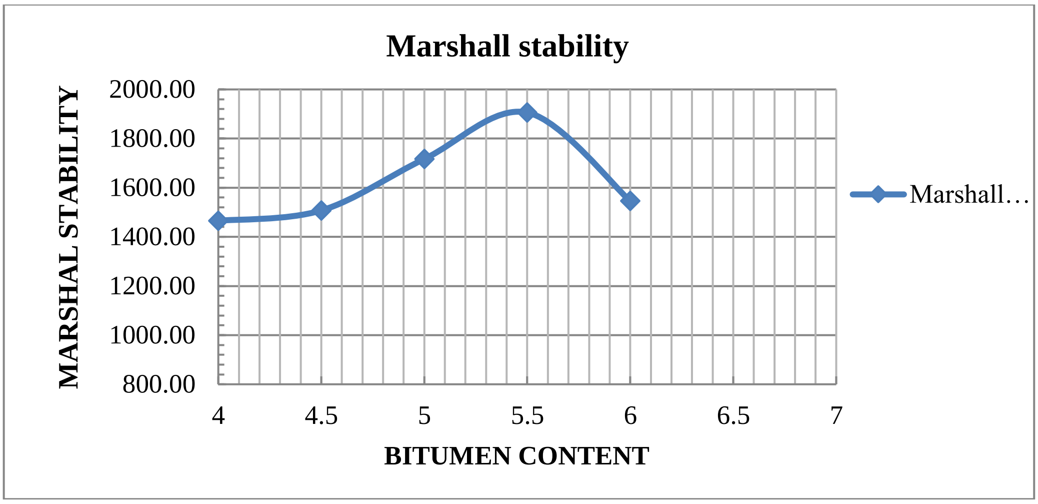
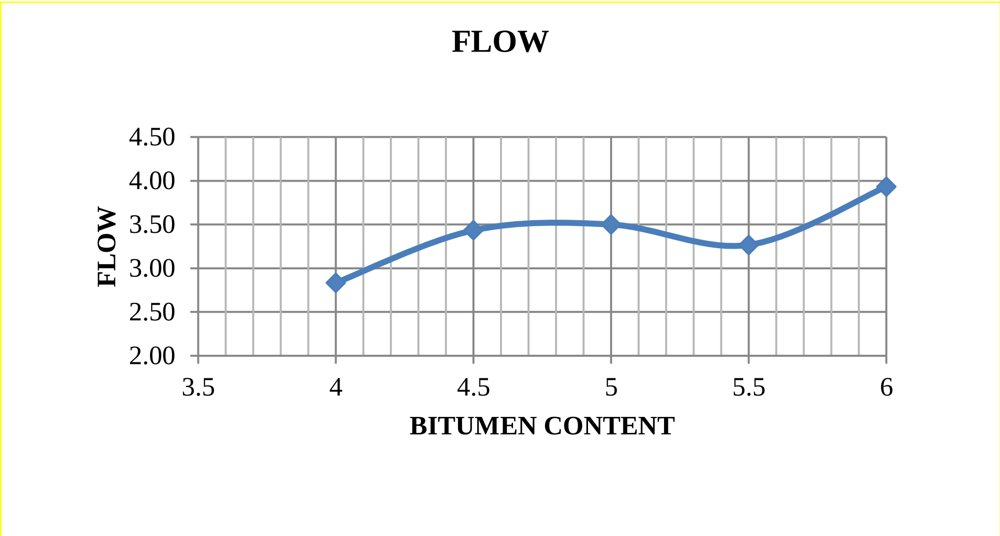
Table 4 Marshall Test Results for Finding OBC of Virgin BC grade II with binder content VG-30

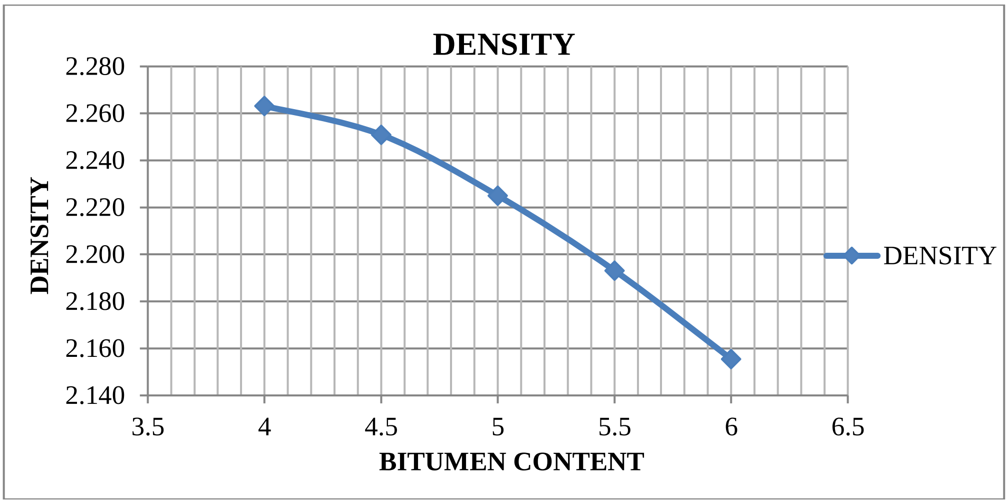
Sl. No.	% of Bitumen	Wt. of Specimen		G_b	G_t	V_v	V_b	VMA	VFB	Corrected Stability	Flow
		In air	In water								
1	4.0	1244	690	2.25	2.375	4.71	8.88	13.58	65.35	1386.52	3
2		1240	688	2.25						1324.32	2.6
3		1220	689	2.30						1312.75	2.9
Average		1234.67	689	2.26						1327.58	3.10
4	4.5	1252	693	2.24	2.343	3.93	9.93	13.86	71.67	1393.92	3
5		1245	670	2.26						1650	3.5
6		1240	675	2.26						1478.4	3.8
Average		1250	694.6	2.251						1507.44	3.43
7	5.0	1247	692	2.25	2.312	3.75	10.91	14.66	74.40	1689.6	3.6
8		1258	690	2.21						1694	3.5
9		1255	688	2.21						1672	3.4
Average		1253.33	690	2.225						1685.20	3.50
10	5.5	1262	709	2.28	2.281	3.87	11.83	15.70	75.34	1774.08	3.2
11		1264	658	2.09						1626.24	3.4
12		1265	693	2.21						1650	3.2
Average		1263.67	686.67	2.193						1683.44	3.27
13	6.0	1268	685	2.17	2.252	4.28	12.68	16.96	74.75	1496	4.1
14		1270	672	2.12						1629.05	3.8
15		1266	682	2.17						1512.19	3.9
Average		1268	679.67	2.156						1545.75	3.93



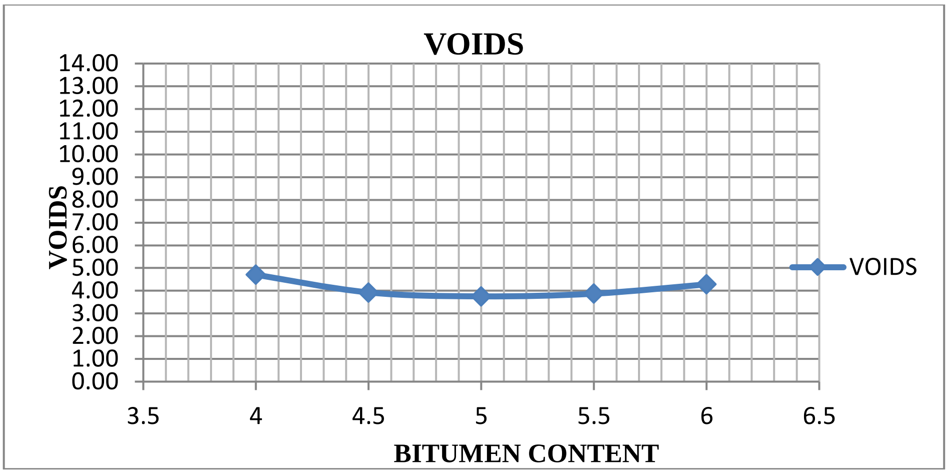
Graph 1 Relation between Marshal Stability and bitumen content



Graph 2 Relation between flow and bitumen content



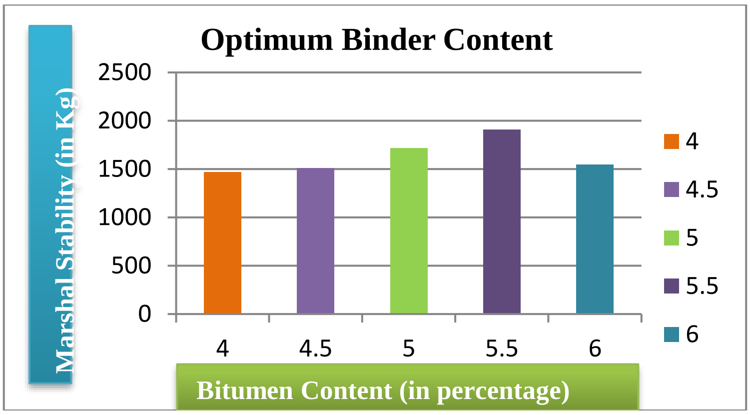
Graph 3 Relation between density and bitumen content



Graph 4 Relation between voids and bitumen content

Table 5 Optimum Binder content

Sl no	Properties	Obtained binder content (from graph)	Average OBC (%)
1	Max stability, Kg	5.7	5.0
2	Max. density, g/cc	4.4	
3	Air voids (%)	5.0	



Graph 5 Optimum binder content

After obtaining optimum binder content (OBC) same procedure is followed for preparing the marshal mould samples, the percentage of HDPE added in 1%, 2%, 3%, 4%, 5% and 6% by weight of the OBC and the test results obtained are as follows

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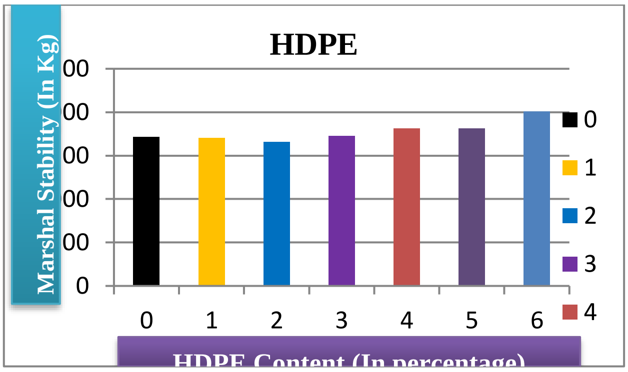
Table 6 Marshall Test Results using HDPE BC grade II with binder content VG-30

sl no	Bitumen content	%of HDPE	Marshall stability	Avg	Flow	Avg	Air wt	Avg wt	water wt	Avg wt	Gb	Avg	Gt	Vv	Vb	VMA	VFB
1			1731.84		3.2		1254		695		2.24						
2	5	1	1668.48	1705.44	4.1	3.50	1258	1253.00	698	695.00	2.25	2.246	2.344	4.20	11.01	15.20	72.40
3			1716		3.2		1247		692		2.25						
1			1672		3		1255		696		2.25						
2	5	2	1626.24	1656.75	3.5	3.43	1248	1251.00	692	694.00	2.24	2.246	2.344	4.18	11.01	15.19	72.49
3			1672		3.8		1250		694		2.25						
1			1647.36		3.5		1258		698		2.25						
2	5	3	1760	1727.15	3.5	3.43	1260	1255.00	700	696.67	2.25	2.248	2.344	4.10	11.02	15.12	72.88
3			1774.08		3.3		1247		692		2.25						
1			1716		3.1		1258		698		2.25						
2	5	4	1761.76	1814.71	3.5	3.30	1255	1254.33	696	696.00	2.25	2.247	2.344	4.15	11.01	15.16	72.62
3			1966.36		3.3		1250		694		2.25						
1			2038.3		4.1		1260		700		2.25						
2	5	5	2062.28	2004.86	3.8	3.93	1255	1255.00	696	696.00	2.25	2.245	2.344	4.22	11.01	15.22	72.30
3			1914		3.9		1250		692		2.24						



Graph 6 Marshal Stability for different percentage of HDPE

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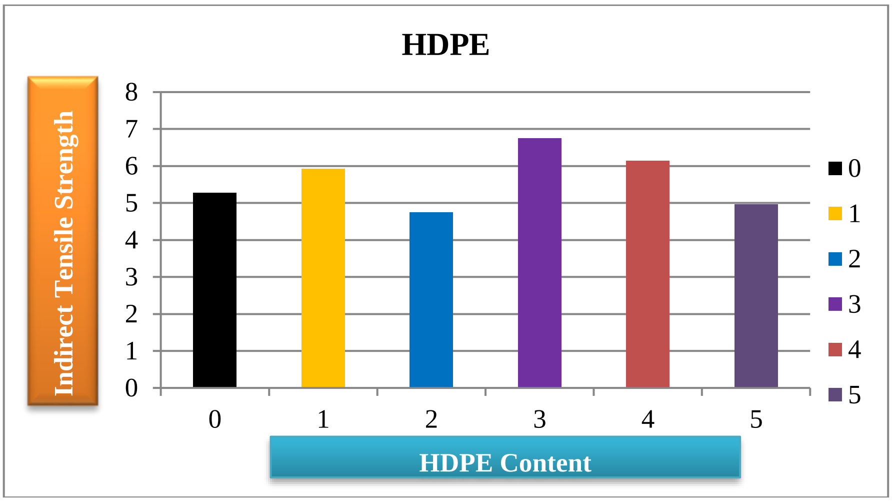
INDIRECT TENSILE STRENGTH:

Same procedure is adopted for this test also, preparing samples, compacting with hammer, heating the materials etc are same but the loading direction is different in the ITS there will be no flow gauge as like Marshal test. Testing is done on the same instrument but load applied will be of different. The ITS results obtained are as follows

Table 7 Indirect Tensile strength Results using HDPE BC grade II with binder content VG-30

sl no	Bitumen content	%of HDPE	Indirect Tensile strength	Avg	Air wt	Avg wt	water wt	Avg wt	Gb	Avg	Gt	Vv	Vb	VMA	VFB
1			4.906289957		1268		705		2.25						
2	5	0	5.430138625	5.28	1264	1267.33	700	701.00	2.24	2.238	2.344	4.52	10.97	15.49	70.81
3			5.49056942		1270		698		2.22						
1			6.023347046		1244		687		2.23						
2	5	1	5.985841772	5.92	1245	1246.33	688	688.33	2.24	2.234	2.344	4.71	10.95	15.66	69.94
3			5.749558544		1250		690		2.23						
1			4.709162236		1263		693		2.22						
2	5	2	4.661804225	4.75	1263.5	1263.50	694	693.67	2.22	2.217	2.344	5.40	10.87	16.27	66.81
3			4.868995524		1264		694		2.22						
1			6.615930379		1257.5		691		2.22						
2	5	3	6.920764914	6.75	1256	1257.17	690	691.00	2.22	2.220	2.344	5.26	10.88	16.15	67.40
3			6.720945147		1258		692		2.22						
1			5.904952018		1245		688		2.24						
2	5	4	6.112143317	6.14	1246	1246.33	688	688.33	2.23	2.234	2.344	4.71	10.95	15.66	69.94
3			6.405900843		1248		689		2.23						
1			4.765399874		1246		688		2.23						
2	5	5	5.04070886	4.96	1248	1248.00	689	689.00	2.23	2.233	2.344	4.75	10.94	15.69	69.74
3			5.076186822		1250		690		2.23						



Graph 7 indirect Tensile strength for different percentage of HDPE

5. APPLICATIONS

Asphaltic/Bituminous concrete consists of a mixture of aggregates continuously graded from maximum size, typically less than 25 mm, through the fine filler that is smaller than 0.075mm. Sufficient bitumen is added to the mix so that the compacted mix is effectively impervious and will have acceptable dissipative and elastic properties. The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregates, and coarse aggregates to produce a mix which is practical, strong, durable and economical. The purpose of the mix design is to produce a bituminous mix by proportioning various components so as to have

1. Sufficient bitumen to ensure a durable pavements
2. Sufficient strength to resist shear deformation under traffics at higher temperatures
3. Sufficient air void in the compacted bitumen to permit for additional compaction by traffic
4. Sufficient workability to permit easy placement without segregation
5. Sufficient resistance to avoid premature cracks due to repeated bending by traffic
6. Sufficient resistance at low temperature to prevent shrinkage crack

6. SOCIAL RELEVANCE

The addition of waste plastic modifies the properties of bitumen.

- The modified bitumen shows good result when compared to standard results.
- The optimum content of waste plastic to be used is between the range of 5% to 10%.
- By the experimental studies marshal stability has be increased around 60% for OBC with adding HDPE
- Also Indirect Tensile strength also increased by 16% for 4% HDPE then that of without HDPE
- The problems like bleeding are reduce in hot temperature region.
- Plastic has property of absorbing sound, which also help in reducing the sound pollution of heavy traffic.
- The waste plastics thus can be put to use and it ultimately improves the quality and performance of road.

7. CONCLUSIONS

The waste plastic addition modifies properties of binder such as bitumen.

- The altered bitumen shows good result when compared as that of standard results.
- The optimal content of plastic to use is between the ranges of 5% to 10%.
- By the investigational studies marshal stability has be increased around 60% for OBC with adding HDPE
- Also Indirect Tensile strength also increased by 16% for 4% HDPE then that of without HDPE
- The problem such as bleeding and flow reduced in hot temperature places.

The plastics therefore can put for use it finally improves the quality properties and performance of road

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