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PERFORMANCE EVALUATION AND SIMULATION ANALYSIS ON SMA MIX DESIGN TECHNIQUE BY USING LDPE

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Abstract
The current examination explores the advantages of settling the stone mastic black-top (SMA) blend in adaptable asphalt with destroyed waste plastic. Customary (without plastic) and the settled SMA blends were exposed to execution tests including Marshall Stability test. SMA, which is stone lattice black-top, is a hole reviewed HMA which is utilized to augment rutting obstruction and solidness in overwhelming rush hour gridlock conditions. The paper audits about the different issues identified with the development of asphalts utilizing SMA. This examination is to check the practicality of waste plastic as balancing out added substances in which the stream esteems and solidness esteems were broke down by performing Marshall Stability test. Different rates, for example, 5%, 5.5%, 6% of bitumen are chosen for this investigation. Plastic substance of 5%,10%,15% by weight of bitumen is suggested for the improvement of the presentation of Stone Mastic Asphalt blends. Natural and monetary contemplations have urged structural architects to discover ways the accommodation of plastic waste as productive material in adaptable asphalts. The ebb and flow paper presents a test research on the chance of using waste plastic in stone mastic asphalt(SMA) blends. Blended in with squander plastic in bitumen to deliver SMA examples. The got outcomes showed the utilization of plastic waste to in part supplanted by bitumen expanded the required folio content in the black-top blends. 10% plastic substance gives an expansion in the solidness of about 64%, 18% and 75% individually contrasted with the customary SMA blend. The channel down worth declines with an expansion in plastic substance and the worth is just 0.09 % at 10% plastic substance and ends up being a successful balancing out added substance in SMA blends. Even in this work we applied stimulation analysis and we created equation for better getting understanding and for advanced usages.
Keywords: Stone mastic asphalt (SMA),Bitumen, Marshall stability, Plastic waste, simulation analysis

1. Introduction

Stone Matrix Asphalt (SMA) is a hot blend black-top that was created in Germany in the late sixties. SMA has been used in other European nations for over two decades to give higher rutting obstruction just as studded tire wear. Due to its achievement in Europe, the United States of America (USA) likewise propelled the development of SMA asphalts in certain states, in a joint effort with the Federal Highway Administration. Ongoing examinations have demonstrated that in excess of 28 states in the USA use SMA due to its expanded strength, up to 20%–30%, contrasted with ordinary blends.

SMA has low air voids with significant levels of full scale surface when laid, bringing about a waterproof layer with great surface waste.

A roadway venture requires gigantic measure of speculation. In current circumstance a Stone Matrix Asphalt (SMA) of solid, protection from weariness load, strong and practical is basically required. SMA is blend of various evaluations of total, black-top as folio and non-regular materials(LDPE squander plastic).

Researchers and architects are continually looking on changed techniques to improve the presentation of black-top asphalts. Extensive exploration has been done to decide the reasonableness of plastic waste modifier in development of bituminous mixes.loe thickness polyethelene(LDPE) basic food item sacks might be valuable in bituminous asphalts bringing about diminished perpetual misshapening through rutting and decreased low temperature splitting of asphalt surfacing.

Different added substances like polymers and strands have been used to improve the high and low temperature qualities of bitumen organizations, just as to improve their strength and toughness. Added

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substances, for example, styrene based polymers, polyethylene based polymers, polychloroprene, gilsonite, different oils, and numerous different modifiers including tall oil have been added to bitumen to upgrade different building properties of bitumen.
The LDPE mostly supplanted by bitumen it improve the properties of the SMA blend by shaping a sort of firmly stuffed structure in the black-top blend to forestall the channel down of the black-top so it will expand the solidness and strength of the blend.
This investigation is an endeavor to build up a plastic balanced out SMA clearing blend that oppose the activity of temperature, temperature changes, the activity of air and water and the activity of traffic.

Simulations
Stimulations (SPICE) depend on glorified straight comparable conditions which perport to precisely depict our Non-Linear Universe. In this way, the admonition/cautioning is : Linear conditions don't exactly depict our Non-Linear Real-World. First I present the Design Algorithm , and Schematica, at that point the Linear Simulation results, at that point Measurements taken from true ongoing estimations. In conclusion, I may give a few conditions, in a supplement, be that as it may, I have discovered that genuine Engineers know conditions quite well. I am as yet refreshing my task (which you are following) with an eye on the above way to deal with documentation. My creative mind is continually observing some new thing to include which will improve the venture. Zest permits me to test my thoughts , rapidly, and ideally remain on the best track. Expectation that helps, a great deal.

2. Materials and Methods

Aggregates:- 12.5mm coarse totals
Bitumen:- Bitumen (5% 5.5% 6%, 6.5% are utilized)
Black-top, in any case called bitumen is a tenacious, dull, and significantly thick liquid or semi-solid sort of oil. It may be found in like manner stores or may be a refined thing, and is classed as a pitch. Preceding the twentieth century, the term asphaltum was similarly used. Plastic is material including any of a wide extent of produced or semi-designed normal worsens that are adaptable in this manner can be molded into solid items. Malleability is the general property of all materials which can bend.

Plastic LDPE basic food item sacks (polythene covers, chocolate covers, coverings, bottles, packs and so forth)

Filler:- Lime(max filler to cover (F/B)ratio 1/2 to 1/5)

Lime is a calcium-containing inorganic mineral made basically out of oxides, and hydroxide, typically calcium oxide and also calcium hydroxide. It is also the name for calcium oxide which occurs because of coal-wrinkle fires and in balanced limestone xenoliths in volcanic ejecta. The word lime begins with its most prompt use as building mortar and has the sentiment of staying or following.

Wax:- Waxes are a varying class of regular irritates that are lipophilic, adaptable solids near encompassing temperatures. They join higher alkanes and lipids, normally with dissolving centers above around 40 °C (104 °F), condensing to give low consistency liquids. Waxes are insoluble in water anyway dissolvable in regular, nonpolar solvents. Customary waxes of different sorts are made by plants and animals and occur in oil.

Optimization of the mixtures :-
Marshall blend plan (ASTM D-1559) system is regularly used to upgrade the SMA blends. In SMA blend plan; for the most part the Marshall technique for blend configuration is utilized to confirm palatable voids in SMA blends . Research center examples were readied utilizing fifty blows of the Marshall hammer per side. Seventy-five compaction blows were not utilized since they would not bring about a huge increment in thickness over that gave by 75 blows. SMA blends have been all the more effectively compacted on the street to the ideal thickness than the exertion required for customary HMA blends.
The ideal black-top substance for SMA blends is generally chosen to deliver 3–5% air voids and a channel down of under 0.3%. In this examination, compaction of all the SMA tests were performed utilizing fifty blows of the Marshall hammer per side. The ideal black-top substance for the control SMA blend was seen as 6.63 % at 4 % air voids.

Preparation of specimens of stabilized SMA mixtures :-
An ideal black-top substance of 6.63 % as found from Marshall control blend plan (by wt. of absolute blend) was utilized in setting up all other plastic adjusted blends to keep up consistency all through the investigation.

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The accompanying advances were performed for the definition of compacted examples:

1. Evaluated totals were warmed at 150-160 0C in a stove and waste plastic in destroyed structure changing from 5% - 12% at an addition of 1% was included into hot totals before blending at ideal folio content in dry procedure. 2. The bitumen was warmed up to 1600 C in a stove.

3. The blend of plastic covered total, filler and changed folio was blended consistently at a temperature of 150 ± 50C. 4. The examples figured were then compacted at 135 0C utilizing Marshall contraption determined by ASTM.
Indeed, even in this work we applied stimulation analysis and we created equation for better getting understanding and for advanced usages.

3. Laboratory Testing

Aggregate gradation for SMA 12.5 mix

Sieve size	Lower limit	Upper limit	% finer
20	100	100	100
12.5	85	95	85.16
10	70	75	70.15
4.75	20	28	21.8
2.36	16	24	21.5
0.6	12	16	13.53
0.3	12	15	15
0.075	8	10	10

Total degree Curve for SMA Mix. Stone Mastic Asphalt (SMA) is a hole reviewed black-top blend that relies upon the stone-tostone contact to give its heap conveying limit against rutting. Nonetheless, fastener draindown is an issue for SMA blends, because of its purposeful high folio content

Aggregate gradation for HMA 12.5 mix

S No	Name of the test	Specification	Test result	Specified value	Remark
1	Impact	IS 2386-Part 4	15.88	30	O.K
2	Crushing	IS 2386-Part 4	23.16	30	O.K
3	Los angels' abrasion	IS 2386-Part 4	23.88	30	O.K
4	Elongation & flakiness	IS 2386-Part 1	14.03	15	O.K
5	Angularity	IS 2386-Part 3	8	0-11	O.K
6	Water absorption	IS 2386-Part 3	0.45	0.1-2.0	O.K

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Total surface and scraped spot attributes. Adjusted particles will in general sneak past each other causing HMA bending under burden while rakish particles interlock with each other giving a decent distortion safe structure. Weak particles cause blend bending since they will in general break separated under fomentation or burden. Tests for molecule shape and surface just as solidness and adequacy can recognize issue total sources. These sources can be maintained a strategic distance from, or at the very least, total with great surface and scraped area qualities can be mixed in to give better generally speaking attributes.

Test results of Bitumen Properties

S No	Name of the test	Specification	Test results	
			CB	PMB
1	Penetration	IS 1203	87.5	81.5
2	Ductility	IS 1208	73	67
3	Softening point	IS 1205	54	64
4	Stripping value	IS 6241	20	15
5	Elastic recovery	IS SP 53	-	77

Essential Physical Properties of Bitumen is that, Bitumen is a thick liquid at medium to high temperatures and a fragile strong at low temperatures. Its consistency is measured as thickness and as firmness, which is characterized as applied pressure separated by relating strain, for these temperature districts, individually.

Specific gravity of the materials

Marshall type	Apparent specific gravity(g/cc)
M1	2.865
M2	2.751
M3	2.62
LIME	2
CB	1
PMB	1.02

Relative thickness, or explicit gravity, is the proportion of the thickness (mass of a unit volume) of a substance to the thickness of a given reference material.

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Gradation of lime

Sieve	Weight retained	Weight retained	Cumulative %Weight retained	% finer
2.36	**12**	**6**	**6**	**94**
1.18	**10**	**5**	**11**	**89**
0.6	**16**	**8**	**19**	**81**
0.3	**6**	**3**	**22**	**78**
0.075	**22**	**11**	**34**	**66**

Lime is produced from either high-calcium or dolomitic limestone. High-grade business stores for the most part contain not in excess of 3 percent absolute polluting influences. Warmth, water, and carbon dioxide are utilized to change limestone into three unmistakable structures. sifter investigation is been accomplished for lime totals degree.

Marshall Stability:-

Mixing of 5% LDPE with 5%, 5.5%, 6% BT

	Sample No.	Mixing of BC with 5% BT	Mixing of 5% LDPE with 5% BT	Mixing of BC with 5.5% BT	Mixing of 5% LDPE with 5.5% BT	Mixing of BC with 6% BT	Mixing of 5% LDPE with 6% BT
Proving Ring readings (Kgs)	1	1078	1113	850	1180	940	1042
	2	1170	1080	955	1060	928	1230
	3	1200	1100	1123	1120	932	1180
	Average	1149.333	1097.667	976	1120	933.3333	1150.667
Dial guage Readings	1	755	890	678	510	1178	485
	2	1348	1080	1723	880	1171	350
	3	960	920	910	733	1175	400
	Average	1021	963.3333	1103.667	707.6667	1174.667	411.6667

Mixing of 10% LDPE with 5%, 5.5%, 6% BT

	Sample No.	Mixing of BC with 5% BT	Mixing of 10% LDPE with 5% BT	Mixing of BC with 5.5% BT	Mixing of 10% LDPE with 5.5% BT	Mixing of BC with 6% BT	Mixing of 10% LDPE with 6% BT
Proving Ring readings (Kgs)	1	1078	1440	850	1026	940	1145
	2	1170	1272	955	1005	928	1290
	3	1200	1320	1123	1100	932	1250
	Average	1149.333	1344	976	1043.667	933.3333	1228.333
Dial	1	755	565	678	858	1178	610

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guage Readings	2	1348	600	1723	918	1171	890
	3	960	575	910	820	1175	722
	Average	1021	580	1103.667	865.3333	1174.667	740.6667

Mixing of 15% LDPE with 5%, 5.5%, 6% BT

Proving Ring readings (Kgs)	**Sample No.**	**Mixing of BC with 5% BT**	**Mixing of 15% LDPE with 5% BT**	**Mixing of BC with 5.5% BT**	**Mixing of 15% LDPE with 5.5% BT**	**Mixing of BC with 6% BT**	**Mixing of 15% LDPE with 6% BT**
	1	1078	1068	850	1250	940	1397
	2	1170	1289	955	1310	928	1205
	3	1200	1250	1123	1300	932	660
	Average	1149.333	1202.333	976	1286.667	933.3333	1087.333
Dial guage Readings	1	755	985	678	619	1178	700
	2	1348	1010	1723	1042	1171	620
	3	960	995	910	980	1175	660
	Average	1021	996.6667	1103.667	880.3333	1174.667	660

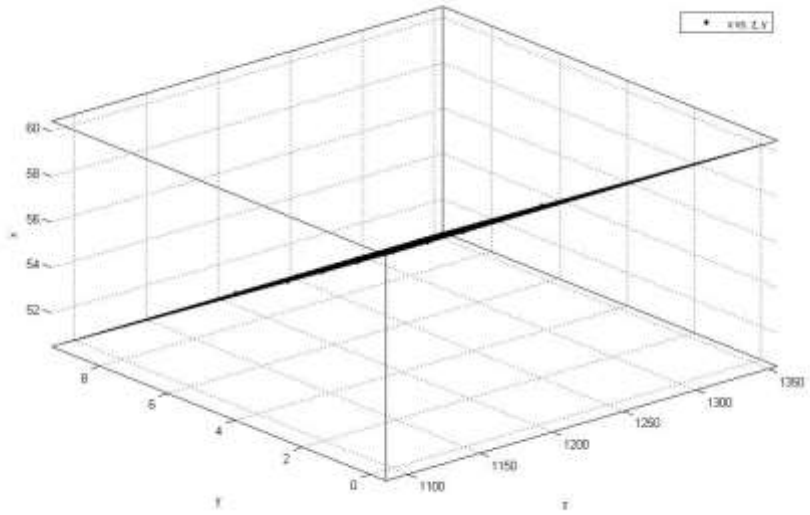
4. SIMULATION

Case1: For bitumen 5%

BITUMEN (PERCENTAGE)	BITUMEN(GRAMS)	PLASTIC (PERCENTAGE)	PLASTIC (GRAMS)	**FINAL BITUMEN (GRAMS)**	**PLASTIC (GRAMS)**	**PROVING RING READINGS (KGS)**
5%	60.00	0%	0.00	**60.00**	**0.00**	1149.30
5%	60.00	1%	0.60	**59.40**	**0.60**	1138.96
5%	60.00	2%	1.20	**58.80**	**1.20**	1128.62
5%	60.00	3%	1.80	**58.20**	**1.80**	1118.28
5%	60.00	4%	2.40	**57.60**	**2.40**	1107.94
5%	60.00	5%	3.00	**57.00**	**3.00**	1097.60
5%	60.00	6%	3.60	**56.40**	**3.60**	1146.88
5%	60.00	7%	4.20	**55.80**	**4.20**	1196.16
5%	60.00	8%	4.80	**55.20**	**4.80**	1245.44
5%	60.00	9%	5.40	**54.60**	**5.40**	1294.72
5%	60.00	10%	6.00	**54.00**	**6.00**	1344.00
5%	60.00	11%	6.60	**53.40**	**6.60**	1315.66
5%	60.00	12%	7.20	**52.80**	**7.20**	1287.32
5%	60.00	13%	7.80	**52.20**	**7.80**	1258.98
5%	60.00	14%	8.40	**51.60**	**8.40**	1230.64
5%	60.00	15%	9.00	**51.00**	**9.00**	1202.30

X= B.T(5%) Y=P.T(0 to 15%) Z= PROVING RING READINGS(Kgs)

For 1st degree polynomial equation: degree of x=1 and y is changing from 1 to 5 and the equation are as follows



Linear model Poly51:

Linear model Poly52:

f(x,y) = p00 + p10*x + p01*y + p20*x^2 + p11*x*y + p02*y^2 + p30*x^3 + p21*x^2*y

+ p12*x*y^2 + p40*x^4 + p31*x^3*y + p22*x^2*y^2 + p50*x^5

+ p41*x^4*y + p32*x^3*y^2

where x is normalized by mean 1204 and std 80.34

and where y is normalized by mean 4.5 and std 2.857

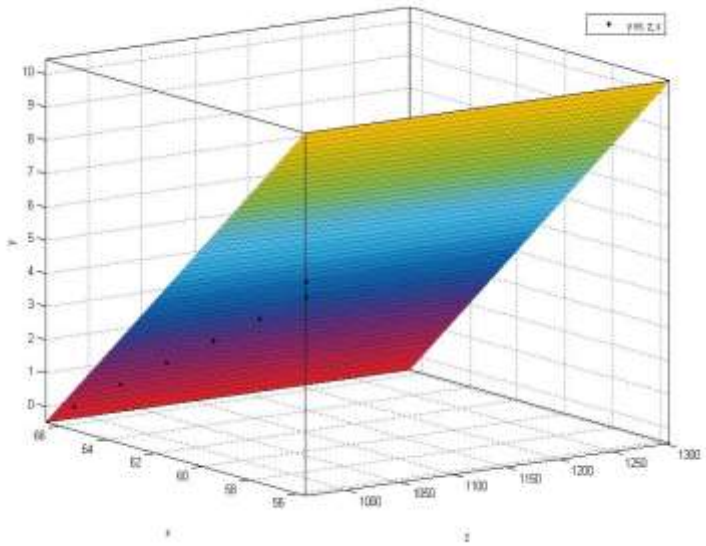
Case2: For bitumen 5.5%

BITUMEN (PERCENTAGE)	BITUMEN(GRAMS)	PLASTIC (PERCENTAGE)	PLASTIC (GRAMS)	**FINAL BITUMEN (GRAMS)**	**PLASTIC (GRAMS)**	**PROVING RING READINGS (KGS)**
5.50	66.00	0%	0.00	**66.00**	**0.00**	976.00
5.50	66.00	1%	0.66	**65.34**	**0.66**	1004.80
5.50	66.00	2%	1.32	**64.68**	**1.32**	1033.60
5.50	66.00	3%	1.98	**64.02**	**1.98**	1062.40
5.50	66.00	4%	2.64	**63.36**	**2.64**	1091.20
5.50	66.00	5%	3.30	**62.70**	**3.30**	1120.00
5.50	66.00	6%	3.96	**62.04**	**3.96**	1104.80

5.50	66.00	7%	4.62	**61.38**	**4.62**	1089.60
5.50	66.00	8%	5.28	**60.72**	**5.28**	1074.40
5.50	66.00	9%	5.94	**60.06**	**5.94**	1059.20
5.50	66.00	10%	6.60	**59.40**	**6.60**	1043.60
5.50	66.00	11%	7.26	**58.74**	**7.26**	1092.20
5.50	66.00	12%	7.92	**58.08**	**7.92**	1140.80
5.50	66.00	13%	8.58	**57.42**	**8.58**	1189.40
5.50	66.00	14%	9.24	**56.76**	**9.24**	1238.00
5.50	66.00	15%	9.90	**56.10**	**9.90**	1286.60

X= B.T(5.5%) Y=P.T(0 to 15%) Z= PROVING RING READINGS(Kgs)

For 1st degree polynomial equation: degree of x=1 and y is changing from 1 to 5 and the equation are as follows



Linear model Poly51:

f(x,y) = p00 + p10*x + p01*y + p20*x^2 + p11*x*y + p30*x^3 + p21*x^2*y +

p40*x^4 + p31*x^3*y + p50*x^5 + p41*x^4*y

where x is normalized by mean 1100 and std 81.63

and where y is normalized by mean 61.05 and std 3.142

Case3: For bitumen 6%

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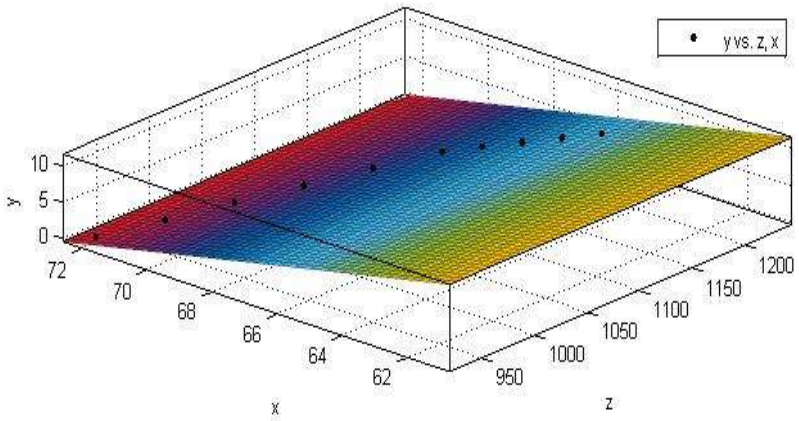
BITUMEN (PERCENTAGE)	BITUMEN(GRAMS)	PLASTIC (PERCENTAGE)	PLASTIC (GRAMS)	**FINAL BITUMEN (GRAMS)**	**PLASTIC (GRAMS)**	**PROVING RING READINGS (KGS)**
6.00	72.00	0%	0.00	**72.00**	**0.00**	933.30
6.00	72.00	1%	0.72	**71.28**	**0.72**	976.76
6.00	72.00	2%	1.44	**70.56**	**1.44**	1020.22
6.00	72.00	3%	2.16	**69.84**	**2.16**	1063.68
6.00	72.00	4%	2.88	**69.12**	**2.88**	1107.14
6.00	72.00	5%	3.60	**68.40**	**3.60**	1150.60
6.00	72.00	6%	4.32	**67.68**	**4.32**	1166.14
6.00	72.00	7%	5.04	**66.96**	**5.04**	1181.68
6.00	72.00	8%	5.76	**66.24**	**5.76**	1197.22
6.00	72.00	9%	6.48	**65.52**	**6.48**	1212.76
6.00	72.00	10%	7.20	**64.80**	**7.20**	1228.30
6.00	72.00	11%	7.92	**64.08**	**7.92**	1200.10
6.00	72.00	12%	8.64	**63.36**	**8.64**	1171.90
6.00	72.00	13%	9.36	**62.64**	**9.36**	1143.70
6.00	72.00	14%	10.08	**61.92**	**10.08**	1115.50
6.00	72.00	15%	10.80	**61.20**	**10.80**	1087.30

X= B.T(6%) Y=P.T(0 to 15%) Z= PROVING RING READINGS(Kgs)



Linear model Poly25:

f(x,y) = p00 + p10*x + p01*y + p20*x^2 + p11*x*y + p02*y^2 + p21*x^2*y +

p12*x*y^2 + p03*y^3 + p22*x^2*y^2 + p13*x*y^3 + p04*y^4

+ p23*x^2*y^3 + p14*x*y^4 + p05*y^5

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where x is normalized by mean 1122 and std 86.61

and where y is normalized by mean 66.6 and std 3.428

Void analysis:-

Void analysis of conventional mix

S.No.	Bitumen Content	Bulk Specified Gravity	Air Voids	Voids in Mineral Aggregate	Voids filled Bitumen
1	5	2.424	7.508	20.513	56.74
2	5.5	2.448	7.05	20.325	63.113
3	6	2.465	6.371	20.19	70.01

Void analysis of 10% Plastic mixed Bitumen mix

S.No.	Bitumen Content	Bulk Specified Gravity	Air Voids	Voids in Mineral Aggregate	Voids filled Bitumen
1	5	2.478	6.85	19.35	59.04
2	5.5	2.494	6.17	19.11	66.37
3	6	2.519	5.36	18.56	74.53

Void analysis of 5% Plastic mixed Bitumen mix

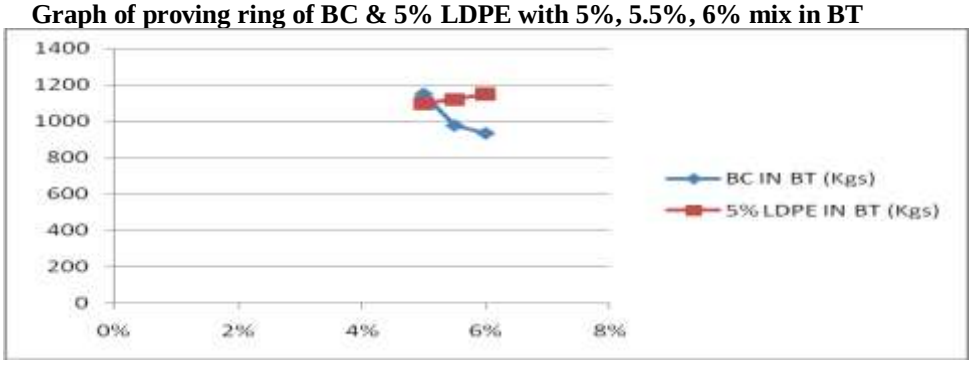
S.No.	Bitumen Content	Bulk Specified Gravity	Air Voids	Voids in Mineral Aggregate	Voids filled Bitumen
1	5	2.431	7.21	19.98	57.65
2	5.5	2.457	6.74	19.712	64.48
3	6	2.478	5.88	19.27	71.87

Void analysis of 15% Plastic mixed Bitumen mix

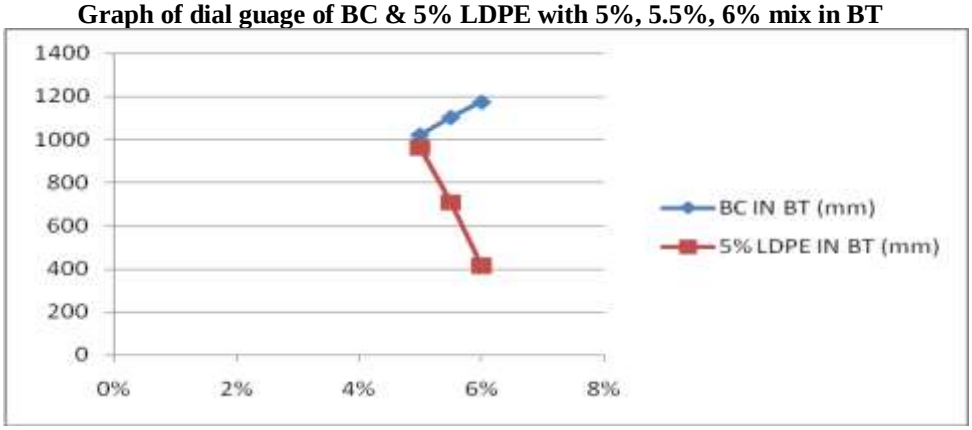
S.No.	Bitumen Content	Bulk Specified Gravity	Air Voids	Voids in Mineral Aggregate	Voids filled Bitumen
1	5	2.455	7.13	19.72	58.54
2	5.5	2.479	6.54	19.54	65.73
3	6	2.495	5.68	18.95	72.69

Graphs:-

Graph of proving ring of BC & 5% LDPE with 5%, 5.5%, 6% mix in BT



Graph of dial guage of BC & 5% LDPE with 5%, 5.5%, 6% mix in BT



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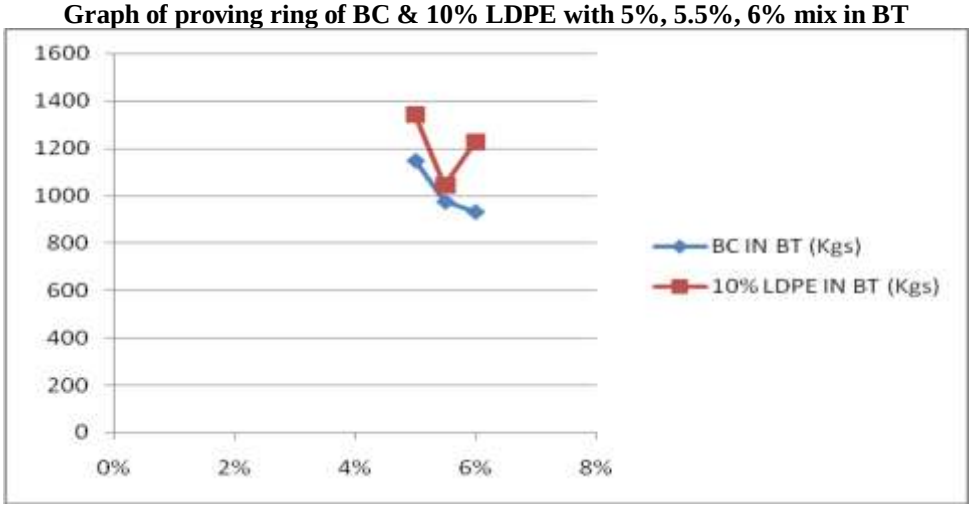
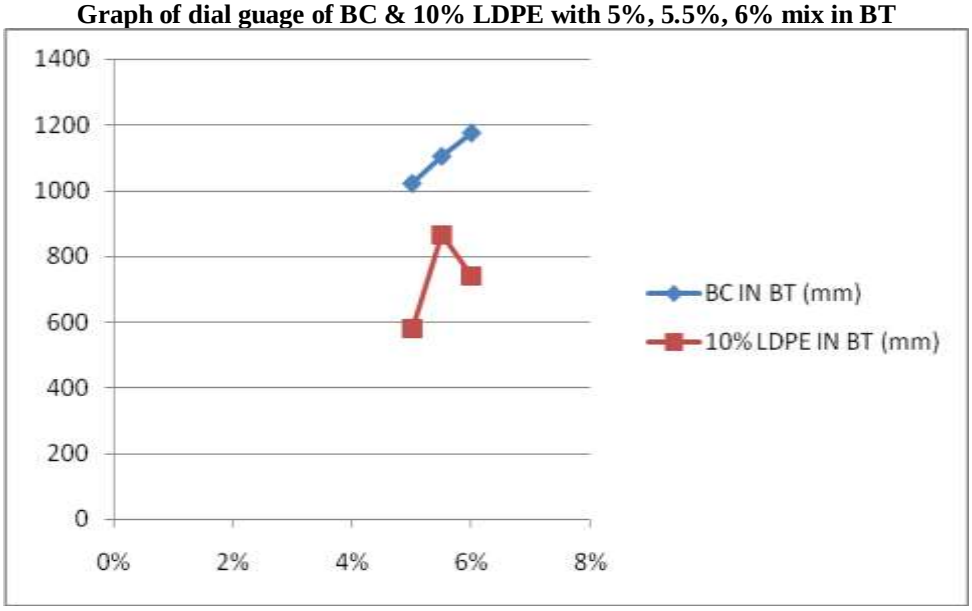
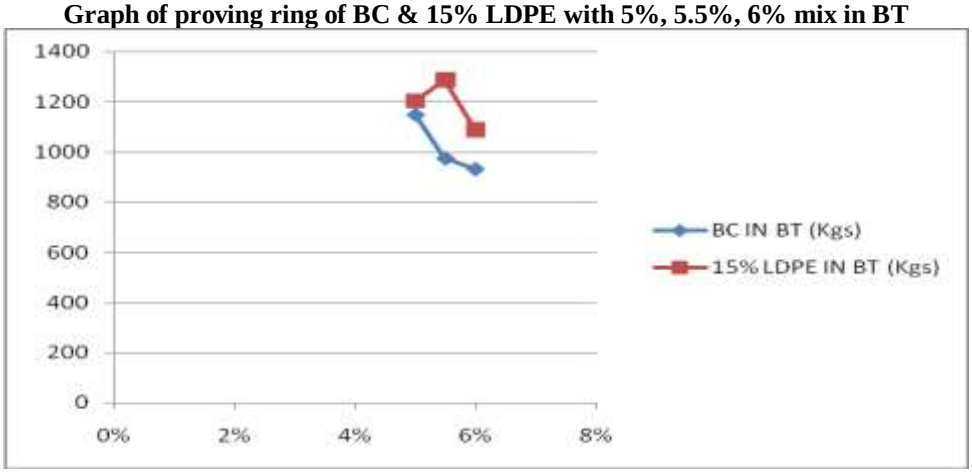
Graph of proving ring of BC & 10% LDPE with 5%, 5.5%, 6% mix in BT



Graph of dial guage of BC & 10% LDPE with 5%, 5.5%, 6% mix in BT



Graph of proving ring of BC & 15% LDPE with 5%, 5.5%, 6% mix in BT



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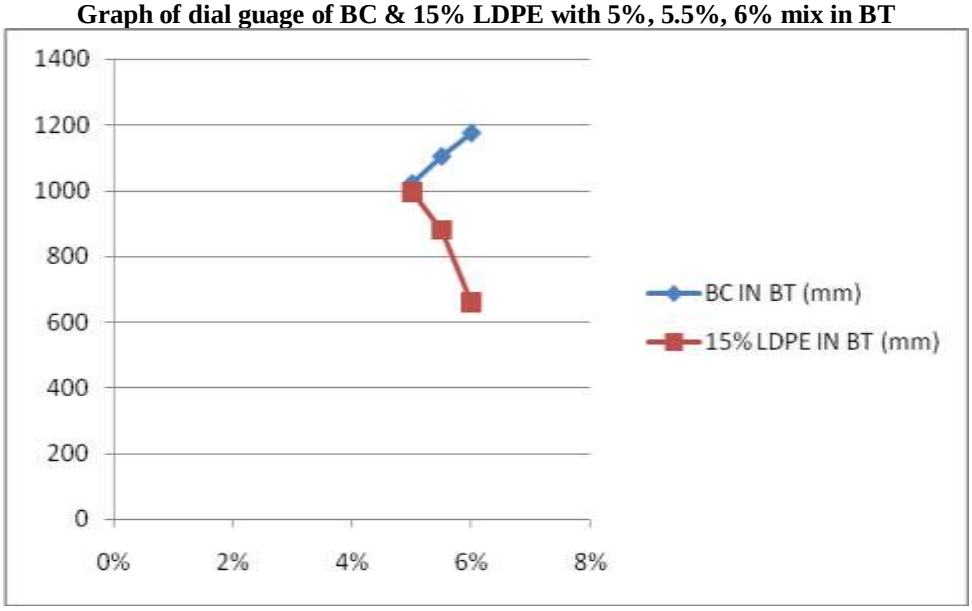
Graph of dial guage of BC & 15% LDPE with 5%, 5.5%, 6% mix in BT



5. Results and Discussion:-

1) 10% plastic substance gives an expansion in the solidness of about 64%, 18% and 75% individually contrasted with the customary SMA blend.
2) The channel down worth declines with an expansion in plastic substance and the worth is just 0.09 % at 10% plastic substance and ends up being a successful balancing out added substance in SMA blends.
3) Marshall test has been conducted and results of proving ring and dial gauge are been noted down and observed at 10-15% LDPE mix with Bitumen has good performance when compared to other mixes.
4) Indeed, even in this work we applied stimulation analysis and we created equation for better getting understanding and for advanced usages. As you can observe in this paper.

6. Reference :-

[1]."Effect of bitumen wax on asphalt mixture performance, " Construction and Building Materials, vol.21, no. 11, pp.1961–1970,2007- X.Luand P.Redelius.
[2]."Enhancement of asphalt concrete mixtures to meet structural requirements through the addition of recycled polythene, use of waste materials in hot mix asphalt", ASTM Special Tech Publication, 1193(1993) -D N Little.
[3]."Performance evaluation of Stone Matrix Asphalt (SMA) using Low Cost Fibres ". Journal of the Indian Roads Congress, Vol.74-2, Paper No.595- K.B.Raghuram and Venkaiah Chowdary 2013.
[4]."Study on effects of short coir fiber reinforcement on flexural properties of polymer matrix ". IJRET , eISSN: 2319-1163. P.A.Udaykumar, Rajanna, Ramalingaiah -2014.
[5].Study of Stone Matrix Asphalt for The Flexible Pavement .2014 IJEDR, Volume 2, Issue 1, ISSN: 2321-9939. , Ashish Talati, Vaishakhi Talati.
[6].Teja Tallam, Katasani Swetha, Dr A.Ramesh, IIT – Bombay."Assessment of Stone Mastic Asphalt Performance with the Inclusion of Fiber Material on Resilient Characteristics".
[7].Performance of Polymer Modified Bitumen for Flexible Pavements, ISSN 2319 – 6009. Pareek, Trilok Gupta and Ravi K Sharma, www.ijscer.com Vol. 1, No. 1, November 2012.
[8]. IRC: SP: 79-2008, Tentative Specifications for Stone Matrix Asphalt.