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Laboratory Investigation on Stone Matrix Asphalt using Shredded Plastic Waste

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Abstract —As the world population grows, so the quantity of waste being generated. The creation of non-decaying waste material is causing a major problem due to lack of waste management techniques. Therefore recycling should be considered as a major step in waste management. The amount of waste in circulation can be decreased by the use of waste materials rather than disposing. Some of the waste materials which can be recycled are glass, scrap tyres, steel slag, plastic etc. Many of these waste materials have been successfully used in pavement construction. Here in this project Stone Matrix Asphalt (SMA) mix is being used for the study, for which is modified by adding shredded plastic waste through dry process and wet process so as to investigate and compare the changes in strength properties of conventional SMA and modified SMA by conducting Marshall test, to find out flow value, stability, percentage air voids, voids present in mineral aggregates, voids filled with bitumen, bulk density and to find optimum binder content, optimum fiber content and drain down characteristics by conducting drain down test.

Keywords-*Stone Matrix Asphalt, MORTH, Shredded Plastic Waste, Optimum Binder Content, Optimum Plastic Content, Marshall Stability, Marshall Flow Value.*

I. INTRODUCTION

Roadway is the common mode of transportation which was used in pre-historic times. Since that time several experiments on pavement are carried out to provide comfort and safety to the road user. In recent day's continuous increase in traffic load and high variation in climatic conditions have compelled the technologists to improve as well as upgrade the specification for bituminous mixes, so as to obtain higher mechanical stability for bituminous concrete roads. Since the limits of upgrading bituminous concrete mix with conventional mix has reached its toll, this leads us to modify the conventional bituminous mix by the addition of additives.

Two types of process are usually used to modify the bituminous mix that is the first method is wet process were additives are added to the bitumen and hence modifying the binder to increase its properties and the second method is dry method where additives are added to the dry mix of aggregates of coarse and fine along with filler at particular temperature. Thus additives added by these process helps in increase stability, durability, decrease in thermal susceptibility, decrease in rutting and other common deformations like temperature cracking etc. and they also provide increased adhesion between binder and aggregates favoring increased tire traction.

Here in this project Stone Matrix Asphalt (SMA) mix is being used for the study, for which is modified by adding shredded plastic waste through dry process and wet process so as to investigate and compare the changes in its strength properties of SMA by conducting Marshall test and to find out flow value, stability, percentage air voids, voids present in mineral aggregates, voids filled with bitumen, bulk density and also to find optimum binder content and drain down characteristics by drain down test thus finding the optimum fiber content.

II. OBJECTIVE OF THE STUDY

- To conduct basic tests on aggregates and VG-30 bitumen.
- Gradation of aggregates so as to arrive at required JMF (Job Mix Formula).
- To prepare specimen for Marshall Test so as to find out OBC (Optimum Binder Content).
- To conduct Marshall Stability Test to find out:
  - Stability
  - Flow value
  - Air voids
  - Voids in mineral aggregates
  - Voids filled with bitumen
- To find out OPC (Optimum Plastic Content) for obtained OBC (Optimum Binder Content) by adding Shredded Plastic Waste to the SMA Mix by dry process and wet process and comparing its Marshall Test values.

- Drain down characteristics of plastic modified SMA by two processes and conventional SMA for varying percentage of plastic, with the help of Drain down Test data.

III. LITERATURE REVIEW

Bindu C S, Beena K S [(1)]. This research paper is a study on the influence of additives like sisal, coir, banana fibers, plastic waste and polypropylene on the potential drain down properties and characteristic of SMA mixtures. Based on drain down characteristic of various stabilized mixture, it indicated that the OFC was 0.3% by weight of OBC for all type of fiber mixture. And for waste plastic and polypropylene (polymer) the optimum fibre contents are 7% and 5% respectively by weight of OBC. This research paper concluded that due to the absorption properties of fiber, fiber stabilizers are found to be more effective in reducing the drain down of the SMA mixtures. The drain down test results for waste plastic mix is within the specified range, out of all the additives coir fiber is the best. Sisal and banana fiber mixtures show almost similar properties of stabilization.

Vivek B R, Dr. Sowmya N J [(2)] This study investigates the potential use of plastic waste as an additive for bituminous concrete and also coir fiber as an additive to stabilize asphalt from SMA mixes. Performance tests are conducted for both conventional and modified SMA mixtures that includes Marshall Test result i.e. Marshall Stability, flow value, void filled with bitumen, air voids, void filled with mineral aggregates, with varying percentage of plastic waste i.e. 4% to 10% in 2% interval by weight of 60/70 grade of bitumen and coir fibers at 0% to 0.3% in 0.1% interval by weight of total aggregates. The research conclusion is that the stability value increases as the percentage waste plastic content is increased up to specific limit and after that limit, stability value decreases. Similarly there is an increase in stability value as the fiber content is increased and with excess addition of fiber contents the stability and other related parameters decrease

Amit P Gawande [(3)]. In this paper the research scholar has worked a technique to add plastic waste for bituminous road and flexible pavement construction. Bitumen is usually used as binder in pavement construction for flexible pavements, so he conducted experiments to modify the binding properties of bitumen by adding and blending it with plastic waste i.e. the process used was wet process and thus can be used for construction purpose. And he also used dry process that is adding plastic to hot aggregates and getting the aggregates coated with plastic that improves the road strength. He concluded that improves the aggregate strength properties, thus improving the road strength. He concluded that plastic added or modified bitumen mix and aggregate exhibit comparatively better durability, binding property, stability, less water susceptibility of road with increase in resistance to wear and tear of road.

Shivaprasad K, Manjunath K R, K V R Prasad [(4)]. The purpose of this research was to evaluate the effect of addition of waste plastic bottles on the stability and strength properties of bituminous concrete mix which is used as wearing course in road construction and here bitumen course of grade one was used . The waste plastic bottle were shredded and mixed with hot bitumen and thus plastic modified binder was prepared, two different grades of bitumen was used i.e. 60/70 grade and 80/100 grade. Laboratory tests were conducted on plastic modified bituminous mix to investigate the engineering properties using Marshall Test and indirect tensile test.

The objective of this research was to:-

1. Evaluate the basic properties of aggregate and two grades of bitumen (60/70 and 80/100).
2. Study the strength and stability characteristic of two grades of bitumen after they are modified with polymer.
3. Study the effect of addition of waste plastic on stability and strength properties of bituminous concrete mix.

The result of this research work is that, higher stability is achieved with addition of plastic to asphalt mix irrespective of the grade of bitumen. The method used was dry mix and can be used highway construction.

Amit Gawande, G Zamare, V C Renge, Saurabh Tayde, G Bharasakale [(5)]. In this paper the researcher has reviewed the technique to use plastic waste for construction of flexible pavements. As we all know in conventional road bitumen undertakes the role of the binder. And this binder can be modified with waste plastic and the bituminous mixture done by this modified binder is made use as top layer i.e. surface coat of flexible pavement. As a result the waste plastic added bitumen mix is having better stability, better binding property, density and less water susceptibility.

IV. METHODOLOGY

Following steps are adopted for the present study:

- Aggregates, bitumen and shredded waste plastic waste are collected and brought from different sources
- Tests are conducted to find out the feasibility of raw materials used for the experiment with reference to codal provisions and obtained results are compared with standard values as per MORTH and Indian Standard codes.
- Proportioning of aggregates as per gradation specified in MORTH to obtain suitable mix.
- Then Marshall Stability test is conducted to find out Optimum Binder Content for conventional SMA Mix.
- Then to add SWP in varied proportioned for mix prepared for obtained OBC by dry process and wet process, and to compare its properties with conventional SMA by conducting Marshall tests and thus finding Optimum Plastic Content.
- Drain down test is conducted to find out the drain down percentage for the mixes prepared with obtained OBC and OPC.

V. LABORATORY INVESTIGATION

Test results for basic properties of materials are as follows:

Table 1.Properties of Coarse Aggregate

SL No.	Properties	Method of Test	Obtained results (%)	Limit (as per table 500-14 of MORTH)	Remarks
1	Impact value	IS:2386(IV)	13.78	18% max	Satisfactory
2	Abrasion value	IS:2386(IV)	19.57	25% max	Satisfactory
3	Specific Gravity	IS:2386(III)	2.57	2.5-3% max	Satisfactory
4	Water Absorption	IS:2386(III)	0.5	2% max	Satisfactory
5	Shape test	IS:2386(I)	28.4	30% max	Satisfactory

Table 2.Properties of Bitumen

Properties	Method of Test	VG 30 Bitumen	Permissible limit	Remarks
Penetration at 25℃, 5sec (mm)	IS:1203-1978	65.8	60-70	Satisfactory
Softening point,℃	IS:1205-1978	48	45-55	Satisfactory
Flash point,℃	IS:1209-1978	276	175 min	Satisfactory
Ductility at 25℃,(mm)	IS:1208-1978	96	75 min	Satisfactory
Specific Gravity	IS:1202-1978	1	0.99 min	Satisfactory

Table 3.Marshall Test results for conventional SMA

% of Bitumen	Unit weight (g/cc)	Stability (kg)	Flow value	Vv (%)	VMA (%)	VFB (%)
5.5	2.223	1080	3.30	5.13	17.34	70.41
6.0	2.250	1181.3	4.0	3.43	16.93	79.74
6.5	2.244	1070.95	4.1	3.03	17.59	82.77
7.0	2.230	990.83	4.5	2.60	18.21	85.7
7.5	2.224	812.15	4.9	2.4	19.08	87.42

Table 4.Marshall Test result for obtained Optimum Binder Content

% of Bitumen	Unit weight (g/cc)	Stability (kg)	Flow value	Vv (%)	VMA (%)	VFB (%)
6.2	2.268	1195.2	4.2	3.47	17.53	80.20

Table 5.Marshall Test result for Modified SMA Mix (Dry Process)

% of SWP	Unit weight (g/cc)	Stability (kg)	Flow value	Vv (%)	VMA (%)	VFB (%)
0	2.268	1195.2	4.2	3.47	17.53	80.20
2	2.274	1204.73	3.6	3.42	17.51	80.47
4	2.280	1207.7	3.1	3.34	17.47	80.88
6	2.287	1210.6	2.9	3.29	17.46	81.16
8	2.293	1215.1	2.5	3.22	17.43	81.52
10	2.294	1200.7	2.3	3.15	17.34	81.83

Table 6.Marshall Test result for Obtained Optimum Plastic Content (Dry Process)

% of Bitumen	Unit weight (g/cc)	Stability (kg)	Flow value	Vv (%)	VMA (%)	VFB (%)
8	2.293	1215.1	2.5	3.22	17.43	81.52

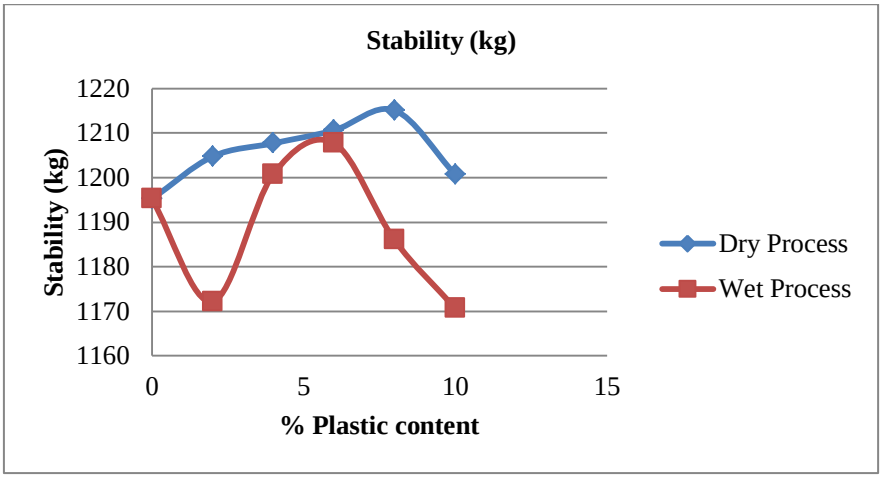
Table 7.Marshall Test result for Modified SMA Mix (Wet Process)

% of SWP	Unit weight (g/cc)	Stability (kg)	Flow value	Vv (%)	VMA (%)	VFB (%)
0	2.268	1195.2	4.2	3.47	17.53	80.20
2	2.338	1172.18	4.22	3.68	18.17	79.75
4	2.344	1200.73	4.15	3.59	18.12	80.18
6	2.348	1207.74	4.00	3.54	18.09	80.43
8	2.335	1185.99	3.82	3.11	17.58	82.31
10	2.324	1170.69	3.27	3.09	17.49	82.33

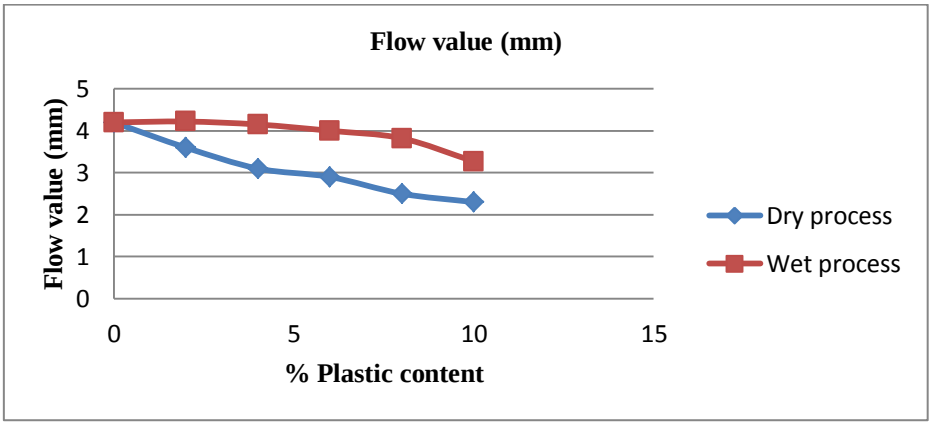
Table 8.Marshall Test result for obtained Optimum Plastic Content (Wet Process)

% of Bitumen	Unit weight (g/cc)	Stability (kg)	Flow value	Vv (%)	VMA (%)	VFB (%)
6	2.348	1207.74	4.00	3.54	18.09	80.43

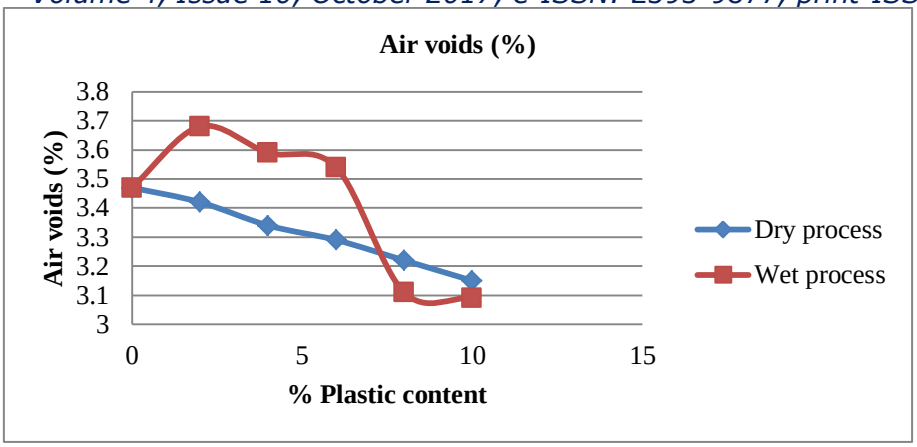
Graphs showing the difference in Marshall Test Properties for SMA modified by Dry & Wet process:



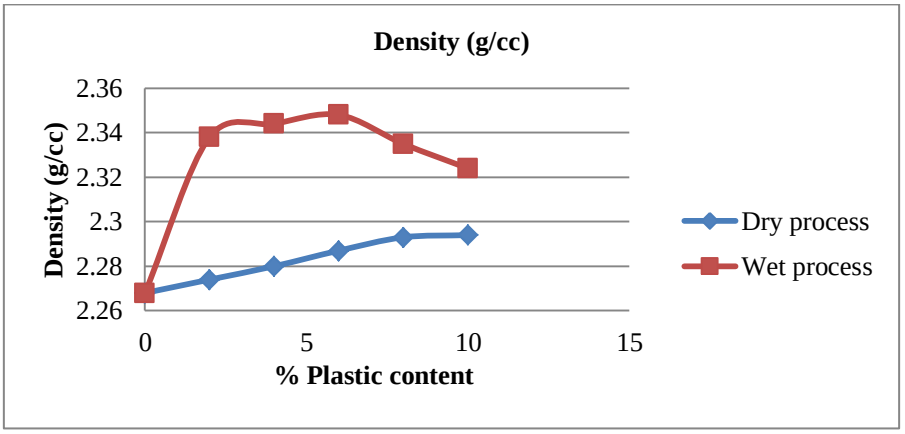
Graph 1: Graph showing Stability v\s Plastic content



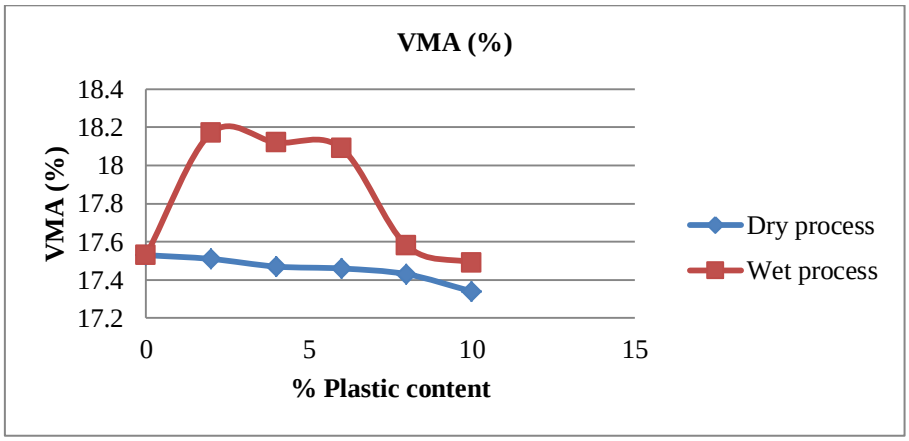
Graph 2:Graph showing Flow value v\s Plastic content



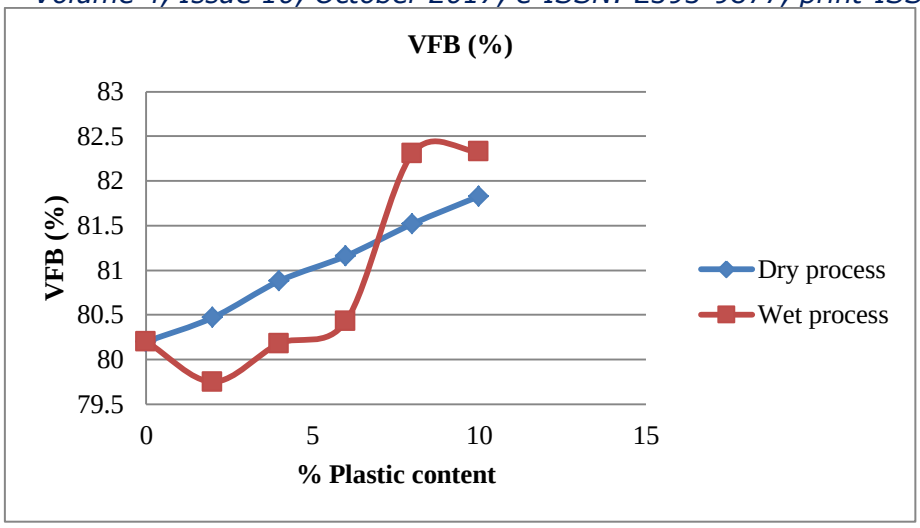
Graph 3: Graph showing Air voids v\s Plastic content



Graph 4: Graph showing Density v\s Plastic content



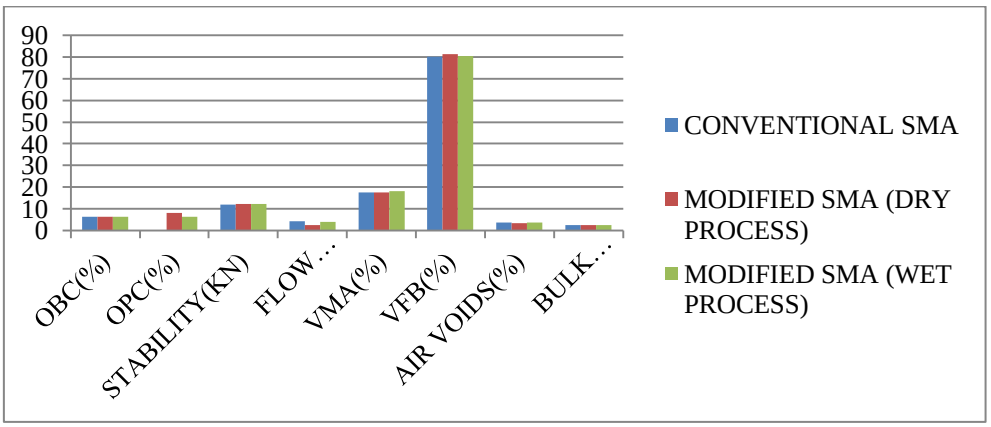
Graph 5: Graph showing VMA v\s Plastic content



Graph 6: Graph showing VFB v\s Plastic content

Table 9.Comparison of Modified SMA (Dry process& Wet process) and Conventional SMA

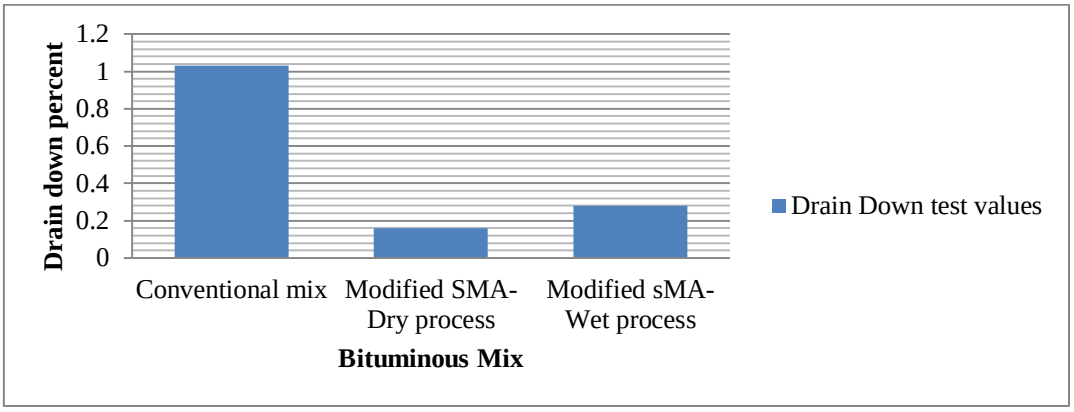
Properties	Conventional SMA	Modified SMA (Dry process)	Modified SMA (Wet process)
OBC (%)	6.2	6.2	6.2
OPC (%)	-	8.0	6.1
Stability Value (kg)	1195.2	1215.1	1207.74
Flow value (mm)	4.2	2.5	4.0
VMA (%)	17.53	17.34	18.09
VFB (%)	80.20	81.52	80.43
Air voids (%)	3.47	3.22	3.54
Bulk Density (g/cc)	2.268	2.293	2.348



Graph 7: Bar Graph showing the difference in Marshall Properties between conventional SMA and modified SMA prepared by Dry process and Wet process

Table 10.Drain down values of Conventional SMA and Modified SMA (dry process & wet process)

Type of SMA Mix	Drain Down value for obtained OBC and OPC (%)
Conventional mix	1.03
Modified SMA Mix-Dry process	0.16
Modified SMA Mix-Wet process	0.28



Graph 8: Graph showing Drain down test for Various Bituminous Mix

VI. CONCLUSION

1) Basic property test results for aggregates and bitumen used in this experiment show that the properties are within permissible limits as per IS codal provisions.
2) JMF obtained is 40%-coarse aggregate; 30%-fine aggregate; 28%-stone dust and 2% cement.
3) The optimum binder content (OBC) is found to be 6.2%
4) Marshall Test results are as follows:
   - The stability value of modified SMA in dry process is 1.6% and in wet process 1.0% more than conventional SMA.
   - The flow value of modified SMA in dry process is 40% and in wet process 4.8% less than conventional SMA.
   - Percentage air voids in modified SMA in dry process is 7.2% less and in wet process 1.9% more than conventional SMA.
   - Bulk density of modified SMA in dry process is 1.1% and in wet process 3.4% more than conventional SMA.
   - Percentage voids in mineral aggregate in modified SMA in dry process is 1.1% less and in wet process is 3.1% more than conventional SMA.
   - Percentage voids filled with bitumen in modified SMA in dry process is 1.6% and in wet process 0.03% more than conventional SMA.
5) The optimum plastic content (OPC) for dry process is found to be 8% and for wet process it is found to be 6%
6) The stabilization criterion in this experiment was the drain down test. The drain down value of conventional SMA Mix is found to be 5.8% which is way beyond the specified limit i.e. 0.3% max as per MORTH. But the drain down value in dry process is 0.17% and in wet process is 0.25%, in both the cases the drain down value is within the threshold limit as specified by MORTH. But the drain down value of modified SMA in dry process is 0.17% and in wet process is 0.25%, in both the cases the drain down value is within the threshold limit as specified by MORTH and from the following experiment it can be observed that SWP additive provides significant stabilization to the modified SMA Mix as compared to the conventional SMA Mix.

VII. REFERENCE

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