EVALUATION OF PERFORMANCE OF WARM MIX ASPHALT WITH GYPSUM AS ADDITIVE

M. Tech Dissertation

By

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CERTIFICATE

I hereby certify that the work which is being presented in the Dissertation entitled **"EVALUATION OF PERFORMANCE OF WARM MIX ASPHALT WITH GYPSUM AS ADDITIVE "** in partial fulfillment of the requirement for the award of degree of **Master of Technology** and submitted in Department of Civil Engineering, Lovely Professional University, Punjab is an authentic record of my own work carried out during period of Pre-Dissertation under the supervision of **Mr. Ajay Kumar**, **Assistant Professor**, Department of Civil Engineering, Lovely Professional University, Punjab.

The matter presented in this Dissertation has not been submitted by me anywhere for the award of any other degree or to any other institute. .

Date: **(Rajbir singh)**

This is to certify that the above statement made by the candidate is correct to best of my knowledge.

Date: **(Mr. Ajay Kumar)**

DECLARATION

I certify that

a) The work contained in the thesis is original and has been done by myself under the guidance of my supervisor.
b) The work has not been submitted to any other institute for any degree or diploma
c) I have followed the guidelines provided by the institute in preparing the thesis

I hereby declare that the dissertation work entitled “Evaluation of performance of warm mix asphalt with gypsum as additive ”is an authentic record of my own work carried out as requirements of dissertation for the award of degree of M.Tech. in Civil Engineering from Lovely Professional University, Phagwara, under the guidance of Mr.Ajay kumar

Acknowledgement

I am very thankful to my supervisor Mr. Ajay Kumar for giving me this great opportunity to work under his supervision. His invaluable guidance continues boosting and constant support makes confidence to my work. He always helps me when I am in any conceptual problem during my study. He enhanced my knowledge about the traffic accidents to a very higher stage and make me understand that how can I do my work. Finally I would like to say that without his kind support and helpful guidance I would not able to complete my work.

I am also very thankful to my Dean Dr. Indrasen Singh, who also helped me during my work. I shall always thankful to my other faculties who have helped me in direct or indirect way.

Rajbir singh

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Abstract

This study is about the effect of gypsum with warm mix asphalt the different percent of gypsum added on paving grade bitumen under various conditions. The basis of the thesis is to find out change in the physical properties of the bitumen with addition of gypsum. Various physical tests Bitumen VG-30 to evaluate its physical properties. Marshall Test was conducted on bituminous mix .Warm Mix Asphalt (WMA) is a technology that allows to reduce the production and paving temperature. By use of warm mix asphalt reducing the viscosity of bitumen and or increasing the workability of mixture for paving. Some WMA technologies can reduce the temperature to 100^{o}C and even lower without compromising the performance of asphalt. The study indicate the use of different percent of gypsum improves the physical properties of Bitumen. Further it also indicated that use gypsum improves Marshall Stability and Flow in the bituminous mix. With addition of different percent of gypsum to check the properties of bitumen mix .The WMA at produce at temperature of between 100°c to 140°c .Which about 22°c to 55°c lower than typical hot mix asphalt (HMA).

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WMA- Warm Mix Asphalt

HMA-Hot Mix asphalt

VMA-Voids in Mineral Aggregate

VFB-Voids Filled by Bitumen

VG-Viscosity Grading

BC-Bitumen Content

VA-Air Voids

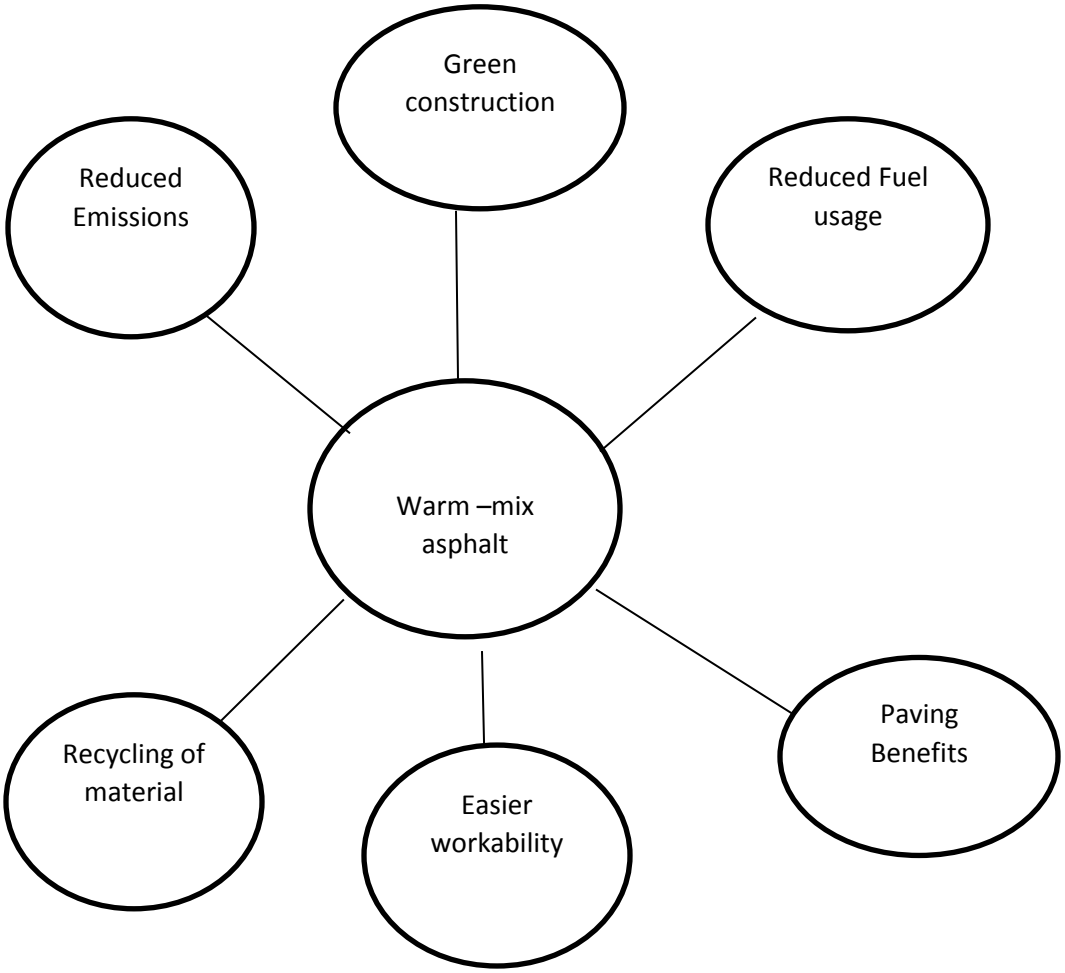
Chapter 1

Introduction:-

1.1 General

The concept of using lower temperature to produce to lower temperature .WMA technology allows the mixing, laydown and compaction of asphalt at low temperature. This technology reduce production temperature 30 percent .WMA produce at temperature of 120°C and the HMA produce temperature of 150° C .WMA offers many advantage over the HMA such as (a)energy saving (b) extend paving season into cold winter months (c)decreased emissions and fumes. The temperature on the order of 30°C to 40° C have been obtained .Its is reported that energy saving and on the order of 30% with reduction in CO2 emission of 30% are realized when WMA is used compared to HMA .The WMA technology in the United States, and long-field performance assessment of WMA pavements have yet to be completed. One approach to predicting the field performance of pavements is to characterize the laboratory properties of WMA and HMA that have been proven to correlate with field performance.

Benefits of using WMA technology



1.2 Need for the Study

As environmental criteria have become stricter , new methodology likes warm mix asphalt and foamed asphalt mixtures have appeared in road industry for energy savings and environmental benefits. Warm mix asphalt mostly depends on combination of binders or chemical additives modifying the properties of asphalt during production. The process is more expansive and environmental friendly. Every country in world have different environmental conditions and effects, so to introduce warm mix asphalt in India there is need for development of warm mix asphalt which is cost effective , user friendly and easier to implement. By reducing the viscosity of bitumen andor increasing the workability of mixture, some WMA technologies can reduce the temperature to 100 ^{0}C and even lower without compromising the performance of asphalt. The decreased viscosity allows effective compaction at lower temperatures where cool down rates are slower. WMA's disadvantages are mainly related to rutting and moisture susceptibility issues.

1.3 Objective of the Study

The main objective of the present study is

- To study the rheological properties of binder with WMA additive
- To study the feasibility of Gypsum as a warm mix additive
- To calculate the energy saving with Warm Mix Asphalt

1.4 Scope of the Study

Scope of the work includes following:

- Study considers BC gradation 2 (MORTH specification) for making bituminous samples.
- Preparation of Marshall samples with different % of gypsum.
- To conduct Penetration test,Sofeting point test resilient modulus test, for WMA .
- An experimental work has been proposed to improve the properties of pavement using gypsum as additive.
- Laboratory studies will be carried out on asphalt mixtures to evaluate engineering properties using marshal stability and flow.

-

1.5 Importance Of Study

- Reduces the binder viscosity and increasing the workability at lower temperature allowing to mix and compact at lower temperature.
- Cost effective for pavement surface for low road
- Green construction
- Reduction of energy consumption
- Reduction of CO_2 emissions
- The bitumen will less harden during construction with WMA

.

Chapter 2

Literature Review

Many researchers have worked on Warm Mix Asphalt technology in last decade. Foamed asphalt technology is widely used for bitumen modification which reduces the binder viscosity and increasing the workability at lower temperature allowing to mix and compact at lower temperature. Following are some recent finding in WMA:

1.Kakade et al (2011) used a chemical identified at IIT Kharagpur to prepare the warm mix asphalt. addition of foamed bitumen to corase aggregate heated up to 130 ^{0}C and mixed at same temperature , compaction was done at 100^{0}C to 120^{0}C. Marshall Test, Static Indirect Tensile, Strength Test, Resilient Modulus Test, Water Sensitivity Test were done on WMA and compared with HMA. Energy saving was calculated.

It is observed that Warm Mix Asphalt (WMA) has test parameters such as Stability, Indirect Tensile Strength, and Resilient comparable to HMA. The WMA have greater resistance to moisture induced damage as compared to HMA. The energy saving was worked out to be 13.5% for WMA.

2.Kandhal (2010) has describes the WMA technologies developed in Europe and the US, such as, synthetic zeolite, Sasobit, Evotherm, WAM Foam, LEA, Rediset WMX, REVIX, and Double Green Barrel together with their laboratory evaluation. It has been recommended to construct WMA demonstration projects in India.

WMA offers many significant advantages, such as, (a) energy savings in producing asphalt mix, (b) decreased emissions from asphalt plants, (c) potential of decreased asphalt binder aging during production, (d) extended paving season especially in colder winter months and in places located on high altitudes, and (e) compaction aid for stiffer mixes.

3.Banerjee et al (2011) has quantified the long-term aging effects on the rheological properties of warm mix asphalt (WMA) binders. thefour warm mix asphalt additives are Sasobit, Rediset, Cecabase and Evotherm, of which the first one is an organic and the latter three are synthetic additives. The rheology of the above mentioned additives

added to a PG 64-22 binder were studied using a frequency sweep test performed over a range of ten different loading frequencies and three different temperatures.

Results indicated that the RedisetWMA binder had the lowest shear modulus, followed by the Evotherm, Cecabase and Sasobit WMA binders. However, a different rate of gain trend was observed in the modulus values where, again, Rediset was slowest of all but followed by Sasobit, Evotherm and Cecabase binders. This implies that, of all the binders investigated in this study, the Sasobit WMA binder will have a significantly lower modulus over time as compared to the control PG 64-22 binder and the Rediset WMA binder will have the lowest modulus in the short-term as well as over time.

4.Kim et al (2011) This study presents laboratory evaluation integrated with field performance to examine two widely used warm-mix asphalt (WMA) approaches—foaming and emulsion technology, trial pavement sections of the WMA mixtures and their counterpart hot-mix asphalt (HMA) mixtures were implemented in Antelope County, Nebraska. Field-mixed loose mixtures col- lected at the time of paving were transported to the laboratories to conduct various experimental evaluations of the individual mixtures. From the laboratory test results, WMA mixtures showed greater susceptibility to moisture condi- tioning than the HMA mixtures, and this trend was identical from multiple moisture damage parameters including the strength ratio and the critical fracture energy ratio.

5.Akisetty et al(2007)

This paper presents the high temperature properties of rubberized binders containing warm asphalt additives. Rubberized binders were produced at 10% by binder weight using five binder sources, and the binders with the additives were produced using two (i.e. Aspha-min andSasobit) of the available processes and artificially short-term aged through the rolling thin film oven (RTFO) method. Tests were conducted on the binders using the rotational viscometer and the Dynamic Shear Rheometer.

5. **Mallick** 2009 . These technologies facilitate reduction in the asphalt binder's viscosity enabling the coating of aggregates particles completely at lower temperatures. The incorporation of WMA also tends to improve compaction reducing the permeability and binder hardening

caused by aging, improving the performance of the asphalt mix in terms of cracking resistance and susceptibility to moisture.

6. **Professor Ladis** Csanyi of Iowa State University identified the potential of using foamed bitumen as a soil binder in 1956. In this process, the introduction of saturated steam at about 40 psi into heated asphalt cement using a specially developed nozzle led to the production of controlled foam. Improved coating and mixing with cold, wet aggregates or soils was possible due to the reduced viscosity and the increased surface energy of the foamed asphalt (Lee, 1980). It was reported that foamed asphalt could be used in preparing mixes for stabilized bases and pavement surfaces of low traffic roads.

7. In 1995, Shell developed a warm-mix technique that used a two-component process that was widely tested in Norway, the United Kingdom and the Netherlands which culminated in the development of WAM-Foam. Moreover, Sasobit, a long chained hydrocarbon additive started to be marketed in Europe as a compaction aid for asphalt mixtures by Sasol Wax International

8. **Wielinski** et al. (2009) and Middleton et al. (2009) described the foaming process as a procedure where a given volume of water is added to the hot binder, with the water turning into steam at atmospheric pressure and leading to the expansion of the binder. Hence, the viscosity of the foamed binder is significantly reduced.

Summery

From above papers it is observed that foamed asphalt technology is widely used and 2 to3 % of water by weight of bitumen gives better foamed asphalt.in other method wax is used . wax melts at some temperature reducing viscosity of bitumen and increasing workability of mix. WMA have many benefits, it is cost effective, environment friendly and saves energy. The only issue is moisture susceptibility. The rutting performance of WMA mixes in the laboratory is reported to be inconsistent when compared to a control HMA mix. The fatigue cracking resistance of WMA may be slightly lower than HMA at low loading levels, based on laboratory mix testing. The findings regarding resistance to thermal cracking of WMA are mixed and are WMA technology-dependent. The findings regarding resistance to moisture of WMA are mixed and are WMA technology-dependent; it has been suggested that anti-stripping additives should be used in WMA for

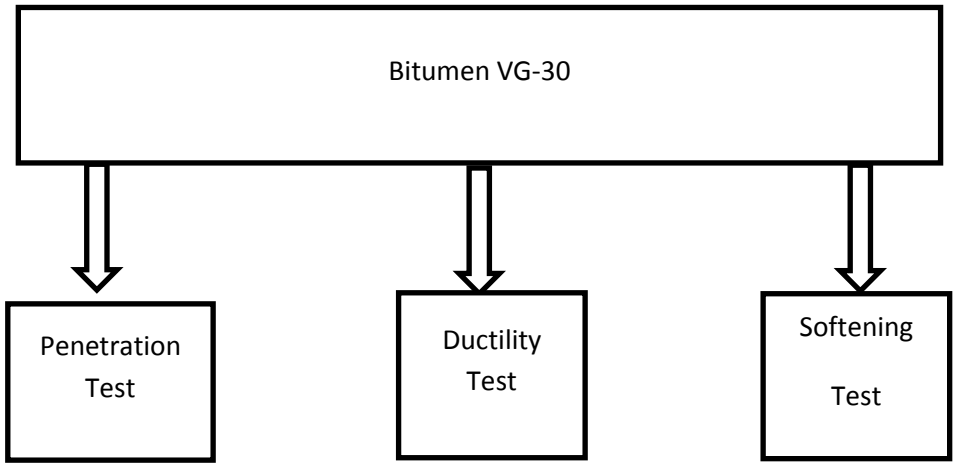
Chapter-3

Methodology

The testing consisted of two parts – at first the properties of bitumen were determined with the traditional test methods. Second properties of bitumen were determine with addition of gypsum .The Marshall Test perform with addition of different percent of gypsum

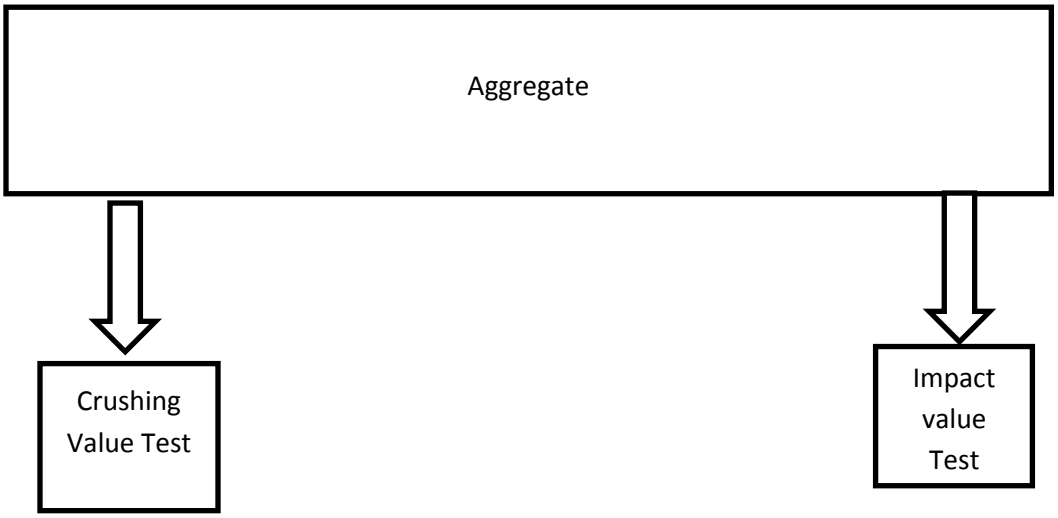
Bitumen:-

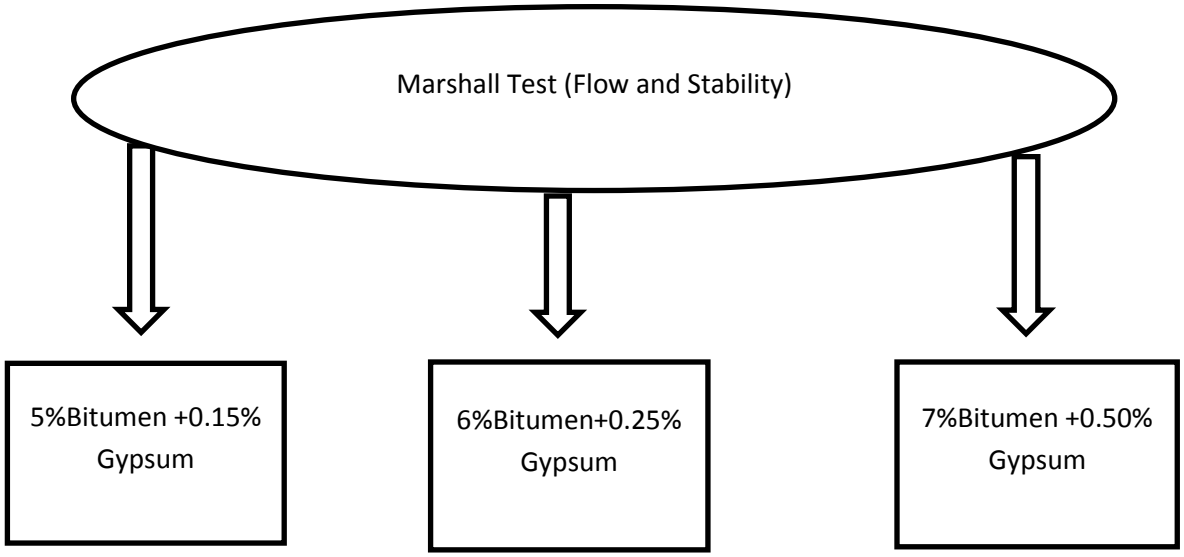
Bituminous binder used in pavement construction work include both bitumen and tar.Bitumen is a petroleum product obtained by the distillation of petroleum crude whereas road tar is obtained by the destruction distillation of coal or wood . In order to determine the viscos-elastic behavior of bitumen after modification with WMA

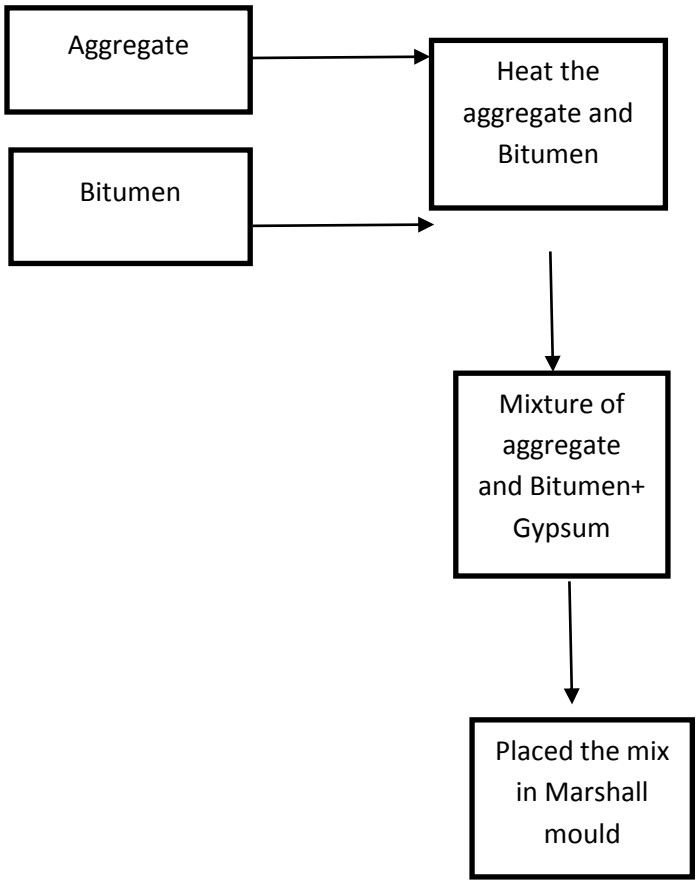


Aggregate:-

The aggregate used in the surface course of pavement have withstand to high magnitude of load stresses and wear and tear.




Marshall Test (Flow and Stability)
5%Bitumen +0.15% Gypsum
6%Bitumen+0.25% Gypsum
7%Bitumen +0.50% Gypsum


Aggregate
Bitumen
Heat the aggregate and Bitumen
Mixture of aggregate and Bitumen+ Gypsum
Placed the mix in Marshall mould

Mechanism of Gypsum:-

Gypsum is used as additive in this process. This is easily available and cheap. The cost of gypsum is 30 Rs/kg. its mechanism is as below:

Gypsum has a crystalline structure which holds the water molecules within the structure, which is released in form of steam when heated. This property of gypsum makes it WMA additive. Gypsum is a very soft sulfate mineral composed of calcium sulfate dihydrate, with the chemical formula $CaSO_4 \cdot 2H_2O$.When the crystal lattice is heated, it loses liquid water molecules to evaporation and thus gains solidity. When the gypsum is heated it releases steam and Plaster of Paris. Released steam produces the foaming. This reduces the viscosity of bitumen at lower temperature allowing the compaction at lower temperature.

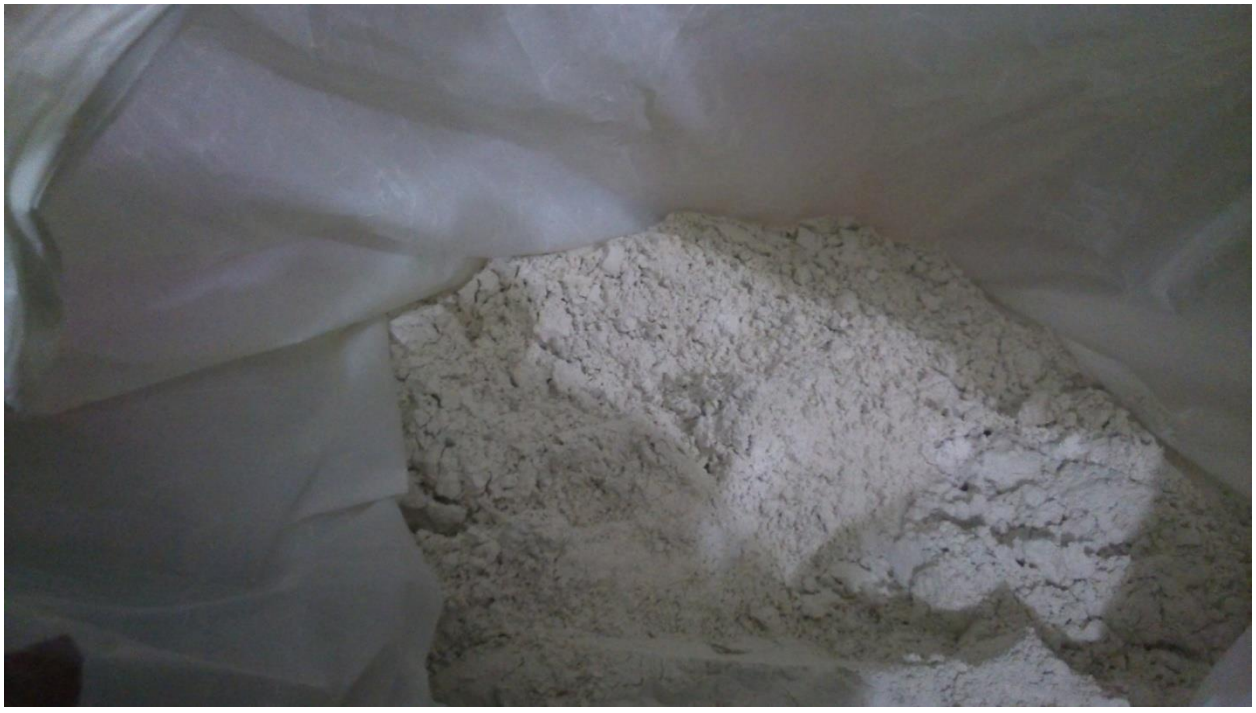


Fig 3.1: Gypsum powder

Chapter 4

Experimental Investigation

4.1 Material Used

4.1.1 Bitumen

Bitumen is a material which is a byproduct of petroleum refining process. It is a highly viscous at temperature above 100 degrees Celsius and is solid at room temperature.

The physical properties of bitumen were given in below table

S.NO	Properties	Grade	Test result Obtained	Permissible value as per BIS	Test method
1	Penetration (mm) 25^0 C	VG 30	57	50-70	IS:1203-1978
2	Ductility (cm)	VG 30	38	40	IS:1203-1978
3	Softening point ^{0}C	VG 30	45	47	IS:1205-1978

4.2 Aggregate

Aggregate have to primarily bear load stresses occurring on the road and runway pavement and have also resist abrasive action of traffic movement under dry and wet condition.when used in surface course of the pavement

Basic physical parameters of aggregates are found using various tests as tabulated below

S.No	Aggregate properties	Test result obtained	Permissible value as per MORTH
1	Impact value (%)	20.8	Max24 %
2	Crushing value (%)	24.8%	Max45 %
3	Water absorption (%)	0.25%	Max 2%
4	Los angles abrasion value (%)	32%	Max 30%
5	Specific gravity of coarse aggregate	2.72	2.5-3.0

DETERMINATION OF BINDER CONTENT FOR ASPHALT MIX

. Figure no:- Bitumen Extractor.

Binder content

Weight of the sample (W_1) grams	1200
Initial weight of filter paper(F_1) grams	4.50
Weight of aggregate after extraction(W2) grams	1149
Weight of filter after extraction with fine material (F2) grams	5.00
Increased weight of filter (W3)=(F2-F1) grams	0.50
% Binder content=W1-(W2+W3)÷W1×100	4.2

Test on bitumen:

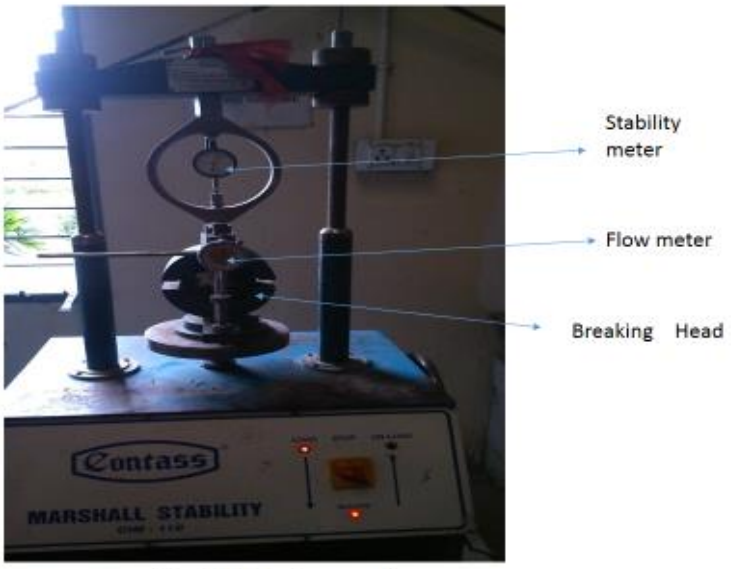
Penetration test, softening point test, ductility test were done on the bitumen with WMA additive and base binder and results are compared as below

Table-5.1 Comparison of fresh binder (VG 30) + addition of gypsum

Test	**VG 30 Binder**	**VG 30 with WMA additive**
Penetration at 25ºC/100 gm /5 sec, 0.1mm	57	56.17
Softening Point, ºC, minimum	45	56.5
Ductility, cm, minimum	38	45

Figure No: Penetration Test Apparatus

Marshall Test



Marshall test apparatus

Figure no: Marshall Test Apparatus

Marshall Test:-

This test procedure is used in designing and evaluating bituminous paving mixes and is used for determine the voids analysis and stability and flow. Strength is measured in term of the 'Marshall stability of the following specification ASTM D1559(2004), which is defined as the maximum load carried by compacted specimen at standard temperature 60° C. The flexibility is measured in term of the "flow value " which is measured by the change in diameter of the sample in direction of load application between the start of loading and at the time of maximum load.This test method has been widely accepted because of its simplicity and low cost .This test to use to determine the Optimal Binder Content (OBC) mixing and also study of various characteristics such as Marshall Stability ,Flow value ,Unit weight ,Air voids .This sample shall be prepared by combining varying percentage of bitumen ranging from 5% by the total weight of aggregate to 6 % to increase 0.5 % for each sample with addition of gypsum of percentage of 1,2,3 and calculate the volume analysis and Stability and flow .To compare the result of Marshall test with or without of Gypsum

Figure No. Marshall Specimen Extractor

Source : Soma Plant at Hoshiarpur road near Phagwara punjab

Figure no:Load apply on the Marshall Specimen

Gradation of aggregate for bituminous concrete pavement layer (BC- II)

IS Sieve (mm)	% Passing	% Retained	Corrected %	Weight in grams
26.50	100.00	0.00	0.00	0.00
19.00	100.00	0.00	0.00	0.00
13.20	92.72	7.28	6.92	83
9.50	77.50	15.22	14.46	174
4.75	57.48	20.02	19.02	228
2.36	47.38	10.11	9.60	115
1.18	39.51	7.52	7.47	90
0.600	29.90	9.64	9.13	110
0.300	21.03	8.82	8.43	101
0.150	14.93	6.10	5.80	70
0.075	5.13	9.80	9.31	112
Pan		5.13	4.87	58
Bitumen content		5.00	5.00	60
		105.00	100.00	1200.00

Sieve size vs. (%)Passing

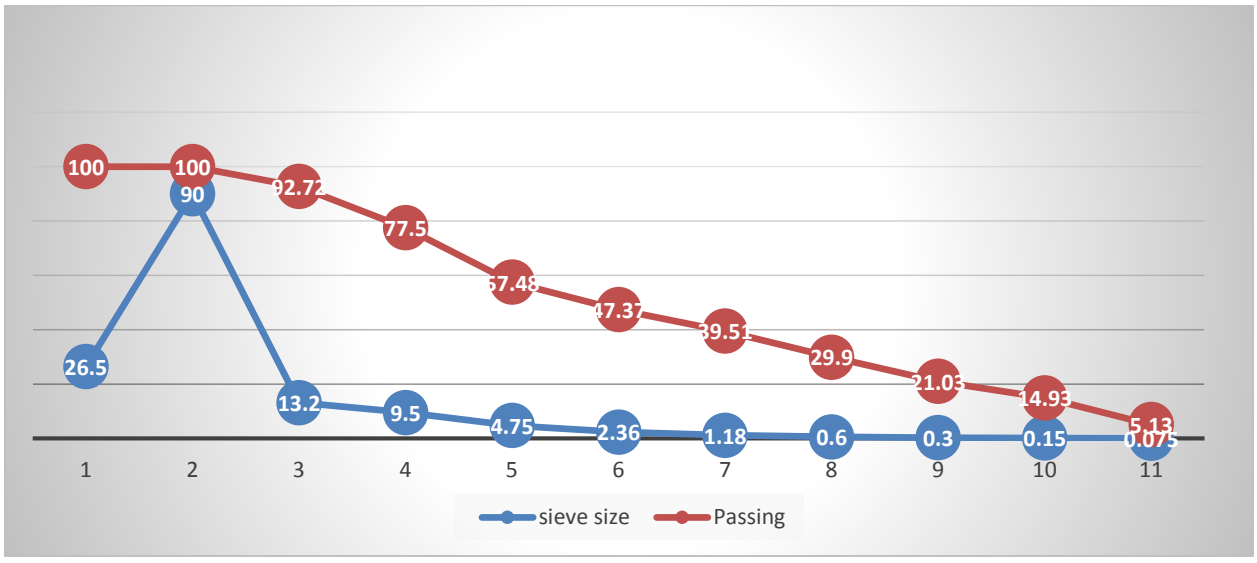


Figure no: Sieve size vs. %Passing

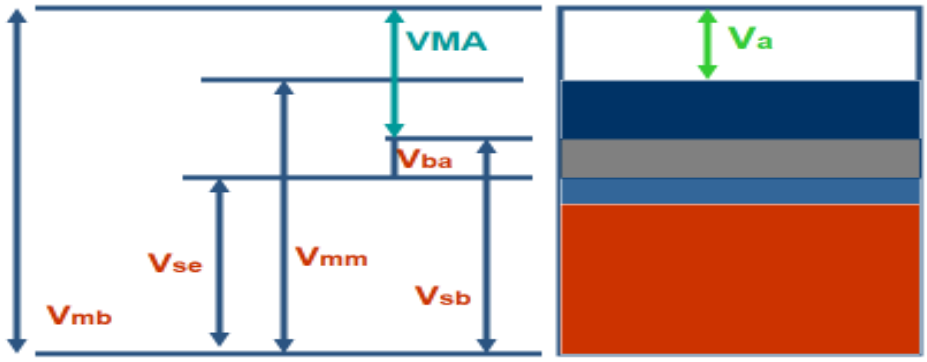
Figure no: Sieve analysis for prepared the Marshall specimen

Figure No. Material prepaid for Marshall Test

Figure No: Heating the aggegate and bitumen

Parameter used volumetric analysis:-

The following properties were obtained from the laboratory studies on Bituminous Concrete



Effective Specific Gravity(Gse):-

$$Gse=100-Pb/100/Gmm-Pb/Gb$$

Where

Pb=Percent asphalt binder by total mass of mixture

Gmm=Th eoretical maximum specific gravity of mixture

Gb=Speci ic gravity of asphalt binder

Percent v oids in Mineral aggregate (VMA):-

$$VMA(\%)=100-[(Gmb*Ps)\div Gsb]$$

Where

Gmb=Bu k specific gravity of mix

Ps=Percent of aggregate of total mix

Gsb=Bulk specific gravity of aggregate

Percent voids Filled with asphalt (VFA):-

$$VFA(\%) = 100*[(VMA - Va) \div VMA]$$

Where

VMA=Percent voids in mineral aggregate

Va=Percent voids in total mix

Marshall Specimen result for (BC-11)

Marshall Test Value :-For every sample the Marshall test result that stability and flow are measured and tabulated .The stability measured in (KN) and flow measured in mm without addition of gypsum

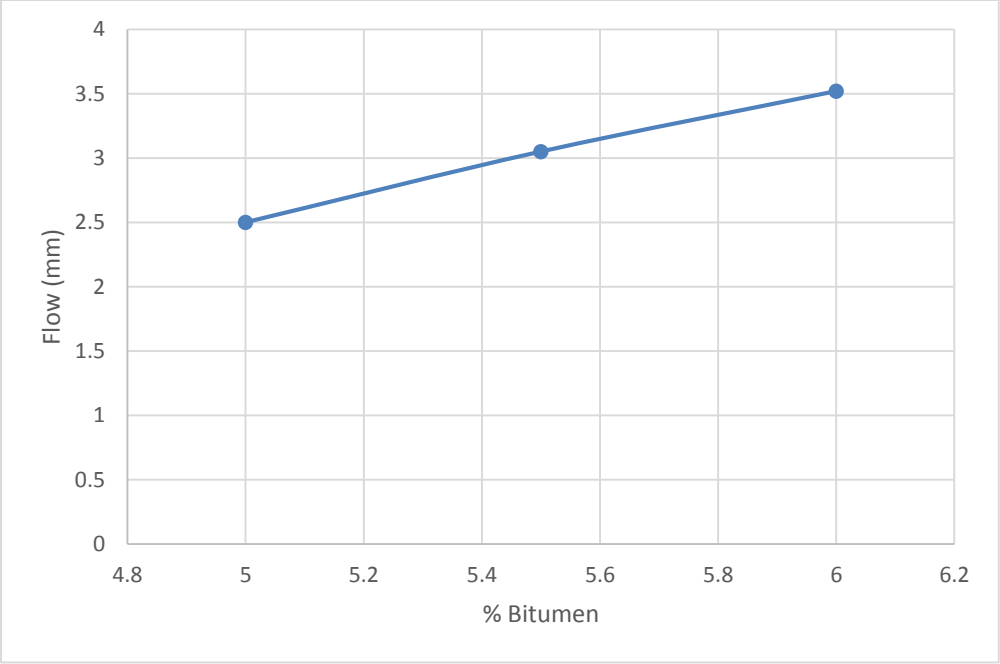
Marshall stability and flow measured without addition of gypsum

Table no:- Marshall Test result

S.No	% of Bitumen	Stability (KN)	Flow (mm)
1	5	11.50	2.50
2	5.5	10.96	3.05
3	6	9.70	3.52

4.1 Flow vs. .Binder content:-

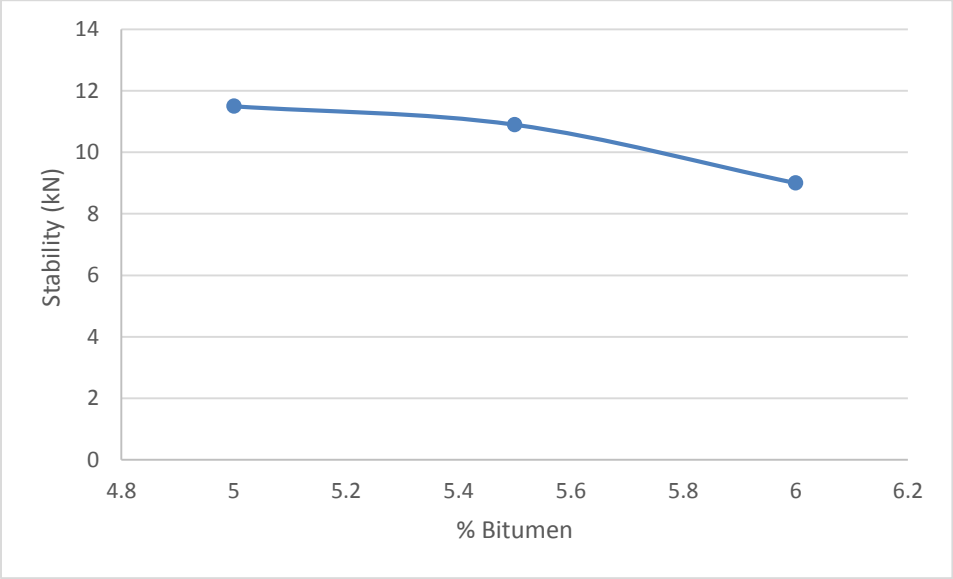
Flow value and Bitumen content plotted against bitumen in x axis and flow in y axis. It observe that flow value increase with increase of binder content and show the variation between bitumen and flow value shown in below graph.



Graph no: Flow vs. Bitumen content

4.2 Stability vs. Bitumen content:-

Stability and bitumen content plotted against bitumen in x axis and Stability in y axis. The stability value decrease with increase of bitumen content. The variation between Bitumen and stability shown in below graph



Graph no: Stability vs. .Bitumen content

Table no-

Table no-

Maximum Sp. Gravity (Gmm) Calculation						
Bitumen content (%)	wt. of pycnometer	Pycnometer + Mix	Pycnometer + Mix + water	Pycnometer + Water	Wt of Mix	Gmm
5	478	935	1543	1270	457	2.484
5.5	478	931	1544	1271	453	2.517
6	478	908	1527	1271	430	2.571

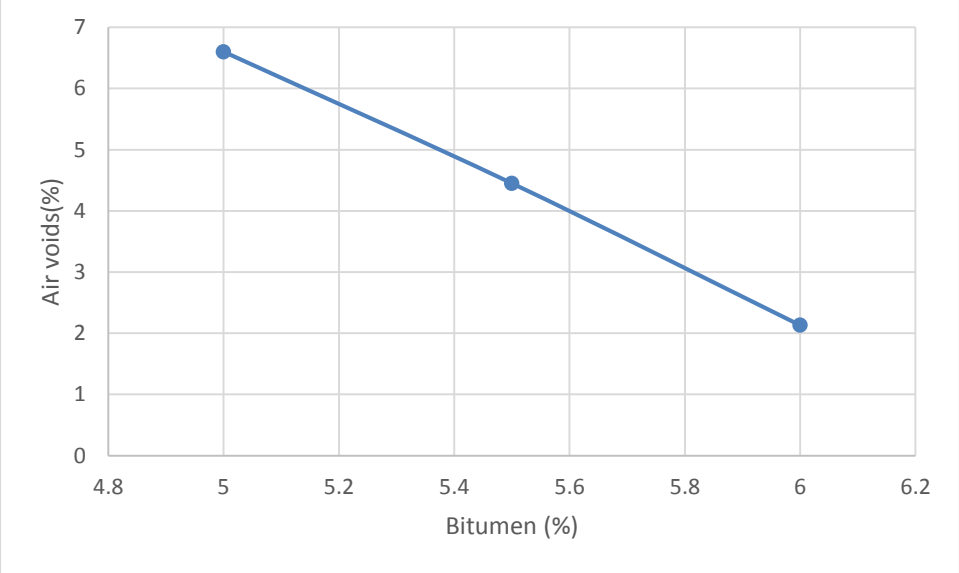
Table no:-

(%)Bitumen content	Gmb
5	2.452
5.5	2.402
6	2.480

Table no:

S.No	% Bitumen content	Gsb	Gmb	Gmm	Va(%)	VMA(%)	VFA(%)
Specified limit					3%-6%	Min 14%	65%-75%
1	5	2.57	2.218	2.375	6.6	18.01	63.29
2	5.5	2.57	2.232	2.336	4.45	17.92	75.16
3	6.6	2.57	2.245	2.294	2.13	17.88	87.4

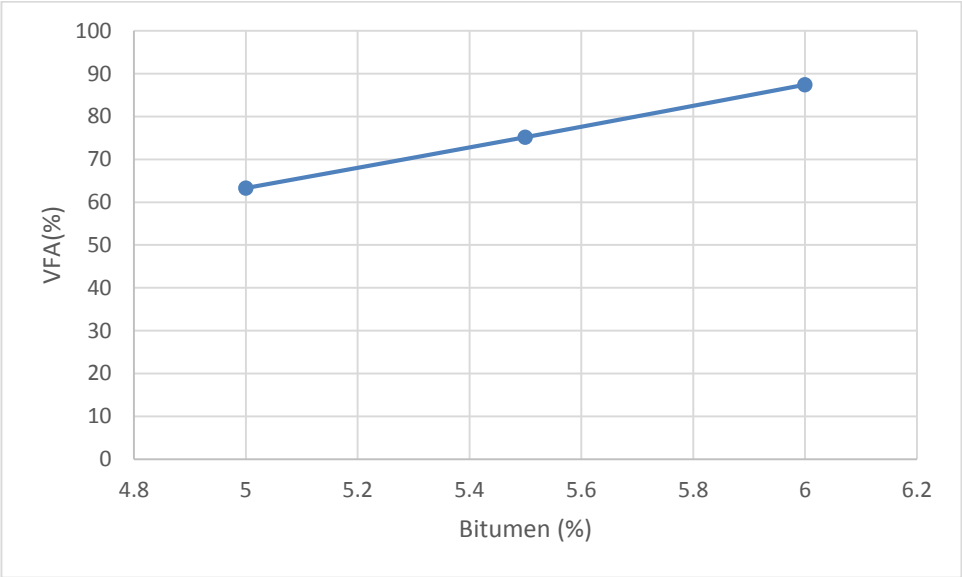
4.3 Air voids vs. Bitumen:- Air voids plotted against bitumen content the Air voids in y axis and bitumen in x axis. The air voids increase with increase of bitumen.



Graph no: Air voids vs. Bitumen content

4.4 V.F.A vs. Bitumen content:-

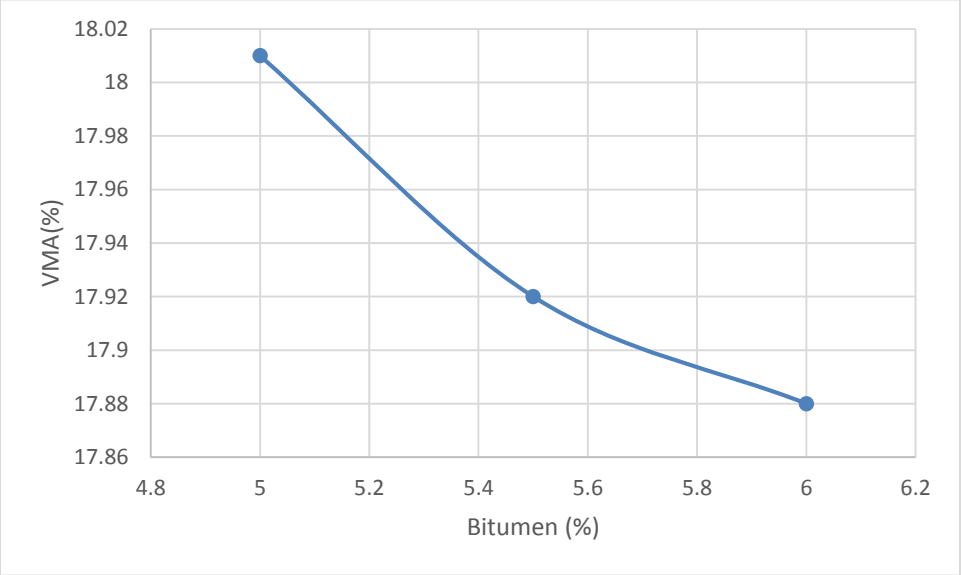
voids filled with bitumen plotted against the V.F.A in y axis and Bitumen in x axis .The VFB increase with increase the bitumen content .The variation between bitumen content and VFA shown in below graph



Graph no:- V.F.A vs. .Bitumen content

4.2 V.M.A vs. Bitumen content**:-**

Voids in mineral aggregate and bitumen content plotted against bitumen in x axis and V.M.A in y axis. The bitumen content increase and VMA decrease .The variation between the bitumen and VMA shown in below graph.

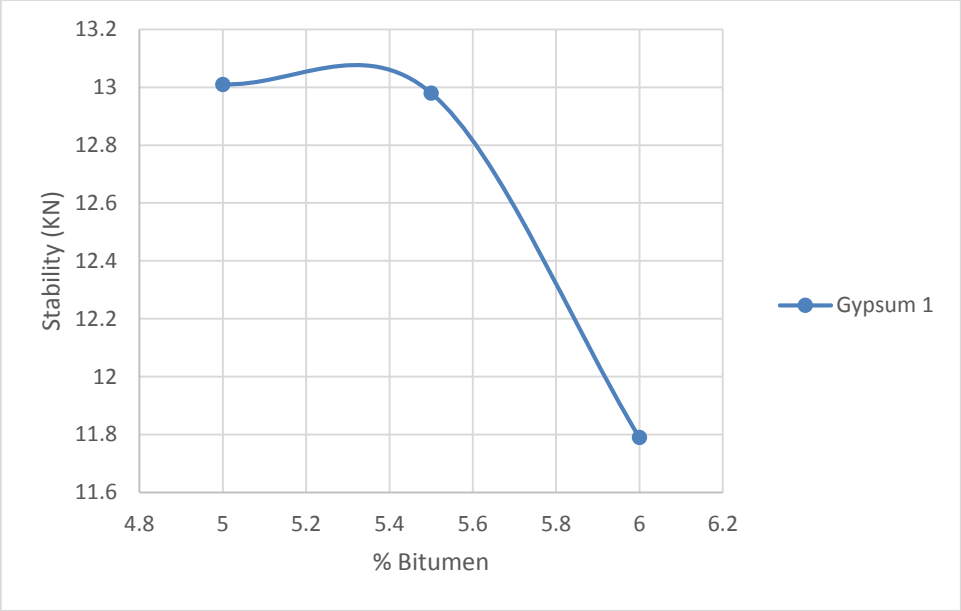


Graph no:-V.M.A vs. Bitumen content

Stability and flow calculated of Marshall test with addition of Gypsum:-

S.No	(%)Bitumen content	Stability (KN)	Flow (mm)
1	5	13.01	2.48
2	5.5	12.98	2.61
2	6	11.79	3.09

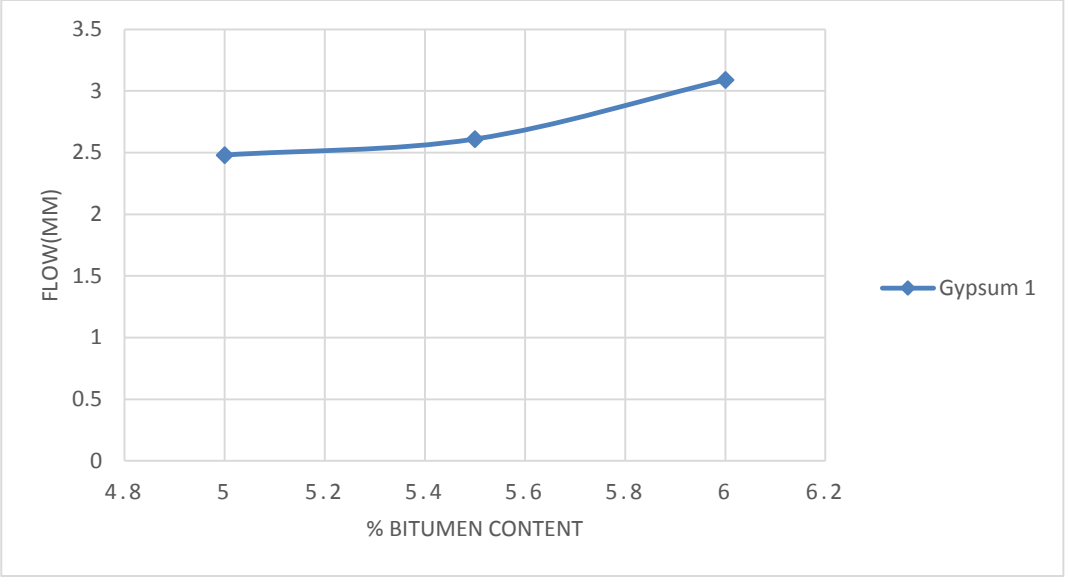
Stability vs. Bitumen content:- The Stability value increase with addition of gypsum at certain percentage of bitumen content after that binder percentage is increase the stability value is decrease



Graph No: Bitumen Vs. Stability

Flow vs. .Binder content:-

The flow value increase with increase of binder content with addition of gypsum .The variation of bitumen and flow value shown in below graph



Graph No: Bitumen content vs. flow

Volumetric analysis of Marshall Test with addition of gypsum:-

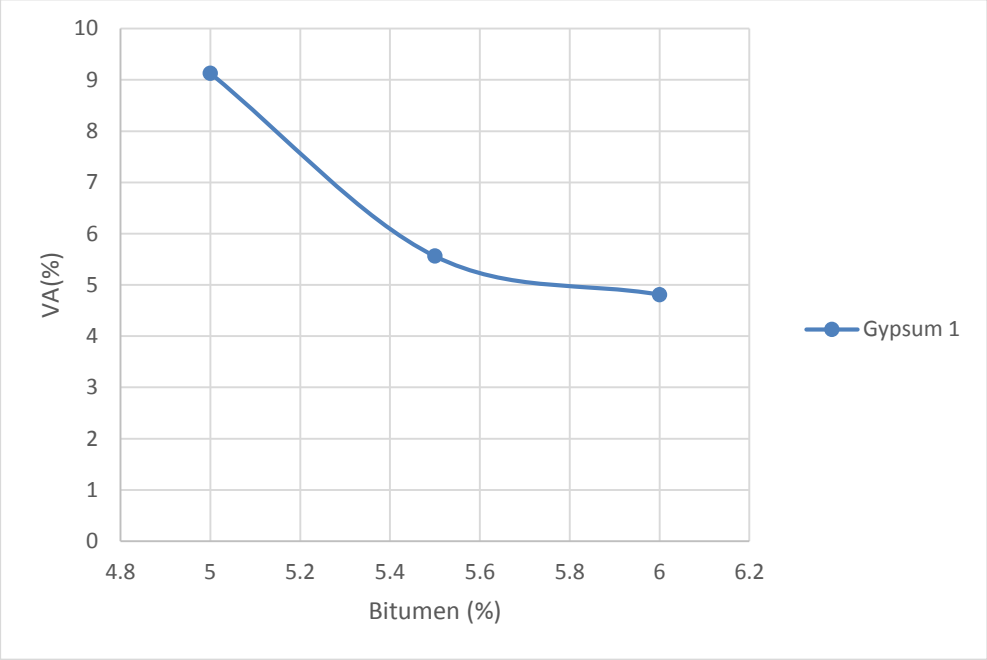
Calculate the value of VMA, VFA, VA, Gmm, Gsb, Gmb with addition of gypsum in Marshall Test

Table no:-

S.No	% Bitumen content	Gsb	Gmb	Gmm	Va(%)	VMA(%)	VFA(%)
1	5	2.7	2.513	2.765	9.13	11.11	17.86
2	5.5	2.7	2.540	2.690	11.18	10.61	47.61
3	6	2.7	2.579	2.710	17.86	9.72	50.47

Air voids vs. Bitumen:-

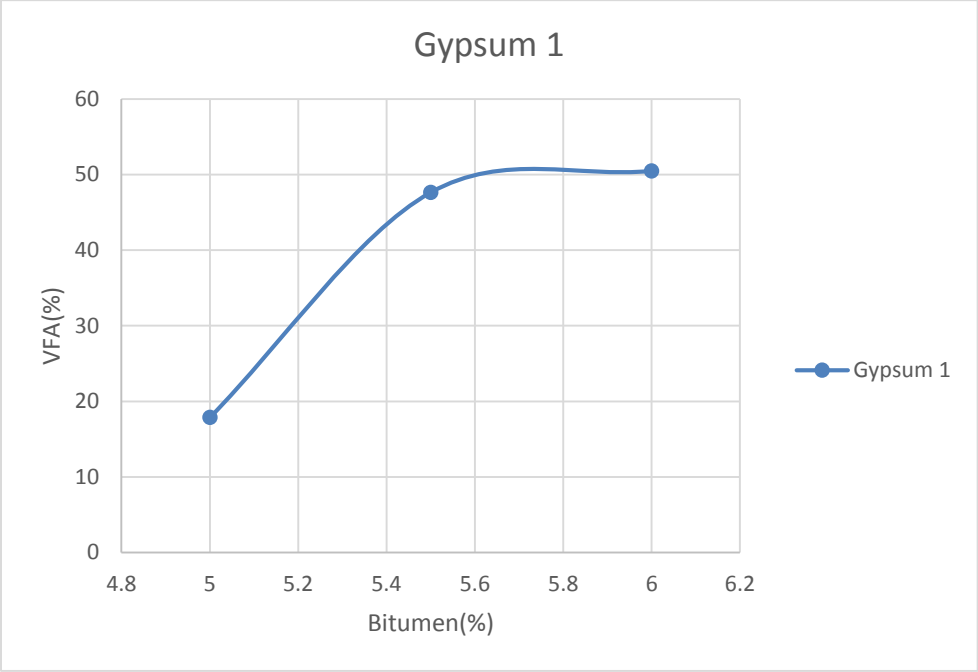
With addition of gypsum the air voids value increase at certain percentage of binder content but after certain limit air voids decrease with increase of binder content.



Graph No: Bitumen Vs. Air voids

V.F.A vs. Bitumen content:-

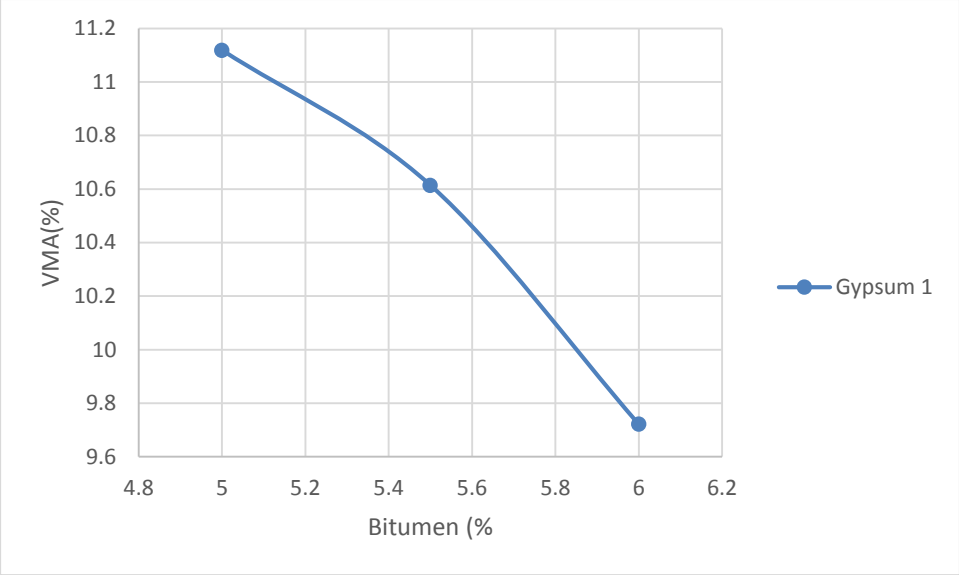
The addition of gypsum the value of void filled with asphalt increase with increase the percentage of binder content



Graph No:Bitumen vs Voids filled in asphalt

V.M.A vs. Bitumen content**:-**

The value of void in mineral aggregate decrease with increase the percentage of binder content w



Graph No:- Bitumen Vs. Voids in mineral aggregate

Chapter 6

CONCLUSION

Conclusion Remarks:

The following conclusion were drawn on the basic of investigation carried out in the present study

1. Few test has been performed till now until we perform on all the test over different percent binder and addition of gypsum and to compare the result of Marshall test with or without gypsum with different percent of bitumen binder

2. Marshall test the stability values were found to be increased with the use of gypsum as additive.

3. The penetration and ductility value of bitumen increase with addition of gypsum as additive

Future Plan

In future the possibility of gypsum with polymer modified binder and crummed rubber modified binder has to be study.

1.To use the different percentage of gypsum to perform the indirect tensile strength on Marshall specimen,

References:-

1. Akisetty, C. K., T. Gandhi, S. J. Lee, and S. N. Amirkhanian. (2010). Analysis of Rheological Properties of Rubberized Binders Containing Warm Asphalt Additives. Canadian Journal of Civil Engineering, Vol. 37, No. 5.
2. Anderson, M., G. Baumgardner, R. May, and G. Reinke. (2008). Engineering Properties, Emissions, and Field Performance of Warm Mix Asphalt Technologies. NCHRP 9-47 Interim Report, Asphalt Institute.
3. Austerman, A. J., W. S. Mogawer, and R. Bonaquist. (2009). Evaluating the Effects of Warm Mix Asphalt Technology Additive Dosages on the Workability and Durability of Asphalt Mixtures Containing Recycled Asphalt Pavement. Paper No. 09-1279, Transportation Research Board Annual Meeting CD-ROM, Transportation Research Board of the National Academies, Washington, D.C.
4. American Association of state Highway and Transportation officials AASHTO (1986):"AASHTO Guide for Design of Pavement Structure -1986",Washington D.C.
5. Akisetty C.,Xiao, F.,Gandhi,T., and Amirkhaniann,S.(2011)."Estimating correlations between rheological and engineering properties of rubberized asphalt concrete mixture

containing warm mix asphalt additive .”Construction and Building material ,Elsevier Ltd ,25(2),950-956.

6. Banerjee,A.,De Fortier smit,A.,and prozzi,J.a.(2012).”The effect of long –term aging on the rheology of warm mix asphalt binder .”Fuel, Elsevier Ltd,97(January (2012),603-611.
7. Cooper, S., L. Mohammad, and M. Elseifi. (2011).
8. Sulfur-Modified Warm-Mix Asphalt. Journal of Materials in Civil Engineering, ASCE, Vol. 23, No. 9 (September).

9. Kandhal ,P.,S.,(2010).”Warm mix asphalt Technologies :An Overview .”Journal of Indian Roads Congress,(561) 144-153.
10. Kakade V.,Das,V.,Reddy ,M.,A.,Pandey,B.,B,.(2011).”An Investigation on warm and Half warm mix Bituminous Mixes.” Journal of the Indian Roads congress,169-174.
11. Kim,Y.-R.,Zhang,J.,and Ban,H.(2012).”Moisture damage characterization of warm mix asphalt mixture based on laboratory –field evaluation .”Construction and Building Material,Elsevier Ltd,31,204-211.
12. Lamia A.Ahmed,”Improvement of Marshall Properties of the Asphalt concrete using the Polyethylene as Additive”,2006.
13. Mahabir panda and Mayajit Mazumdar (1999).”Engineering Properties of EVA-Modified Bitumen For Paving Mixes “.Journal of Material In Civil Engineering ASCE/May 1999.
14. Perkins,S.(2009) Synthesis of warm mis asphalt paving strategies for use in Montana highway construction.Western Transportation Institue .Report No.FHWA/MT-09-009/811738-Montana.,Montana Department of Transportation.

15. Wang,H.,Dang,Z.,You,Z.,and Cao,D.(2012).”Effect of warm mix asphalt (WMA) additive on high failure temperature properties for crumb rubber modified (CRM) binder”.Construction and Building Material ,Elsevier,35.281-288.