ISSN No:-2456-2165

Determination of Optimum Bitumen Content for the Bituminous Concrete Mix Design

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Abstract:- 98% of highways are constructed in flexible pavement roads. The performance of pavement is determined by the properties of bitumen. Bitumen is the naturally occurring byproduct of crude oil. Bituminous Concrete mix design emphasizes determining the proportion of bitumen, Filler, fine aggregate, and coarse aggregates are combined to create a mix that is workable, strong, durable, and economical. The most frequent material utilised in the construction of flexible paving roads is bituminous concrete mix. The construction of Bituminous Concrete (BC) is used as the road Wearing course in this project. The Bituminous Concrete (BC) consists of a proportioned mixture of coarse aggregates, fine aggregates and bitumen and the Mix design is carried out by the Marshall method of Mix design to fulfill the requirements of Stability, Flow, Density, and Voids analysis. In general, bitumen acts as an adhesive agent that binds aggregate particles into a cohesive mass. The bitumen mix is tested for penetration test, softening point, ductility, and marshal stability to evaluate different properties like flow value, voids, unit weight, aggregate voids, and marshal stability. Aggregates are tested for Grain size analysis, Impact test, Specific gravity test, Flakiness test, and Elongation test. Our project emphasizes the mix design consideration to find out the Optimum Binder Content. In this design, we have used the Marshall Stability test method.

I. INTRODUCTION

➢ *General*

The weight transfer occurs by contact between the grains of the flexible pavement, which is a layered system. The bitumen, which creates the binder matrix and holds the aggregates in place, will be combined with the aggregate blend of various sizes in each of these layers. The design of the bituminous concrete mixture is a difficult task. Marshall's method of mix design is the most popular in India where the optimum binder content will be found by considering different trial binder contents. the Marshall specimen made with the OBC must meet the requirements for stability, flow, volume filled with bitumen, volume of mineral aggregates, and volume of voids (VV). The specifications for these parameters have been defined by organisations from many nations, and it is necessary to confirm these specifications before using a particular mixture in the field.

➢ *Bituminous concrete mix design*

The goal of the bituminous mix design is to establish the ratio of bitumen to filler to fine aggregate to coarse aggregate to produce a mix that is workable, strong, durable, and economical.

- *Objectives of mix design*

Mix design's goal is to create a bituminous mixture by balancing various components to have:

- ✓ Enough bitumen to provide a long-lasting pavement.
- ✓ Enough strength to withstand shear deformation while being subjected to traffic at the increased temperature.
- ✓ The bitumen has enough air gaps to allow for extra compaction by traffic.
- ✓ Enough workability to allow for simple placement without segregation.
- ✓ Sufficient flexibility to prevent early cracking brought on by repetitive traffic bending.
- ✓ Sufficient flexibility at low temperatures to prevent shrinkage cracks.

➢ *Marshall Mix Design*

The mix design (Dry mix) determines the optimum bitumen content. There are many methods available for combination design that alters test specimen size and compaction, and other test specifications. Marshall's Method of mix design is the most popular.

The performance prediction metric for the Marshall Mix design method is provided by the Marshall Stability and flow test. The maximum load that the test specimen can sustain while being loaded at a rate of 50.8mm per minute is measured during the stability section of the test. The specimen is loaded up until it breaks, and the maximum load is considered stability. A dial gauge that is affixed to the specimen measures the plastic flow (deformation) that results from loading. When the maximum load is recorded, the flow value is also recorded in 0.25mm (0.01 inch) increments at the same time.

- *Objectives*

- ✓ To find the Optimum Bitumen percentage for VG-30 by using the Marshall Mix design.
- ✓ The objective of the Design of the Bituminous mix is to determine an economical blend through several trail mixes.

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- ✓ The gradation of aggregates and the corresponding binder should be such that the resultant mix should satisfy stability, flexibility, and workability.

II. LITERATURE REVIEW

A. General

There are many methods of mixture design for bituminous concrete wearing courses.

One of these widely used techniques is the Marshall's Technique of Mix Design.

- ➢ *Marshall Mix Design as per MORTH specification:*

Marshall Mix Design :

- *Overview:*

Bituminous mixes should be stable, durable, flexible, and workable and should offer sufficient skid resistance. The mix consists of coarse and fine aggregates, fillers, and binders. Depending on the criteria, it may be well-graded, open-graded, gap-graded, or unbounded. As far as possible, it should be economical also. Dry mix design and wet mix design are the two different types of mix design. In this project, a dry mix design is used.

Determine how many different sizes of mineral aggregates to use in a dry mix to achieve the highest possible density. Three crucial steps are involved in the dry mix design: the choice of aggregates, the gradation of the aggregates, and the proportion of aggregates.

- *Selection of Aggregates:*

A bituminous paving mixture's desirable characteristics depend in large part on the type of aggregates employed. Coarse, fine, and filler aggregates are the three categories. Because of the interlocking and frictional resistance of nearby particles, coarse aggregates play an important role in enhancing the stability of a bituminous paving mixture. Sand or fines, which fill the spaces between coarse aggregates, also contribute to stability failure. Mineral filler is typically thought of as a void-filling substance. When opposed to gravel and rounded sands, crushed aggregates and sharp sands make a combination that is more stable.

- *Specimen Preparation:*

The temperature of 1200g of aggregate and filler is raised to 150–170°C. With the first trial percentage of bitumen (let's say 4 or 4.5% by weight of the mix), bitumen is heated to a temperature of 150-165°C. At a temperature between 150 and 165 °C, the heated aggregates and bitumen are properly combined. The mixture is poured into a heated mould and rammed with 75 blows.

Table 1 Mixing, Laying and Rolling Temperatures for Bituminous Mixes as per MORTH (5th revision)

Bitumen viscosity grade	Bitumen temperature	Aggregate temperature	Mixed material temperature	Laying temperature	*Rolling temperature
VG-40	160-170	160-175	160-170	150 Min	100 Min
VG-30	150-165	150-170	150-165	140 Min	90 Min
VG-20	145-165	145-170	145-165	135 Min	85 Min
VG-10	140-160	140-165	140-160	130 Min	80 Min

- ➢ *Determination of Marshall Stability and Flow:*

When a test specimen is heated to a specific temperature, placed in a specified test head, and subjected to a constant load, its Marshall stability is the highest load needed to cause failure (5 cm per minute). Dial gauge is used to assess the specimen's vertical deformation as the stability test is being conducted. The specimen's Marshall flow value is the amount of deformation at the failure point measured in units of 0.25 mm.

- ➢ *Preparation of graphical plots:*

The following graphical graphs are created after calculating the average value of the aforementioned attributes for each mix with a varying bitumen content:

- Binder content versus corrected Marshall stability
- Binder content versus Marshall flow
- Binder content versus percentage of void (Vv) in the total mix
- Binder content versus voids in mineral aggregates (VMA)
- Binder content versus unit weight or bulk specific gravity (Gm).

- ➢ *Determination of Optimum Bitumen Content:*

- By averaging the following three bitumen contents that were used to create the graphs acquired in the previous phase, you may determine the ideal binder content for the mix design.
- Binder content corresponds to maximum stability.
- Binder content corresponds to maximum bulk specific gravity (Gm).
- Binder content corresponds to the median of designed limits of percent air voids (Vv) in the total mix.
- The Marshall mix design specification chart, which is shown in the table below, is used to verify the stability value, flow value, and VMA. Mixtures with very high stability values and low flow values should not be used since they increase the risk of pavement cracking from large moving loads.

III. MATERIALS AND EXPERIMENTATION

A. *Materials*

The different materials used in the binder course are as follows:

- *Bitumen*
- *Aggregate*
- *Stone Dust*
- *Filler*

- *Bitumen:*

A typical binder used in the construction of roads is bitumen. It is mostly produced at petroleum refineries as a residual product following the removal of higher fractions such gas, petrol, kerosene, diesel, etc.

- *Bitumen Grading in India : Grading Systems :*

Physical characteristics are the most typical way that bituminous binders are described.

- *Penetration Grading :*

In order to describe the consistency of semi-solid asphalts, the penetration grading method was created in the early 1900s. Committee D04 on Road and Paving Materials of the American Society for Testing and Materials (ASTM) adopted the grading of bitumen by penetration test at 250C in 1903. According to the standard IS:73-1992, the following asphalt concrete parameters must be assessed in order to estimate the penetration grading;

- ✓ The penetration depth of a 100g needle; at 25°C
- ✓ Flashpoint, °C
- ✓ Softening point °C Penetration ratio Ductility at 25°C, cm
- ✓ Viscosity at 60°C and 135°C
- ✓ Water content
- ✓ Specific gravity at 27°C

- *Viscosity Grade:*

An enhanced asphalt grading system was created in the early 1960s and included a logical, scientific viscosity test. The empirical penetration test was replaced by this scientific test as the primary characterisation of the asphalt binder.

- ✓ The following properties of asphalt concrete are assessed in accordance with IS to qualify the viscosity grading: 73-2006
- ✓ Absolute viscosity poises at 60 °C Kinematic viscosity in cSt at 135 °C Quick point
- ✓ Trichloroethylene-based solubility 100g needle penetration depth at 25°C the breaking point
- ✓ Experiments on thin film oven residue (RTFOT); ductility at 25°C and the viscosity ratio at 60°C, cm Four grades are availabe namely VG-10, VG-20, VG-30 and VG-40

- *Aggregates*

- *Overview*

The term "aggregate" refers to the group of mineral components, such as sand, gravel, and crushed stone, that are combined with a binder (such as water, bitumen, Portland cement, lime, etc.) to create compound materials (such as bituminous concrete and Portland cement concrete). Between 70 and 80 percent of Portland cement concrete and 92 to 96 percent of bituminous concrete are typically made up of aggregate. For both flexible and rigid pavements, aggregate is also utilised for base and sub-base courses. Aggregates can be created artificially or naturally. Larger rock formations are typically mined for natural aggregates using an open excavation (quarry). Usually, mechanical crushing is used to reduce extracted rock to sizes that may be used. Aggregate that has been manufactured is frequently a byproduct of other industrial sectors. This chapter also covers the specifications for the pavement's aggregates.

- *Classification of Aggregates:*

The aggregates are divided into different groups based on size:

- ✓ *Coarse Aggregate*
- ✓ *Fine Aggregate*

- ✓ *Coarse Aggregate:*

Crushed rock, crushed gravel, or other hard material retained on the 2.36mm filter must make up the coarse aggregates. They must be free of dust, soft or friable materials, organic material, and other harmful substances. They must also be sturdy, rigid, and cubical in shape. Since the Contractor's chosen source of aggregates has a low affinity for bitumen, the aggregates must be tested for stripping in order for that source to be approved. The aggregates must meet the physical specifications for dense bituminous macadam listed in table 500-8.

- ✓ *Fine Aggregate:*

Crushed or naturally occurring mineral material that has passed through a 2.36mm sieve and been kept on a 75-micron sieve constitutes fine aggregate, as does a mixture of the two. They must be free of dust, soft or friable matter, organic material, or any other harmful material. They must also be clean, hard, durable, dry, and free of hard, soft, or brittle material. When evaluated according to IS:2720 specifications, the fine aggregate must have a sand equivalent value of at least 50. (Part 37). The percentage passing through the 0.425mm sieve must have a plasticity index of no more than 4.

ISSN No:-2456-2165

Table 2 Requirements of Aggregates as per MORTH (5th revision)

Grading	1	2
Nominal aggregate size*	19 mm	13.2 mm
Layer thickness	50 mm	30-40 mm
IS Sieve (mm)	Cumulative % by weight of total aggregate passing	
45		
37.5		
26.5	100	
19	90-100	100
13.2	59-79	90-100
9.5	52-72	70-88
4.75	35-55	23-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	8-20	18-28
0.15	5-13	12-20
0.075	2-08	4-08
Bitumen content % by mass of total mix	Min 5.2*	Min 5.4**

- *Desirable Properties Strength*

The aggregates used in the top layers are stressed as a result of wheel weight from traffic and wear and tear crushing. Aggregates should have a strong resistance to crushing and be able to bear strains from traffic wheel load in order to produce high-quality pavement.

- *The experiments carried out on the aggregates to establish their parameters are listed below.*

- ✓ Hardness
- ✓ Toughness
- ✓ Shape of aggregates
- ✓ Adhesion with bitumen
- ✓ Durability

- *Freedom from Deleterious Particles:*

The majority of specifications for aggregates used in bituminous mixes call for the aggregates to be free of excess dust, clay balls, flat or elongated pieces, and other undesirable material. They also need to be robust and resilient. Comparable requirements must apply to aggregates used in Portland cement concrete mixes, which must be clear of harmful materials such clay lumps, chert, silt, and other organic contaminants.

The total grading of the coarse and fine aggregates and any added filler for the specific mixture shall fall within the limitations stated in the table, for dense bituminous macadam grading 1 or 2 as defined in the contract, as tested by IS:2386 Part 1 (wet sieving method). For each sort of mixture, the type and quality of bitumen as well as the necessary thickness are also mentioned.

- *Dust*

The majority of the aggregate's thickness exceeds 4.75mm. is a sieve and only holds the amount of coarser that the specification allows. The fine aggregate, according to the source, is best described as:

Natural Sand - Natural Sand is a sedimentary material that has been left behind by glaciers or streams after rock has naturally broken down.

- ✓ Crushed Stone Dust - It is the fine aggregate produced by crushing hard stones.
- ✓ Crushed Gravel Sand - It is the fine aggregate produced by crushing natural gravel.

- *Fillers:*

In this study, four filler types—LSD (limestone dust), CWD (ceramic waste dust), CFA (coal fly ash), and SSD (steel stag dust)—were evaluated by direct comparison with varied particle sizes (passing 75 m and 20 m) and filler proportions (100/0, 50/0, and 0/100). Fillers were powdered and crushed to pass through 0.075 mm and 0.02 mm standard sieve diameters.

- *Calculations of Quantities*

Calculations of the quantity of Bitumen required for Optimum Bitumen trials:

- ✓ 4% of 1200gm of aggregate = 48gm
- ✓ 4.5% of 1200gm aggregate = 54gm
- ✓ 5% of 1200gm aggregate = 60gm
- ✓ 5.5% of 1200gm aggregate = 66gm
- ✓ 6% of 1200gm aggregate = 72gm
- ✓ For each trail Bitumen required is =300gms.
- ✓ No of Trails = 3
- ✓ Total Bitumen content =900gms

- *Quantity of Aggregate Required :*

Table 3 Quantity of Aggregates Required for Blending

Sieve Size(mm)	% of passing	% weight retained	Weight of aggregate	Cummulative of aggregates
19	100	0	0	0
13.2	91.48	8.52	96.67	96.67
9.5	86	5.48	62.18	158.84
4.75	67.57	18.43	209.11	367.95
2.36	46.13	21.44	243.26	611.21
1.18	37.16	8.97	101.77	712.98
0.6	29.36	7.8	88.5	801.48
0.3	21.03	8.33	94.51	895.99
0.15	16.25	4.78	54.23	950.23
0.075	5.99	10.26	116.41	1066.64

B. Experimentaion

- *Tests on bitumen*

The characteristics of bituminous materials can be evaluated using a variety of tests. The following tests are typically carried out to assess various bituminous material qualities.

- Penetration test
- Ductility test
- Softening point test
- Specific gravity test
- Viscosity test
- Flash point test
- Float test
- Water content test
- Loss on heating test

➢ *Tests on Aggregates:*

- *Aggregate Tests:*

The following tests are conducted to determine whether the aggregate is suitable for use in the building of pavements:

✓ Abrasion test
✓ Impact test
✓ Soundness test
✓ Shape test
✓ Bitumen adhesion test

- *Results:*

Table 4 : Physical properties of the aggregate

Property	***Test***	***Test method***	***Results***
Strength	Los Angeles Abrasion Value	IS 2386 Part IV	20%
	Aggregate Impact Value		19%
Shape test	Flakiness index	IS 2386 Part I	8.50%
	Elongation index		9.20%
Specific Gravity	Coarse aggregate	IS 2386 Part III	2.68
	Fine aggregate		
	Stone Dust		

➢ *Marshall Test Procedure as Per ASTM D6927-06:*

The Marshall stability test-flow test on bitumen was developed by the Mississippi State Highway Department and is used with hot mix designs including bitumen and aggregates with a maximum size of 2.5 cm. The Marshall Method is frequently used in India to create bituminous concrete mixtures. This test is frequently included in testing regimens for pavement projects.

Maximum load carried by a compacted specimen at a standard test temperature of 600C is used to determine the mix's stability. The flow is calculated as the difference in shape between the specimen's no-load and maximum load during the stability test, expressed in units of 0.25 mm (flow value may also be measured by deformation units of 0.1 mm).

The goal of this test is to determine the ideal binder content given the kind of aggregate mix and traffic volume. This test aids in the calculation of Marshall Stability vs. percent bitumen.

Apparatus: The total vertical moment upward should be precisely measured by the flow meter's dial gauge. Equipment such as a hot plate or oven, a water bath, thermometers with a temperature range of 200°C and a sensitivity of 2.5°C, and other items including containers, mixing implements, and handling tools.

- *Preparation of Test Specimen*

✓ Measured and baked in the oven to the mixing temperature are 1200 gram of aggregates mixed in the required ratios.
✓ At the mixing temperature, bitumen is added to provide a viscosity of 170 centistokes at varying percentages.
✓ A hot pan and heated mixing implements are used to combine the ingredients.
✓ In order to achieve a viscosity of 28030 centistokes, the mixture is put back into the oven and heated to the compacting temperature.
✓ The slurry is then spaded all the way around the sides of a heated Marshall mould with a collar and base. The sample is put on top of and underneath a filter paper.
✓ The Marshall compaction pedestal is where the mould is set.
✓ The sample is inverted and compressed on the opposite face with the same number of hammer blows after the material has been crushed with 50 (or as directed) blows.
✓ The mould is inverted after compression. The base is removed using the collar on the bottom, and the sample is extracted by pushing it out of the extractor.
✓ The sample is left to stand and cool for a few hours.
✓ To determine the specimen's density and calculate the void characteristics, the sample's mass in air and while immersed is employed.


Fig 1 Mixing of Different Size Aggregates by weight


Fig 2 Heating of Aggregates

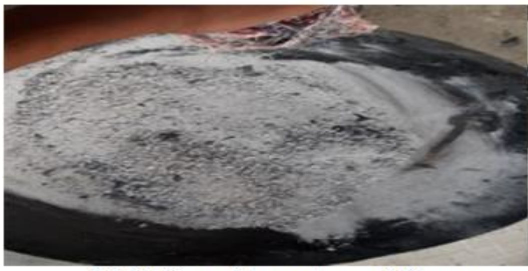


Fig 3 Mixing of Aggregates and Bitumen


Fig 4 Placing of Aggregates and Bitumen in The Mould After Mixing


Fig 5 Compaction of Specimen


Fig 6 Marshall Stability test apparatus

IV. RESULTS AND DISCUSSION

➢ *General :*

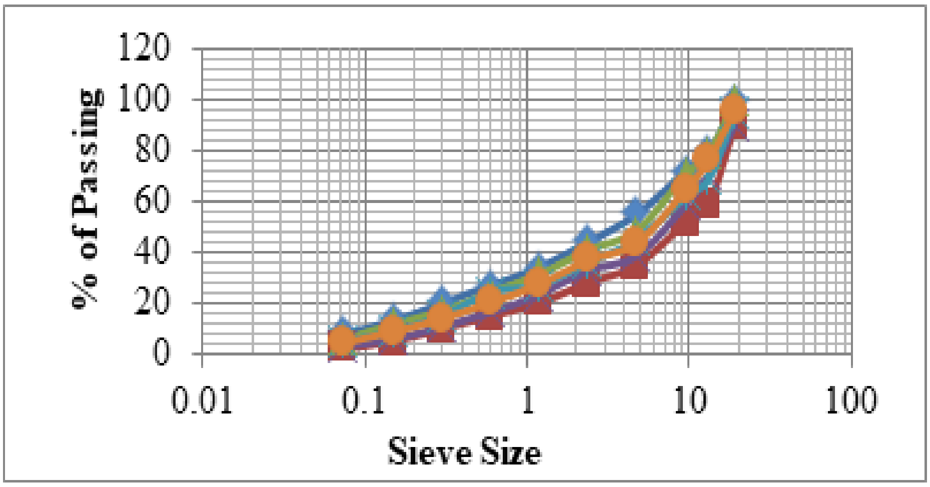
As a performance prediction metric, the bituminous mixture underwent the Marshall stability test. The procedure involves measuring the bitumen properties of the mix, including penetration depth, flash point, softening point, ductility, and viscosity; aggregates; Marshall stability and Flow analysis; and, lastly, determining the OPTIMUM BITUMEN CONTENT. Calculations are performed using the idea of a phase diagram.

- *Results :*

Table 5 Gradation and Blending of Aggregates

Sieve Size (mm)	% of passing				Design Proportions					
	20mm	10mm	6mm	Dust	20mm	10mm	6mm	Dust	Cement	% of Passing
					28	10	20	40	2	
26.5	**100**	**100**	**100**	**100**	**28**	**10**	**20**	**40**	**2**	**100**
19	85.26	100	100	100	23.87	10	20	40	2	**95.87**
13.2	16.24	99.38	100	100	4.55	9.94	20	40	2	**76.49**
9.5	1	25.25	100	100	0.28	2.53	20	40	2	**64.81**
4.75	0.34	0.32	8.16	99.8	0.1	0.03	1.63	39.9	2	**43.66**
2.36	0	0	1.18	86.6	0	0	0.24	34.62	2	**36.86**
1.18	0	0	0.86	62.9	0	0	0.17	25.14	2	**27.31**
0.6	0	0	0	46	0	0	0	18.38	2	**20.38**
0.3	0	0	0	29.6	0	0	0	11.82	2	**13.82**
0.15	0	0	0	17.1	0	0	0	6.82	2	**8.82**
0.075	0	0	0	5.95	0	0	0	2.38	2	**4.38**

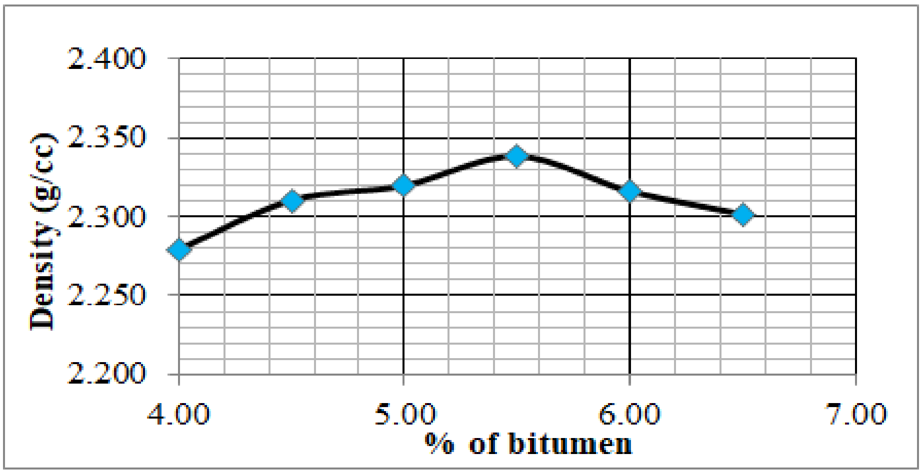
ISSN No:-2456-2165



Graph 1 Gradation of Aggregates

Table 6 Values of Density, % Air Voids, VMA VFB, Stability and flow

Bitumen content %	Density g/cc	Air voids (%)	VMA (%)	VFB (%)	Stability (in Kn)	Flow in mm
4.00	2.279	8.10	16.48	50.86	1060	1.5
4.50	2.310	6.19	15.78	60.80	1205	2.0
5.00	2.320	5.15	15.88	67.61	1252	2.8
5.50	2.338	3.72	15.66	76.25	1434	3.2
6.00	2.316	3.97	16.46	75.86	1183	3.9
6.50	2.302	3.91	16.98	76.95	1038	4.3



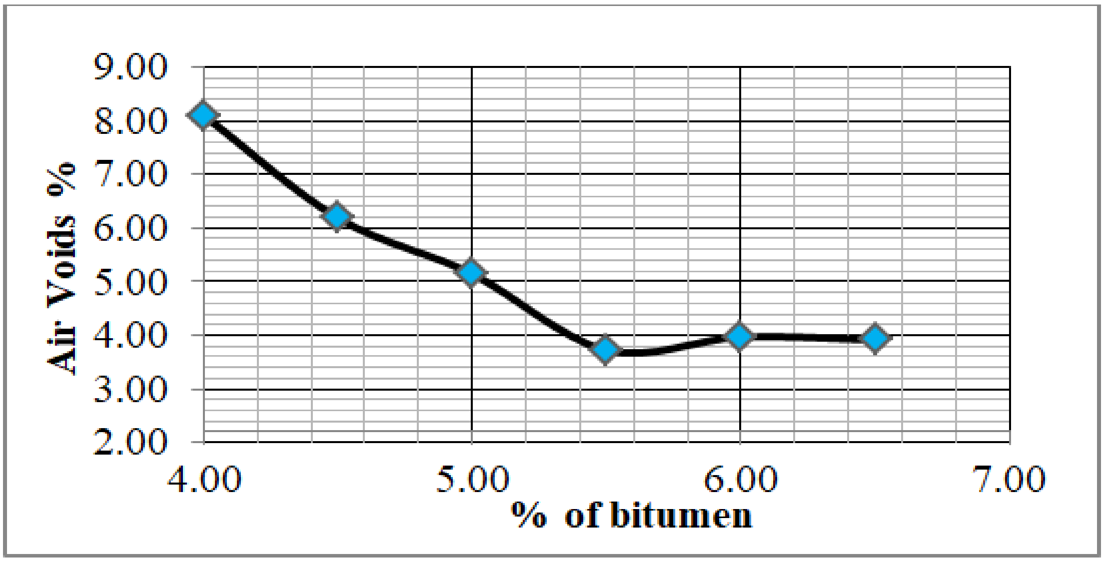
Graph 2 Bitumen Content VS Bulk Density

ISSN No:-2456-2165

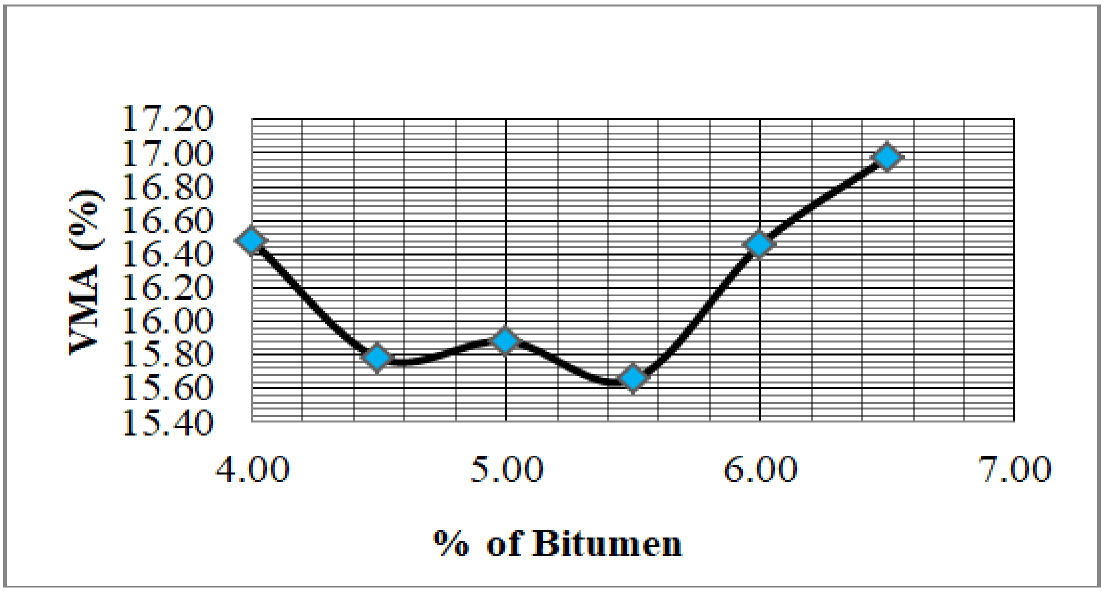
Table 10 Combined Blending and Calculation of Bulk Specific Gravity, VMA, VFM, % Air Voids, Stability and Flow

SAMPLE NO	AGG. % BY TOTAL WEIGHT OF MIX	BITUMEN % BY TOTAL WEIGHT OF MIX	Max. SP. GR. OF MIX	Mass of Specimen in gms.			Thickness of specimen (mm)	stability correction Ratio	BULK VOL (cc)	BULK Density Of COMPACTED MIX	% AIR VOIDS (3-6)/3 X 100	% V.M.A 100-[(6 X 1)/Gsb]	% VFB (8-7)/8 X 100	STABILITY Kgs.		FLOW (mm)
				Weight in air (gms)	Weight in Water (gms)	SSD Weight (gms)								LOAD	Stability	
	1	2	3	4					5	6	7	8	9	10	11	12.00
1				1250.2	704	1251.2	68.8	0.880	547.2	2.285	7.88	16.28	51.58	335	1044	1.80
2				1250.9	701.1	1251.9	68.1	0.890	550.8	2.271	8.44	16.79	49.75	342	1078	1.30
3				1249.8	703.2	1250.8	66.2	0.880	547.6	2.282	7.98	16.37	51.25	340	1059	1.40
Average	**96**	**4.00**	**2.480**				**67.7**			**2.279**	**8.10**	**16.48**	**50.86**	**339.00**	**1060**	**1.5**
4				1249.9	709.2	1250.5	65.1	0.910	541.3	2.309	6.24	15.83	60.56	372	1198	2.01
5				1249.8	710.2	1250.9	64.8	0.920	540.7	2.311	6.15	15.75	60.96	368	1199	2.00
6				1250.2	710.5	1251.5	65.2	0.930	541	2.311	6.17	15.77	60.87	370	1218	2.04
Average	**95.5**	**4.50**	**2.463**				**65.0**			**2.310**	**6.19**	**15.78**	**60.80**	**370.00**	**1205**	**2.0**
7				1250.2	712.2	1251.2	63.2	0.920	539	2.319	5.16	15.90	67.54	392	1277	2.80
8				1249.9	711.2	1250.2	63.2	0.910	539	2.319	5.18	15.92	67.44	391	1260	2.90
9				1249.7	711.9	1250.3	63.5	0.880	538.4	2.321	5.09	15.84	67.84	392	1221	2.80
Average	**95**	**5.00**	**2.446**				**63.3**			**2.320**	**5.15**	**15.88**	**67.61**	**391.67**	**1252**	**2.8**
10				1248.9	715.5	1249.8	64.3	0.930	534.3	2.337	3.76	15.69	76.04	432	1422	3.20
11				1249.2	715.9	1250.2	63.8	0.930	534.3	2.338	3.74	15.67	76.16	435	1432	3.10
12				1250.2	716.9	1251.2	63.3	0.930	534.3	2.340	3.66	15.60	76.55	440	1449	3.30
Average	**94.5**	**5.50**	**2.429**				**63.8**			**2.338**	**3.72**	**15.66**	**76.25**	**435.67**	**1434**	**3.2**
13				1251.1	712.2	1252.2	62.5	0.910	540	2.317	3.95	16.43	75.98	365	1176	3.90
14				1250.1	711.5	1251.1	63.8	0.920	539.6	2.317	3.95	16.44	75.96	367	1195	4.10
15				1250.2	711.2	1251.2	64.3	0.910	540	2.315	4.02	16.49	75.65	366	1179	3.80
Average	**94**	**6.00**	**2.412**				**63.5**			**2.316**	**3.97**	**16.46**	**75.86**	**366.00**	**1183**	**3.9**
13				1250.2	706.9	1251.1	63.1	0.950	544.2	2.297	4.10	17.14	76.07	314	1056	4.20
14				1251.1	708.9	1252.2	64.2	0.930	543.3	2.303	3.87	16.94	77.13	311	1024	4.40
15				1250.2	708.9	1251.2	63.1	0.940	542.3	2.305	3.77	16.85	77.65	311	1035	4.30
Average	**93.5**	**6.50**	**2.396**				**63.5**			**2.302**	**3.91**	**16.98**	**76.95**	**312.00**	**1038**	**4.3**

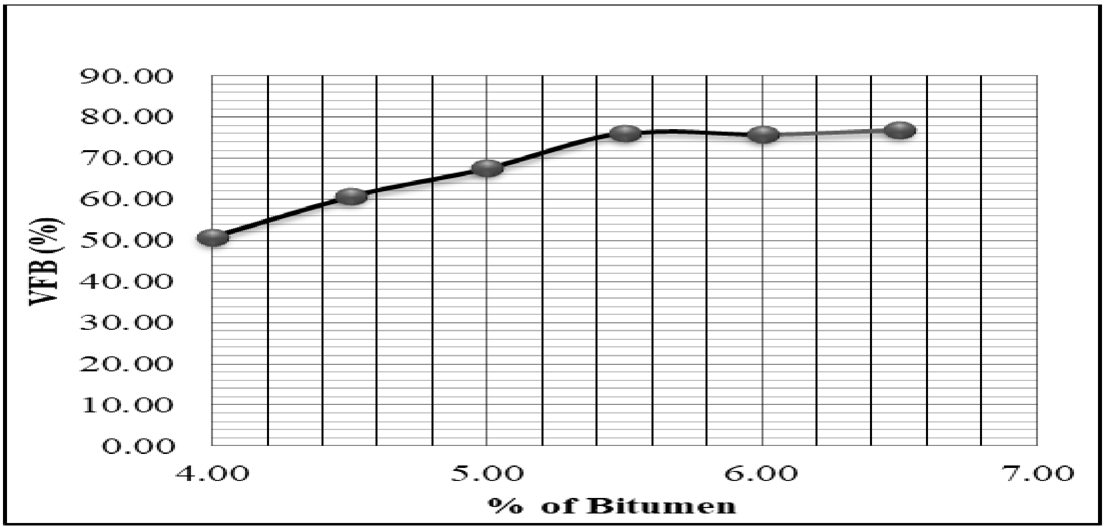
ISSN No:-2456-2165



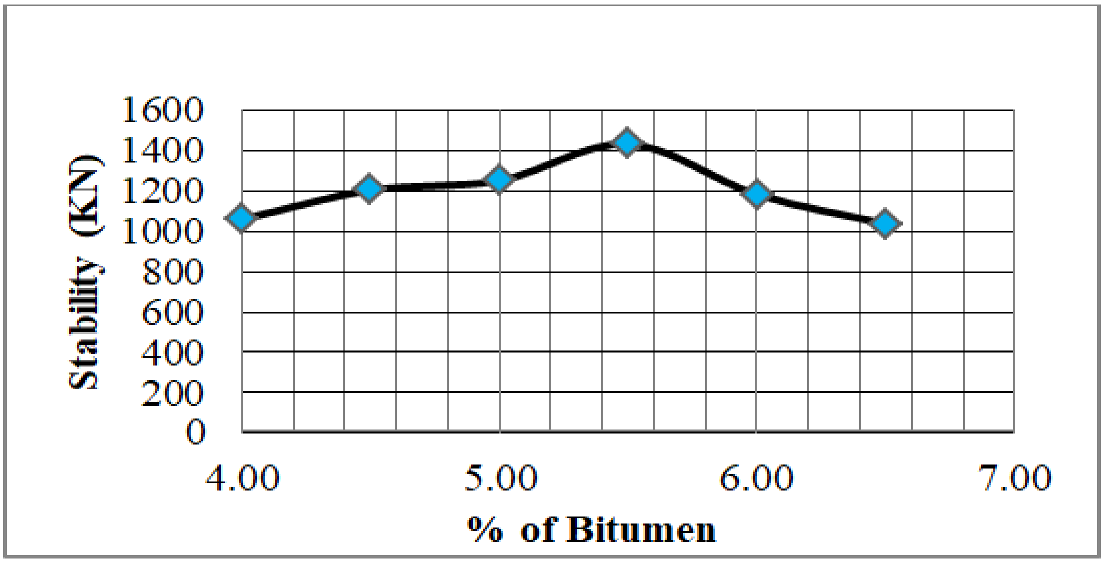
Graph 3 Bitumen Content VS Air Voids



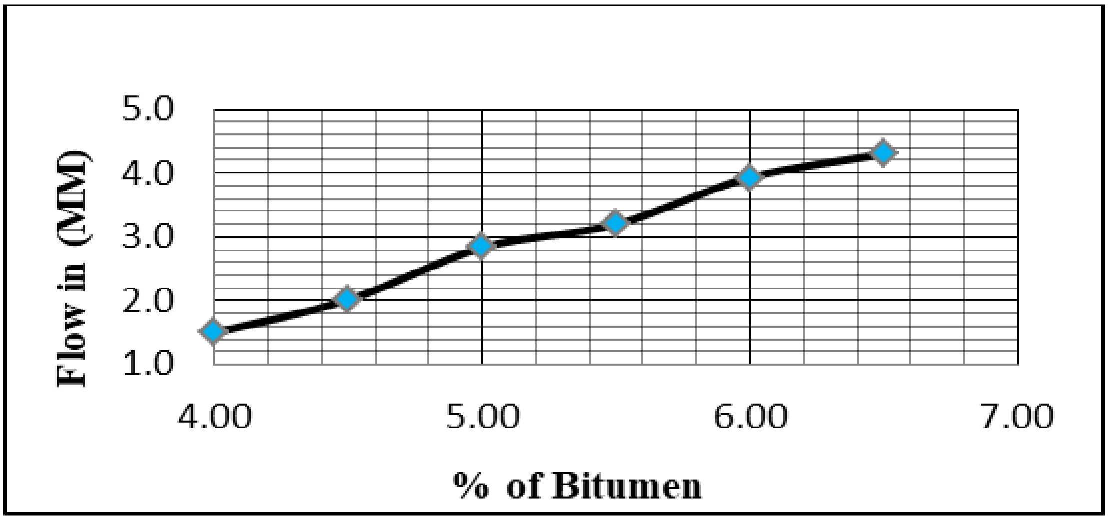
Graph 4 Bitumen Content VS VMA



Graph 5 Bitumen Content VS VFB



Graph 6 Bitumen Content VS Stability



Graph 7 Bitumen Content VS Flow

➢ *Results from Graphs :*

- GRAPH 2: The maximum density of mix is 2.34 g/cc is obtained at Bitumen content of 5.50%.
- GRAPH 3: The minimum % Air voids value is 3.8% is obtained at Bitumen content of 5.50%.
- GRAPH 4: The minimum VMA value is 15.6% is obtained at Bitumen content of 5.50%
- GRAPH 5: The maximum VFB value is 76.96% is obtained at Bitumen content of 6.50%.
- GRAPH 6: The maximum stability value is 1434 is obtained at Bitumen content of 5.50%.
- GRAPH 7: The optimum Flow value is 2.8-3.2 which is obtained in the range of 5.0-5.5% of bitumen content.
- RESULT : The optimum bitumen content is acquired as 5.33

V. SUMMARY AND CONCLUSIONS

➢ *Summary of the Project:*

- Gathered information about the project by studying the literature.
- Calculated the number of materials required for the project.
- Collected apparatus and materials required for the project.
- Conducted empirical tests like penetration, softening point, and ductility tests on VG-30.
- Conducted empirical tests like Los Angeles Abrasion Test, Specific Gravity, Impact Test, Elongation test, Flakiness test, and Crushing Test on aggregates.
- The casting of Marshal Specimens with different bitumen contents for VG–30.
- Conducted Marshal Test to the above specimens and obtained with Optimum Bitumen Content for VG-30.
- Conducted Marshal Test to the above specimens and obtained the best results.
- Conclusions were drawn based on the above results.

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