# EVALUATING THE VIABILITY OF MOLASSES ON PENETRATION GRADE OF BITUMEN AND BITUMINOUS MIX DESIGN

**Submitted in partial fulfillment of the requirements**

**of the degree of**

**MASTER OF TECHNOLOGY**

**in**

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**by**

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**LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA**

**2017**

# DECLARATION

I, Shivek Sharma (11501897), hereby declare that this thesis report entitled **"Evaluating the viability of molasses on penetration grade of bitumen and bituminous mix design"** submitted in the partial fulfillment of the requirements for the award of degree of Master of Civil Engineering, in the School of Civil Engineering, Lovely Professional University, Phagwara, is my own work. This matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

**Date:** **Shivek Sharma**

**Place:**

# CERTIFICATE

Certified that this project report entitled "Evaluating the viability of molasses on penetration grade of bitumen and bituminous mix design" submitted individually by student of School of Civil Engineering, Lovely Professional University, Phagwara , carried out the work under my supervision for the Award of Degree. This report has not been submitted to any other university or institution for the award of any degree.

**Signature of Supervisor**

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# ABSTRACT

The objective of this research is to evaluate the viability of molasses on penetration grade of bitumen and bituminous mix design. In this research work molasses is used in the bituminous mix design by doing the partial replacement of bitumen. As we all know bitumen is a petroleum product and nowadays temperature of the pavement is getting increased more than 50 degrees in summer and in such situation the rainfall is very dangerous for bituminous pavements because bitumen is a petroleum product. So by using waste material like molasses we can save our environment by considering our main global objective that is "ZERO EMISSION". By this investigation it was found that the modified bituminous mix having enhanced and better Marshal Characteristics as compared to the conventional bituminous mix. It was observed that the stability value of the marshal mix increases up to 12% and then decreases. The flow value of the mix decreases as per the addition of molasses. The other volumetric parameters such as volume of voids (Vv), volume of bitumen (Vb), voids in mineral aggregates (VMA), and voids filled with bitumen (VFB). By addition of molasses in bitumen it was found that up to 10% the value of penetration is within the penetration range of 60/70, but when the percentage of molasses exceeds from 10% to 12% and above its showing drastic change in the penetration value of VG30 grade of bitumen corresponding to 80/100 penetration grade which is used as a penetration grade of VG10. So, we can come to the conclusion that after adding more than 10 percent of molasses in bitumen (VG30) the grade of the bitumen changes from 60/70 to 80/100 which is same as the VG10 grade of the bitumen. So, as per the penetration test, we can relate that the viscosity of the bitumen (VG30) is getting reduced if the molasses is added more than 10% in the bitumen and it's showing the characteristics of VG10 grade of bitumen and the VG30 grade of bitumen losses its actual property. By this investigation the molasses is not only utilized beneficially, but it also improved the pavement characteristics such as road safety, defects, long life of flexible pavements, stability, recycling of sugarcane waste and most important environment.



**Keywords**: molasses, partial replacement, bitumen mix design, sugarcane waste, penetration grade, flexible pavements, DBM, wearing course

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# List of abbreviations

| Abbreviations | Full form |
|---|---|
| VG | Viscosity grade |
| CTM | Compressive testing machine |
| Rpm | Rotation per minute |
| % | Percentage |
| Com. | Cumulative |
| STD | Standard specifications |
| DBM | Dense Bituminous Macadam |
| MIN | Minute |
| Cm | centimeters |
| Mm | millimeters |
| Gm | Bulk specific gravity |
| Gt | Theoretical specific gravity |
| Vv | Volume of voids |
| Vb | Volume of voids filled with bitumen |
| VMA | Voids in mineral aggregates |
| VFB | Voids filled with bitumen |
| OBC | Optimum binder content |
| OMC | Optimum molasses content |
| KG | Kilograms |
| KN | Kilo-Newton |

# CHAPTER 1

# 1. INTRODUCTION

## 1.1 OVERVIEW:

Pavement is a structure that lies above the natural soil sub-grade and consist of superimposed layers of processed materials. On one hand it should be able to withstand the applied vehicle load by distributing it to the sub grade while on the other hand it must ensure that the transmitted stresses due to wheel load are sufficiently reduced so that they will not exceed bearing capacity of the sub-grade. It must also possess acceptable riding quality, favorable light reflecting characteristics, low noise pollution and adequate skid resistance. Two types of pavements are generally recognized namely flexible pavements and rigid pavements, each of them having their own pros and cons in terms of their structure, design life, construction period, etc. Flexible pavements are also called asphalt pavements/bituminous pavements and they have low manufacturing cost as well as good riding quality. The transfer of load in flexible pavements is from grain-to-grain/layer-to-layer. Flexible pavements are generally used in construction of normal roads, highways etc. Rigid pavements are having good resistance against bending and the transfer of load is through slab action. Rigid pavements are used where there is high volume of traffic and where the sudden load (impact load) is high in frequency. The material used for the construction of flexible pavements is bitumen, aggregates and fillers. Stability, durability and resistance against skid depend upon the type and quality of material that we are going to use in our pavements.

## 1.2 SCOPE OF THIS STUDY:

Bitumen pavements are flexible pavements and their stability and OBC are only determined by using Marshall Test. There are still various other tests and experiments that should be conducted to check out for the other properties that are enhanced by molasses as a partial replacement with bitumen like viscosity grading, stripping test, penetration, softening point etc and also use of waste materials like molasses as a partial replacement in different grades of bitumen for making less impact on environment and making things eco-friendly. So a lot of work can be done in this research area and economical yet efficient infrastructures can be built.

## 1.3 OBJECTIVES OF THE STUDY:

A pavement if not designed properly deteriorates fast, so some forethought is necessary before we embark on the project. Proper and efficient resources are chosen so that the lifetime of the pavement can be increased. In India, 98% of the roads are having flexible pavements. To reduce the cost of construction a holistic approach was required, so a lot of research has been made on the use of waste materials like fly ash, coal bottom ash, boiler slag, stone dust, egg shell, molasses etc. It has been observed that the partial or full replacement with these waste materials can not only reduce the cost of construction but also enhance the properties of bitumen mix. The objective of this study is to check the effect of molasses on the VG30 grade of bitumen by doing partial replacement with bitumen and to check what will be the effect on the penetration grade, viscosity grade and marshal stability of mix design.

# CHAPTER 2

## 2. REVIEW OF LITERATURE:

A study done by **Metin Guru, Denzin arsalan**, on sugar beet molasses and molasses-based boron oxide compound Molasses-based boron oxide is a synthetic material obtained chemically in laboratory conditions by using proper amounts of sugar beet molasses and boron oxide. Each material was used by percentage replacement with 50/70 grade of bitumen and they found that the performance using molasses-based boron oxide compound was improved and remain same with the use of sugar beet molasses[2]

A study done by **Sameer Vayas, Neelam Phogat** on dispersive soils because they are having low bearing capacity and prone to erosion and they used different materials for soil stabilization like fly ash, molasses etc and they found remarkable stabilization with these wastes and polymers[3]

A research has been done with percentage replacement of bitumen mix with molasses by **S.RAM SURYA, J. NARESH** in which they have used molasses with percentage replacement in bituminous mix and they have concluded that marshall stability increases up to 13% and then decreases[4]

An article was published on the use of molasses by **Clarence, W.W (1942). U.S Patent No. 2,287,849** for the manufacturing of anti-sticking surfaces because using the high grade of molasses is having similar properties like high viscosity grade bitumen, due to this there is a problem of sticking of high concentrated molasses. So they have given some measures and the percentage range for using the high concentrated molasses so as not to stick with the other surfaces when transported or placed.[5]

A study done on the inventory of various streams in an industrial port and planning by **Mohee,R, Surroop,D, Mudhoo** for post management system because that port area is subjected to wide range of cargo ranging from petroleum products, coal, cement, edible oils, molasses etc. this study shows the suggestions on how to improve the port's environmental performance with respect to waste management were recommended.[6]

A study has been done on the concrete mix by using molasses obtained from paper and sugar industries by **Yildirim,H,&Altun,B**.Use of molasses shows good plasticizing effect on concrete Three molasses obtain from different sugar factories are used in this study at two admixture content, such as 0.4% and 0.7% of cement content. Two types of concretes are prepared with two cement content, such as 270 and 320 kg/m$^3$, in that order [7].

Another research has been done on concrete by **Amanmyrat Jumadurdiyev** and his colleges and they have found that the utilization of beet molasses as a retarding and a water reducing agent and they found that the strength of concrete using molasses is slightly increased at all ages except early age and it show no adverse effect on durability properties for a long period (900 days).[8]

**Study by Abalaka, A. E. (2011)** on effects of molasses with different percentage of 0, 0.05, 0.06, 0.08. 0.10, 0.20, 0.40, 0.60, 0.80 and 1% by weight of cement on cement paste and grade C35 concrete cured at 3,7,14 and 28 days was investigated by ordinary Portland cement. The initial setting time of cement paste was longest at 0.06% sugar content with soundness of 0.35 mm. Flash setting with no increase in strength was observed at sugar content of 0.2- 1%. The compressive strength investigation outcome show some minor strength gains at all ages but peaks at 11.84% at 3 days at 0.05% molasses content.[9]

A research has been done by **Ben, Booth Robert** for increasing the plasticity of the Portland cement which is one of the serious problems in concrete industry. They used the black strap molasses in the range of 0.075% in one batch and they found that the concrete showed 53% increase OS in slump and the strength changes at the end of 7 day and 28 days were -1.6 and +9.3 % and the plasticity was improved respectively.[10]

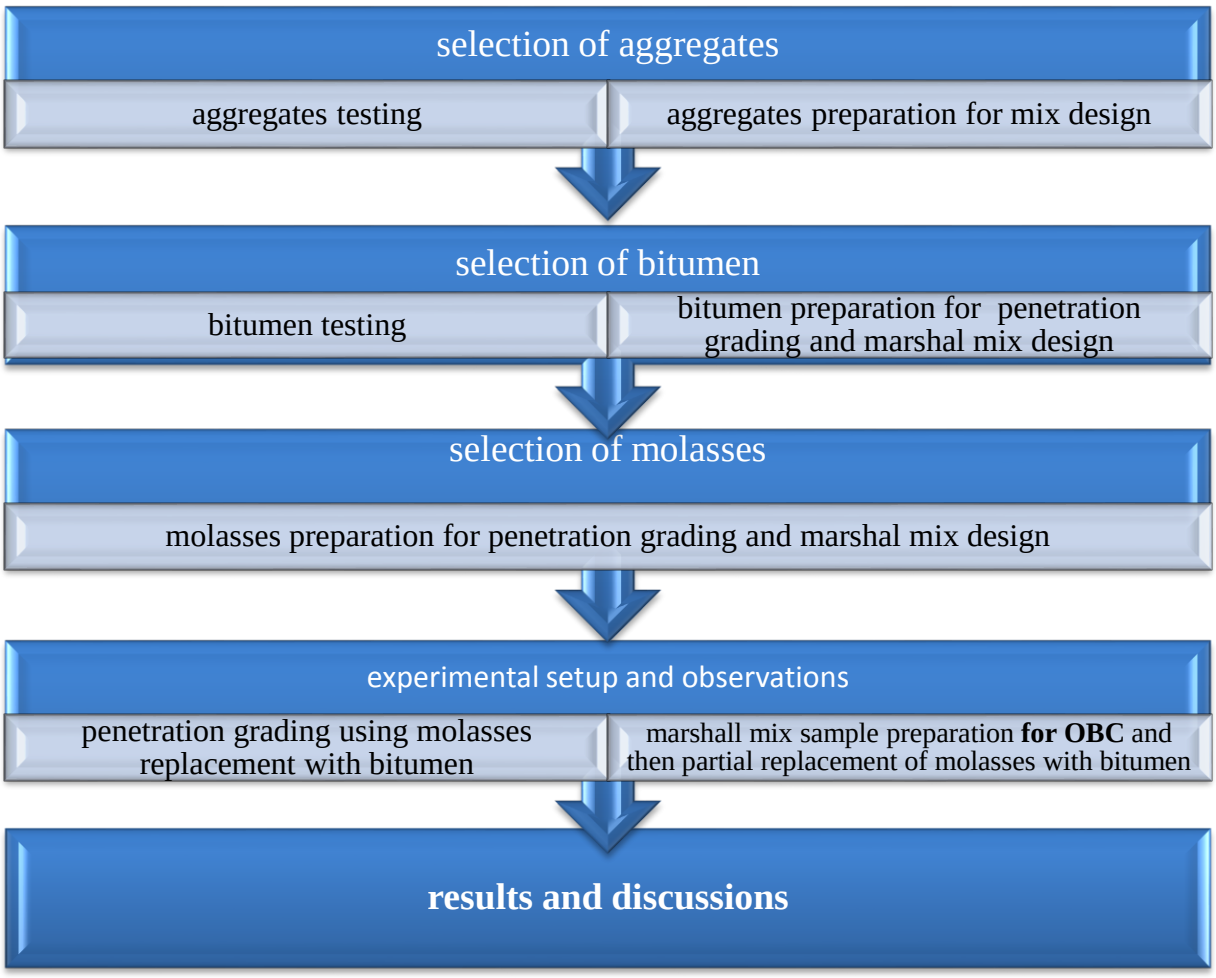
A paper published by **Cem Akar, Mehmet Canbaz** on the effect of molasses as an admixture on concrete durability and they found that by adding molasses as admixture there was a decrease in water cement rates in concrete and having negative effect on durability with the addition of molasses, but they found that all samples didn't exceed the damaging limits of durability so thus for low cost and environment- friendly concrete molasses can be used.[11]

A paper by **Gao, X, Yang, Y., & Deng, H** investigates the viability by using beet molasses as a grinding support for blended cements with high volume of mineral admixtures. A different percentage of beet molasses (0.01–0.05% by weight of cement) was added into a blended cement containing 41% of fly ash and GBFS. The influence of beet molasses on performances of blended cement was premeditated by comparing with one commercially accessible, triethanolamine-based grinding aid (TA). The consequences show that when comparing with the blank cement mixture, the cement containing 0.02–0.03% molasses shows higher compressive strength at 3 days and 28 days, yet greater than the TA mixture. The enhanced microstructure of the molasses customized cement paste was also demonstrated by the pore arrangement and SEM size.[12]

# CHAPTER 3

# 3. RESEARCH METHODOLOGYAND MATERIAL CHARACTERISATION:

## 3.1 RESEARCH METHODOLOGY




## 3.2 WHAT IS MOLASSES

Molasses is another waste material which is obtained from the sugar industries and nowadays it's very popular due to its good properties. Molasses (black treacle) is one of the bi-product comes while refining of sugarcane or sugar beets into sugar. Molasses is differentiated according to the percentage of sugar, extraction method, and the age of the plant where we are doing the refining of the sugarcane.

## 3.3 BASIC CONCEPT AND PROPERTIES OF MOLASSES:

Molasses can be differentiated according to the color range, nutrition content and sweetness. Molasses is having a very high production rate in Caribbean and southern united states, because of very high cultivation of sugar beets and sugarcanes. Molasses is generally made while sugar making process, the juices are extracted from the sugar beets and sugarcane are boiled out unless and until the sugar crystallized and precipitated out. The left residual is called as molasses. The extraction of sugar has three different cycles, and with each cycle the amount of sugar decreases in remaining molasses.

**Figure 3.1** Picture of molasses

## 3.4 TYPES OF MOLASSES:

**1. LIGHT MOLASSES**: This molasses is obtained during the first cycle of extraction of sugar. This molasses is having very light color and contain the maximum amount of sugar in it.

**2. DARK MOLASSES**: This type of molasses is obtained during the second cycling of extraction. It is generally more viscous and darker as compared to light molasses, and the amount of sugar is also less.

**3. BLACK STRAP MOLASSES**: The final product obtained by third cycle of extraction is black strap molasses contain the lowest amount of sugar and the highest amount of vitamins and minerals. It is having the darkest color among all and is extremely viscous in case of texture.

**4. SULFURED AND UNSULFURED MOLASSES**: sulfured molasses is generally that type of molasses which is treated with sulfur dioxide for preservation. For pre-mature sugarcanes this treatment is adopted, so the molasses obtained from matured molasses is unsulfured molasses and its lighter and having good sugar flavor.

## 3.5 Bitumen as a Binder

Bitumen is generally obtained by the fractional distillation of petroleum. Bitumen binder is used for the proper binding of aggregates with overall mix. Bitumen is basically obtained from the fractional distillation of petroleum. It is available in different grades on which 60/70 is considered good for high volume traffic roads. There are some various tests done for bitumen binders. But as per new recommendations viscosity grading is now preferred in place of penetration test, it is because of some issues that we are generally facing with penetration test like in penetration test the temperature at which bitumen is used as a sample for testing, is not maintained constantly throughout the trial with the penetration needle, and when it comes to viscosity test there is a constant temperature of bitumen while performing the test. So viscosity test give more accurate values as compare to penetration grading.

**TABLE 3.1** showing the properties of bitumen (60/70) grade:

| TESTS | STD SPECIFICATIONS |
|---|---|
| Penetration test @25°C | 60/70mm |
| Softening point test | 35-70° C |

Bitumen was taken from the shop situated in Chandigarh named **DELHI BITUMEN AGENC**Y and the grade was adopted VG30


**Fig. 3.2** showing the market from where bitumen VG30 grade is taken

### 3.5.1 TESTS FOR BITUMEN

1. Viscosity test
2. Stripping test
3. Ductility test
4. Penetration test
5. Softening point etc.

**Viscosity test**: This test is basically used to determine the behavior of bitumen under different temperatures i.e. what should the resistance of bitumen against flow, how it's going to perform when there should be high temperature and low temperature or under different climatic conditions.

**Stripping test**: This test is generally used to check the adhesion of bitumen with the aggregates under water condition. This test will be adopted after preparation of marshal samples and some samples will be used to test the adhesion of bitumen with aggregates while partial replacement with molasses and fly ash as filler.

**Ductility test**: After getting the different grades of bitumen from the bitumen market, these grades will be checked under the ductility machine in which their ductility will be determined using standard briquette specimen under specified speed and temperature.

**Penetration test:** This test is generally used to determine the consistency of the bitumen by using a penetration of a standard needle under specified conditions of time and temperature. The penetration is taken as $1/10^{th}$ mm. For penetration grade of 60/70, it means that the penetration value lies between 60 to 70 mm.

## 3.6 AGGREGATES

For the preparation of mix design, the aggregates should have proper strength, hardness, toughness, durability, adhesion with bitumen binder. So there are some tests that are to be performed before selection of aggregates to determine their properties like flakiness and elongation index, crushing test, impact test, soundness test, stripping test etc. [1]

### 3.6.1 PROPERTIES OF AGGREGATES

1. **Strength**: The aggregates should be strong enough to bear the stresses due to traffic wheel load. The aggregates which are mainly used in top layers (wearing course) should be capable to bear the stresses in addition to wear and tear. Therefore the aggregate should have proper/ enough strength and resistance towards crushing.

2. **Hardness**: The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic. This happens due to heavy duty vehicles with steel tires or the sand between the rubber tires which will lead to the deformation of the pavement course. Therefore, the aggregates should be hard enough to resist wear due to abrasive action of traffic.

3. **Toughness**: The aggregates used in the pavements should be tough enough to bear the sudden impact load caused by the heavy duty vehicles especially on the WBM roads. Therefore, the resistance to impact or toughness is hence another desirable property of road aggregates.

4. **Durability**: The aggregate should be durable to bear the weathering conditions or we can say that aggregates should be sound enough to bear the weather e.g. rainfall, snow, frost action, acidic rain etc.

5. **Shape of the aggregates**: The size of the aggregates should be appropriate because size decides the strength of the aggregate. The aggregate should not be too heavy and too elongated because their strength is low as compare to other shapes. So too flaky and too elongated aggregates are not preferred for the construction of roads. The test is also conducted by passing aggregates from different sieves and passing from thickness and elongation gauge.

6. **Adhesion with bitumen**: The aggregate should have less affinity with water when compared with bitumen, if it is not then the bitumen will stripped off from the aggregates within the presence of water.

## 3.7 PROPERTIES OF FILLER IN BITUMEN MIX:

Fillers play an important role to enhance the properties of bituminous mix. It helps to fill the voids formed in the mix which helps to reduce the formation of cracks and also tends to increase the viscosity of bitumen by making it dense. Due to heavy wheel load, tire pressure, high traffic volume, variation in seasonal and daily temperature the symptoms like raveling, undulation, rutting, cracking, bleeding, shoving and potholing of bitumen surfaces takes place. So if we use suitable combination of materials like modified binders with a proper type and good percentage of filler, it will lead to longer life of bitumen wearing course.

### 3.7.1 Figures showing different type of filler materials


**Fig. 3.3** Cement and fly ash

**Table 3.2** Composition of fly ash

| Chemical composition of class F fly ash | Percentage % |
|---|---|
| SiO | 54.9 |
| $Al_2O_3$ | 25.7 |
| $Fe_2O_3$ | 6.80 |
| CaO | 8.60 |
| MgO | 1.70 |
| $SO_3$ | 0.59 |

**Fig. 3.4** Stone dust

**Fig. 3.5** Limestone powder

**Source of these three figures**: Internet source: “types of fillers”.

# CHAPTER 4

# 4. EXPERIMENTAL SETUP AND LABORATORY INVESTIGATION

## 4.1 MARSHALL METHOD OF MIX DESIGN

Marshal stability and flow value is the test used to determine the resistance to plastic deformation of cylindrical specimen of bituminous mixture and is measured when the same is loaded at the periphery at a rate of 5cm per minute. The test procedure is used in the design and evaluation of bituminous paving mixes

## 4.2 INSTRUMENTS REQUIRED FOR MARSHALL STABLITY TEST

1. Sieving arrangement
2. Sieved aggregates
3. Bitumen
4. Cylindrical mould of 7.5cm height and 10cm diameter
5. Collar
6. Sample extractor
7. Compaction pedestal having size 20*20*45cm
8. Rammer having 4.54kg weight dropped from 45.7cm height
9. Breaking head
10. Loading machine


**Figure 4.1** showing preheated cylindrical mold with collar and base plate

**Figure 4.2** showing rammer required for giving blows to the specimen

**Figure 4.3** breaking head of marshal machine

**Figure 4.4** Marshal Machine (loading machine)

Sieving of aggregates is done and the nominal size of aggregates is taken as 20mm to 25mm. weighing of aggregates and filler material is done in such a way that the final mix should have a weight of 1200grm. If we take 20mm as nominal size of aggregates then the sample retained in 20mm sieve should be zero. The bitumen is heated at a temperature of 145 degree Celsius. The cylindrical mold and the aggregates have to be pre-heated in the hot air oven. The bitumen is poured hot in the pre-heated aggregates with correct proportion of 1200grm. The mixing is done thoroughly and the mix is poured into the pre-heated mold. 75 blows are given on each side of the mold with rammer. The rammer should be dropped vertically from the height of 45.7cm. After this the mold is kept for cooling for 24 hours at room temperature. Now the extraction of mold is done by sample extractor, the bearing ball should be kept between the extracting tool and specimen is collected by hitting with the hammer carefully. The mold is kept into the water bath having 60 degree temperature for 20 minutes. Take the submerged weight after 20 minutes. The mold is properly placed in the breaking head and fixes the setup and takes the reading of stability and flow of specimen when the deformation is noticed. After that the tested mold is removed from the machine and average of three is taken.

## 4.3 TESTS FOR AGGREGATES PROPERTIES FOR DBM COURSE AS PER IS 2386 (PART IV):

### 4.3.1 Crushing test:

This test is used to determine the strength of aggregates

Dry aggregates passing from 12.5mm sieve size and retained in 10mm sieve is used

Aggregates are filled in the cylinder and tamped in three layers with the help of tamping rod by giving 25 times. (W1) Plunger is placed on the cylinder and load of 40 tons is applied at the rate of 4 tons/min. by CTM.

Crushed aggregate is sieved and weight is calculated. (W2)

Crushing value = W2/W1*100

### 4.3.2 Los Angeles abrasion test

Principle of Los Angeles abrasion test is to find the percentage of wear due to relative rubbing action between steel balls. It consists of a hollow cylinder closed at both ends having inside dia. 70cm and 4.8cm and weight 390-445g. Aggregate specimen generally depends on the gradation with the steel balls. Machine is rotated at the speed of 30-33rpm with the revolution of 50-100 depending upon the gradation of specimen. After that the aggregates are received with 1.7mm and weightened and the value is calculated in percentage.

For high quality pavement material it shouldn’t increase more than 30%

### 4.3.3 Impact test:

Apparatus consists of cylinder having dia. 10.2cm and 5cm. It consists of hammer weight 13.5-14kg with freefall of 38cm. Dry aggregates passing from 12.5mm sieve size and retained in 10mm sieve is used. Aggregates are filled in the cylinder and tamped in three layers with the help of tamping rod by giving 25 times. After that aggregates are hammered by 15 blows and sieved by 2.36.

### 4.3.4 Specific gravity of aggregates:

The purpose of this test is used to check whether the aggregates which we are using in our construction are having good strength and better quality or not.

# CHAPTER 5

## RESULTS AND DISCUSSIONS

### 5.1 Test results for aggregates properties for DBM course as per IS 2386 (part IV):

### Aggregate gradation:

### Table 5.1

| Sieve size | Upper limit | Lower limit | Adopted value |
|---|---|---|---|
| 26.5 | 100 | 100 | 100 |
| 19 | 100 | 85 | 90 |
| 13.2 | 82 | 63 | 75 |
| 9.5 | 75 | 52 | 59 |
| 4.75 | 54 | 40 | 48 |
| 2.36 | 42 | 26 | 33 |
| 0.60 | 30 | 15 | 22 |
| 0.3 | 21 | 8 | 19 |
| 0.15 | 15 | 5 | 11 |
| 0.075 | 8 | 2 | 5 |

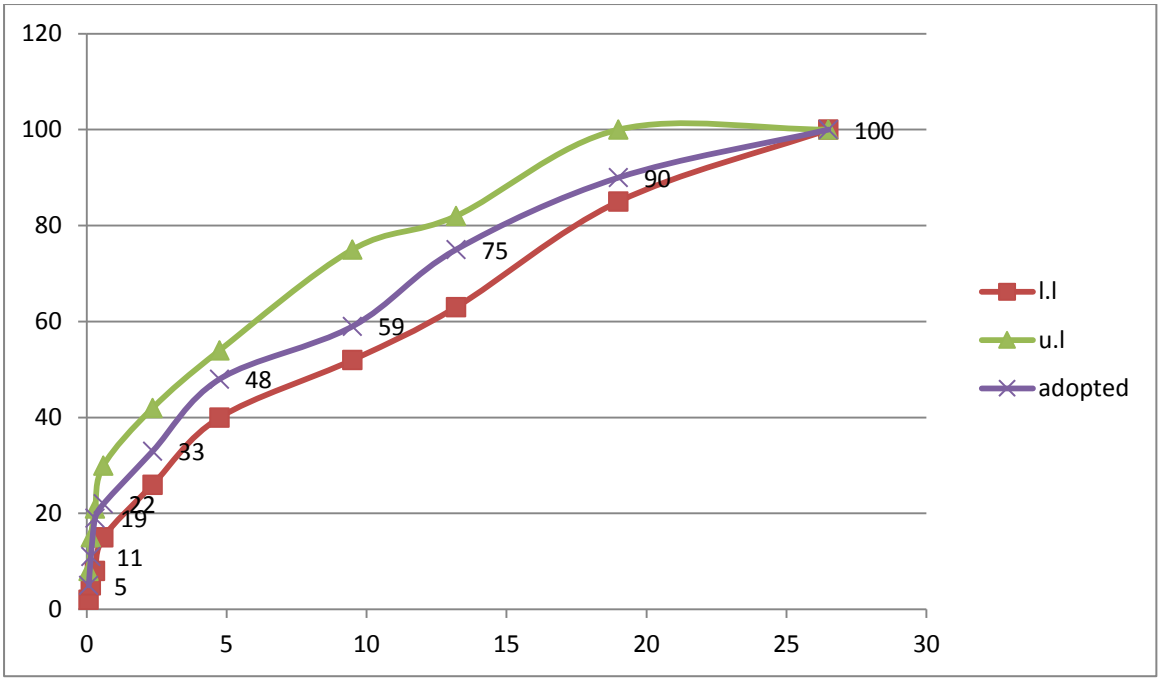



**Figure 5.1** Aggregate gradation

## Crushing value:

## TABLE 5.2

| | |
|---|---|
| Weight of sample with mold | 6490 kg |
| Weight of mold | 2.940 kg |
| Weight of sample after tamping (w1) | 3550 grams |
| After sieve from 2.36mm (passing weight)/ w2 | 350 grams |
| Crushing value = 350/3550*100 | 9.8% < 30% (As per IRC these aggregates are having good strength) |

## Abrasion value:

**TABLE 5.3** results as per IS: 2386 PART (IV):

| | |
|---|---|
| Total weight of the aggregate sample(w1) | 2.5 kg |
| Weight of aggregate retained(w2) | 1950 grams |
| Weight of aggregates passing from 1.7mm(w3) | 540 grams |
| Abrasion value = w1-w2/w1*100 | 22% less than< 35% as per gradation 10mm-6.3mm, therefore it's having a satisfactory value. |

## Impact value:

**TABLE 5.4** Results as per IS: 2386 PART (IV):

| | |
|---|---|
| Weight of mold | 1.270 grams |
| Weight of mold with sample | 1.795 grams |
| Weight of sample | 535 grams |
| After reduction ( 10mm space provided for blows) w1 | 500 grams |
| Percentage passing from 2.36 after 15 blows by hammer (w2) | 40 grams |
| Impact value = w2/w1*100 | 8% < 27%% as per IRC its having very good impact value |

**TABLE 5.5** sieve analysis of 25mm aggregates taken from ACC PLANT near chaheru phagwara (lpu) jalandhar:

| Sieve size (mm) | Mass Retained | % Retained | Com. Retained | % Passing | STD |
|---|---|---|---|---|---|
| 40 | 0 | 0 | 0 | 100 | 100 |
| 20 | 330 | 10.09 | 10.09 | 89.91 | 85-100 |
| 10 | 2750 | 84.10 | 94.19 | 5.81 | 0-20 |
| 4.75 | 190 | 5.81 | 100 | 0 | 0-5 |
| Pan | 0 | - | - | - | - |

Wet weight – 3300 grams

Dry weight -3270 grams

Moisture content = wet-dry/dry*100 = 0.90%

**TABLE 5.6** sieve analysis of 10mm aggregates taken from ACC PLANT near chaheru phagwara (lpu) jalandhar:

| Sieve size | Mass Retained | % Retained | Com. Retained | % Passing | STD |
|---|---|---|---|---|---|
| 12.5mm | 160 | 6.56 | 6.56 | 93.44 | 100 |
| 10mm | 340 | 13.93 | 20.49 | 79.51 | 85-100 |
| 4.75mm | 1730 | 70.90 | 91.39 | 8.61 | 0-20 |
| 2.36mm | 200 | 8.20 | 99.59 | 0.41 | 0-5 |
| Pan | 10 | 0.41 | 100 | - | - |

Moisture content of 10mm aggregates:

Wet weight - 2500 grams

Dry weight- 2440

Moisture content= $\frac{\text{wet}-\text{dry}}{\text{dry}}$* 100 =2.35%

**Specific gravity:**

## TABLE 5.7:

| | |
|---|---|
| Total weight of aggregates | 2kg |
| Weight of bucket in air | 900 grams/0.9 kg |
| Weight of submerged bucket w2 | 700 grams/0.7kg |
| Weight of bucket+ aggregates | 2.9 kg |
| Weight of bucket+ aggregates (submerged)/ w1 | 1.9 kg |
| Dry weight of aggregates (w3) | 1.8 kg |
| Specific gravity= w3/w3-(w1-w2) | Specific gravity=3 / range is 2.5-3 for road construction as per IRC. |

**Specific gravity of fine aggregates and fly ash**

## TABLE 5.8

| Specific gravity with STD | Observed value |
|---|---|
| Fine aggregates ( 2.5 -3) | 2.92 |
| Fly ash class F (1.9-2.8) | 2.3 |

**Fig. 5.2** showing test performed for aggregates

## 5.2 Results obtained from bitumen testing of VG30 as per IS- 73 (2006) for DBM course:

**TABLE 5.9** Bitumen test results

| VG 30 Bitumen | Standard Specifications | Observed Value |
|---|---|---|
| Penetration test | 60/70 | 64 |
| ductility | 40cm MIN | 42.5 |
| Softening point C | 47 | 50.5 C |
| Specific gravity | 0.9-1.06 | 0.96 |

**Fig. 5.3** showing different tests performed for bitumen VG30:

**Table 5.10** Showing percentage replacements of molasses with bitumen for checking the effect of molasses on vg30 grade of bitumen

| Penetration trial with 300grm of sample | Percentage of molasses (%) | Value of penetration obtained | Penetration range of VG30 |
|---|---|---|---|
| 100 | 0 | 64 | 60/70 |
| 98 | 2 | 65.2 | 60/70 |
| 96 | 4 | 66.3 | 60/70 |
| 94 | 6 | 67 | 60/70 |
| 92 | 8 | 68.9 | 60/70 |
| 90 | 10 | 79.2 | 60/70 |
| 88 | 12 | 82.9 | 80/100 |
| 86 | 14 | 88 | 80/100 |

The results shown in this table is as per the replacement of bitumen with molasses. The percentage trial starts from 2%, 4% and up to 10% its within the penetration range of 60/70, but when the percentage of molasses exceeds from 10% to 12% and above its showing drastic change in the penetration value of VG30 grade of bitumen corresponding to 80/100 penetration grade which is used as a penetration grade of VG10. So, we can come to the conclusion that after adding more than 10 percent of molasses in bitumen (VG30) the grade of the bitumen changes from 60/70 to 80/100 which is same as the VG10 grade of the bitumen. So, as per the penetration test, we can relate that the viscosity of the bitumen (VG30) is getting reduced if the molasses is added more than 10% in the bitumen and it's showing the characteristics of VG10 grade of bitumen and the VG30 grade of bitumen losses its actual property.

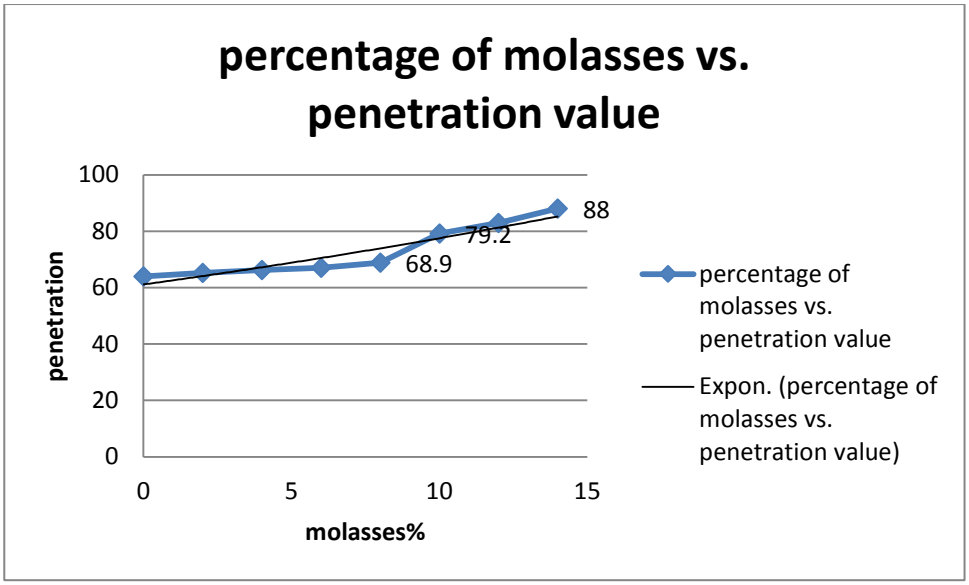



**Figure 5.4** showing the graph plotted between percentage replacements of molasses with respect to the change in penetration grade of bitumen

## 5.3 MARSHALL MIX DESIGN FOR OBC:

For finding the OBC, different samples were made by changing the percentage of bitumen 3, 3.5, 4, 4.5, 5 and for every mix three samples were made and the average of every three samples from different percentage of bitumen were taken and the following calculations were made for finding the OBC.

### 5.3.1 VOLUMETRIC ANALYSIS OF MIX DESIGN:

**1. Bulk specific gravity (Gm)**

Gm = Wa/Wa-Ww

Where,

Wa - weight of sample in air

Ww - weight of sample in water

**2. Theoretical specific gravity of the mix (Gt)**

Gt =W1+W2+W3+Wb/ (W1/G1+W2/G2+W3/G3+Wb/Gb)

Where,

W1 – Weight of coarse aggregates

W2 – Weight of fine aggregates

W3 – Weight of filler material

Wb – Weight of bitumen

G1- Specific gravity of coarse aggregates

G2- Specific gravity of fine aggregates

G3- Specific gravity of filler material

Gb- Specific gravity of bitumen

**3. Volume of voids (Vv)**

Vv = Gt-Gm/Gt

**4. Volume of voids filled with bitumen (Vb)**

Vb = Wb/Gb/W1+W2+W3+Wb/Gm

**5. Voids filled with mineral aggregates (VMA)**

VMA = Vv+Vb

**6. Voids filled with bitumen (VFB)**

**VFB = Vb*100/VMA**

**Table 5.11 Gradation for finding OBC and sample preparation**

| Sieve size | Interval | Adopted value | Percentage retained | Aggregates with binder content | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 4 | 4.5 | 5 | 5.5 | 6 | 7 |
| 26.5 | 100 | 100 | 0 | 1152 | 1146 | 1140 | 1134 | 1128 | 1116 |
| 19 | 85-100 | 90 | 10 | 115.2 | 114.6 | 114.0 | 113.4 | 112.8 | 111.6 |
| 13.2 | 63-82 | 75 | 15 | 172.8 | 171.9 | 171 | 170.01 | 169.2 | 167.4 |
| 9.5 | 52-75 | 59 | 16 | 184.3 | 183.36 | 182.4 | 181.44 | 180.48 | 178.56 |
| 4.75 | 40-54 | 48 | 11 | 126.72 | 126.06 | 125.4 | 124.74 | 124.08 | 122.76 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.36 | 26-42 | 33 | 15 | 172.8 | 171.9 | 171 | 170.1 | 169.2 | 167.4 |
| 0.60 | 15-30 | 22 | 11 | 126.72 | 126.06 | 125.4 | 124.74 | 124.08 | 122.76 |
| 0.3 | 8-21 | 19 | 3 | 34.56 | 34.38 | 34.2 | 34.02 | 33.84 | 33.48 |
| 0.15 | 5-15 | 11 | 8 | 92.16 | 91.68 | 91.2 | 90.72 | 90.24 | 89.28 |
| 0.075 | 2-8 | 5 | 6 | 69.12 | 68.76 | 68.4 | 68.04 | 67.68 | 66.96 |
| Filler | 8-12 | 9 | 9 | 103.68 | 103.14 | 102.6 | 102.06 | 101.52 | 100.44 |
| Binder content | | | | 48 | 54 | 60 | 66 | 72 | 84 |

**Figure 5.5** heating of bitumen

**Figure 5.6** showing the preparation of mix for finding OBC:

**Figure 5.7** Giving blows using hammer (50-60 in 2 minutes)

**Figure 5.8**sample extraction

**Figure 5.9** showing samples preparation for finding OBC

**Figure 5.10** Placing of sample in breaking head of loading machine

Now after finding these all parameters the graph is plotted between stability, bulk specific gravity, volume of voids with respect to 4% as per the design median limits, with bitumen content and the average of these three is taken as OBC.

**Table 5.12** showing marshal mix values for OBC

| Bitumen content (%) | Stability (kg) | Flow value (mm) | Volume of voids (Vv) | VFB | Gm |
|---|---|---|---|---|---|
| 4 | 450.3 | 2.97 | 4.18 | 38.25 | 2.18 |
| 4.5 | 556.4 | 3.25 | 3.47 | 47.33 | 2.28 |
| 5 | 612.3 | 3.86 | 3.32 | 55.66 | 2.32 |
| 5.5 | 719.6 | 4.58 | 2.45 | 62.44 | 2.35 |
| 6 | 689.6 | 5.32 | 2.12 | 65.25 | 2.37 |
| 7 | 676.2 | 5.57 | 1.98 | 69.56 | 2.38 |

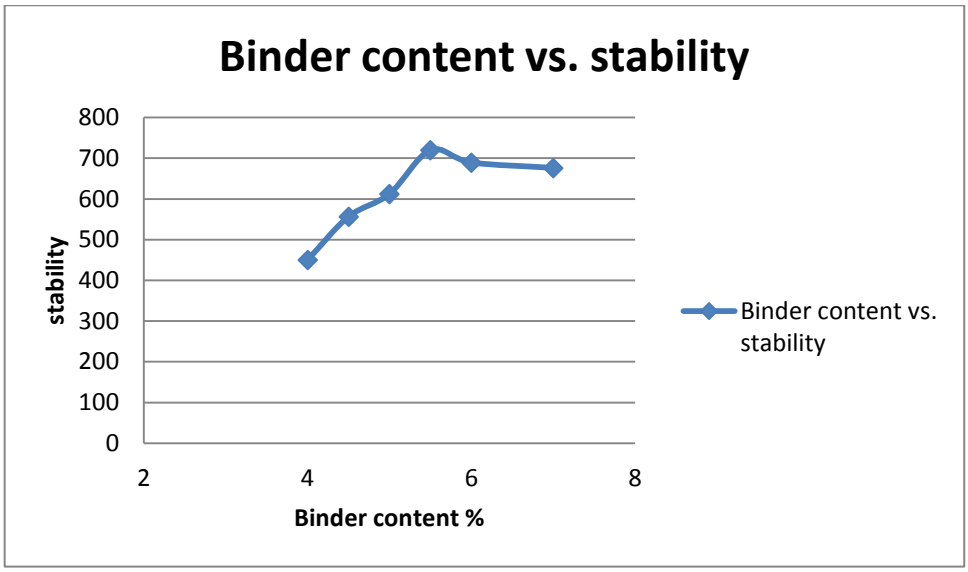



**Figure 5.11** showing stability with respect to binder content

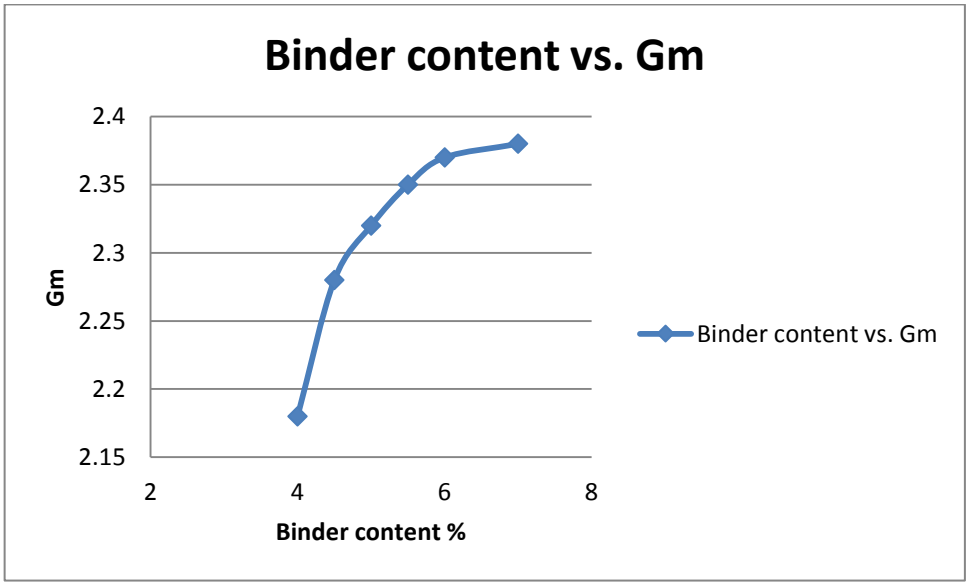



**Figure 5.12** showing bulk specific gravity with respect to binder content

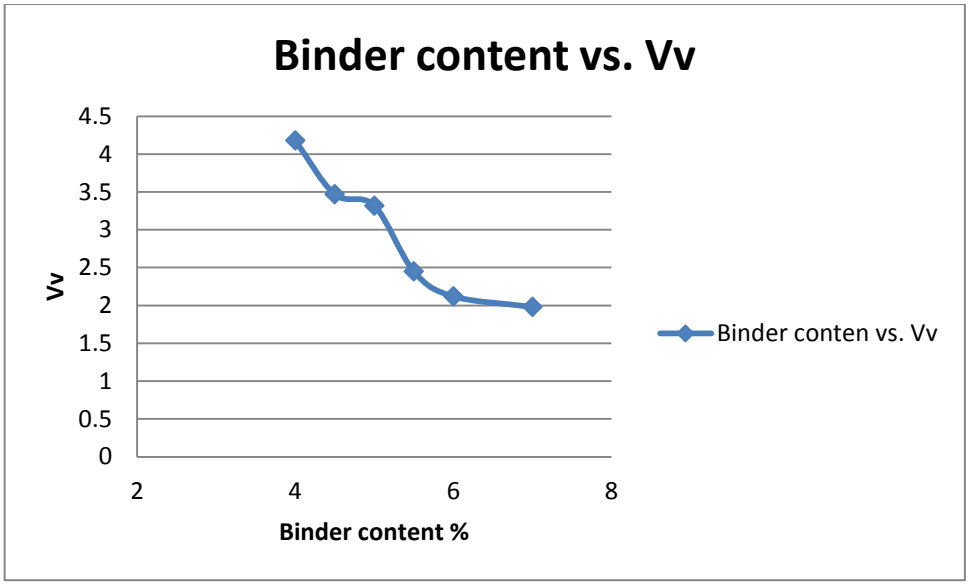



**Figure 5.13** showing volume of voids with respect to binder content

**The optimum binder content found to be 4.12%**

### 5.3.2 Percentage replacement with molasses:

Now after finding the OBC, the next step is to do the partial replacement of bitumen with the molasses by increment of 2 percent in every trial unless the desirable stability, flow value with volumetric analysis. The first sample is prepared with 100% bitumen which is free from the molasses. Aggregates are added to bitumen by melting the bitumen at a temperature of 200 degree Celsius. The mix shouldn't be over heated because the mix should lose its properties. Stir the mix properly for the removal of water and air voids and stir until the mix become uniform. Gently fill the mold by mix and should be compacted from both sides with minimum 50 blows. If the specimen is broken or sticking with the mold then the sample should be rejected because the sample is failed and this is because of over-heating, improper compaction etc. Apply grease or wax to the mold and kept the sample in water bath for 24 hours. Weight the sample before and after placing in water bath. Marshal test is conducted with a load of 25KN, after the specimen is completely dry out. Note down the flow value and dial gauge readings.

By using the same process this test is conducted for every specimen of 2% to 16% replacement of molasses with bitumen. Fly ash was used during mixing to control the water absorption when kept in water bath for 24 hours.

**Figure 5.14** showing different percentage of molasses for preparation of samples


**Figure 5.15** Normal bitumen vs. Molasses sample


**Figure 5.16** showing 12% replacement of bitumen with molasses

The above figure shows the 12% replacement of molasses with bitumen. By this we can conclude that molasses can be replaced with bitumen up to certain percentage.

**Table 5.13:** Calculation of optimum molasses content after replacement

| Bitumen content (%) | Molasses content (%) | Air voids (Vv) | Voids in mineral aggregates (VMA) | Voids filled with bitumen (VFB) | Stability (kg) | Flow value (mm) |
|---|---|---|---|---|---|---|
| 100 | 0 | 4.62 | 15.01 | 68.9683 | 672.183 | 5.467 |
| 98 | 2 | 4.520 | 14.20 | 69.9703 | 1112.628 | 4.232 |
| 96 | 4 | 4.492 | 13.67 | 70.18 | 1292.829 | 3.918 |
| 94 | 6 | 4.38 | 13.22 | 69.418 | 1430.69 | 3.23 |
| 92 | 8 | 4.11 | 12.98 | 70.27 | 1642.78 | 3.01 |
| 90 | 10 | 3.93 | 12.01 | 70.55 | 1894.59 | 2.532 |
| 88 | 12 | 2.63 | 11.96 | 77.88 | 2021.276 | 2.18 |
| 86 | 14 | 4.08 | 13.49 | 69.67 | 1910.875 | 2.35 |
| 84 | 16 | 4.87 | 13.88 | 63.45 | 1893.867 | 2.59 |

### 5.3.3 Graphical representation for OMC:

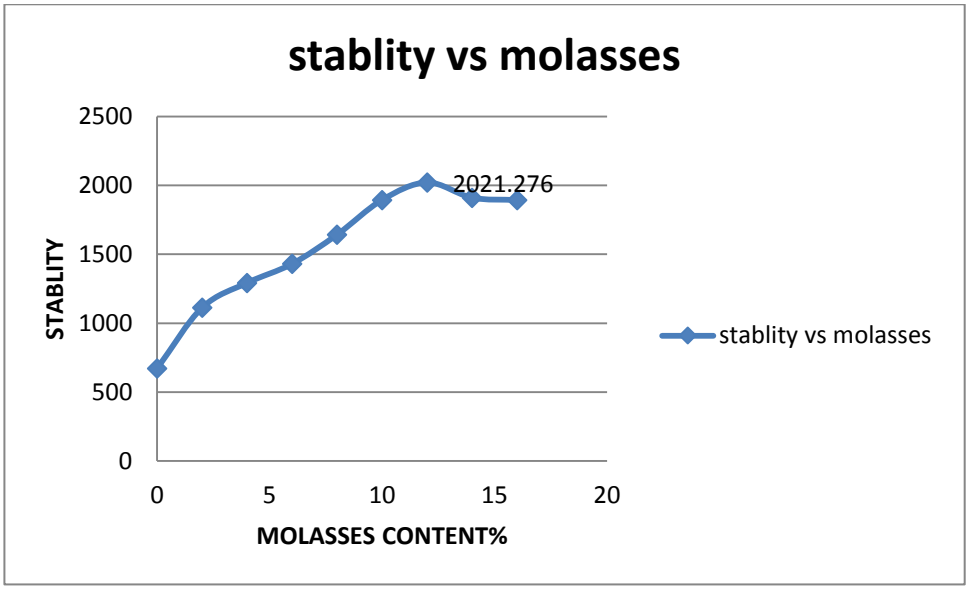



**FIGURE 5.17** Molasses (%) Vs Stability (KGS)

The above graph is plotted between stability and the molasses content. The stability is taken over y- axis and molasses content is taken over x- axis. The stability is getting increased up to 12% and then goes on decreasing, so we can conclude that by using molasses we can do the partial replacement of bitumen up to 12% and by this strength and life of the bituminous mix design is improved. The minimum stability is 672 kg. The highest point in the stability graph

is taken as optimum molasses content and because of the increase in the stability the bonding between the aggregates is strong and by this the damage on the pavements will be less.

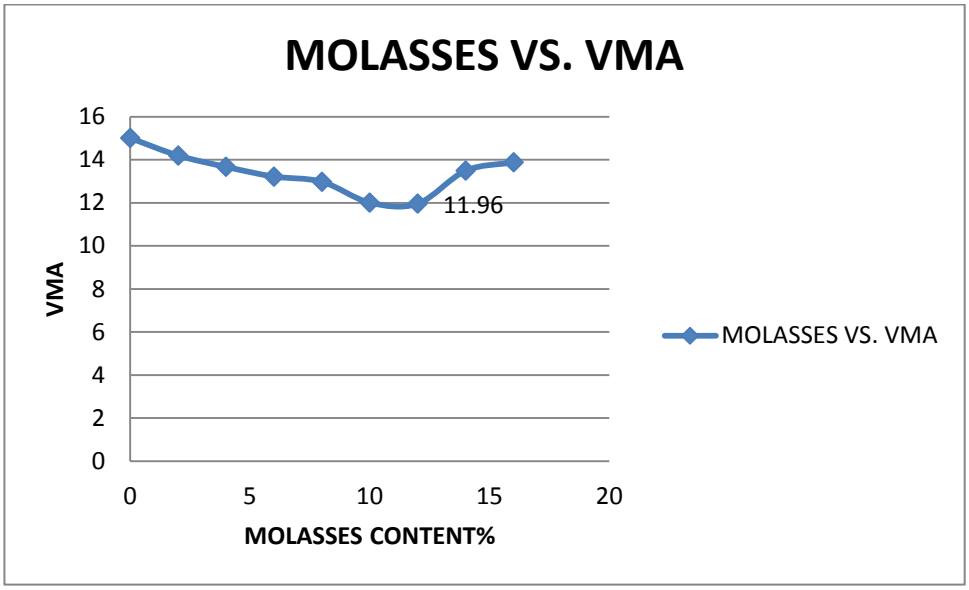



**FIGURE 5.18** Molasses (%) Vs VMA (%)

This above graph is plotted between molasses content and voids filled with minerals aggregates (VMA). The values of molasses are plotted over x- axis and the value of VMA is plotted over y-axis. By this graph we can see that the voids filled with the mineral aggregates are getting reduced up to 12% and then gradually increasing as the percentage of the molasses is increased above it. The desirable value of the VMA is less than 18% and thus the VMA is decreasing the stability will be increased and this means that the strength is high at 12% and then it's getting decreased as per the VMA is increasing. Due to high voids in the bituminous mix the sub-grade soil and sub- base layer gets affected due to the percolation of water from the voids, and if the water absorption rate of the aggregates is higher than they absorb water and it causes defect like undulations, wavy surface of the pavement.

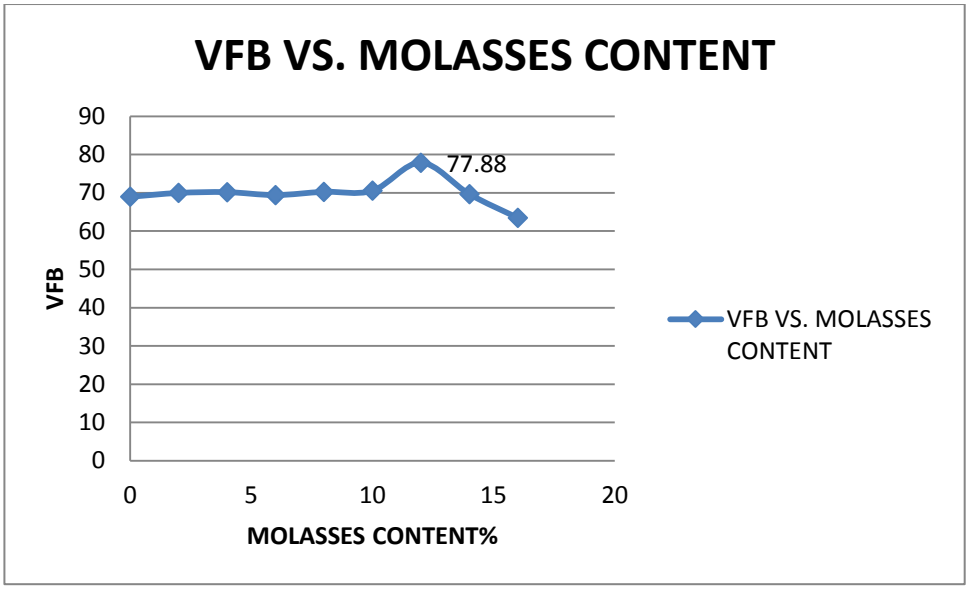



**FIGURE 5.19** Molasses (%) Vs VFB (%)

This graph is plotted between molasses content with respect to the voids filled with the bitumen. The value on the x- axis is the molasses content and the value on the y- axis is voids filled with bitumen (VFB). By this graph it can be observed that the value of the VFB is getting increased up to 12% and then its start to decrease. The value of voids filled with bitumen should be greater than 75% so that the bitumen mix will be in a good condition, If the voids are properly filled with the bitumen then the bonding between the materials of the mix like aggregates, filler will be better and if it's not, then there should be the formation of pot holes on the pavements and by the heavy duty vehicles the pavement will get damaged.

## CONCLUSION:

From this above study the behavior of the molasses modified bitumen mix it was found that the modified bituminous mix having enhanced and better Marshal Characteristics as compared to the conventional bituminous mix. It was observed that the stability value of the marshal mix increases up to 12% and then decreases. The flow value of the mix decreases as per the addition of molasses. The other volumetric parameters such as volume of voids (Vv), volume of bitumen (Vb), voids in mineral aggregates (VMA), and voids filled with bitumen (VFB). By addition of molasses in bitumen it was found that up to 10% the value of penetration is within the penetration range of 60/70, but when the percentage of molasses exceeds from 10% to 12% and above its showing drastic change in the penetration value of VG30 grade of bitumen corresponding to 80/100 penetration grade which is used as a penetration grade of VG10. So, we can come to the conclusion that after adding more than 10 percent of molasses in bitumen (VG30) the grade of the bitumen changes from 60/70 to 80/100 which is same as the VG10 grade of the bitumen. So, as per the penetration test, we can relate that the viscosity of the bitumen (VG30) is getting reduced if the molasses is added more than 10% in the bitumen and it's showing the characteristics of VG10 grade of bitumen and the VG30 grade of bitumen losses its actual property. So by this we can conclude that the molasses should be used within the specified limit because if we go beyond that limit the bitumen will lose its actual grade which can lead to various defects of the pavements.

## FUTURE SCOPE

By this investigation the molasses is not only utilized beneficially, but it also improved the pavement characteristics such as road safety, defects, long life of flexible pavements, stability, recycling of sugarcane waste and most important environment. As we all know the temperature of the earth is getting increased above 50 degree and in that condition the rainfall is very dangerous for bituminous pavements because bitumen is a petroleum product, so by using molasses we can save our environment by considering our main global objective "ZERO EMISSION". By adding molasses to the bituminous mix the amount of carbon dioxide decreases and also the use of molasses made products which are very harmful to the human health. The bonding of the aggregates is also increased by using molasses. The modified mix reduces the voids present in the mix. By the reduction in voids the moisture absorption is getting reduced which will led to the less damage of pavements and the sub grade soil and the roads can sustain heavy traffic and provide better riding quality and better

services. The use of molasses not only adding value to the molasses but also improves the betterment in technology which is eco- friendly.

So by this it is recommended that more research regarding waste materials like molasses should be done and more trial should be done for betterment and their performance should be considered further.

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