Investigating the Effect of Cane Molasses on the Performance of Base Bitumen

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Abstract- **Molasses is a byproduct of the sugar refining industry. A hundred tons of sugar cane will give 10-11 tons of sugar and 3-4 tons of molasses. There are thirteen sugar factories in Ethiopia and each factory produces molasses in the form of by-product. The objective of this research is investigating the effect of cane molasses on performance of the base bitumen. Sugar cane molasses is an organic waste material obtained from raw sugar during the refining process at sugar refineries. The effects of cane molasses percentage replacement on bitumen were examined by means of a various laboratory tests including PG (Performance Grade), RTFO (Rolling Thin-Film Oven). The study revealed that as percentage of molasses-A, molasses-B and molasses-C increases from 0 to 20%, 0 to 10% and 0 to 5%, the PG was improved by 28.12%, 15.79% and 8.57% respectively. The PG decreases by 36.87%, 28.38% and 12.76% and similarly, the ductility decreases by 21.36%, 6.79% and 5.83% for 15% molasses-A, 10%molasses-B and 10% molasses-C mixtures respectively. The cost analysis also signifies that, the cost of base bitumen improved by 17.4%, 8.93% and 2.35% for using molasses-A, molasses-B and molasses-C respectively. From this study, it was concluded that as per DSR performance testing machine, 20% molasses-A, 10% Molasses-B and 5% Molasses-C improves the performance of original bitumen with different rate.**

Keywords: **Bitumen, Molasses, Performance and Sugar Cane**

I. INTRODUCTION

Cane molasses is a product of tropical agriculture and is more widely known as 'blackstrap' molasses, a term which derives from the Dutch word 'stroop' meaning syrup. Sugar, in particular sucrose, is the major component of molasses. Indeed, molasses is actually a solution of sucrose, plus some glucose, fructose and other organic and inorganic matter in water.

Cane and beet molasses are the end-products of the sugar manufacturing process and once no more sugar can be crystallized from the raw crop, the residual product is molasses. About 145 million tons of sugar is produced worldwide each year, of which 76% comes from sugar cane and 24% from beet. In 2020, it is expected that global sugar production will generate about 80 million tons of cane molasses and 36 million tons of beet molasses.

There are about 45 sugar cane producing countries in the world, but the main molasses producers are Brazil, India and Thailand. Around 6 million tons of cane molasses are traded internationally each year. The different components of molasses are Trace element, Vitamins, growth substances, water, sugar and non-sugars.

Molasses-A has sugar purity of 98-99.5% with high binding property and less percentage of water than molasses – B and Molasses-C. Molasses-B is obtained with refining product of sugar-A with percentage purity of 92-94% with less binding capacity than molasses-A. Molasses-C is the residual final product of sugar –B with 33-35% sugar purity and the molasses production capacity of Finchaa Sugar Factory with the expansion project is 10-11 tons/day and is exported to England.

A. Statement of the Problem

The world has become increasingly concerned over the global climate change thought to be caused by greenhouse gases, chief among them anthropogenic carbon dioxide which is released into the atmosphere from burning carbon fuels. This has led to the introduction of bitumen alternatives that are more environmentally friendly and non-toxic.

Molasses is used in a diverse range of industries due to its excellent non pollutant binding properties. It has an advantage over other binding materials such as tar and lignin sulphonate as it does not produce a toxic emission on combustion instead much safer for the environment. In addition as a liquid it is easy to handle and incorporate into various manufacturing processes.

The problem in most of developing country like Ethiopia in upgrading the existing gravel road to paved one is due to the higher cost of bitumen. Many bitumen buyers are looking for an alternative form of bitumen with least cost and with parallel comparable to bitumen performance. And the current price ranges US $ 800-1000/metric tone for 40/50 penetration grade of the bitumen.

Ethiopia is one of the developing country in East Africa and the economy of the country is more dependent on agriculture. Few years back, the plan and transformation of the government was more focusing on changing agriculture to industry to bring sustainable development and one of the industry target area was to expand sugar factory projects in different regional locations. There are thirteen sugar factories in Ethiopia and each factory produces molasses in the form of byproduct and this research investigates on the effects of improving the performance of base bitumen with three stage molasses and is conducted in Finchaa Sugar Factory.

In this study the researcher will be investigating different laboratory tests on the mixture of sugar cane molasses with bitumen material and aims to minimize the cost of bitumen and improve the performance of the base bitumen.

Fig. 1 Locations of sugar factories in Ethiopia

B. Objectives the Study

- To determine the super paving performance test and engineering properties of bitumen with different stage molasses at different percentage replacement.
- To compare the laboratory results of super paving performance test and engineering properties of bitumen with standard specification of bitumen using AASHTO, ASTM, ERA and SHR Manuals.
- To compare the material and transportation cost of mixture with base bitumen.

II. STUDY AREA

The molasses sample was collected from Finchaa sugar factory. The factory is found in Oromiya Regional State in Horro Guderru Wellega Zone, Abay Chomen District in Fincha Rift Valley around 350 Kilo Meters away from the capital – Addis Ababa and it is located at $9^0$30'-$9^0$60'E to $37^0$30'E with an altitude of 1550m.

The factory started production in 1998. The average annual production capacity of Finchaa Sugar Factory was 110,000 tons of sugar. The factory has carried out expansion projects both on its sugarcane plantation field and its sugar mill.

Fig.2 Fincha Sugar Factory, Ethiopia

Hence, it has come up with a plant of 12,000 TCD design capacity capable of annually producing 270,000 tons of sugar. The Mill's previous design capacity was 5,000 TCD. To acquire and cultivate cane cultivation field capable enough to feed the expanded plant with more than double crushing capacity. This area was chosen because of high molasses production capacity and unlike other factories, Finchaa Sugar Factory has production through 11(eleven) months of a year.

III. MATERIALS AND METHODOLOGY

A. Grade of Bitumen

Bitumen grade S35 -30/40, S45- 40/50 S55- 50/60, S65-60/70, S45-40/50, S90- 80/100, S200 -175/225 with penetration grade S which stands for straight run bitumen (not blended neither modified nor blown). Some of bitumen grade mostly used in construction of road in most of the country.

B. Cane Molasses

Cane molasses is a common ingredient in baking and cooking. To make cane molasses, sugar cane is harvested and stripped of leaves. Its juice is extracted, usually by cutting, crushing, or mashing. The juice is boiled to concentrate it, promoting sugar crystallization. The result of this first boiling is called first syrup, and it has the highest sugar content. First syrup is usually referred to in the Southern states of the U.S. as cane syrup, as opposed to molasses. Second molasses is created from a second boiling and sugar extraction, and has a slightly bitter taste.

Fig.3 Sample sugar cane and Cane molasses in the bottle by Alison Spiegel.

C. Binding property of molasses

Cane Molasses gives a consistent and stable performance as a binding agent for easier, safer and more efficient handling of fine carbon powder which is used to reinforce and color pneumatic tyre rubber in addition to being employed in printing, pigments, sugar refining and other chemical processes. Absence of impurities which are found in alternative products, coupled with consistent specific gravity, makes cane molasses the ideal carbon black binder. And the main use of cane molasses is as a binding agent in feed mills.

Molasses allows the feed granules to stick together during the pelleting process, which produces pellets that are less likely to break down during transportation and passage

through feeding equipment. Molasses also reduces dustiness in fine-particle feeds. Due to its sucrose content, it improves the palatability of feeds and can even mask the bitter taste of urea .The amount used in dry feeds is usually small, lower than 15% and usually in the 2-5% range.

D. Experimental methods

Twenty five liter molasses sample were taken from the three stage sugar production process; that is for molasses –A with sugar purity 98 to 99.5 %, molasses –B with sugar purity 92% to 94%, and molasses-C with sugar purity 33% to 35%. In the laboratory the unmodified bitumen was mixed with the three stage molasses production extracted from Finchaa sugar refining factory using different percentages 5%, 10%, 15% and 20%. The effectiveness of sugar cane molasses mixture with bitumen having penetration grade of 40/50 were evaluated by comparing tests conducted on unmodified bitumen with the same grade with the mixtures. All tests on bitumen were conducted according to AASHTO, ASTM, ERA, and SHR testing standard manuals.

Fig.4 Molasses Sample Extraction from Factory Outlet

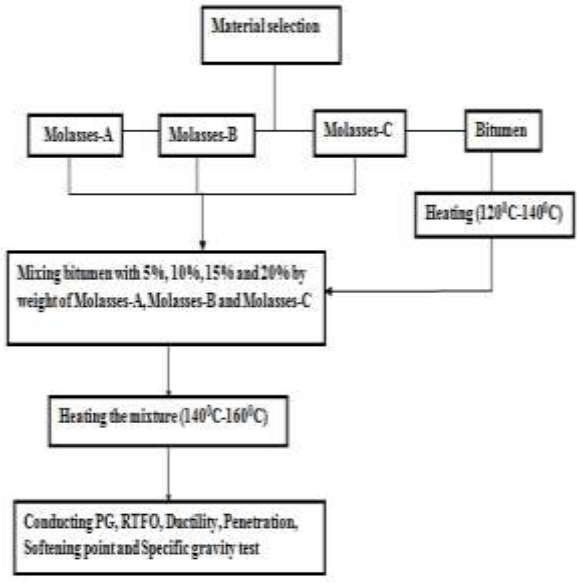

Fig.5 Study Methodology Chart

E. Study variables

1)Dependent variables

- Performance of bitumen with molasses.

2)Independent variables

- Performance grade before aging using Dynamic Shear Rehometer test
- Performance grade after aging using Rolling Thin Film Oven test
- Hardness using penetration test
- Tensile behavior using ductility test
- Softening temperature using softening point temperature test
- Specific Gravity
- Dosage of molasses
- Cost

IV. ANALYSIS AND RESULTS

The results of laboratory test on different percentage molasses replaced bitumen and discussion on their relevance to practice. The test includes PG (Performance Grade) test, RTFO (Rolling Thin film Oven) test, Ductility test, Penetration test, Softening Point test and Specific Gravity test.

A. Engineering properties of bitumen with molasses

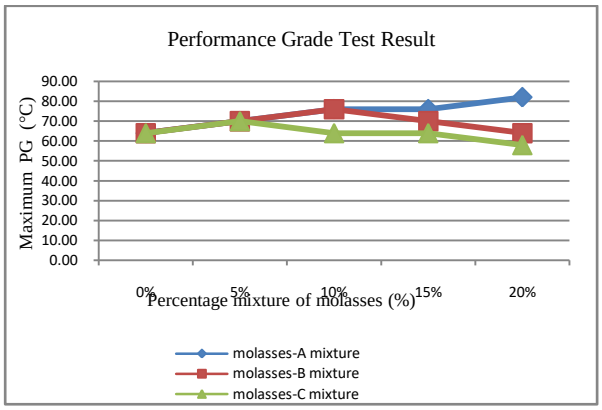

Fig.6 Effect of molasses mixed with bitumen on PG

The PG test was performed to determine the effect of adding molasses to the base bitumen for describing the maximum pavement temperature effect on the climate. Twelve sample mixtures of three stage molasses in four type percentage 5%, 10%, 15% and 20% with 40/50 base bitumen were conducted. The results indicate that, the maximum performance grade was found in the bitumen mixed with 20% molasses-A, 10% molasses-B and 5% molasses-C than other percentage mixtures as shown in the Figure 6. The result signifies that 20% molasses-A improves three grades as shown in the above figure from 64-XY to 82-XY; where, 82 describes the maximum pavement temperature and –XY shows the minimum pavement temperature to be determined using bending beam shear rehometer test. Similarly, 10% molasses-B and 5% molasses-C improves the original bitumen by two and one grade respectively.

In addition the result of shear stress and elastic modulus were decreased as the PG increases for the critical percentage mixture effects. The result signifies that, the PG of the

mixture is inversely related to shear stress and internal resisting capacity (elastic modulus).

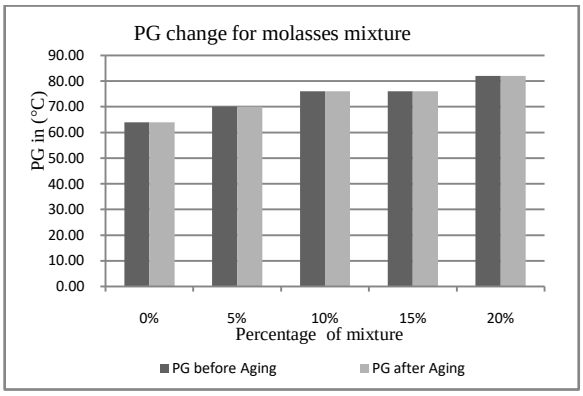

Fig.7 After and before aging PG effect on molasses-A mixture

The Rolling Thin-Film Oven (RTFO) test was conducted for the three stage molasses mixed bitumen with different percentage replacement to determine short term aging bitumen effect. A result of performance grade after RTFO test as it was determined using DSR machine are as shown in Figure 7, for molasses.

It can be seen that for most of the mixtures the performance grade before aging and after aging were the same, however for 15% and 20% molasses-B, and 15% molasses-C mixture the performance grade of the mixture were decreases by one grade. The PG loss after aging signifies that, grade loss will comes during hot mix asphalt mixture and placement.

Penetration test was performed to determine the effect of adding different percentage of molasses to the original bitumen 40/50. Twelve sample mixtures were prepared for three stage molasses with different percentages replacement. The results of penetration of molasses mixed with bitumen were determined using penetrometer instrument and the result was analysed. It can also be seen that, by adding small percentage of molasses to the base bitumen led to major improvement in the density of original bitumen.

The higher the penetration, the softer the bitumen. Bitumen with penetration grade 40/50 means that penetration of needle in bitumen is in range of 40mm to 50mm at standard test condition. Thus, from the result it can also be seen that 15% molasses-A, 10% molasses–B and 10% molasses-C mixture results more improvement than other percentage of mixtures.

The ductility test was performed to determine effect of adding molasses to base bitumen (40/50). The original bitumen(40/50) were mixed with three stage molasses with different percentage treatment i.e. 5%,10%,15% and 20% of the total weight of base bitumen. The test result indicates that, the treated base bitumen with 15%,10% and 10% mixture of Molasses-A, Molasses-B and Molasses-C respectively, results to less ductility value as compared to other percentages of mixture and conventional. It means that, addition of molasses to the bitumen will decrease tensile behavior and increase density of bituminous binder.

Softening point is a measure of temperature susceptibility and flow of bitumen in service. The molasses replaced bitumen with different percentage was placed in small ring separately and the ring was immersed in bicker holding water; a small steel ball was placed on the bitumen and heat was applied to the liquid. The molasses mixture content increases with increasing the softening point in different rate for some of the percentages and decreases slowly. The result signifies that at 15% molasses-A, 15% molasses-B and 10% molasses-C were having high density than other percentages.

Specific gravity of bitumen was performed to determine effect of adding molasses to the bitumen mixture. The base bitumen was mixed with molasses at different percentage replacement i.e. 5%, 10%, 15% and 20% of the total weight of bitumen. It can be observed that, as molasses-A, molasses-B and molasses-C content increases from 10%to 15%, 5% to 15% and 10% to 15% respectively the specific gravity of the bitumen decreases as compared with other percentages. Also from the result, it can be observed that, beyond 15% molasses can no longer improves engineering property of the base bitumen.

B. Material cost analysis of mixing base bitumen with molasses

The cost of bitumen (40/50) treated with molasses are much lower than the original bitumen. In fact, Molasses-A, Molasses –B, and Molasses –C can lowers the base bitumen (40/50) overall cost by 17.44%, 8.93% and 2.35% as shown in Table.1. The treated bitumen (40/50) with sugar cane molasses improves the engineering properties and performance of the original bitumen.

Treating base bitumen with molasses does not require significant amounts of additional knowledge during mixture. However, understanding of percentage by weight and pouring temperature of material to be blended is sufficient, and no special tools are needed to carry out the process.

Table 1. Material cost analysis of mixing base bitumen with peak percentage of Molasses-A

S.no	Description	Cost analysis of molasses-A (birr/tone)	Cost analysis of base bitumen (40/50) (birr/tone)
1	Estimated cost of purchasing molasses – A at factory (FSF) including VAT	2,300	-
2	Transportation cost including loading and unloading	140	-
3	Cost of base bitumen (40/50)	-	18,650
Total		2,440	18,650

Cost analysis of bitumen (40/50) mixed with molasses-A (20%) is:

$$= \frac{20}{100} * (2{,}440\ ) + \frac{80}{100} * (18{,}650\ ) = 15{,}408\ \text{birr/tone}$$

Net saving cost =18,650-15,408=3,242 birr/tone

Percentage of saving $= \frac{3{,}242\ \text{birr /tone}}{18{,}650\ \text{birr /tone}} * 100 = 17.4\%$

V. CONCLUSIONS

A. *Engineering property of bitumen with different stage molasses at different percentage replacement*

This research was conducted to study the effect of adding three stage cane molasses with different percentage replacement on the performance of the original bitumen (40/50). The molasses mixed base bitumen with (0%, 5%, 10%, 15% and 20%) percentage replacement were tested for PG test, RTFO test, Penetration test, Ductility test, Softening point test and Specific gravity test using AASHTO,ASTM,ERA and SHR standard test procedural manuals.

As per the laboratory results, the performance grade of the treated base bitumen(40/50) with 20% molasses-A, 10% molasses-B and 5% molasses-C improves the performance of the original bitumen by 28.12%,15.79% and 8.17% respectively. The penetration grade decreases by 36.87, 28.38% and 12.76% and similarly, the ductility decreases by 21.36%, 6.79% and 5.82% for 15% molasses-A, 10%molasses-B and 10% molasses-C mixtures respectively. Also, as per RTFO test result the performance grade after aging remains the same for molasses-A and decreases by one grade for molasses-B and molasses-C treated bitumen as compared with performance before aging.

B. *Comparison of laboratory results with standard specification*

As per SHRP (Strategic Highway Research Program), the PG grade system is based on climate with maximum and minimum pavement service temperature. The performance grade of the original bitumen was improved using addition of different percentage of molasses with different rate when compared with the original bitumen. As per RTFO test result the performance grade after aging and before aging were the same except for 15%and 20% of molasses-B and 15% of molasses-C mixtures. Generally, molasses-A 20% mixture improves 4 grades as compared with SHRP manual from 58 to 82 similarly molasses-B and molasses-C improves 3 and 2 respectively.

The penetration and ductility test result reveals that the value were decreased as the percentage mixture increases as compared with ASTM D 5 and AASHTO D 113 specifications respectively.

The softening point average temperature was increased as percentage of mixture increases; and which signifies that, the density and hardness of the mixture improved as in accordance with ASTM D36 specification.

C. *Cost analysis of base bitumen with different percent molasses replaced bitumen*

The cost of bitumen (40/50) treated with molasses are lower than the original bitumen. In fact, Molasses-A, Molasses –B, and Molasses –C can lowers the base bitumen (40/50) overall cost by 17.44%, 8.93% and 2.35% respectively.

Generally, from this research we can conclude that as per DSR performance testing machine result, the three stage cane molasses improves the performance of original bitumen with different rates.

VI. RECOMMENDATIONS

This investigation was conducted to study the effect of adding molasses on 40/50 penetration grade of bituminous material. Based on the result of this study and on the practical engineering considerations, it is recommended that the following special provisions be developed.

- The local authorities such as ERA and AACRA should be aware to permit using molasses mixed bitumen in asphalt pavement depending on results of this research as an alternative form.
- The Ethiopian sugar corporation should use the molasses to mix with base bitumen instead of exporting the molasses to reduce quantity of bitumen to be imported.
- Lastly, further studies are recommended to determine the molasses mixture effect to other penetration grade of bitumen's.

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