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Diversifying the Use of Molasses Towards Improving the Infrastructure and Economy of Kenya

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Abstract
Sugar factories in the sugar belt of Kenya produce a lot of molasses. Sony Sugar factory alone for example, produces about 140,000tonnes of molasses annually. All the sugar factories in Kenya in 2002 milled a total of 5.3million tonnes of sugar cane with molasses production being about 30% of this tonnage. The molasses produced is sold to farmers as animal feed or to distillers and food processing factories. This paper is an analysis of the production of molasses and sugar in four factories in Kenya with an examination of these components and how they contribute to the economy and or infrastructure of the country. The study was conducted through laboratory analysis of cane molasses to establish the components of the molasses that have an impact on quality of road construction soil materials. Data on production was collected from four sugar factories through a questionnaire. The data on sugar production was found necessary because molasses production depend on sugar production. This implies that the higher the sugar production the higher the molasses production. The data also showed a growing trend in annual sugar productions. Consequently this would translate to an increase in molasses production annually.
Keywords: Sugar molasses, Laboratory, Expansive soil, Stabilization

1. Introduction
Generally, when roads are built they are expected to remain in good condition throughout their design life with minimum maintenance. In order for them to remain that way, material standards and specifications should be met among other things. But sometimes good natural materials that satisfy the stipulated requirements may be not economically available at or near the site. In that case, decision has to be made on what course of action to take. There are many alternative actions that can be taken in order to ensure pavement remains stable throughout its design life. But the most obvious ones regarding the quality of construction soil material are three. One is to remove the existing soil and replace it with good quality soil, another is to improve or even to completely change the engineering properties of the soil to meet the intended purpose, and the third is to design the pavement to suit the existing conditions of the soil material. The purpose of this study was to find out whether the adequacy of molasses production in the country to meet the increased demand of molasses being used to improve engineering properties of soil for road construction. It has been established in other studies that molasses can be used in improving the sub-grade material. The sub-grade layer is normally considered to be the in-situ soil over which the road is constructed. This is shown in Figure 1. However, the term sub-grade is also applied to all native soil materials exposed by excavation, and to excavated soil that is artificially deposited to form a compacted embankment.

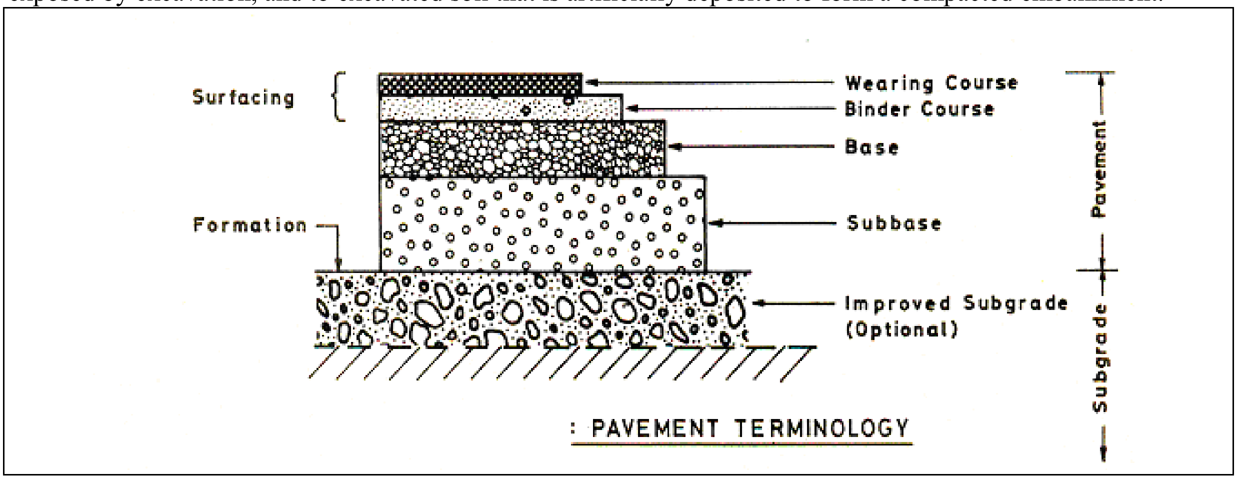

Figure 1: Cross-Section of Highway Pavement (MoT & C., 1987)

1.1 Sugar Molasses Production
Molasses is a very thick dark brown syrupy liquid obtained as a by-product in processing cane sugar. It is also called treacle. It contains resinous and some inorganic constituents that renders it unfit for human consumption. This liquid is mildly discomforting and adhesive when it gets into contact with a person's skin. It is slippery when spilt and could be a cause of road accident if a major spill takes place on the road. Molasses could cause

environmental pollution through aesthetic degradation if spills are not properly cleaned. It can also cause water pollution if major spills or factory effluents drain into river streams. It is therefore important to consider critically the handling and disposal of molasses particularly in situations where supply exceeds demand. Excess supplies can arise especially where industrial use of molasses is not diversified. The molasses produced in Kenya is mainly used in the manufacture of gasohol, production of alcoholic drinks, manufacture of confectionaries and also used as animal feeds.

During sugar processing some materials are added into the process as clarification agents and evaporator decadents. These materials include lime and sulphur dioxide among others. During crystallization of the sugar juice those elements remain in molasses and are then included in the natural molasses ingredients. Those elements plus others imbibed from the soil by the sugar cane as nutrients to support growth are the ones, which probably interacted with expansive soil to change its characteristics during stabilization. However, the exact composition of molasses is difficult to predict. The reason is that molasses composition is influenced by the soil where the cane is grown, climatic conditions, variety and maturity of the cane and the processing conditions at the factory. It is for that reason only ranges with indicative averages of the composition are usually given. In detailed sugar processing, the better grades of molasses, which are lighter in colour and contain more sucrose, are the ones sold to food processing factories. The lowest grade called blackstrap is sold to farmers as animal feed.

However, sugar factories in Kenya do not grade molasses. They only ensure that nearly all the sucrose is removed before molasses is disposed of. In the past a lot of molasses went to waste because the demand for it was low. In fact it was only the Agro-chemical factory at Muhoroni in Nyando district, and a few local farmers who were utilizing it. Thus many sugar factories were just dumping their molasses in the sugar farms. Others directed it out of the factory into natural drainage systems together with other factory effluents. One of the factories tried to use it as dust palliative on the footpaths but the stuff became messy when it rained thus its usage for that purpose was stopped.

1.2 Contribution to the Economy and Infrastructure

1.2.1 Roads Improvement

Very often roads linking the sugar growing estates around the sugar factories are in poor condition due to the high cost of construction materials and inadequate construction equipment. The Kenya Sugar Board (KSB) actualized the problem and is now trying to assist the factories to overcome it. For instance, in October 2004, the board gave Mumias Sugar Company one hundred and fourteen million shillings (Sh.114million) worth of equipment to be used in improving roads linking the sugar belt to Mumias Sugar Company (Malonza, 2014).

It is suggested that since Mumias Sugar Company produces molasses, the cost of road construction and maintenance will be greatly reduced if molasses can be used in improving the properties of soils for constructing roads in those areas. The same will be applicable to all other sugar manufacturing factories. Furthermore if construction cost of roads can be reduced through the use of molasses, then road conditions around sugar growing estates will in turn be improved greatly. Improved road conditions may in turn lead to reduction in spillage of sugar cane when being hauled from the farms to the factory. This will possibly result in increased earnings for both the farmers and sugar millers.

Improved road conditions will most likely stimulate development of other socio-economic activities around the lake region; Lake Victoria for instance, with activities such as growing of cash crops and efficient ferrying of fish from the lakeshores through road to processing plants will be revitalized. Generally good road conditions will bring about diverse land uses which are beneficial to the community. It is also anticipated that if molasses is prevalently used in stabilizing expansive soil, premature failure of minor roads constructed on them might be stopped provided other factors that contribute to road failure are taken care of.

1.2.2 Technology Advancement

The use of molasses in stabilization of expansive soil will provide an alternative cheap technique for stabilizing heavy clay soil. Indeed it will make construction of accessible roads in areas covered by expansive soils cheap. In addition it will minimize other problems associated with expansive clay soil particularly in those areas where sugar cane is grown and processed to produce sugar.

1.2.3 Environmental Protection

Molasses that remain unused can be led into wastewater drains and find its way into natural drainages sometimes without being sufficiently treated. If that happens it may become a source of environmental pollution especially in the rivers. The use of this material in road construction can most likely ensure such an eventuality does not take place because the added usage will ensure that all the molasses produced by factories is wholly taken care of in road constructions. The use of molasses in treatment of soil to improve its engineering properties will most probably bring about a considerable saving on the current expenditure on repairs for damaged structures. In that aspect it will immensely contribute to sustainable development of infrastructure.

1.2.4 Poverty Eradication

Sugar industry provides direct employment to about 40,000 Kenyans and employs about 460,000 persons indirectly (Ministry of Agriculture, 2004). Molasses being good and cheap ought to be adopted as material for road construction. If that is effected those Kenyans who are indirectly employed by sugar industry might increase in numbers due to increased activities on road works. Furthermore sugar cane growing being the major source of income for over 200,000 small-scale farmers whose production accounts for more than 85% of all sugar cane milled by sugar factories, use of molasses in soil treatment will stimulate increased earnings. The millers will most likely increase their earnings from the increased sale of molasses. The farmers will also benefit if the sugar factories agree to pay more for their cane as a result of increased earnings from sale of molasses.

1.3 Diversification of Molasses Use

Cane molasses production in Kenya is fairly high but so far it has not found much use in construction industry. The use of molasses in road construction will therefore ensure diversification for its use. The idea of using cane molasses in soil stabilization is based on the fact that low sugar content in lateritic concrete increases its strength (Oyekan, 2003). Since cane molasses has low sugar content it is expected to improve strength of expansive soil. Furthermore molasses can be used as dust palliative as well as a binder for granular soils that are structurally stable.

1.4 Cleaner Production

The use of cane molasses in soil stabilization will be a way of utilizing the philosophy of cleaner production. Cleaner production describes a preventive approach to environmental management. It is a general term that includes eco-efficiency, waste minimization, pollution prevention, or green productivity. It is also a mentality of how goods and services are produced with minimum environmental impact under the current technological and economic limits. The philosophy is applicable to both environmental strategies and economic considerations. The main difference between pollution control and cleaner production lies in timing. Whereas pollution control is an after-the-event "react and treat" approach, cleaner production is a forward looking, "anticipate and prevent" philosophy. The United Nations Environmental Programme (UNEP) defines cleaner production as a continuous application of an integrated preventive environmental strategy to processes, products, and services to increase overall efficiency and reduce risks to humans and environment (Guenther & Vittori, 2008). In accordance with this definition cleaner production can be applied to the processes used in the industry, to products themselves and to various services provided to the community.

Considering the production processes, cleaner production is a consequence of one or a combination of conserving raw materials, water, energy, eliminating toxic and hazardous raw materials and reducing the quantity and toxicity of all emissions and wastes at the source during production process. As concerns the products, cleaner production aims at reducing the environmental, health and safety impacts of the products over the entire life cycles, from extraction, through manufacturing use, and subsequent disposal of the product involved incorporating environmental concerns into designing and delivering services. The use of molasses in road construction is therefore a contribution to cleaner production.

2. Methodology

The study used literature analysis, interviews, and laboratory tests to collect data from a total of four factories in Kenya; Mumias, Muhoroni, Chemilil and Sony sugar.The laboratory tests on molasses included its chemical analysis in order to identify the main elements and compounds that comprise it. The knowledge of these ingredients helped understand the suitability of molasses as road construction material.

Interviews were conducted at the sugar factories during molasses sample collection. The questions were designed specifically to be answered by chemical analysts and chemical engineers working with the sugar factories and Kenya Sugar Board so that they could provide the information that was required for the study. Cane molasses contained sugars, organic and non-organic matter, inorganic constituents and water. The tests on cane molasses therefore basically involved analysis to determine the proportions of organic and inorganic compounds, and water contained in it. The anticipated organic compounds were mainly invert sugars and sucrose while the inorganic ones were basically in form of minerals imbibed from the soil water by the sugar cane. Since molasses' constituents include both organic and inorganic, various procedures were used in its analysis. The sucrose and invert sugars were determined as per Kenya Bureau of Standards – KS 05-344.But the inorganic constituents were determined through Atomic Absorption Spectrophotometric method (AAS). The procedure involved determining the specified inorganic constituents and ascertaining their respective proportions. The determination of each physical property was carried out according to standard procedure employed in the laboratory for that property.

3. Results

3.1 Molasses and Sugar Productions' Data from Sugar Factories

The sugar production data is shown in Table 1. The data on sugar production was found necessary because molasses production depends on sugar production. This implies that the higher the sugar production the higher the molasses production. The data also showed an increased trend in annual sugar productions. Consequently this would translate to an increase in molasses production annually. It was observed that at the factories the records for molasses production were kept separately from those of sugar production. Thus the data collection for molasses production was independent of that for sugar production. Tables 1 and 2 show the trends for sugar and molasses productions respectively.

Table 1: Recorded Annual Sugar Productions in Tonnes by Four Factories

Factory	**Annual Sugar Production in Tonnes**						
	1998 - 1999	1999 -2000	2000 -2001	2001-2002	2002 – 2003	2003 –2004	Total
Chemilil	63,607.85	69,305.85	41,978.85	54,922.41	50,170.24	5,056.68	**325,042**
Muhoroni	29,404.75	19,234.50	3,633.05	21,550.00	5,903.55	2,005.30	**141,731**
Mumias South	72,796.15	267,056.51	216,538.86	219,375.00	237,084.10	263,785.84	**1,276,636**
Nyanza	59,064.39	32,569.10	65,412.73	59,396.46	68,701.87	85,118.00	**370,263**
Total	**224,873**	**388,166**	**327,563**	**355,244**	**391,860**	**425,966**	**2,113,672**

Table 2: Recorded Annual Molasses Production in Tonnes by Four Factories

Factory	**Annual Molasses Production in Tonnes**						
	1998-1999	1999 - 2000	2000- 2001	2001 - 2002	2002 - 2003	2003 - 2004	Totals
Chemilil	23,077.75	24,890.45	16,006.52	20,218.00	18,747.95	18,396.31	**121,337**
Muhoroni	16,617.79	11,851.74	3,261.99	9,904.78	12,656.83	14,909.93	**69,203**
Mumias South	23,070.50	75,716.24	67,721.75	68,206.58	72,198.35	82,272.77	**389,186**
Nyanza	19,383.35	11,335.46	19,737.43	18,022.31	22,338.49	24,811.86	**115,629**
Total	**82,149**	**123,794**	**106,728**	**116,352**	**125,942**	**140,391**	**695,355**

The Projection for sugar and molasses production can be figuratively represented as in Figure 2 below:

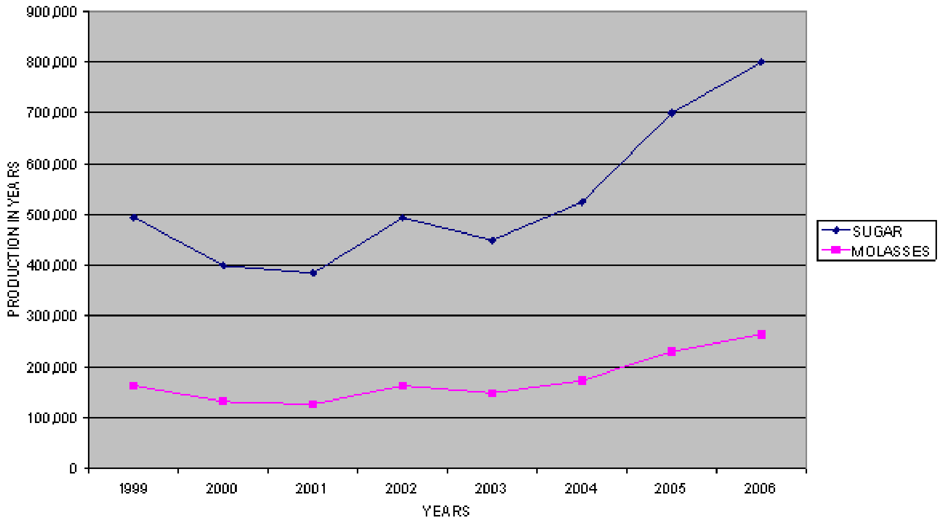

Figure 2: Projected Sugar and Molasses Productions by All factories

Table 3: Molasses Production as a Ratio of Sugar Production Based onAnnualProductions

Year	**Molasses(MT)**	**Sugar(MT)**	**Molasses/SugarRatio**
1998 -1999	82,149	224,873	0.37
1999 – 2000	123,794	388,166	0.32
2000 – 2001	106,728	327,563	0.33
2001 – 2002	116,352	355,244	0.33
2002 – 2003	125,941	391,860	0.32
2003 - 2004	140,391	425,966	0.33
Mean			**0.33**

Standard Deviation with reference to data in table 4 was obtained as follows:

Variance $= \sum\{x_{j} - x_{mean}\}^2 / n$

$= \{(0.37-0.33)^2 + (0.32-0.33)^2 + (0.32- 0.33)^2\}/ 6$

$= \underline{0.0003}$

Standard deviation $= \sqrt{0.0003}$

$= \underline{0.017}$

Actual mean = 0.33 ± 0.02

4. Discussion

4.1 Sugar and Molasses Productions

It was observed that a lot of molasses is wasted at the factories through spillage. Sometimes it was deliberately poured into a pit to create space at the molasses storage reservoir but most frequently spillage occurred through careless handling. If molasses which was lost through spillage could be prevented or minimized, it would result in increased financial gain. Comparing the sugar production data with that of molasses, it was noted that in every metric tonne of sugar produced 0.33 ± 0.02 metrictonne of molasses was obtained.

Using this relationship and discounting for molasses spillage it would be possible to estimate the amount of molasses produced in any given year. Although the data collected covered the period between 1998 and 2004, projections showed that sugar production is set to increase due to increased acreage plantation with sugar cane and increased cane crushing capacity by factories. This is evidenced by the development of sugar cane plantations at Tana Delta by Mumias Sugar Company and revival of Ramisi sugar factory and sugar cane growing in Kwale district and surrounding areas. Indeed crushing capacity will be increased through operationalization of Ramisi Sugar factory in Kwale district and Miwani Sugar factory in Nyando district. Through vision 2030, it is anticipated that more sugar factories will be opened in order to provide employment opportunities and reduce poverty amongst the citizens in the country. That could indeed increase sugar production. As sugar production increase molasses production will also increase.

4.2 Molasses Analysis

The analysis showed that sucrose content of the molasses varied from 36.6 to 37.6% among the three factories; Chemilil Mumias and Sony sugar. Thus the highest difference in sucrose between the three factories was 1% and least was 0.4%. The percentages of sucrose were found to be within those given by Kenya Bureau of Standard (2014). There was also a variation in invert sugar whose content ranged from 15.7% to 22.1%. But this range was within that found in the literature review for the same material. Other insignificant differences between results on molasses from the three factories were also observed. Nevertheless, those differences were also within acceptable range.

Considering the physical properties of molasses, it was observed that pH values were between 5.7 and 5.8. The pH value in this case is important because it serves as an indicator of the need to use equipment that could not be corroded during handling of molasses. It also provides the basis on which to warn the operatives against not wearing protective clothing. In fact it was stated earlier in the paper that molasses could be discomforting if it got into contact with a person’s skin. The acidic nature of molasses makes it reactive with montmorillonitic clay soil and cause flocculation of the soil.

Moisture content may be regarded as a physical condition of the material and probably not a physical property. However, moisture content of molasses was found to range from 20.0% to 25.4%. The highest moisture content was found in molasses from Chemilil. But molasses from the other two factories complied with requirements of KEBS (2014) which specified that moisture content in cane molasses ought to be 18-20%.

The ash content which was obtained after molasses was ignited at 1000^0C, was a parameter specified in various standards including KEBS. Test results showed that percentage of ash after ignition was 11.6% for Chemilil cane molasses; 7.3% for Mumias and 5.4% for Sony Sugar. These percentages of ash content did not fall within the range specified by KEBS. But the average for the three factories fell within the specified range. However, the figures were not unique because it could be seen from the results that a big variation existed as far as ash content was concerned. The reason for this discrepancy could be attributed to the factors mentioned earlier which caused differences in molasses results.

Other important parameters analyzed included specific gravity and viscosity of molasses. Specific gravity is important because it can be used in determination of other physical properties such as bulk density. The specific gravity obtained was within the range given by KS 01-953: 1998. It was also similar to that obtained by Curtin (1983).The viscosity of molasses is an important parameter because it shows the flow behaviour of the material. Rheologic properties of a material are essential particularly if it is to coat another through mixing the two materials.

As in this case where molasses is expected to coat the soil particles and bind them together besides providing elements responsible for cationic exchanges. The concern in this study was only the viscosity of molasses and not so much on other rheologicbehaviours of the material. Molasses rheologic properties should be such that it is able to coat soil particles and remain steadfast on them without stripping. But it was seen from the literature (O’Flaherty, 1974) that molasses dissolves in water and therefore it needs to be protected from water after mixing with subgrade soil. Another important aspect of viscosity is to enable molasses to be pumped during application to the road subgrade or any other part of the road.

The values of viscosity obtained compared well with those of fluid bitumen at the same temperature. That showed that molasses is pumpable using an appropriate pump for that purpose. The viscosity values for all molasses samples ranged from 4,895-5,285 centistokes at 60^{0}C. It is found from the literature review that a fluid which had a viscosity value similar to one obtained for molasses flowed. In fact it was also pumpable. Fluid bitumen like rapid curing cutback has a minimum viscosity of 7,000cSt. at 60^{0}C (MoW, Standard Specifications, 1970). This grade of bitumen is applied to the road surface through spraying using a pump. Therefore molasses whose viscosity is much lower than that of cutback bitumen at 60^{0}C can also be applied through pumping. It was also evident during sampling of molasses from the reservoir at the sugar factory, pumping into sampling containers was applied. Indeed even when preparing molasses-soil mixtures the material could be poured out from one container to another or to the mixing pan.

Among the elements and compounds found in molasses analysis, were those responsible for cationic exchange reactions. They included calcium, magnesium, sodium and potassium. The percentage of calcium in molasses was expected to be within 1.2-2.4% according to KEBS standard KS 01-953:1998.The values obtained in this study were 1.27% for Chemilil cane molasses, 1.23% for Mumias cane molasses and 0.77% for Sony Sugar cane molasses. The first two values fell within the range given by Kenya Bureau of Standards. But even the value of approximately 0.8% found in Sony Sugar cane molasses, was a common one as seen in various cane molasses analyses.

The magnesium content found in Chemilil cane molasses was 0.05% (500 ppm); Mumias sugar 0.29% and Sony Sugar 0.10%. In that case only cane molasses from Chemilil gave values similar to those of standard KS 01-953: 1998. However, the magnesium content found in Mumias sugar was the same as that found in the analysis of cane molasses by United States Sugar Corporation (2003).

The potassium and sodium contents ranged from 2.10% - 4.48% and from 0.01 – 0.04% respectively. According to standard KS 01-953: 1998, the maximum percentage of potassium expected in molasses was 5000ppm (0.5%) but it did not show the sodium content. However, Curtin (1983) found 2.4% potassium and 0.2% sodium. U.S molasses was found to contain 0.09% sodium (US Sugar Corporation, 2003).

5. Conclusion

Sugar factories in Western Kenya record high production levels of sugar and molasses with the trend hoped to increase over time. There is however much wastage on molasses especially due to over-spillage. Molasses is also underutilized despite the possible diversified uses. The higher the production of sugar in the factories, the higher the production of molasses. If well managed, molasses can be put to various uses including construction of roads. This may have a big positive impact on infrastructural development and particularly development of minor rural roads. This will definitely lead to quickened economic development of rural communities.

6. Recommendations

1. Further research should be carried out to establish how widely cane molasses is adopted as a road construction material.
2. Although molasses construction is cheaper than lime it should be limited to roads which do not carry heavy traffic.
3. Use of molasses would be handy for access roads in rural areas and feeder roads in sugar plantations.

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