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Volumetric Analysis of Cold Asphalt Mixtures Compacted Using the Marshall Compactor and the Superpave Gyratory Compactor

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Abstract:
Understanding the behaviour of an asphalt mixture in terms of its volumetric properties is important since volumetric properties provide an indication of the performance of the asphalt mix when subjected to various conditions of traffic loading.
This paper discusses the volumetric properties of cold asphalt mixes prepared at the optimum residual bitumen content using selected aggregates and bitumen emulsion binder. The main focus was the density and voids content of laboratory specimen compacted using the Marshall compactor and the superpave gyratory compactor, at compactive efforts recommended for low to medium traffic loading. Density and void contents for Marshall compacted samples at a compactive effort of 50 blows on either side of the specimen were compared to achieved parameters at 75 superpave gyrations. For superpave gyratory compacted specimen, it was possible to estimate the density and voids content of the mix during the compaction process as the number of gyrations were increased.
The percent air voids content of the cold asphalt mix samples remained very high (>7%) for both methods of compaction. However, mixes that were densely graded had lower air void contents compared to those with less dense particle parking.

Keywords: *Cold mix asphalt, density, air voids, Marshall, Superpave gyratory*

1. Introduction

Cold mix asphalt refers to cold mixed, cold laid mixture of graded aggregates and bituminous binder. The aggregates may be dense graded or open-graded. Bituminous binders for cold mixes include bitumen emulsions and cutback bitumen. The Asphalt Institute (2014), Manual MS-2 – Asphalt Mix Design methods recommends the use of cold mixes as surfacing material for light and medium traffic levels. When used for base or subbase construction, the manual recommends cold asphalt mixes for all levels of traffic.

For a long time, the design of bituminous mixes for road pavement construction was carried out using the Marshall method. The Marshall method was originally developed for the design of hot asphalt mixes. However, various researchers have successfully applied a Modified Marshall method in the design of cold mixes (Lavin, 2003). The Modified Marshall method for the design of cold mixes outlined in the Asphalt Institute (1989) Cold Mix Manual MS-14 was based on research conducted at the University of Illinois using bitumen emulsion and aggregates.

The design of asphalt mixes has evolved and most designers are moving away from the Marshall method in preference of the superpave method. The superpave method was developed under the Strategic Highway Research Program by the US congress which was completed in 1993. The aim of the research program was to develop performance based asphalt binder and mixture specifications so as to correlate laboratory methods with field performance (FHWA, 2005). The superpave mix design method was hence developed mainly to address the shortcomings of the Marshall method.

The main difference between the two methods is the procedure of compaction where the Marshall uses an impact type of compaction (using the Marshall Hammer) and the Superpave uses a combination of a static load and a gyrating mould to knead the specimen (using a Gyratory Compactor). The impact type of compaction by the Marshall method does not realistically duplicate the type of compaction that an asphalt mixture undergoes in the field by both construction traffic and rollers. The Superpave gyratory compactor is currently preferred for since the compactive effort can be correlated to the expected traffic loading (Lavin 2003).

Alan (2006) in his analysis of the various approaches used for cold mix design in the USA, emphasized on the need to update the traditional method of cold mix design using the Modified Marshall to incorporate compaction using the Superpave Gyratory Compactor. He acknowledges that the Modified Marshall method allows the ratio of the components in the mix to be determined but generally does not address practical issues such as changes in the workability and compactability of the material.Thanaya, Zoorob, and

Forth (2009) studied cold mix surfacing materials in the UK and made a correlation of compaction levels by the Marshall and gyratory compactor where 80 revolutions in the Gyropac would be equivalent to the compaction effort generated when applying 50 blows to each end of the sample using a Marshall hammer.

This paper presents a comparison of the volumetric properties of cold asphalt mixtures when compacted with the Marshall compactor and the superpave gyratory compactor. The volumetric properties studied included Air voids content (V_a) and bulk densities of the compacted specimen.

2. Methodology

Laboratory mix design of cold asphalt mixes was first carried out using the Modified Marshall method to obtain the Optimum Residual Bitumen Content (ORBC) of each mix. The aggregates used for the mixes were sourced from the following quarries:

- Gachocho quarry in Murang'a;
- Issaco quarry in Tebere; and,
- Aristocrats quarry in Mlolongo.

The emulsion binders used for the mixes were cationic slow set bitumen emulsion (K3-65) or anionic slow set bitumen emulsion (A4-60) from the manufacturer (COLAS-East Africa).

Two sets of samples were then prepared at the determined ORBC and were subjected to gyratory compaction up to 128 gyrations at 240Kpa, at 2° angle of gyration. This aimed to establish the density and voids achieved with the superpave gyratory compaction and to compare with the Marshall compacted samples.

3. Results and Discussions

The single sized aggregates from the quarries were proportioned and combined based on the predetermined job mix formula and the achieved grading of the mixes is presented in Figures 1 and 2.

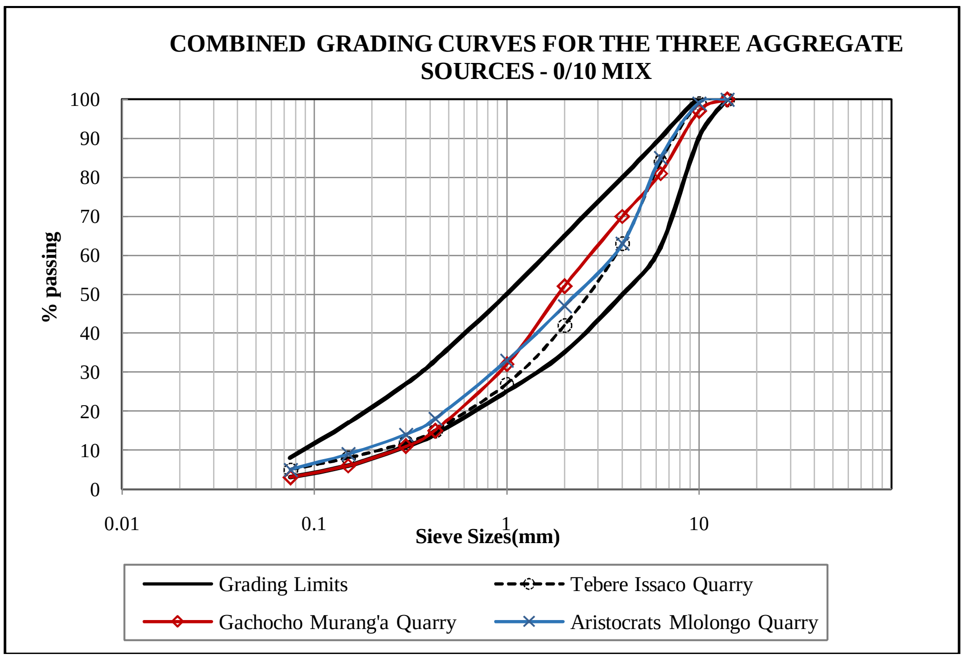

Figure 1: Graph showing the grading of 0/10mm mixes from the three quarries.

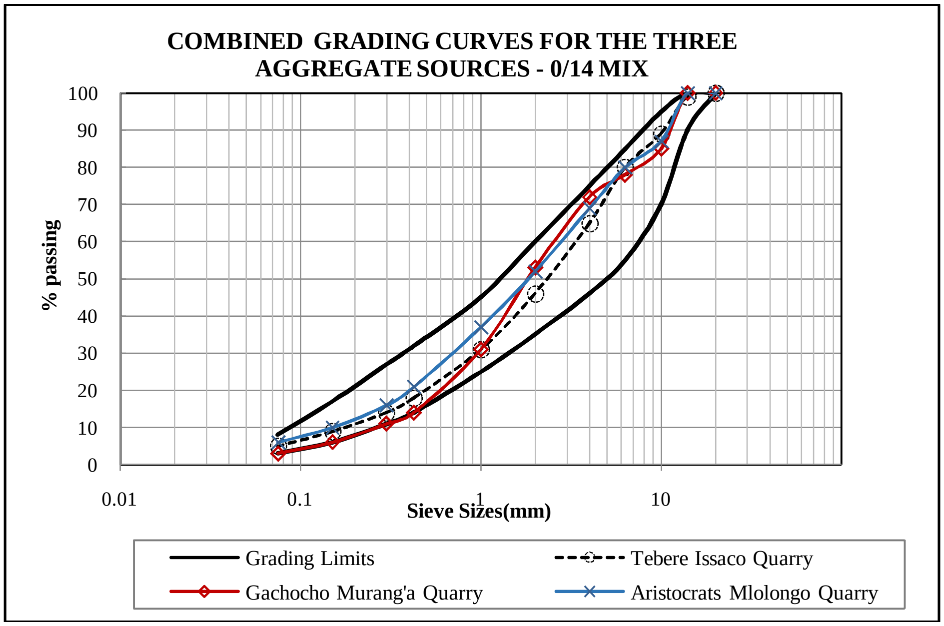

Figure 2: Graph showing the grading of 0/14mm mixes from the three quarries.

During the Modified Marshall mix design process, the volumetric properties for each sample at different residual bitumen contents were determined at the end of the compaction and curing process.

For superpave gyratory compacted samples, it was possible to determine the density and voids content with increase in the number of gyrations. With prior knowledge of the mass of the mixture placed in the mould, the diameter of the mould (150mm) and measurement of the specimen height with increase in number of gyrations, the volume of the specimen was calculated. This determined volume is an estimate since the calculation considers the specimen to be a smooth walled cylinder. The actual specimen is an irregular surface caused by the aggregate. The bulk densities determined were therefore corrected by physically completing a bulk density test on the extruded specimen at the end of the compaction. Figures 3 to 6 show a graphical presentation of the density and voids for the superpave gyratory compacted samples.

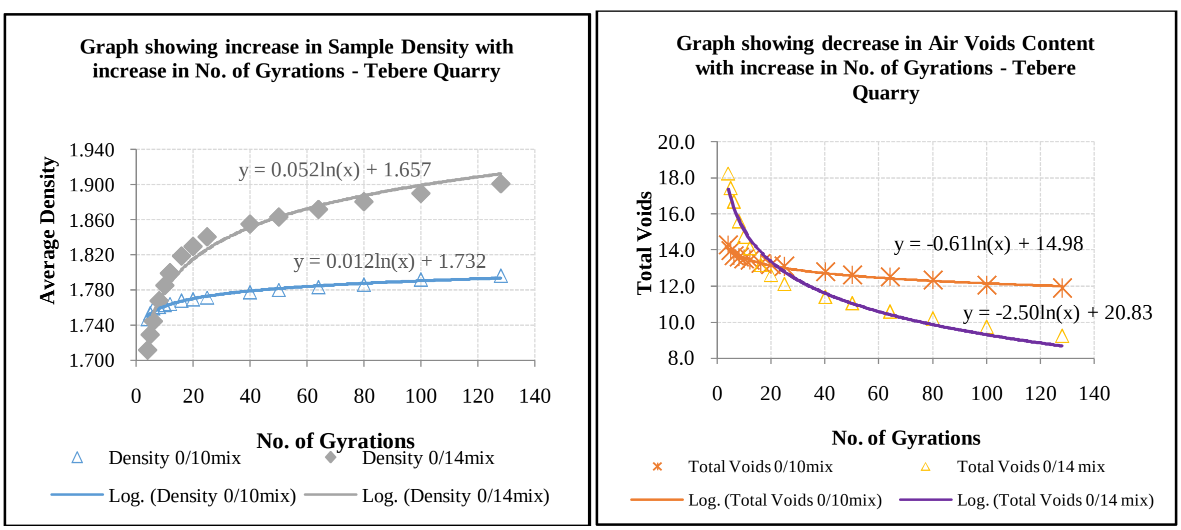

Figure 3: Graph showing variations in density and voids of samples with increase in No. of gyrations – Tebere aggregates

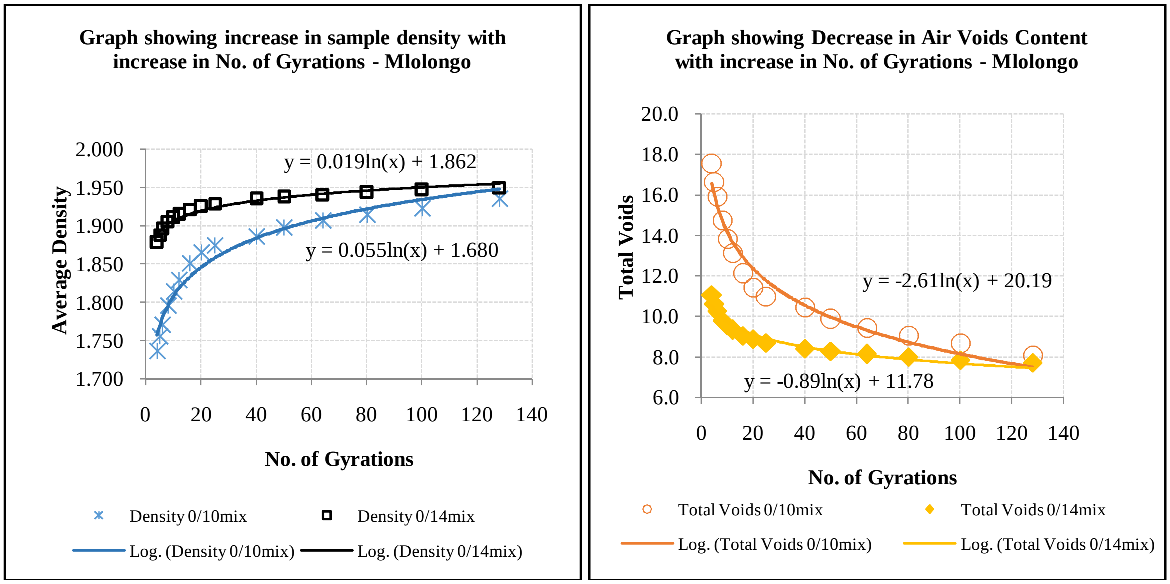

Figure 4: Graph showing variations in sample density and voids with increase in No. of gyrations – Mlolongo aggregates

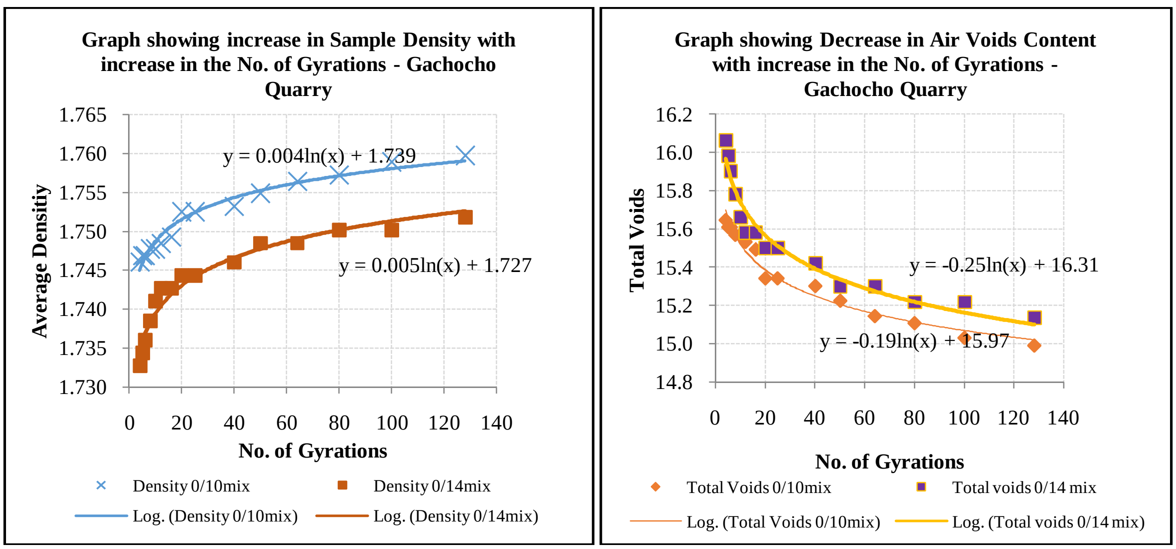

Figure 5: Graph showing variations in sample density and voids with increase in No. of gyrations – Gachocho aggregates

As the number of gyrations were completed, the sample density increased and the air voids decreased. At the end of the compaction (after 128 gyrations), the Mlolongo aggregates mix 0/14mm had the lowest air voids content of 7.7% while the Gachocho aggregates had the highest air voids of 15.0%. The lower air voids content achieved by the Mlolongo aggregate was due to the denser grading of the aggregate mix. The coarse aggregate grading of the Gachocho aggregates resulted in a high air voids content after compaction.

For medium to low traffic levels(<0.3 to 3million cumulative equivalent standard axles), the Superpave specification recommends a compaction effort of up to 75 gyrations for design.A comparison of the density and voids content at 75 gyrations of the Superpave compactor was made with those achieved at 50blows of the Marshall compactor.

Quarry Source	**Mix Sizes**	**Determined ORBC**	**Marshall Samples at a compactive effort of 50Blows**		**Gyratory Samples at a compactive effort of 75 Gyrations**	
			Bulk Density	***VIM***	***Bulk Density***	***VIM***
Gachocho	0/10mm	7%	1.962	17.1	2.000	15.1
	014mm	6.5%	1.946	17.2	2.090	15.2
Tebere	0/10mm	6.5%	2.000	14.1	2.047	12.4
	014mm	7%	2.015	14.5	2.140	10.2
Mlolongo	0/10mm	6.5%	2.000	13.4	2.080	9.1
	014mm	5.5%	2.050	12.5	2.115	8.0

Table 1: Density and Voids achieved at 75gyrations in comparison to 50blows of the Marshall compactor

From Table 1 above, the samples compacted with the superpave gyratory compactor had relatively higher densities and lower voids content at 75gyrations compared to the Marshall hammer compacted samples. For both methods of compaction, the air voids content of the mixes was high (>7%).However, the denser graded mixes had lower voids content compared to the others.

3. Conclusions

The main conclusions drawn from this investigation are as follows:

a) For the same asphalt mix, higher densities can be achieved in the laboratory when compacted with the superpave gyrator compactor as compared to the Marshall hammer.
b) The air voids and binder content of the mix depends more on the gradation and properties of aggregates than the compaction effort applied.
c) The air void content of the cold asphalt mixes remained high even with increased number of compaction gyrations.

It is acknowledged that the Marshall equipment is readily available, less expensive and portable and can therefore be used even in remote areas for quality control and testing of cold asphalt mixes. However, the superpave gyratory compactor offers a better alternative to mix design, testing and field quality control of cold asphalt mixes. In addition to simulating the type of compaction the asphalt mix undergoes in the field, the kneading and squeezing effect of the gyratory compactor expels excess liquid from the cold mix asphalt and the resultant specimen has desirable volumetric properties. The specimen height measurement function makes it possible to determine the ease of compactability of a prepared mix and also to have an insight on mixes which exhibit very low air voids content after secondary compaction and therefore prone to rutting.

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