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Contribution to the Study of Materials Commonly Used in Goma, DR Congo for Concrete Production

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ABSTRACT: A study was conducted to investigate the suitability of commonly used materials in Goma, DR Congo for concrete production. The objectives of the study were to characterize the raw materials and determine their optimal use for desired resistances. Idjwi sand used, with a fineness modulus of 2.53 and a sand equivalent of 83, was found to be suitable for concrete production. Volcanic origin gravel was well graded but required consideration for its water absorption coefficient of 13.5%. Nyiragongo and Hima cements met standard requirements. Compression tests were carried out on laboratory specimens made using the Dreux Gorisse method, and material quantification results were used to create a table for 1 m3 of concrete based on desired resistances.

KEYWORDS: Compressive strength, Concrete, dosage, Workability.

1 INTRODUCTION

Concrete is a composite material made up of aggregates, water, a binder, and optional additives [1]. It is a true artificial rock, one of the most widely used materials in all fields of construction [2]. Concrete is characterized primarily by its mechanical strength, durability, impermeability, and workability (ease of use) [3]. The compressive strength, the main characteristic sought in hardened concrete, depends on the degree of compactness of the mix, the curing conditions, and the quality and proportions of its constituents [2], [3].

Making concrete in a particular environment involves mixing the mentioned constituents available in that environment. In the city of Goma, since previous and recent volcanic eruptions have deposited huge amounts of lava whose magmatic rocks are crushed into gravel, this gravel is widely used in making concrete in this city.

The production of concrete requires appropriate quantities of constituent materials to easily achieve the desired strength as an infinite number of concretes can be obtained by varying the proportions of the constituents [4]. The quality of concrete depends not only on the quality of its constituents, but also on their proportions [4]. The engineer must therefore know the characteristics of the materials he uses as well as the proportions of the different elements involved in making a given concrete according to the strength required [5]. This requires time and financial resources to conduct various laboratory studies.

Our observations have shown that in Goma, most users do not formulate concrete before making it and instead rely on routine. Even when some users do so, they generally do not take into account the water absorption coefficient of Goma aggregates involved in the constitution of the concrete. This results in concretes with compressive strengths that are either higher or lower than the required strength for a given application [6], [7], [8], [9], [10].

Given all of the above, a question arises: Is it possible to characterize the materials used daily in making usual concretes and develop a chart that facilitates the use of these materials according to the desired strengths of these concretes?

The main objective of this article is to develop a chart for the constituents of concrete for the builders in Goma according to the different usual compressive strengths. This would contribute to the improvement of the quality of the concrete produced and therefore to the reduction of technical accidents in this city.

2 MATERIALS AND METHODS

The constituents used in concrete are of various types and origins. In the following paragraph, we present the nature and origin of the cement, water, sand and gravels used, respectively.

HIMA and NYIRAGONGO cements were used in the making of different types of concrete. The selected cements in this study are of the pozzolanic type CEM IV/B 32.5, grey in color and produced respectively in Uganda and DRC.

According to the standard NF P18-303, potable water is suitable for making concrete [11]. The potable water supplied by the Congolese water distribution company (REGIDESO) was used as mixing water in making the concrete.

The sand used is a rolled sand dredged from Lake Kivu, class 0/5. The gravel used is of the crushed type extracted from basaltic rock, respectively classed as 5/15 and 15/25.

The composition of the concrete was analyzed using the Dreux-Gorisse method [12], [13]. The constituents of the concrete were determined for various strengths ranging from 8Mpa to 22Mpa.

The sieve analysis of aggregates was carried out according to the standard NF P 18-560 [14]. The unit weight of the sand was determined according to the standards NF P 18-555 [15] and the standards NF P 18-554 [16] for the gravels. The sand equivalence was determined according to the standards NF P 18-598 [17]. The water absorption rate was determined according to the standards NF P 18-554 and NF P 18-555 [15], [16]. The absolute unit weight of the cement was determined by applying the graduated test tube method according to the standard NF P 18-558 [18]. The workability was evaluated using the Abrams cone, in accordance with the standard NF P 18-451 [19]. The compression test on a cylindrical sample was performed in accordance with the standard NF EN 12390-7 [20].

3 RESULTS AND DISCUSSIONS

This section presents the results obtained for the various tests carried out in the laboratory and their interpretation.

3.1 COMPONENT PROPRERTIES

3.1.1 SAND

The granulometric analysis was carried out on the Idjwi sand with a sample of 2000g. The granulometric composition is presented in Fig. 1.

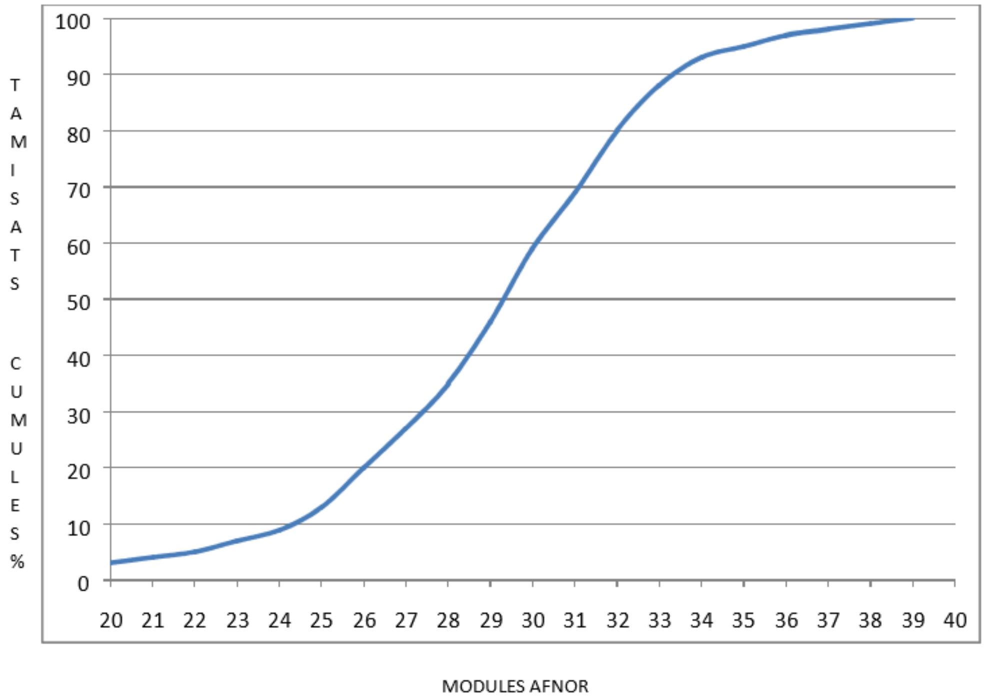

Fig. 1. Particle size distribution curve of sand

The coefficients of uniformity (Cu) and curvature (Cz) are 4 and 1 respectively. It is observed that Cu is greater than 2, indicating a spread granulometry, while the curvature coefficient has a value of 1, indicating a well-graded granulometry.

The value of the fineness module, which is 2.53, confirms that the granulometry of this material is better suited for making concrete because the Mf is in the range [2.2; 2.8].

The sand equivalent has been determined to have a value of 83%. This indicates that this sand is clean and suitable for concrete formulation.

The results of the determination test of the absolute and apparent density, as well as the moisture content of the sand, are presented in Table 1.

Table 1. Densities of Idjwi rolled sand

	Absolute dry density (g/cm^3)	Apparent density (g/cm^3)
Sand	2,3078	1,03

3.1.2 Gravel

3.1.2.1 The Particle Size Distribution Of 5-15 Volcanic Origin Gravel

The particle size distribution of 5-15 volcanic origin gravel is presented in figure 2.

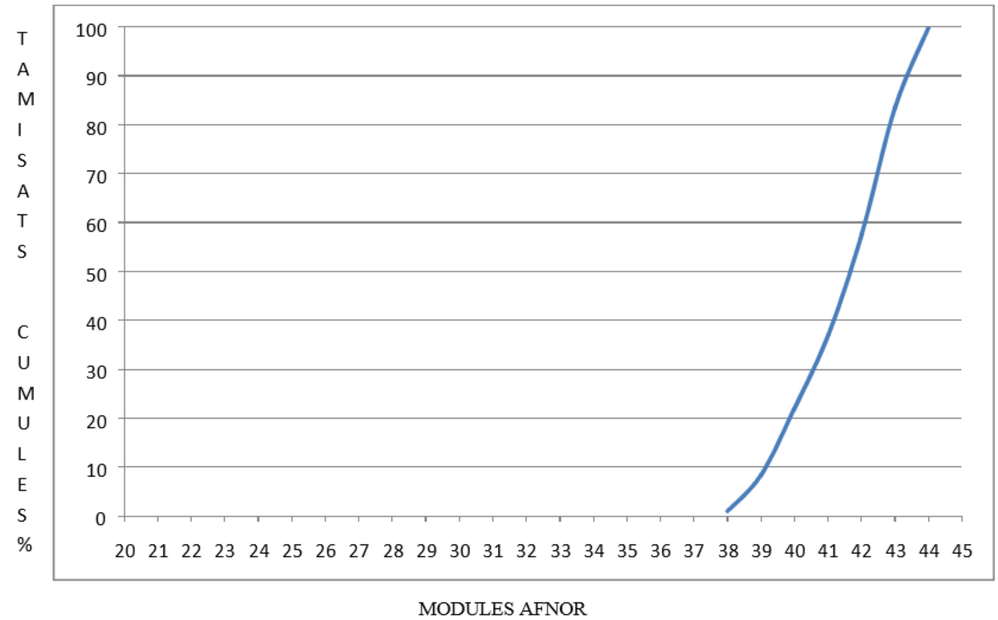

Fig. 2. Particle size distribution curve of 5-15 gravels

The uniformity coefficient Cu and curvature coefficient Cz are 1.98 and 1.27, respectively. The gradation is poorly spread, but with a Cz value of 1.27, the particle size distribution is well-graded.

3.1.2.2 The Particle Size Distribution Of 15-25 Volcanic Origin Gravel

The uniformity coefficient Cu and curvature coefficient Cz are 1.25 each. The gradation is also poorly spread, but with a Cz value of 1.25, the particle size distribution is well-graded. Figure 3 displays the particle size distribution of Idjwi rolled sand.

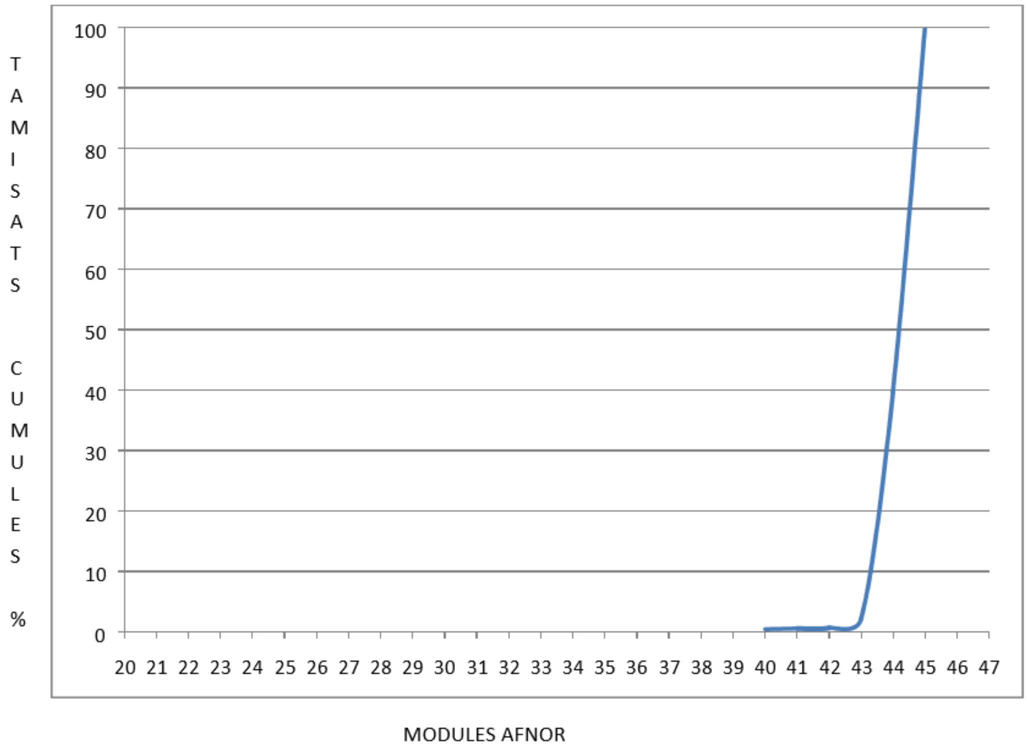

Fig. 3. Particle size distribution curve of 15-25 gravels

The densities found are given in Table 2.

Table 2. Volcanic gravel density results

	Absolute dry density (g/cm^3)	Apparent density (g/cm^3)
Gravel	2,3684	1,44

The water absorption coefficient observed for Goma volcanic aggregates is around 13.5% [22].

3.1.3 Cement

3.1.3.1 Setting Time Test

The results of setting time test of studied cements are presented in table 3.

Table 3. Setting time of studied cements

Cement name	Initial setting	Final setting
Nyiragongo	13h40'	15h10'
Hima	14h 28'	16h15'

3.1.3.2 Normal Consistency Test

Normal consistency test results for the cements studied are presented in Table 4.

Table 4. Consistency of studied cements

Denomination	Amount of water in %
1. Nyiragongo	27.3
2. Hima	35

3.1.3.3 Densities

The absolute densities of the cements studied are presented in Table 5.

Table 5. Absolute density of cements

Denomination	**Absolute density** (g/m^3)
1. Nyiragongo	2.997
2. Hima	2.916

Table 5 shows that Nyiragongo cement has the highest density. All these cements have densities close to the reference density of 3.1 g/m3 [18].

3.2 Results Of Formulation Using The Dreux-Gorisse Method

The basic data for concrete formulation are given in Table 6, i.e. desired compressive strength of concrete, desired consistency, type of vibration, true class of cement, aggregate condition and maximum aggregate size (D).

Table 6. Basic data for concrete mix design

	Data
Desired resistance	8, 10, 12, 14, 16, 18, 20, 22 MPa
Expected slump	7cm
Type of vibration	Weak
True class of cement	32,5MPa
Granular coefficient	0,5
D	25 mm

The theoretical proportional quantities of various constituents for concrete, determined by the Dreux Gorisse method, are presented in Table 7. The abbreviations C, E, S, G_1, G_2 represent the following proportions: C for cement; E for water; S for sand; G_1 for gravel size 5-15; and G_2 for gravel size 15-25.

Table 7. Proportions of various constituents for formulated concrete

28-day strength	Dosage Kg/m^3	Type of cement	
		Nyiragongo	Hima
8MPa	C	208	208
	E	218	218
	S	627	625
	G	G_1=678, G_2=417	G_1=676, G_2=416
10 MPa	C	235	235
	E	218	218
	S	641	639
	G	G_1=710, G_2=364	G_1=707, G_2=362
12 MPa	C	289	265
	E	217	220
	S	618	635
	G	G_1=694, G_2=386	G_1=677, G_2=386
14 MPa	C	318	289
	E	218	217
	S	647	615
	G	G_1=630, G_2=407	G_1=691, G_2=384
16 MPa	C	343	318
	E	217	218
	S	578	644
	G	G_1=695, G_2=407	G_1=627, G_2=407
18 MPa	C	371	343
	E	217	217
	S	567	576
	G	G_1=675, G_2=430	G_1=692, G_2=405
20 MPa	C	400	371
	E	219	217
	S	556	564
	G	G_1=638, G_2=470	G_1=672, G_2=428
22 MPa	C	289	400
	E	217	219
	S	556	553
	G	G_1=638, G_2=470	G_1=634, G_2=467

3.3 Concrete Properties

This section presents the characteristics of concrete in its fresh state, including workability, as well as its characteristics in its hardened state, including compressive strength.

3.3.1 Workability

The verification focused on the dosages found for 16MPa, 20MPa, 22MPa with Hima Cement, and 22MPa, 20MPa, 18MPa, 16MPa, 14MPa, and 12MPa with Nyiragongo Cement. The results of workability tests are presented in Table 8.

Table 8. Results of workability tests on manufactured specimens

	Nyiragongo	Hima
16MPa	6.5	6.1
20MPa	7.3	6.7
22MPa	7.4	6.9
18 MPa	7	-
14 MPa	8	-
12 MPa	7.1	-

It is noted that all the concrete produced is plastic, as it falls within the 5 to 9 cm range of the Abrams cone slump value.

3.3.2 The Compressive Strength

The results of the compression strength tests are presented in tables 9 and 10.

Table 9. Results on Hima cement specimens

Desired strength	1st specimen	2nd specimen	3rd specimen	Average
16 Mpa	15.7	16.67	14.97	15.78
20 Mpa	19.5	18.98	20.69	19.72
22 Mpa	21.5	21.88	22.89	22.09

Table 10. Results on Nyiragongo cement specimens

Desired strength	1st specimen	2nd specimen	3rd specimen	Average
12 Mpa	8.1	8.93	7.99	8.34
14 Mpa	10.955	9.8	10.1	10.285
16 Mpa	12.28	11	13.3	12.19
18 Mpa	14.422	13.95	14.02	14.13
20 Mpa	15.5	16	16.52	16
22 Mpa	18.67	17.5	18.8	18.3

Based on the results obtained from the tested specimens presented in the previous tables, it was observed that the specimens made with Hima cement offer compressive strengths that match those desired in Dreux Gorisse's theoretical formulation. This validates all the theoretical dosages of materials found in said formulation for Hima cement (Table 7).

Furthermore, the tested Nyiragongo cement specimens offer lower compressive strengths compared to the desired values in the theoretical formulation. It was observed that these strength values found are approximately four less than the desired value (found value = desired value - 4) as shown in Table 10.

Finally, these results allow for the development of the proposed chart for the rational use of commonly used materials in Goma for making concrete. The validated final dosages are presented in Table 11.

Table 11. Chart for the use of commonly used materials in Goma, based on desired compressive strength at 28 days

28-day strength	Dosage Kg/m³	Type of cement	
		Nyiragongo	Hima
8MPa	C	265	208
	E	220	218
	S	637	625
	G	1087	1092
10 MPa	C	289	235
	E	217	218
	S	618	639
	G	1080	1069
12 MPa	C	318	265
	E	218	220
	S	647	635
	G	1037	1063
14 MPa	C	343	289
	E	217	217
	S	578	615
	G	1102	1075
16 MPa	C	371	318
	E	217	218
	S	567	644
	G	1105	1034
18 MPa	C	400	343
	E	219	217
	S	556	576
	G	1108	1097
20 MPa	C	-	371
	E	-	217
	S	-	564
	G	-	1100
22 MPa	C	-	400
	E	-	219
	S	-	553
	G	-	1101

The proportions indicated in Table 11 correspond to one cubic meter of concrete based on the common gravels of volcanic origin in Goma, rolled sand from Idjwi that is commonly used in Goma, drinking water supplied by REGIDESO/Goma, and Nyiragongo and Hima cement.

These provided dosages are established for dry materials. It is imperative to consider the water content of the aggregates that will be used before mixing [22]. A measure of the water content must therefore be taken [23].

It should also be emphasized that the mixing conditions for concrete on the site must be rigorously followed, especially with regards to the quantity of water indicated in Table 11 [24]. If a concrete mixer is unavailable, the concrete mixing should be done on an impermeable surface (a surface covered in a tarp or a hardened slab, etc.) and not mixed on the ground as is the case on most Goma construction sites. This is to prevent a certain quantity of water from being lost through infiltration in the soil or through any other permeable surface.

4 CONCLUSION

In summary, this article highlights the importance of rational use of materials for concrete production in Goma, which can lead to both technical and economic benefits.

To achieve the desired strength for intended applications, it is recommended for constructors to use various available materials and consult the usage chart provided in this article [21].

Further research can be conducted to expand this study to include other types of materials used in the city, such as different types of cement.

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