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Contribution To The Characterization Of The Butembo Sands (North Kivu, DRC) For Use In Concrete

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Abstract
Despite the gradual professionalization of the construction sector and the abundance of sand extraction sites in the eastern DRC town of Butembo, local builders' lack of knowledge of materials persists. In the present work, the physical characterization of the river sands of Thalihya, Mutinga, Musienene, Kimemi, Kihuli, Kaliva and Kalengera has been carried out. Experimental laboratory studies show that Kalengera sand requires washing before it is used in concrete because it has a sand equivalent of less than 70%, i.e. 44.81%. All the other sands have a sand equivalent of more than 70%, indicating that these materials are clean sands for making concrete. The materials of the Mutinga River, Kaliva and Kalengera, have a spread out and well graduated particle size. However, the materials of the river Thalihya, Musienene, Kimemi, kihuli have a spread out and poorly graduated particle size. Thalihya, Mutinga, Kimemi, Kihuli sand fineness modulus is within the preferred range of concrete sand fineness modulus ($2{,}2 \leq Mf \leq 2{,}8$). As for the Kaliva and Kalengera sands, they have a fineness modulus of 3.3 and 3.11 respectively; values which attest to the coarse nature of these materials. As for Musienene sand, it has a modulus of fineness of 2, a value which attests to the fine character of this material. In view of this, it is proposed that the Kaliva and Kalengera sands be associated with the Musienene sand to an appropriate extent using the tables developed in the course of this work. The compression tests carried out on the concrete test pieces produced with the use of the proposals developed in this work give good strengths, which attests to their validity. Thalihya and Mutinga sand-based concretes can be used in reinforced concrete structures, located in a frost-free humid exterior or interior environment. Kimemi and Kihuli sand-based concretes can also be used in reinforced concrete structures located in a dry interior environment. However, for concretes obtained by combining Kaliva and Kalengera sand with Musienene sand, the latter can be used for unreinforced concrete structures located either in a non-aggressive environment, or in a dry internal environment or else in a wet external or internal environment not presenting a risk of freezing.

Keywords*: River Sand, Concrete, Materials, Characterization*

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I. Introduction

The Democratic Republic of Congo is a construction site [1]. The constructions are identifiable on both the individual and the state side. Regardless of this affiliation, various structures under construction are noticeable such as buildings, roads, bridges, etc. Located in the northeast of the country, on the Rwenzori graben and west of the Virunga National Park between 0°05′ and 0°10′ north latitude and 29°17′ and 29°18′ east longitude and 17 km north of the equator [2, 3], the town of Butembo has an area of 190.34 km^2 [2], one of three towns in the North Kivu province of the Democratic Republic of the Congo (DRC), adjacent to the towns of Goma and Beni [4] ; with an altitude between 1600 and 2000 m [5, 6].

River sand, in particular, is a common source for concrete production, and is widely used as building material. According to industry estimates, river sand accounts for more than 60% of the total sand used in concrete production worldwide [7]. However, the quality and characteristics of river sand vary depending on its origin, and these variations can significantly affect the properties of concrete made from this sand [8, 9, 10].

Several studies have examined the effect of the use of river sand, sea sand and crushed rock sand on concrete properties [11, 12, 13]. For example, some studies have examined the mechanical properties of concrete from a partial substitution of river sand. As a result, the properties of concrete change when the origin or quality of the sand changes [14, 15, 16]. Another study analyzed the demand for natural river sand in the construction industry and explored alternative sources of sand [17]. It should be noted that the failure of concrete structures leading to the collapse of buildings has given rise to various research on the quality of construction materials. Building collapses resulting in injuries, loss of life and investment have been widely attributed to the use of poor quality concrete ingredients.

During the rainy season, waters of various origins travel to rivers, taking with them considerable quantities of the materials that they wash on their course. These materials are washed naturally by water and accumulate on the beds of the rivers of Thalihya, Mutinga, Musienene, Kimemi, Kihuli, Kaliva and Kalengera. Throughout these rivers, communities have set up quarries to extract huge quantities of sand to make concrete and mortars. However, the dosages of different constituents are most often chosen arbitrarily which, while not useless, is not sufficient for a better use of this heritage offered by nature. This results in harmful consequences on the structural plane of the structures, in particular poor resistance of the coating coatings on the walls; cracking and crumbling of the beams, lintels, posts or even the destruction of the structures).

The objective of this study is to characterize the Butembo sands for better use in concrete production. To achieve this objective, it is necessary to take representative samples of the sands of the rivers created by their abundance and their high use; to carry out laboratory tests, including the classification of materials; and to draw up proposals for a better use of the materials studied.

II. Test equipment and method

In this section, all the tests for the qualitative and quantitative characterization of the aggregates are presented, as well as those relating to the concrete obtained.

2. 1. Origin of constituents

2. 1. 1. Sands

The sands used are Class 0/5 sands from the Thalihya, Mutinga, Musienene, Kimemi, Kihuli, Kaliva, and Kalengera rivers in the Democratic Republic of Congo.

2. 1. 2. Gravel

The gravels used are class 5/15 and 15/25 crushed from the basaltic rock of the quarry at Goma airport in the Democratic Republic of Congo.

2. 1. 3. Binder

The cement used is a CEM II cement of commercial class 42.5N produced in Rwanda. The physico-mechanical characteristics are presented in Table 1.

Table 1. Physico-mechanical characteristics of CEM II 42.5N cement

Physico-mechanical characteristics	
Water demand (%)	28
Start of dosing (min)	220
Blaine area (cm^2/g)	3,800
Density (g/cm^3)	3.05
Compression strength (MPa)	40

2. 1. 4. Water

The water used is drinking water supplied by the Goma Water Supply Authority (REGIDESO).

2. 2. Experiments

The water content was determined by baking the materials in accordance with the requirements of standard NF P 94-050 [18]. The particle size analysis was carried out by dry method in accordance with the requirements of NF EN ISO 17892-4 [19]. Sand equivalent was determined according to NF EN 933-8+A_1 [20]. The absolute density was determined by measuring the solid grains using a pycnometer and by successive weighing operations in accordance with the recommendations of standard NF EN ISO 17892-3 [21]. The apparent density was studied using the NF EN 1097-6 balloon method [22]. As regards the formulation of concretes, in the present work, the Dreux method was used [23, 24]. The workability was determined in accordance with the requirements of NF EN 12350-2 [25]. As for the compressive strength, standard NF EN 12390-3 [26] has been used.

III. Results and discussion

A good knowledge of the characteristics of the aggregates makes it possible to use them better in construction. The physical characteristics of the sands used in Butembo are presented, including density, sand equivalent and particle size composition. Proposals were then drawn up for a better use of these sands, specifically the formulation of the concretes, the washing of the sand and the correction of the fineness modulus. Finally, the characteristics of concretes formulated on the basis of said sands are particularly exposed to the composition of the concretes, workability and compressive strength.

3. 1. Characteristics of constituents

The characteristics of sand and gravel are presented. For sands, this includes density, sand equivalent, and particle size composition. As regards the chips, their density and their particle size composition are exposed.

3. 1. 1. Density of sand

The values of the absolute density as well as the apparent density of the sands studied are presented in Table 1.

Table 1. Butembo sands density

Parameters	Types of Sands						
	Thalihya	Mutinga	Musienene	Kimemi	Kihuli	Kaliva	Kalengera
Absolute density (g/cm^3)	2.59	2.50	2.52	2.46	2.45	2.40	2.45
Apparent density (g/cm^3)	1.40	1.28	1.35	1.22	1.21	1.26	1.27

The results presented in Table 1 show that the values of the absolute density of the various sands are between 2 and 2.60 g/cm^3. This result shows that these are common aggregates, specifically alluvial materials [23, 24] and can be used for concrete formulation.

As regards the apparent density, only the sand of the Thalihya river has an apparent density of between 1.40 and 1.60 g/cm^3 [27]. Then come the sand of the Musienene river with an apparent density of about 1.40 or 1.35 g/cm^3. All the other sands have an apparent density of less than 1.40 g/cm^3.

3. 1. 2. Sand equivalent

The sand equivalent is the average of the visual sand equivalent and the piston sand equivalent. The sand equivalent values of the materials studied are presented in Table 2.

Table 2. Butembo Sand Equivalent Values

Type of sand	Thalihya	Mutinga	Musienene	Kimemi	Kihuli	Kaliva	Kalengera
Sand equivalent (%)	95.07	73.61	79.17	71.81	73.08	71.70	44.81

On the one hand, the results of the sand equivalent presented in Table 2 show that the sands of Thalihya, Mutinga, Musienene, Kimemi, Kihuli and Kaliva are respectively 95.07; 73.61; 79.17; 71.81; 73.08 and 71.70. The sand equivalent of the materials studied being greater than 70, indicates that, from the point of view of cleanliness, these materials are clean sands usable for the production of high-quality concrete [1, 23, 24, 28, 29, 30, 10, 31, 32, 33]

On the other hand, Kalengera sand has a low equivalent of less than 60, or 44.81. There are therefore more impurities which could present a risk of shrinkage or swelling. This sand requires washing before it can be used in concrete [23, 24, 28].

3. 1. 3. Granulometric composition of sand

The particle size composition of the sands of the Thalihya, Mutinga, Musienene, Kimemi, Kihuli, Kaliva and Kalengera rivers is presented in the form of the curves in figure 1. The grain size curves of all the sands are also shown in figures a, b, c, d, e, f and g in Appendix 1.

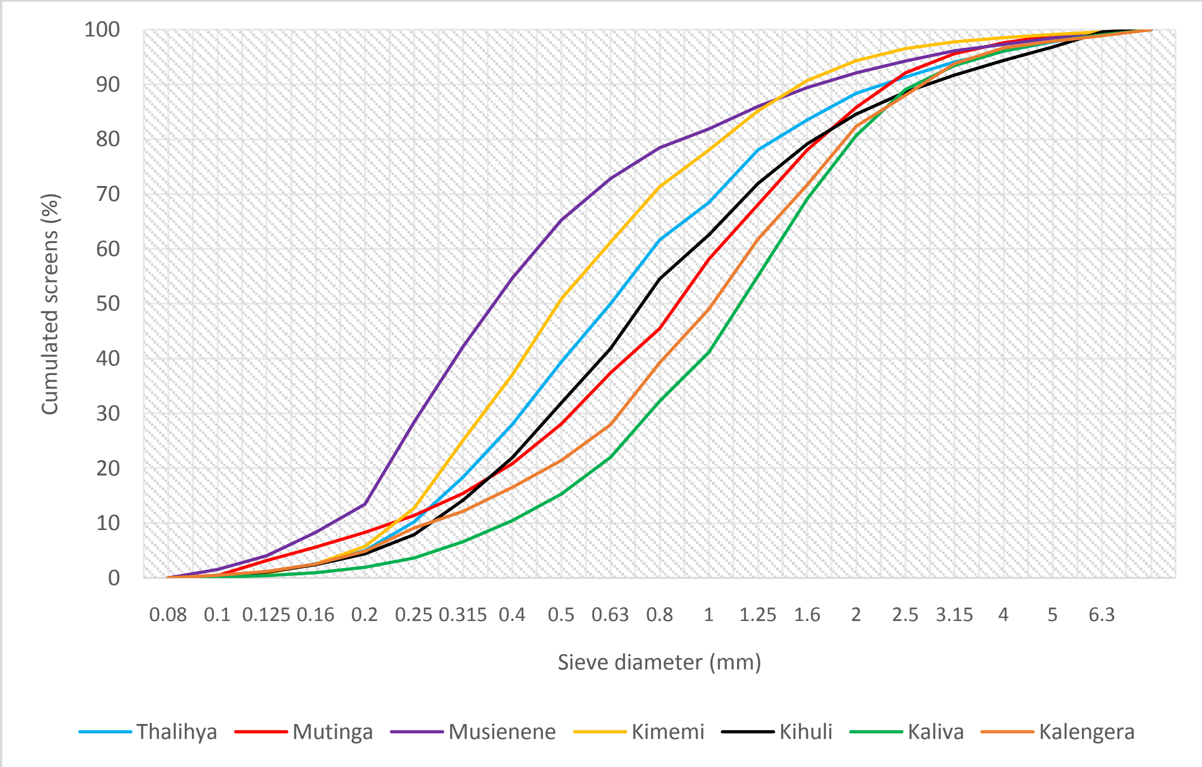

Figure 1. Particle size curve of Butembo sands

Observation of the particle size curves shown in Figure 1 shows that the materials contain all the granular classes. The grain size curves of the Kaliva and Kalengera sands are concave upwards, indicating that these materials are rich in large elements. While Musienene sand has a downward concavity, indicating that this material is rich in fine elements. In addition, the curves are offset from one another, which testifies to the differentiation of these materials although all are river sands. The overall shape of the curves is substantially the same (doucine shape), showing that the materials are the common aggregates.

3. 1. 4. Classification of Butembo sands by uniformity, curvature and modulus of fineness

Classification based on the coefficients of uniformity and curvature, as well as the modulus of fineness of the sands, was used. The coefficients of uniformity, curvature and modulus of fineness determined with the use of the particle size composition shown in Figure 1 are presented in Table 3.

Table 3. Coefficients of uniformity, curvature and modulus of fineness of the sands studied

Materials	**Coefficient of uniformity Cu**	**Coefficient of curvature Cz**	**Module of fineness Mf**
Thalihya sand	3.13	0.91	2.62
Mutinga sand	4.59	1.16	2.52
Musienene sand	2.60	0.85	2
Kimemi sand	2.67	0.86	2.3
Kihuli sand	3.45	0.91	2.8
Kaliva sand	3.53	1.09	3.3
Kalengera Sand	4.52	1.33	3.11

Table 3 shows that the values of the coefficient of uniformity (Cu) for all the sands studied are greater than 2, so the particle size is spread out. The curvature coefficient (Cz) is 1.16; 1.09 and 1.33 for Mutinga, Kaliva and

Kalengera, which means that the particle size is well graduated, indicating a wide variety of dimensions. For the river sand Thalihya, Musienene, Kimemi, kihuli, the value of Cz is respectively 0,91; 0,85; 0,86; 0,91 less than 1, indicating the absence of certain diameters between the diameters D10 and D60. The granulometry of the sands of Thalihya, Musienene, Kimemi, kihuli is therefore poorly graduated.

The modulus of fineness was determined as the sum of the cumulative densities on the sieves of diameter 0.16; 0.315; 0.63; 1.25; 2.5 and 5 reduced to one. The value of the fineness modulus obtained for the sand of the quarry Thalihya, Mutinga, Kimemi, Kihuli is respectively 2.62; 2.52; 2.3 and 2.8 which falls within the preferential range of the fineness moduli of the sand for concrete ($2{,}2 \leq Mf \leq 2{,}8$).

As for the Kaliva and Kalengera sands, they have a fineness modulus of 3.3 and 3.11 respectively, values which attest to the coarse nature of these materials. As for Musienene sand, it has a modulus of fineness of 2, a value which attests to the fine character of this material. Such high or low values do not fall within the preferred range of the fineness moduli of concrete sands. In view of this, the particle size of these sands requires correction. This particle size may lead to non-optimal strength of the concretes from which it is incorporated, which may in turn be one of the causes of the crumbling, cracking or even ruin of the structures (poles, beams, lintels, etc.) observed on several buildings a few years after their construction.

3. 1. 5. Density of chippings

The combined use of the studied sands, combined with a good formulation, would make it possible to improve their quality for the production of concretes, which would lead to an improvement in the strength of the latter. In order to study the preferred combinations of these sands for the manufacture of concretes, the study of mixtures at certain proportions of the materials was carried out. For this purpose, concrete specimens were made using crushed class 5/15 and 15/25 gravels from the basaltic rock of Goma. The density parameters of the latter are presented in Table 4.

Table 4. Density of gravel used

Parameters	**Gravel Class**	
	5/15	15/25
Absolute density (g/cm^3)	2.50	2.50
Apparent density (g/cm^3)	1.38	1.38

Table 4 shows that the apparent density and the absolute density of the gravel of Goma class 5/15 and 15/25 are respectively 1.38 g/cm^3 and 2.50 g/cm^3. These granular classes have the same density values because they are derived from the same parent rock. These values are consistent, in order of magnitude, with those of other aggregates, resulting from the physical decomposition of the rocks [1].

3. 1. 6. Particle size composition of chippings

The particle size composition of the class 5/15 and 15/25 gravel from Goma is presented in the form of a curve in figures 2 and 3.

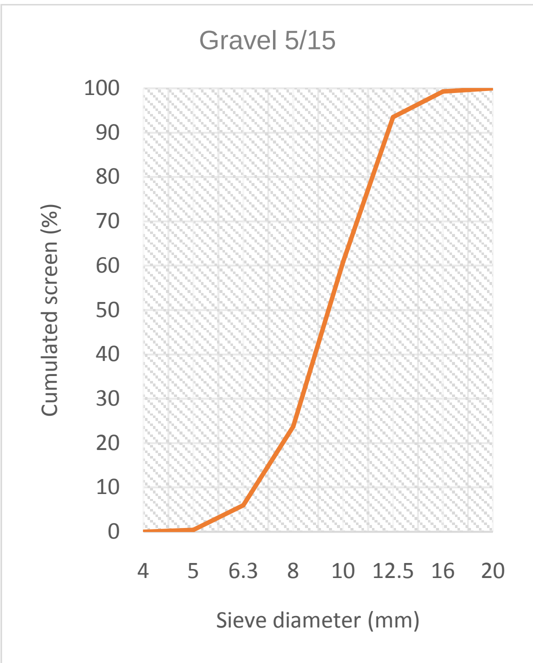

Figure 2. Gravel particle size curve 5/15

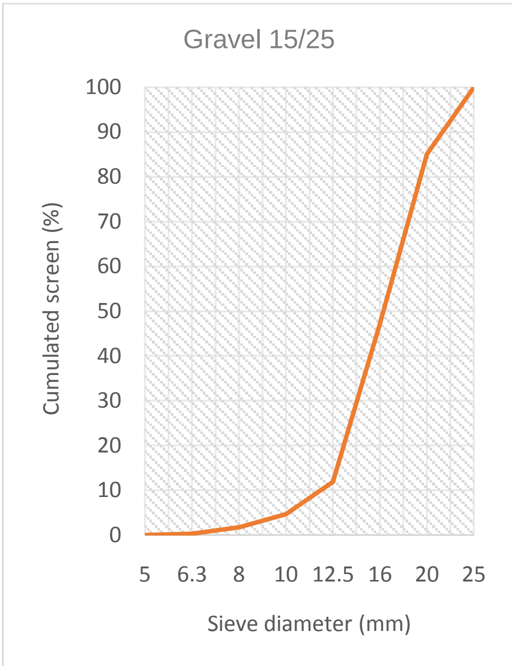

Figure 3. Gravel particle size curve 15/25

Figures 2 and 3 show that the particle size curve of the 5/15 and 15/25 crushed gravel from Goma is fairly regular, indicating a wide variety of diameters.

3. 1. 7. Classification of chips according to the coefficient of uniformity and curvature

The classification of these materials according to the coefficients of uniformity and curvature is presented in Table 5.

Table 5. Coefficients of Uniformity and Curvature of Goma's 5/15 and 15/25 Crushed Chips

Granular class	Coefficient of uniformity Cu	Coefficient of curvature Cz
5/15	1.49	1.04
15/25	1.46	1.01

Table 5 shows that the particle size of the crushed chips 5/15 and 15/25 from Goma is tight because Cu is less than 2 and well graduated because Cz is located between 1 and 3.

3. 2. Proposals for a better use of the Butembo sands

In this paragraph, the aim is to draw up, on the basis of the characterization results obtained, proposals for a better use of the materials studied in the construction of civil engineering works, in particular in the construction of concrete structures, and to give prospects for future research.

3. 2. 1. Proposal on wording

The assays currently carried out do not take sufficient account of the characteristics of the aggregates despite the fact that they vary and have a considerable influence on the strength of the concretes. Moreover, these dosages do not take into account the concrete strength to be achieved specifically for each structural or project case. In order to improve the qualities of concrete made from Butembo sands, we propose that Civil Engineering actors should formulate well using one of the existing modern methods such as the Dreux Gorisse method, the Bolomey method, etc.

In the context of material recovery, the Thalihya, Mutinga, Kimemi and Kihuli river sands (ES over 70) may be used for the production of high-quality concrete provided that the measurements of different concrete constituents are obtained by formulation using one of the existing modern methods.

3. 2. 2. Sand washing

TheKalengera river sand has a low sand equivalent of less than 60 or 44.81; it therefore has more impurities which would present a risk of shrinkage or swelling. This sand requires washing before it can be used in concrete. The value of the sand equivalent after washing the Kalengera sand is presented in Table 6.

Table 6. Value of sand equivalent of Kalengera sand after washing

Type of sand	**Sand equivalent (%)**	
	Before washing	After washing
Kalengera	44.81	71.62

3. 2. 3. Fineness modulus correction

The Musienene, Kaliva and Kalengera sand fineness modulus values of 2, 3.3 and 3.11, respectively, indicate that their particle size curves do not enter the preferred spindles for the granularity of concrete sands, we propose that a particle size correction be made to these sands in order to improve the quality of the concrete made. To this end, each of the Kaliva and Kalengera sands must be combined with the Musienene sand, in proportions suitable for obtaining sands of good particle size for the preparation of the concretes. In order to make it easier for users to choose the appropriate proportions, proposals have been drawn up in this study. The proportions proposed are presented in Tables 7 and 8. In the same tables are presented the moduli of fineness obtained, for each association of sands.

Table 7. Proportions for the association of Kaliva and Musienene sands

Proportion of Kaliva sand (%)	Proportion of Musienene sand (%)	Module of fineness obtained by association of Kaliva and Musienene sands
15.38	84.62	2.2
23.08	76.92	2.3
30.77	69.23	2.4
38.46	61.54	2.5
46.15	53.85	2.6
53.85	46.15	2.7
61.54	38.46	2.8

Table 8. Proportions for the Kalengera and Musienene Sands Association

Proportion of Kalengera sand (%)	Proportion of Musienene sand (%)	Module of fineness obtained by association of Kalengera and Musienene sands
18.02	81.98	2.2
27.03	72.97	2.3
36.04	63.96	2.4
45.05	54.95	2.5
54.05	45.95	2.6
63.06	36.94	2.7
72.07	27.93	2.8

3. 3. Concrete test results

3. 3. 1. Composition of concretes

The Dreux Gorisse method was used [23, 24]. Tables 9 and 10 show the composition of the concretes on cylindrical test pieces 11*22 cm for desired resistances of 20 MPa and 25 MPa respectively. Tables I and II in appendix 2 show the composition per cubic meter of concrete.

Table 9. Composition of C20 concretes on cylindrical test pieces 11*22 cm

Concrete	Composition (kg)				
	Cement	Sand	5/15 Gravel	Gravel 15/25	Water
Concrete 1 (Thalihya)	3.40	6.47	1.78	9.38	2.06
Concrete 2 (Mutinga)	3.40	6.79	1.59	9.26	2.06
Concrete 3 (Kimemi)	3.40	5.53	1.83	9.80	2.06
Concrete 4 (Kihuli)	3.40	6.81	1.46	9.36	2.06
Concrete 5 (Kaliva+Musienene)	3.40	7.00	1.73	8.90	2.06
Concrete 6 (Kalengera+Musienene)	3.40	5.77	1.46	10.40	2.06

Table 10. Composition of the C25 concretes on cylindrical test pieces 11*22 cm

Concrete	Composition (kg)				
	Cement	Sand	5/15 Gravel	Gravel 15/25	Water
Concrete 1 (Thalihya)	3.95	6.31	1.74	9.14	2.04
Concrete 2 (Mutinga)	3.95	6.62	1.55	9.02	2.04
Concrete 3 (Kimemi)	3.95	5.39	1.79	9.56	2.04
Concrete 4 (Kihuli)	3.95	6.64	1.43	9.13	2.04
Concrete 5 (Kaliva+Musienene)	3.95	6.82	1.68	8.68	2.04
Concrete 6 (Kalengera+Musienene)	3.95	5.62	1.43	10.14	2.04

3. 3. 2. Workability

The results of the Abrams cone subsidence test are presented in figure 4 and in Table III in appendix 3.

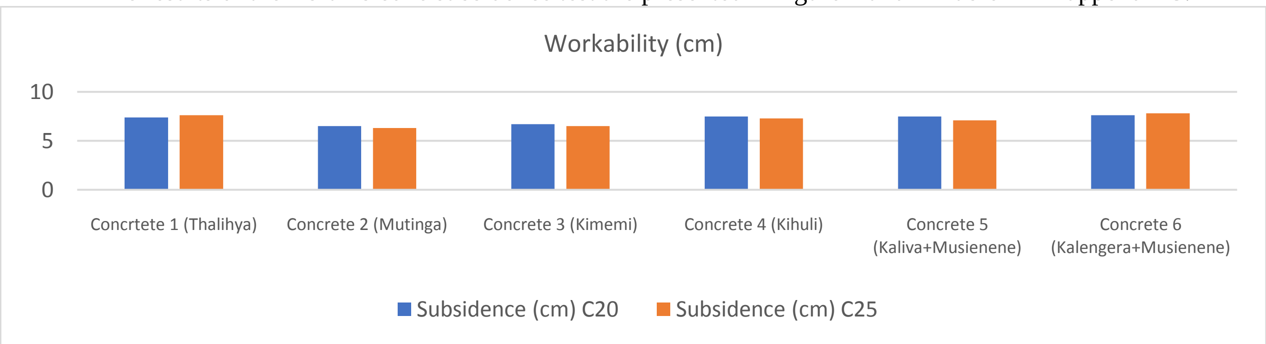

Figure 4. Abrams cone subsidence

Figure 4 shows that the different concretes formulated are plastic concretes because the Abrams cone subsidence is 5 cm and 9 cm. Formulated concretes can be used to construct formwork soles, retaining walls, slabs, pavements, beams, and columns.

3. 3. 3. Compressive strength

The results of the compressive strength test on 11×22 cm cylindrical test pieces of the various concrete samples are presented in figures 5 and 6 and in Tables IV and V in appendix 4. The concrete samples were formulated by the Dreux-Gorisse method.

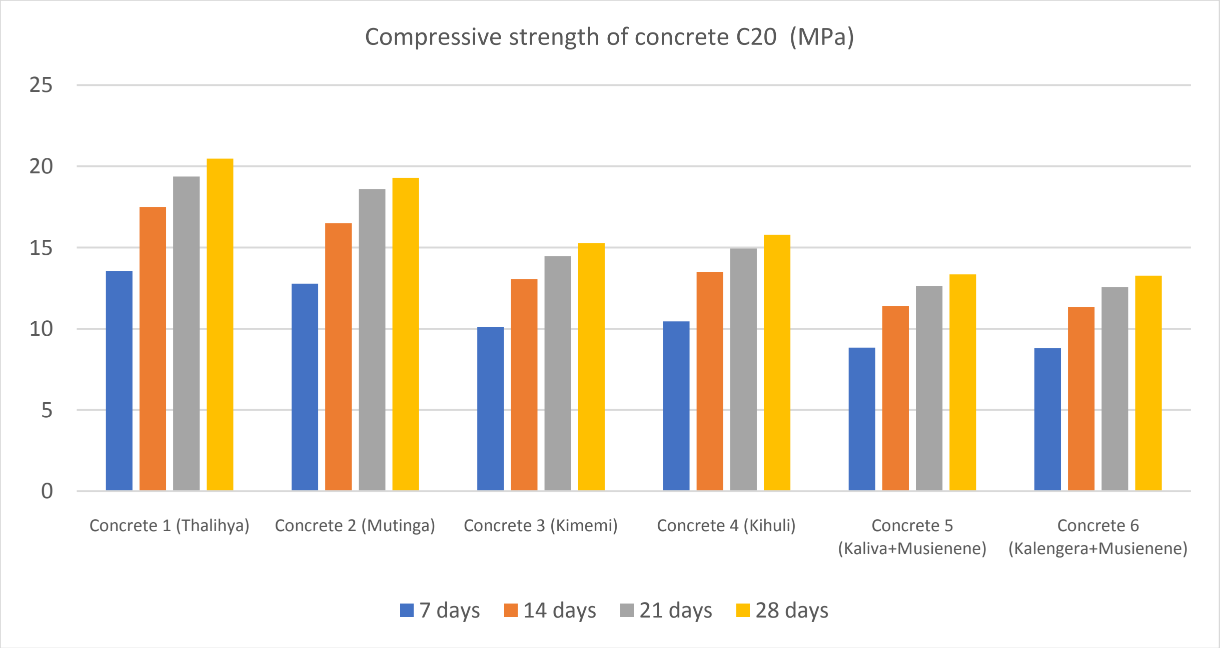

Figure 5. Concrete compression strength C20

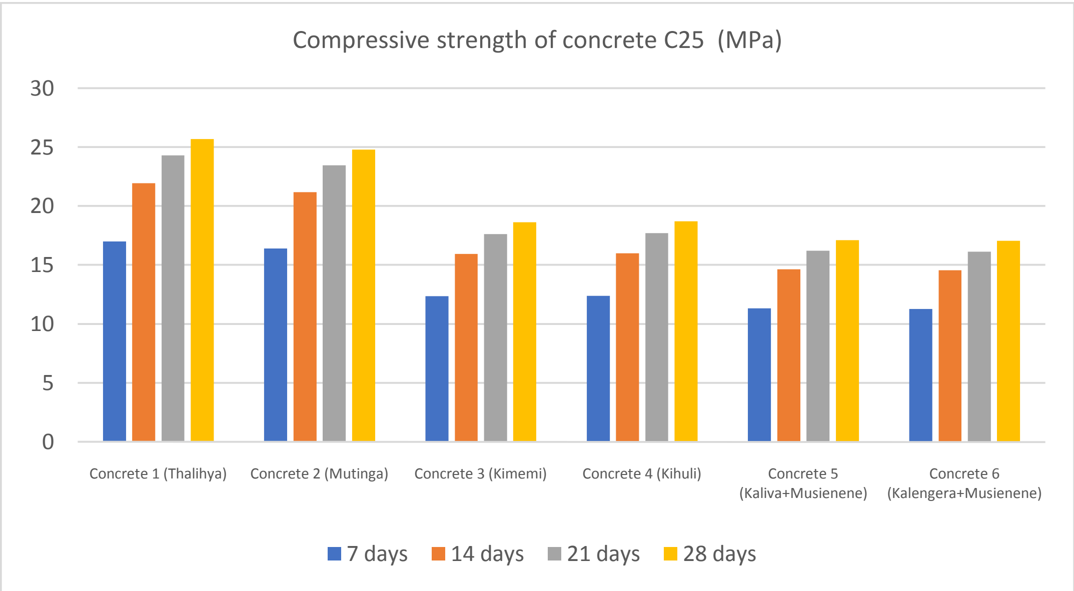

Figure 6. Concrete compression strength C25

Figures 5 and 6 and Tables IV and V in appendix 4 show that concrete test pieces formulated by the Dreux-Gorisse method give the strengths of 20,47 MPa and 19,29 MPa for Class C20 concrete; these strengths are 25,67 MPa and 24,78 MPa for Class C25 concrete at 28 days for Thalihya and Mutinga sands respectively. These values reach the expected resistance (20 MPa and 25 MPa respectively at 28 days) are satisfactory. These higher strengths obtained with the use of Thalihya and Mutinga sand confirm once again that the latter can be used without correction in the manufacture of concretes.

Kimemi sand and Kihuli sand formulated concrete specimens give the strengths of 15.28 MPa and 15.79 MPa for Class C20 concrete respectively; these strengths are 18.63 MPa and 18.70 MPa for Class C25 concrete at 28 days. These values approximate the expected strength (20 MPa and 25 MPa at 28 days, respectively) and are satisfactory but require a much higher cement dosage or the use of adjuvants to achieve the expected strength.

Concrete specimens made from the different combinations (concrete 5 and concrete 6) gave the strengths of 13.34 MPa and 13.27 MPa for class C20 concrete and 17.11 MPa and 17.04 MPa for class C25 concrete at 28 days respectively. From these results, it can be seen that the combination of Kaliva and Kalengera sand with Musienene sand gave slightly lower but still good resistances. At the same time, these combinations make it possible to avoid the risks of segregation and shrinkage, but also make it possible to increase the degree of impermeability of the concretes obtained, which ensures their better strength and their durability.

IV. Conclusion and outlook

This work has focused on the physical characterization of the Butembo sands with a view to their better use in the manufacture of concrete. The results of this study show that the sand equivalent values are 95.07; 73.61; 79.17; 73.08; 71.70 and 44.81 for the Thalihya, Mutinga, Musienene, Kimemi, Kihuli, Kaliva and Kalengera sands, respectively. These results show that these materials have a suitable degree of cleanliness for the preparation of concretes except that of Kalengera which requires washing before its use in concrete.

The particle size curves show that the materials contain all the granular classes. The grain size curves of the Kaliva and Kalengera sands have upward concavity, indicating that these materials are rich in large elements. While Musienene sand has a downward concavity, indicating that this material is rich in fine elements. In addition, the curves are offset from one another, which testifies to the differentiation of these materials although all are river sands.

It is proposed that the formulation be carried out using one of the existing modern methods. It is also proposed that the Kaliva and Kalengera sands be associated with the Musienene sand in proportions that are appropriately determined using the tables developed in the course of this work. The compression tests carried out on the concrete test pieces produced with the use of the proposals developed in this work give good strengths, which attests to their validity.

However, with regard to use [34, 35], Thalihya and Mutinga sand-based concretes can be used in reinforced concrete structures, located in a frost-free humid outdoor or indoor environment. Kimemi and Kihuli sand-based concretes can also be used in reinforced concrete structures located in a dry interior environment. However, for concretes obtained by combining Kaliva and Kalengera sand with Musienene sand, the latter can be used for unreinforced concrete structures located either in a non-aggressive environment, or in a dry internal environment or else in a wet external or internal environment not presenting a risk of freezing.

As part of future work, it will be important to carry out an experimental study of concrete test pieces made using all the values of the modulus of fineness presented in Tables 7 and 8, in order to propose proportions according to all the usual strengths of the concretes. The chemical and mineralogical characteristics may be studied with a view to preventing any deterioration factors in the concretes made from these Butembo sands.

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Appendices

Appendix 1. Particle size composition of sand

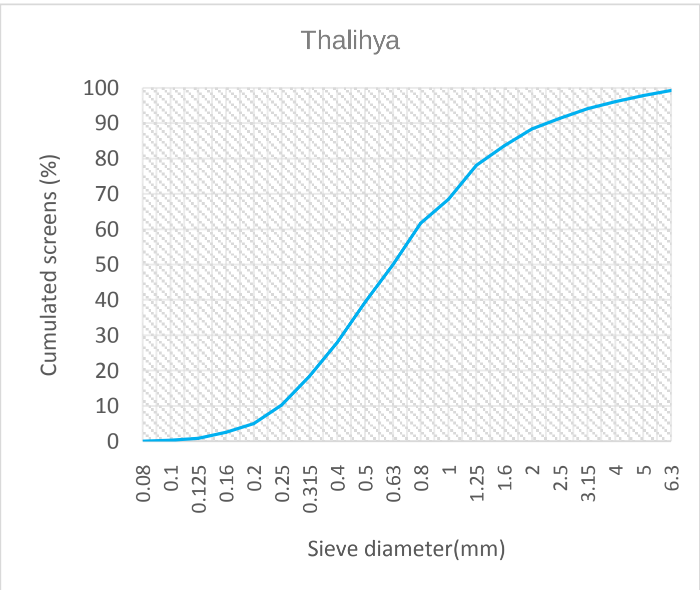

Figure a. Grain size curve of Thalihya sand

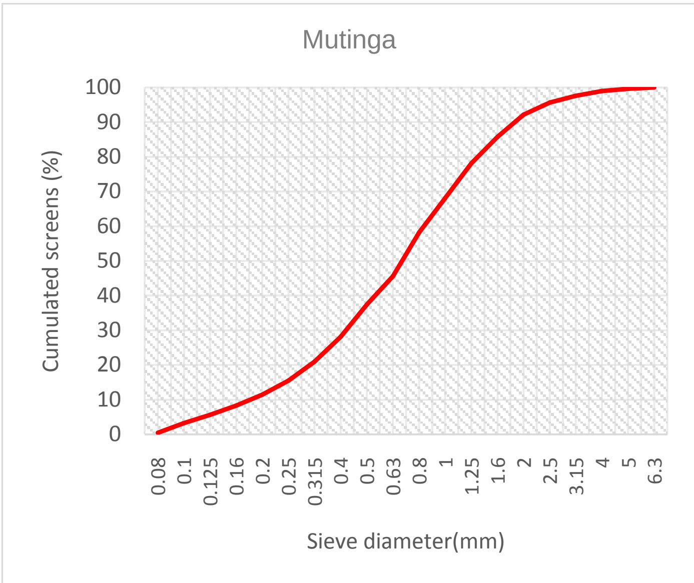

Figure b. Particle size curve of Mutinga sand

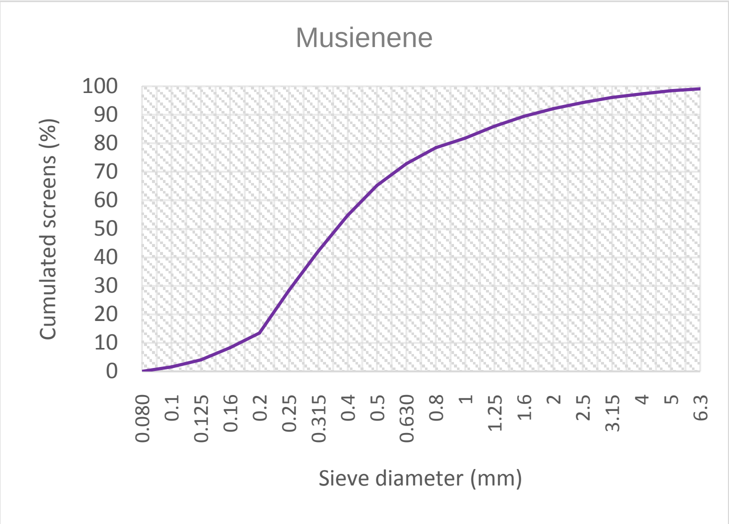

Figure c. Particle size curve of Musienene sand

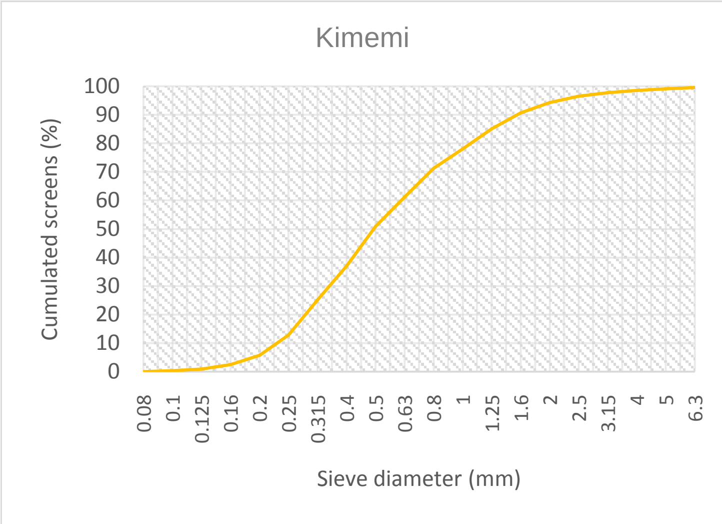

Figure d. Particle size curve of Kimemi sand

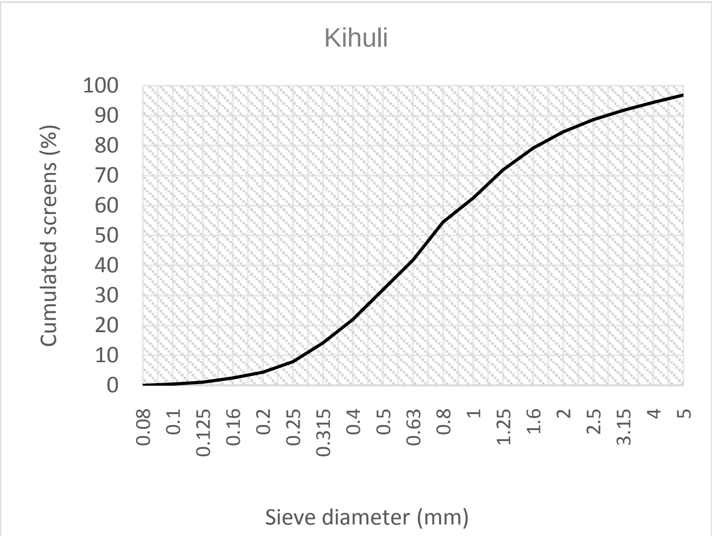

Figure e. Grain size curve of Kihuli sand

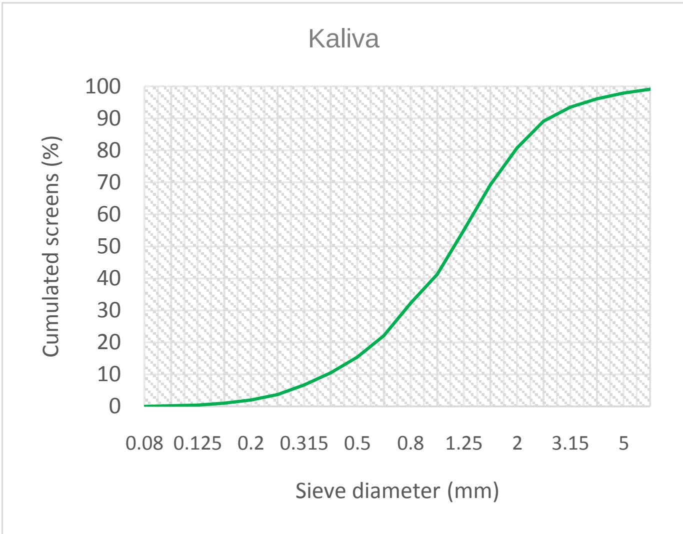

Figure f. Grain size curve of Kaliva sand

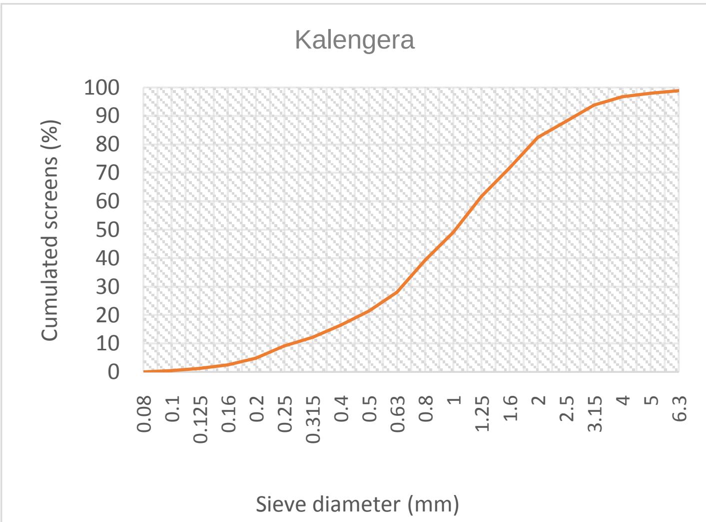

Figure g. Grain size curve of Kalengera sand

Appendix 2: Formulation of concrete

Table I. Concrete composition C20 (per cubic meter of concrete)

Concrete	Composition (kg)				
	Cement	Sand	5/15 Gravel	Gravel 15/25	Water
Concrete 1 (Thalihya)	340	647	178	938	206
Concrete 2 (Mutinga)	340	679	159	926	206
Concrete 3 (Kimemi)	340	553	183	980	206
Concrete 4 (Kihuli)	340	681	146	936	206
Concrete 5 (Kaliva+Musienene)	340	70	173	890	206
Concrete 6 (Kalengera+Musienene)	340	577	146	1040	206

Table II. Concrete composition C25 (per cubic meter of concrete)

Concrete	Composition (kg)				
	Cement	Sand	5/15 Gravel	Gravel 15/25	Water
Concrete 1 (Thalihya)	395	631	174	914	203.87
Concrete 2 (Mutinga)	395	662	155	902	203.87
Concrete 3 (Kimemi)	395	539	179	956	203.87
Concrete 4 (Kihuli)	395	664	143	913	203.87
Concrete 5 (Kaliva+Musienene)	395	682	168	868	203.87
Concrete 6 (Kalengera+Musienene)	395	562	143	1014	203.87

Appendix 3. Abrams Cone Subsidence Test

Table III. Result of the workability test

Concrete	Subsidence (cm)	
	C20	C25
Concrete 1 (Thalihya)	7.4	7.6
Concrete 2 (Mutinga)	6.5	6.3
Concrete 3 (Kimemi)	6.7	6.5
Concrete 4 (Kihuli)	7.5	7.3
Concrete 5 (Kaliva+Musienene)	7.5	7.1
Concrete 6 (Kalengera+Musienene)	7.6	7.8

Appendix 4. Concrete compression test

Table IV. Compressive strength of concrete test pieces C20

Concrete	Compressive strength of concrete C20 (MPa)			
	7 days	14 days	21 days	28 days
Concrete 1 (Thalihya)	13.56	17.50	19.37	20.47
Concrete 2 (Mutinga)	12.77	16.50	18.61	19.29
Concrete 3 (Kimemi)	10.12	13.06	14.46	15.28
Concrete 4 (Kihuli)	10.46	13.50	14.95	15.79
Concrete 5 (Kaliva+Musienene)	8.84	11.40	12.63	13.34
Concrete 6 (Kalengera+Musienene)	8.79	11.34	12.56	13.27

Table V. Compressive strength of concrete test pieces C25

Concrete	Compressive strength of concrete C25 (MPa)			
	7 days	14 days	21 days	28 days
Concrete 1 (Thalihya)	17.00	21.94	24.30	25.67
Concrete 2 (Mutinga)	16.41	21.18	23.45	24.78
Concrete 3 (Kimemi)	12.34	15.93	17.63	18.63
Concrete 4 (Kihuli)	12.38	15.98	17.69	18.70
Concrete 5 (Kaliva+Musienene)	11.33	14.63	16.20	17.11
Concrete 6 (Kalengera+Musienene)	11.28	14.56	16.12	17.04