# GEOMECHANICAL CHARACTERISTICS OF CONTINUOUS SANDSTONE CONCRETE BASED ON ECOLOGICAL CEMENT WITH A KIMBUNGU BASALT SUBSTITUTION

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**Abstract:** Concrete is a geo-material highly used throughout the world. It is made up of granules, cement, and water. It is a composite material of which aggregates are coated by hydrated cement that plays a binder role. The current production of cement factories is estimated to 4.2 billion of tons a year [1]. Its production results in $CO_2$ emissions. Referring to yearly produced cement quantity, it is obvious that it poses the environmental pollution. A previous study emphasized the possibility of creating composite cement of 75 % clinker, and 25% basalt [2]. Throughout this study, we discovered that the strength of this cement-based concrete is slightly lower than 2 days, but 28 days and 90 days higher than the control concrete composed of the same materials as the current Portland cement.

**Keywords:** continuous concrete, Inkisi's sandstone, Mukimbungu's basalt, compressive strength

## 1. INTRODUCTION

Concrete is a geomaterial that is primarily used in civil engineering construction, and its properties are still determined by empirical methods [3]. Concrete is a porous composite material comprising granular phase (sand

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and aggregates) coated with hydrated cement as binder. The pores in these materials are connected and the water present in it facilitates hard paste formation. Nowadays, the performance of concrete is increased by some additives such as fiber. Concrete formulation requires important quantities of cement, and the cement plants produce nearly 4.2 billion tons per year [1]. This amount is increasing each year [4]. The Portland cement production emits greenhouse gases such as carbon dioxide ($CO_2$) and methane (CH4). Thus, a production of one ton of Portland cement requires an emission of 800-900 kg of $CO_2$ [5], [6] which showed that it takes approximately 905 kg of CO2 to produce one ton of cement. Noting the amount of cement produced each year, it is clear that cement production emits significant amounts of $CO_2$.

It is clear that the cement factories release huge amounts of pollutants in the atmosphere every year. Recently, the conferences of the parties (COP) emphasized the reduction of greenhouse gases. The world faces a dilemma, since, producing more cement to satisfy the companies' needs, the emission of carbon dioxide cannot be kept low. Therefore, an experimental study on the pozzolanicity of Kimbungu basalt in Kongo, the Central province in DR Congo was conducted to address this issue. According to this study, Portland cement comprises 25% of basalt substituting clinker.

The present study examines the geomechanical properties of a continuous sandstone concrete made with Congo River sand and Inkisi sandstone as the Portland cement binder. This sandstone from Inkisi is an arkoses comprising about 60% and 25 % of quartz and feldspar, respectively. The compressive strength at 7 days is a slightly lower than that of reference concrete of the same type made with ordinary Porland cement. Following that, measurements show that between 28-90 days, the concrete has exceptional compressive strengths that are far superior to the reference one. In terms of results, the control concrete has a higher strength than the ecological cement-based concrete at 7 days; however, at 14 days, the strength values of 33.7 MPa (BT) and 33.8 MPa (BSE1) or 33.9 MPa (BSE2) are similar for the control concrete (BT) and the ecological cement-based concrete under study (BSE 1 and BSE2) based on ecological cement. From 21 days to 100 days, continuous concretes based on ecological cement demonstrated higher strength values of 40.4 MPa (BSE1) and 40.5 MPa (BSE2) at the same dosage.

## 2. EXPERIMENTAL SETUP

The continuous concrete under study is made up of Congo River sand with a maximum diameter of 0.8 mm, crushing sand with a size range of 0 mm to 8 mm, crushed 8/15 and 15/25 Inkisi sandstone, and Portland composite cement based on 25 % basalt and mixing water.

The crushed sandstone used in this concrete was mined in Kinshasa and is of Paleozoic age, it is known as the Inkisi formation which is in eastern part of the West-Congo chain [7, 8, 9]**.** This formation, consisting of a sandstone sedimentary body of "lie-de-vin" color with a thickness of about 600 m, was previously interpreted as a tardi-Pan-African Molasse. The Inkisi deposit is not consistent with the formation of the Mpioka. This deposit is recent to the Pan-African orogeny whereas it was previously thought to be Neoproterozoic. These silico-clastic sediments correspond to a fluvio-deltaic deposit that was formed in an extension basin connected to the Karoo [10]. This arkoses, with rare greenish pasts due to the sporadic presence of detrital chlorites of continental origin, generally consists of three main minerals: quartz, feldspar (orthosis, microcline) and mica in very small proportions; palygorskite and calcite are very rare, as shown in Figure 1a and 1b.


a b

Fig. 1. (a) Palygorskite at carrigrès quarry; (b) Trace of calcite at the carrigrès quarry in Kinshasa.

Finally, this feldspathic sandstone containing quartzitic pebbles also shows some limestone pebbles and cherts corresponding to the facies of the schisto-limestone cycle underlying the schisto-greseux cycle as well as rare indurated purple clay pebbles (Figure 2) [7].

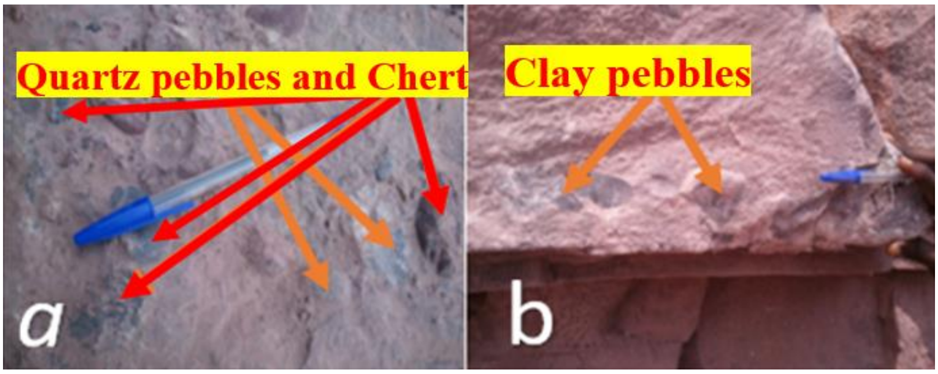


Fig. 2. Conglomerate Sandstone (a); Quartz and Chert pebbles et clay pebbles (b).

We raided the sandstone quarry in Kinshasa and took samples of 0/8, 8/15 and 15/25 crushed sand.

On this quarry, we found a succession of benches whose lithostratigraphy is presented from bottom to top as follows: medium-grained Inkisi sandstone, with a thickness of about 17 m, with a thin layer of about 10 cm of clay intercalated. Then there is a massive bank of fine-grained Inkisi sandstone with a thickness of 18 m. Following this bench there is another level of about 10 m of very fine-grained Inkisi sandstone at the top of which is the soft sandstone with some siliceous pebbles with an average thickness of 4 m. Palygorskite can be found in many places associated with discontinuities in this quarry [12].

In laboratories, X-ray fluorescence spectrometry was performed to determine the major oxides of aggregates from the material below (Figure 3a). The X-ray diffractometer was used to determine the mineral phases of aggregates and cement (Figure 3b). The particle size analyses of the aggregates (Figure 4) were performed using the Afnor series column of sieves, the equivalent sand test, to determine the proportion of the grains in relation to their sizes as well as the suitability of the river sands and the crushed sands.

The Los-Angeles coefficients were determined on the crushed 8/15 and 15/25 from the Los-Angeles machine with 11 balls (Figure 5) of class B (according to [12, 13]) to know the state of fragmentation of these aggregates. Vicat's apparatus was used for the physical tests of the control cement and the Portland composite cement to determine the setting time. All these tests were carried out at the National Laboratory of Public Works. Distilled water was used to spoil the mixture and avoid any external intake of sulphate, chloride that may cause other harmful reactions to concrete. The compressive strength for specimens of continuous concrete was determined by using the NDT (No destructive Test) method (Figure 6) and the crushing press (Figure 7).

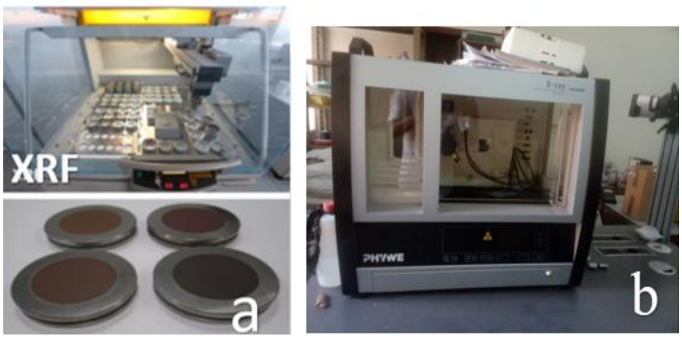


Fig. 3. a) XRF of model Bruker Tiger S8 b) XRD of model Phywe.

Fig. 4. Sieve column.


Fig. 5. (a) Los- Angeles Machine; (b) The 11 balls v; (c) Sampling the sandstone sample after test; (d) Sieving.

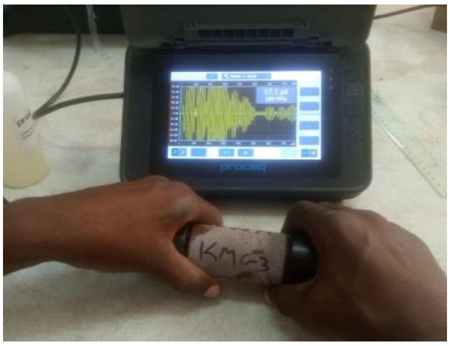


Fig. 6. Proceq ultrasonic generator with transducers and sandstone core.


Fig. 7. (a) Crushing press for control mark; (b) test piece 110 x 220; (c) test piece after crushing.

The investigation started by analyzing the Congo River sand, the crushed sand (0/8 mm) and (8/15 mm and 15/25 mm) used as aggregates. After testing all of these materials, it was necessary to formulate the concrete. Concrete formulation entails determining the quantity of materials to be used in the mixture to achieve good compactness and resistance. These quantities are specifically determined to optimize the performance of concrete. An equally important parameter in evaluating these performances is the Cement / Water ratio following the expected subsidence (Figure 8) with the dosage of the cement used, that of 350 $kg.m^{-3}$. Various methods are used to determine the percentages of materials to be used in the mixture, including the Dreux Gorisse method [14] used in this study.

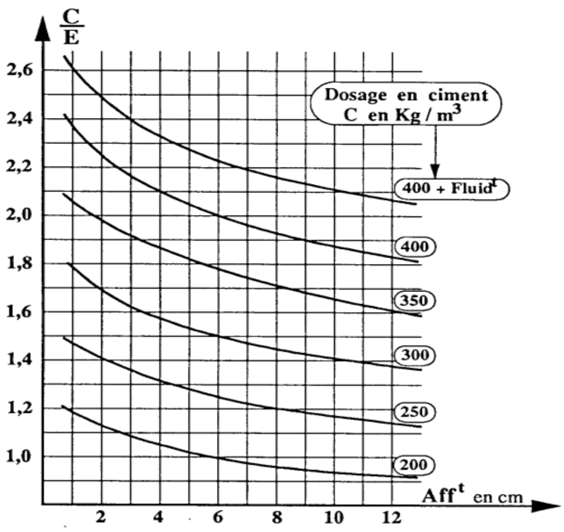


Fig. 8. Ratio of cement to water (C/E) as a function of concrete subsidence [7].

As for the percentage of aggregates, it is imperative to determine the proportion of sand and crushed sand in order to achieve good concrete compactness as well as better resistance. Knowing both the granulometry of aggregates and the granular curve will provide the compactness, as well as the resistance of concrete. It is therefore imperative to model the particle size curves of the aggregates used (Figure 9) before determining the proportion of the mixture of fine and coarse aggregates.

[15] dictates the particle size to be obtained from the mixture, that will be represented by two lines (Figure 10). This model is interesting because the theoretical curve closely resembles the actual granular curve. It is done using three points (the axes origin, point O; the breaking point A and the end point B). We must emphasize that the two points of origin and end are invariable for any percentage of mixtures.

The following steps allowed us to trace the formulation curve of our concretes:
- First put the point O at the origin of the axes that is to say at 0 % of the tamisats and 80 µm, it is the point whose two x coordinates, y are (0.08mm; 0 %);
- Put the point B located at 100 % of the largest diameter D of the aggregates considered (for our study it is 25 mm for all scenarios), this is the point whose two coordinates x, y are (25 mm; 100 %);
- Set point A, called breaking point, remains consistent across all scenarios. If the largest diameter D is less than (or equal to) 20 mm (D ≤ 20 mm), A equals D/2 so 10 mm. While the largest diameter D is greater than 20 as in the present study, the breaking point is between 5 and D (5 and 25 mm). In this study, the abscissa X of point A measures 15 mm;
- Determine the ordinate Y which is the proportion of the sieves of point A and will give the best compactness of the concrete and thus its best resistance; this point is optimized by the formula:

$$Y = 50 - (\sqrt{1.25D} + k + ks + kp) \quad (1)$$

The coefficients k, ks and kp are determined as follows:
- K is optimized for compactness considering the type of vibration, cement dosage and grain shape from the Table 1;
- Kp adjusts the dosage of the sand to facilitate the implementation of concrete. Kp = 0 when the concrete is not pumped as our case and for pumped concrete is between 5 and 10;
- Ks adjusts the particle size of the sand and is calculated by ks = (6 x MF) – 15. MF being the modulus of fineness which is 2.7.

Table 1. Presents the values of k according to [7].

| | | Weak | | Normal | | Strong | |
|---|---|---|---|---|---|---|---|
| Grain shape | | Rolled | Crushed | Rolled | Crushed | Rolled | Crushed |
| Dosage of | 400+f | -2 | 0 | -4 | -2 | -6 | -4 |
| | 400 | 0 | +2 | -2 | 0 | -4 | -2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| cement kg.m$^{-3}$ | 350 | +2 | +4 | 0 | +2 | -2 | 0 |
| | 300 | +4 | +6 | +2 | +4 | 0 | +2 |
| | 250 | +6 | +8 | +4 | +6 | +2 | +4 |
| | 200 | +8 | +10 | +6 | +8 | +4 | +6 |

The vibration is consistent because we used the shaking table, with the cement dosage of 350 kg.m$^3$ and the crush used, the value of k is according to the table at +2 for this concrete. Since concrete cannot be pumped, kp is zero. For MF being equal to 2.73, ks = (6 x MF) - 15 = 1.38 with k = +2, YA = 47.79 = 48%.

- The last step is to set the dividing line: that will be used to determine the percentages of sand and crush.
- The following steps are required to determine the dividing line:
- Locate the intersection of 9 5% Y-axis with the size grading (granulometric) curve of sand;
- Locate the intersection of 5 % Y-axis with the size grading (granulometric) curve of 15/25 crushed rock;
- Link both points to form a line called dividing line.

The intersection of the dividing line and the OA line, determined long before results in percentages of sand and 15/25 crushed rock could be read on Y-axis (fines/ undersize) size grading (granulometric) analysis chart (Figure 9 mentioned below). The value at the bottom represents the relative percentage of sand (proportion of sand), and the one at the top is the first value supplement, will represent the relative percentage (proportion) of crushed rocks (See curve). Subsequently, 8/15 and 15/25 must be marked out in the same manner, using the same steps as before.

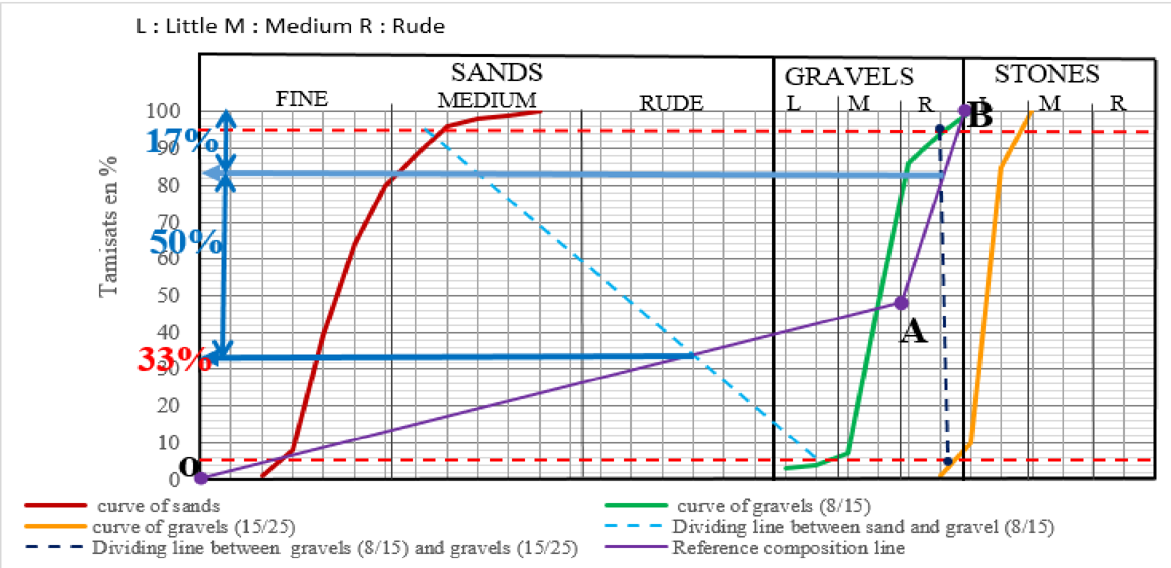


Fig. 9. Concrete formulation curve with aggregate proportions.

We can notice from the curves and dividing lines that Congo river sand for sandstone concrete is estimated at 33 % in which sand from crushed rock is added; and 8/15 crushed rocks are estimated at 17 % with 50 % of 15/25 crushed rocks.

**The last step** is to determine the mass of sand and crushed rocks for a good formulation using the percentages of each type of granular material. The following formulas are used to convert proportions of each granule into mass. According to [15], the compactness coefficient “g” of concrete is determined empirically; Table 2 provides approximate values.

Table 2. Approximate values of compactness coefficients as per concrete consistency [15].

| Consistency | Tightning/ Clamping | Compactness coefficient g based on Dmax (mm) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 5 | 10 | 12.5 | 20 | 31.5 | 50 | 80 |
| Soft | Pitting | 0.750 | 0.780 | 0.795 | 0.805 | 0.810 | 0.815 | 0.820 |
| | Weak vibration | 0.755 | 0.785 | 0.800 | 0.810 | 0.815 | 0.820 | 0.825 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Normal vibration | 0.760 | 0.790 | 0.805 | 0.815 | 0.820 | 0.825 | 0.830 |
| Plastic | Pitting | 0.760 | 0.790 | 0.805 | 0.815 | 0.820 | 0.825 | 0.830 |
| | Weak vibration | 0.765 | 0.795 | 0.810 | 0.820 | 0.825 | 0.830 | 0.835 |
| | Normal vibration | 0.770 | 0.800 | 0.815 | 0.825 | 0.830 | 0.835 | 0.840 |
| | Strong vibration | 0.775 | 0.805 | 0.820 | 0.830 | 0.835 | 0.840 | 0.845 |
| Rigid | Weak vibration | 0.775 | 0.805 | 0.820 | 0.830 | 0.835 | 0.840 | 0.845 |
| | Normal vibration | 0.780 | 0.810 | 0.825 | 0.835 | 0.840 | 0.845 | 0.850 |
| | Strong vibration | 0.785 | 0.815 | 0.830 | 0.840 | 0.845 | 0.850 | 0.855 |

Dreux Gorisse's values are true to rounded granules, whereas crushed rocks required corrections such as:

- Rounded sand and crushed rock – 0.01;
- Sand and crushed rocks – 0.03.

- "g" compactness coefficient is calculated using the following relationship:

$$g = \text{Absolute Volume (Vab)} / \text{Apparent Volume (Vap)} \quad (2)$$

- In this case, the apparent volume of material amounts to:

$$Vab = Vcement + Vgravel + Vsand \quad (3)$$

The apparent volume amounting to 1 $m^3$, therefore, Vgravel + Vsand = Vab – Vcement.

- True density of cement would be:

$$yc = C / Vc \quad (4)$$

where C" cement mass; therefore,

$$Vc = C / yc \quad (5)$$

- Based on specific weight, absolute volume of sand Vs would be:

$$Vs = Ps \times (g – Vc) \quad (6)$$

- The absolute volume crushed rock or gravel Vg would be:

$$Vg = Pg \times (g – Vc) \quad (7)$$

- The True densities of sand (ys) and the one of crushed rock (yg) can be calculated using the following relationships:

$$ys = Ms / Vs \text{ with } Ms = ys \times Vs \quad (8)$$

$$yg = Mg / Vg; Mg = yg \times Vg \quad (9)$$

Ms and Mg being respectively mass of sand and mass of crushed rock.

The manufacture of cylindrical shaped test pieces of 110 mm x 220 mm was the last step (Figure 10) for the common cement based control concrete and the composite Portland cement based concrete.

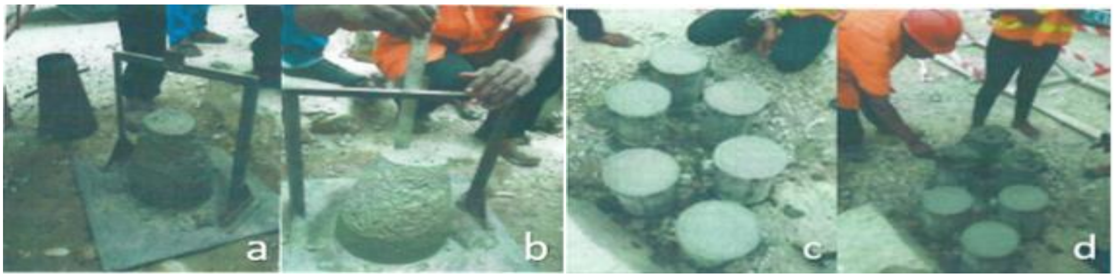


Fig. 10. Determination of slump test: (a) concrete under study; (b) control concrete; (c) moulding concrete under study; (d) moulding control concrete before immersion.

After all the calculations using the abovementioned formulas, the concrete formulation gave the dosage results for each type of grain size (Table 3).

Table 3. Proportion of sandstone-made concrete constituents in mass and in litter.

| Constituents | Proportion in mass kg for 1m$^3$ of concrete | Proportion in apparent volume (in liter) |
|---|---|---|
| River sand | 637,56 | 396,00 |
| Crushed rocks 8/15 | 363,12 | 204,00 |
| Crushed rocks 15/25 | 1056,00 | 600,00 |
| Cement 32.5 R | 350,00 | - |
| Water (liters) | 210,00 | - |
| Bulk density (T.m$^{-3}$) | 2,40 | - |

## 3. RESULTS AND DISCUSSION

The results of the XRF analysis are shown in Figure 11.

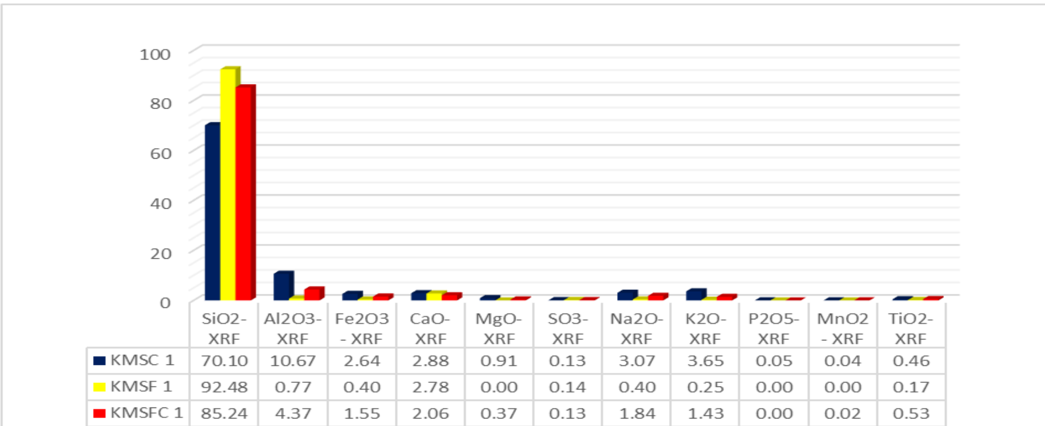


Fig. 11. Results of oxides for sands samples.

The continuous concrete is made by the mixture of river sand (KMSF) and crushed sand (KMSC) which gave the KMSFC following the low fineness modulus of the river sand. The three sand samples were analyzed following the X-ray fluorescence spectrometry. The quartz content of KMSFC mixing sand is 85.24% and can be used as fine concrete aggregates.

The analyses of Portland cement used on control concrete are mentioned in Figure 12.

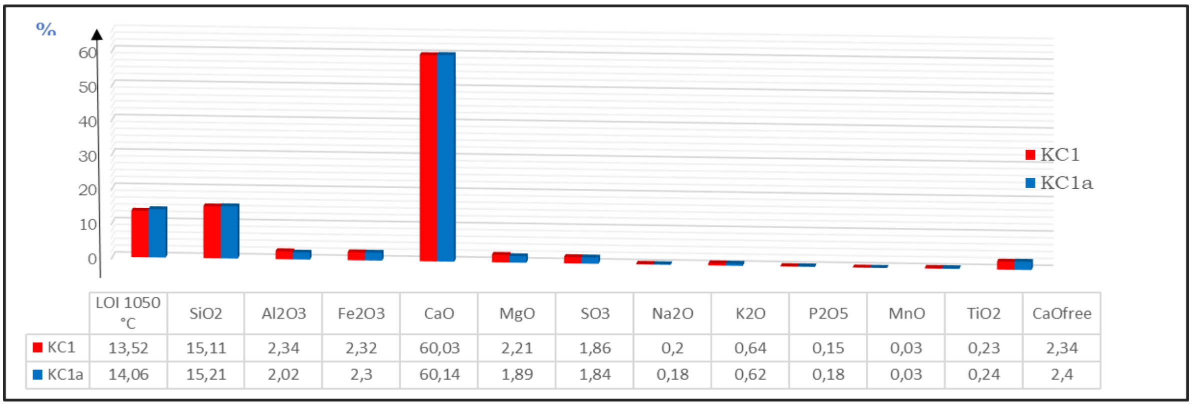


Fig. 12. Results of major oxides of Portland cement.

Portland cement samples gave an average CaO content of 60.11% followed by silica with an average of 15.16%, MgO which becomes harmful if greater than 4% [16], rregistered an average of 2.05%. In France, a maximum rate of 5% is accepted. The other oxides are in low proportions compared to the standards [16]. Free lime has an average content of 2.37%.

Size grading (Granulometric) analysis and other tests upon granules are represented in table 4.

Table 4. Characteristics of sandstone's granules.

| N° | CHARACTERISTICS | GRANULES | | | | SPECIFICATION |
|---|---|---|---|---|---|---|
| | | Sand | 0/8 | 8/15 | 15/25 | |
| 1. | Granulométry AFNOR | | | | | |
| | - D max (mm) | 0.8 | 8 | 15 | 25 | |
| | - % refusal at 1,56D | - | 0 | 0 | 0 | 0% |
| | - % refusal at D | - | 0 | 3 | 6 | 1 à 15% |
| | - % passing at d | - | 0 | 10 | 12 | 1 à 15% |
| | - Σ% RD + % Pd | - | 0 | 13 | 18 | < 20% |
| | - % passing at 0,63d | - | 2 | 1 | 1 | < 4% |
| 2. | Cleanliness | | | | | |
| | Sand equivalent (%) | 80 | 75 | - | - | ≥ 75% |
| 3. | Coefficient LA (%) | - | - | 29 | 29 | < 35% |
| 4. | Specific weight (T/m$^3$) | 2.62 | 2.72 | 2.62 | 2.68 | - |
| 5. | Bulk density | 1.61 | 1.76 | 1.78 | 1.76 | - |
| 6. | Shape factor | - | 0.16 | 0.18 | 0.19 | > 0.15 |
| 7. | Fineness modulus | 1.57 | 2.73 | - | - | 2.2 à 2.8 |

The sand is very fine, the fineness modulus displays it correctly, however, there are a few coarse particles, and that is why 0/8 sand from crushed rock is added in order to complete the size grading (so that it really becomes continue or spread out) and also to improve fineness modulus with 2.7. Other aggregates (crushed rocks) display very good physical and mechanical characteristics that comply with specifications. The compressive strength by the NDT method for some sandstone cores gave the following results (Table 5).

Table 5. Compressive strength of sandstone cores (by NDT).

| | KMG1 | KMG2 | KMG3 | KMG5 | KMG6 | KMG7 | Average |
|---|---|---|---|---|---|---|---|
| Maximum value (MPa) | 175.0 | 175.0 | 171.0 | 160.0 | 167.0 | 160.0 | 168.0 |
| Mean value (MPa) | 172.6 | 173.5 | 171 | 158.4 | 165 | 157.6 | 166.4 |
| Minimum value (MPa) | 165 | 171 | 171 | 156 | 163 | 154 | 163.3 |
| Standard deviation | 3.9 | 1.7 | 0.0 | 2.0 | 1.8 | 2.3 | |
| Coefficient of variation | 2.25 | 0.96 | 0.00 | 1.24 | 1.08 | 1.48 | |

Compressive strength by crushing (the destructive method) for the same sandstone cores gave the following results.

Table 6. Compressive strength of sandstone cores (by crushing).

| | KMG1 | KMG2 | KMG3 | KMG5 | KMG6 | KMG7 | Average | Standard deviation | Coefficient of Variation |
|---|---|---|---|---|---|---|---|---|---|
| Value (MPa) | 70.77 | 43.33 | 114.10 | 101.82 | 116.27 | 52.72 | 83.17 | 27.56233 | 33.14038 |

The sandstone that was used as aggregates has very high mechanical compressive resistance which average value is 83.17 MPa than the (Table 6).

The mineralogical composition of cement using XRD provided grades for different mineral phases and their polymorphs [2] (Table 7).

Table 7. Grades of different mineral phases of clinker used on composite Portland cement [2].

| Phases | Polymorphs | Grades (%) |
|---|---|---|
| Alite | Monoclinic-1<br>Monoclinic-3 | 28.9<br>23.2 |
| Belite | Orthorhombic α'-$C_2S$<br>Monoclinic β-$C_2S$ | 3.9<br>18.3 |
| Cerite | Cubic<br>Orthorhombic | 3.1<br>6.0 |
| Tetracalcium aluminoferrite | Orthorhombic | 12.7 |
| Free lime | Cubic | 3.3 |
| Periclase | Cubic | 0.6 |

This Portland composite cement is made up of an alite clinker, which has the four anhydrous mineral phases of which the alite is 52.1% this mineral phase contributes to the early concrete strength. Belite at 22.2% will contribute to late strength of the concrete. Aluminite is at 9.1% and alumino-ferrite at 12.7%. Free lime represents 3.3% while periclase 0.6%.

Physical testing of control Portland cement and composite Portland cement at 25% of basalt provided the following results (Table 8).

Table 8. Results of physical testing of control Portland cement (KC1) and composite Portland cement (KC2).

| Physicals properties of cements | | KC1 | KC2 |
|---|---|---|---|
| Blaine $cm^2.g^{-1}$ | | 3950 | 4000 |
| Refusal at 100µm (%) | | 12.48 | 9.13 |
| Refusal at 200µm (%) | | 1.79 | 1.22 |
| Setting time | | 2h47' | 2h58' |
| Duration (min) | | 90 | 100 |
| Stability (mm) | | 0.21 | 0.24 |
| Compression strength (MPa) | 2 days | 16.97 | 15.49 |
| | 28 days | 32.98 | 38.08 |

[14], [15] worked on several formulations continuous and discontinuous concretes and gave minimum values, 17.24 MPa for 7 days and 25 MPa for 28 days, for a well-made concrete (Table 9). These strength values of concretes in Table 9 based on Ordinary Portland Cements (OPC) are the averages of several measurements carried out experimentally. Table 9 contains theoretical strength (BTH) values that were used to compare the results of this study. We also compared the results of the continuous concretes based on ecological cement (BSE1 and BSE2) with the continuous control concrete based on ordinary Portland cement (BT), as shown in Figures12 and 13.

Table 9. Theoretical minimum values of compressive strength of concrete specimens according to [14, 15].

| DOSAGE OF | CEMENT | $Kg.m^{-3}$ | 250 | 300 | 350 | 400 |
|---|---|---|---|---|---|---|
| | Cylinder | Bars | 180 | 200 | 250 | 300 |
| | | MPa | 18 | 20 | 25 | 30 |
| | | $kg.cm^{-2}$ | 184 | 204 | 255 | 306 |
| σ28days | | Bars | - | 241 | 301 | 361 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | cubic | MPa | - | 24.1 | 30.12 | 36.14 |
| | | $kg.cm^{-2}$ | - | 246 | 307 | 369 |
| σ7days | | Bars | 124 | 138 | 172 | 207 |
| | Cylinder | MPa | 12.41 | 13.79 | 17.24 | 20.7 |
| | | $kg.cm^{-2}$ | 127 | 141 | 176 | 211 |
| | | Bars | - | 166 | 208 | 249 |
| | cubic | MPa | - | 16.62 | 20.77 | 24.92 |
| | | $kg.cm^{-2}$ | - | 170 | 212 | 254 |

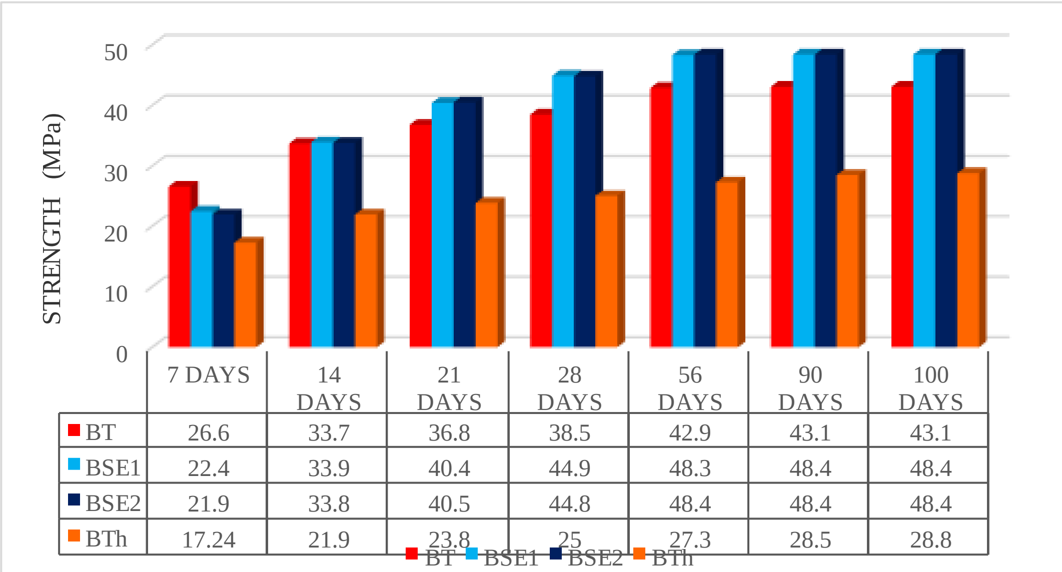


Fig. 13. Compressive strengths for the theoretical concrete (BTh) according to [7] and the control concrete (BT) as well as the composite Portland cement concretes (BSE1 and BSE2), BSE: Studied concrete.

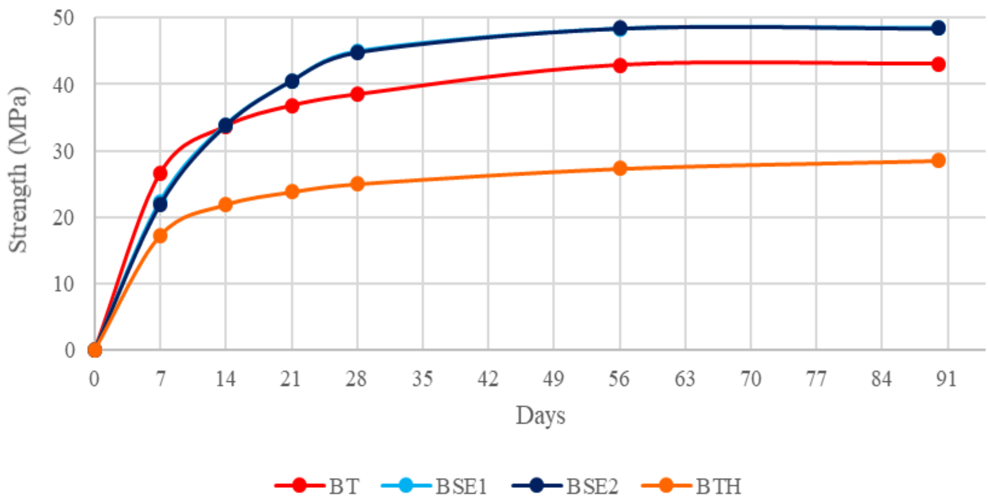


Fig. 14. Resistance curves showing the appearance of concrete according to age.

Figures 13 and 14 show that at 7 days, the control concrete based on ordinary Portland cement has a higher resistance than the concrete based on ecological cement; at 14 days, the strength values 33.7 MPa (BT) and 33.8 MPa (BSE1) or 33.9 MPa (BSE2) are close; but from 21 to 100 days, the continuous concretes based on ecological cement showed the higher strength curve on the Figure 13 than the control concrete based on ordinary Portland cement with the same formulation.

## 4. CONCLUSIONS

In a previous study [2], tests carried out on the natural composite cement produced with 75% industrial clinker and 25% basalt substitution from Kimbungu yielded average resistances of 15.49 MPa and 38.08 MPa after 2 days and 28 days of treatment. The pozzolanic conditions of this basalt were well checked for the production of an ecological cement.

In this new study which looked at the performance and mechanical characteristics of this cement in the concrete, we discovered that the strength of the continuous concrete is slightly lower at a young age. At 7 days, the control concrete based on ordinary Portland cement has a higher strength than the concrete based on ecological cement; but at 14 days, the strength values 33.7 MPa (BT) and 33.8 MPa (BSE1) or 33.9 MPa (BSE2) are close for the control concrete (BT), based on ordinary Portland cement and the concrete under study (BSE 1 and BSE2) based on ecological cement. Continuous concretes based on ecological cement showed higher strength values 40.4 MPa (BSE1), 40.5 MPa (BSE2) for 21 days to 48.4 MPa (BSE1 same value with BSE2) for 100 days; than the control concrete (BT) values 36.8 MPa for 21 days to 43.1 MPa for 100 days; this is for the same formulation and same dosage. Thus, Kimbungu's the ecological cement with 25% basalt substitution has acceptable mechanical properties and good performance in continuous concretes with the crushed sandstone.

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