



Study of the characteristics of a mortar formulated from a mixture of river sand and crushing sand

AYITE Yawovi Mawuénia Xolali Dany*, PACHOUKOVA Irina, P'KLA Abalo and AGBO Komitse Edoh

Laboratory of Research in Engineering Sciences, Engineers High National School of University of Lome, TOGO
danyayite@gmail.com

Available online at: www.isca.in, www.isca.me

Received 8th September 2020, revised 8th November 2020, accepted 29th January 2021

Abstract

In Togo, quarry sands (silty sand) and river sands are the most used in the construction of structures, particularly for mortar manufacture. Crushing sands from rock crushing quarries are very little used because they contain enough fine elements. In this work, the characteristics of a mortar obtained by mixing river sand with crushing sand are studied. Identification tests were carried out on the mortar components which are river sand, crushing sand and cement. Then the river sand mass is varied in the mixture in proportions ranging from 0 to 100% and in steps of 25%. Tests of measurement of slump, density, porosity and flexural and compressive strengths at 28 days of age are carried out on each mixture. It appears that the characteristics of the mortar studied are improved by the addition of river sand. A mixture of 50% river sand and 50% crushed sand is the optimal mixture which makes it possible to have characteristics of the mixed mortar better than those of a mortar containing unmixed sand.

Keywords: River sand - crushing sand - mortar - compressive strength - flexural strength.

Introduction

Sand is the most widely used construction material worldwide where it is mainly used in the manufacture of mortars and concretes. There are two main categories of sands¹⁻²: natural sands coming from sea, mountains, rivers or extracted from quarries and artificial sands coming from the crushing of slag blocks in blast furnaces.

In Togo, for the manufacture of mortars to be used for making bricks, concrete or plaster, quarry silty sands and river sands are very often used.

The use of crushing sands is infrequent although there are several rock crushing quarries in Togo. While crushing sand can be used in the manufacture of concrete, mortars and bricks. The use of these sands improves the characteristics of concrete or reduces the use of natural sands³⁻¹⁰.

In this work, the characteristics of a mortar based on crushing sand and a mortar obtained by mixing the crushing sand with river sand in various proportions are studied.

Materials and methods

The materials used during this study include: i. the sand of the Zowla river located 71.7km east of Lomé, the capital of Togo, ii. crushing sand from the crushing quarry of the China Road and Bridge Corporation (CRBC) located in Agbélouvé 60km north of Lomé, iii. CPJ35 cement produced by CIMTOGO, one of the cement factories in Togo and iv. drinking water from

“Société Togolaise des Eaux”, the drinking water production and supply company in Togo.

Table-1 shows the characteristics of the sands used, the grain size curves of which are shown in Figure-1. The river sand used is an average sand, very clean and can provide good concrete with good workability, good resistance and limited risks of segregation². The crushing sand used is coarse sand with enough fine elements. It is clean and can allow quality concrete with good strength but with workability defects and risks of segregation².

Table-1: Sands characteristics.

Characteristics	Zowla river sand	CRBC Crushing sand
Sand equivalent	89.9	71
Absolute density	2.67	2.78
Apparent density	1.42	1.66
Fineness modulus	2.60	2.99
Porosity	46.53	40.43

The characteristics of the cement used are presented in Table-2 and comply with European standard N EN 197-1¹².

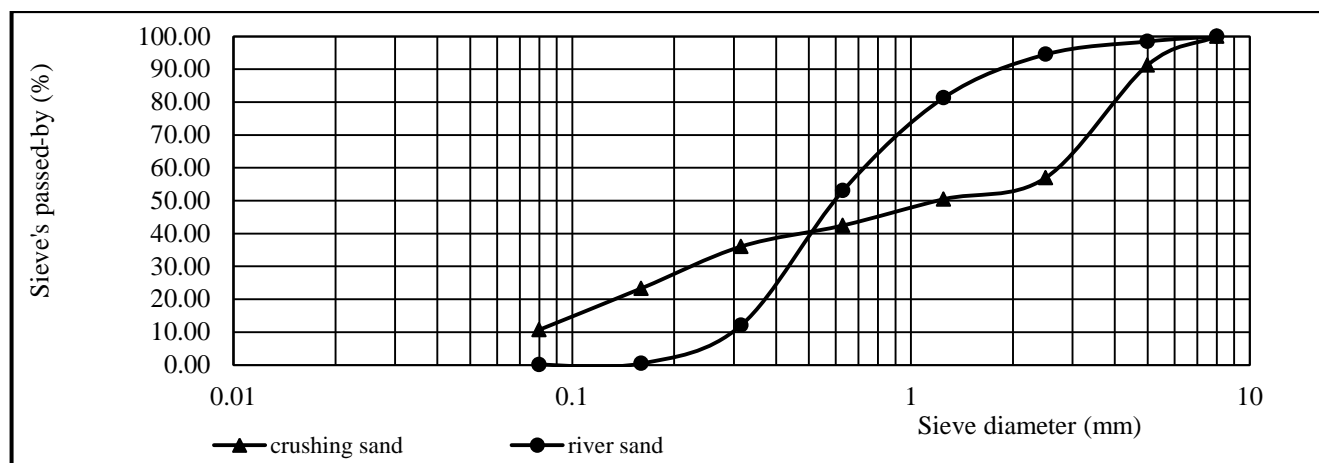


Figure-1: Sands grading curve.

Table-2: Cement characteristics.

Characteristics	Value
Fineness modulus	2.66
Stability (mm)	0.5
Consistency (%)	25.8
Compressive strength at 28 days (MPa)	30.51

To achieve the objective of this study, the mass rate of river sand is varied compared to the total mass of the mixture for rates ranging from 0 to 100% in steps of 25%. The mass of cement is fixed at 250kg/m³ of mortar which corresponds to the dosage commonly used for the manufacture of bricks in Togo. Two Water/Cement (W/C) ratios are used, namely 0.45 and 0.5; this would give an idea of the influence of water on the characteristics. Table-3 summarizes the materials quantities used for each mixture performed.

Table-3: Material quantities for each mixture.

Sand river ratio (%)		0	25	50	75	100
Sand river mass (kg)		0	187.5	375	562.5	750
Crushing sand mass (kg)		750	562.5	375	187.5	0
Cement mass (kg)		250	250	250	250	250
Water mass according to W/C ratio	0.45	112.5	112.5	112.5	112.5	112.5
	0.50	125	125	125	125	125

From these dosages, mortar specimens of dimensions 4*4*16 cm³ are made in accordance with standard NF P18-400¹³.

These test pieces are then kept in the shade and crushed on the 28th day. On these test pieces, it is determined: i. the slump on the fresh mortar using the Abrams cone according to standard NF EN12350-8¹⁴. ii. the density at manufacture and at 28th day according to standard NF EN 12350-6¹⁵. iii. the porosity accessible to water according to standard NF P18-459¹⁶. iv. the flexural strength in accordance with the standard NF EN 12390-5¹⁷. v. the compressive strength according to standard NF EN 12390-3¹⁸.

The porosity accessible to water is determined by immersing the composites in water for 48 hours, after which the specimens reach full saturation. After saturation, the test pieces are weighed (M_w); then the dry mass (M_d) is determined by drying the test pieces at a temperature of 105° to constant mass. This porosity is calculated by the following equation:

$$\text{porosity (\%)} = \frac{M_w - M_d}{M_d} \quad (1)$$

Results and discussion

Table-4 shows the results of slump measurement according to the assay.

Table-4: Slump test results.

River sand ratio (%)	0	25	50	75	100
Slump (cm) for W/C = 0.45	11.45	11.20	11.05	11.15	11.30
Slump (cm) for W/C = 0.50	11.80	11.40	11.10	11.20	11.50

The Table-4 shows that the slump is greater for the mortar containing 100% crushing sand. Adding river sand reduces slump by up to 50%. Beyond this rate, slump increases. This variation can be linked to the cleanliness and the fineness modulus of the two materials. Indeed, the addition of river sand improves the cleanliness of the crushing sand and decreases its

fineness modulus, which results in slump reduction. However, this reduction ceases above 50%, the river sand being more important in the mixture. The increase in water content, which corresponds to an increase in the plasticity of the mortar, increases slump. Table-5 presents the density measurement results on fresh mortar and that of 28 days of age.

Table-5: Densities results.

River sand ratio (%)	0	25	50	75	100
Density of fresh mortar for W/C = 0.45	0.5911	0.5902	0.5897	0.5893	0.5888
Density of fresh mortar for W/C = 0.50	0.5886	0.5874	0.5867	0.5856	0.5851
Density at 28days for W/C = 0.45	0.5873	0.5836	0.5792	0.5777	0.5733
Density at 28days for W/C = 0.50	0.5816	0.5785	0.5771	0.5752	0.5716

It should be noted that the density decreases when the rate of river sand increases in the mixture: in fact, the river sand being lighter than the crushing sand, its increase in the mixture makes it possible to lighten the mortar obtained. Densities decreased for all mixtures after 28 days of shade storage, reflecting water loss from the mixtures. The densities of the mixtures with W/C = 0.45 are higher than those of the mixtures with W/C = 0.5 probably because the former underwent better compaction favored by the water content. In fact, excess or lack of water harms compaction and leads to an increase in voids in a material. The results of the porosity determination are presented in Table-6.

Table-6: Porosity results.

River sand ratio (%)	0	25	50	75	100
Porosity for W/C = 0.45	14.5	13	12	11	7
Porosity for W/C = 0.50	20	18	16.5	15	11

The porosity of the mortar decreases with the increase in the rate of river sand in the mixture. This decrease indicates that adding river sand to the mixture reduces voids in the mortar. This reduction can be favored by the rolled shape of the grains of river sand which is favorable to compaction unlike the grains of crushing sand which have angularities.

The increase in the W/C ratio resulted in an increase in porosity thus translating to better compaction of the mortar with the lower W/C ratio. This confirms the high density observed at the level of the mixtures having a W/C of 0.45.

Table-7 summarizes the results of the flexural strength and the compressive strength of the different mixtures illustrated in Figure-2.

Table-7: Strength results.

River sand ratio (%)	0	25	50	75	100
Flexural strength for W/C = 0.45 (MPa)	2.27	2.4	2.53	2.23	2.1
Flexural strength for W/C = 0.50 (MPa)	2.1	2.2	2.25	1.9	1.8
Compressive strength for W/C = 0.45 (MPa)	5.4	6.3	7.2	6.4	5.6
Compressive strength for W/C = 0.50 (MPa)	4.9	5.7	7.03	5.9	5.2

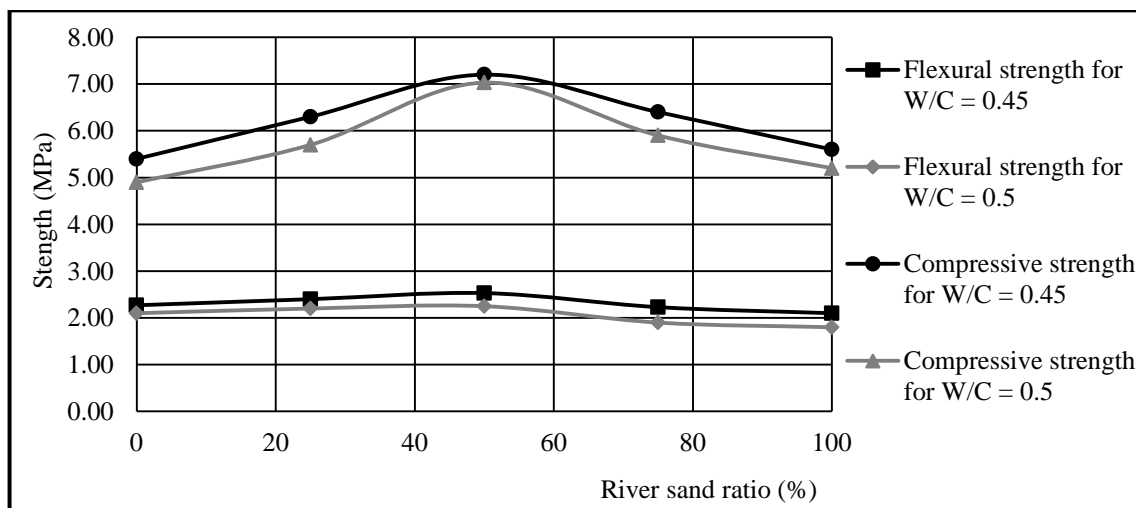


Figure-2: Strength variation according to river sand ratio.

The flexural and compressive strengths increase with the rate of river sand up to a rate of 50% beyond which the resistances drop. At a rate of 50% of river sand, there is an increase in flexural strength of 7%, for W/C = 0.50, and 11.5% for W/C = 0.45 compared to the mortar containing no river sand. This increase for compressive strength is 33.33% for W/C = 0.45 and 43.5% for W/C = 0.50. The results confirm that the W/C = 0.45 ratio is better than that of 0.50. These results also confirm the beneficial effect of adding river sand to the characteristics of crushing sand mortar. The resistance values obtained allow the use of these mortars for the manufacture of bricks.

Conclusion

The objective of the work is to study the influence of the addition of Zowla river sand on certain characteristics (slump, porosity, flexural and compressive strengths) of the mortar based on crushing sand. From the results obtained, it can be said that the mixture of 50% river sand and 50% crushing sand allows to obtain the best characteristics. A use for the manufacture of bricks with regard to the dosage of cement used and the obtained compressive strength is possible.

References

1. Dupain R., R. Lanchon et J.C. Saint-Arroman (2004). Granulats, sols, ciments et bétons: caractérisation des matériaux de génie civil par les essais de laboratoire. Ed. Casteilla, Paris, 235p, ISBN-10: 2713514711
2. Festa J. and Dreux G. (1998). Nouveau guide du béton et de ses constituants. France, Edition Eyrolles, 403 p.
3. Nkengue C., Malanda N., Ganga G., Louzolo-Kimbembe P. and Mouengue G. (2019). Influence of aggregate grain size on the formulation of sand concrete in the construction industry in Congo. *Geomaterials*, 9(4), 81-96. doi: 10.4236/gm.2019.94007.
4. Hamidi A, Alizadeh M and Soleimani S. (2009). Effect of Particle Crushing on Shear Strength and Dilation Characteristics of Sand-Gravel Mixtures. *International Journal of Civil Engineering*, 7(1), 61-71. <http://ijce.iust.ac.ir/article-1-196-en.html>
5. Sanjay Mundraa, Sindhib P.R., Vinay Chandwania, Ravindra Nagara and Vinay Agrawala (2016). Crushed rock sand – An economical and ecological alternative to natural sand to optimize concrete mix. *Perspectives in Science*, 8, 345-347.
6. Pathan MA, Maira MSM and Ahmed AJ (2020). The Engineering Properties of Manufactured Sand with Rock Quarry Dust and Muck Material District Jamshoro Sindh Province Pakistan. *Science Forest Journal of Environmental and Earth Science*, 3(2), 1043.
7. Çelik T. and Marar K. (1996). Effects of crushed stone dust on some properties of concrete. *Cement Concrete Research*, 26(7), 1121-1130.
8. Ilango R. (2000). Studies on strength and behaviour of concrete by using quarry dust as fine aggregate proceedings of All India Seminar on Materials and Machines for Construction. New Age International, 99-102.
9. M. Shahul Hameed, A.S.S. Sekar (2009). Properties of green concrete containing quarry rock dust and marble sludge powder as fine aggregate ARPN J. Eng. Appl. Sci., 4 (4), pp. 83-89
10. Mohammed Abbou, Adrar, Abdelaziz Semcha and Fatiha Kazi-Aoua (2020). Stabilization of compressed earth block clayey materials from Adrar (Algeria) by lime and crushed sand. *Journal of building materials and structures*, 7(1): 42-50. <https://doi.org/10.5281/zenodo.3744137>
11. Joel M. (2010). Use of Crushed Granite Fine as Replacement to River Sand in Concrete Production. *Leonardo Electronic Journal of Practices and Technologies*, 9, 85-96.
12. European Standards N EN 197-1 (2012). Cement — Part 1: Composition. Specifications and conformity criteria for common cements
13. French Standards NF P18-400 (1981). Concretes - Moulds for cylindrical and prismatic test specimens.
14. European Standards NF EN 12350-8 (2010). Testing fresh concrete- Part 8: Self-compacting concrete-Slump-flow test.
15. European Standards NF EN 12350-6 (2012). Testing fresh concrete — Part 6: Density.
16. French Standards NF P18-459 (2010). Concrete — Testing hardened concrete — Testing porosity and density.
17. European Standards NF EN 12390-5 (2012). Testing hardened concrete — Part 5: Flexural strength of test specimens.
18. European Standards NF EN 12390-3 (2019). Testing hardened concrete - Part 3: compressive strength of test specimens.
19. Vivek R Das., Nagarjun Gowda B. S., Apoorva M (2020). Comparative study on concrete mix with replacement of fine aggregate. *International Research Journal of Engineering and Technology*, 7(9), 1495-1498.