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Valorization of glass from waste in Togo: study of the formulation of a glass-sand mortar

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Abstract

This paper objective is to study the formulation of a glass-sand mortar in order to enhance the use of crushed glass bottles in construction in Togo. The study involved conducting specimens of glass -sand mortar obtained by varying the rate of glass from sand. The study has revealed that the addition of glass increases the compressive strength and decreases the absorption rate of mortar containing sand.

Keywords: Crushed glass, Sand, Mortar, Compressive strength, Absorption.

Introduction

For several years, Lome, the capital of Togo, has faced sanitary problems due to the difficult collection of household waste. The township of Lome in partnership with "French Development Agency" via the Lome Urban Environment Project (LULP) is trying to set up a viable collection system. However, the collection rate remains low (around 35%) except in the privileged neighborhoods and the final treatment of waste is almost non-existent. In August 2011, the NGO ENPRO (Clean Environment), in addition to its pre-collection activities and in partnership with the township of Lomé, began a composting platform to recycle organic waste (about 30% of the waste). After a year of operation, this platform processes about 10 to 15 tons of waste per day and will reach 80 tons per day in the years to come. Today, the quantity of glass collected is constantly increasing. At the composting site, sorted bottles and glass containers represent 2-3% of the incoming waste. In 2013, 225 tons of glass were collected and sorted on site. This quantity can reach 500 tons of glass per year. Thus, if there is no viable recycling or reuse method for the collected glasses, they will eventually constitute a new source of waste. It is in this context that the NGO ENPRO initiated a project to enhance the glasses in collaboration with the Service of Cooperation and Cultural Action of the French Embassy in Lome. This project aims at setting up a device for grinding the glasses collected of household waste on its composting platform for other purposes. In this article, the proposed exploitation is an operation in the construction sector in Togo.

Materials and methods

The glasses used are of green, brown and white color (Figure-1). Their characteristics are shown in Table-1. These glasses have a continuous particle size distribution with the same granular grade of 0.063/4.5 as shown in Figure-2. They can be assimilated to coarse sand.

The sand used comes from the Dalavé quarry located at 27 km north of Lome. It is a clean sand free from humus. These characteristics are shown in Table-1. Its granulometric curve is shown in Figure-2.

The cement used as a binder in this study is the CPJ 35 supplied by the company CIMTOGO, one of the cement plants in Togo. The water used is the drinking water supplied by the company "Togolaise des Eaux (TdE)".

The formulation of the mortar is based on the European normal mortar whose composition is[1]: i. 1350 ± 5 g of standardized sand; ii. 450 ± 2 g of cement; iii. 225 ± 1 g of water.

Figure-1: Crushed white, brown and green glasses.

Table-1: Used glasses and sand Characteristics.

Characteristics	White glass	Brown glass	Green glass	Sand
Absolute Density	2,55	2,31	2,5	2,48
Apparent density	1,46	1,43	1,43	1,53
Water content (%)	0	0	0	2,02
Finesse modulus	3,91	4,12	4,11	2,12
Equivalent of sand (%)	-	-	-	79,6

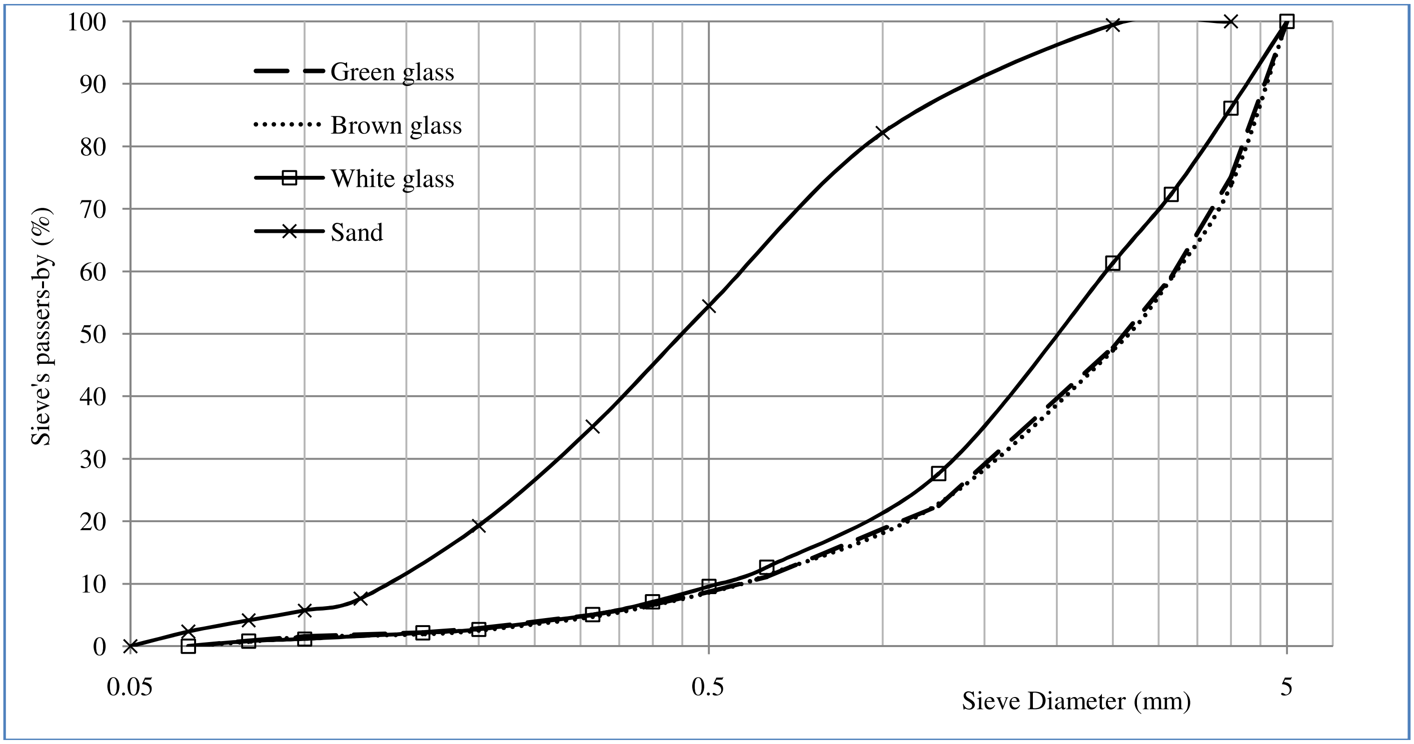

Figure-2: Glasses and sand granulometric curve.

A variation of the quantity of glass with regard to the sand is made from these normal points. This variation consisted in the replacement in the normal mortar of a mass of sand by a mass of glass at rates ranging from 0% to 50% in 10% increments. For each of the variations made, the quantity of water is also varied. Table-2 summarizes the variations.

From this formulation, prismatic specimens measuring 4cm x 4cm x 16cm are made according to the French norms NF P 18-400[2]. These specimens are then stored in a water bath at a temperature of 20°C ± 2°C in accordance with NFP 18 – 404[3]. On these specimens, are determined the density and the compressive strengths at 7 and 28 days of age according to the European norm EN 772-1[4]. Each result is an average of six (06) values.

Results and discussion

Table-3 gives the densities of the samples of the different mixtures at one (01), seven (07) and twenty-eight (28) days of age.

For each mixture, the density increases with age: the specimens are therefore porous and have absorbed water during the cure. It is also observed that the density increases with the glass dosage: since the glass is heavier than the sand used, its increase in the mixture impacts on the density of the specimens. From Table-3, we calculate the absorption rate of the mortars on the 28th day. This rate is shown in Table-4 as well as the results of the compression test.

Table-2: Quantities of materials used to make specimens.

Cement mass (g)	Sand mass (g)	Sand mass (%)	Glass mass (g)	Glass mass (%)	Water mass (W) (g)	Water/Cement ratio (W/C)
450	1350	100	0	0	215	0,48
					205	0,46
					195	0,43
	1215	90	135	10	215	0,48
					205	0,46
					195	0,43
	1080	80	270	20	215	0,48
					205	0,46
					195	0,43
	945	70	405	30	215	0,48
					205	0,46
					195	0,43
	810	60	540	40	215	0,48
					205	0,46
					195	0,43
	675	50	675	50	215	0,48
					205	0,46
					195	0,43

Table-3: Sample Density.

Glass rate (%)	W/C ratio	White glass			Brown glass			Green glass		
		1 day of age	7 days of age	28 days of age	1 day of age	7 days of age	28 days of age	1 day of age	7 days of age	28 days of age
0	0,48	2,186	2,207	2,242	2,186	2,207	2,242	2,186	2,207	2,242
	0,46	2,162	2,202	2,247	2,162	2,202	2,247	2,162	2,202	2,247
	0,43	2,161	2,200	2,232	2,161	2,200	2,232	2,161	2,200	2,232
10	0,48	2,221	2,241	2,259	2,216	2,259	2,262	2,198	2,202	2,245
	0,46	2,193	2,263	2,230	2,190	2,228	2,236	2,170	2,185	2,221
	0,43	2,190	2,233	2,234	2,175	2,186	2,221	2,180	2,200	2,216
20	0,48	2,198	2,234	2,231	2,236	2,229	2,280	2,201	2,215	2,246
	0,46	2,195	2,236	2,228	2,251	2,257	2,300	2,204	2,236	2,254
	0,43	2,210	2,257	2,242	2,211	2,241	2,261	2,175	2,186	2,230
30	0,48	2,217	2,247	2,253	2,270	2,234	2,322	2,258	2,292	2,302
	0,46	2,220	2,318	2,258	2,244	2,279	2,294	2,228	2,234	2,273
	0,43	2,208	2,271	2,245	2,267	2,292	2,320	2,251	2,265	2,289
40	0,48	2,222	2,259	2,256	2,245	2,273	2,295	2,254	2,271	2,300
	0,46	2,205	2,251	2,253	2,235	2,263	2,287	2,228	2,263	2,283
	0,43	2,220	2,279	2,259	2,255	2,285	2,302	2,251	2,280	2,306
50	0,48	2,204	2,228	2,244	2,295	2,260	2,338	2,199	2,223	2,239
	0,46	2,206	2,260	2,256	2,293	2,264	2,330	2,222	2,244	2,267
	0,43	2,227	2,254	2,276	2,278	2,270	2,314	2,271	2,294	2,316

Table 4: Compressive Strength and Sample Absorption Rate

Glass ratio (%)	W/C ratio	White glass			Brown glass			Green glass		
		7 days of age	28 days of age	Absorption (%)	7 days of age	28 days of age	Absorption (%)	7 days of age	28 days of age	Absorption (%)
0	0,48	14,83	25,30	2,56	14,83	25,30	2,56	14,83	25,30	2,56
	0,46	14,74	25,03	3,93	14,74	25,03	3,93	14,74	25,03	3,93
	0,43	12,93	19,63	3,29	12,96	19,63	3,29	12,96	19,63	3,29
10	0,48	16,06	26,30	1,69	19,27	25,92	2,09	17,90	25,10	2,12
	0,46	16,56	27,20	1,69	19,14	26,20	2,08	18,27	25,13	2,34
	0,43	17,10	28,40	2	21,18	26,80	2,1	18,37	25,67	1,64
20	0,48	17,76	26,20	1,51	19,06	26,33	1,99	17,72	25,40	2,02
	0,46	18,40	26,60	1,51	20,57	27,25	2,19	17,85	26,33	2,25
	0,43	18,54	29,80	1,44	22,53	28,10	2,25	19,97	26,50	2,53
30	0,48	16,18	28,90	1,6	20,53	28,98	2,3	19,34	26,18	1,94
	0,46	16,13	28,20	1,7	21,07	29,85	2,23	20,16	28,23	2,01
	0,43	19,12	31,40	1,69	24,27	30,67	2,33	21,04	30,83	1,69
40	0,48	15,52	27,40	1,53	21,91	26,57	2,22	19,84	27,92	2,04
	0,46	16,06	28,40	2,16	21,42	27,53	2,31	19,78	28,95	2,46
	0,43	16,86	29,60	1,76	22,37	28,70	2,09	20,56	29,10	2,45
50	0,48	13,76	24,60	1,82	20,05	28,20	1,89	18,37	25,96	1,84
	0,46	16,88	25,20	2,29	20,54	28,22	1,63	18,18	27,68	2,04
	0,43	18,32	27,50	2,18	22,12	28,63	1,59	20,34	28,63	1,97

From this table, one notes: i. for each mixture, the compressive strength increases with age: the conservation of the samples in water is therefore beneficial to their resistance; ii. the compressive strength decreases, for each glass-containing mixture and for each crushing day, with the water dosage as it increases with the water dosage for the non-glass-containing mixtures: the addition of the glass in the mixture corresponds to a reduction of sand. The glass is a material which does not absorb water, only the sand must be moistened in the glass-sand mortar and consequently the quantity of water necessary for the mixing must decrease, since the sand rate decreases; iii. the absorption rate of the mortar decreases with the addition of glass: the addition of glass to the sand allows to have a mixture containing fewer voids; iv. for each of the mixtures envisaged there is an optimum water dosage which allows the obtaining of a better compressive strength: if, for mixtures without glass, the best compressive strength is obtained for an W/C ratio equal to 0.48 , for mixtures with glass, this resistance is obtained for an W/C ratio equal to 0.43. Note that it is impossible to manufacture the mortar for W/C ratios of less than 0.43 because the mixture becomes too dry and therefore difficult to knead. Table-5 presents the optimum values of the compressive strength of each mixture.

From this Table-5, we obtain the curves in Figure-3 which illustrate, for each glass color, the variation of the compressive strength as a function of the glass dosage.

Table-5: Optimum values of compressive strength.

Glass ratio (%)	W/C ratio	White glass			Brown glass			Green glass		
		7th day	28th day	Absorption (%)	7th day	28th day	Absorption (%)	7th day	28th day	Absorption (%)
0	0,48	14,83	25,30	2,56	14,83	25,30	2,56	14,83	25,30	2,56
10	0,43	17,10	28,40	2	21,18	26,80	2,1	18,37	25,67	1,64
20	0,43	18,54	29,80	1,44	22,53	28,10	2,25	19,97	26,50	2,53
30	0,43	19,12	31,40	1,69	24,27	30,67	2,33	21,04	30,83	1,69
40	0,43	16,86	29,60	1,76	22,37	28,70	2,09	20,56	29,10	2,45
50	0,43	18,32	27,50	2,18	22,12	28,63	1,59	20,34	28,63	1,97

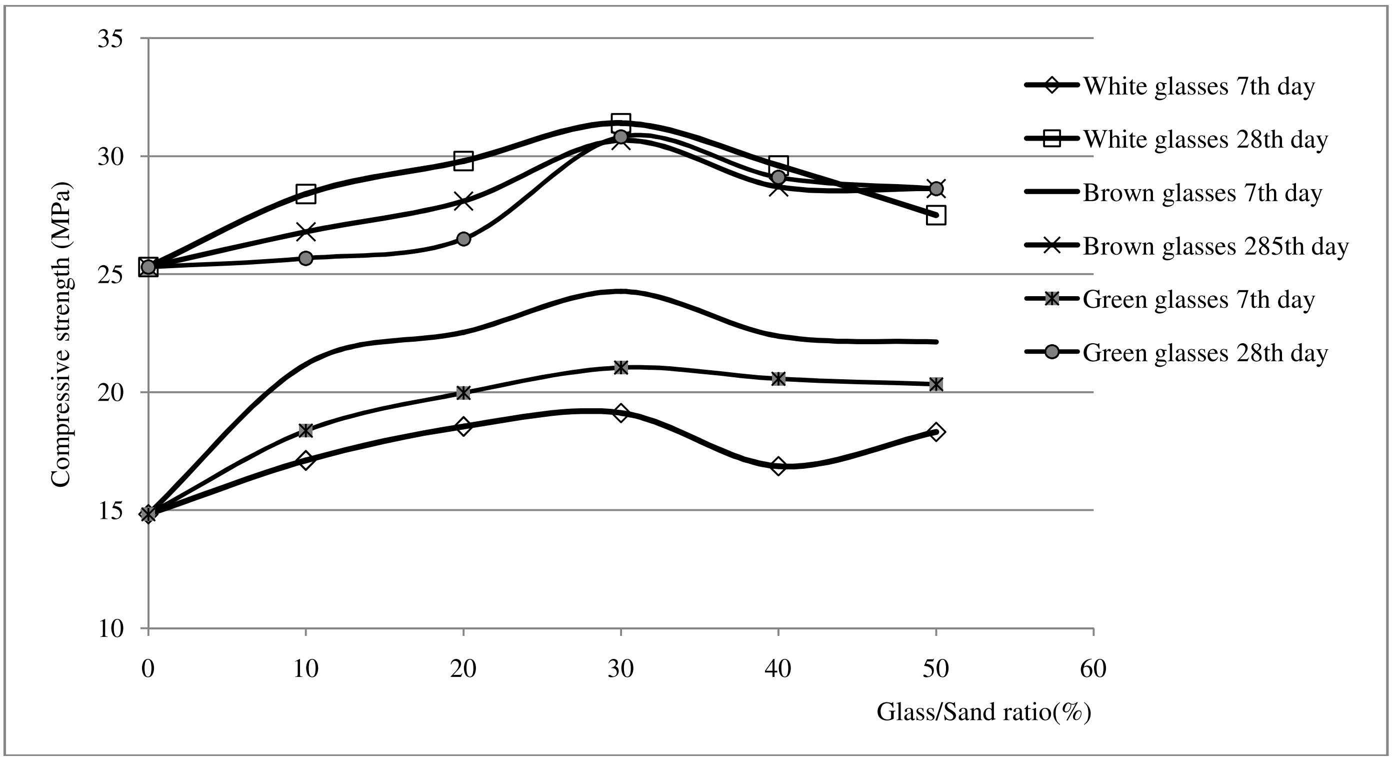

Figure-3: Variation of compressive strength as glass content function.

It will be noted that compressive strength increases with glass dosage until reaching an optimum value and then decreases. The coarse glass and the fine sand require a judicious mixing in order to obtain good compressive strength. Indeed, as in the case of concrete, the finer sand must fill the voids left by the glass. Increased strength with glass dosage indicates insufficient glass and excess of sand in the mixture. The decrease in strength, on the other hand, reflects a lack of sand in the mixture to fill the voids. For the optimum value of the compressive strength, the mortar obtained is also less porous (low absorption rate), which increases the cohesion inside the material. For the three colors of used glass, the optimum glass dosage of glass-sand mortar is 30% glass: 405g of glass, 975g of sand, 450 of cement and 195g of water, i.e. a water / cement ratio equal to 0.43.

Conclusion

This work aims to study possibility of using crushed glass in the construction in Togo in order to upgrade these glasses and thus avoid environmental pollution by these bottles. For this, a study of the formulation of a glass-sand mortar is done. It emerges that the use of glasses in construction is possible in Togo. Indeed, the glass considerably improves the compressive strength of the mortar. In order to have this effect, the glass must be carefully mixed with sand and cement, since the study revealed that an insufficiency or an excess of glass impairs the compressive strength. For a better compressive strength, Glass / Sand ratio of 0.30 is recommended.

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