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RESEARCH ARTICLE

STUDY OF THE PROPERTIES OF MORTAR INCORPORATED FROM MELTED PLASTIC BAGS

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Abstract

The aim of this research is to study the physical-mechanical behaviour and durability of mortars containing melted plastic bags. To this end, 4cmx4cmx16cm test specimens of mortar containing cement or not and melted plastic bags at a mass ratio ranging from 10 to 25% of the mixture were produced. Compressive strength, flexural strength and acid durability were measured. The results show that the quantity of plastics in the mortars is inversely proportional to water absorption. Similarly, cementless mortars containing 25% plastic bags (MWC_{25}) and cement mortars containing 25% plastic bags (CM_{25}) gave maximum compressive strengths of 9.45MPa and 10.45MPa respectively. The durability test in a 5% sulphuric acid solution showed that CM_{25} and MWC_{20} lost 50% of their mass after 28 days.

1. Introduction

Plastics have revolutionised a number of areas, including electricity, building construction, communications, sales, trade and the distribution of consumer goods. It is therefore impossible for any vital sector of the economy to function effectively without the use of plastic [1]. Global plastic production in 2019 has been estimated at 460 million tonnes, 75% of which is discarded as waste that pollutes land and oceans. This figure could rise by 40% by 2030 if concrete initiatives are not developed [2]. Plastic debris, or plastic articles, are persistent, mobile and ever-present in terrestrial and aquatic environments, and even in urban, rural and remote areas. Large pieces of plastic waste are easily visible and harm species through entanglement and ingestion. [3]. It should be noted that the disposal of plastic waste is a serious problem, as plastics can take up to 4,500 years to degrade. [1]. Clearly, plastics cannot be totally banned, but we need toencourage the possibility of recycling them by reusing them in various forms after use, in order to reduce the pollution observed on a global scale.

In Africa and around the world, a number of researchers have tackled the issue of recycling plastic waste invarious ways, particularly as aconstruction material. In Togo, work by Tsala-Mbala et al in 2022 produced paving blocks with a compressivestrength of 29 MPa using plastic water bags. [4] ; Amey et al, in 2014 obtained a compressive strength of 10.3MPa by adding to cement mortar with 22% plastic bags of types « voltic » [5].These researchers have obtained some interesting results. It would also be interesting to evaluate the effect of cement in such a mixture

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and the durability factor. The general objective of this work is to add value to plastic bags while evaluating the effect of cement on the physico-chemical and mechanical properties of specimens formulated with sand and or cement and melted plastic bags as a binder.

2. Materials and Methods

2.1. Materials used in the formulation of mortars

The plastic bags (Figure 1) used in this study were purchased on the Togolese market and therefore not used. These bags are burnt in a specially designed prototype burner called PE_1 (Figure 2), which has three compartments: the tank (diameter D=250 mm, height H= 330mm), the firebox, which operates on charcoal residue, and a model solar panel (model YB156-15P, P=15W, U= 12V). Sand from the Ewaou stream (Figure 3) located in Kara, 415 km north of Lomé, the capital of Togo, is also used. This is a clean sand, to be used if satisfactory workability and good strength are required with limited risk of segregation, with reference to its fineness modulus and granular class, which is 0/4 (Figure 4), (Table 1). Its uniformity coefficient is greater than 3 (Cu > 3), which shows that this sand has a varied or spread granulometry, with a grading coefficient outside the range 1 to 3, which also indicates the absence of certain diameters between D_{10} and D_{60}.[6]

Figure 1: Plastic bags.

Figure 2: PE_1 Prototype

Figure 3: Sand from the Ewaou stream.

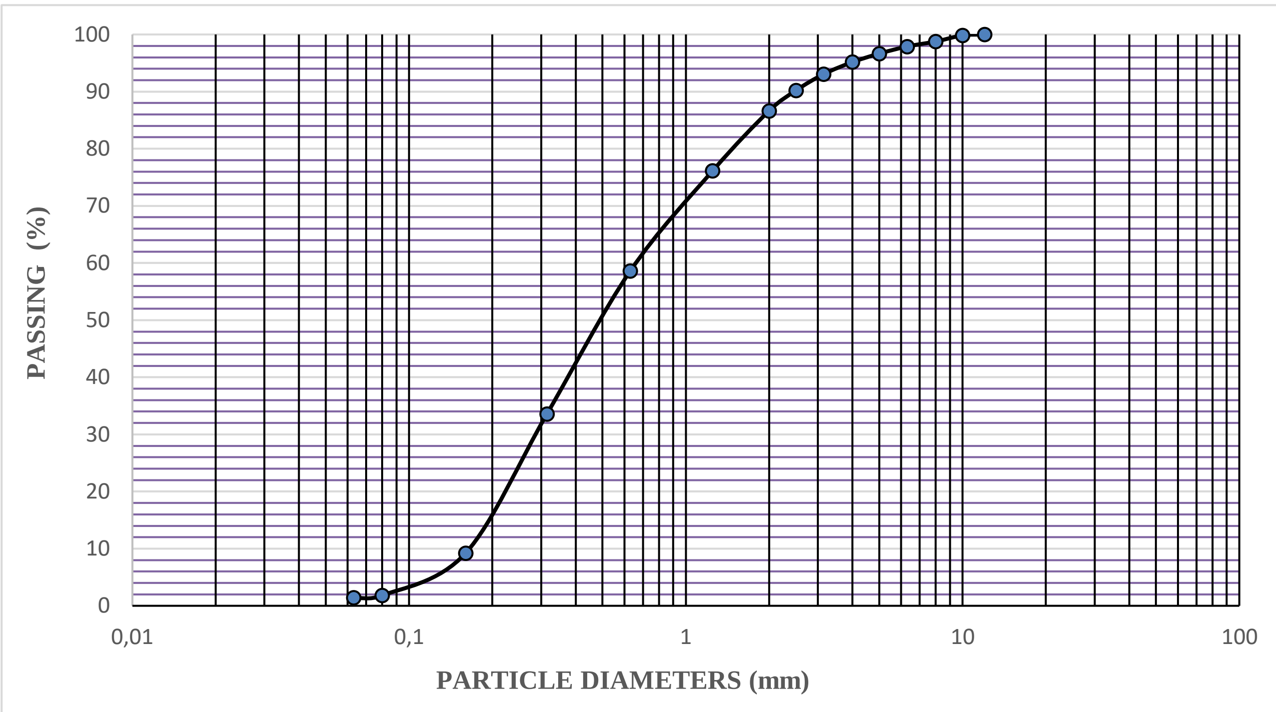

Figure 4: Sand grading curve

Table 1: Sand characteristics

Parameters	Sand
Apparent mass volume	1,62
Absolute density	2,72
Sand equivalent	79,93
Thinness module	2,36
Uniformity coefficient	3,61
Classification coefficient	0,76
Granular class	0/4

2.2. Mortar formulation and characterisation

Two types of mortar are formulated: an ordinary mortar called control mortar containing sand, cement and water, and a mortar in which melted bags are incorporated. The formulation of the control mortar is based on the normal European mortar, the composition of which is as follows [7]:

- 1350 ± 5g of standard sand;
- 450 ± 2g cement;
- 225 ± 1g water

To determine the cement dosage that gives the best resistance with the sand used, the quantity of cement is varied around the normal value (Table 2).

These variations are used to produce 4x4x16 cm^3 test specimens in accordance with standard NF P 18-400 [8].
Two types of mortar containing melted plastic bags were used: CMx and MWCx, which stand for cement mortar and mortar without cement respectively, with x representing the ratio of melted plastic bag to the mass of the mixture. The mass ratios considered are 10 to 25% and 5% steps (table 2). The total mass for the mortar containing cement is, according to the European Standard, 2025g and that for the mortar with cement is 1800g.

Table 2: Formulation of mortars based on plastic bags

Type of mortar	Plastic bags(g)	Sand (g)	Cement (g)	Total (g)
Control mortar	0	1350	450	2025
CM_{25}	450	1125	225	1800
CM_{20}	360	1215	225	1800
CM_{15}	270	1305	225	1800
CM_{10}	180	1395	225	1800
MWC_{25}	450	1350	0	1800
MWC_{20}	360	1440	0	1800
MWC_{15}	270	1530	0	1800
MWC_{10}	180	1620	0	1800

All the prepared test specimens are then kept in a water bath at a temperature of 20°C±2°C in accordance with NFP 18 - 404 standard [9]. The flexural strength and compressive strength of these specimens at 7 and 28 days of age are determined in accordance with European standard EN 12 390 [10].

The water absorption rate and acid resistance of the test specimens are also determined. This is obtained by immersing 4x4x16cm^3 test specimens in water. The specimens are dried for 24 hours in an oven at 105°C, then immersed in a vat of water until the mass of the specimen is completely stabilised.[11]. The open porosity is calculated by equation 1:

$$P = \frac{msat - msec}{msec} x100 \qquad (1)$$

P : open porosity, accessible to water
$msat$: saturated mass
$msec$: dry mass

To check the durability of the specimens, we immersed the two types of specimens containing 20 and 25% binder for 54 days at a temperature of 20°C ± 5°C after demoulding in a 5% sulphuric acid solution. The specimens not containing cement were weighed and introduced directly into the acid solution, unlike the specimens containing cement, which were cured in a water tank before testing. The chemical resistance of the specimens immersed in the acid solution was assessed in accordance with ASTMC standard 267-96 [12]. The measurement is carried out every 7 days. The test specimens are cleaned with distilled water to remove altered mortar. After 30 min, the sample is dried and weighed. The acid attack is evaluated by equation 2.

$$P = \frac{M_t - M_i}{M_i} x100 \quad (2)$$

M_t : is the mass at time t (g)
M_i : is the initial mass before exposure(g)

3. Results

3.1. Test results for control mortar

Tests on the control mortar were carried out at 7 and 28 days. Tables 3 and 4 illustrate the flexural and compressive strength tests.

Table 3: Variation in bending strength.

W/C	Strength at 7 days (MPa)			standard deviation	CV (%)	Strength at 28 days (MPa)			standard deviation	CV (%)
	Minimum	Average	Maximum			Minimum	Average	Maximum		
0,42	4,69	5,02	5,35	0,46	9,16	5,88	6,05	6,22	0,24	3,97
0,44	4,69	4,98	5,27	0,41	8,23	5,50	5,51	5,53	0,02	0,36
0,45	4,50	4,68	4,86	0,25	5,34	5,75	5,91	6,07	0,23	3,89
0,47	4,54	4,6	4,66	0,08	1,74	5,15	5,36	5,57	0,29	5,41
0,5	4,02	4,2	4,38	0,25	5,95	5,35	5,55	5,74	0,27	4,86
0,52	3,83	4,1	4,37	0,38	9,26	5,21	5,24	5,26	0,14	2,67

CV: variation coefficient

For a given formulation, the test results show an increase in flexural stress for a variation from 7 to 28 days. We also note that this variation is proportional to the increase in cement.

Table 4: Variation in compressive strength

W/C	Strength at 7 days (MPa)			standard deviation	CV (%)	Strength at 28 days (MPa))			standard deviation	CV (%)
	Minimum	Average	Maximum			Minimum	Average	Maximum		
0,42	18,45	19,38	20,31	1,31	6,75	23,46	24,16	24,86	0,98	4,05
0,44	19,76	20,46	21,17	0,99	4,83	25,84	26,24	26,64	0,56	2,13
0,45	21,70	22,37	22,76	0,47	2,10	28,56	28,95	29,34	0,91	3,14
0,47	19,39	19,77	20,14	0,53	2,68	26,25	26,9	27,55	0,91	3,38
0,5	18,71	19,09	19,47	0,54	2,83	25,53	26,14	26,75	0,86	3,21
0,52	16,85	17,65	18,46	1,36	7,70	24,5	24,75	25	0,35	1,41

The results in Table 5 show an increase in strength with age. This increase decreases at values of Water/Cement ratio (Water/Cement below 0.45. It can therefore be said that the ratio giving the best compressive strength is the one with a Water/Cement ratio of 0.45, with an average strength of 28.95 MPa at 28 days of age. The coefficients of variation were less than 10, and therefore very good, showing a low dispersion of results and therefore good mortar formulation

3.2. Results of tests on mortars containing melted plastic bags

The results of the immersion absorption, flexural strength and compressive strength tests are shown in Figures 5 to 7.

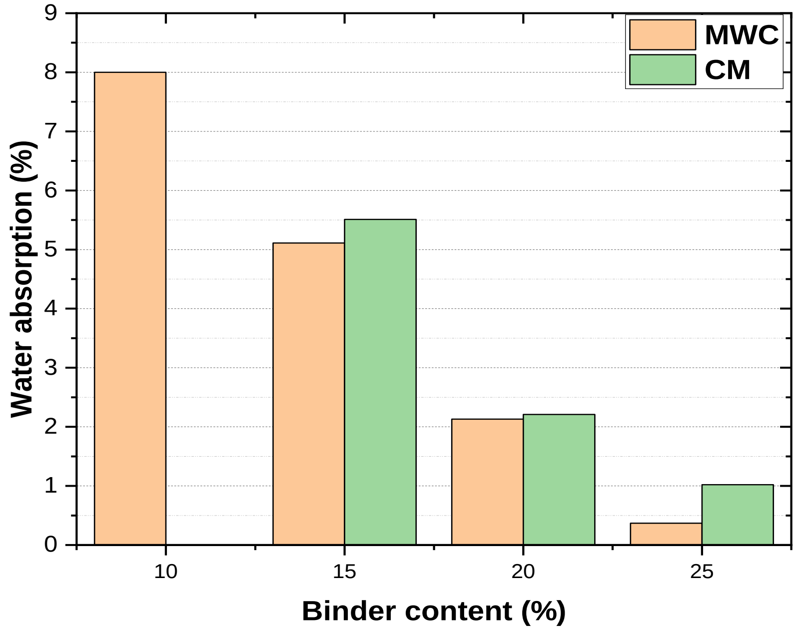

Figure 5: Water absorption as a function of binder content.

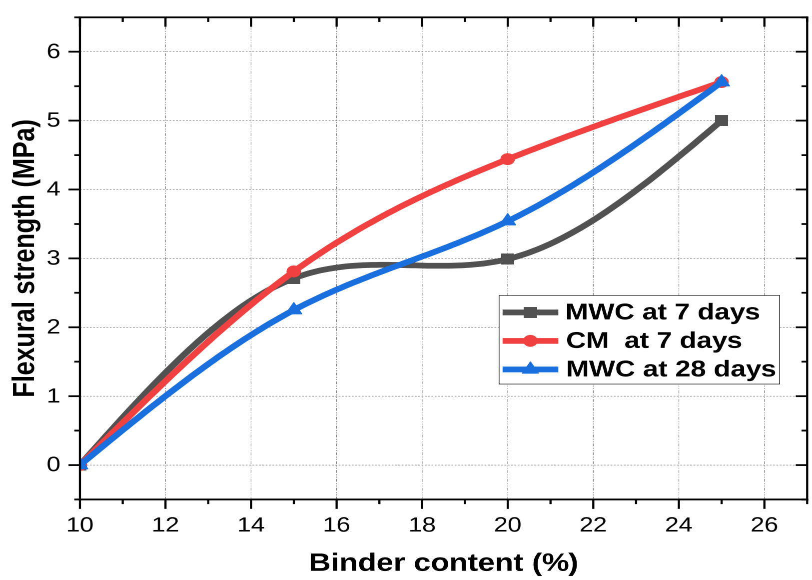

Figure 6: Flexural strength as a function of binder content.

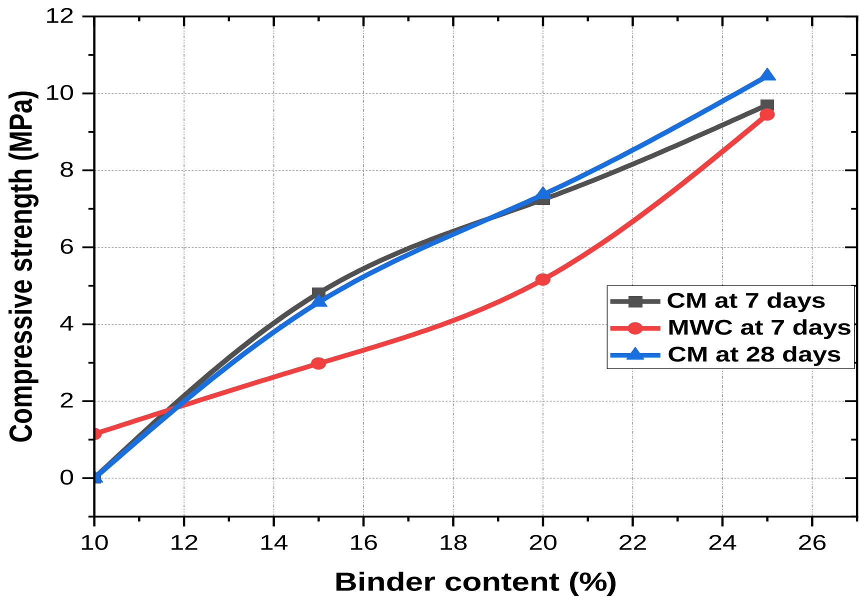

Figure 7: Compressive strength as a function of binder content.

Mechanical tests were carried out at 7 and 28 days after immersion in a water bath only for cement mortars (CM). Cementless mortars (MWC) were not immersed and the tests were carried out at 7 days. This difference in crushing date is explained by the fact that the presence of cement in a matrix increases its strength over time when it is kept in water. Figure 5 shows the water absorption of the two types of specimens. The specimens reached saturation after 72 hours, except for MWC_{25} and CM_{20}, which reached saturation after 48 hours. The low absorption rateof MWC_{25} could be explained by the tightness of the mortar due to the considerable quantity of melted sachet. The progressive decrease in the absorption rate from 10 to 25% of melted bags could be due to aprogressive sealing ofthe mortar. These results are in agreement with the experimental study of the formulation of mortar based on silty sand from Togo and "voltic" type plastic bag binder [8].

It can be seen that the quantity of plastic is inversely proportional to the water absorption of the test specimens. Similarly, a comparison of the water absorption of CM and MWC shows that CM absorbs more water than MWC in all ratios. This difference could be explained by the incorporation of cement into the mix, which absorbs water over time.

The 7-day flexural strength of cementless mortars (MWC) shows zero strength for MWC_{10} and an average strength of 5MPa for MWC_{25}, this could be explained in part by the friability due to the low quantity of binder. At 7 days, the compressive strength varies from 1.15 to 9.45 MPa when the rate of melted bag increases from 10 to 25%. This shows that the increase in strength is proportional to the binder content. These results are slightly lower than those found by Amey[8] which found a strength of 10.3MPa with a binder content of 22% using "voltic" type bags. This difference can be justified by the low density of plastic bags compared with "voltic" type bags. However, there was a slight increase compared with the study carried out by Tchehouali et al. [13] which found a strength of 9MPa using the melted plastic bags while substituting the sand with 30% clay. At 28 days, the compressive strength is 10.45 MPa for CM_{25}, slightly higher than for MWC_{25} (9.45 MPa). This difference could be explained by the presence of cement, whose matrix increases in strength over time. Figure 8 shows the results of chemical tests by immersing the specimens in acid.

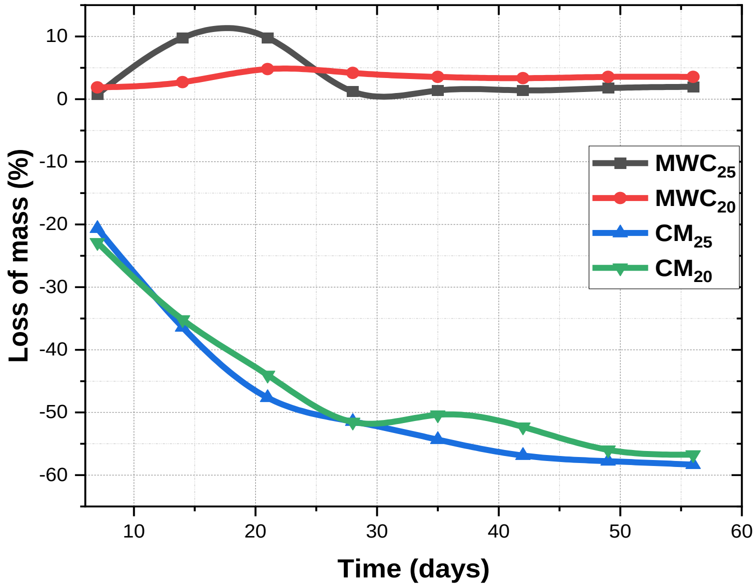

Figure 8: Mass loss as a function of immersion time with 5% (H_2SO_4).

Overall, it can be seen that mortars not containing cement are not attacked by the acid solution, unlike cement mortars, which are almost totally destroyed by the solution. After 14 days of immersion, the cement-less mortar specimens (MWC_{25} and MWC_{20}) underwent a 10% gain in mass. This gain reflects the start of swelling due to the chemical reactions taking place between the hydrates and the sulphuric acid [14].

After 28 days, the acid solution was replaced by another due to the impurities deposited in it as a result of the gradual degradation of some of the mortar specimens. According to the graph, for an interval of 0 to 28 days before the acid solution was changed, the cement mortar specimens lostmore than 50% of their mass, while overthe same time interval, there was an increase in mass, reaching a peak of 10% in the cement-free mortars. This difference could be explained by the deposition of residue on the cementless mortar specimens due to erosion of the cement mortar specimens. The erosion of the cement mortar specimens could be explained by the reaction between the cement and the acid, unlike the cementless mortar specimens. After 28 days following the replacement of the acid solution, a mass loss of 10% was observed for the cement mortar specimens compared with a constant of cement mortar specimens. These observations were also made by Recioui and Siradji [15]. They produced test specimens with or without brick waste, incorporating polyethylene terephthalate (PET) plastic waste in various proportions, and observed that those containing only PET had good durability. Figures 9 and 10 illustrate the changes undergone by the test specimens.

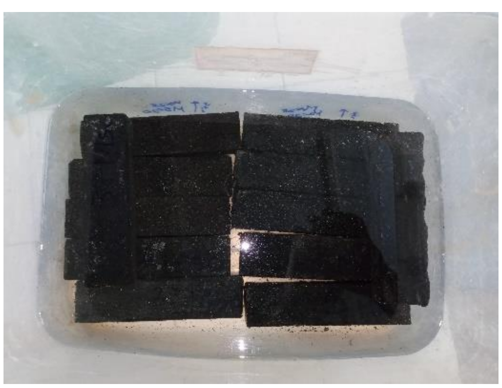

Figure 9: First day of CM and MWC

Figure 10: Appearance on day 54 of CM and MWC

4. Conclusion

The aim of this study was to investigate the effect of adding molten plastic bags on the properties (flexural and compressive strength, durability in acid) of the mortar. The maximum strength obtained after 28 days was 28.95 MPa for the control. The highest strength obtained for the samples containing plastic was 9.45 and 10.45 MPa for the cement-free and cement-containing mortar samples respectively. These results show that adding half the amount of cement (225g) gives a slight increase in compressive strength, but less than the control (28.95MPa). Durability, assessed by decalcification in a 5% sulphuric acid solution, showed that specimens made from melted plastic bags containing cement underwent progressive erosion until a loss of mass close to 50% after 28 days, unlike specimens containing only melted plastic bags. From an economic and durability point of view, the choice should therefore be made in favour of plastic specimens containing no cement.

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Conflicts of Interest

The authors declare no conflicts of interest

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