Journal of Recent Advances in Applied Sciences

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Research Article

EXPERIMENTAL STUDY OF THE MECHANICAL CHARACTERISTICS OF MORTARS PRODUCED WITH A BINDER CONTAINING TWO COW DUNG ASHES

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Received May 01, 2018; Accepted July 21, 2018; Published August 02, 2018;

Cite This Article: Houehanou, E., Ahlinhan, M., Olodo, E., Gbaguidi-Aisse, G., Degan, G.(2018). Experimental study of the mechanical characteristics of mortars produced with a binder containing two cow dung ashes. Journal of Recent Advances in Applied Sciences, 5(1). 1-11

ABSTRACT

This study concerns the evaluation of the mechanical characteristics of five mortars produced with a binder containing different proportions of cow dung ash produced in laboratory with objective to its using as additional mineral in the production of mortars. Five other mortars are produced with the same binder containing the same proportions cow dung ash produced traditionally and a standard mortar (control) is also produced with the same binder without any mineral in addition. Some compressive strength tests are carried out on test specimens of mortar (40x40x160 mm^3). The compressive strength and chemical characteristic allowed us to estimate and to compare the mechanical characteristics and the pozzolanic activity ratio of both used ashes. The pozzolanic activity ratio of both types of cow dung ash is estimated to 75% and 68% in 28 days. The mechanical characteristics of the mortars containing some cow dung ash produced in laboratory are superior for the greater part to those of the mortars containing some cow dung ash produced traditionally. On the other hand, the medium-term (56 and 90 days) mechanical characteristics of the mortars containing until 15 % of cow dung ash produced in laboratory are equivalent to those of reference mortar.

KEYWORDS: cow dung ash, additional mineral, mechanical characteristics, pozzolanic activity.

INTRODUCTION

The use of the mineral additions in mortars and concretes constitutes a stake of sustainable development. In the developed countries, the mineral additions are perceived as an important element of the concept of sustainable development today. Concretes produced in those countries contain from 10% to 25% of mineral additions (flying ash, silica fume, blast furnace slag) [4]. In developing countries, the mineral additions are little known and are not almost used while the needs in infrastructures are still enormous. Some countries like Benin, Nigeria, Sudan, the Asia-Pacific regions, Central Europe and Eastern Europe etc., which try to improve their insufficient Infrastructure are confronted with numerous challenges. Mortars and concretes are the main basic materials for the construction. The activities linked to the cement produce manufacturing are produces many greenhouse gases. Furthermore, the cement which is the main binder, is also the most expensive element in the production of mortars and concretes [1]. It becomes then necessary to valorize the alternative solutions for using of the cement which reduce the costs of construction as well as the greenhouse gas emissions.
The cow dung is used in the construction for: the erection of walls, the treatment of cracks, the coatings and waterproofing of facings [8]. The ashes stemming from the

incineration of the cow dung are also used as additional mineral [11, 10]. Some works have already shown the interest of the use of the cow dung in the construction, in particular in the traditional constructions when it is mixed with the bar ground [5]. Some studies although limited indicate the opportunities offered by this material [9, 10]. Most of these studies concern the mechanical and thermal characteristics of the cow dung ash. The results of these studies vary according to the nature of the cow dung and the used aggregates. Globally the studies recommend to substitute of 10 % of the mass of cement which gives satisfactory compressive strengths [11]. A new study on the pozzolanic activity and the mechanical characteristics of mortars produced with a binder containing some cow dung ash find well its relevance. The present article aims at estimating the pozzolanic activity and the compressive strengths of two cow dung ashes (ash produced in laboratory and second one produced traditionally) from mortars containing.

MATERIAL AND METHODS

1. **Experimental program**

   The experimental program contains eleven (11) mortars. On standard mortar produced with a commercial binder (normal cement), 5 mortars produced with a binder containing respectively 5 %, 10 %, 15 %, 20 % and 25 % of cow dung ash produced in laboratory as well as 5 other mortars produced with a binder containing 5 %, 10 %, 15 %, 20 % and 25 % of ash of dung of cow produces traditionally. The compressive strengths are determined on test specimens of size 40x40x160 mm^3. The pozzolanic activity ratios of two different types of used cow dung ash are estimated according to the ASTM-C618 standard [2].

2. **Materials**

   a. **The cow dung ash**

Two (02) types of cow dung ash were used. The cow dung ash produced in laboratory, named ash A and a cow dung ash produced traditionally, named ash B. The cow dung used for the production of both types comes from the same source.

a) *Cow dung ash produced in laboratory (ash A)*

The cow dung ash produced in laboratory is obtained by incineration of the cow dung taken from an experimentation site of cattle farm of the University of Abomey Calavi (UAC). The material is taken fresh and pre-dried under sun until constant mass. It is then incinerated by temperature of 550 °C. Table 01 presents the physical properties and the chemical characteristics of the cow dung ash produced in laboratory. The values are very comparable to those obtained in the literature [9, 3].

Table 01: Physical properties and chemical composition of the ash A.

Physical properties							
Tests			**Results**		**Specifictation**		
Specific density (Kg/m^3)			1234		EN 1097-7		
Bulk density (Kg/m^3)			683		P 94-050		
Specific surface BET (m²/g)			362		-		
Chemical characteristics							
Oxides	MgO	Al_2O_3	SiO_2	K_2O	TiO_2	Fe_2O_3	CaO
Content (%)	0.92	4.56	66.86	1.23	0.87	3.92	13.99

b) *Cow dung ash produced traditionally (ash B)*

The cow dung ash traditionally produced is also obtained by traditional incineration of the cow dung taken from the same site and underwent the same treatment (drying). The cow dung so dried was then burned and passed through the sieve. The maximal diameter of particles is 120 µm. The produced material is in the powder form similar to the one produced in the laborator. Table 02 presents the physical properties and the chemical characteristics of the cow dung ash produced traditionally. The obtained values are also in accordance with those obtained in the literature [9, 3]. The figure 01 presents the picture of a heap of dried cow dung and a heap cow dung in process of traditional incineration.

Table 02: Physical properties and chemical composition of the ash B

Physical properties							
Tests			**Obtained results**		**Used specifictation**		
Specific density (Kg/m^3)			1118		EN 1097-7		
Bulk density (Kg/m^3)			647		P 94-050		
Specific surface BET (m²/g)			349		-		
Chemical characteristics							
Oxides	MgO	Al_2O_3	SiO_2	K_2O	TiO_2	Fe_2O_3	CaO
Content (%)	2.02	4.28	64.26	2.93	0.65	3.16	14.59

Figure 01: Traditional incineration of the cow dung.

b. Cement

The cement used for the present study is Portland cement CEM II / A-LL 42.5 R fulfilling the new european specification. It is an initial high resistance Portland-limestone cement. According to the specification EN 197-1: 2002, it is mainly made by clinker (between 80-94 %) and of additament mixed at the rate of 6-20 %.

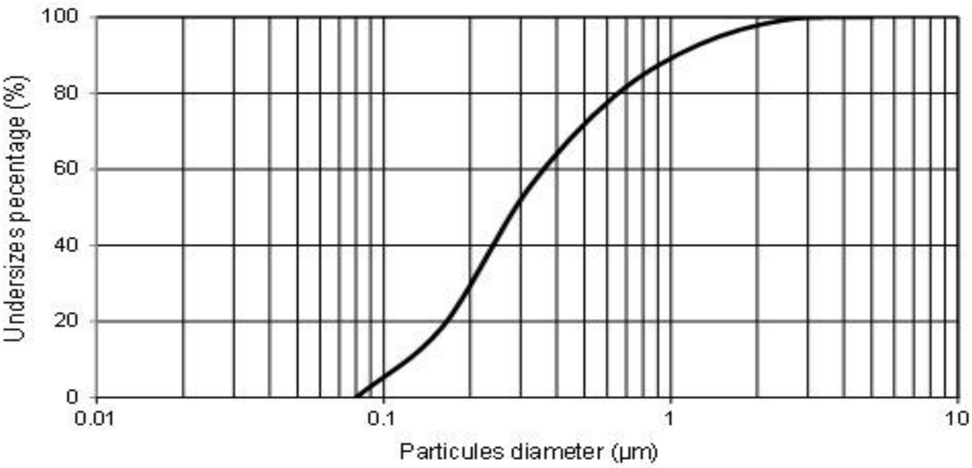
c. Water reducing adjuvant

The water reducing adjuvant is Sika-Fluid type used for the preparation of mortars. It is a new generation water reducing adjuvant which improves the implementation of mortars and concretes by increasing the mechanical resistance strength. This adjuvant is in compliance with the NF EN 934-2. specification. Its density is 1.15; its pH is 7.5; its ion Cl^- content is lower than 0.1 % and its Na_2O éq content is lower than 1. The dosage variation indicated by the manufacturer is from 0.1 to 5.0 % of the binder weight or of the cement weight according to the fluidity and the sought performances.

d. Sand

All the mortars were produced with an alluvial siliceous sand having a density (SSS) of 2.67, and absorption of 0.6 %. The maximal diameter of particles is 5 mm and presents a spread grading. This is a natural sand marketed for the production of mortars and concretes. The results of the granulometric analysis are presented in the figure 02.

Figure 02: Sizing Curve of the used sand.



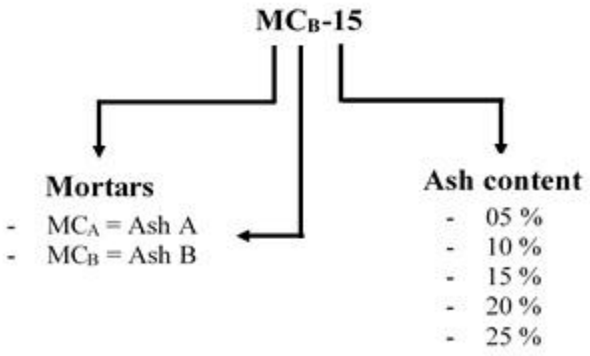
3. Procedures

Besides the characterization test of the materials (sand, cow dung ashes), we proceeded to the determination of the density, slump and temperature on the fresh mortars. We also proceeded to compressive strength on the mortars.

i. Identification of the mixtures

The standard mortar is identified M-Control. The mortars containing some cow dung ash produced in the laboratory (ash A) or some of cow dung ash produced traditionally (ash B) are identified by a code with two components. A group of three letters indicates the category of mortar (MC_A for mortars containing some ash A and MC_B for mortars containing some ash B and a number which indicates the substitution content.

Figure 03: Identification plan of mortars.



ii. Characterization of mortars

The compression test is carried out according to NF EN 12390-3 and NF EN 12390-5 specifications. The taken test specimens are cuboid of dimensions 4x4x16 cm^3, in compliance with the NF EN 12390-01 specification. The compressive test are realized in 14, 28, 56 and 90 days. The density, the workability and the temperature were determined on mortars in the cool state.

iii. Composition and production of mortars

The table 03 and table 04 present the composition of mortars. The indicated quantities of sand are in the saturated state dry surface (SSS). For all the mortars, the ratio water/binder is 0.5 and the ratios water/cement vary according to the ash content. The ratios water/cement are between 0.5 and 0.67. All the mortars contain 5 kg/m^3 of water reducing agent, that to say a dosage of 0.1 % of the total binders weight. The measured densities are between 2012 kg/m^3 and 2139 kg/m^3 with an average of 2061 kg/m^3. The workability of the mortars is measured with the test in mini slump cone. The values obtained for the slump tests are between 75 mm and 95 mm. The temperatures measured on the cool mortars are between 20° and 21° Celsius. The characteristics of the mortars are in compliance with the requirements and the practice.

Table 03: Composition and characteristics of ash A mortars.

Mortars						
	Control	**MC_A-5**	**MC_A10**	**MC_A15**	**MC_A20**	**MC_A25**
Cement (kg/m^3)	470	440	410	381	357	333
Ash (kg/m^3)	-	23	45	67	89	111
Total binders (kg/m^3)	470	463	455	448	446	444
Water (kg/m^3)	237	232	228	224	223	221
Ratio (E/C)	0.5	0.53	0.56	0.59	0.62	0.66
Sand (kg/m^3)	1426	1409	1381	1357	1354	1342
Density (kg/m^3)	2139	2109	2069	2034	2028	2012
Temperature (°C)	20	20	21	20	21	20
Slump (mm)	80	80	85	85	90	95

Table 04: Composition and characteristics of ash B mortars.

Mortars						
	Control	**MC_B-05**	**MC_B-10**	**MC_B-15**	**MC_B-20**	**MC_B-25**
Cement (kg/m^3)	470	442	414	380	358	336
Ash (kg/m^3)	-	25	47	63	91	114
Total binders (kg/m^3)	470	467	461	443	449	450
Water (kg/m^3)	237	234	230	221	223	224
Ratio (E/C)	0.50	0.53	0.56	0.58	0.62	0.67
Sand (kg/m^3)	1426	1422	1379	1361	1350	1336
Density (kg/m^3)	2139	2128	2075	2030	2027	2015
Temperature (°C)	20	20	20	21	20	19
Slump (mm)	80	75	75	80	80	85

iv. Preparation of mortars and maturing of test specimens

All the mortars are produced in a mixer of Hobart type. The sand is firstly introduced into the mixer, then half of gauging water comes, the binder and finally the second half of the mixing water containing the water reducing agent. Each introduced material is mixed until homogenization. The made test specimens are kept in a wet environment (wrapped in some wet jute). They are placed in drying condition (50 % of relative humidity) 24 hours before being put to compressive strength test.

RESULTS

The tables 05 and 06 present the results of the compressive strength tests. They indicate the values obtained on three test specimens used for each concrete, average of three tests and standard deviation between the three values. The data of the tables 05 and 06 show that the average compressive strength of all the test specimens for all the typesof mortar is 31.09 MPa with an average relative variability of ± 4% (1.12/31.09). The most important deviations between the test specimens are obtained with mortars MC_B-5 in 56 days (1.82 MPa), MC_B-15 in 28 days (1.73 MPa), and MC_B-25 in 14 days (1.66 MPa) (1.66 MPa) whereas the lowest deviations between the test specimens are obtained with mortars MC_B-20 in 14 days (0.62 MPa), MC_B-10 in 14 days (0.65 MPa), and MC_B-20 in 28 days (0.71 MPa). The average of the deviations for mortars containing ash A is 1.06 whereas one of mortars containing ash B is 1.19. Table 07 presents the pozzolanic activity ratio for both experimented ashes. It is estimated according to the ASTM C618 specification [2].

Table 05: Mechanical characteristics of ash A mortars.

		Mortars					
Resistances		**Control**	**MC_B-5**	**MC_B10**	**MC_B15**	**MC_B20**	**MC_B25**
14 days	A	33.49	29.17	26.44	24.73	22.82	19.85
	B	31.77	30.26	25.73	26.37	23.78	22.16
	C	32.86	28.51	25.15	25.15	22.61	20.34
	Average	32.71	29.31	25.63	25.42	23.07	20.78
	Standard deviation	0.87	0.88	0.65	0.85	0.62	1.22
28 days	A	34.32	34.10	33.43	31.74	29.44	28.49
	B	37.24	33.65	31.45	33.23	30.51	26.88
	C	35.12	32.36	30.89	30.38	28.74	27.39
	Average	35.56	33.37	31.92	31.78	29.56	27.59
	Standard deviation	1.51	0.90	1.33	1.43	0.89	0.82
56 days	A	38.04	37.43	33.65	32.90	34.52	33.28
	B	36.38	35.60	34.74	34.72	32.89	31.65
	C	37.13	35.62	35.56	35.85	33.97	31.50
	Average	37.18	36.22	34.65	34.49	33.79	32.14
	Standard deviation	0.83	1.05	0.96	1.49	0.83	0.99
90 days	A	38.63	34.95	36.27	35.15	33.56	34.46
	B	36.77	37.40	35.22	36.45	35.78	33.66
	C	38.28	37.26	35.65	34.67	35.60	34.23
	Average	37.89	36.54	35.71	35.42	34.98	34.12
	Standard deviation	0.99	1.38	1.38	0.92	1.23	1.40

Table 06 : Mechanical characteristics of ash B mortars.

		Mortars					
Resistances		**Référence**	**MC_B-5**	**MC_B10**	**MC_B-15**	**MC_B20**	**MC_B25**
14 days	A	33.49	25.61	23.89	23.67	20.32	16.88
	B	31.77	27.33	23.82	20.92	18.94	19.52
	C	32.86	26.06	22.33	20.78	21.18	19.93
	Average	32.71	26.33	23.35	22.12	20.15	18.78
	Standard deviation	0.87	0.89	0.88	1.63	1.13	1.66
28 days	A	34.32	34.21	29.78	28.84	25.62	25.38
	B	37.24	32.89	31.22	25.42	26.29	24.34
	C	35.12	32.27	30.44	26.69	24.87	23.33
	Average	35.56	33.12	30.48	26.98	25.59	24.35
	Standard deviation	1.51	0.99	0.72	1.73	0.71	1.03
56 days	A	38.04	36.21	34.12	32.92	31.58	29.21
	B	36.38	37.45	35.87	30.62	30.12	27.63
	C	37.13	33.87	32.72	30.63	30.26	29.32
	Average	37.18	35.84	34.24	31.39	30.65	28.72
	Standard deviation	0.83	1.82	1.58	1.33	0.81	0.95
90 days	A	38.63	35.89	34.84	35.25	30.32	31.48
	B	36.77	37.75	37.23	32.18	32.22	29.13
	C	38.28	36.55	34.84	33.61	31.11	28.35
	Average	37.89	36.73	35.64	33.68	31.22	29.65
	Standard deviation	0.99	0.94	1.38	1.54	0.95	1.63

Table 07: Pozzolanic activity ratio of both experimented ashes.

	Ashes									
Days	**5%**		**10%**		**15%**		**20%**		**25%**	
	A	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
14	0.90	0.80	0.78	0.71	0.78	0.68	0.71	0.62	0.64	0.57
28	0.94	0.93	0.90	0.86	0.89	0.76	0.83	0.72	0.78	0.68
56	0.97	0.96	0.93	0.92	0.93	0.84	0.91	0.82	0.86	0.77
90	0.96	0.97	0.94	0.94	0.93	0.89	0.92	0.82	0.90	0.78

DISCUSSION

1) Pozzolanic activity ratio of ashes

Figure 04 presents the values of the compressive strength in 14 days, 28 days, 56 days and 90 days of the standard mortar (Control), MC_A-25 (mortar containing 25 % of ash of A) and MC_B-25 (mortar containing 25 % of ash B). The figure 05 present the pozzolanic activity ratio of each of the mortars of both series (ash A mortars and ash B mortars) for a substitution in 25%.

The activity ratio is the parameter by which is quantitatively estimated the degree of reaction in the time or the rate of reaction between a pozzolanic material and the $Ca(OH)_2$ in the presence of water [2]. The ASTM C618 specification, considers a material as pozzolanic if it fills two conditions. Its chemical composition will have to verify the condition $Al_2O_3 + SiO_2 + Fe_2O_3 > 70\%$ and its pozzolanic activity ratio (*i*) in 28 days superior to 0.67 for a substitution rate of 25%. The chemical composition of both types of cow dung ash (tables 01 and 02) indicates that the ash produced in laboratory contains 75.34% of alumina Al_2O_3, oxide of silica SiO_2 and iron oxide Fe_2O_3. That produces by craftsmen contains 71.70 % of alumina Al_2O_3, some oxide of silica SiO_2 and some oxide of iron Fe_2O_3. The analysis of data of the table 08 and the figures 04 and 05 shows that the pozzolanic activity ratio (*i*) in 28 days of the ash A is 0.78 and the one of the ash B (ash produced traditionally) is 0.68 for a substitution rate of 25 %. This result confirms the previous studies on the pozzolanic character of the cow dung ash [3]. From 14 to 90 days, the pozzolanic activity ratio of both ashes increases with the enhancement of the age of mortars and tends to 1.

Figure 04: Compressive strength in 28 days, the reference mortar as well as those of the mortars containing 25 % of ash A and 25 % of ash B.

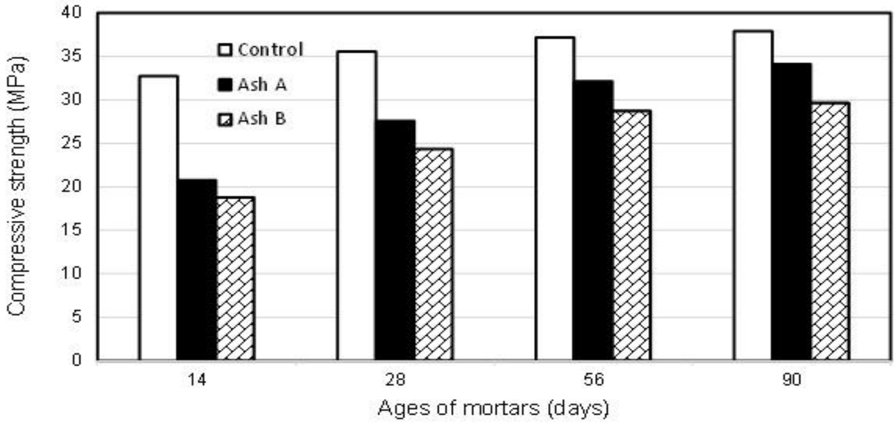


Figure 05: Pozzolanic activity ratio of mortars containing 25 % of ash A and 25 % of ash B at different ages.

The pozzolanic activity ratio of the ash A is relatively higher than ash B one at all the ages. Both experimented ashes are stemming from combustion of the cow dung both, rich in silica containing more a content in $Al_2O_3 + SiO_2 + Fe_2O_3$ superior to 70 %. Both ashes present both a pozzolanic activity ratio superior to 0.67 for a substitution rate of 25 %. According to the ASTM C618 specification, the ash produced in laboratory like the one traditionally produced one can both be considered like pozzolanic materials. Those two materials mixed with cement contribute to the hardened concrete properties by hydraulic action or pozzolanic or both at the same time [14, 13].

The pozzolanic activity ratio of the ash A (ash produced in laboratory) is higher than the ash B one (ash produced traditionally). The contents in Silica, in Alumina, iron and in Calcium are superior to the minimal requirements. The chemical composition explains the reactivity observed for both ashes. The contents in Silica, in Alumina, iron and in Calcium higher at the level of the ash A are at the origin of the performances relatively better when we compare it to those of the ash B, [6]. The ash A is produced in laboratory condition with constant calcination temperature (550°C). The traditional production was not able to offer a temperature so high as well as a constancy in the process of incineration. The conditions of the ash A production (constant temperature of 550°C) favoured a little more the pozzolanic character of the ash comparatively with the ash B. The low content in alkalis will eliminate the reaction alkali-aggregates in mortars and concrete. We can conclude that it is about two clean ashes which can be used in the mortars preparation and concretes [14].

2) Resistance in compression of mortars

The figure 06 presents the compressive strengths of mortars containing 5, 10, 15, 20 and 25% of ash A. The figure 07 presents the compressive strengths in 90 days for the same mortars. The tables 06 and 07 show that the compressive strengths in 28 days and in 90 days some mortars produced with the ash A (ash produced in laboratory) are systematically higher than the resistances observed on mortars produced with the ash B (ash produced traditionally). The values of the compressive strengths for the mortars produced with the binder containing some ash B are relatively lower than those obtained with mortars containing some ash A. For the same ash contents, the ash A gave values of compressive strength systematically higher and that for all the produced mortars.

The analysis of data of tables 05 and 06 as well as curves of figures 08 to 11 shows clearly and in systematic way that the compressive strengths of mortars containing some ash A (ash produced in laboratory) are superior to those of mortars containing some ash B. The best performance of the ash A confirms the results obtained during the evaluation of the pozzolanic activity ratio of both ashes [11, 10]. Indeed, the pozzolanic activity ratio of ash A is superior to the one of the ash B. The conditions of production of the ash A (constant temperature of 550°C) which favoured a pozzolanic activity ratio relatively high of the ash A also favored a better development of the compressive strength comparatively with the ash B [7].

Figure 06: Compressive strength in 28 days of mortars containing some ash A and B.

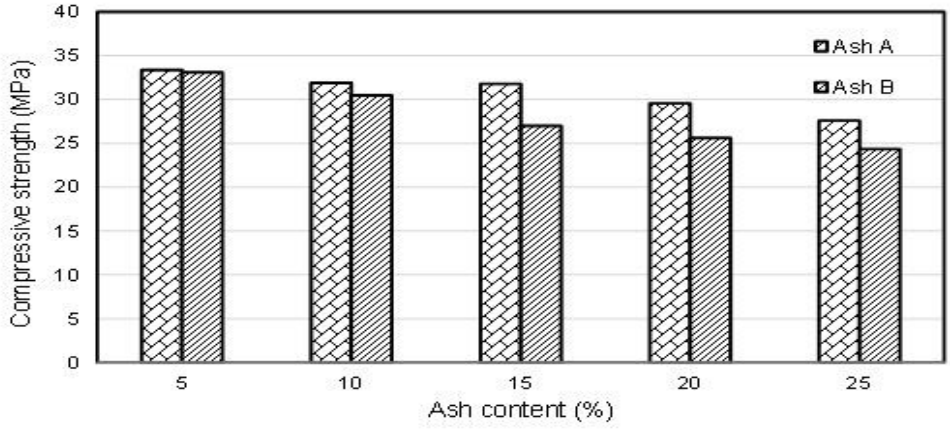
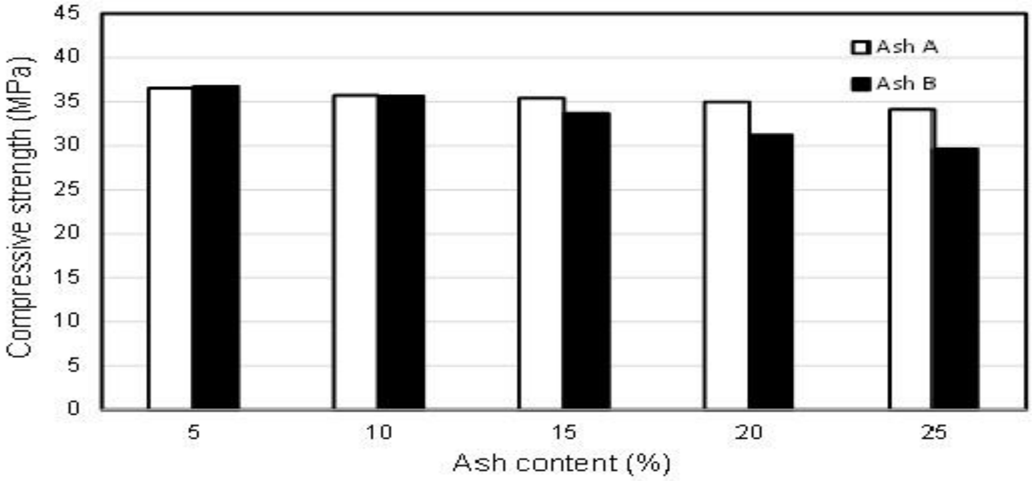


Figure 07: Compressive strength in 90 days of mortars containing some ash A and B.



The figures 08 and 09 respectively present evolution of the compressive strength of mortars containing some ash A as well as those containing some ash B according to the age (14, 28, 56 and 90 days). The curves of figures 08 and 09 also show that for all the mortars, the compressive strength increases with the age of the mortar. Globally, the compressive strength increasing is similar for all the mortars between 0 day and 14 days. From 14 days to 90 days, the compressive strength increasing is relatively higher for mortars containing some ash when we compare them with the reference mortar. The deviations between the compressive strength of the reference mortar and those containing some ash A are respectively 4.29 MPa in 14 days, 2.80 MPa in 28 days, 1.78 MPa in 56 days and 1.31 MPa in 90 days. For mortars containing some ash B, the deviations are 5.07 MPa in 14 days, 4.45 MPa in 28 days, 3.27 MPa in 56 days and 3.22 MPa in 90 days. Those curves also show that for all the mortars, the use of both ashes (ash produced in laboratory like the ash produced traditionally) globally contributed to a development of the compressive strength as mortars evolve in age.

In a cement grout, the consequent pozzolanic effect in the presence of the ash begin to show itself from the liberation of the calcium and alkalis ions during the hydration of the cement. However, the big part of this effect responsible for the development of the resistance occurs after several days of hydration. It is obvious that the resistance at young age (0 in 14 days) is more or less proportional to the quantity of present cement. The pozzolanic effect happens later. The development of resistances in cement womb containing a additional mineral is thus slow. The long-term resistances amount to or exceed sometimes those of Portland cement without addition agents, when the quantity of addition agent is well optimized. This increase of resistances is due to the refining of pores and grains as well as to the increase of the quantity of silicate of calcium hydrated (C-S-H). The significant development of the compressive strengths of mortars containing some ash (ash A and ash B) is sign of a refining of pores and grains as well as of an increase of the quantity of C-S-H [6].

Figure 08: Compressive strength at different ages of mortars containing some ash A

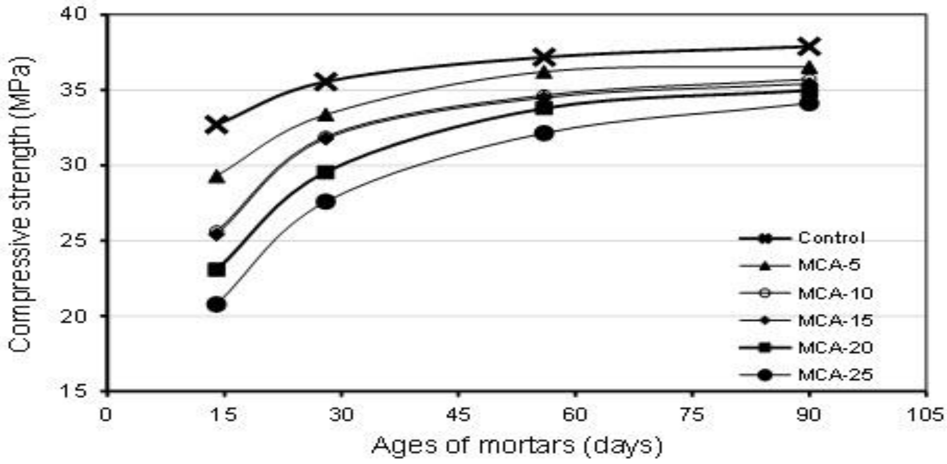
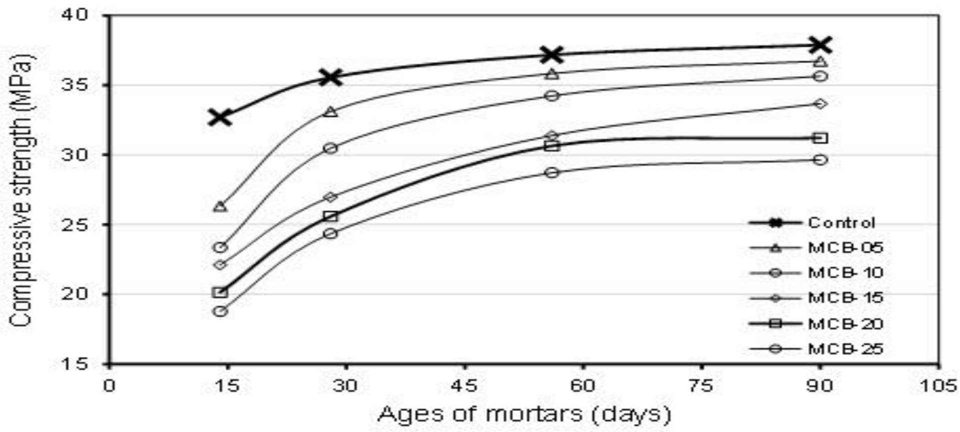


Figure 09: Compressive strength at different ages of mortars containing some ash B



The figures 10 and 11 indicate evolution of the compressive strength according to the ash content for the different ages of mortars and for both experimented ashes. It is necessary to note globally that for the different ages of mortars and for both experimented ashes, the compressive strength decreases with the increase of the ash content. From 5 % to 15 % of substitution, the compressive strength decrease is relatively lower when we compare it with the decrease observed between 15 % and 25 % of substitution for both types of ashes. The same figures indicate a systematic improvement of deviations bound with the increase of ash content, when mortars get older. This effect is observed on both experimented ashes. The effect is more significant about the mortars containing some ash A than the one containing some ash B.

Figure 10: Compressive strength of mortars with different contents containing some ash A

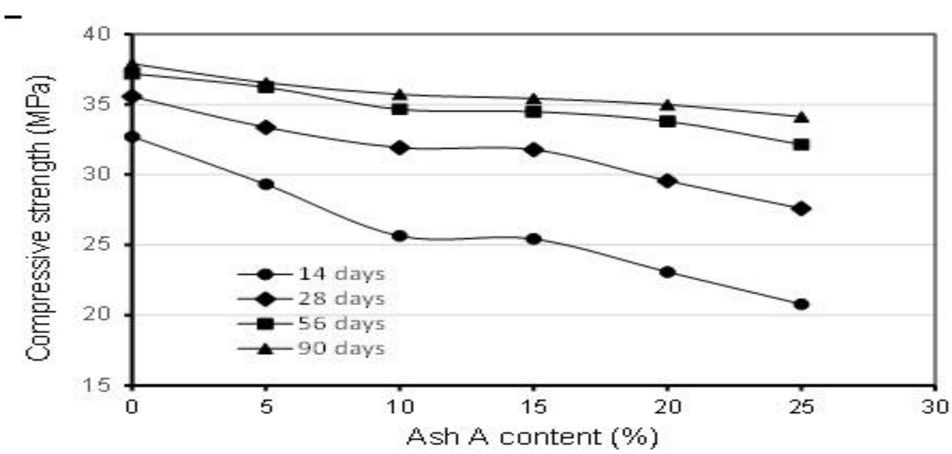
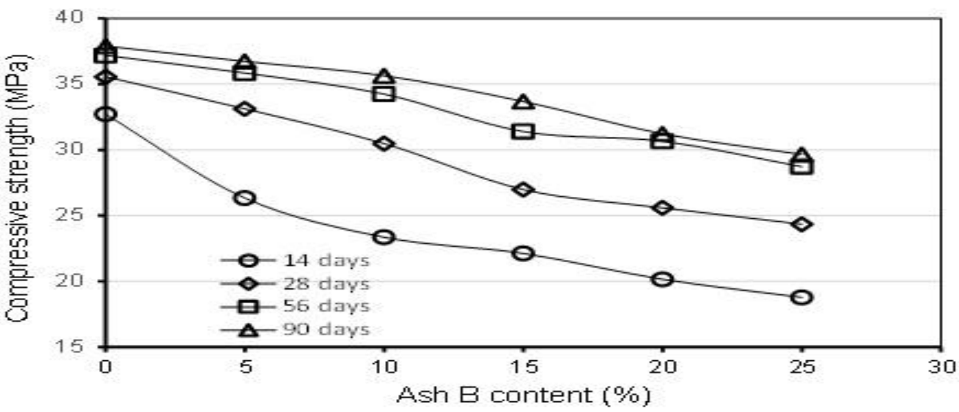


Figure 11: Compressive strength of mortars with different contents containing some ash B



Globally, mortars containing small proportion of ash A (5% and 10%) developed resistances equivalent to the one of the reference concrete in 28 days and 90 days of age. The mortars containing some ash B in the same proportions and for the same ages developed resistances relatively lesser. About the mortars containing higher contents ash (between 15% and 25%), the resistances are significantly lower at all the ages. The development of the resistance, particularly at young age is consequent to the quantity of cement present in the cement womb, it is normal that the evolution of the ash content decreases globally. In reality, the increase of the air content amounts to a decrease of the quantity of cement and consequently to a decrease of silicates of calcium hydrated in the hardened cement grout (at young age). In the medium term (between 28 and 90 days), the cement wombs containing some small (less than 15%) proportion of addition agent present resistances equivalent to those of the mortars having the same characteristics of formulation (ratio E/C and binder content) [12, 9]. For high ash contents (between 15% and 25%), the beneficial effect of the pozzolanic reaction on the development of hydrated silicates of calcium is not considerable in the point to compensate for the effect of the decrease of the quantity of cement present in the hardened cement grout [12, 9]. It would not thus be recommended, the use of the high contents as well some ash produced in laboratory as the one produced traditionally.

CONCLUSION

The cow dung ashes are materials stemming from the dejection incineration of the ruminants with hollow horns. They can be produced in laboratory conditions or traditionally. As they are traditionally produced traditionally or in laboratory, the cow dung ashes present interesting pozzolanic properties. The chemical composition and the pozzolanic activity ratio show that the cow dung ashes are pozzolanic materials which can be used in mortars and concretes as mineral additions.

The chemical composition of the cow dung ash produced in laboratory indicates that the contents in Silica, in Alumina, in iron and in Calcium are higher than the ash traditionally produced. The pozzolanic activity ratio of ash produced in laboratory is higher ash traditionally produced. The ash produced in laboratory seems better than the ash traditionally produced when it is a question of using them as mineral additions.

The compressive strength of mortars containing ash produced in laboratory are relatively higher than those of the mortars containing ash produced traditionally. For both ashes the increase of the ash content decreases the compressive strength. The use of both ashes globally contributed to a development of the compressive strength as mortars evolve in ages. The mortars containing 5% and 10% of ash produced in laboratory have compressive strengths in 28 days equivalent to the one of the reference mortar. For the ash contents exceeding 10% (between 15% and 25%), the resistances are significantly lower at all the ages.

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