Tagabo Volcanic Ash as Cement Replacing Materials

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المستخلص تهدف هذه الورقة إلى تقييم الخصائص البوزولانية للرماد البركاني تم الحصول عليها من جبال تقابو من ولاية شمال دارفور في غرب السودان كمادة بديلة لاستخدامها في الاسمنت المخلوط. تم جلب أربعة عينات من الرماد البركاني كمادة بوزولانية طبيعية، الأولى رماد بركاني من منطقة قرما (TG1VA)، والثانية من منطقة مابو (TG2VA)، والثالثة من منطقة مو (TG3VA) والأخيرة من منطقة ديم السنوسي (TG4VA). وقد بحثت هذه الدراسة الخصائص الكيميائية والفيزيائية للعينات وأنشطتها البوزولانية مع الاسمنت البورتلاندي العادي (OPC) في مستويات احلال مختلفة من الاسمنت بالوزن، وهي 10، 20، 30، 40، و 50 %. ونتائج التحليل الكيميائي تظهر أن جميع العينات يمكن تصنيفها على أنها من الفئة N حسب المواصفة الأمريكية ASTM C618. وتبين أن مؤشرات معامل الفاعلية البوزولانية مع الأسمنت الخاصة بالعينات الأربعة بنسبة 20 في المائة بلغت 75، 84، 89، و 83 في المائة على التوالي. تشير هذه النتائج إلى أن عينات البوزولانا من جبال تقابو هي مواد من المحتمل استخدامها في الاسمنت المخلوط.

الكلمات المفتاحية: البوزولانا، الاسمنت المخلوط، الرماد البركاني، جبال تقابو -شمال دارفور

ABSTRACT This paper aims to assess the pozzolanic characteristics of the volcanic ash obtained from Jebel Tagabo (Tagabo Mountains) in western Sudan (North Darfur State) as potential Supplementary Cementitious Materials for use in blended cement and concrete. Four natural Pozzolanic materials samples have been obtained; the first is volcanic ash from the Garma region (TG1VA), the second from the Mabo region (TG2VA), the third from the Mawo region (TG3VA) and the last from the Daim Sanosi region (TG4VA). This study has investigated the chemical and physical characteristics of the samples and their pozzolanic activities with Ordinary Portland cement (OPC) at different substitution levels of cement by weights, which are 10, 20, 30, 40, and 50%. And the results of chemical analysis show that all samples can be classified as Class N according to the American standard ASTM C618. The strength activity indices of the four samples at 20% level were found to be 75, 84, 89, and 83% respectively. These results indicate that the Jebel Tagabo Pozzolans are potential supplementary cementitious materials for use in blended cement.

Keywords: pozzolanic reactivity, Blended cements, volcanic ash, Jebel Tagabo -Darfur.

1. INTRODUCTION

Cement is an important material used in the construction field. The constant search for additional materials are required to replace a part of the cement in the mixtures or to reduce its quantities, thus reducing carbon dioxide

emissions, transportation and energy with a mix or to improve the rate of gain in strength, durability, and its others properties.

Research had been carried out on the use of cement replacement material (SCMs) that can be blended with Portland cements like fly ash (FA), volcanic ash (VA), blast furnace slag (BFS), etc.

[1–6]. The FA and VA are pozzolanic materials, because of their reaction with lime (calcium hydroxide) liberated during the hydration of cement. Amorphous silica present in the pozzolanic materials combines with lime and forms cementitious materials ASTM C618 (2005) [7].

The Natural pozzolans are those materials which do not require any further treatment apart from grinding to react with lime F.MASSAZZA (1976) [8].

In Sudan, natural pozzolanas have been reported by Mamoun, (2004) [9] who characterized some natural pozzolana in Sudan such as obsidian deposits (Sabaloka-Northern Khartoum), Natural burnt clay (Southern Bayouda) and Diatomite deposits (Gregrieb - Gezira). He determined their pozzolanic reactivity through compressive strength, and factors affecting the compressive strength of lime pozzolan mortar. He also reported the existence of volcanic ash in Marra Mountain, Meidoub Mountains and Tagabo in Darfour with no detailed information or characterization for these deposits. Elsharif M. I (2014) [10] has investigated Jebel Marra Volcanic Ash as SCM for Use in Blended Cements.

Volcanic ash (VA) is a natural pozzolanic material that is available in many volcanic areas in the Sudan and is inexpensive. It only needs to be crushed and grinded. The use of these volcanic materials can transform them into natural resources for the production of low-cost building materials and environmentally friendly with acceptable strength and durability characteristics, that can contribute to the sustainable development.

The partial replacement of Portland cement by volcanic ash in mortars and concrete, when available, may be better in practice and lead to an economic solution especially in place like Northern Darfur state. This paper aims to assess the pozzolanic characteristics of the volcanic ash obtained from Jebel Tagabo (Tagabo Mountains) in the northern Darfour state; it's located in the Mara and Meidoub mountain series at 125 Km from Al Fasher town in Northern east direction. It is characterized by the volcanic field which is

considered as potential SCMs for use in blended cement and concrete.

2. MATERIALS AND METHODS

A. Materials

1. Cement

Ordinary Portland cement (OPC) from Atbara Cement Company.

2. Sand

River sand from Wadi Nyala was washed, dried, sieved and graded from 90 μm to 1.18 mm according to ASTM: C 778 – 02[11] have been used in the present study.

3. Volcanic ash (VA)

Four natural Pozzolanic samples were brought from Jebel Tagabo. Sample one is Tagabo volcanic ash from the Garma region (TG1VA) at coordinates (N 14° 27' 40.6'', E 25° 39' 54.9''), sample two is Tagabo volcanic ash from the Mabo region (TG2VA) at coordinates (N 14° 34' 39.9'', E 25° 44' 02.1''), sample three is Tagabo volcanic ash from the Mawo region (TG3VA) at coordinates (N 14° 34' 33'', E 25° 43' 54.42'') and sample four is Tagabo volcanic ash from the Daim Sanosi region (TG4VA) at coordinates (N 14° 28' 14.68'', E 25° 33' 44.37''). The four samples were grounded, sieved and then characterized using chemical and physical analysis according to ASTM C311-02 [12].

4. Water

Water from the public main supply in Wadi Nyala was used for the mixing and the curing of the mortar cubes.

B. Methods

1. Grinding of the pozzolanic materials

When the fineness of the pozzolanic materials affecting the reactivity of the blended cement, to achieve desired fineness, local made Ball mill for laboratory purposes, about one kilogram capacity was used, desired fineness can be achieved depending on operating time.

2. Preparation of control and blended cement mortar

A control mix was prepared in 50mm cubes moulds (area of face 25 cm²). The control mix was

produced using OPC only as binder with the proportions of materials one part of cement to 2.75 parts of graded standard sand by weight and water-cement ratio of 0.485 such as to produce a flow table of 110 ± 5 as specified in ASTM C 109/C 109M – 02[13]. The proportions of the different mixes with blended cement used in this study are listed in Table (1). As specified in ASTM C 311 – 02[12] to produce the same flow of the control mixture ± 5 .

The Four samples were incorporated in the mixes at 10%, 20%, 30%, 40%, and 50% replacement levels, the blended mixes (OPC/ xi) were made with the same workability (flow of the control mixture ± 5) as needed in practice. Where: xi represent the four samples that brought from Jebel Tagabo (TG1VA, TG2VA, TG3VA & TG4VA). Changes in mortar properties were investigated related to different types of Pozzolanic samples (xi) under the study where xi represents TG1VA, TG2VA, TG3VA and TG4VA.

3. Mixing and casting

The fresh mortar was mixed and 12 cubes for each mix (total of 300 cubes) were casted as required by ASTM C 109/C 109M – 02[13]. The specimens were de-molded after at least 24 hours and immersed into the curing tank until testing.

3. RESULTS AND DISCUSSION

A. Chemical properties

Results of the chemical analysis of TG1VA, TG2VA, TG3VA and TG4VA are shown in Table (2). They show that the sum of principal oxides of Silica (SiO_2), Alumina (Al_2O_3) and Iron (Fe_2O_3) are within the limits (at least 70%) of the ASTM C 618 - 05 [7]. They also conform to the specification of loss on ignition $\leq 10\%$, $\text{SO}_3 \leq 4\%$, and moisture content $\leq 3\%$.

B. Physical and mechanical properties of pozzolanic materials

Table (3) enlists physical properties such as fineness and mechanical properties of mortars incorporating the pozzolanic samples such as strength activity index and water requirement. All natural pozzolan specimens are complied with class (N) of the ASTM C 618 – 05 [7].

C. Water consistency and setting time limits

The results presented in Figure (1), indicated that addition of Tagabo volcanic ash samples improve Consistency and workability of pozzolanic cement mixture. This may be attributed to higher fineness and surface area of pozzolans particles. Most natural pozzolanas tend to increase the water requirement in the normal consistency test as a result of their micro porous character and high surface area ACI 232.1R (2000) [14]. Also in Figure (2), addition of Tagabo volcanic ash retarded the initial and final setting time. This in agreement with Ramezaniapour et al [15], who reported that the setting time of cements containing various natural pozzolans are extended with level of replacement of the cement.

Fig. 1: Effect of Tagabo pozzolans samples in the consistency of the Portland cement.

Fig. 1: Effect of Tagabo pozzolans samples in the setting time of the Portland cement.

TABLE 1: MORTAR MIXES PROPORTIONS (RATIO BY WEIGHT)

Mix ref.	OPC	Jebel Tagabo Pozzolan samples(xi)	Sand	Water
Control (CTR)	1	0	2.75	0.485
OPC/ 0.1	0.9	0.1	2.75	water required for flow ± 5 of control mixture
OPC/ 0.2	0.8	0.2	2.75	
OPC/ 0.3	0.7	0.3	2.75	
OPC/ 0.4	0.6	0.4	2.75	
OPC/ 0.5	0.5	0.5	2.75	

TABLE 2: CHEMICAL PROPERTIES OF OPC, TG1VA, TG2VA, TG3VA AND TG4VA

Materials	Chemical Composition (%)								
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	K ₂ O	Na ₂ O	LOI
OPC	19.83	5.35	2.795	65.88	1.71	2.3	0.4	--	2
TG1VA	64.04	17.85	1.588	0.849	1.086	0.02	2.701	1.825	6.3
TG2VA	61.31	18.29	2.425	0.972	1.558	0.18	4.645	2.372	4.6
TG3VA	64.80	20.10	1.77	0.596	0.790	0.18	1.384	1.171	6.7
TG4VA	71.13	14.76	1.756	0.539	1.359	0.11	1.596	0.905	3.8

TABLE 3: POZZOLAN PHYSICAL PROPERTIES AND ASTM C 618 – 05 REQUIREMENTS

Test	TG1VA	TG2VA	TG3VA	TG4VA	ASTM C618-05 Class N Pozzolan
Fineness (Amount retained when wet-sieved on 45 μ m sieve) %	12	18	14	18	34 (max.)
Strength Activity Index at 7 days,%	83	91	88	88	75 (min.)
Strength Activity Index at 28 days,%	75	84	89	83	75 (min.)
Water requirement of control % (max)	108 (max.)	106 (max.)	104 (max.)	108 (max.)	115 (max.)

D. Compressive strength results

The compressive strength results of the TG1VA, TG2VA, TG3VA and TG4VA with replacement levels of 10%, 20%, 30%, 40% and 50 % at various ages of curing time up to 90 days are presented in Figure (3), (4), (5) and (6) respectively. Clearly seen that the four samples contributes to the strength of mortars after 3 days of curing. However 20% addition of the four samples provided 75% and more than the control compressive strengths at 7 and 28 days as reported in table(3) . These percentages additions met the ASTM C 618 – 05 [12] specifications. The compressive strength of the mortars containing 10 - 20 % TG3VA and 10% TG4VA pozzolans replacement were even higher than control mortar after 90 days. Lower strengths were obtained for those blends with higher substitution

levels of Pozzolanas, so the compressive strength values decreases with increase in the substitution ratio of Pozzolan samples used.

Fig. 2: Strength development of blended cement made with TG1VA Pozzolana

E. Summary

(1) The results of the chemical analysis are conforming to the ASTM C 618 - 05 [1].

(2) The samples of Tagabo natural pozzolans affect the consistency and setting time of the pastes. They led to an increase in the water demand and the setting time.

(3) The strength reactivity of Tagabo natural pozzolans samples with OPC at 7 and 28 days are provided 75% and more than the control strength complying to the ASTM C 618 – 05 [7] requirements.

(4) There is a need to investigate the long term engineering properties of these mixtures such as shrinkage and durability performance.

Fig. 3: Strength development of blended cement made with TG2VA Pozzolana

Fig. 5: Strength development of blended cement made with TG3VA Pozzolana

Fig. 6: Strength development of blended cement made with TG4VA Pozzolana

4. CONCLUSIONS

The evaluations of the chemical, physical and mechanical properties of the Tagabo pozzolans or mixtures incorporating them have revealed their compliance to Class N of ASTM C 618 – 05 [7] Specifications. This means they can be safely used as supplementary for OPC in the Northern Darfur area saving energy and money.

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