CHARACTERIZATION OF JEBAL MEIDOUB VOLCANIC ASH AND PUMICE AS CEMENT REPLACING MATERIALS FOR USE IN BLENDED CEMENTS

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مستخلص

تهدف هذه الورقة إلى تقييم الخصائص البوزولانية للرماد البركاني والـ pumice التي تم الحصول عليها من جبال الميدوب في غرب السودان (دارفور) كمواد بديلة لاستخدامها في الاسمنت المخلوط . ولتحقيق درجة النعومة المطلوبة فقد تم تطوير نوعين من الطواحين المحلية بكفاءة عاليه ، أحداهما طاحونة كرات للأغراض المعملية والاخرى هي طاحونة شواكيش للإنتاج التجاري. تم جلب ثلاث عينات بوزولانا طبيعيه ، احداهما مسحوق الرماد البركاني (MVA) ، والاخرى pumice (MP) ، والثالثة تحتوي علي خليط من الرماد البركاني و الـ pumice كما وجدت في الطبيعة (MVP) وقد بحثت هذه الدراسة الخصائص الكيميائية والفيزيائية للعينات وأنشطتها البوزولانية مع الاسمنت البورتلاندي العادي (OPC) في مستويات احلال مختلفه من الاسمنت بالوزن، وهي 10 ، 20 ، 30 ، 40 ، و 50 ٪. ونتائج التحليل الكيميائي تظهر أن جميع العينات يمكن تصنيفها علي انها من الفئة N حسب المواصفة الامريكية .ASTM C618 وتبين ان مؤشرات معامل الفاعلية البوزلانية مع الأسمنت الخاصة بالعينات الثلاثة بنسبة 20 في المائة بلغت 81 ، 90 و 90 في المائة علي التوالي. تشير هذه النتائج إلى ان عينات البوزولانا من جبال الميدوب هي مواد من المحتمل استخدامها في الاسمنت المخلوط.

الكلمات المفتاحية: *الاسمنت المخلوط، جبال ميدوب –دارفور، البوزولانا، الرماد البركاني والpumice*

ABSTRACT

The aim of this paper to evaluate the pozzolanic characteristics of the volcanic ash and pumice obtained from Jebal Meidoub (Meidoub Mountains) in western Sudan (Darfur) as potential Supplementary Cementitious Materials for use in blended cement and concrete. To achieve desired fineness, two types of local mills have been developed with high efficiency, one is a ball mill for laboratory purposes and another is a grinding mill for commercial production. Three natural Pozzolanic samples have been obtained, one is volcanic ash powder (MVA), another is pumice (MP), and the third contains a mixture of volcanic ash and pumice as found in the nature (MVP). This study has investigated the chemical and physical characteristics of the samples and their pozzolanic activities with Ordinary Portland cement (OPC) at different replacement levels of cement by weight, namely 10, 20, 30, 40, and 50%. The results of the chemical analysis have shown that all samples could be classified as Class N of the ASTM C618. The strength activity indices of the three samples at 20% level were found to be 81, 90, and 90% respectively. These results indicate that the Jebal Meidoub Pozzolans are potential supplementary cementitious materials for use in blended cement.

Keywords: - *Blended cements, Jebal Meidoub -Darfur, pozzolanic reactivity, pumice, volcanic ash*

1. INTRODUCTION

There are many types of materials such as additives, fillers, admixtures, aggregates and supplementary cementitious materials (SCMs) that can be blended with Portland cements to reduce its quantities, lowering the CO_2 emissions, transportation and energy with a mix. Pozzolanic materials are defined as siliceous and aluminous material, which in itself possesses little or no cementitious value, but in finely divided form and in the presence of moisture, chemically reacts with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties ASTM C618 (2005) [1]. They are widely used as supplementary cementitious material (SCMs) for Portland cements [2]. The Natural pozzolans are those materials which do not require any further treatment apart from grinding to react with lime F. MASSAZZA-(1976) [3].

In Sudan, natural pozzolanas have been reported by Mamoun, (2004) [4] 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) [5] has investigated Jebel Marra Volcanic Ash as SCM for Use in Blended Cements.

The volcanic ash is one of the natural pozzolana found abundantly in volcanic areas in the Sudan. Using these volcanic materials can be converted to sources of local building materials in order to reduce the cost of construction and provide opportunities for sustainable development with inexpensive, environmentally friendly materials with adequate and durable resistance.

The partial replacement of cement by volcanic ash in constructions, when available, will be better in practice and lead to an economic solutions especially in place like Darfur state. This paper aims to evaluate the pozzolanic characteristics of the volcanic ash and pumice obtained from *Jebal Meidoub* (Meidoub Mountains) in the northern Darfour state, 180Km 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

2.1. Materials

2.1.1. Cement and sand

Ordinary Portland cement (OPC) from Atbara Cement Company and river sand from Wadi Nyala was washed, dried, sieved and graded from 90 µm to 1.18 mm as specified in ASTM: C 778 – 02[8] have been used in this study.

2.1.2. Volcanic ash (VA) and Pumice

Three natural Pozzolanic samples were brought from Jebal Meidoub. Sample one is a Meidoub volcanic ash powder (MVA) at coordinates (N 15º 06´ 39.9´´, E 26º 09´ 50.1´´), and sample two is a Meidoub pumice (MP) at coordinates (N 15º 79´ 9.49´´, E 26º 11´ 39.57´´), and sample three is a Meidoub mixture of volcanic ash and pumice (MVP) as found in the nature at coordinates (N 15º 06´ 34.6´´, E 26º 10´ 47.3´´). The samples were grounded, sieved and then characterized using chemical and physical analysis according to ASTM C311-02 [10].

2.1.3. Water

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

3.2 Methods

3.2.1 Grinding of the pozzolanic materials

When the fineness of the pozzolanic materials affecting the reactivity of the blended cement, to achieve desired fineness, two types of local mills have been developed with high efficiency as follows:

1- Ball mill for laboratory purposes: about one kilogram capacity, desired fineness can be achieved depending on operating time.

2- Grinding mill for commercial production: this mill uses air flow and screw conveyor to feeding materials in constant rate to the mill grinding chamber. Then the materials are classified through developed air classifier to separates the material into the fine and course fraction. After that the coarser fraction are recirculated for further grinding and conveys fine particles out to the collector or cyclone, all in one continuous operation. This mill produces fine particles with a nominal top size of 63 microns or finer, depending on the types of pozzolanic materials.

3.2.2 Preparation of control mix and blended cement mortar

The all mixes were prepared in 50mm cubes moulds (face area 25 cm^2). 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[9]. The mortar proportions of the different mixes with blended cement in this study are listed in Table (1). As specified in ASTM C 311 – 02[10] to produce the same flow of the control mixture ± 5.

The three samples types were incorporated in the mortar mixes at 10%, 20%, 30%, 40%, and 50% replacement levels, the blended mixes (OPC/ x_i) were made with the same workability (flow of the control mixture ± 5) as needed in practice. Where: x_i represent the three samples that brought from Jebal Meidoub (MVA, MP& MVP). Changes in mortar properties were investigated related to different types of Pozzolanic samples (x_i) under the study where x_i represents MVA, MP& MVP

3.2.3 Mixing and casting

The fresh mortar was mixed and 12 cubes for each mix (total of 240 cubes) were casted as required by ASTM C 109/C 109M – 02[9]. The specimens were de-molded after at least 24 hours and immersed into the curing tank until testing.

4. RESULTS AND DISCUSSION

4.1 Chemical properties

Results of the chemical analysis of MVA, MP and MVP are shown in Table (2). They show that the sum of principal oxides of Silica (SiO_2), Alumina (Al_2O_3) and Iron (Fe_2O3) are within the limits (at least 70%) of the ASTM C 618 - 05 [1]. They also conform to the specification of $SO_3 \leq 4\%$, moisture content ≤3%, and loss on ignition ≤10%.

4.2 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 ASTMC618-05[1].

4.3 Water consistency and setting time limits

The results presented in Figure (1), indicated that addition of Meidoub volcanic ash samples improve Consistency and workability of pozzolanic cement mixture. This may be due to 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) [11]. Also in Figure (2), addition of Meidoub volcanic ash retarded the initial and final setting time. This in agreement with Ramezanianpour et al [12], who reported that the setting time of cements containing various natural pozzolans are extended with level of replacement of the cement.

4.4 Compressive strength results

he compressive strength results of the MVA, MP and MVP with replacement levels of 10%, 20%, 30%, 40% and 50 % at various ages of curing time up to 90 days are presented in Figures (3), (4) and (5) respectively. Clearly it can be seen that the all samples contribute to the strength of mortars after 3 days of curing. However 20% addition of the three samples provided more than 80% of the control compressive strengths at 7 and 28 days as reported in table(3) . These percentages additions met the ASTM C 618 – 05 [1] specifications. The compressive strength of the mortars containing 10% MP and 10 - 20 % MVP 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 decrease with increase in the substitution ratio of Pozzolanic samples used.

Table 1: Mortar mixes proportions (ratio by weight)

Mix ref.	OPC	Jebel Meidoub Pozzolanic samples(x_i)	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, MVA, MP and MVP

Materials	Chemical Composition (%)								
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	LOI
OPC	19.83	5.35	2.795	65.88	1.71	2.3	0.4		2
MVA	58.80	18.10	5.305	2.103	1.843	0.009	0.491	1.404	9.3
MP	53.26	16.04	6.089	1.701	0.659	0.001	1.567	2.390	5.8
MVP	55.53	17.07	4.658	1.902	1.251	0.005	1.029	1.825	8.3

Table (3): Pozzolan Physical Properties and ASTM C 618 – 05 requirements

Test	MVA	MP	MVP	ASTM C618-05 Class N Pozzolan
Fineness (Amount retained when wet-sieved on 45 μm sieve) %	11	17	13	34 (max.)
Strength Activity Index at 7 days,%	80	92	82	75 (min.)
Strength Activity Index at 28 days,%	81	90	90	75 (min.)
Water requirement of control % (max)	112 (max.)	108 (max.)	110 (max.)	115 (max.)

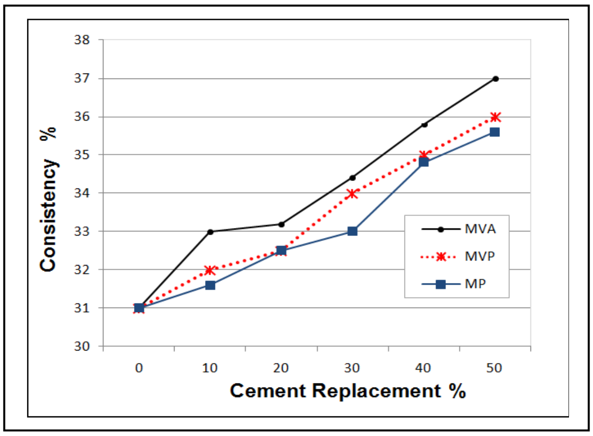

Figure 1: Effect of Meidoub pozzolans samples in the consistency of the Portland

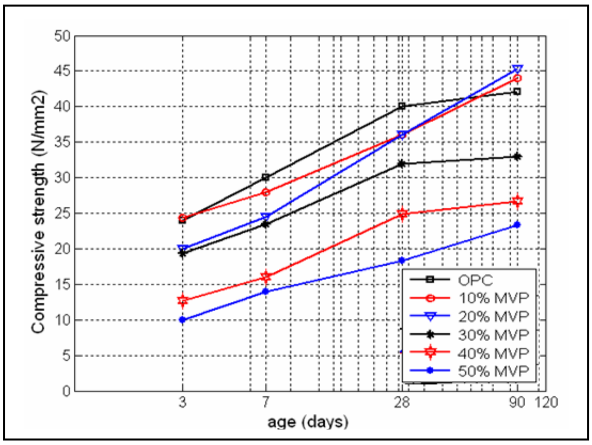

Figure 2: Strength development of blended cement made with MVP Pozzolana

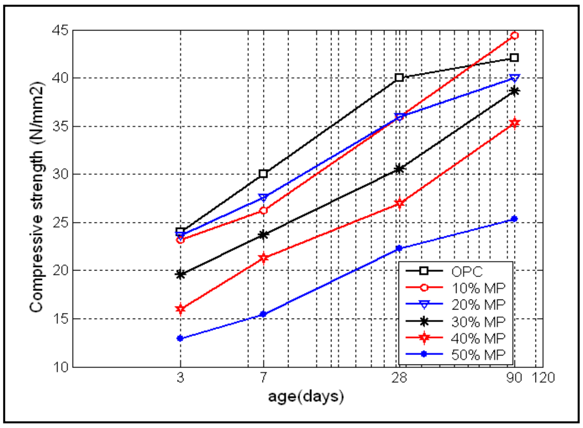

Figure 3: Strength development of blended cement made with MP Pozzolana

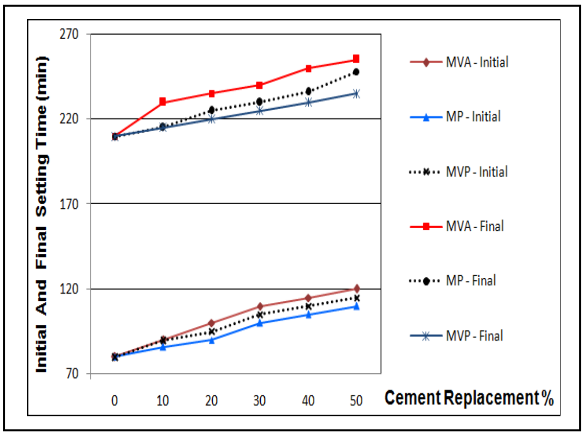

Figure 4: Effect of Meidoub pozzolans samples in the setting time of the Portland cement

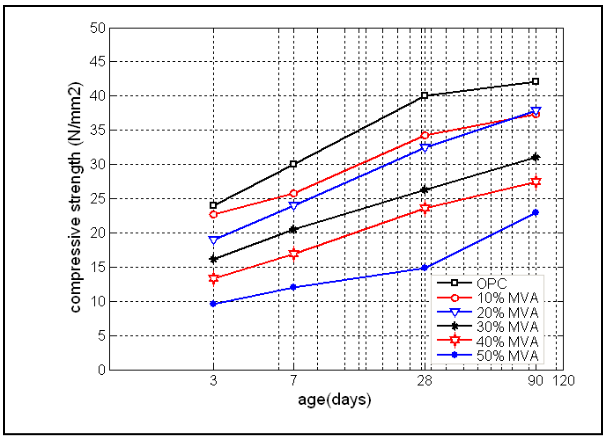

Figure 4: Strength development of blended cement made with MVA Pozzolana

4.5 Summary

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

(2) The samples of Meidoub 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 Meidoub natural pozzolans samples with OPC at 7 and 28 days are provided more than 75% of the control strength complying to the ASTM C 618 – 05 [1] requirements.

(4) There is a need to investigate the long term engineering properties of these mixtures such as creep, shrinkage and durability performance which are currently carried out in the second phase of this study.

5. CONCLUSIONS

The evaluations of the chemical, physical and mechanical properties of the Meidoub pozzolans or mixtures incorporating them have revealed their compliance to Class N of ASTM C 618 – 05 [1] Specifications. This means they can be safely used as supplementary for OPC in Darfur area saving energy and money, provided the long term properties are not proved to be adversely affecting the hardened concrete properties.

REFERENCES

[1]. ASTM C 618 - 05, Standard Specification for Fly Ash or Raw or Natural Pozzolan for Use as a Mineral Admixture in Portland cement Concrete, American Society for Testing and Materials,

[2]. LEA, F.M. (1970), the chemistry of Cement and Concrete, (3rd. Edition, Edward Arnold, London)

[3]. F. Massazza, Chemistry of pozzolanic additions and mixed cements. Il Cemento 1, 3–38(1976)

[4]. Mamoun, E.M. (2004) "Natural Pozzolanas in Sudan: characterization and factors affecting compressive strength of lime/pozzolana mortar", doctoral diss., University of Khartoum, Sudan.

[5]. Elsharif M. Ibrahiem, Salih A. M. Ahmed (2014) "Evaluation of Jebel Marra Volcanic Ash as Supplementary Cementitious Material for Use in Blended Cements". IOSR Journal of Engineering (IOSRJEN) Vol. 04, Issue 03 (March. 2014), ||V2|| PP 31-37.

[6]. A/Ellatif Eltayeb, Mohamed Salih Elhadi (2014) "The Quality of Natural Pozzolanic Materials at Bayuda desert in Northern Sudan". IOSR Journal of Engineering (IOSRJEN) Vol. 04, Issue 04 (April. 2014), ||V7|| PP 08-14

[7]. Mona. A. Gumma, Abdurahman A. Mohamed (2016) "The Effect of Jebel Marra Natural Pozzolana on the Strength and Permeability of Mortar". Imperial Journal of Interdisciplinary Research (IJIR) Vol-2, Issue 05, 2016, Page 341

[8]. ASTM C 778 – 02. "Standard Specification for Standard Sand"

[9]. ASTM C 109/C 109M – 02"Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)"

[10]. ASTM C 311– 02 "Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete"

[11]. Paul J. T. (2000)," Use of Raw or Processed Natural Pozzolanas in Concrete" ACI Committee 232

[12]. A.A. Ramezanianpour, H. Rahmani, Durability of concretes containing two natural pozzolans as supplementary cementing materials, in 7th International Congress on Concrete, 8–10 July 2008, Dundee, UK