Available online at www.sciencedirect.com
ScienceDirect
Construction and Building Materials 21 (2007) 1122–1128
Construction and Building MATERIALS
www.elsevier.com/locate/conbuildmat

The effect of fineness on the properties of the blended cements incorporating ground granulated blast furnace slag and ground basaltic pumice

Hanifi Binici *, Hüseyin Temiz, Mehmet M. Köse

K.S. University, Department of Civil Engineering, Avsar Campus, Kahramanmaras 4605-9, Turkey

Accepted 11 November 2005
Available online 19 May 2006

Abstract

In this study, the effect of the fineness on the compressive strength, sodium sulfate resistance and the heat of hydration of the both blended and plain Portland cement (PPC) were investigated. The grinding time of both clinker and additives were also studied. The result indicated that ground basaltic pumice (GBP) and clinker had lower grindability compared to ground granulated blast furnace slag (GGBFS). Blended cement had higher strength values, particularly at later ages, compared to PPC for the same Blaine values. It was observed that the finer ground blended cement specimens had higher compressive strength, sodium sulfate resistance compared to the coarser blended cement and PPC. The heat of the hydration of blended cement was lower than the heat of hydration of PPC when the fineness was held constant.

Keywords: Blended cement; Ground basaltic pumice; Granulated blast-furnace slag; Fineness

1. Introduction

Turkey, one of the leading manufacturers of cement and steel in Europe, produces around 35 Mt of cement and 13 Mt of crude steel annually [1]. However, the production of Ground Blast Furnace Slag (GBFS) was about 0.75% and 2.2% of the cement production in 1996 and 1998, respectively. Use of GBFS in cement production has been increased with the installation of new GBFS grinding mills around the country utilizing all GBFS production from three integrated steel factories.

Turkey is also rich in natural pozzolans, which are also called ''trass'' in the cement industry. Almost 155,000 km^2 of the country is covered by Tertiary and Quaternary-age volcanic rocks, among which tuffs occupy important volumes. Although there are many geological investigations on these volcanic rocks, their potential as natural pozzolans is not well established [2]. In Turkey, like in most Mediterranean countries, tuff was used with lime to have a bonding agent in historical ages. Today, the cement industry in Turkey is one of the well-established and developed industry and has a permanent interest in new supply sources of tuffs since almost one-third of the total cement production in recent years was ''trass cement'' which is a Portland-pozzolan cement [3].

Additives were defined as natural or artificial materials that could contribute to the properties of cement [4]. In blended cement production, mineral additives can be introduced to the cement by separate grinding or intergrinding. These grinding methods provide different products from many aspects. For granulated blast furnace slag incorporated cements, it was shown that separately ground and interground cements had different particle

* Corresponding author. Tel.: +90 344 219 1051/1078; fax: +90 344 219 1077/1050.
E-mail addresses: hbinici@ksu.edu.tr (H. Binici), htemiz@ksu.edu.tr (H. Temiz), mmkose@ksu.edu.tr (M.M. Köse).

0950-0618/$ - see front matter
doi:10.1016/j.conbuildmat.2005.11.005

size distributions [5]. It was also shown that intergrinding of raw materials required less amount of energy than separate grinding, especially in the production of high-fineness products [6].

The concrete materials must possess not only the good workability in fresh concrete, excellent mechanical properties and durability but also the environmental friendliness and economical benefits [7]. The additional components, trass (compact volcanic tuff), fly ash and limestone, satisfy the requirements mentioned above [8].

It is well known that the incorporation of GBFS at normal fineness reduces the early strength of concrete. Incorporating GBFS in place of 20% of clinker by weight can significantly increase the compressive strength of concrete after 3 days. Thus, the combination of fly ash and GBFS can be used as a strengthening agent of concrete [9].

In this study, the effect of the fineness on the compressive strength, sodium sulfate resistance and the heat of hydration of the both blended and plain Portland cement (PPC) were investigated. The grinding time of both clinker and additives were also studied.

2. Materials and methods

2.1. Materials

Ground basaltic pumice (GBP) was obtained from pyroclastic exposures around Osmaniye region. Ground granulated blast furnace slag (GGBFS) was obtained from Iskenderun iron and steel plant. The ground basaltic pumice has rhyolictic composition. It contains glass shards, small amount of volcanic rock and minerals such as feldispat, quartz, biotite and clay [10]. Basaltic pumice used in this study was called as Scoria. It has dark brown/blackish color, porous structure and low crystal water. Its hardness is about 5.2 in Mohs scale. The clinker was obtained from Adana Cement Plant. Chemical, mineralogical and physical characteristics of materials used were given in Table 1.

2.2. Methods

In this study, two different series of the cements samples were prepared using clinker, gypsum, GBP and GGBFS. The first series of specimens were used as control specimens and denoted by A_1, A_2 and A_3 for the Blaine values of $250 \pm 5\ m^2/kg$, $400 \pm 5\ m^2/kg$ and $550 \pm 5\ m^2/kg$, respectively. The second series of specimens were blended cements and denoted by B_1, B_2 and B_3 for the Blaine values of $250 \pm 5\ m^2/kg$, $400 \pm 5\ m^2/kg$ and $550 \pm 5\ m^2/kg$, respectively. The terminology for all specimens was given in Table 2. In the first series, specimens were prepared by clinker and gypsum that was equal to 4% of clinker replacement. In the second series, specimens were prepared by clinker and addition of gypsum, GBP and GGBFS that were equal to 4%, 20% and 20% of clinker replacements, respectively. Pozzolanic activity, grinding times, compressive strength for 3, 7, 28, 90 and 180 days, sodium sulfate resistance for 1, 2 and 3 years and the heat of hydration for 100 h of both blended and PPC cements were investigated.

Table 1
Chemical, mineralogical and physical characteristics of materials used

Specimens	Oxides (%)						
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	LOI (loss on ignition)
Clinker	20.2	5.5	3.8	64.7	1.9	0.8	–
$A_1 = A_2 = A_3$	19.4	5.5	3.9	63.4	1.8	2.0	–
GBP	51.8	22.1	7.3	6.2	8.3	–	0.4
GBFS	41.6	13.7	7.3	28.2	4.9	1.8	0.01

Specimens	Cement modulus				Bouge component			
	HM	SM	AM	LM	C_3S	C_2S	C_3A	C_4AF
Clinker	2.1	2.1	1.4	98.2	65.7	8.6	8.2	11.7
$A_1 = A_2 = A_3$	2.1	2.0	1.4	99.7	66.5	5.6	8.1	11.9

Materials	Physical properties of materials			
	Specific gravity (kg/m^3)	Blaine (m^2/g)	Sieve analysis (%)	
			Residue on 90 μm	Residue on 200 μm
GBP	2910	250, 400 and 550	0.1	0.05
GBFS	2970	250, 400 and 550	0.2	0.08
Clinker	3205	250, 400 and 550	0.2	0.08

TS 12142 Standard requirements for basaltic pumice and GGBFS

$SiO_2 + Al_2O_3 + Fe_2O_3$	SO_3	LOI
>61	<3.5	<10

HM: Hydraulic modulus $= \frac{CaO}{SiO_2+Al_2O_3+Fe_2O_3}$, SM: Silicate modulus $= \frac{SiO_2}{Al_2O_3+Fe_2O_3}$, AM: Aluminate modulus $= \frac{Al_2O_3}{Fe_2O_3}$, LM: Lime modulus $= \frac{100.CaO}{2.8SiO_2+1.1Al_2O_3+0.7Fe_2O_3}$.