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Communication

Properties of BRECEM Ten-year results

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Abstract

The compressive strengths of 0.45 and 0.56 w/c ratio concretes made from mixtures of "Ciment Fondu" calcium aluminate cement and ground granulated blast furnace slag (BRECEM) have been measured after 10 years' ageing in water at 20°C and 38°C. The compressive strengths of the BRECEM concrete increased slightly at 10 years compared to the value at five years when kept under water at 20°C. At 38°C, however, there was a slight reduction in strengths compared to the five-year values. From these results it would appear that C_2ASH_8 is likely to be a stable phase in BRECEM concretes at ambient temperatures for at least 10 years. The strength of concrete made from the 1:1 BRECEM composition and used externally is likely to show modest, if any, reduction in strength at least up to 10 years.

Keywords: Calcium aluminate cement; Ground granulated blast furnace slag (ggbs); Compression strength

A considerable amount of interest has been shown in recent years in the properties of cements made by mixing calcium aluminate cements (CAC) with different types of pozzolanic or latently hydraulic materials [1,2,3]. Concretes made using high alumina cement can lose compressive strength under warm and wet conditions due to a process known as conversion. However, concretes made using these blended high alumina cements have been found to maintain or increase in compressive strength under similar conditions. These concretes have also shown good chemical resistance and reduced temperature rise on curing.

BRECEM is the trademark granted to the Building Research Establishment describing certain mixtures of the "Ciment Fondu" type of calcium aluminate cement and ground granulated blast furnace slag (ggbs). The strength properties of concretes made using a 1:1 mixture of CAC and ggbs kept under water at 20°C and 38°C for up to five years have already been reported [1]. These results showed that the compressive strengths of BRECEM concretes increased with time throughout the test. This short communication reports the 10-year strength results for these concretes. A more comprehensive programme of work aimed at studying the long-term durability of a range of BRECEM concrete mixes in different environments was started at the Building Research Establishment nearly five years ago and some interim results from this study have been published [4,5]. Further results will be published in due course.

1. Experimental

The chemical compositions of the calcium aluminate cement (Ciment Fondu, supplied by Lafarge Special Cements, Grays, Essex, UK) and ggbs (Cemsave, supplied by the

Table 1
Chemical analyses of CAC and ggbs used in the study

Oxide (wt %)	CAC (Ciment Fondu)	ggbs (Cemsave)
CaO	39.21	40.80
Al_2O_3	38.05	13.5
Fe_2O_3	16.70	0.54
SiO_2	3.55	33.10
MgO	0.27	6.54
Na_2O	0.11	0.30
K_2O	0.02	0.51
TiO_2	1.65	0.41
P_2O_5	0.05	0.03
BaO	0.04	0.04
Mn_2O_3	0.01	0.67
SrO	0.01	0.06
Cr_2O_3	0.29	—
V_2O_5	0.16	0.02
Total S	—	1.54

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Table 2
Concrete mix proportions and wet concrete properties

	Concrete mix proportions				Fresh concrete properties		
Cement type	Thames valley aggregate (5–20mm)	Sand (<5 mm)	Cement	Total w/s ratio	Slump (mm)	VB	CF
HAC	3.6	2.4	1.0	0.45	4	11	0.77
50:50 HAC + ggbs	3.6	2.4	1.0	0.45	5	11	0.77
HAC	3.6	2.4	1.0	0.56	32	4	0.89
50:50 HAC + ggbs	3.6	2.4	1.0	0.56	65	4	0.91

Frodingham Cement Company, Scunthorpe, South Humberside, UK) used in this study are given in Table 1. 100-mm concrete cubes were made from neat CAC and the 1:1 BRECEM mixture using w/c ratios of 0.45 and 0.56. Mix proportions and the properties of the wet concretes are summarised in Table 2. The cubes were kept underwater at 20°C and 38°C for 10 years and tested for compressive strength.

The hydrated phases present in the samples were identified by x-ray diffractometry and thermogravimetric analysis. X-ray diffractometry was carried out by means of a Siemens D500 diffractometer (Siemens, Karlsruhe, Germany) using Cu kα radiation operating at 40 KV and 30 mA. Data were accumulated over one scan of 2α between 5° and 50°. Assignments of lines were made by comparisons with Joint Committee on Powder Diffraction Standards (JCPDS) files. Thermogravimetric analyses was carried out using a Du Pont 2000 instrument (DuPont, Wilmington, DE, USA).

2. Results and discussion

The compressive strength development with time for CAC and BRECEM concretes prepared using w/c ratios of 0.45 and 0.56 respectively are shown in Figs. 1 and 2. It is

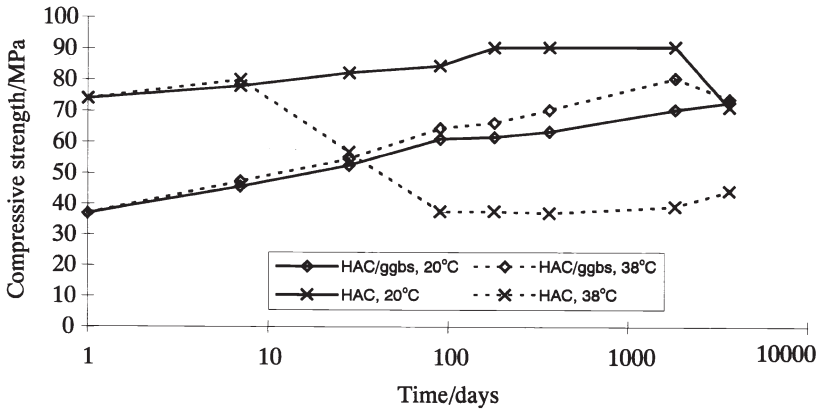

Fig. 1. Compressive strength development of 100-mm cubes made from CAC and BRECEM at 20°C and 38°C; w/c = 0.45.

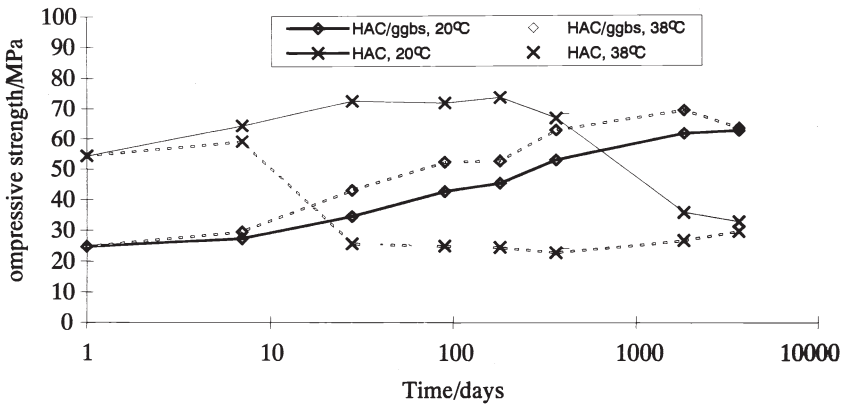

Fig. 2. Compressive strength development of 100-mm cubes made from CAC and BRECEM at 20°C and 38°C; w/c = 0.56.

Table 3
Phases detected by XRD in 10-year-old concrete samples

Material	T/°C	CAH_{10}	C_3AH_6	AH_3	C_2ASH_8	Hydrotalcite
CAC	20	+	−	−	+	+
	38	+	−	−	+	+
50:50 CAC + ggbs	20	+	+	+	−	−
	38	+	+	+	−	−

+, detected by XRD; −, not detected by XRD. Calcite and quartz (from the aggregate) were detected in all samples.

clear that the compressive strength of the BRECEM concrete increased slightly at 10 years compared to the value at five years when kept underwater at 20°C. At 38°C, however, there was a slight reduction in strength compared to the five-year values. The strength of CAC concretes stored at 20°C fell slightly between the five-year and 10-year tests but increased slightly at 38°C. It is important to note that the w/c ratios of 0.45 and 0.56 used in these tests are higher than the maximum value of 0.4 recommended for concretes made from Ciment Fondu at the present time [6].

The hydrated phases detected in the 10-year-old concrete samples by X-ray diffractometry are tabulated in Table 3. The same hydrates were present at both of the w/c ratios studied. It is seen that neat Fondu concrete samples contained C_3AH_6 and AH_3 in abundance but these phases were not detected in BRECEM samples at both 20°C and 38°C. The predominant phase in BRECEM concretes was C_2ASH_8.

Thermogravimetric analysis traces of 10-year-old BRECEM and CAC concretes are shown in Fig. 3. The traces for the BRECEM samples show peaks in the range 180–200°C and also at approximately 220°C. These peaks are due to the phase C_2ASH_8. The small peak at about 300°C in the 10-year-old BRECEM concrete kept at 38°C is probably due to the presence of a small amount C_3AH_6.

The phases present in both CAC and BRECEM concretes stored at 20°C differ from those present after five years. The metastable hydrate CAH_{10} was present in trace amounts in both concretes after five years. This phase was not detected after 10 years. In CAC concrete it had been replaced by C_3AH_6 through the conversion reaction. In the BRECEM concretes it had probably been replaced by additional C_2ASH_8 through the continuing hydration of the ggbs component.

3. Conclusions

From these results it would appear that C_2ASH_8 is likely to be a stable phase in BRECEM concretes at ambient temperatures for at least 10 years. The strength of concrete made from the 1:1 BRECEM composition and used externally is likely to show only a modest, if any reduction in strength at least up to 10 years.

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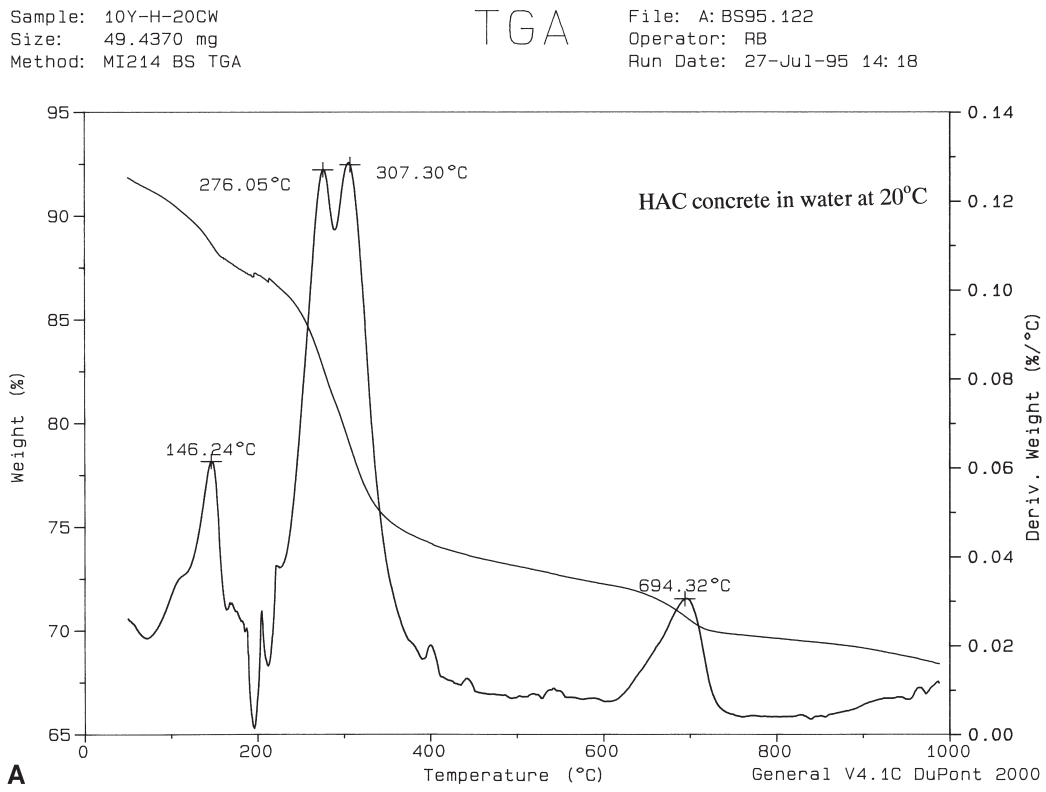


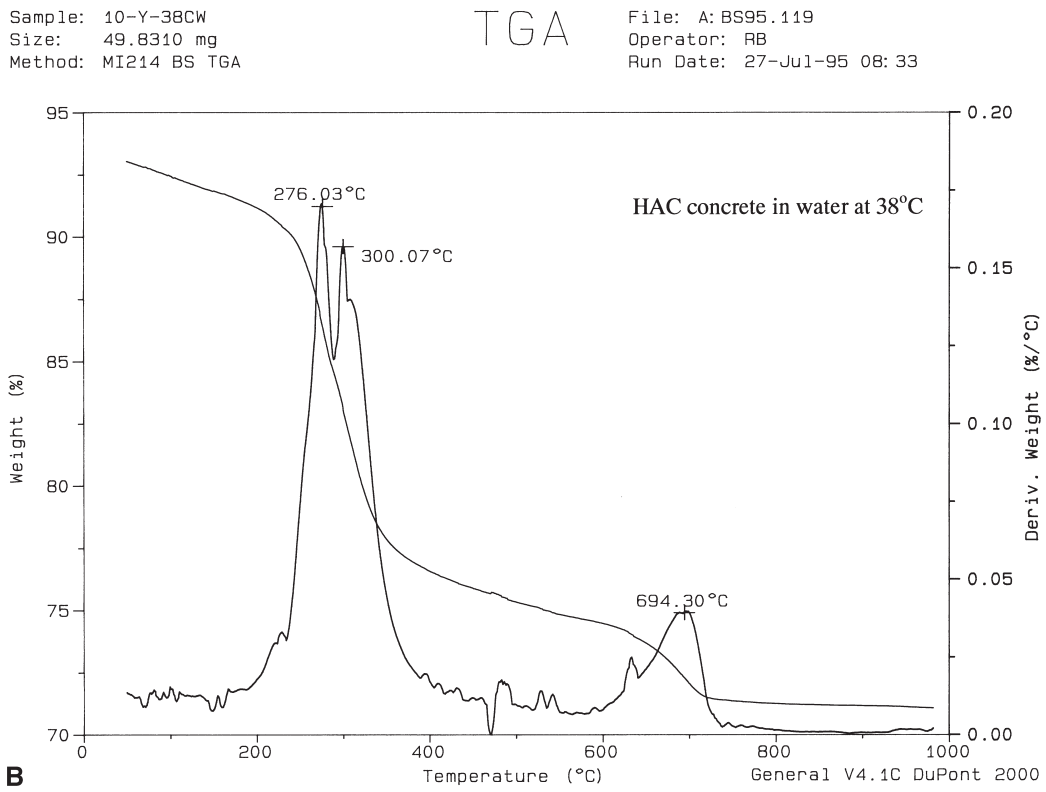
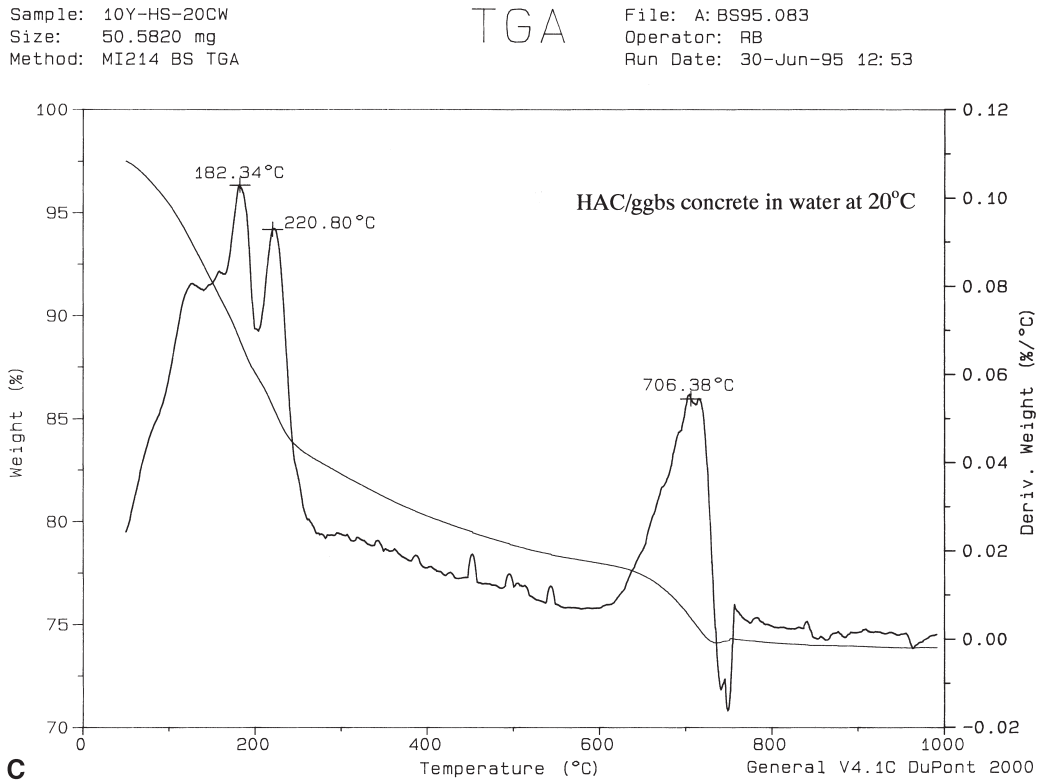


Fig. 3. TGA traces of 10-year-old concrete made with HAC alone (*A*, *B*) and 50/50 mixture of HAC and ggbs (*C*, *D*) , stored in water at 20°C and 38°C. Note: (*D*) the peak marked * is caused by problems with the apparatus and is spurious.



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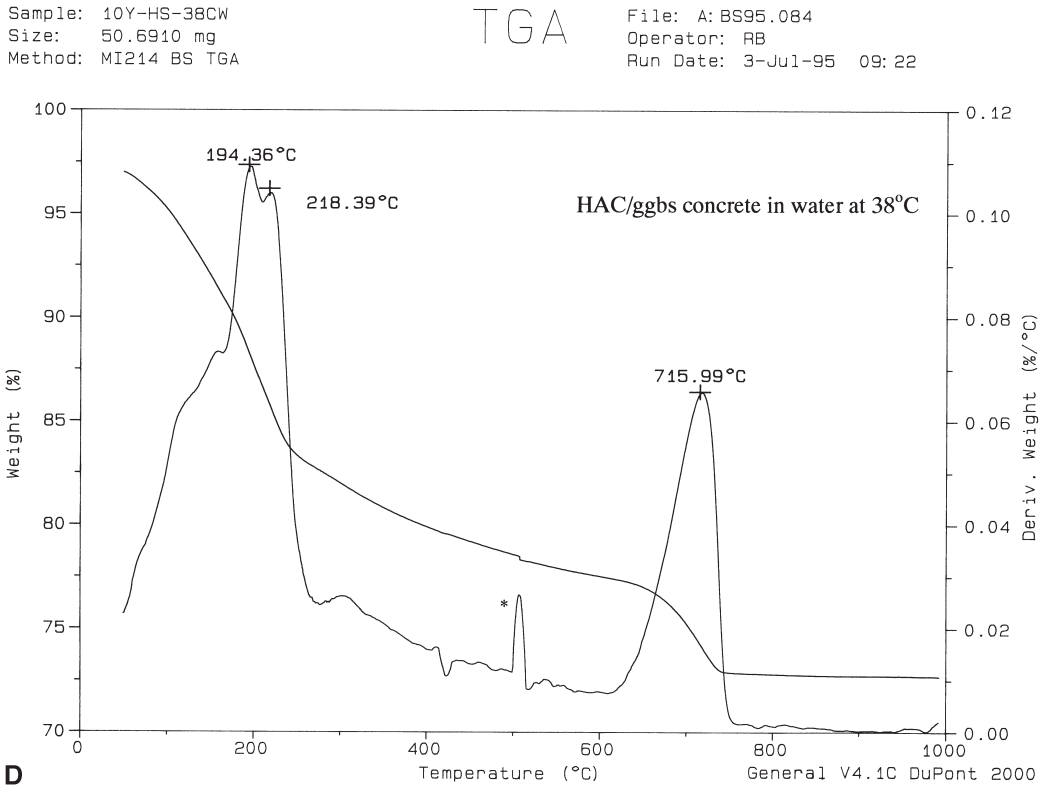

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Fig. 3. Continued.