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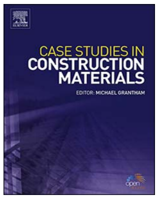

Case study

Study of heat of hydration of Portland cement used in Iraq

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A R T I C L E I N F O

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(COP-1)
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A B S T R A C T

This study aims to obtain the heat generated from cement hydration, effect of chemical properties and curing temperature on heat of hydration.

Ordinary Portland cement used from different plants, which were north (COP-1), middle (COP-2) and south (COP-3) of Iraq. Two water to cement ratios (w\c) (0.4 & 0.6) and four levels of curing temperature (25°, 30°,40° and 50 °C) were used.

The experimental results showed that the optimum heat generation from hydration of cement was from (COP-1) cement, then (COP-2) cement and finally (COP-3) cement. Also the causes of variation were discussed.

1. Introduction

When Portland cement is blended with water, heat will be generated. This heat is named the heat of hydration, and it is the product of the exothermic chemical reaction between cement and water.

Ordinary Portland cement (OPC) is hydraulic cement and composed primarily of four kinds of minerals: "alite (C_3S), belite (C_2S), aluminate (C_3A), and aluminoferrite (C_4AF)". These four fundamental compounds specify the hydraulic characteristics of the cement because they assimilate for over 90% of Portland cement [11].

Kim [7] stated that when these fundamental compounds and water are mixed together, hydration products will be produced. Calcium silicates are composed of (C_3S) and (C_2S). The two calcium silicates produce very analogous hydration reactions. Eqs. (1) and (2) depict the hydration reaction of calcium silicates. The fundamental hydration product are calcium silicate hydrate (C-S-H) and calcium hydroxide. C-S-H gel represents the role of a binder of the cement paste and ultimately has an influence on the strength and durability of concrete. C_2S and C_3S lead to produce a C-S-H gel of about 82 percent and 61 percent, sequentially. The maximum strength and durability of an elevated – C_2S cement would be greater than for one with an elevated proportion of C_3S.

$$2C_3\ S + 11\ H \rightarrow C_3S_2H_8(C-S-H) + 3CH(\text{calciumhydroxide}) \tag{1}$$

$$2C_2\ S + 9\ H \rightarrow C_3S_2H_8(C-S-H) + CH(\text{calciumhydroxide}) \tag{2}$$

C_3A (tricalcium aluminate) interacts instantly with water. The swift hydration of C_3A can be delayed by the addition of gypsum. Therefore, the last hydration products alter with the gypsum quantity. The hydration outputs of C_3A are generally created ettringite in the headmost step and monosulfoaluminate posterior (Eq. (3)). The deposition of ettringite shears in stiffening, setting, and early strength evolution. Ettringit becomes unsettled and is progressively transformed into monosulfoaluminate after the depletion of sulfate, (Eq. (4)). monosulfoaluminate can mutate back to ettringite again if a new exporter of sulfate is added. C_3A (tricalcium aluminate) participates little to the strength of cement paste [7]

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$$C_3A + 3C\bar{S}H_2 + 26H \rightarrow C_6A\bar{S}_3H_{32} \text{ (ettringite)} \quad (3)$$

$$C_3A + C_6A\bar{S}_3H_{32} + 4H \rightarrow 3C_4A\bar{S}H_{12} \text{ (monosulfoaluminate)} \quad (4)$$

The hydration of (C_3A) is identical to hydration products of tetracalcium aluminoferrite C_4AF, but the hydration reactions of C_3A are faster and include more heat.

Depending on the availability of gypsum, two possibility hydrates can be composed (Eqs. (5) and (6)).

$$C_4AF + 3C\bar{S}H_2 + 21H \rightarrow C_6(A,F)\bar{S}_3H_{32} + (F,A)H_3 \quad (5)$$

$$C_4AF + C_6(A, F)\bar{S}_3H_{32} + 7\,H \rightarrow 3C_4(A, F)\bar{S}H_{12} + (F, A)H_3 \quad (6)$$

($\bar{S}$ = SO_4, S = SiO_2, C = CaO, A = Al_2O_3, F = Fe_2O_3, H = H_2O, CH = $Ca(OH)_2$)

Cement hydration is a robustly exothermal reaction that occurs in a number of phases [10]:

I Speedy primary processes
II Dormant (recumbent) period
III Precipitation (acceleration) period
IV Delay (retardation) period
V Long-range reactions

Mehta and Monteiro [8] stated that various parameters; namely, cement composition, fineness, temperature, and w/c ratio influence the heat of hydration of cement.

2. Materials and methods

2.1. Cement

Three industrial Ordinary Portland Cement (OPC) (COP-1, COP-2, COP-3) according to (ASTM C150 Type 1 [2]) commercially available in Iraq market were tested for heat of hydration (HOH). These samples were carefully selected from three Iraqi regions and coded for this research as follow:

Code	Industrial Trade Name	Region
COP-1	Cresta	North of Iraq
COP-2	Kufa	Middle of Iraq
COP-3	Mabrouka	South of Iraq

Test results indicated that the certified cement types were stratified to Iraqi specifications [6].

Table 1
Chemical composition of cement.

Compound composition	Chemical composition	Percentage by weight			Limits of IQS 5:1984
		COP-1	*COP-2*	*COP-3*	
Lime	CaO	62	60.77	61.32	–
Silica	SiO_2	19.66	19.35	19.34	–
Alumina	Al_2O_3	5.48	5.2	4.78	–
Iron oxide	Fe_2O_3	3.72	3.6	4.68	–
Magnesia	MgO	2.87	2.95	2.65	< 5
Sulfate	SO_3	2.2	2.5	1.96	< 2.8
Free lime	Free CaO				
Loss on ignition*	L.O.I	3.55	1.15	3.89	< 4
Insoluble residue	I.R	1.39	0.2	0.52	< 1.5
Lime saturation factor	L.S.F		0.5		0.66–1.02

Main compounds (Bogue's equation) percentage by weight of cement

	COP-1	COP-2	COP-3
Tricalcium silicate (C_3S)	54.5088	53.0569	58.1884
Dicalcium silicate (C_2S)	15.32456	15.5296	11.63175
Tricalcium aluminate (C_3A)	8.2352	7.696	4.7578
Tetraclcium aluminoferrite (C_4AF)	11.3088	10.944	14.2272