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Effect of carbon dioxide on chloride penetration and chloride ion diffusion coefficient of blended Portland cement mortar

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Abstract

This paper presents a study of the effects of carbon dioxide on chloride penetration and chloride ion diffusion coefficient of blended Portland cement mortar containing ground palm oil fuel ash (POA), ground rice husk ash (RHA) and classified fly ash (fine fly ash, FA). Ordinary Portland cement (OPC) is partially replaced with pozzolan and blends of pozzolans. Mortars with constant water to cement ratio and similar flow were used for the tests. This research used accelerated testing environment with 5% CO_2. Rapid chloride penetration test (RCPT), modified rapid migration test (MRMT) and chloride penetration depth after 30 days of immersion in 3% NaCl solution of mortars were determined on the mortars with and without exposure to carbon dioxide environment. For OPC mortar, the exposure to carbon dioxide environment does not lower the chloride penetration resistance of mortar as measured by RCPT, MRMT and NaCl immersion test. However, the exposure to carbon dioxide significantly decreases the chloride penetration resistance of mortar containing pozzolans. This decrease is related to the replacement level of pozzolans.
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Keywords: Fly ash; Palm oil fuel ash; Rice husk ash; Carbonation; Chloride; Diffusion

1. Introduction

Carbonation and chloride attacks are two main factors of the corrosion of reinforcement in concrete structures. In normal circumstances when the carbon dioxide or chloride reaches the reinforced steel, the depassivation of the steel occurs and the steel reinforcement starts to corrode. It is recognized that addition of pozzolan generally improves the durability of concrete especially for sulphate resistance and chloride penetration [1–4].

Palm oil fuel ash is one promising pozzolan and is available in many parts of the world. It is a by-product obtained from a small power plant, which use the palm fiber, shells and empty fruit bunches as a fuel and burnt at 800–1000 °C. Palm oil fuel ash is receiving more attention now since its use generally improve the properties of the blended cement concrete and also reduce negative environmental impact. Research indicates that partial replacement of OPC with palm oil fuel ash of which its main chemical composition is silica helps improve permeability, chloride resistance and sulfate resistance of concrete [4–6].

Rice husk is one of the major agricultural wastes. When rice husk is burnt at temperatures lower than 700 °C, rice husk ash with cellular microstructure is produced. Rice husk ash contains high silica content in the form of non-crystalline or amorphous silica. Therefore, rice husk ash is a pozzolanic material and can be used as supplementary cementitious materials [4,7].

Fly ash is the most common pozzolan and is being used worldwide. The use of fly ash to replace part of Portland cement reduces the amount of calcium hydroxide in the cement paste. The mechanical properties of the fly ash concrete are generally improved. Although, the porosity of the paste is increased as a result of the incorporation of fly ash,

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the average pore size is reduced. This results in a less permeable paste [8,9]. The interfacial zone of the interface between aggregate and the matrix is also improved as a result of the use of fly ash [10,11].

The objective of this research is to study the effect of carbon dioxide on chloride penetration and chloride ion diffusion coefficient of blended Portland cement mortar containing ground palm oil fuel ash (POA), ground rice husk ash (RHA) and fine fly ash (FA). When CO_2 is reached through mortar or concrete, they were tested with the chloride attack; this is behavior that needs to be known. The results of the study would be beneficial for future applications of the material in increasing the durability of mortar and concrete.

2. Experimental details

2.1. Materials

Ordinary Portland cement (OPC) type I, palm oil fuel ash from a thermal power plant from the south of Thailand, local rice husk, lignite fly ash from Mae Moh power plant in the northern part of Thailand, river sand with specific gravity of 2.63 and fineness modulus of 2.82, and type-F superplasticizer (SP) were the materials used. Ground palm oil fuel ash (POA) and ground rice husk ash (RHA) were obtained using ball mill grinding until the percentage retained on sieve No. 325 was 1–3%. Fine fly ash (FA) also with 1–3% retained on sieve No. 325 was obtained from air classification of original coarse fly ash. The SEM (scanning electron microscopy) and grading analysis was used on POA, RHA, FA and OPC. For fly ash, the refinement and separation process is shown in Fig. 1.

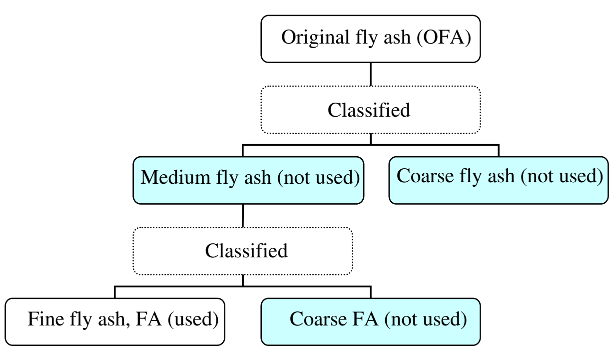

Fig. 1. Fly ash materials for program test.

2.2. Mix proportions and curing

OPC is partially replaced with 20% and 40% of single pozzolan viz., POA, RHA and FA; blend of equal portion of POA and FA (BPF); and blend of equal portion of RHA and FA (BRF). Sand-to-binder ratio of 2.75 by weight and water to binder ratio (W/B) of 0.5 were used. SP was incorporated in order to obtain mortar mixes with similar flow of 110 ± 5%. The cast specimens were covered with polyurethane sheet and damped cloth and placed in a 23 ± 2 °C chamber. They were demoulded at the age of 1 day and cured in water at 23 ± 2 °C until the test. The mortar mix proportions and compressive strength are given in Table 1.

2.3. Rapid test on resistance to chloride penetration

The cylinder samples of 100 mm diameter and 200 mm height were prepared in accordance with ASTM C39 [12]. They were demoulded at the age of 24 h. After being cured in water until the age of 27 days, they were cut into 50 mm thick slices with the 50 mm ends discarded. The 50 mm slices were epoxy-coated around the cylinder. The samples were separated into two groups namely group A and group B. The group A samples were used for the determination of rapid chloride penetration test (RCPT), modified rapid migration test (MRMT) and chloride immersion test without subjected to prior carbonation. The group B samples were subjected to accelerated carbonation for a period of 28 days and were then tested for rapid chloride penetration test (RCPT), modified rapid migration test (MRMT) and

Table 1
Mortar mix proportions and compressive strength

Mix	OPC	FA	POA	RHA	SP (%)	Compressive strength (MPa)		
						7 d	28 d	90 d
OPC	100	–	–	–	1.9	43.5	57.0	60.0
20FA	80	20	–	–	0.4	43.5	57.5	62.0
40FA	60	40	–	–	0.1	32.5	53.5	61.5
20POA	80	–	20	–	2.0	44.5	58.5	62.5
40POA	60	–	40	–	3.2	33.5	55.0	62.0
20RHA	80	–	–	20	2.2	44.5	59.5	63.5
40RHA	60	–	–	40	3.7	33.0	56.5	62.0
20BPF	80	10	10	–	0.8	43.5	57.5	63.0
40BPF	60	20	20	–	1.1	43.0	56.5	60.0
20BRF	80	10	–	10	1.1	42.0	58.0	64.0
40BRF	60	20	–	20	1.6	41.0	55.5	61.5

Note: Sand-to-binder ratio 2.75, W/B = 0.5, flow 110 ± 5%.