

การซึมผ่านของคลอไรด์ของมอร์ต้าที่ใช้มวลรวมละเอียดที่ปนเปื้อนคลอไรด์

Chloride Penetration of Mortar Containing Fine Recycled Concrete Aggregate Contaminated with Chloride Content

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บทคัดย่อ

คลอไรด์ไอออนเป็นสาเหตุหลักของการสึกกร่อนของเหล็กเสริมในโครงสร้างคอนกรีตเสริมเหล็ก โดยเฉพาะอย่างยิ่งกับสภาวะแวดล้อมที่สัมผัสกับน้ำทะเล อันเป็นสาเหตุทำให้โครงสร้างเกิดการวิบัติ การทดลองนี้ศึกษาผลของการปนเปื้อนของมวลรวมละเอียดจากคอนกรีตเก่าที่ถูกทำลายที่มีผลต่อการซึมผ่านของคลอไรด์ของมอร์ต้าโดยใช้ปูนซีเมนต์ปอร์ตแลนด์ชนิดที่ 1 มวลรวมละเอียดจากคอนกรีตเก่าที่มีการปนเปื้อนของโซเดียมคลอไรด์ โดยมีปริมาณความเข้มข้นของสารปนเปื้อน คือ 0.25, 0.5, 1 และ 3 โมลาร์ อัตราส่วนผสมแทนที่มวลรวมละเอียดจากคอนกรีตเก่าที่ถูกทำลายร้อยละ 0 และ 20 โดยน้ำหนัก เปรียบเทียบกับ มอร์ต้าควบคุมโดยใช้ทรายธรรมชาติที่ไม่มีการปนเปื้อน และอัตราส่วนระหว่างน้ำต่อปูนซีเมนต์ (w/c) เท่ากับ 0.5 และแช่ในสารละลายโซเดียมคลอไรด์ความเข้มข้น 3% เป็นเวลา 30, 90 และ 150 วัน จากการศึกษาพบว่า ปริมาณคลอไรด์ในทุกตัวอย่างมอร์ต้าลดลงเมื่อเพิ่มความลึกเฉลี่ยของตัวอย่างมอร์ต้า นอกจากนี้ เมื่อเพิ่มปริมาณความเข้มข้นของสารปนเปื้อนจะพบปริมาณคลอไรด์ที่สูงขึ้นเช่นกัน และปริมาณคลอไรด์เพิ่มขึ้นอย่างมีนัยสำคัญเมื่อแช่ตัวอย่างมอร์ต้าในสารละลายโซเดียมคลอไรด์ที่ 150 วัน

คำสำคัญ : การปนเปื้อน มวลรวมละเอียดจากคอนกรีตเก่า การซึมผ่านของคลอไรด์

Abstract

Chloride is the main cause of corrosion of concrete reinforcement steel. This could decrease the service life of reinforced concrete structures, especially those in marine environment. This study investigated the effect of contaminated recycled fine aggregate on the chloride penetration of mortar. Type I Portland cement and recycled fine aggregate contaminated by Sodium Chloride (NaCl) with the concentrations of 0.25, 0.5, 1 and 3 Molar were used. The contaminated recycled fine aggregate replacements were 0 and 20% by weight of fine aggregate, compared to the control mortar containing only natural sand. The water to cement ratio of mortar was 0.5. The specimens were immersed in 3% sodium chloride solution for 30, 90 and 150 days. The test results indicated that the chloride content of all of the specimens decreased with increasing specimens average depths. Moreover, highly contaminated fine recycled aggregate exhibited high chloride content in the mortar. Significant increase in the chloride content could also be observed when the specimens were immersed in chloride solution for 150 days.

Keyword: contaminated, recycled fine aggregate, chloride penetration

1. Introduction

Nowadays use of demolition waste as a source of old building for the production of a new concrete has become an importance issue in the construction industry. For example 3,000 million tons per years of waste are reported to produce in the European Union, about 31% of which are obtained from construction and demolition (C&D) wastes (Munck-Kampmann, 2003). Most of the C&D wastes contain concrete road material and masonry from old building (Hansen & Lauritzen, 2004).

Hendricks (1999) found that the consumptions of recycled concrete aggregate (RCA) obtained from concrete and masonry in Europe accounted for 11% and 10% respectively. These consumptions are projected to be about 15% and 14%, respectively in the years 2015. Moreover, BS 8500-2 (British Standard, 2002) suggested that quantity of

RCA could be replaced up to 30% in new concrete without an adverse effect on the quality of concrete.

However, RCA from recycling may be contaminated if the existing building has been subjected to chloride, sulfate, oil or other harmful materials. These contaminants may affect to the properties of RCA on the fresh or hardened properties of concrete. Therefore, it is important to understand the effect of contaminants on the diffusion characteristics of recycled concrete.

Most of this studies relating to the use of RCA in new concrete have been focused only on the mechanical properties of concrete containing clean RCA (Debieb, Courard, Kenai, & Degeimbre, 2010). However, concrete structures in some environment; such as in marine environment, may contact with sea water, which these demolished structures may contain many chemical contaminants, particularly chloride content. Therefore, the use of contaminated RCA

obtained from these structure for new structures may be impeded by these contamination level.

2. Objectives

The main objective was to determine the effect of sodium chloride contaminated in fine RCA on chloride penetration of mortar.

3. Materials and Method

3.1 Materials

3.1.1 Material and mixture proportioning

Ordinary Portland cement according to ASTM C150 (2007) was used throughout the study. The fine natural aggregate was river sand with the nominal maximum size of 4.75 mm as shown in Figure 1(a). Fine RCA was separated into 2 types; namely uncontaminated samples as show in Figure 1(b) and contaminated samples. The contaminated samples were obtained from fine RCA containing different levels of sodium chloride content. Contaminated fine RCA were prepared by immersing uncontaminated fine RCA in these sodium chloride solution with the concentration of 0.25, 0.5, 1, and 3 molar as shown in Figure 1(c), 1(d), 1(e) and 1(f) for 1 month. The concrete mixture was prepared using a water-cement ratio (w/c) of 0.5. Detailed mix proportions are given in Table 1

Table 1 Mixture proportions used in the study

Types of mortar	Mixing Proportions				
	Cement	Water	Fine	Fine	w/c
	(kg)	(kg)	NA	RCA	
			(kg)	(kg)	
Reference	523	262	1439	-	0.5
uncontaminated	523	262	1151	288	0.5
contaminated	523	262	1151	288	0.5



a) Natural sand



b) Uncontaminated



c) NaCl 0.25 Molar



d) NaCl 0.5 Molar



e) NaCl 1 Molar



f) NaCl 3 Molar

Figure 1 Natural sand and Fine RCA (contaminants and uncontaminants)

3.1.2 Epoxy

Epoxy was a solvent-free, moisture tolerant and thixotropic material. Two parts of epoxy, containing epoxy resins and special fillers were used. Figure 2 shows the epoxy material which has been used in the study.



Figure 2 Epoxy resin material

3.2 Specimen preparation

3.2.1 Casting and curing of mortar specimens

The concrete mixture was casted in three 5×5×5 cm cubic moulds. The cubic moulds were poured in two layers. Each layer was consolidated on a vibrating table. After casting, the specimens were covered with plastic sheet for 24 hours, demoulded and then cured in moist-cured room for 28 days.

3.2.2 Specimens preparation for surface coating

Before being coated, the specimens were stored in air-dried condition for 1 day, then coated with epoxy resin on five surfaces of mortar specimens, including as-cast, bottom, and three sides of surface as shown in Figure 3



Figure 3 Coated specimens with epoxy

3.2.3 Immersing specimens in Sodium Chloride Solution

After being coated, specimens were immersed in 3% sodium chloride solution for 30, 90 and 150 days as shown in Figure 4



Figure 4 Immersing specimens in 3% sodium chloride box

3.2.4 Cutting the Specimens

At the ages of 30, 90 and 180 days, the specimens were removed from sodium chloride solution. Epoxy coated on five sides of the specimens were removed. The specimens were marked and sliced at the depths of 1.5 and 3 cm, from the exposed surface as shown in Figure 5.

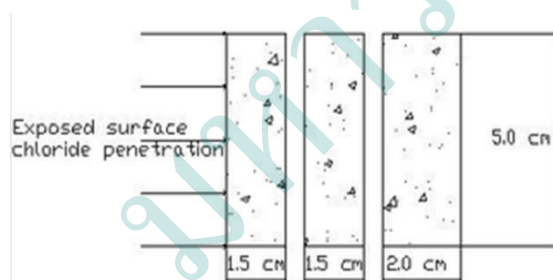


Figure 5 Specimens from cutting

3.2.5 Specimens powder collection

Slided specimens were crushed using a rotary crusher to obtain powder samples for use in the chloride analysis. Typical picture of collected powder is shown in Figure 6



Figure 6 Powder samples

3.3 Test procedures

3.3.1 Compressive strength test

Specimens were cast by mixing all mixtures and cast in 5-cm cube molds. After casting, the specimens were vibrated on vibrating table for 5 seconds then leveled with trowel and covered with plastic sheet to prevent water evaporation. After 24 hours, the specimens were demolded and cured in moist – cured room for 28 days, and then all specimens were tested by compressive strength testing machine to obtain compressive strength at age of 28 days.

3.3.2 Determination of chloride content

The collected powder were analyzed to determine the chloride content using acid-soluble extraction method conforming to ASTM C 1152 (2007b). Ten grams of powder sample were added to a 250-ml beaker and 75 ml of deionized water were followed in the beaker. The 25 ml of 65% nitric acid was then slowly added. The mixture was stirred with a glass rod. After that 3 ml of hydrogen peroxide and

then 3 drops of methyl orange were added. The beaker containing the prepared mixture was covered by a watch glass. After that the mixture containing in the beaker was heated and stirred for 1 minute and then left in the laboratory to cool for 2 minutes. The mixture was filtered into a flask using vacuum suction. Filtrate was transfer from flask to glass tube. The solution was allowed to cool. After 24 hours, 1 ml of prepared solution was added into a 100-ml beaker and followed by 2.5 ml of mercury(II) thiocyanate reagent and 0.5 ml of Iron (III) sulphate hydrate reagent. The mixed solution was stirred for 1 minute and left to stand for further 1 minute. The mixed solution was then placed in the spectrophotometer as shown in Figure 7. The light absorbance of the solution was measured, and then converted into the chloride concentration using the internal calibration for Merck standard within the spectrophotometer.



Figure 7 Spectrophotometer used for the measurement of chloride content

4. Result and Discussion

4.1 Compressive strength test of mortar

Figure 8 shows the compressive strength of mortar containing natural sand, uncontaminated fine RCA, and contaminated fine RCA. It could be seen that the 28 day compressive strength were found to be within range of 36.5 - 41.8 MPa, which could be averaged as 39.9 MPa.

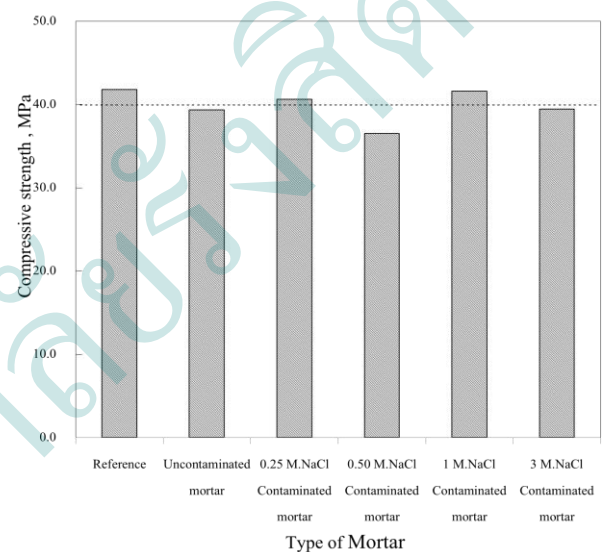


Figure 8 Compressive strength of mortar at 28 days

4.2 Chloride penetration depth

4.2.1 Effect of exposure time and contamination level on chloride penetration of mortar

The result indicated that increase concentration of contaminants resulted in increasing chloride penetration. This is apparent from the graphs of the Figures 9, 10 and 11, which the specimens were immersed in 3% sodium chloride solution for 30, 90 and 150 days, respectively. The test results were found that the chloride content of the specimens containing no fine RCA (Reference), uncontaminated

fine RCA (control), or contaminated fine RCA decreased with increasing the average depths from the exposed surface. High chloride content was found to increase with increasing contamination level. Moreover, mortar containing 3M NaCl contaminated fine RCA exhibited the highest chloride content.

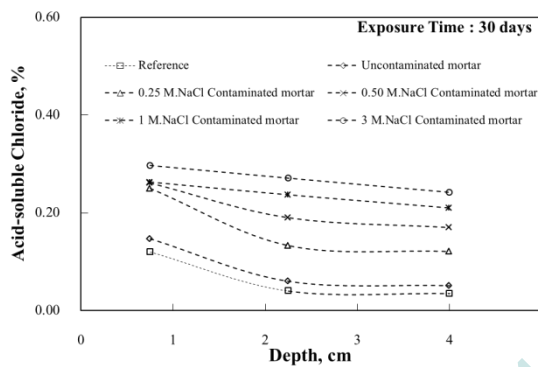


Figure 9 Chloride penetration depth of mortars immersing in sodium chloride for 30 days

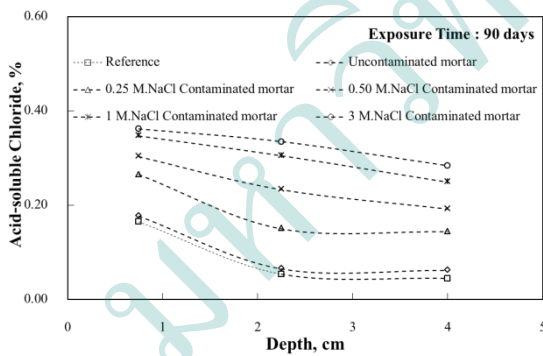


Figure 10 Chloride penetration depth of mortar immersing in sodium chloride for 90 days

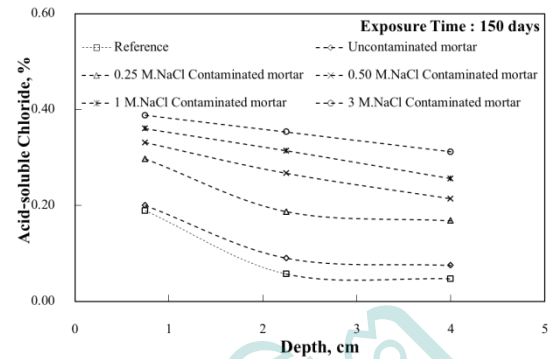


Figure 11 Chloride penetration depth of mortar immersing in sodium chloride for 150 days

5. Conclusion

- Fine RCA increased the chloride penetration depth of mortar, comparing to natural sand
- Longer immersion in 3% sodium chloride solution was prone to increase the chloride penetration of mortar, especially high contamination level of fine RCA.

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