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EFFECTS OF LEACHING ON THE PROPERTIES OF MORTAR

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ABSTRACT
Leaching of calcium and other ions from hydrates increases the porosity of cement based materials which has a negative effect on strength and durability. This study investigated the effects of leaching on the properties of mortar. Compressive strength and weight of the mortar and pH of leached water at different leaching periods were evaluated. The mortar specimens were subjected to tank leaching test where samples were exposed to demineralized water for 15, 30 and 90 days. The experimental results demonstrate that after leaching, the alkalinity of leached water increased due to the dissolution of calcium and other ions from mortar samples. Generally, for the first 30 days leaching there was no significant negative effect on the properties of mortar, rather leachant act as a curing medium. Due to the dissolution of hydration products, after 90 days leaching period, weight of the mortar specimen was decreased by 0.75% compared to without leaching sample. On the other hand, after 90 days leaching compressive strength of mortar increased by 72.60% compared to without leaching sample. In addition, after 90 days leaching period, compressive strength and weight decreased by 23.48% and 1.48% respectively compared to 30 days leached specimens.

Keywords: Leaching; dissolution; demineralized water; hydration products; mortar.

INTRODUCTION

Dissolution and alteration of cementitious materials occur due to long term contact with water. Concrete structures such as hydraulic structures, underground structures, radioactive waste containers, water purification plants, tunnels etc. when contacted with water leaching occurs. Leaching is a diffusion reaction phenomenon which takes place when cementitious materials are exposed to poorly mineralized or demineralized water (Rozière et al., 2009). The mechanism of leaching is very slow but can be a risk at longer periods (Kamali et al., 2003).

Hardened cement concrete is a porous material which contains solid hydration products such as portlandite (CH), calcium silicate hydrates (C-S-H), monosulfate (AFm), ettringite (AFt), etc. as well as pore space. Pore space is filled up with interstitial solution which is highly charged with Ca^{2+}, OH^-, Na^+, K^+, etc. (Faucon et al., 1998). Normally solid hydration products and the interstitial solutions remain in thermodynamic equilibrium condition. However, when concrete contacts with demineralized or poorly mineralized water the thermodynamic equilibrium condition does not exist. Leaching is accelerated with soft or demineralized water. Water creates concentration gradients which lead to the diffusion of ions from the highly concentrated interstitial solution to demineralized water and progressively dissolution or precipitation of the solid product occurs (Burlion et al., 2006; Faucon et al., 1998; Planel et al., 2006). The rate of attack depends on the quality and shape of the concrete, the rate at which the water percolates through or flows over it, the temperature, pH and the concentration of solutes in the water (Taylor, 1997; Kamali et al., 2003).

Porosity and transport properties of concrete increased due to leaching. Porosity of concrete has great influence on strength, toughness, durability and overall performance of concrete. Pore of the concrete leads to the cracks in concrete structures and degrade the performance. Moreover, other aggressive chemical such as chloride, sulphate, magnesium, etc. can penetrate into the concrete structure during the leaching process (Moranville et al., 2004). Chemical properties of pore water, such as pH, Eh (oxidation potential) and element concentration are also affected due to the process of leaching (Carde and Francois, 1999; Haga et al., 2005). Therefore, deterioration due to leaching causes severe damages on concrete structures such as cracking, delamination, spalling or even fracture (Weiting et al., 2011).

METHODOLOGY

Materials

Ordinary Portland Cement (OPC) was used as the binding material in this study. The specific gravity and specific surface area of cement were 3.15 and 3600 cm^2/gm, respectively. Natural silica sand was used as a fine aggregate. The physical properties of the sand are shown in Table 1.

Table 1: Physical properties of fine aggregate

Property	Sand
Bulk specific gravity (OD basis)	2.60
Absorption capacity (%)	2.48
Fineness modulus (FM)	2.7

Mix Proportions and test methods

The sand to cement ratio of the mortars was 2.75. The water to cement ratio was kept constant at 0.55. The mortar mixture was prepared on a water tight platform. First, the fine aggregates and cement were dry mixed thoroughly. Then the required amount of water was added carefully so that no water was lost during mixing. The fresh mortar was then put into the 50 mm sides cube moulds and compacted using the standard temping method. The specimens were allowed to remain in the mould for the first 24 hours at ambient condition. After that these were demoulded with care so that no edges were broken and were placed in the curing tank at the ambient temperature for curing of 28 days until the leaching process began.

Tank leaching test was conducted in order to evaluate the effect of leaching on mortar. To conduct the tank leaching test, after 28 days curing period, hardened mortar was exposed to demineralized water in accordance with NEN 7345 (1995) standard. To prepare the leachant, 5 ml of the demineralized water was used per 100 mm^2 of the surface area of the specimen. The properties of leachant and leached mortar specimen were evaluated at 15, 30 and 90 days leaching periods.

pH of leached water was recorded at different leaching periods. Compressive strength tests were performed following the ASTM C109/C109M (2016) standard. First compressive strength tests were conducted after 28 days curing of sample in normal water before leaching process. After that the compressive strength of mortar was determined at 15, 30 and 90 days leaching periods. Three specimens were tested at each leaching period and an average value of the compressive strength is reported. In addition, the weight of the mortar specimen was accumulated at 0, 15, 30 and 90 days leaching periods in order to evaluate the change of weight after different leaching periods.

RESULTS AND DISCUSSION

pH variations of leached water

Fig. 1 shows the variation of pH of leached water at different leaching periods. From the Fig. 1 it is observed that the pH of the pure water was 6.6 and pH of the leached water varies from 6.9 to 9.2 which suggests the alkalinity of leached water. Alkalinity of leached water increased compared to pure water due to the dissolutions of ions such as Ca^{2+}, Na^{+}, K^{+}, OH^{-}, etc. from the mortar specimen. It is also seen that pH variation is not so high for the different leaching period because pH also depends on many factors such as temperature, CO_2 in the surrounding environment, etc.

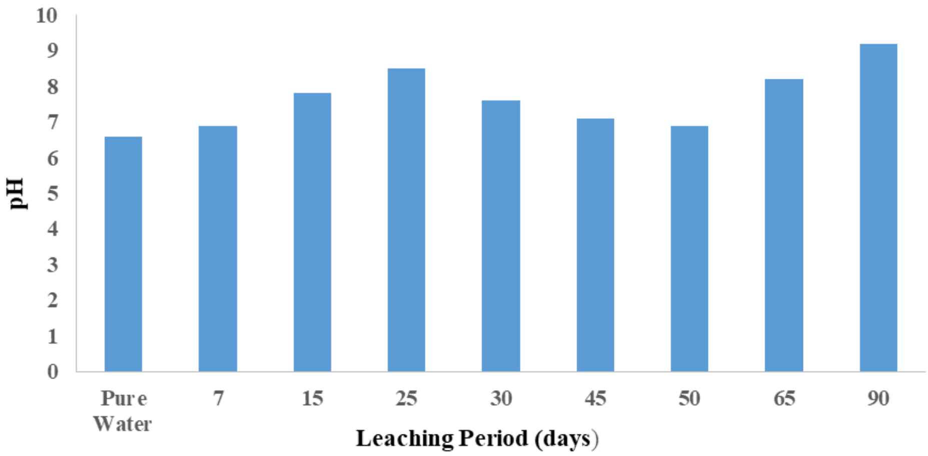

Fig. 1: pH of leached water at different leaching periods

Compressive strength variations

Fig. 2 illustrates the change of the compressive strength of mortar at different leaching periods. It is noticed that after 28 days curing period (0 days leaching period), the compressive strength of mortar was 21.9 MPa. The compressive strength of mortars were 27.9, 49.4, 37.8 MPa for 15, 30 and 90 days leaching periods, respectively. After 15 and 30 days leaching, the compressive strength of mortar specimens was increased by 27.39% and 125.67%, respectively compared to without leaching sample. This result suggests that up to 30 days leaching, there was a formation of solid products which might come from further curing and leads to increase compressive strength. In contrary, after 90 days leaching, the compressive strength was decreased by 23.48% compared to 30 days leaching specimens. This result indicates that dissolution of hydration products was happened due to 90 days leaching and consequently compressive strength was decreased.

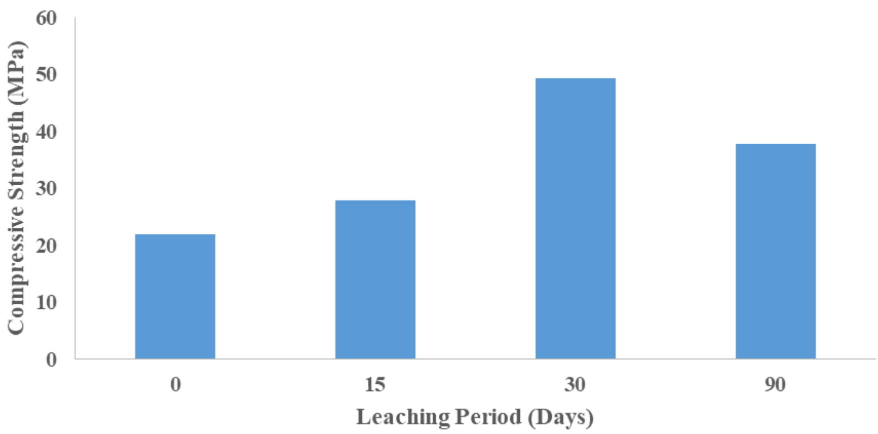

Fig. 2: Compressive strength of mortar at different leaching periods

Weight variations

The weight variations of the mortar specimen due to leaching are shown in Fig. 3. The weight of the specimen were 268, 268, 270 and 266 gm for 0, 15, 30 and 90 days leaching periods, respectively. It can be seen that after 15 days leaching, weight of mortar specimen is same as without leaching sample. However, after 30 days leaching the weight of mortar increased by 0.75% compared to without leaching sample. This result also indicates that there was a formation of solid products for up to 30 days leaching period, which might come from further curing and leads to increase the weight of mortar. On the other hand, after 90 days leaching the weight of mortar decreased by 0.75% and 1.48% compared to without leaching and 30 days leaching specimens, respectively. This result suggests that dissolution of hydration products due to leaching leads to decrease the weight of mortar.

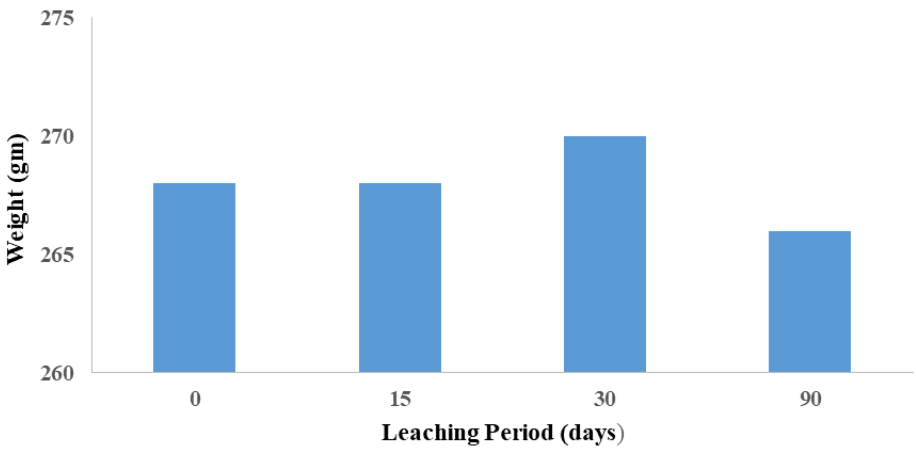

Fig. 3: Weight of mortar at different leaching periods

CONCLUSIONS

In this study the effect of leaching on mortar specimens was investigated. Leaching was conducted using tank leaching test. Based on the experimental analysis of this study, the following conclusions could be drawn:

- Alkalinity of leached water increased due to the dissolution of ions such as Ca^{2+}, Na^{+}, K^{+}, and OH^{-} etc. from the mortar specimen.
- After 15 and 30 days leaching the compressive strength of mortar was increased by 27.39% and 125.67%, respectively compared to without leaching sample. In contrary, after 90 days leaching, the compressive strength was decreased by 23.48% compared to 30 days leaching specimens.
- After 30 days leaching the weight of mortar increased by 0.75% compared to without leaching sample. On the other hand, after 90 days leaching the weight of mortar decreased by 0.75% and 1.48% compared to without leaching and 30 days leaching specimens, respectively.
- In general, for the first 30 days leaching there was no significant negative effect on the properties of mortar, rather leachant act as a curing medium. However, after 90 days leaching period, performance of mortar gradually deteriorated.

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