Correlating chloride migration, diffusion and resistivity of limestone calcined clay mortar based on low grade clay

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Abstract. Recent years, a potential blended cement - which is a combination of calcined clay and limestone has been promoted as a promising choice among conventional SCMs. However, high grade kaolin clays are not easily available everywhere or they have a more favourable application. One of the possibilities to consider is using low grade kaolin clays, more easily available in sufficient quantities for cement industry. This paper discusses the durability performance of cementitious systems based on low kaolin clays collected in South-East region of Europe. Chloride penetration resistance was evaluated by chloride migration test (NT BUILD 492) and chloride diffusion test (NT BUILD 443) along with the surface resistivity using Wenner probe method. Thereafter, chloride transport coefficients from both tests were correlated with their corresponding surface resistivity. Chloride diffusion coefficients of limestone-calcined clay systems were found to be lower than chloride migration coefficients, and migration coefficients were strongly influenced by the electrical resistivity of the system.

Keywords: Calcined clay cement, Chloride migration coefficients, Chloride diffusion coefficients, Surface resistivity

1 Introduction

Limestone-calcined clay cement (LC3) has been identified as a promising blended cement in the modern era. However, the scarcity of high-kaolin clay continues to be a barrier to widespread LC3 use. It is therefore that more studies focus on low-kaolin clay with a high level of replacement and their potential application in concrete [1][2]. The aim of this study was to discuss different chloride penetration parameters of concrete based on low-kaolin clay and limestone, both collected in southern Europe. Among analysed parameters are chloride migration, chloride diffusion and electrical resistivity, as well as their correlation.

2 Materials and method

Reference mixes were labelled as C1, C2, and C3, which were prepared with CEM I, CEM II (B-LL) 42.5 N, and CEM III/B 32.5N. The blended mixtures were made by replacing 30% of CEM I with calcined clays (mixes labelled CC1_30 and CC2_30) and 45% with calcined clay-limestone combinations with 30% calcined clay and 15% limestone (mixes labelled LCC1_45 and LCC2_45). There were two clays, *i.e.*, CC1 and CC2, which had 18% and 14%. The mix design and preparation were based on EN 196-1. All mixtures were tested for chloride penetration resistance according to NT BUILD 492 and 443, after 28 and 90 days of curing. Surface resistivity of mixes was evaluated after 28 and 90 days using Wenner probe.

3 Results and discussion:

Fig 1a-c illustrates the results of chloride migration and diffusion coefficients and surface resistivity after specified curing duration. C3 had the lowest chloride transport coefficient. Ternary blends, especially LCC2_45, have high chloride resistance. Additionally, the amount of kaolinite in the clay influenced chloride ingress [3].

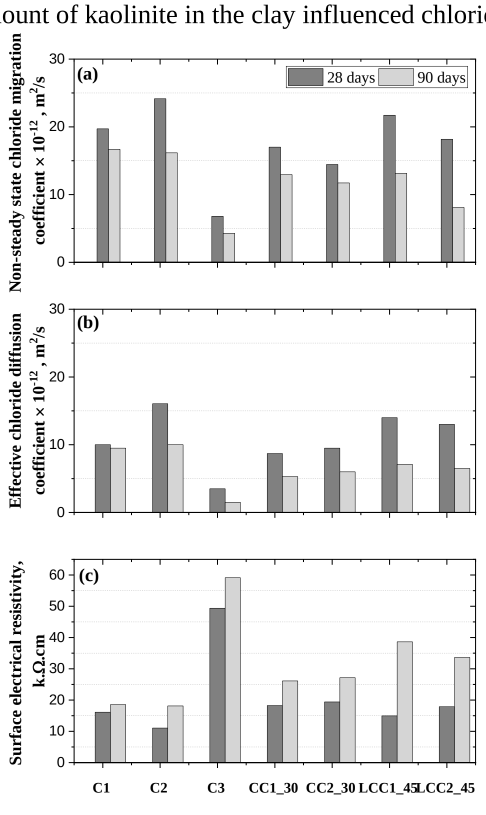

Fig 1. a) Non-steady state chloride migration coefficients, b) Effective chloride diffusion coefficients, and c) Surface electrical resistivity of all mixtures

Furthermore, the additional improvement in chloride migration coefficient was obtained with the presence of limestone powder in the system with kaolin clay [4]. Correlation between migration coefficients and diffusion coefficients are shown in the Fig. 2a. Chloride migration coefficient exhibits around 1.69 times higher values of chloride transport compared to the chloride diffusion coefficient. In the case of diffusion of chloride ions, the binding capacity is considered as an influential factor - especially for alternative binders with alumina [5]. Correlation between surface resistivity and two chloride transport coefficients is shown in Fig. 2b. Migration coefficients correlate better with surface resistivity than diffusion coefficients, which proved that the migration is highly influenced by the electrical resistivity of the system and over-estimates the real-time chloride penetration rate. Also, the interconnectivity of pores is a major factor in both migration and surface resistivity, which may explain good correlation between these two parameters [6].

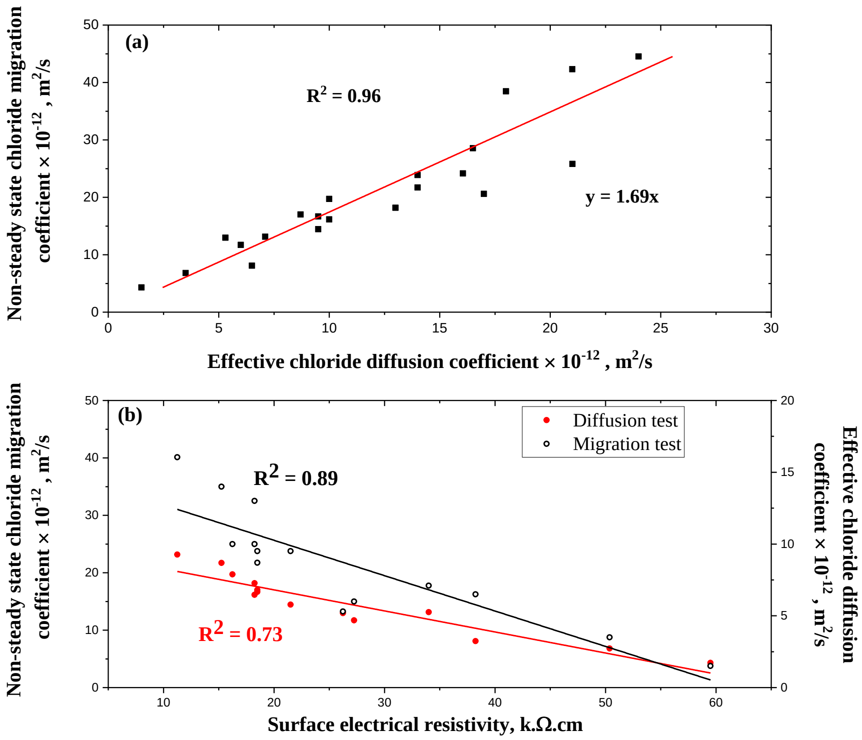

Fig. 2. Correlation between a) migration vs diffusion coefficients, b) chloride transport coefficients vs surface electrical resistivity

4 Conclusion

Based on the experimental study, following conclusions can be drawn:

- Combination of binder with low kaolin clay and limestone can be used to prepare mortar with better resistance against chloride penetration compared to mortar with CEM I and CEM II.
- Surface resistivity values correlate with chloride migration coefficients stronger than with diffusion coefficients.
- Chloride migration coefficients are 1.69 times higher than chloride diffusion coefficients, which highlights the importance of chloride binding effect in systems based on limestone-calcined clay.

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