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Influence of Sulphate on the Moisture Movement of Calcium Silicate Brick Masonry Wall

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Abstract This paper presents the behaviour of moisture movement of calcium silicate brick masonry walls exposed to sodium sulphate environment. The walls were exposed to three sodium sulphate conditions with sulphate concentrations of5%, 10% and 15%. For comparison, some walls were also exposed to dry and wet condition which acts as a control conditions. All specimens were prepared and cured under polythene sheet for 14 days in a controlled environmental room and maintained at relative humidity and temperature of 80 ± 5% and 25 ± 2ºC, respectively. After the curing period, the specimens were exposed to sodium sulphate as well as drying and water exposures, during which moisture movement was measured and monitored for a period of up to 7 months. As a result, the moisture expansion was observed and recorded for all masonry wall specimens after exposed to the sulphate condition.

Keywords: Moisture expansion, sodium sulphate, calcium silicate brick, brickwork

Introduction

The purpose of this study is to discuss the moisture movement of calcium silicate brick masonry wall under sodium sulphate condition. Calcium silicate bricks was considered as one of the advanced building material which manufactured by mixing silica sand, lime and water. In contrast to fired clay bricks, the strength of calcium silicate bricks is lower and also shrinks with time. Calcium silicate brick also has the same properties as a concrete. Although they have high reputation in durability, calcium silicate bricks still not popular in Malaysia and the demands are lower than fired clay bricks. Furthermore, the performance of calcium silicate brickwork in sodium sulphate environment is important for use them in Malaysia. By means of a experimental study, it is found that although calcium silicate bricks are durable in sodium sulphate solutions, for the brickwork, the deterioration still occurs which influenced by the expansion and deterioration of the mortar joints. It is in agreement with Zsembery (2001) indicated that soluble salt which transport by the moisture from natural condition or environment could be causes the problem to the masonry walls especially in sub-tropical and tropical climates.

Rijniers et al. (2005) agreed that the cause of decay and deterioration are due to the influence of the existence and movement of water and damaging salt. Damaging salt that most frequent and destructive for masonry material are sulphate attack (Binda and Molina 1990). Moisture movement and soluble salt can give rise to the deterioration of porous building materials. The damage that may occur due to salt crystallization is strongly influenced by both pore structure and strength properties. Pore structure has a great influence on salt crystallization, including nucleation and precipitation, capillary rise of solutions, evaporation of water and the effects of the wetting and drying cycles (Benavente et al. 2006). The presence of sulphate attack also could affect the expansion of mortar chemically which later could be induces a cracking in mortar joint due to salt crystallization pressure. DeVekey (2008) explained that sometimes small horizontal cracks are visible in the centre of the wall because typically the mortar is affected more within the body of the wall than on the surface. The cracking in mortar joint could result the damaging of masonry wall due to the deterioration of brick-mortar bond. Therefore any deterioration or deformation occurs in brick unit or mortar, will affect the overall performance of masonry wall.

Material and Experimental Procedure

Masonry Material The calcium silicate brick was supplied by Bata Mas Sdn Bhd, Ipoh, Malaysia. The properties of calcium silicate brick unit were tested using unbonded specimens. The properties of masonry unit which have been determined are compressive strength, water absorption and initial rate of suction. The compressive strength of calcium silicate brick used is 16 MPa with water absorption of 17.1% for 24 hours immersion. Meanwhile the initial rate of suction is about 1.80 kg/m^2/min.

The walls were constructed using 1: 1: 6 (Ordinary Portland cement: hydrated lime: sand) design mortars. This mix design of mortar used in order to produces a well filled mortar but with the extra adhesion and flexibility given by lime, balance by the strength of cement. This proportion also can be considerable benefit to the durability of the final brickwork. The range of water cement ratio of mortar mix is 1.70 to 1.74.

The experimental work involves in measuring shrinkage or expansion of calcium silicate brick and masonry single leaf wall. Six single leaf masonry walls with 1.5 brick wide x 5 course high were constructed. After casting, the masonry wall specimens were immediately covered with polythene sheet for 14 days in controlled environmental room with temperature of 25 ± 2 °C and relative humidity of 80 ± 5 %. This environment condition selected according to average condition in Malaysia. Then, the all specimens were exposed to the sodium sulphate solution with concentration of 5%, 10% and 15% (by weight volume) using a spray method which carried out every 24 hours. The moisture movement readings then were taken at 0, 14, 28, 56, 90, 120, 150, 180 and 210 days. At the same time the moisture movement of unbonded brick and mortar prism were also recorded.

Result and Discussion

Moisture Movement Three 300 x 75 x75 mm partly sealed mortar prisms were prepared for each batch of mortar. Fig. 1 and Fig. 2 show the shrinkage and expansion of the partly sealed mortar prism for calcium silicate brickwork. According to Beard et al. (1969), mortar could expand when increase in moisture due to the effect by the change in moisture content. The expansion could be occurring due to the chemical reaction in the mortar as well. These expansions occur when excessive hydrated aluminate phases present in the cement react with the sulphate ions in the presence of calcium hydroxide (Al-Dulaijan et al. 2003).

The results also clearly indicated that the sodium sulphate was causes a significant expansion on the mortar (see Fig. 2). This expansion induces the development of cracking in the mortar prism. The rates of expansion of the samples after being exposed to sulphate solution was quickly occur after certain period and depend on the concentration of sulphate solution. The maximum shrinkage of the control specimens at 210 days are 988 and 809 microstrain for dry control and water condition. However, the effect is very obvious appear after exposed to sodium sulphate whereby the specimens expand significantly. The maximum expansion of mortar prism under 5% sulphate solutions was about -19389 microstrain at age 180 days. However for 10% and 15% concentration the mortar prism was deteriorated and crumbled, hence no data could be recorded after 150 and 90 days. The maximum magnitude for 10% and 15% solution at this period are -33963 and -12982 microstrain respectively. After this period the mortars become soft and brittle cause by the crystallization pressure developed by sulphate attack.

The movement of masonry units used in the wall was determined by testing partly sealed unbonded specimens. The movement is related with the amount of moisture absorbed. The calcium silicate exhibits shrinkage when exposed to moisture and expansion when dry as shown is Fig. 3. As in water or wet condition, the figure shows that the calcium silcate brick absolutely shrink after exposed to sulphate environment. The average shrinkage of the calcium silicate brick unit over 210 days under sulphate exposure is in range between 600 and 800 microstrain. Fig. 3 also shows that the shrinkage of calcium silicate brick unit exposed to 15% sulphate concentration has the highest magnitude compared with 5% and 10% sulphate concentration. The shrinkage of calcium silicate brick occur due to the adsorption of moisture and no significant effect of chemical reaction due to sulphate attack.

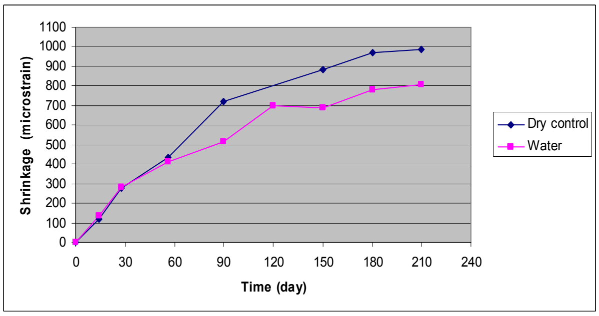

Figure 1: Shrinkage of mortar under control condition

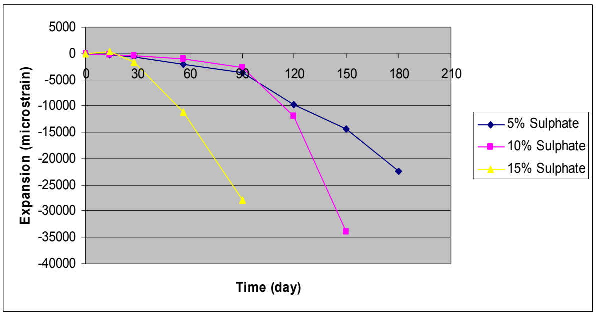

Figure 2: Expansion of mortar prism under sodium sulphate condition

The movements of brickwork normally depend on the movement characteristics of mortar or brick unit or both. The movement-time curves for the entire tests wall are presented in Fig. 4 for control condition and Fig. 5 for sodium sulphate condition. Fig. 4 shows that the all calcium silicate brickworks shrink in control condition.

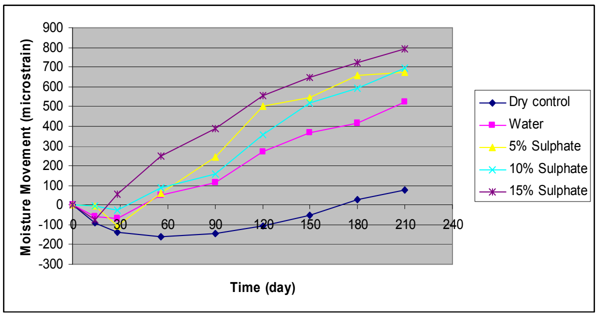

Figure 3: Moisture movement of calcium silicate brick unit

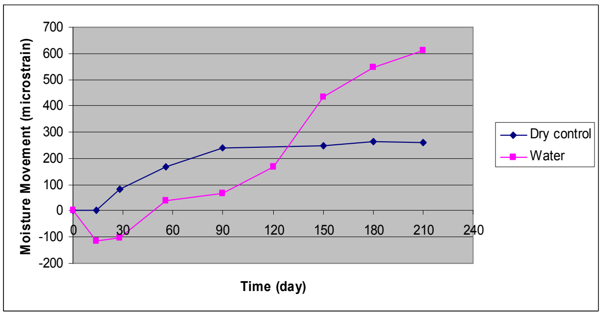

Figure 4: Moisture movement of calcium silicate masonry wall under control condition

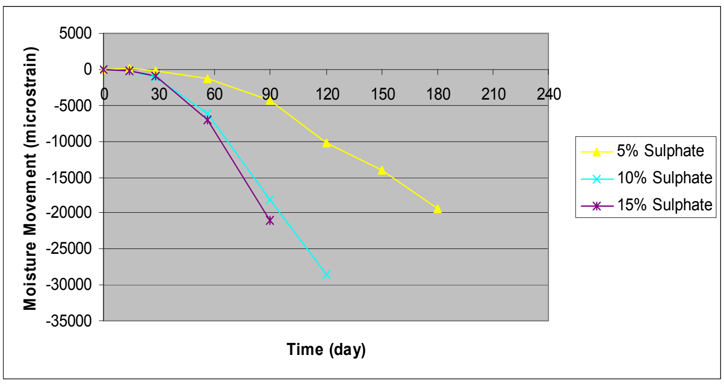

Figure 5: Moisture expansion of calcium silicate masonry wall under sodium sulphate condition

Contradict, the brickwork experienced significant expansion after being exposed to sodium sulphate where the expansion of the brickwork increases with the increase of sodium sulphate concentration (see Fig. 5). Fig. 5 also shows that the overall brickwork exposed to sulphate condition sharply expand after 56 days.The expansion of brickwork occurs totally due to the expansion of the mortar. The life time of the brickwork also short when sulphate concentration increase. The life time of the brickwork for 5%, 10% and 15% sulphate exposure are 180, 150 and 90 days. The maximum magnitude at this period are -19389, -33963 and -12982 microstrain for 5%, 10% and 15% sulphate solution. After this period also, the local disruption of mortar beds occurs where the binder properties in the mortar was loss and very weak. Veniele et al. (2003) also report the same finding whereas the resulting expansion of the mortar due to sulphate attack causes both local disruption of mortar beds and induces stresses in the brickwork.

Conclusion

The resistance and durability of both brickwork materials which is brick unit and mortar in an aggressive environment is one of the important things that should be considered in order to produce durable masonry wall structures. This is because, from the finding, although calcium silicate bricks are durable in sodium sulphate solutions, for the brickwork, the deterioration still occurs which influenced by the expansion and deterioration of the mortar joints. This problem due to the crystallization pressure that control by chemical nature of crystallizing salt. The finding also shows that the rates of deterioration and life time of calcium silicate brickwork depending on the concentration of sulphate solution where increasing in the sulphate concentration, the rate of deterioration rise and the life time becomes short. This deterioration could verify that the sodium sulphate exposure could cause very damaging effects on the calcium silicate brickwork but not to the calcium silicate brick units.

References

[1] Al Dulaijan, S U, Maslehuddin, M, Al Zahrani, M M, Sharif, A M, Shameem, M, and Ibrahim, M (2003). “Sulfate resistance of plain and blended cements exposed to varying concentration of sodium sulphate.” *Journal of Cement and Concrete Composite,* 25, 429 -437.

[2] Beard, R, Dinnie, A, and Richards, R (1969). “Movement of brickwork: Experimental unrestrained walls of Fletton bricks.” *Trans.* 68(73), 73-90.

[3] Benavente, D, Linares-Fernandez, L, Cultrone, G, and Sebastian, E (2006). “Influence of microstructure on the resistance to salt crystallization damage in brick.” *Journal of Materials and Structures,* 39, 105–113.

[4] Binda, L, and Molina (1990). “Building material durability: Semi Markov approach.” *Journal of Material in Civil Engineering*, 2(4), 223-239.

[5] DeVekey, R C (2008). “Brickwork and blockwork.” *Construction Materials; Their Nature and Behaviour*, Third edition, Spone Press, New York.

[6] Rijiniers, L A, Pel, L, Huinink, H P, and Kopinga, K (2005). “Salt crystallization as damage mechanism in porous building materials – A nuclear magnetic resonance study.” *Journal of Magnetic Resonance Imaging*, 23, 273-276.

[7] Veniele, F, Setti, M, Navarro, C R, Lodola, S, Palestra, W, and Busetto, A (2003). “Thaumasite as decay product of cement mortar in brick masonry of a church Near Venice.” *Journal of Cement and Concrete Composite,* 25, 1123-1129.

[8] Zsembery, S (2001). “Manual 2: The properties of clay masonry units.” *Clay Brick and Paver Institute (CBPI),* Australia.