Elasticity and Moisture Movement of Calcium Silicate Brick under Sulphate Environment

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Abstract

The influence of sodium sulphate (Na_2SO_4) on the elasticity and mositure movement of calcium silicate brick has been investigated. The samples of calcium silicate brick units were exposed to three different concentration of sodium sulphate i.e. 5%, 10% and 15%. For comparative purpose, several other calcium silicate brick units were exposed to dry and water exposures as control specimens. All specimens were prepared and cured under polyethene sheet for 14 days in controlled environment room maintained at relative humidity and temperature of 80 ± 5% and 25 ± 2ºC respectively. The modulus of elasticity of the samples were tested at the age of 28, 56 and 180 days, meanwhile, the moisture movement was measured and monitored for a period of up to 7 months. As a results, with the increases of sodium sulphate concentration the elasticity of calcium silicate bricks reduce and shrinkage were recorded.

Keywords: elasticity, moisture movement, sodium sulphate, calcium silicate brick,

1. Introduction

Calcium silicate bricks are considered advanced building materials manufactured by mixing silica sand, lime and water. In contrast to that of fired clay brick, the strength and elasticity of calcium silicate brick is lower and its size also shrink with time. Its dimensional control is better than that of fired clay brick.

Durability properties are very important and need to be considered and evaluated for the proper building material selection. Durability is affected when the brick bodies are exposed to aggressive environments such as one containing sulphate. Binda and Molina [1] reported that the microstructure, mechanical strength and deformability, types of salt and exposure frequency as well as duration of wetting drying cycles could influenced the durability of masonry material to salt decay. Sodium sulphate is the most problematic salt as it can cause damage to brickwork materials [2].

Sulphate attack is very damaging salts and provides more extreme condition which could be causes a deterioration or decay on the performance of masonry walls. Any masonry buildings located close to the sea has a high risk of undergoing deterioration. This is agreed by Ahmad and Abdul Rahman [3] who reported the restoration of defects of the Penang Municipal Council (MPPP) building in Malaysia which is located about 50 meters away from the sea. From the ground floor wall testing, it was found that all inspected walls had high levels of salt contamination which was exceeded the safe level of 0.020% with the highest level recorded at 6.27%. These problems were considered as serious and could affect the strength of the existing load bearing capacity of the walls. Van Hees and Brocken [4] also agreed that the sodium sulphate provide more severe condition where in sodium sulphate, brick masonry showed quite intensive spalling and scalling of bricks and push out the mortar joints.

Due to the all criterion discussed the sulphate attack problems should be considered as a serious case because this situation clearly could cause damage or deterioration of building material when the brickwork material exposed to the surrounding environment for certain periods. They could affect the brick in terms of performance and mechanical properties such as modulus of elasticity and moisture movement. Any form of change in masonry material may affect the overall structure performance of masonry wall. Therefore the main aim of this paper is to present the influence of sulphate attack on the elasticity and moisture movement of calcium silicate brick units.

2. Experimental Work

The modulus of elasticity and moisture movement of calcium silicate brick units were determined using forty unbonded samples. The samples were selected randomly from one type of calcium silicate brick that was supplied by Batamas Sdn Bhd, Batu Gajah, Perak, Malaysia. All samples were partly sealed before cured under polythene sheet for 14 days in controlled environment room with temperature of 25 ± 2 °C and 80 ± 5 % relative humidity respectively. After the curing process, all specimens were exposed to the sodium sulphate with concentrations of 5%, 10% and 15% (by weight volume) using spraying method on the surface of the samples every 24 hours. The specimens were gradually sprayed with salt solution for three times every 30, 60 and 90 minutes. The modulus of elasticity was obtained using a tangent value from stress-strain graph at an elastic region. The elasticity tests were carried out at 28, 56 and 180 days. Meanwhile, the moisture movement readings were taken at 0, 14, 28, 56,180 and 210 days. The unsealed brick specimens also were tested for compressive strength, water absorption and initial rate of suction

3. Result and Discussion

3.1 Properties of Calcium Silicate Bricks

The properties of calcium brick units which have been determined are compressive strength, water absorption and initial rate of suction as given in Table 1. The compressive strength of calcium silicate brick used was 25.31 MPa with water absorption of 14.13 % for 24 hours immersion. Meanwhile the initial rate of suction is approximately 2.18 kg/m^2/min. The all testing were carried out according to BS 3921: 1985 [5].

Table 1. Properties of unsealed calcium silicate brick used in the tests

Parameter	Modulus of elasticity (GPa)	Water absorption (%)	IRA (kg/m^2/min)	Porosity (%)
Mean	6.77	14.13	2.18 x 10^{-3}	25.31
Standard deviation	1.09	0.913	0.0003	1.08

3.2.1 Modulus of Elasticity

The modulus of elasticity of the brick units depend on the strength of the unit. According to Shrive and Jessop [6] indicated that a small change in the density of the brick units will cause a reduction in the modulus of elasticity and other intrinsic properties, which depend on the microstructural properties of the brick units such as the distribution and shape of voids. The measurement of the modulus of elasticity of the masonry unit was carried out by testing the partly sealed unit.

The modulus of elasticity of the partly sealed calcium silicate brick units is shown in Figure 1. The results show that the overall modulus of elasticity of the partly sealed calcium silicate brick units under control condition was 60% lower than that of the unsealed specimens. For example, the modulus of elasticity of the partly sealed calcium silicate brick units exposed to dry control conditions for 180 days was in the range of 3.11 to 3.94 GPa, respectively. Meanwhile, for the specimens exposed to moisture conditions, the modulus of elasticity recorded at 180 days was 4.30 GPa and 2.55 GPa for fired-clay brick and calcium silicate brick units, respectively.

Figure 1 also shows that the magnitudes of modulus of elasticity is inconsistent and fluctuating. For the calcium silicate bricks exposed to sodium sulphate conditions, the range of the modulus of elasticity was not obviously different with the specimens exposed to water. This result indicates that calcium silicate brick units are durable in the sodium sulphate conditions. The modulus of elasticity of the calcium silicate brick unit after 180 days exposed to sodium sulphate ranged between 2.30 and 2.80 GPa. However, the elastic modulus of the brick units decreases when the soluble salt concentration increases.

4.3 Moisture Movement

The moisture movement curves for all the partly sealed unbonded calcium silicate bricks under control and sodium sulphate, conditions are presented in Figures 2 to 3, respectively.

Figure 2 shows that for control purposes, the moisture movement of the partly sealed calcium silicate brick can be of shrinkage or expansion. The moisture movements at 210 days for the control partly sealed calcium silicate brick units are presented in Table 2. For the control partly sealed calcium silicate brick units, the specimens showed expansion after exposure to dry conditions and shrinkage in wet or moisture condition. Table 4.16 shows that the expansion recorded for partly sealed calcium silicate brick units was between -14 to -160 x 10^{-6} and that the shrinkage was about 276 x 10^{-6}.

The partly sealed calcium silicate brick samples exhibited shrinkage after exposure to soluble salt conditions, as shown in Figure 3. The average of the shrinkage values of calcium silicate bricks at 210 days is presented in Table 2. From the table, the average shrinkage of the partly sealed calcium silicate bricks exposed to 5%, 10%, and 15% of sodium sulphate at 210 days was about 459, 360 and 488 x 10^{-6}, respectively. The average shrinkage of units measured still in range of the shrinkage that was proposed by the BS 5628 Part 2 about 500 X 10^{-6}. Therefore, the calcium silicate brick used in this study has good resistance in soluble salt conditions. However, future investigations are required to clarify the above statement.

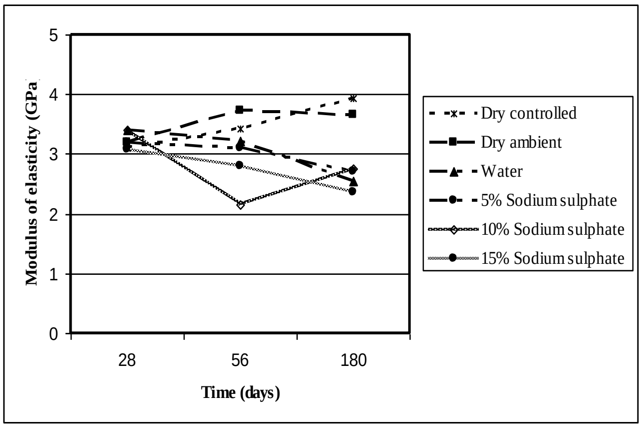

Figure 1. Modulus of elasticity of calcium silicate brick units

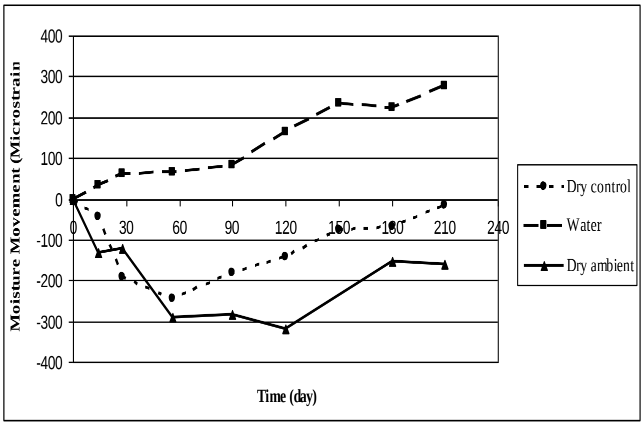

Figure 2. The moisture movement of control calcium silicate brick

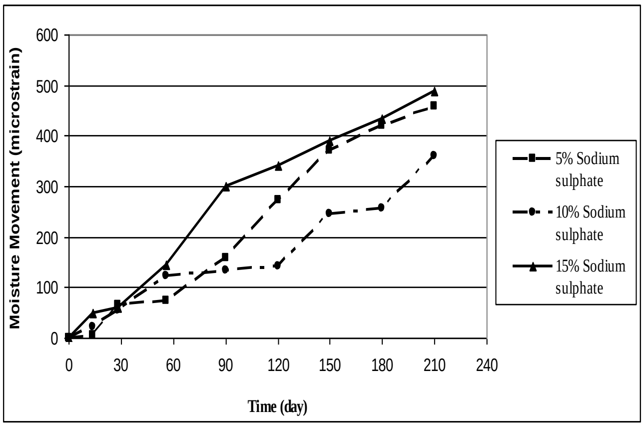

Figure 3. The shrinkage of partly sealed unbonded calcium silicate brick under sodium sulphate conditions

Table 2. The moisture movement of calcium silicate brick at the age of 210 days

Brick exposure condition	Maximum age (days)	Shrinkage (1×10^{-6})
		Horizontal
Dry (Control)	210	-14
Dry (Ambient)	210	-160
Water	210	276
5% Sulphate	210	459
10% Sulphate	210	360
15% Sulphate	210	488

5. Conclusion

The sodium sulphate solutions were found to cause a reduction in modulus of elasticity after 180 days. Nevertheless, the modulus of elasticity of calcium silicate brick units affected with sodium sulphate are varied due to the variety of strength and modulus of elasticity of the brick units during manufacturing and could be considered as the nature of calcium silicate brick.

For the moisture movement, the calcium silicate brick units were significantly shrink after exposed to sodium sulphate. The shrinkage still in the range that given by the BS 5628 Part 2. The increment in the rate of concentration also did not give any significant effect where by the shrinkage in each concentration of sodium sulphate were not obviously different. Therefore this result could be clarify that the calcium silicate brick units are durable in sodium sulphate environment.

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