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Elasticity of Calcium Silicate Brick Masonry Wall due to Sulphate Attack

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Abstract The aim of this study is to investigate the behaviour of the calcium silicate brick masonry wall exposed to sulphate condition. This paper presents some result about the effect of sodium sulphate attack on the elasticity of the calcium silicate brick masonry structures. All specimens were cured under polythene sheet for 14 days in environmental controlled room with temperature of 25± 2°C and 80 ± 5% relative humidity. After curing, the specimens were exposed to sodium sulphate solution before tested at 14, 28, 56 and 180 days respectively. As a result, the modulus of elasticity of the calcium silicate brick masonry wall reduces with the increase of sulphate concentration.

Keywords: Elasticity, sodium sulphate, calcium silicate brick

Introduction

Calcium silicate brick was manufactured by mixing high calcium lime with a very fine siliceous aggregate and water. The bricks then moulded at high pressure, followed by high-pressure steam curing. According to Bowley (1993), calcium silicate brick has a good durability properties and resistance to any condition. However, masonry structure is anisotropic material comprise of two material which are mortar and brick units. Although calcium silicate bricks have high reputation in durability, when it is combined with the mortar, the calcium silicate masonry wall still uncovered with any attack in an aggressive environment.

The ability to resist the action of salt attack by masonry material is the main consideration because salt attack especially sulphate attack is a damaging process to masonry wall in sub-tropical and tropical climates, such as Malaysia. By mean of experimental study, it is shown that the modulus of elasticity of the calcium silicate brick masonry wall reduces with the increase of sodium sulphate concentration. The average annual temperature in Malaysia is about 26°C with high humidity of 80%. Due to this criterion the salt problems should be considered as well to the country because this situation could cause a damage or deterioration of building material when the masonry material exposed to the surrounding environment for certain periods.

Santhanam et al. (2003) has proposed the mechanism of sulphate attack in mortar. The proposed mechanism start after the mortar exposed to sulphate solution with the formation of gypsum and ettringite in the regions close to the surface of mortar. These substances then try to expand but were resist by the bulk of mortar underneath which is chemically unaltered. Furthermore, due to this reaction, a resultant compressive force is generated in the surface region, while the bulk of the mortar is subjected to tensile force. This situation then causes a micro cracking or cracks to appear in the interior of the mortar.

According to Larbi (2004), microscopically, deterioration due to salt crystallization is characterized by local scaling of the surface, micro cracking in the mortar, loss of binder-aggregate bond and cohesion of binder and in severe cases spalling. However, macroscopic stress by means of the modulus of elasticity could determine the time dependent course of the material strain due to the crystallization pressure (Espinosa et al. 2008). In fact, the reduction in modulus of elasticity may occur because of micro cracking induced by the crystallization pressure.

Therefore, the main aim of this paper is to presence the influence of aggressive salt environment such as sodium sulphate on the elasticity of calcium silicate masonry wall.

Material and Experimental Procedure

The experimental work involves in measuring the modulus of elasticity of masonry single leaf wall with 5 brick height x 1.5 brick width. The test was carried out in Heavy Structures Laboratory, School of Civil Engineering, University Sains Malaysia. The numbers of twenty walls were constructed with 1: 1: 6 design mortar. Meanwhile, unbonded calcium silicate brick units and mortar prisms also were prepared for comparison. The all specimens were cured under polythene sheet for 14 days in the controlled environmental room with temperature of 25 ± 2 °C and 80 ± 5 % relative humidity. For unbonded brick units and mortar prisms, the specimens were partly sealed with bituminous tape after 3 days curing and completed within 7 days. After curing process, the all specimens were exposed to the sodium sulphate with concentration of 5%, 10% and 15% (w/v) using a spray method and it was carried out every 24 hours. The modulus of elasticity was obtained using a tangent value from stress strain graph at an elastic region. The test was carried out at 14, 28, 56 and 180 days with rate 1.5 mm/min for wall and mortar prism and 2.0 mm/min for brick units.

Results and Discussion

Material Properties Table 1 present the strength of mortar cube that was used to construct masonry wall specimens. The range of water cement ratio of mortar mix is 1.73 to 1.75. Meanwhile the average strength of mortar was more than 4.0 MPa which fulfill the minimum requirement of BS 5628 Part 1: 1992 for mortar mix 1: 1: 6 at 28 days. BS 5628 also stated that the increase of mortar strength leads to a decrease in the ability to accommodate movement.

Table 1 *Water cement ratio and strength of mortar cube under water curing condition*

Batch of mortar	*Masonry exposure condition*	*Strength of mortar cube under water curing*		*Water cement ratio*
		7 days	*28 days*	
1	Dry ambient temperature	5.78	7.08	1.73
2	Dry control temperature	5.89	6.71	1.75
3	Water	4.17	6.29	1.75
4	5% sulphate	4.64	6.58	1.73
5	10% sulphate	4.11	5.63	1.75
6	15% sulphate	4.70	6.28	1.75

Properties of calcium silicate brick units were measured using ten unbonded specimens which were selected randomly. The properties of each type of masonry unit 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 is 19 MPa with water absorption of 17.1% for 24 hours immersion. Meanwhile the initial rate of suction is about 1.8 kg/m^2/min.

Table 2 Properties of calcium silicate brick

Parameter	*Strength (MPa)*	*Water absorption (%)*	*IRA kg/m²/min*
Mean	16	17.1	1.80

Modulus of Elasticity Figs.1 and 2 shows the elastic modulus of mortar prism under control and sulphate condition. The modulus of elasticity of mortar prism specimens was tested at 14, 28, 56 and 180 days using twelve 75 x 75 x 300 mm partly sealed mortar prisms. Figure 1 show that the modulus of elasticity for control specimens increases with time. The range of elasticity for control condition at 180 days is between 4.40 and 5.90 GPa respectively. The water condition which could be considered as 0% sulphate solution shows the maximum elasticity properties in control condition about 5.90 GPa.

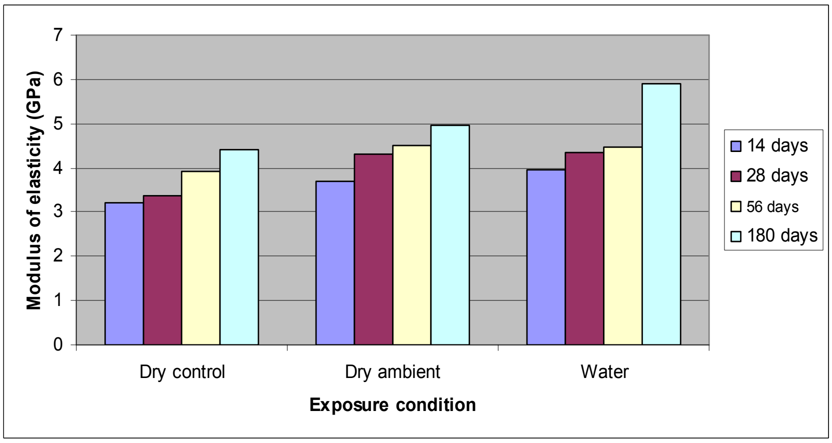

Figure 1: Modulus of elasticity of mortar prism under control condition

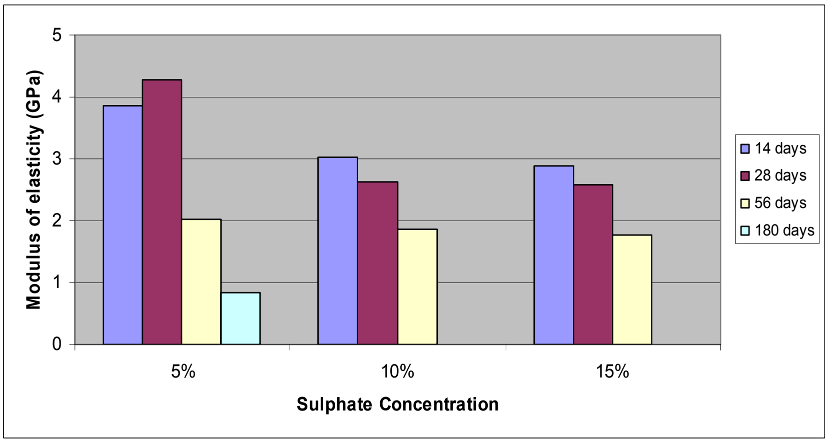

Figure 2: Modulus of elasticity of mortar prism under sodium sulphate condition

As expected, the modulus of elasticity of mortar prism under sulphate condition decreases with the increasing of sulphate concentration. For instance, with 5% sulphate concentration, it can be seen that the elastic modulus of mortar prism at first 28 days increase about 11%. However, after 56 and 180 days, the reduction in elasticity rapidly occurs about 48% and 78%, respectively. For 10% and 15% sulphate solution, the elasticity of mortar sharply decreases about 14 % and 40% and 11% and 39% at

28 and 56 days. On the other hand, after 180 days the mortar prism was become soft and brittle causes no data could be recorded. The reduction in modulus of elasticity of mortar occurs due mainly to the crystallization of sodium sulphate. It is in agreement with Lee et al. (2008) which reported that the mortar specimens deteriorate due to sulphate attack and resulting surface damage and reduction in compressive strength. The reduction in compressive strength causes the reduction in elastic modulus.

The elastic modulus of brick units depends on the strength of the unit where the strength is proportional with the modulus of elasticity. According to Shrive and Jessop (1980), the modulus of elasticity of brick unit depending on the microstructure of the brick units such as distribution and shape of voids. Any change in the density of the brick unit will cause an effect on the modulus of elasticity.

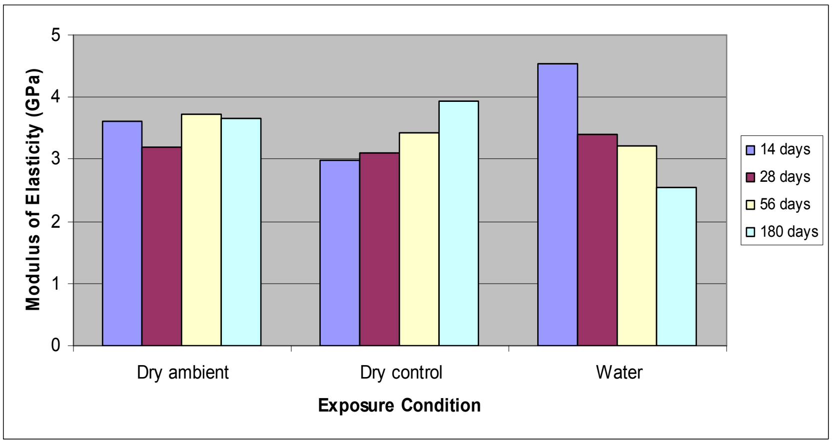

Figure 3: Modulus of elasticity of calcium silicate brick unit under control condition

The condition of the unit at the time of the testing also affects the elasticity properties of the unit. Fig. 3 present the elastic modulus of the entire calcium silicate brick unit exposed to control condition. It can be seen that the modulus of elasticity of calcium silicate bricks for dry control temperature and dry ambient temperature condition at 180 days are between 3.65 and 3.94 GPa approximately. Meanwhile, for water or wet condition exposure although shows some reduction occurs, the modulus of elasticity was in range between 2.55 and 4.53 GPa.

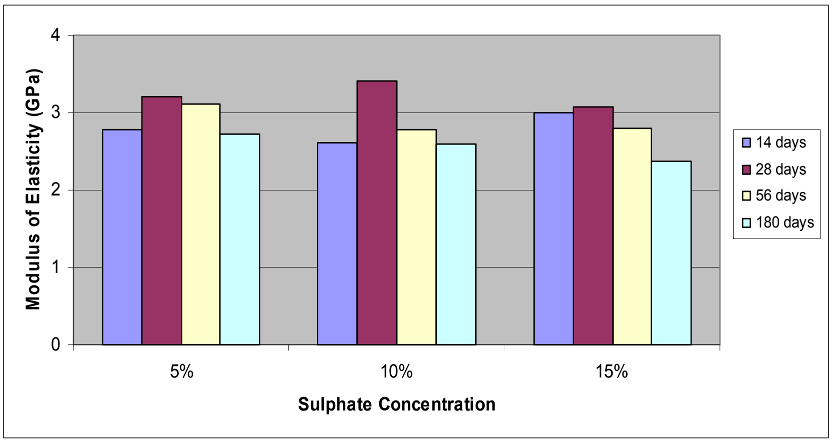

Figure 4: Modulus of elasticity of calcium silicate brick under sodium sulphate condition

After exposed to sulphate condition (see Fig. 4), the modulus of elasticity of the calcium silicate brick units shows some reduction, but not too obvious and still in range with the control condition especially water condition exposure. The range of elasticity of calcium silicate brick units are between 2.70 and 3.31GPa, 2.80 and 3.40 GPa and 2.60 and 3.15 GPa for 5%, 10% and 15% sulphate solution. This result clearly shows that the calcium silicate brick is durable in severe sulphate solution.

The modulus of elasticity is linearly related to the ultimate failure strength of masonry (Jessop 1980). Figure 5 also shows that the modulus of elasticity of specimens under control condition increases with time. The modulus of elasticity for masonry wall under control condition was in ranged between 7.20 GPa and 14.70GPa respectively.

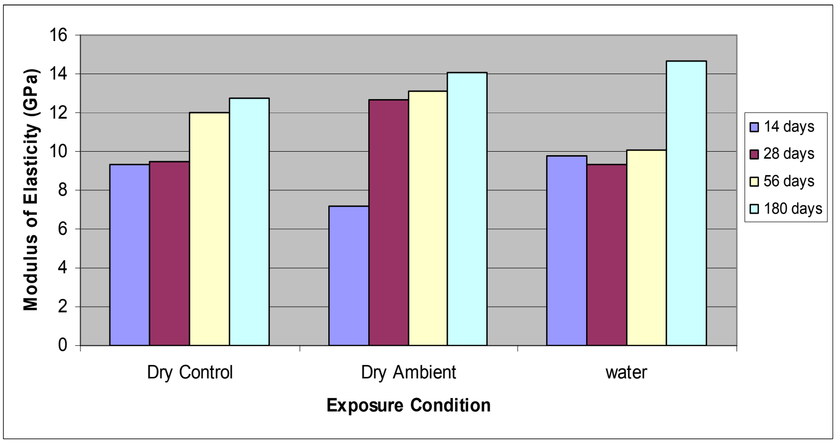

Figure 5: Modulus of elasticity of calcium silicate masonry wall under control condition

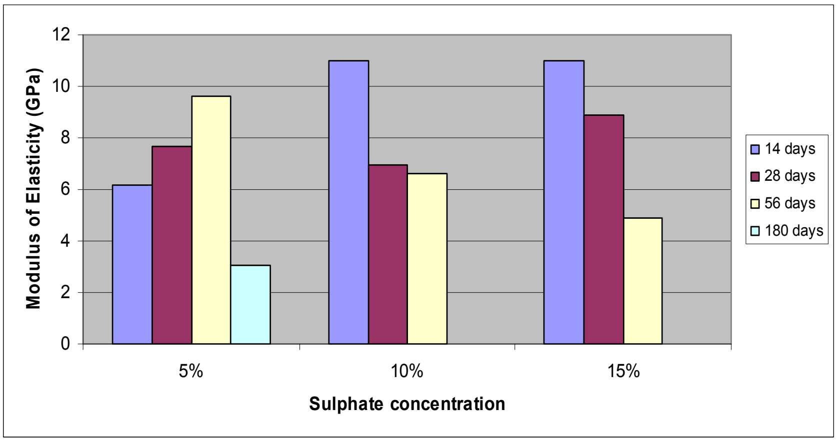

Figure 6: Modulus of elasticity of calcium silicate masonry wall under sodium sulphate condition

Figure 7: Calcium silicate brickwork after exposed to severe sulphate condition

The significant effect of sodium sulphate was shows in Figure 6 where the reduction of elasticity increase when the sulphate concentration increase. The figure shows that a 10% and 15% sulphate concentration gave the severe experience for the specimens with 100% reduction after 180 days exposure. Meanwhile for the 5% sulphate solution the reduction in elasticity recorded about 51% approximately. The reduction in modulus of elasticity was calculated by comparing with the specimens in water condition which could be considered as 0% sulphate solution. As shows in Figure

7, the reduction in elasticity of calcium silicate brick masonry wall clearly occurs because the deterioration of mortar due to the crystallization of sodium sulphate. At this period the mortar become soft and brittle.

Conclusion

Calcium silicate brick are durable when exposed in sodium sulphate condition. Although the elastic modulus of calcium silicate brick units shows some reduction occur, but the difference not too obvious with control specimens. From the result, the sodium sulphate attack in calcium silicate brick unit could be negligible because unlikely to contribute any deterioration or damage on the brick units. Instead, for the mortar prisms, the specimens exhibit a deterioration and brittle after exposed to sodium sulphate solution.

Significant deterioration was noted in the masonry wall specimens due to sulphate attack. Deterioration in the masonry wall was influenced by the deterioration of mortar joint due to crystallization pressure that control by chemical nature of crystallizing salt. Due to this problem the mortar joint slightly open until causes the brick unit separate. The rates of deterioration for masonry material increase and quickly occur when the sulphate concentration increases. The 100% elastic modulus reduction occurs in masonry wall after six months exposed to 10% and 15% concentration of sodium sulphate.

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