INFLUENCE OF SALT EFFLORESCENCE ON RENDERING MORTAR OF BRICK MASONRY WALLS

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ABSTRACT

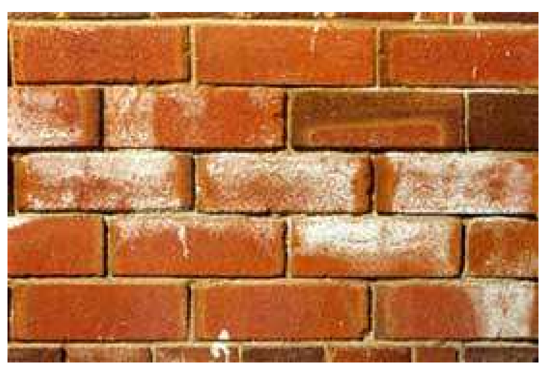
The effect of salt efflorescence on masonry structures is produced by rising of saline solution. The main chemical reagents, responsible for causing efflorescence on rendering mortar are chloride ion (Cl^-) and sulphate ion (SO_4^{2-}). As the study area, Khulna, is situated in coastal zone of Bangladesh, near Bay of Bangle, the structures are prone to saline attack. The main purpose of this study is to evaluate the percent of surface area affected by efflorescence in relation with weather exposed area on ground floor and to the entire exposed surface of the building. And also to determine the amount of chloride (Cl^-) and sulphate (SO_4^{2-}) ion which are mainly responsible for efflorescence in the collected sample mortar. And finally, put some recommendations to remedy the destructive effects of efflorescence on rendering mortar. In this study, twelve buildings were surveyed and sample mortar from five sites were collected and tested on the laboratory to determine chloride (Cl^-) and sulphate (SO_4^{2-}) ion. From field study, the damaged areas due to efflorescence were found 6.54% and 2.91% with respect to ground exposed surface and entire exposed building surface respectively. Through the laboratory test, the severity of chloride ion (Cl^-) was found greater than sulphate ion (SO_4^{2-}). It is hoped that the outcome of this study will help people to generate understanding the effects of efflorescence on rendering mortar.

Keywords: *Building, salinity, masonry wall, rendering, efflorescence, management*

1. INTRODUCTION

Efflorescence has been a major problem for many years in the surface of a masonry wall and rendering mortar. Efflorescence is the crystalline deposit of salts which initially produce a white thin film on the surface of masonry or plaster. It often occurs on masonry façades, and depending on its intensity, changes the colour impression and appreciation of the facade as a whole (Harold & Timo, 2004).

(a)



(b)

Figure 1: Efflorescence on (a) rendering wall (b) brick masonry wall

Architectural heritage is subjected to a range of decay processes which endanger its future conservation in many of the world's historic city centres. Salt crystallization is one of the most common causes of such decay

(Cultrone & Sebastian, 2008). When disregarded, they can produce a negative impact, either esthetical, on the living conditions or, in the worst case scenario, in the structural performance (Jose, 2011).

1.1 Causes of Efflorescence

Primary efflorescence is the first to appear. It develops as a whitish bloom or colour fades during setting and curing of the concrete. It involves the water used to mix the fresh concrete. Secondary efflorescence develops later, sometimes even months later. It is related largely to outside water, for example from external sources like rain or ground water travelling through the concrete, and may appear as a uniform discolouration or as localised encrustations where water exits the concrete. Cryptoflorescence or subefflorescence is salt crystallisations within the pore structure of the concrete. It forms below the surface and is not visible unless the crystal growth is sufficient to cause surface scaling (Efflorescence, 2008). The location of salt crystallization depends on the flow of the water and the permeability of the substrate, which allows the salt to move. The crystallization of salt crystals is accompanied by an increase in volume, which produces internal stresses (Benavente et al., 2007; Evans, 1970). Identification of minerals present in the efflorescence by X-ray diffraction showed that these were easily soluble alkali sulphates, notably Na_2SO_4, $K_2Ca(SO_4)_2$, $K_3Na(SO_4)_2$, occasionally accompanied by the lesser soluble gypsum, $CaSO_4.2H_2O$ (Harold & Timo, 2004). Cement containing higher proportions of tricalcium aluminate may be less susceptible to chlorides. Chloride ions can react with the tricalcium aluminate in the cement to form an insoluble new product. However, when chloride undergoes through wetting and drying cycles, changes in humidity and temperature, can result in the formation of salt crystals that exert a physical stress on concrete (Sydney South, Department of Environment and Climate Change NSW, 2008). Three conditions must exist simultaneously for efflorescence to a result: a. soluble salts must be present within the masonry assembly, b. water must come in contact with the salts to form a solution, and c. the salt solution must have a path to migrate to a surface where the water can evaporate. Eliminating all three of this condition in conventional masonry wall which exposed to weather, chance of efflorescence can be ignored.

1.2 Sources of Salts

In general, building walls are made with various ingredients such as sand, aggregates and water that may contain salts. On the other hand, the wall constituents may be stored in a location which may allow the addition of salts carried by wind, rain or from the ground to enter the finished product. According to Masonry Institute of America (MIA), a chemical analysis of efflorescence salts in the Southern California found that about 90% of the efflorescence was occurred due to soluble alkali sulphate. The necessary sulphates may originate from several sources: brick, mortar, soil, air or rain. In brick, sulphates are formed during the firing process, and may remain present depending on the maximum temperature of firing. In the mortar, sulphates generally originate from Calcium Sulphates (gypsum, anhydrite, hemihydrate) added to control setting (Harold & Timo, 2004). Six mechanisms govern chloride ingress into concrete: absorption, diffusion, chloride binding, permeation, wicking, and dispersion. For structures exposed to cyclic wetting and drying, absorption and diffusion are two of the most significant mechanisms (Hong & Hooton, 1999).

2. METHODOLOGY

In this study, a field survey was performed, from where information about the sites was collected. Sample mortar was collected from five sites for laboratory test on the basis of their severity of dampness.

2.1 Study Area

The study area of this research is at KUET (Khulna University of Engineering & Technology), located at

Figure 2: Map of study area taken from Google earth

Khulna division in Bangladesh. Khulna is one of the largest cities in Bangladesh which is situated at the vicinity of the Bay of Bangle. As the city is located near the sea, the building of this locality is very much prone to efflorescence caused by soluble salts. KUET covers about 101 acres of land. Across the land about 55 concrete buildings have been built.

2.2 Data Collection

The efflorescence affected area of finished exterior surface of a building was calculated by using Trapezoidal Rule (Basak, 1994). The ordinates (Q) were measured using a measuring tape.

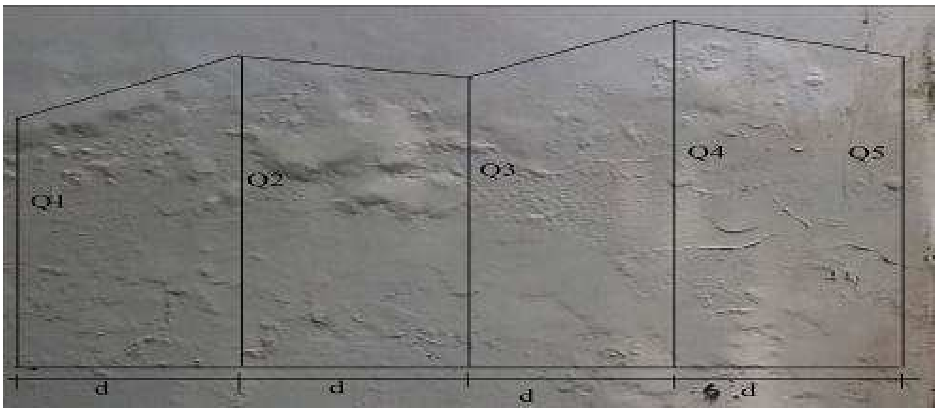


Figure 3: Illustration of Trapezoidal Rule

Total Area, $A = \frac{d}{2}(Q_1 + 2*Q_2 + 2*Q_3 + 2*Q_4 + Q_5)$ (1)

In general,

Total area = (common distance)/2*{(1st ordinate + last ordinate) + 2*(sum of other ordinates)}

In equation (1), d is the common distance between ordinates, Q_1, Q_5 are 1st and last ordinates respectively, and Q_2, Q_3, and Q4 are other ordinates as illustrated in figure 3.

Figure 4: Some picture taken during field survey showing decay of mortar

A total twelve building were surveyed and salt decayed area was estimated using equation (1). The floor plan of the studied buildings was collected from Planning and Development section of KUET. The exposed surface area was then calculated by multiplying the periphery of the floor plan with height of each floor. Then the result was presented as percentage of affected area of total ground floor surface area and also of total exposed surface area of the structure.

2.3 Test of collected mortar sample

Total five numbers of samples were collected from five different sites of the study area and then they were tested in the laboratory to measure the concentration of chloride ion (Cl^-) and sulphate ion (SO_4^{2-}). In the testing procedure, 25 gm sample was mixed with 100 ml distilled water and then kept for 24 hours to dissolved the salts in water which was in collected sample mortar. The concentration of sulphate ion (SO_4^{2-}) was determined by USEPA Method 375.4 by using Sulfaver 4 Reagent Powder Pillows and Spectrophotometer (United States Environmental Protection Agency, 1983). On the other hand intensity of chloride ion (Cl^-) was determined by Argentometry method.

3. RESULTS AND DISCUSSION

The outcome of this research is presented in table 1. The table represents the percentage efflorescence affected area with respect to total exposed ground area as well as with respect to total exterior surface area. Analysing the data, it is noticed that the ground floor is more severely affected by salts action than other floors of the same building. As the ground floor is in contact with the ground, soluble salts of chloride (Cl^-) and sulphate (SO_4^{2-}) ion can easily penetrate in the rendering mortar of a masonry wall by means of capillary rise. Besides this when rainfalls in the ground, the rain droplets often spread out on the surface of rendering mortar and thus increase the intensity of salts decay.

Table 1: Rendering mortar affected salts efflorescence

	Ground floor			Total floor		
Project no	**Exposed area(ft^2)**	**Affected area(ft^2)**	**Percent (%)**	**Exposed area(ft^2)**	**Affected area(ft^2)**	**Percent (%)**
1	2400	300.00	12.50	2400	300.00	12.50
2	2450	112.00	4.57	7350	112.00	1.52
3	2450	272.50	11.12	7350	290.00	3.95
4	2450	63.00	2.57	7350	94.00	1.28
5	2450	372.00	15.18	7350	382.00	5.20
6	2425	180.00	7.42	9700	365.00	3.76
7	2425	146.00	6.02	9700	175.00	1.80
8	1700	30.00	1.76	5100	37.00	0.73
9	1700	163.00	9.59	5100	185.00	3.63
10	7410	460.00	6.21	220230	528.00	0.24
11	4650	25.00	0.54	13950	40.00	0.29
12	7410	73.00	0.99	220230	103.00	0.05
		Average (%) =	**6.54**		**Average (%) =**	**2.91**

Table 1 shows on an average, in this study area, the damaged areas are 6.54% and 2.91% with respect to ground exposed surface and the entire exposed surface of building respectively. The bar diagram shown in figure 5 refers that the maximum damaged area is 15.18% for project 5. On the other hand the project no. 11 occupied minimum damaged area 0.54% at its ground floor.

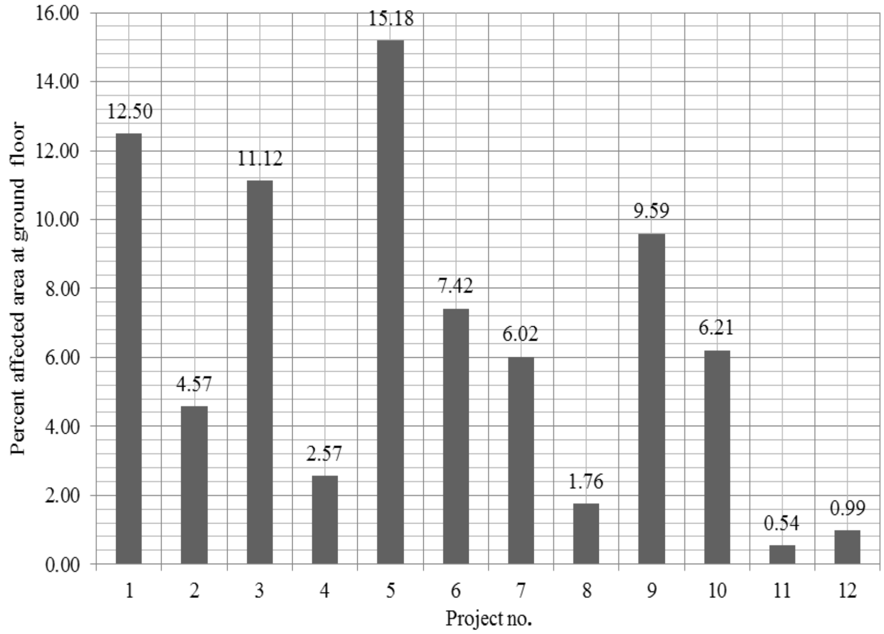


Figure 5: Percentage affected area vs. project no. at ground floor

In figure 6, percentage damage area in relation with total exposed building area is presented in the bar diagram. The bar diagram refers the maximum damaged area is 12.50% for project 1. On the other hand the project no. 12 occupied minimum damaged area 0.05% at its ground floor. In conclusion, it is noticeable the ground floor is very prone to be decayed due to salt attack.

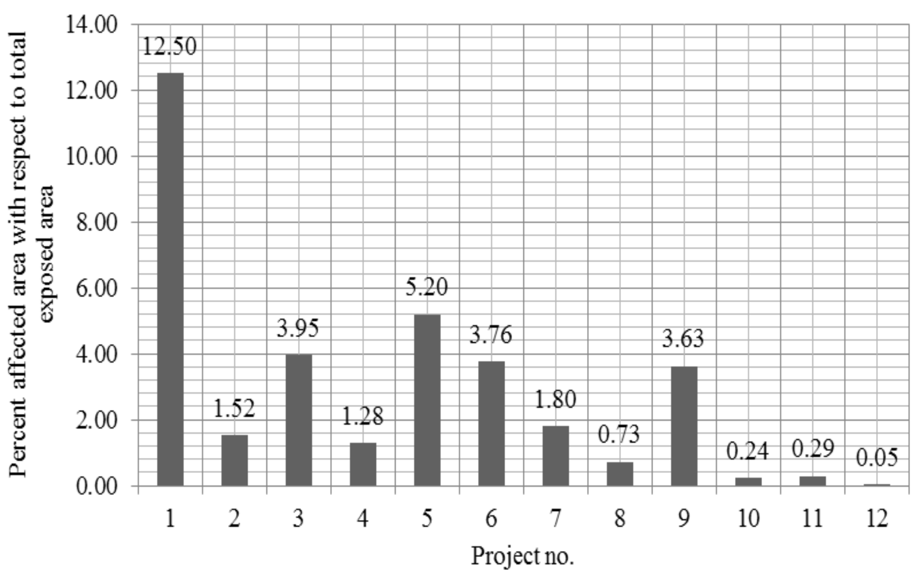


Figure 6: Percentage affected area vs. project no. with respect to total exposed area

The test results of five samples have been presented in table 2. As mentioned before the study area is located at the vicinity of the ocean bay of bangle. Most of the water sources in this area contain saline compounds mostly sodium chloride (NaCl). The test results refer the damaged mortar contains much chloride ion (Cl^-) than sulphate ion (SO_4^{2-}). The maximum chloride (Cl^-) concentration found 3779 mg. per litre which is huge for damaging the finished mortar of brick masonry wall. The least chloride (Cl^-) ion was found 1207 mg. per litre. On the other hand, maximum sulphate content was found 920 mg. per litre in sample 2 which is almost onefourth of maximum chloride concentration. Analysing the data, chloride ion content is proportional to sulphate ion content as with the increase in chloride ion content, sulphate ion also increases for each sample.

Table 2: Test results of the collected samples

Sample No.	Cl^- (mg/L)	SO_4^{2-} (mg/L)
1	2177	781
2	3779	920
3	1207	427
4	2585	827
5	1937	617

An estimation from public consultation shows that about Tk. 18 required for repairing unit square feet of damaged area. The estimated cost includes the cost of scraping, mortar and painting. Details estimation has been presented in table 3. The cost of mortar includes cement, sand, and labour.

Table 3: Repairing cost per square feet

Items	Cost (tk./ft^2)
Scraping	4
Mortar (including labour)	10
Painting	4
Total =	**18**

Described by Masonry Institute of America (MIA) if soluble alkali sulphates exist in a masonry wall, before the sulphates can cause efflorescence the salts must be dissolved into solution by water. If no moisture reaches the sulphates then they cannot be rendered into solution and migrate to the surface where the water will evaporate, leaving the sulphate salts on the surface to crystallize and become efflorescence. Attention must be given to preventing any soluble alkaline sulphates from being rendered into solution by water. Mortars contain vary amount of soluble salts, depending mainly on the type of cement used. Cement high in alkali is most likely to Reducing efflorescence potential. Other mortar ingredients also should be selected with care. Type S-hydrated lime that meets the requirements of ASTM C 207 should add little efflorescence potential to mortar (Kenneth, 1994). Most precisely mixing water, while making mortar paste, should be drinkable and clean. Sand should never be with sea water or other water which contains soluble salts. Washing the concrete with an appropriate dilute acid like hydrochloric acid HCl and incorporating waterproofing admixtures/polymeric membranes into blocks, bricks to maintain their original condition upon prolonged exposure to the weather (John, 2000). During field survey, it was noticed that the parts of a building situated in the shady area were greatly decayed.

4. CONCLUSIONS

Field study and test result show that soluble salts play the role for the deterioration process of rendering mortar. Plaster containing a high range of alkali since to be a recurrent cause of decay and renders crack accelerates the degradation rate (Teresa et al., 2006). The aim of this study was to calculate the percentage of efflorescence damaged surface and test the concentration of soluble salts (mainly Cl^- and SO_4^{2-}) in the decayed mortar. After testing the decayed mortar, it was found that about 3779 mg/L Cl^- and 920 mg/L SO_4^{2-} were found which is highest in five test samples. In this region concentration of Cl^- creates greater threat than SO_4^{2-} as most of the water sources contain saline. The damaged area was found 6.54% and 2.91% with respect to the ground surface and entire building surface respectively. For better execution of efflorescence problem, it is better to take soluble salts free water, sand and cement in mortar as recommended.

ACKNOWLEDGEMENTS

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