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EXTENT OF EFFLORESCENCE IN A BRICK MASONRY PARTITION WALL OF A GARAGE

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ABSTRACT

Efflorescence is widely recognized as an aesthetic problem of brick masonry. Till now there is no authentic solution found out for this phenomenon. Efflorescence is a crystal-like deposit, usually white, that may develop on the surface of masonry construction. On porous construction materials it may cause staining, but can sometimes specify the deterioration of internal structure by relocating and degrading of component materials especially mild steel reinforcing bar. The provided research concentrates on the efflorescence procedure and growing factors. The purpose of the test is to develop the techniques for resolution of the efflorescence risk and to evaluate the potential solutions for the problem. To continue the research a salinity affected brick masonry wall was taken into study. To understand both horizontal and vertical movement of salt, twenty-four samples including cement plaster and underlying bricks were collected from different point of the wall as well as the corresponding point of the opposite side of the wall. After chloride content test and conductivity test of samples, the result demonstrates that lower part of the wall is affected very much and upper part is less affected. The research described in the present paper aims to achieve better understanding of the relationship between chloride content and conductivity of the samples based on the laboratory test. It is also tried to figure out the factors of the unsuccessful repairs of masonry wall conducted in the past and to recommend possible alternatives to end or reduce the corrosion process based on primary research of field data and continuous observation of affected spot.

Keywords: *Efflorescence, brick masonry, chloride content test, conductivity test, repairing process*

1. INTRODUCTION

Efflorescence is a crystalline deposit on surface of masonry or concrete. It appears as a mostly white and thin, foggy salt deposit on the surface. Efflorescence has been an issue for many years. Depending on its intensity, efflorescence changes the colour impression and appreciation of the material surface and the facade as a whole (Hall, Hoff, & Nixon, 1984). In some cases, efflorescence appears directly after construction. In other cases, efflorescence starts to appear after a couple of years for taking appropriate maintenance of the façade. Most building materials contain a number of various ions which may be natural part of the material or can be additionally introduced to the pore system from the atmosphere in the form water solution (Benavente, García del Cura, & Ordóñez, 2003). Water disappears after a change of environmental circumstances and salt crystallizes either inside the pores or on the surface area (Pavlíková, Pavlík, Keppert, & Černý, 2011). The formation of salt deposition is not unidentified. For dissolving and transporting the salts, water must be present. It is required for dissolution of elements of the efflorescing salts as well as for their transportation between brick or concrete block and mortar joint, and lastly, to the brickwork surface (Brocken & Nijland, 2004). It is difficult for water to transport salts to the surface in denser materials whether it be brick, stone or concrete. Conversely, for the porous materials, transportation and deposition are very easy (Bari, Rahman, Islam, & Alam, 2016). Temperature, humidity and wind affect efflorescence mainly (Abu Bakar, Wan Ibrahim, & Megat Johari, 2011). For example, in the summer, moisture disappears so rapidly that relatively a bit of salt is introduced to the surface. Typically, in the winter when a slower rate

of evaporation lets migration of salts to the surface, efflorescence is more frequent (Lee & Moon, 2006). During drying of a wall salt is migrated to the evaporation front, where it crystallizes and builds up. Generally, the evaporation front is located near the surface of the wall, i.e. the plaster, runs the maximum risk of corrosion. Even though the plaster used in recovery is usually regarded as a sacrificial part, a long service life of the plaster is pursued (B. Lubelli, van Hees, & Groot, 2006).

Groundwater in Khulna region is a vigorous source of efflorescence (Morshed, Uddin, Islam, & Linda, 2016). Efflorescence can be caused by the use of unwashed seashore aggregate (Bosunia & Choudhury, 2001). They are, for the most part, water-soluble salts that come from many possible sources like clay bricks contain the initial soluble salt content as a parameter of efflorescence (Ahl & Lü, 2007).

According to PCA (Portland Cement Association), most efflorescence can be classified as temporary. On the other hand, recurrent efflorescence indicates a chronic moisture problem. Sometimes efflorescence is removed by some treatment measures, but if it returns, it is a sign that water is entering the wall and driving the salts out. If it does not return, then the reason is initial moisture and salts at the time placing the concrete. Beginning efflorescence can be eliminated with a brush and water. Large remains may require acidity treatment of the surface of the concrete. Initiatives should be taken to appropriate the wetness issue, thereby avoiding and removing repeated efflorescence.

Since many issues influence the formation of efflorescence, it is tough to predict when it will appear: There is no approved conventional analyse means for identifying the efflorescence prospective of brickwork mortar. Numerous time, money and initiatives have been spent trying to fix troubles efflorescence produces. Many test applications have been designed and several efforts have been made to remove the efflorescence problem but none has been known as efficiently forecasting the efficiency of mortar components in real use (Barbara Lubelli, van Hees, & Groot, 2006). However, even though no certain treatment process has been found, a good deal has been found all about how efflorescence works and ways to avoid it, and if safety actions are insufficient, how to remove the efflorescence if it does appear.

This article describes the techniques of white efflorescence, how to help avoid efflorescence and to find cost-effective possible methods to remove efflorescence from new surfaces.

In this research, a brick masonry wall of a car parking of KUET campus which is affected by repeated efflorescence has been taken into consideration.

This research includes developing a low-cost solution for efflorescence problem. This research investigates the inefficiency of the repairing works regarding this problem. Moreover, being unawareness and maintenance difficulties, the number of structures affected this problem increasing at an alarming rate. An attempt has been taken to minimize this problem and providing some recommendations for sustainable use of the structure are also the goals of this research.

2. METHODOLOGY

2.1 Selection of The Affected Area

To accomplish this study, a seriously affected masonry wall was needed. For this reason, a salinity affected wall in Garage 3 situated in Khulna University of Engineering & Technology was selected. In this wall, there is no presence of water line. It is completely free of rainwater. The wall is an interior partition wall used for car parking. The spot is shown in Figure 2(a).

2.2 Observation different stages of efflorescence

For the research, it is necessary to observe whole process of efflorescence (Figure 1). There are number of reasons which directly or indirectly cause efflorescence. The study continued for year and half to find the reasons that come into play of the severe efflorescence problem.

As the older the structure the more susceptible to have this problem. For this project, it was necessary to find an old structure where change is rapid due to efflorescence in plaster.

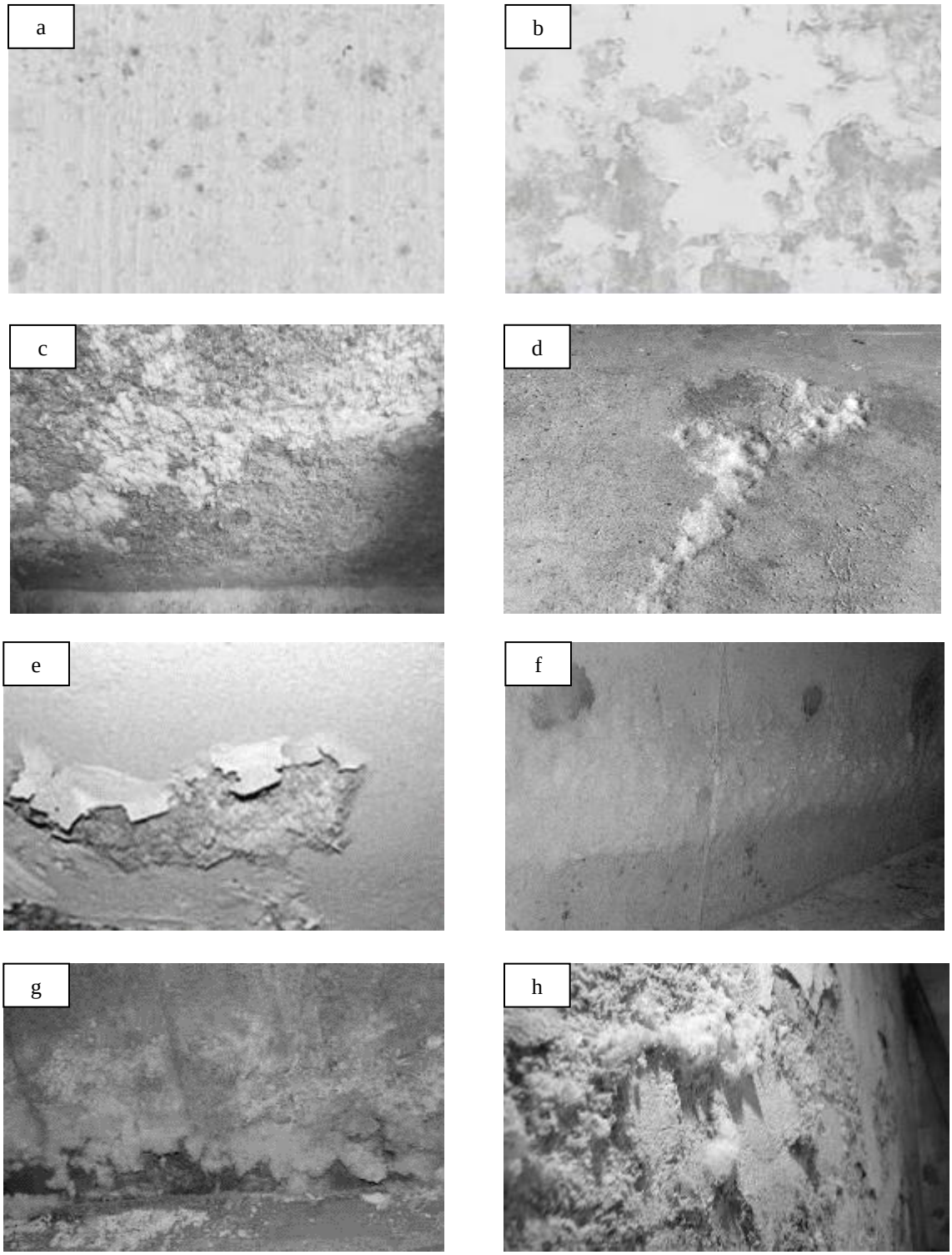

Figure 1: Different stages of efflorescence

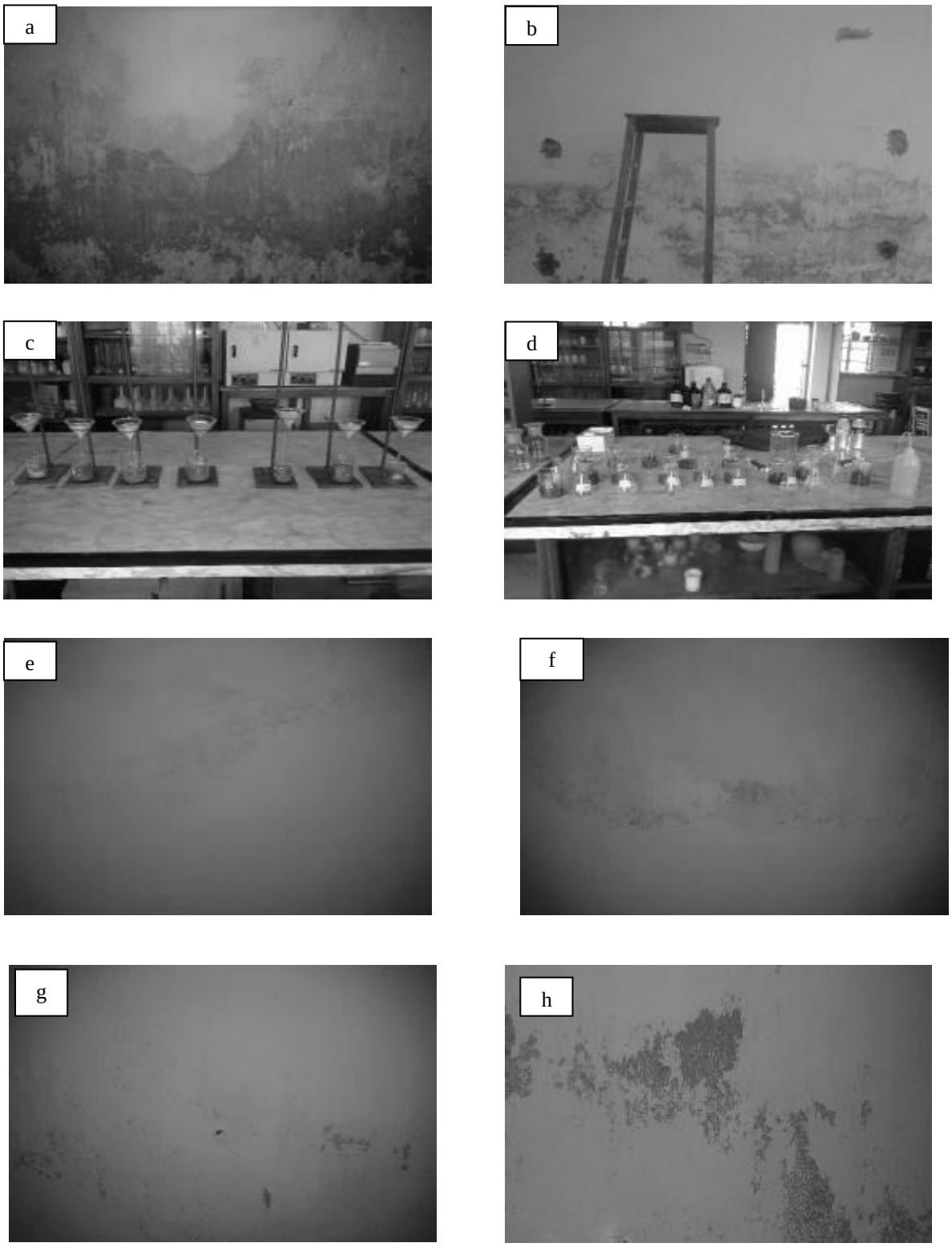

Figure 2: Stepwise procedure of this study

2.3 Collection of Cement Plaster and Brick Sample of The Affected Wall

To conduct the test and to know the severity of the efflorescence, samples including cement plaster and underlying bricks were collected from different point of the wall as well as the corresponding point of the opposite site of the wall to understand the movement of salt both horizontally and vertically. 12 cement plaster and 12 brick samples were collected (Figure 2 b).

2.4 Performing Chloride content test and Conductivity Test

To comprehend the severity of efflorescence problem, its propagation and the movement of the soluble salts, two tests were performed. For these, samples both bricks and cement plaster were oven dried. Performing conductivity test and silver nitrate titration for chloride content test. (Figure 2. c & d).

2.5 Computing the Area of The Salinity Affected Zone

The wall is 33 feet long and 15 feet in height. The efflorescence affected zone was selected very carefully. Then total area of the affected zone was calculated by dividing the length of the wall into 33 segments.

2.6 Computing the Area of The New Plastered Zone

To understand the post repairing state, the efflorescence affected area were repaired by new cement plaster. The total area of new cement plaster was also calculated.

2.7 Continuous Observation of The Affected Area

This research had been performing more than 18 months. During this period, it was under observation to identify the change which was a continuous process. The whole time was divided into three phases.

2.7.1 Before Repairing Work

First, the observation before the repairing work which is about eight months, displaying gradual propagation of efflorescence from its starting to the serious level (Figure 1). As this masonry wall is an example of severe attack of efflorescence, the gradual change is reflected significantly. Maintaining a certain time interval these images were taken to understand the change of the state of efflorescence.

2.7.2 During Repairing Work

To remove efflorescence from wall, at first wetting the walls with water and rinsing with water. Water used was pure and salt free. For repairing purpose high quality cement paste containing minimal water was used. Fly-ash was also used because adding fly-ash to cement paste binds some salts which minimize efflorescence. At the end of the remedial strategies, it was tried to ensure the least possible presence of moisture in the wall.

2.7.3 After Repairing Work

The last part started after remedial process had been completed. After some days, it was seen that the problem had not been solved totally. The severity of the problem was reduced but still the wall was attacked by efflorescence. It was noticed how the surfaces be affected by efflorescence again and the way of its duplication. These images figure 2 (e, f, g and h) were taken keeping a certain time period to comprehend regeneration process. Finally, decision was taken which ingredient or sealer should be used to diminish this problem by further treatment process and it would be the vital result of the experimental study.

3. ILLUSTRATIONS

3.1 Figures

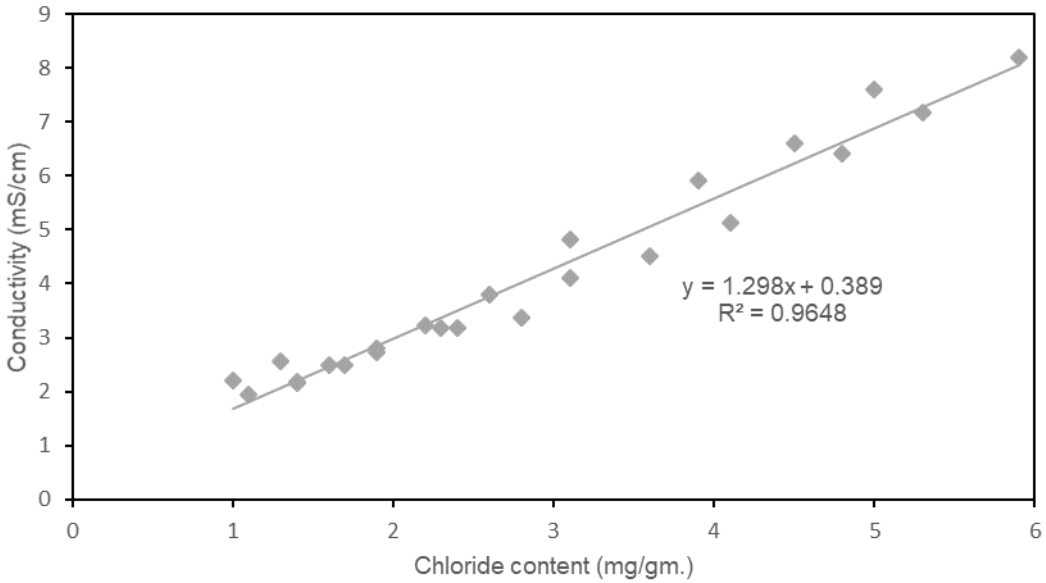

Figure 3: Variation of conductivity with respect to chloride content

3.2 Tables

Table 1: Chloride content test and Conductivity test of the brick and cement plaster

Chloride content of plaster (mg/gm)											
Wall											
Point 1						**Point 2**					
Lower Level		**Middle Level**		**Upper Level**		**Lower Level**		**Middle Level**		**Upper Level**	
West	**East**	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**
A	A'	B	B'	C	C'	D	D'	E	E'	F	F'
4.5	5.3	2.4	2.8	1.0	1.3	5.0	5.9	3.1	3.6	1.6	1.9
Conductivity of plaster (mS/cm)											
Wall											
Point 1						**Point 2**					
Lower Level		**Middle Level**		**Upper Level**		**Lower Level**		**Middle Level**		**Upper Level**	
West	**East**	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**
A	A'	B	B'	C	C'	D	D'	E	E'	F	F'
6.60	7.17	3.18	3.38	2.21	2.57	7.62	8.21	4.14	4.53	2.51	2.84

Chloride content of brick (mg/gm)											
Wall											
Point 1						**Point 2**					
Lower Level		**Middle Level**		**Upper Level**		**Lower Level**		**Middle Level**		**Upper Level**	
West	**East**	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**
A	A'	B	B'	C	C'	D	D'	E	E'	F	F'
3.1	3.9	1.9	2.3	1.1	1.4	4.1	4.8	2.2	2.6	1.4	1.7
Conductivity of brick (mS/cm)											
Wall											
Point 1						**Point 2**					
Lower Level		**Middle Level**		**Upper Level**		**Lower Level**		**Middle Level**		**Upper Level**	
West	**East**	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**
A	A'	B	B'	C	C'	D	D'	E	E'	F	F'
4.83	5.90	2.73	3.18	1.95	2.18	5.13	6.40	3.23	3.79	2.17	2.48

From the comparison of chloride content test and conductivity test (Table 1), it is found the lower part of the wall is badly affected by efflorescence and upper part is less affected and it is also seen that chloride content of a point and the corresponding point of opposite side of the wall is very close. From (Figure 3), the gradual change of conductivity with respect to chloride content is very clear. Though Khulna is situated in the coastal belt but there are some other reasons responsible for this problem. These are at first, there must be water soluble salts exist in the fired clay bricks during the construction period of the garage. Secondly, presence of sufficient moisture in the wall. Lastly and the most important is that, there must be a pathway in the wall for the soluble salts to migrate through to the surface where the moisture can easily evaporate, by this way salts are deposited which then crystallize and finally cause efflorescence. These three reasons are combinedly responsible for the severe efflorescence problem.

Table 2: Measurement of the efflorescence affected area and repaired area of the wall

Wall (west) (ft.)	**Net area of efflorescence affected zone (ft²)**	**Net area of the new plastered zone (ft²)**
1	0.7	1.3
2	1.4	2.6
3	1.1	2.7
4	0.5	2.8
5	0.3	3.1
6	0.3	3.5
7	0.5	3.7
8	1.2	3.8
9	1.3	3.8
10	0.5	3.9
11	0.4	4.1
12	0.5	4.2
13	0.6	4.0
14	0.7	4.0
15	0.8	4.1
16	0.7	4.1
17	0.7	4.2
18	0.7	4.1
19	0.7	4.2
20	0.9	4.3
21	0.9	4.3
22	0.7	4.3
23	0.4	3.9
24	0.5	3.8
25	0.7	3.8
26	0.6	3.9
27	0.5	3.8
28	0.7	3.6
29	2	3.5
30	3.1	3.4
31	1.6	2.5
32	0.4	2.2
33	0.5	2.8
Total	27.1	118.0

Net area of efflorescence affected zone = 27.10 ft^2
Net area of the new plastered zone = 118 ft^2
So, the ratio of repaired area and affected area = 118/27.10 = 4.35
Analysing the total area of affected zone by efflorescence and newly plastered area it is found that almost four and half times area is plastered corresponding to the affected area (Table 2). Apparently, it looks good for the recovery of efflorescence but the final result is not satisfactory. During the repairing process only one side of the wall (west) was plastered keeping other part of the wall (east) unrepaired. As there is a horizontal movement of the soluble salt and plenty of water-soluble salts present in the wall, the repaired wall affected by efflorescence again in a continuous process. While repairing the wall, it is urgent to renovate the wall exposed to the weather. The finest way to reduce the problem is to prevent water from infiltrating and letting outside water in.
To prevent further efflorescence, it is required to apply a concrete sealer to the surface of the affected wall. In this garage wall, film sealer can be used to protect pavers by blocking the effects of water and other contaminants. Film formers generate a barrier on the surface of the paves. Penetrant sealers can also be used. It is very effective to repel water in this condition.

4. CONCLUSIONS

- Chloride content is higher in lower portion of the masonry wall and less in the upper portion of the wall.
- There remains always a horizontal movement of soluble salts in the affected wall.
- It should be ensured that there must not be any path for the soluble salts to migrate.
- In case of fixing an efflorescence affected wall, it is necessary to renovate both the external and the internal part of the walls.
- In severe condition it is required to apply a concrete sealer on the repaired surface to reduce the problem.

It is not easy to remove the efflorescence problem completely. It will be better, if some precautionary steps are taken into consideration from the beginning of the construction process, there is less possibility of arising this problem. Low-alkali mortar for stone or brick work should be used so that alkali salts don't leach into the masonry. Mortar should be firm and free of cracks. No leak should be allowable inside the brick masonry. It is required to be sure the manufacturer of fired clay bricks has added chemicals during manufacture to make salts in them insoluble and limit efflorescence. Structures those are constructed maintaining these factors will be less vulnerable to efflorescence.

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