STUDY ON SALINITY CONTENT OF BRICKS AND SANDS IN KHULNA REGION

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ABSTRACT

Break out of efflorescence is a result of high salinity content in the local construction materials in coastal regions, like local bricks and sands in Khulna region. In coastal regions, high concentration of salt is present in soil and water. Masonry structures, when subjected to salt attack or exposed to aggressive environment during their service life, may suffer degradation due to formation of crystallization pressure as a result of evaporation of soluble salts in masonry structures. Eventually the efflorescence occurs and causes manifold harms to the structural masonry elements like brick and plaster overlaid onto it. This study was carried out for the characterization and easy removal of salinity content of bricks and sands in Khulna region. Characterization was done by titration to quantify Chloride ions on various particle sizes; among which the size range of 4.75 to 2.36 mm produced an optimum extraction of salinity content. Repeated soaking and washing was found to be an easy removal process. In case of brick aggregates, 60 hours soaking produced optimum removal of salinity content. [Cl-] concentration reduced from 192.5 mg/L (0.032% by wt.) to 120 mg/L (0.02% by wt.) in 60 hours for a typical local brick brand. Optimum soaking periods were found 3 and 48 hours for Sylhet and Local sands respectively while for Kushtia sand, no effects of soaking were found to reduce salinity content. [Cl-] concentration of Local sand reduced from 190 mg/L (0.031% by wt.) to 30 mg/L (0.005% by wt.) in 48 hours. In case of mortar cubes, soaking for 60 hours was found most effective for cubes of Local sand but for cubes composed of either Sylhet or Kushtia sand, it was 48 hours. [Cl-] concentration of mortar cube of Local sand reduced from 110 mg/L (0.018% by wt.) to 77.5 mg/L (0.013% by wt.) in its optimum soaking period, i.e., 60 hours.

Keywords: *Efflorescence, easy removal process, particle size, soaking, optimum duration*

1. INTRODUCTION

Salinity content in bricks and sands is no doubt a major threat to the durability of the structures composed of these materials. This problem is even more severe in three coastal divisions in Bangladesh including Khulna (Linda, 2012). The structures in this region bear testimony to it.

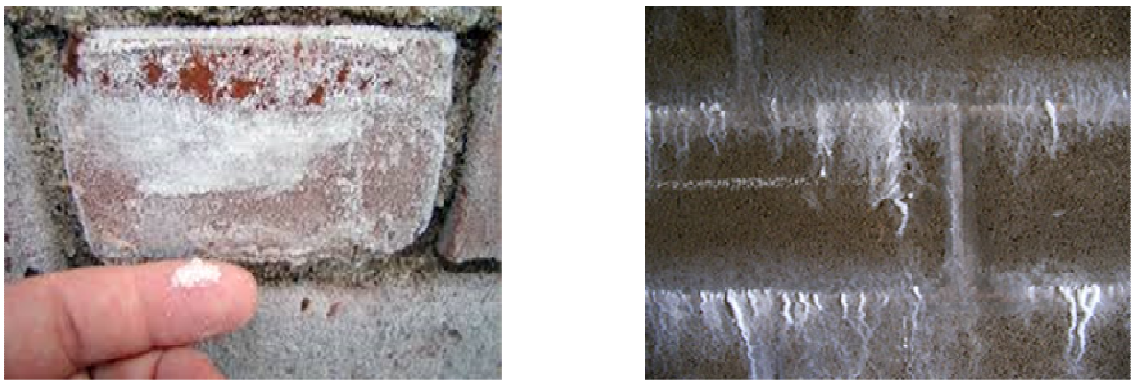

Figure 1: Effect of salinity of bricks and sands on masonry structures

But we can reduce salinity content of these materials to a certain extent by easy and cheap removal processes like repeated soaking and washing. The objectives of this research are:

- To measure the salinity content of bricks of different local brick companies.
- To investigate the effect of gradation on extraction of salinity content.
- To measure the salinity content of Sylhet, Kushtia and Local sands.
- To measure the salinity content of mortar (i.e., cement-sand) cubes of Sylhet, Kushtia and Local sands.
- To obtain optimum soaking periods to reduce the salinity content of bricks, sands and mortar cubes.

2. MATERIALS AND METHODS

2.1 Method of Determining Salinity Content

Salinity content was determined as concentration of [Cl^-] ions in mg/L according to Mohr Method, which consists of titration using standard 0.0141N $AgNO_3$ solution with standard K_2CrO_4 as indicator (Yoder, 1919). At the end of titration, AgCl precipitates with reddish end point as a product of the reaction which can be shown as follows: $NaCl + AgNO_3 = AgCl + NaNO_3$. We can also determine the amount of salinity content which is caused due to [NaCl] salt multiplying the concentration of [Cl^-] ions by 1.65, i.e., [NaCl] = 1.65*[Cl^-].

2.2 Determination of Salt Content and Size Effect

1. Bricks were collected from five local brick-fields between Fultala and Bezerdanga in Khulna city.
2. Following four types of aggregates of four different sizes were prepared from a brick of each brand:
   - Aggregates passing through the ½ inch sieve & retaining on the 3/8 inch sieve
   - Aggregates passing through the 3/8 inch sieve & retaining on the #4 sieve
   - Aggregates passing through the #4 sieve & retaining on the #8 sieve
   - Aggregates passing through the #50 sieve & retaining on the #100 sieve
3. 100 gm of each aggregate type was soaked in 100 ml of distilled water for 24 hours.
4. After 24 hours sample was filtered and 20 ml of filtrate was taken into a conical flask.
5. The salinity content as mg/L of [Cl^-] concentration was then determined by Mohr Method as described in 2.1.

Figure 2: Aggregate of different sizes from 5 local brands

2.3 Determination of Soaking Period for Bricks

2.3.1 Smaller Final Size of Aggregates

1. 1800 gm of aggregates passing the ¾" sieve and retaining on the ½" sieve was produced from each brand.
2. This 1800 gm of aggregates from each brand was divided into 9 equal portions each having 200 gm.
3. For each brand, the 9 divisions, each containing 200 gm, were primarily soaked into 200 ml of distilled water for 9 different durations in separate beakers as 01, 03, 06, 12, 24, 36, 48, 60 and 72 hours.

Figure 3: Soaking of brick aggregates for different time durations

4. After soaking for specified time duration, aggregates in each beaker were separated from water by means of filtration.
5. Then the aggregates were washed clearly by distilled water.
6. After washing, the aggregates were kept in the drying oven in separate beakers for 24 hours to dry up.
7. After drying up, 100 gm of aggregates passing through the #4 sieve and retaining on the #8 sieve was produced from 200 gm (¾ inch ~ ½ inch) aggregates of each beaker.
8. Then the salinity content was determined following the steps 3, 4 and 5 of the previous article 2.2.

2.3.2 Similar Final Size of Aggregates

It is a completely similar procedure as described in article 2.3.1 above, except that, the size of aggregates is no further reduced in this case after primary soaking for different durations.

2.4 Determination of Soaking Period for Sands

1. FM values and gradation curves of Sylhet, Kushtia & Local sand samples were obtained by sieving each sample through six standard sieves.
2. Then 1000 gm sample of each of the 3 sands was divided into 10 equal portions each having 100 gm.
3. One of the 100 gm samples from each of the 3 sand types was soaked into 100 ml of distilled water for 24 hours, then each sample was filtered and 10 ml of the filtrate was titrated to determine the initial salinity of each of the 3 sand types by Mohr Method.
4. Then the other 9 divisions of each sand type, each containing 100 gm, were primarily soaked into 100 ml of water for the similar 9 different durations as for bricks.

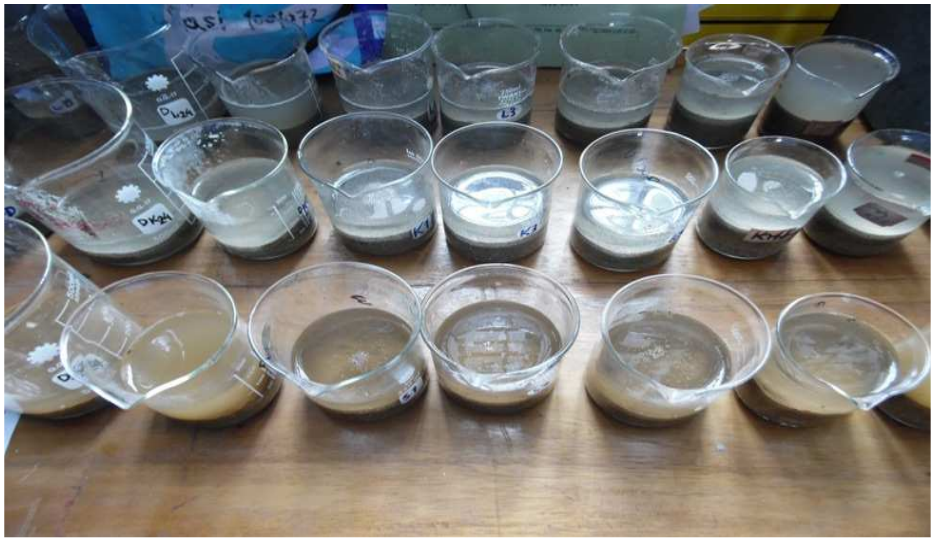

Figure 4: Soaking of Sylhet, Kushtia and Local sands for nine different time durations

5. After soaking for specified time duration, sands in each beaker were separated from water by means of filtration.
6. Then the sands were washed clearly by distilled water.
7. 100 gm of washed sands in each beaker was finally soaked into 100 ml of distilled water for 24 hours.

8. After soaking for 24 hours, salinity content of each sample was determined following the 3rd step described above.

2.5 Determination of Soaking Period for Cement-Sand Cubes

1. 10 numbers of 2" cement-mortar cubes of each of the 3 sand types were made and were demoulded after 24 hours.
2. Then they were soaked in distilled water for 7 days.
3. One of the 2" cement-mortar cubes of each of the 3 sand types was soaked into 250 ml of distilled water for 24 hours and then 10 ml of the soaking water was taken to determine the initial salinity of the cubes of each of 3 sand types by Mohr Method.
4. Then the other 9 cubes of each sand type were primarily soaked into 250 ml of water for 9 different durations as for bricks or sands.

Figure 5: Soaking of 2" mortar cubes of Sylhet, Kushtia & Local sands for nine different durations

5. After soaking for specified time duration, the cubes were washed clearly by distilled water.
6. After washing, the cubes were kept in the drying oven for 24 hours to dry up.
7. After drying up, each cube was converted into cement-sand aggregates passing through the #4 sieve and retaining on the #8.
8. Aggregates of reduced size from each cube were finally soaked into 250 ml of distilled water in separate beakers for 24 hours.
9. After soaking for 24 hours, salinity content of each sample was determined following the 3rd step described above.

3. RESULTS AND DISCUSSION

3.1 Salt Content in Bricks

The salinity content as mg/L concentration of [Cl^-] ions for bricks from five local companies was measured. The average [Cl^-] concentration values varied from 124.4 mg/L (0.021% by wt.) to 169.4 mg/L (0.028% by wt.) which is shown in the following table.

Table 1: Salinity contents of bricks from 5 local companies and effect of gradation on extraction of salinity

Brick Brand No.	[Cl⁻] Concentration (mg/L)				
	Aggregate Sieve Size				
	½" ~ 3/8"	3/8" ~ #4	#4 ~ #8	#50 ~ #100	Average
1	137.5	150.0	192.5	197.5	169.4
2	130.0	160.0	182.5	190.0	165.6
3	130.0	132.5	150.0	157.5	142.5
4	122.5	142.5	142.5	152.5	140.0
5	117.5	122.5	125.0	132.5	124.4

3.2 Particle Size Effect on Salt Extraction

The effect of gradation of brick aggregates on extraction of salts from it was investigated. As usual, the smaller the size, the higher the salt extraction level is. However, the size passing #4 sieve (4.75 mm) and retaining on #8 sieve (2.36 mm) produced optimum value which can be more clearly understood by the bar chart diagrams for brick brands '1' and '2' shown in the figure below.

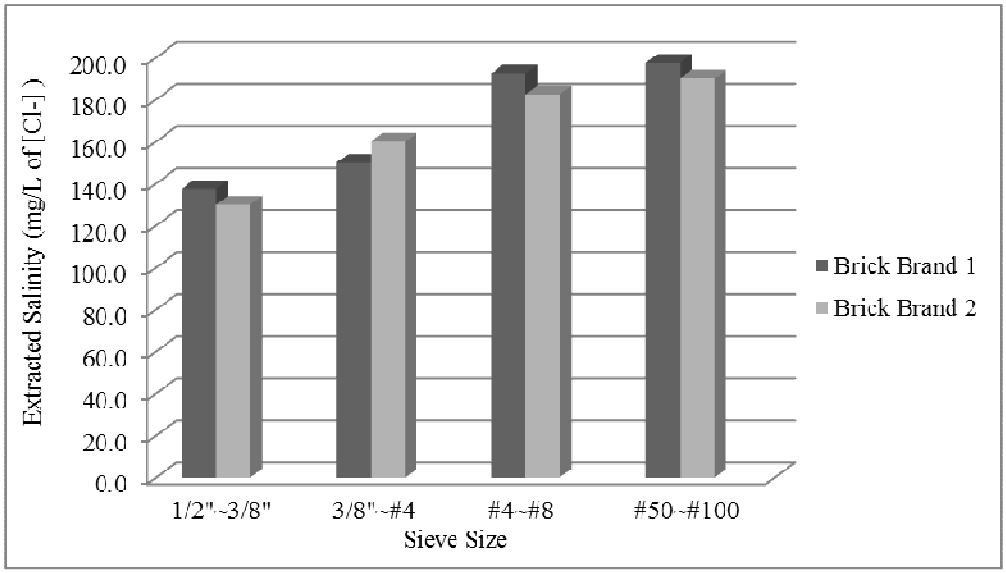

Figure 6: Effect of gradation on extraction of salts for brick brands '1' and '2'

3.3 Optimum Soaking Period for Brick Aggregates

3.3.1 Smaller Final Size of Aggregates

The effect of duration of soaking on extraction of salts from bricks was firstly investigated for smaller final sized aggregates.

Table 2: Residual salinity after soaking for different durations for 5 local brick brands [For smaller final aggregate size]

Brick Brand No.	[For smaller final aggregate size:] Residual Salinity (mg/L of [Cl⁻] Concentration)									
	Primary Soaking Time (hrs.)									
	Initial	1	3	6	12	24	36	48	60	72
1	192.5	167.5	162.5	155.0	145.0	127.5	125.0	122.5	120.0	120.0
2	182.5	160.0	157.5	152.5	147.5	130.0	130.0	127.5	125.0	125.0
3	150.0	132.5	130.0	125.0	120.0	107.5	105.0	105.0	102.5	102.5
4	142.5	122.5	120.0	117.5	112.5	102.5	102.5	100.0	97.5	97.5
5	125.0	110.0	110.0	107.5	102.5	92.5	92.5	90.0	90.0	90.0

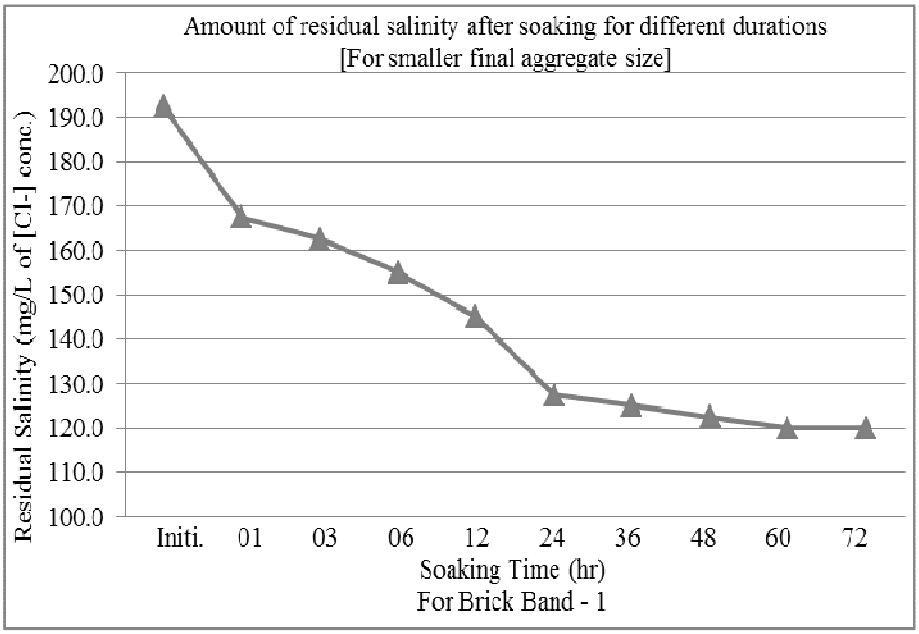

Figure 7: Residual salinity after soaking for different durations for brick brand -1 [For smaller final aggregate size]

From the figure above, it is clear that, salinity content decreases up to 60-hours soaking, though after 24 hours it decreases slowly.

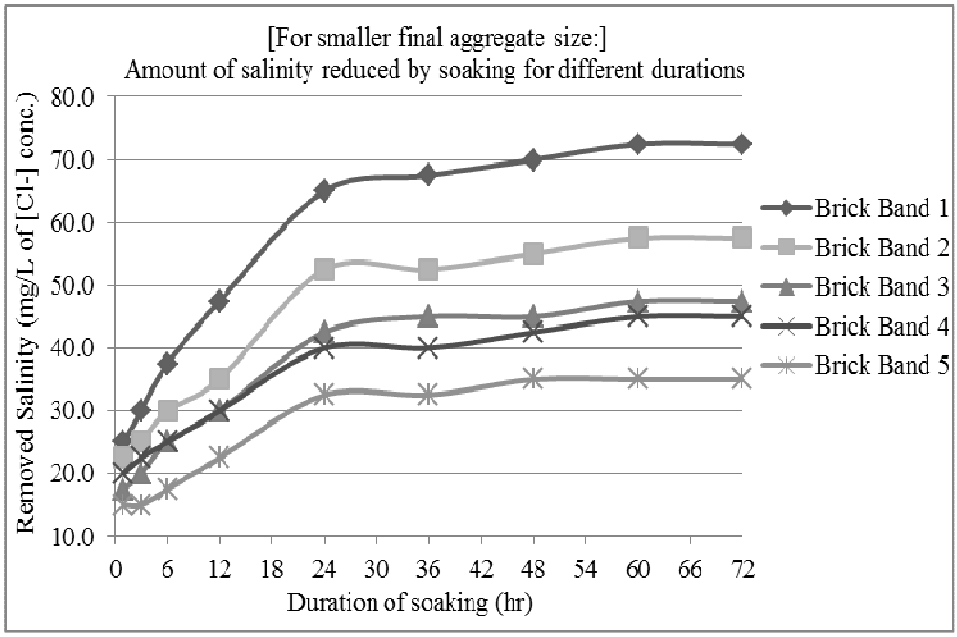

Figure 8: Salinity reduced by soaking for different durations for 5 local brick brands [For smaller final aggregate size]

From both of the above figures, it is observed that, 60 hours soaking produced optimum removal of salinity content.

3.3.2 Similar Final Size of Aggregates

The effect of duration of soaking on extraction of salts from bricks was also investigated for similar primary & final aggregate size (¾ inch ~ ½ inch). The findings in this case are shown in the following table and figures.

Table 3: Residual salinity after soaking for different durations for 5 local brick brands [For similar final aggregate size]

Brick Brand No.	[For similar final aggregate size:] Residual Salinity (mg/L of [Cl^-] Concentration)									
	Primary Soaking Time (hrs.)									
	Initial	1	3	6	12	24	36	48	60	72
1	135.0	115.0	112.5	107.5	100.0	87.5	87.5	85.0	82.5	82.5
2	132.5	110.0	107.5	105.0	100.0	90.0	87.5	85.0	82.5	82.5
3	127.5	107.5	105.0	102.5	97.5	87.5	85.0	82.5	80.0	77.5
4	115.0	97.5	95.0	92.5	87.5	80.0	75.0	75.0	72.5	72.5
5	112.5	97.5	97.5	95.0	90.0	80.0	77.5	75.0	75.0	75.0

As like smaller final aggregate size in 3.3.1, salinity content decreases up to 60-hours soaking, though after 24 hours it decreases slowly. It may be realized more clearly from Figure 9.

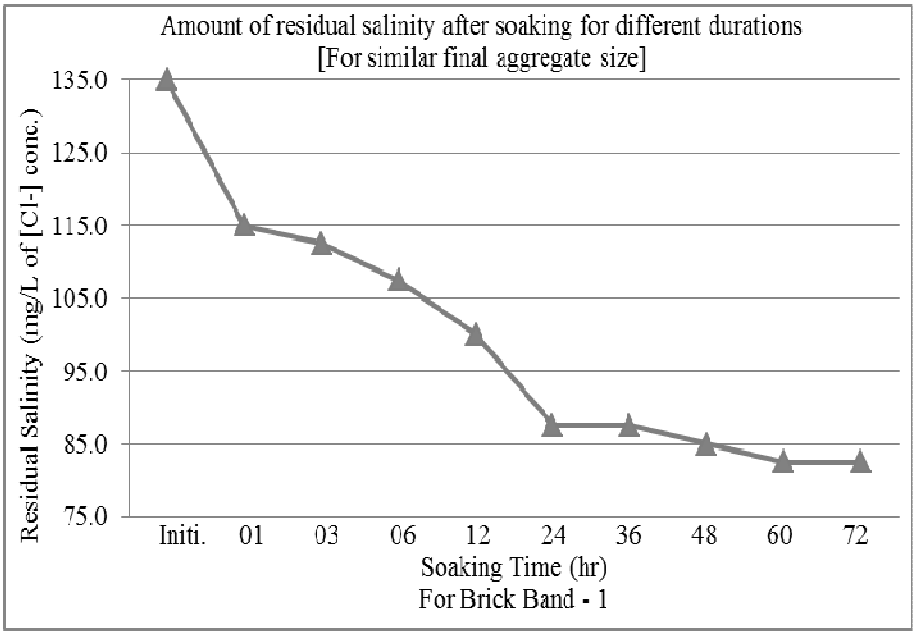

Figure 9: Residual salinity after soaking for different durations for brick brand -1 [For similar final aggregate size]

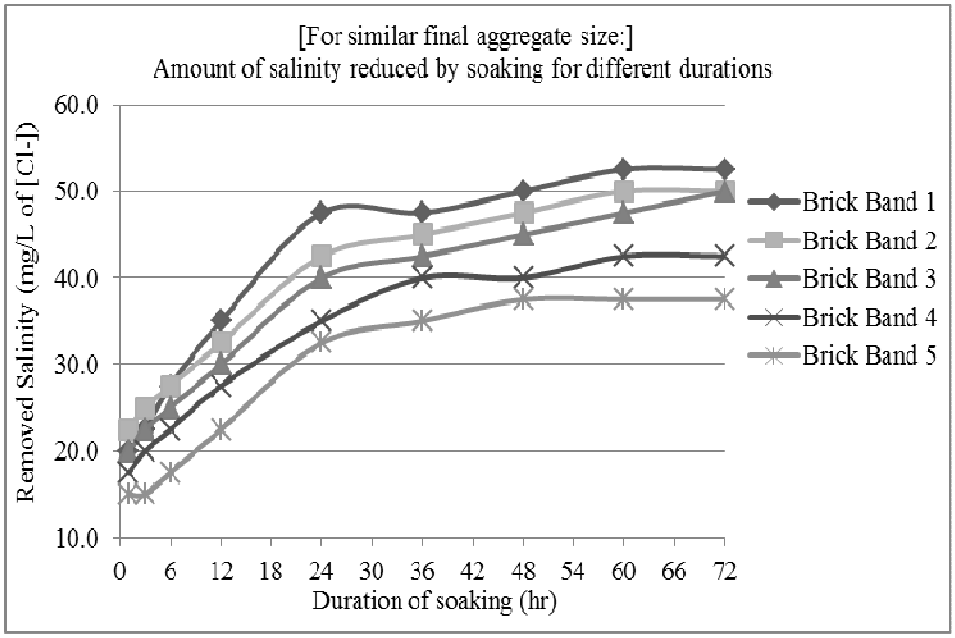

Figure 10: Salinity reduced by soaking for different durations for 5 local brick brands [For similar final aggregate size]

As like smaller final aggregate size in article 3.3.1, also in case of similar final aggregate size, as usual, the more the soaking time, the higher the salt removal level is, but 60 hours soaking produced optimum removal of salinity content in both cases.

3.4 Salinity Content and Optimum Soaking Period for Sands

The effect of duration of soaking on extraction of salts from Sylhet, Kushtia and Local sands was also investigated.

Table 4: Initial salinity as well as Residual salinity after soaking for different durations [Sylhet, Kushtia and Local sands]

Type of Sand	Residual Salinity (mg/L of [Cl⁻] Concentration)									
	Primary Soaking Time (hrs.)									
	Initial	1	3	6	12	24	36	48	60	72
Sylhet	20.0	20.0	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Kushtia	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Local	190.0	175.0	157.5	137.5	107.5	62.5	42.5	30.0	27.5	27.5

The initial salinity of Local sand is found much higher than that of Sylhet and Kushtia sands.

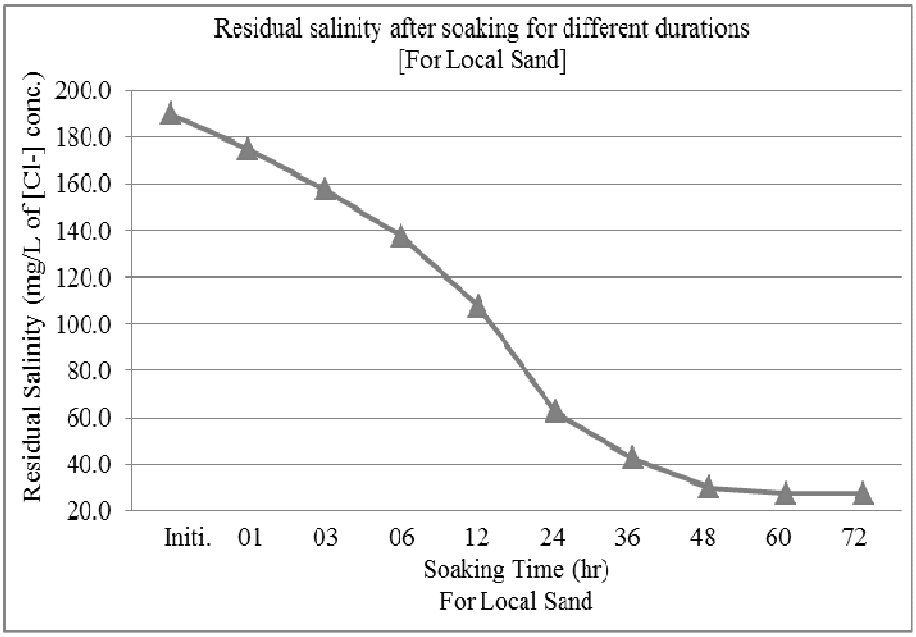

Figure 11: Amount of residual salinity after soaking for different durations in case of Local sand

The amount of residual salinity after soaking for different durations in case of Local sand is shown in Figure 11.

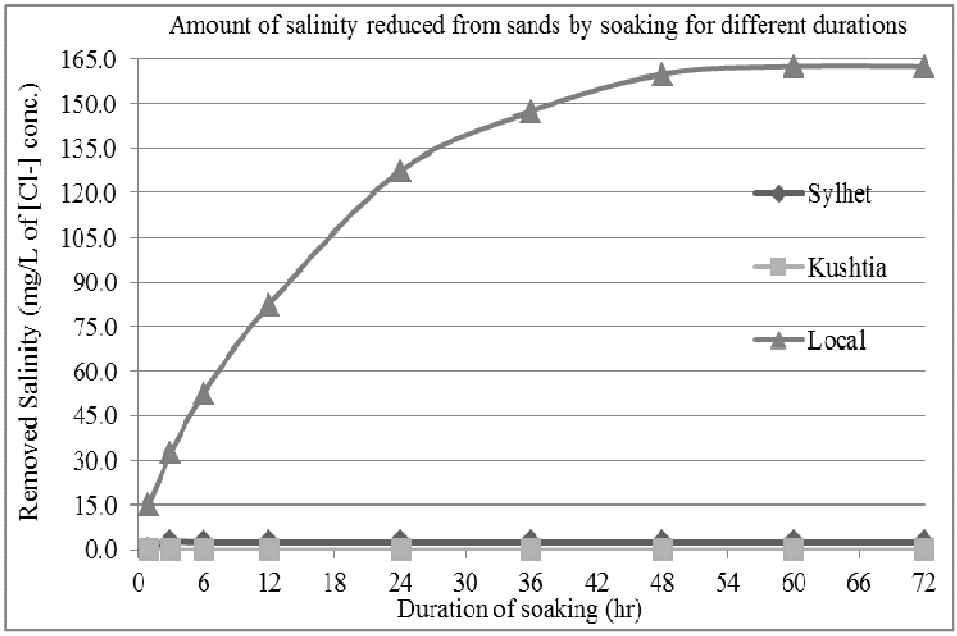

Figure 12: Amount of salinity reduced from Local, Sylhet and Kushtia sands by soaking for different durations

In Figure 12, the highest curve represents Local sand while the other two represent Sylhet and Kushtia sands respectively.
From both of Table 4 and Figure 12, optimum soaking period for removal of salinity content can be stated as 3 and 48 hours for Sylhet and Local sands respectively while for Kushtia sand, no effect of soaking is found to reduce salinity content.

3.5 Salinity Content and Optimum Soaking Period for Cement-Sand Cubes

The effect of duration of soaking on extraction of salinity from mortar cubes composed of Sylhet, Kushtia and Local sands was investigated too.

Table 5: Initial salinity as well as Residual salinity after soaking for different durations

Sand in Mortar Cube	Residual Salinity (mg/L of $[Cl^-]$ Concentration)									
	Primary Soaking Time (hrs.)									
	Initial	1	3	6	12	24	36	48	60	72
Sylhet	22.5	22.5	22.5	22.5	22.5	20.0	20.0	17.5	17.5	17.5
Kushtia	22.5	22.5	22.5	22.5	22.5	20.0	20.0	12.5	10.0	10.0
Local	110.0	110.0	110.0	110.0	107.5	102.5	97.5	87.5	77.5	77.5

The initial salinity of cubes consisting of Local sand is found much higher than that of Sylhet and Kushtia sands.

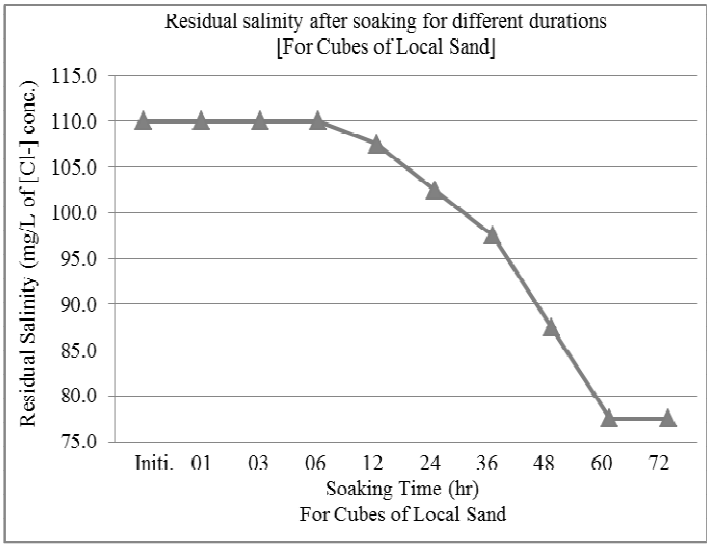

Figure 13: Residual salinity after soaking for different durations in case of cubes containing Local sand

The amount of residual salinity after soaking for different durations in case of mortar cubes composed of Local sand is shown in the figure above.

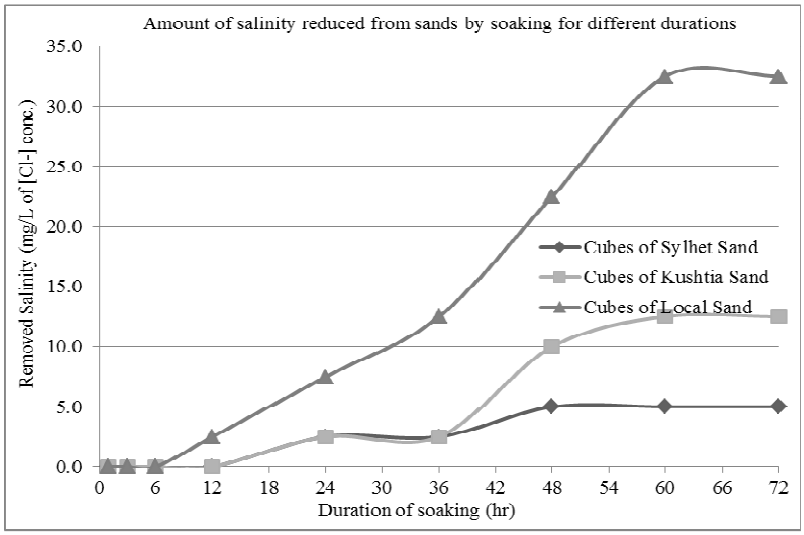

Figure 14: Reduced salinity from mortar cubes of Local, Sylhet and Kushtia sands after soaking for different durations

In Figure 14, the highest curve represents mortar cube of Local sand while the other two represent that of Kushtia and Sylhet sands respectively.
From both of Table 5 and Figure 14, it is clear that soaking for 60 hours is found most effective for cubes of Local sand but for cubes composed of either Sylhet or Kushtia sand, it is 48 hours.

4. CONCLUSIONS

This study was carried out for characterization and easy removal of high salinity content in local bricks and sands in Khulna region.

- Characterization was done by titration to quantify Chloride ions on various particles sizes; among which the size range of 4.75~2.36 mm (B.S. sieve #4~#8) produced an optimum extraction of salinity content.
- Repeated soaking and washing was found to be an easy removal process.

- Optimum soaking period for removal of salinity content was found 60 hours for brick aggregates. [Cl-] concentration reduced from 192.5 mg/L (0.032% by wt.) to 120 mg/L (0.02% by wt.) in 60 hours for a typical local brick brand.
- Optimum soaking duration for Local sands was found 48 hours. [Cl-] concentration reduced from 190 mg/L (0.031% by wt.) to 30 mg/L (0.005% by wt.) in 48 hours.
- Optimum soaking time was found to be 3 hours for Sylhet sand while for Kushtia sand, no effects of soaking were found to reduce salinity content. [Cl-] concentration of Sylhet sand reduced from 20 to 17.5 mg/L in its optimum soaking period.
- In case of mortar cubes, soaking for 60 hours was found most effective for cubes of Local sand but for cubes composed of either Sylhet or Kushtia sand, it was 48 hours. [Cl-] concentration of mortar cubes consisting of Local sand reduced from 110 (0.018% by wt.) to 77.5 mg/L (0.013% by wt.) in optimum soaking period, i.e., 60 hours.

Though distilled water was used for research purposes, water from any source that does not contain high salinity content as ground water may be used in the practical field. For example, water from clear ponds or more encouragingly rain water may be used. But underground water or sea water which is rich in salinity content should never be used. A small reservoir built to store rain water can soak thousands of bricks, or a pond may be reserved for this purpose. Distilled water was used in research purposes only to bring out the actual results.

REFERENCES

Aziz, M.A. (1995). *A Text Book of Engineering Materials.* Hafiz Book Centre.

Bakar, B.H.A., Ibrahim, M.H.W., Johari, M.A.M. (2009). A review: Durability of fired clay brick masonry wall due to salt attack. *International Journal of Integrated Engineering, Malaysia.*

Ibrahim, M.H.W. (2011). *Engineering properties and microstructure of brickwork under aggressive environment* (PhD thesis). University Sains Malaysia.

Jenkins, M. (2007). *Repairing Brickwork.* Historic Scotland, Scotland.

Kishore, S.K. *What is efflorescence in bricks and concrete?*

Linda, A.A. (2012). *Effect of salinity on clay brick and masonry structures at selected zones in Khulna* (Unpublished Undergraduate thesis). Department of Civil Engineering, Khulna University of Engineering and Technology (KUET), Khulna-9203, Bangladesh.

Mohr Method. *Volumetric procedure of Chloride measurement.*

Neville, A.M. (1995). *Properties of Concrete* (4th ed.).

Yoder, Lester (1919). Adaptation of the Mohr Volumetric Method to general determinations of Chlorine. *Industrial & Engineering Chemistry,* 11(8), 755.