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# SALINITY MOVEMENT AND DISTRIBUTION IN PREPARED BRICK SAMPLES

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## ABSTRACT

Brick structures due to hygroscopic ability absorb moisture from surrounding environment mainly from soil. The absorbed water rise from bottom to top of the structure through the pores of material. Water evaporates and deposits salt in pores. High salinity of water near coastal area causes damages such as efflorescence, corrosion, deformation etc. to brick structures. In Bangladesh locally available bricks are used for construction work cause they are lighter, cheaper and more locally available than stone. The structures near coastal area are more vulnerable to saline intrution because of high salinity of sea water. Accumulation of salt in pores hamper mechanical strength, aesthetic view of brick structures. The distribution pattern of saline water intrusion needs to be investigated throughly to reduce or solve this problems. For this reasons, in this experimental study salinity movement and distribution in locally available normal clay bricks, machine made bricks and mortar are investigated. Movement and distribution of sodium chloride solution in brick samples is mainly focused in this paper. 12 samples of 4.75”x4.5”x6.5” dimension were prepared by joining bricks with mortar. The samples were wrapped to allow unidirectional movement of water through pores of material. Four sets of experiment were done. Distilled water, tap water, saline water of 2000mg/L and 35000mg/L concentrations were applied to each set respectively. After observing for 105 days salinity test was conducted on the samples. From the observation, it is found that higher porosity indicates higher absorption and evaporation. Bricks with higher porosity are more susceptible to saline intrusion and salt attack near coastal region. Accumulation of salt increases with increase in concentration of saline solution. Distilled water dilutes salt in pores of both brick and motar and removes salt with the movement of water.

***Keywords:*** *Absorption, Evaporation, Salinity movement, Porosity.*

## 1. INTRODUCTION

Even though brick was invented thousands of years ago, it is still popular and widely used as construction material in developing country because it is light, durable and economic. Brick are non-combustible, environmentally friendly and provides heat insulation, sound isolation. Bricks in the presence of moisture absorb it and by capillary uptake moves through the pores and gets distributed. When the moisture evaporates, salt deposits, brick absorbs more moisture and the process continues. It is a natural phenomenon. Soil moisture, humid environment, rain water, water bodies near the structure are the sources of moisture. Similarly brick structures near coastal area absorbs saline water which rises through the pores of material from bottom level to top level. Thus, saline water gets distributed in brick structures near coastal area.

Sea water contains several dissolved salts and among them sodium chloride is predominant. Presence of natural moisture does not affect the mechanical strength of brick. Increase in moisture content alone can decrease mechanical strength of brick (Sathiparan & Rumeshkumar, 2018). In natural condition saline water absorbed by brick structure, migrates through the pores of material and then salt crystal forms when water evaporates. Salt crystallization causes crystallization pressure, tensile stress, deformation of brick (Stryszewska & Kańka, 2017). When the tensile stress in pores exceeds tensile strength of material it causes crack in brick resulting in decrease in mechanical strength. Corossive exposure to sodium chloride environment causes most rapid destruction (Stryszewska & Kańka, 2017). Moreover saline intrution causes efflorescence which arises aesthetic problem.

Cement based materials deteriorates in presence of chloride ion. Chloride ion can enter and diffuse in cement-based materials (Cao, Guo, & Chen, 2019). It results in movement of saline water through mortar. When water evaporates salt crystal forms in mortar pores. Different types of materials have been proposed to mix with mortar, plaster (Karoglou, Bakolas, Moropoulou, & Papapostolou, 2013) for protection brick structure against salt dampness.

Previous researches investigated effect of salt crystallization on deformation (Stryszewska & Kańka, 2017), change in hygric properties (Todorovic´ & Janssen, 2018), moisture transport (Koronthalyova & Bagel, 2015) in brick. The intrusion pattern and distribution of sodium chloride is not fully understandable yet. Due to climate change sea level is rising resulting in increase in saline concentration near coastal area. It is increasing the probability of deformation, degradation, efflorescence of the brick structures near coastal areas. Therefore, salinity movement and distribution in brick and mortar are needed to be investigated to control or to mitigate the problems which arises from saline water intrusion.

## 2. METHODOLOGY

### 2.1 Collection of Bricks

For this investigation, locally available machine-made bricks and normal clay bricks were collected. Machine-made bricks of AFIL and TABL frog mark and normal clay bricks of SONY frog mark were used.

### 2.2 Preparation of Brick Samples

To accomplish this study, the bricks were cut perpendicular to the length into two equal halves. Two brick parts of different brick of same frog mark were joined using mortar. 1:6 mixing ratio was used to prepare mortar using Portland Pozzolana Cement (PPC) and locally available kushtia sand. To allow unidirectional movement of water through the samples and to allow evaporation through upper part of the samples, only specific outer sides were wrapped by pressure-sensitive tapes. Similarly, 12 samples of 4.75”x4.5”x6.5” dimension were prepared. Each of samples were placed in different brick container made of polypropylene. The containers were sealed and air tight using silicon sealant.


Figure 1: Preparation of brick samples

## 2.3 Application of Distilled Water and Saline Solution

The samples were divided into four sets. Each set consisting three samples. Distilled water, tap water, saline solution (NaCl solution) of 2000 mg/L and 35000 mg/L were applied respectively to each set. Distilled water and saline solution absorption data were recorded regularly.

## 2.4 Porosity and Absorption of Bricks

Porosity and 24-hour absorption of water of the bricks were determined to understand effect of porosity on absorption of water.

Table 1: Experimental program.

| **Brick container** | **Brick frog mark** | **Concentration of saline solution (mg/L)** | **Brick container** | **Brick frog mark** | **Concentration of saline solution (mg/L)** |
|---|---|---|---|---|---|
| A-D | AFIL | 0 | A-2 | AFIL | 2000 |
| T-D | TABL | 0 | T-2 | TABL | 2000 |
| S-D | SONY | 0 | S-2 | SONY | 2000 |
| A-T | AFIL | 1250 | A-35 | AFIL | 35000 |
| T-T | TABL | 1250 | T-35 | TABL | 35000 |
| S-T | SONY | 1250 | S-35 | SONY | 35000 |

Here, brick containers are designated as X-Y [where, X= A (AFIL), T (TABL), S (SONY) and Y= D (Distilled water), T (Tap water), 2 (NaCl solution 2000 mg/L), 35 (NaCl solution 35000 mg/L)]

### 2.5 Determination of Chloride Ion in Samples

After observing absorption of distilled water and saline water by the prepared brick samples for 105 days they were removed from the brick containers. The samples were crushed into small pieces. To extract salt properly from the pores ½" sieve passing and #8 sieve retaining brick chips were taken. The samples were soaked into distilled water for 24 hours. Chloride content of the samples were determined using argentometric method.

## 3. ILLUSTRATIONS

### 3.1 Figures and Graphs

Cumulative absorption of different types of solution are shown in figure (2~5) and total absorbed solution by the samples are shown in figure (6). From the observations, it is seen that normal clay bricks absorb more distilled water or saline solution than machine made bricks and is true for solution of different concentration of salt in same environmental conditions. The absorption amount in case of machine-made bricks of two different frog mark is found almost same for same type of saline solution as shown in figure (2~5). Higher absorption means higher evaporation of water. It is found that the absorption of saline water is corresponding to porosity of material. Bricks with greater porosity showed more absorption and evaporation of water than other bricks. According to the porosity of the bricks as shown in table (3) normal clay brick has greater porosity and figure (2~5) confirms that higher porosity indicates higher absorption and evaporation. Total absorption of normal clay brick in 105 days were maximum for different saline solution as shown in figure (6) also confirms it. The exceptional behaviour of A-2 sample may have occurred due to impurities or crack in the brick but that is beyond the scope of this study. High absorption and evaporation eventually deposit large amount of salt which is increased by the increase of concentration of saline solution. Though the total absorption of each sample subjected to 35000 mg/L saline water is lower than other solutions (figure 6) but high amount of salt was deposited. Hence, brick structures with high porosity are more vulnerable to salt attack and saline intrusion near coastal region. Table (2) shows the salinity of the samples subjected to distilled water. Salinity of brick parts in box shows the value of salinity after 105 days and value of other half brick is salinity before 105 days. Salinity of mortar before 105 days were 499 mg/kg and the values in table (2) is after 105 days observation. It is found that in the brick container salinity of the bottom brick decreased and salinity of upper brick increased. It occurred due to movement of salinity from bottom to top. Distilled water diluted the salt in brick and carried toward the flow and when water evaporated salt deposited. Thus, the excess salinity in the upper part of the sample accumulated from bottom parts. Similarly, salinity of the mortar decreased for two of the samples which indicates that salts in the pores of the mortar diluted with distilled water and removed with the movement of water. The salinity of mortar between TABL auto bricks increased. Investigating reasons behind deposition of salt instead of dilution is beyond the scope of this study. To understand this behaviour further investigation is required.

### 3.2 Equations

According to argentometric method,

$$Chloride\ ion\ (mg/L) = (FR - IR - 0.2) \times 24.96478 \times DF \quad (1)$$

Where,
FR= Final burette reading
IR= Initial burette reading
DF= Dilution factor.

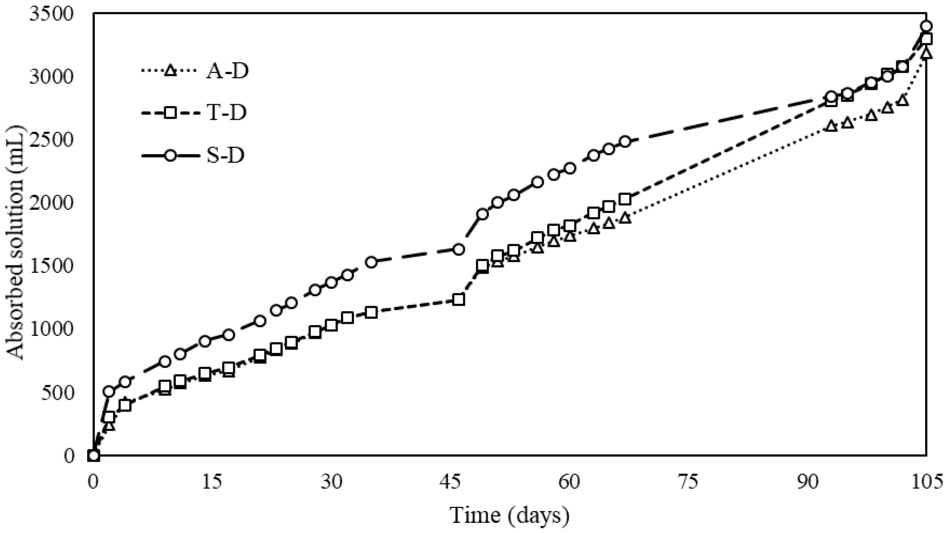


Figure 2: Cumulative absorption of distilled water with time

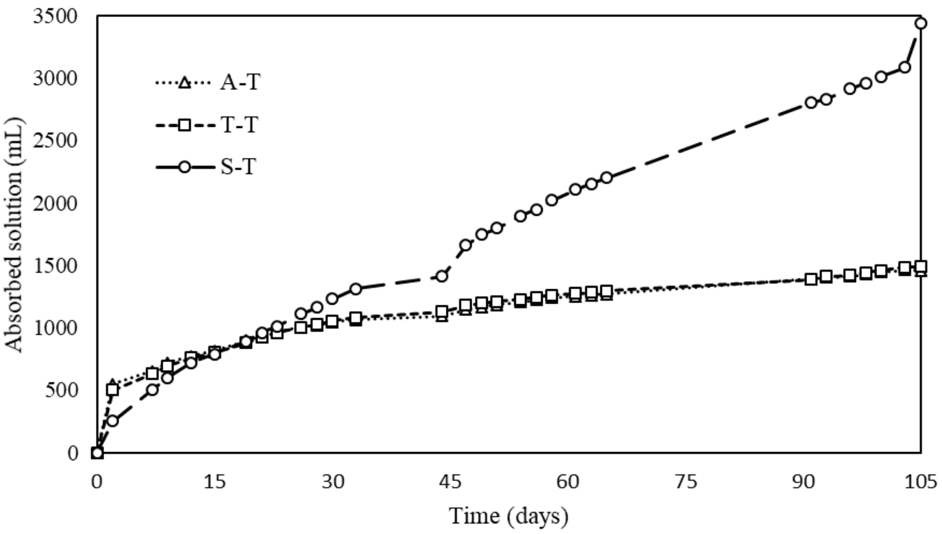


Figure 3: Cumulative absorption of tap water with time

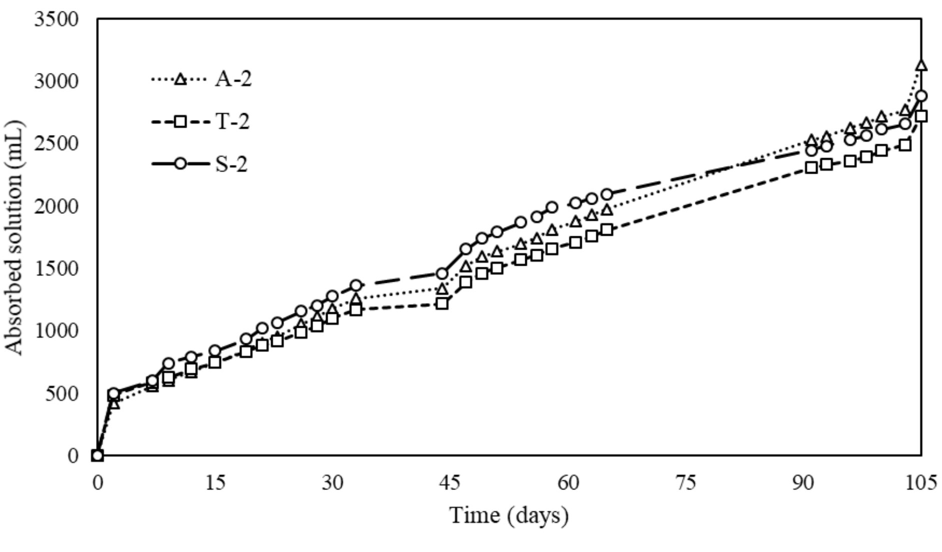


Figure 4: Cumulative absorption of sodium chloride solution (2000mg/L) with time

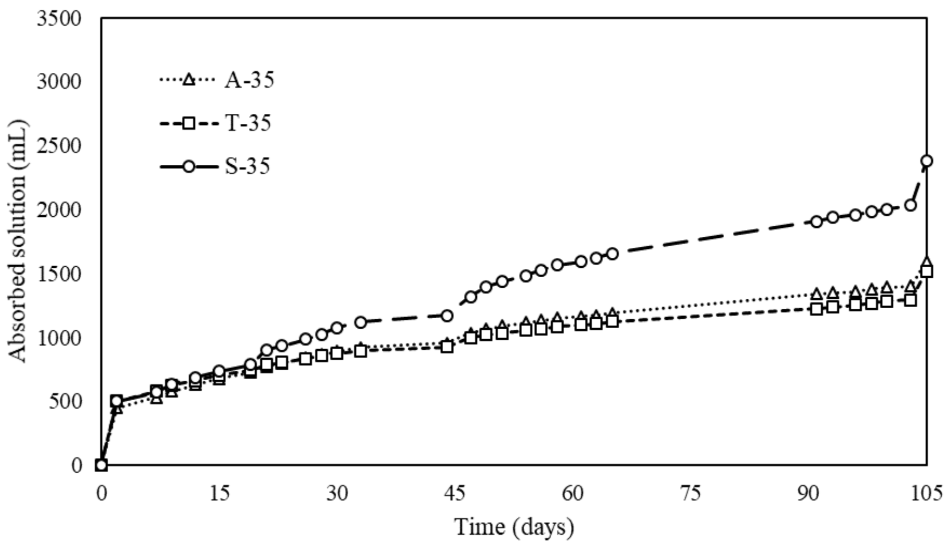


Figure 5: Cumulative absorption of sodium chloride solution (35,000mg/L) with time

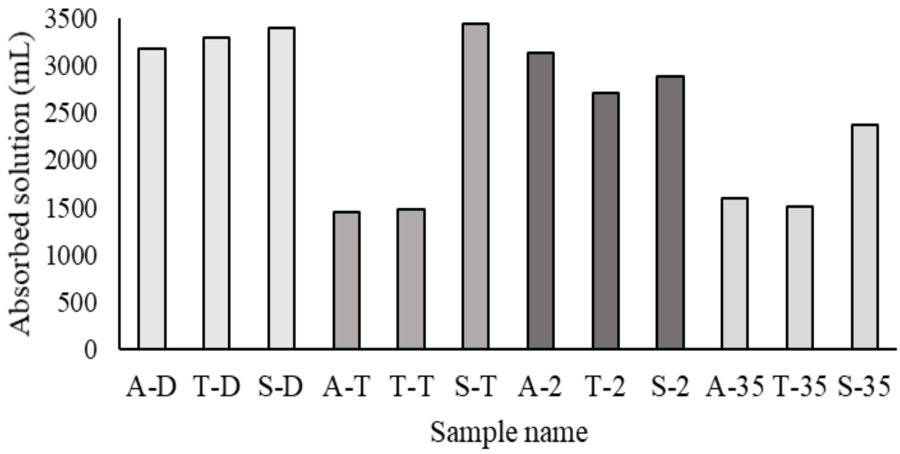


Figure 6: Total absorbed solution after 105 days

### 3.3 Tables

Table 2: Saline distribution in brick

| Solution Type | Brick container | Brick frog mark | Brick parts in box (top/bottom) | Salinity (mg/kg) | Other half of brick | Salinity (mg/kg) | Mortar Salinity (mg/kg) |
|---|---|---|---|---|---|---|---|
| Distilled water | A-D | AFIL | 82 | 583 | 81 | 516 | 383 |
| | | | 72 | 399 | 71 | 649 | |
| | T-D | TABL | H1 | 682 | H2 | 566 | 516 |
| | | | G1 | 399 | G2 | 449 | |
| | S-D | SONY | 8A | 599 | 8B | 499 | 366 |
| | | | 7A | 383 | 7B | 566 | |

Table 3: Porosity and 24 hours absorption of bricks.

| Solution Type | Brick container | Brick frog mark | Brick parts in box (top/bottom) | Other half of brick | 24 hrs Absorption (%) | Porosity (%) |
|---|---|---|---|---|---|---|
| Distilled water | A-D | AFIL | 82 | 81 | 18.04 | 30.57 |
| | | | 72 | 71 | 15.30 | 26.22 |
| | T-D | TABL | H1 | H2 | 12.16 | 22.68 |
| | | | G1 | G2 | 15.43 | 27.64 |
| | S-D | SONY | 8A | 8B | 23.67 | 35.38 |
| | | | 7A | 7B | 19.74 | 31.84 |
| Tap water | A-T | AFIL | 11 | 12 | 16.34 | 29.16 |
| | | | 21 | 22 | 17.15 | 30.26 |
| | T-T | TABL | A1 | A2 | 18.55 | 32.36 |
| | | | B1 | B2 | 14.39 | 26.53 |
| | S-T | SONY | 2B | 2A | 21.80 | 33.52 |
| | | | 1B | 1A | 19.12 | 30.58 |
| Saline water (NaCl solution 2000 mg/L) | A-2 | AFIL | 31 | 32 | 11.39 | 20.22 |
| | | | 41 | 42 | 12.84 | 22.23 |
| | T-2 | TABL | C1 | C2 | 17.21 | 29.88 |
| | | | D1 | D2 | 16.77 | 30.29 |
| | S-2 | SONY | 3B | 3A | 21.43 | 33.21 |
| | | | 4A | 4B | 21.09 | 32.97 |
| Saline water (NaCl solution 35000 mg/L) | A-35 | AFIL | 61 | 62 | 13.96 | 24.41 |
| | | | 52 | 51 | 10.54 | 19.18 |
| | T-35 | TABL | E1 | E2 | 15.65 | 28.49 |
| | | | F1 | F2 | 15.78 | 28.56 |
| | S-35 | SONY | 5A | 5B | 20.55 | 32.51 |
| | | | 6B | 6A | 19.05 | 31.02 |

## 4. CONCLUSIONS

1. Normal clay bricks absorb and evaporate more water than machine-made bricks in same environmental conditions.
2. Higher porosity of brick indicates higher absorption and evaporation.
3. Accumulation of salt increases with increase in concentration of saline solution in the same duration of time.
4. Distilled water dilutes salt in pores of brick and mortar. Diluted salt removes with the movement of water.

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## REFERENCES

Cao, Y., Guo, L., & Chen, B. (2019). Influence of sulfate on the chloride diffusion mechanism in mortar. *Construction and Building Materials*, 398-405.

Karoglou, M., Bakolas, A., Moropoulou, A., & Papapostolou, A. (2013). Effect of coatings on moisture and salt transfer phenomena of plasters. *Construction and Building Materials*, 35-44.

Koronthalyova, O., & Bagel, L. (2015). Moisture transport in salt free and salt contaminated ceramic bricks. *6th International Building Physics Conference* (pp. 1401-1406). Bratislava: Elsevier Ltd.

Sathiparan, N., & Rumeshkumar, U. (2018). Effect of moisture condition on mechanical behavior of low strength brick masonry. *Journal of Building Engineering*, 23-31.

Stryszewska, T., & Kańka, S. (2017). The effects of salt crystallization in ceramic bricks in terms of line. *International Conference on Analytical Models and New Concepts in Concrete and Masonry Structures* (pp. 120-127). Cracow: Elsevier Ltd.

Todorovic´, J., & Janssen, H. (2018). The impact of salt pore clogging on the hygric properties of bricks. *Construction and Building Materials*, 850-863.