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Evaporative Salinity Movement Pattern through Different Types of Brick Setup

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Abstract

Brick is basically a porous material. Brick buildings absorb moisture this way. This coastal area may have salt-contaminated groundwater and soil moisture. Thus, salt may severely destroy the bricks. Salt water seeping into the basement floor may evaporate, leaving a salty residue in the building's fissures. The brick structure is threatened by salt crystallization and pressure. The brick building may be brittle. Understanding how salty water flows through brick and distributes saltiness is critical. In this study, the tests for investigation of salinity movement through brick samples are analyzed. The tests were performed in two different sets. The equations of saline water absorption or evaporation and salinity distribution are developed for two different sets of tests. Again, the 65th and 105th day saline water absorption for the first set is determined for different concentration by using developed equation though test was performed for 77th day. The nature of salinity distribution through brick at different concentrations and conditions are studied. The variation of absorption or evaporation pattern at two different set up under similar concentration are analyzed. For distilled water, the higher absorption or evaporation rate is observed for first set up but using saline water of different concentration, the second set up shows higher absorption or evaporation rate. The study is performed to show that absorption of saline water or evaporation generally decreases with increasing concentration.

Keywords: *Salinity, Crystallization, Absorption, Evaporation, Concentration*

1. Introduction

Brick is most widely used building and construction materials throughout all over the word including Bangladesh because it is low costly, eco-friendly and easily available. Brick absorbs moisture because it is porous. Moisture comes from soil, humidity, rain, and nearby water. In coastal region where there is a problem of salinity or where the natural water contains large amount of salinity, bricks used in different construction purposes like building construction, bridge construction etc. absorb salt with the water. The water evaporates but the salt contents may deposit into the pores (Barua & Bari, 2020).

The amount of salt that is present in either the soil or the water is what is meant to be measured when referring to salinity. The salinity of water or any other liquid can be conceptually understood to refer to the amount of dissolved salt present in the liquid. The movement of salts through porous masonry materials such as bricks, stones, concrete, and other similar materials is known as salinity movement. This movement occurs as a result of the porous materials' ability to absorb moisture. The salts are dissolved in the water that is absorbed by the materials, and as the water evaporates, crystals of salt are left behind inside the pores. Chlorides, sulfates, and nitrates are the three types of salt that are found in masonry materials the most frequently (Delgado et al., 2016).

The porosity of bricks makes salt attack on masonry buildings a persistent problem. Salt crystals continue to grow larger even as the bricks continue to absorb more water and the rate of evaporation increases as the salinity varies, causing the salt to settle in the pores of the bricks. This causes the salt to form crystals. Sodium chloride predominates among the dissolved salts in sea water, which are numerous. The mechanical strength of brick is unaffected by the presence of natural moisture. But brick's mechanical strength can be reduced by an increase in moisture content alone (Sathiparan & Rumeshkumar, 2018). When salty water is absorbed by a brick construction, the water evaporates and salt builds up in the pores to produce salt crystals. Salt continuously crystallizes within brick pores, potentially distorting the brick's shape. Tensile stress may also be produced there. Brick may crack if the resulting tensile stress is higher than the tensile stress of brick (Stryszewska & Kańka, 2017).

2. Methodology

2.1.1 Sample preparation

The brick samples without mortar joint are sliced into three equal part and crushed out. The mortar jointed brick specimens are separated and the brick portions and mortar portions are crushed out. Salinity of each portion of samples are determined by measuring chloride content applying titration process.

2.1.2 Materials and Reagents

For measuring salinity basically argentometric method is adopted. 0.1M Silver Nitrate Solution ($AgNO_3$) and Potassium Chromate ($K_2Cr_2O_7$) indicator are used. Again, laboratory equipment like burette, conical flask, beaker etc. are very common for this process (Siddique et al., 2014) and (Barua, 2020).

2.1.3 Dilution of liquid samples

The brick samples without mortar joint or the test performed in AUST, the dilution process was adopted and the samples of NaCl concentration more than 1000 mg/l (like 35000 mg/l), 100 times dilution was adopted and 10 times dilution is taken for samples of NaCl concentration less than 1000 mg/l (like 1000 mg/l and 2000 mg/l). The samples were first taken into beaker having 50 ml distilled water. From this, 5 ml is taken; putting into another beaker and 45 ml distilled water is taken and stirred. Thus, 10 times dilution is completed. If again 5 ml is taken from the beaker and after putting into another beaker again 45 ml of distilled water is taken and stirred, then 100 times dilution will be completed (Siddique et al., 2014).For the test performed into KUET, no specific dilution is applied. The 300 mg brick pieces and 100 mg of mortar were soaked into 300 ml and 100 ml of distilled water respectively (Barua, 2020).

2.1.4 Titration

The water after dilution or soaking is titrated using 0.1M $AgNO_3$ with $K_2Cr_2O_7$ indicator. Normally 5ml of water is taken for titration. The titration is continued until reddish color is seen. The chloride ion can be found using the following formula, which is based on the argentometric method,

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

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

2.2 Collection of secondary data

Previous tests have been performed about the observation of salinity transmission through brick samples at two different set up. One test is performed in Ahsanullah University of Science & Technology (AUST) which consist Brick samples without mortar joint and waxed outsides, equally halved lengthwise. The other test is performed in Khulna University of Engineering & Technology (KUET) lab. The secondary data is collected from the previously performed tests.

2.3 Averaging of cumulative absorption of saline water

The cumulative intake or absorption of water for three different samples of a specific concentration were previously determined. Then the cumulative absorption values of three samples were averaged and a single column of cumulative intake or absorption values in prepared.

2.4 Plotting the cumulative intake with respect to time

The cumulative absorption of water is plotted in MS Excel with respect to time. Then the linear equation with coefficient of determination (R^2) for both cases is determined for each concentration of water.

2.5 Plotting the brick height vs salinity distribution curve

The distribution of salinity for three different samples of a specific concentration is plotted with respect to brick height in MS Excel. For each water concentration, the linear equation with the coefficient of determination (R^2) is calculated.

2.6 Comparing the equation at two different cases with similar concentration

The equation at two different set up with similar concentration are then plotted on MS Excel and comparison is shown. The slope of the lines and R^2 is compared for two set up.

2.7 Calculating 65th and 105th day cumulative absorption of saline water for first set up

The 65th and 105th day absorption for first set up is calculated from the developed linear equation for different concentration and compared with the obtained values of second set up.

3. Results and Discussion

Tables 1 to 6 show the average of cumulative absorption of water at various concentrations for two different set up. The figure 1 represent comparison of developed equation of the two set up for concentration 0 mg/l (distilled water). The slope of the equation of first set up (23.204) is smaller than in second set up (26.331). Again, the figure 2 represent comparison of developed equation of the two set up for concentration 2000 mg/l (saline water). The slope of the equation of first set up (20.028) is less than in second set up (21.51). Finally, the figure 3 represent comparison of developed equation of the two set up for concentration 35000 mg/l (saline water). The slope of the equation of first set up (14.308) is greater than in second set up (10.657). For concentration 0 mg/l and 2000 mg/l, the absorption rate or evaporation for second set up is greater than first set up and for 35000 mg/l concentration, the absorption rate or evaporation for first set up is greater. Figure 4 and 5 shows the comparison of salinity distribution at two different set up. The figure 4 and figure 5 (concentration 2000 mg/l and 35000 mg/l respectively) indicates that the salinity distribution increases in both set up, but much higher rate for second set than for first set up because of greater slope.

Table 1. Average of Cumulative absorption of distilled water (0 mg/l)

Time (Days)	Absorption of distilled water			Cumulative absorption of distilled water			Average of the Cumulative values (ml)
	A1(ml)	B1(ml)	C1(ml)	A1(ml)	B1(ml)	C1(ml)	
5	449	448	410	449	448	410	436
8	50	50	50	499	498	460	486
11	200	260	250	699	758	710	722
15	500	400	250	1199	1158	960	1105
25	100	20	50	1299	1178	1010	1162
35	150	100	280	1449	1278	1290	1339
54	300	200	300	1749	1478	1590	1606
77	250	200	600	1999	1678	2190	1956

Table 2. Average of Cumulative absorption of saline water (2000 mg/l)

Time (Days)	Absorption of Saline water			Cumulative absorption of Saline water			Average of the Cumulative values (ml)
	A2(ml)	B2(ml)	C2(ml)	A2(ml)	B2(ml)	C2(ml)	
5	283	332	474	804	787	474	688
8	0	0	210	804	787	684	758
11	200	200	200	1004	987	884	958
15	200	200	200	1204	1187	1084	1158
25	350	150	250	1554	1337	1334	1408
35	200	100	200	1754	1437	1534	1575
54	300	200	300	2054	1637	1834	1841
77	500	250	550	2554	1887	2384	2275

Table 3. Average of Cumulative absorption of saline water (35000 mg/l)

Time (Days)	Absorption of saline water			Cumulative absorption of Saline water			Average of the Cumulative values (ml)
	A1(ml)	B1(ml)	C1(ml)	A1(ml)	B1(ml)	C1(ml)	
5	474	475	450	474	475	450	466
8	200	50	50	674	525	500	566
11	200	200	230	874	725	730	776
15	150	100	200	1024	825	930	926
25	100	150	150	1124	975	1080	1060
35	100	100	100	1224	1075	1180	1160
54	200	100	200	1424	1175	1380	1326
77	320	250	250	1744	1425	1630	1600

Table 4. Average of Cumulative absorption of distilled water (0 mg/l)

Day	Cumulative Absorption of distilled water			Average of absorbed distilled water into the samples (ml)
	A-D (ml)	T-D (ml)	S-D (ml)	
2	240	300	505	348
9	520	548	745	604
14	630	647	905	727
21	775	792	1065	877
32	1087	1085	1430	1201
46	1231	1230	1630	1364
60	1736	1820	2270	1942
65	1841	1968	2427	2079
93	2606	2808	2842	2752
98	2696	2938	2952	2862
100	2756	3013	2997	2922
105	3181	3297	3392	3290

Table 5. Average of Cumulative absorption of saline water (2000 mg/l)

Day	Cumulative Absorption of Saline water			Average of absorbed Saline water into the samples (ml)
	A-2 (ml)	T-D (ml)	S-D (ml)	
2	420	485	500	468
9	605	625	740	657
15	745	745	840	777
23	955	915	1065	978
33	1257	1167	1360	1261
49	1592	1462	1737	1597
58	1810	1657	1987	1818
65	1976	1807	2097	1960
91	2526	2307	2447	2427
96	2626	2362	2532	2507
100	2716	2440	2612	2589
105	3132	2715	2878	2908

Table 6. Average of Cumulative absorption of saline water (2000 mg/l)

Day	Cumulative Absorption of Saline water			Average of absorbed Saline water into the samples (ml)
	A-2 (ml)	T-D (ml)	S-D (ml)	
2	420	485	500	468
9	605	625	740	657
12	670	695	790	718
26	1053	990	1155	1066
33	1257	1167	1360	1261
44	1342	1217	1460	1340
51	1637	1502	1792	1644
58	1810	1657	1987	1818
65	1976	1807	2097	1960
91	2526	2307	2447	2427
103	2769	2490	2658	2639
105	3132	2715	2878	2908

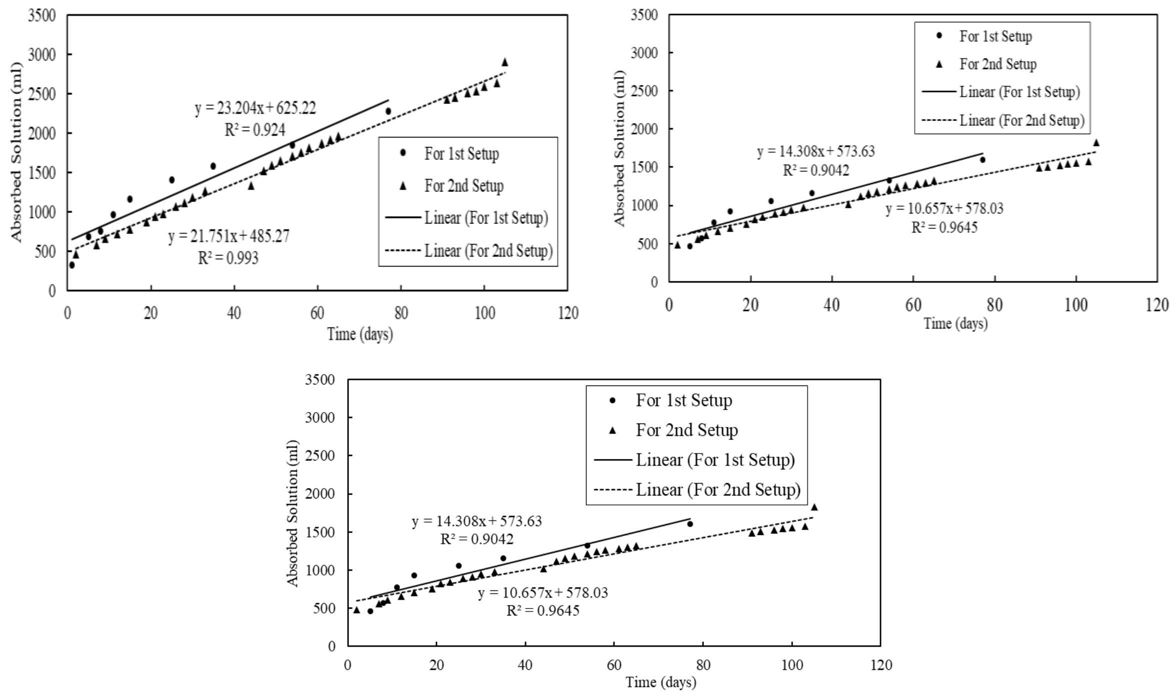

Figure 1. Cumulative value of the average absorption of water (for concentrations 0, 2000 and 35000 mg/l) vs time at two different set up

Table 7. Average Salinity distribution g/kg at three equal heights of brick specimens (2000 mg/l) for 1st setup

Brick Height (cm)	**A1 (g/kg)**	**B1 (g/kg)**	**C1 (g/kg)**	**Average Salinity (g/kg)**
8.043	17.6682	12.9879	13.5729	14.743
16.086	35.8045	18.7213	38.7296	31.0851
24.129	61.5462	22.3485	51.0155	44.9701

Table 8. Average Salinity distribution g/kg at three equal heights of brick specimens (35000 mg/l) for 1st setup

Brick Height (cm)	**D1 (g/kg)**	**E1 (g/kg)**	**F1 (g/kg)**	**Average Salinity (g/kg)**
8.043	93.1384	122.273	116.54	110.651
16.086	175.044	169.194	204.179	182.806
24.129	251.099	251.099	245.132	249.11

Table 9. Average Salinity distribution g/kg after absorption of water (2000 mg/l) for 2nd setup

Different part	**Salinity absorption for different container (g/kg)**			**Average of Salinity Absorption (g/kg)**	**Brick Height (cm)**
	A-2	**T-2**	**S-2**		
At Bottom	0.566	0.516	0.616	0.566	3.429
At Mortar portion	0.666	0.699	0.732	0.699	8.255
At Top	1.465	1.115	1.032	1.204	13.081

Table 10. Average Salinity distribution g/kg after absorption of water (35000 mg/l) for 2nd setup

Different part	**Salinity absorption for different container (g/kg)**			**Average of Salinity Absorption (g/kg)**	**Brick Height (cm)**
	A-35	**T-35**	**S-35**		
At Bottom	3.162	3.495	7.157	4.605	3.429
At Mortar portion	3.229	2.596	3.695	3.173	8.255
At Top	7.989	10.485	13.148	10.541	13.081

Figure 2 shows the comparison of salinity distribution at two different set up. The figure (for both concentration 2000 and 35000 mg/l) indicates that the salinity distribution increases in both set up, but much higher rate for second case than for first set up because of greater slope.

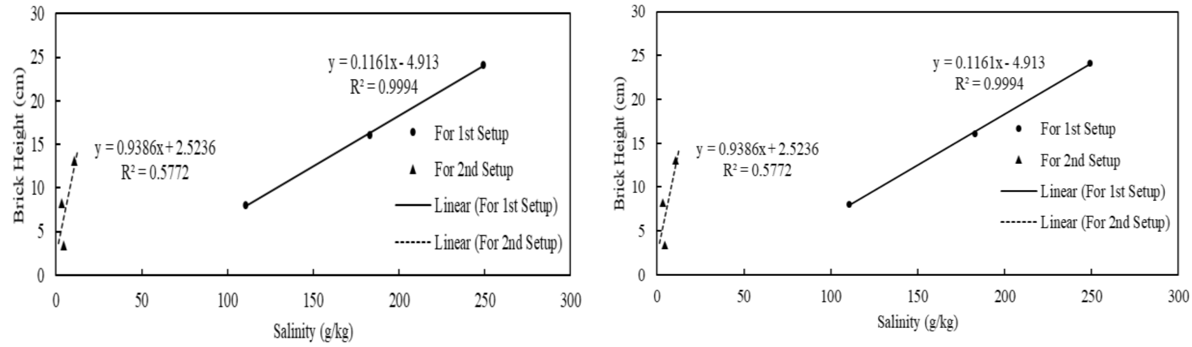

Figure 2. Average salinity of specimens of 2000 and 35000 mg/l concentration of brick height at different set up

The table 11 shows comparison of 65^{th} and 105^{th} day cumulative absorption of water at two set up (brick without mortar joint and waxed, equally halved lengthwise and brick with mortar joint and not waxed, equally halved widthwise).

Table 11. Comparison of 65^{th} and 105^{th} day cumulative absorption of water at two set up

Concentration	**For 1st set up Cumulative absorption of water (ml)**		**For 2nd set up Cumulative absorption of water (ml)**	
	65^{th} day	**105^{th} day**	**65^{th} day**	**105^{th} day**
0 mg/l	1828	2629	2079	3290
2000 mg/l	2133	3062	1916	2908
35000 mg/l	1504	2076	1323	1830

4. Conclusions

1. The equations of each concentration for the two conditions are compared.
2. The absorption of saline water generally decreases with increasing concentration for both cases; brick samples equally halved lengthwise, without mortar joint between the pieces and brick samples equally halved widthwise, with mortar joint between the pieces.
3. The evaporation also decreases with increasing NaCl concentration as evaporation directly related to absorption. But reverse phenomena are observed for 0 mg/l and 2000 mg/l for first set up of samples.
4. The distribution of salinity generally has increased with increases with increasing concentration for both cases.
5. The 65^{th} and 105^{th} day water absorption of different concentration for first set up are determined and compared with the obtained value of second set up.

References

Barua, S., & Hamidul Bari, Q. (2020). Salinity Movement and Distribution in Prepared Brick Samples. *5 Th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020), Bangladesh*.

Delgado, J. M. P. Q., Guimarães, A. S., De Freitas, V. P., Antepara, I., Kočí, V., & Černý, R. (2016). Salt Damage and Rising Damp Treatment in Building Structures. *Advances in Materials Science and Engineering*, *2016*. https://doi.org/10.1155/2016/1280894

Ishtiak Imam Siddique, Rafi Redwan, & Md Jafrul Alam. (2014). *Effect of Salt Water Movement in Brick Masonry due to Climate Change*. Ahsanullah University of Science and Technology.

Sathiparan, N., & Rumeshkumar, U. (2018). Effect of moisture condition on mechanical behavior of low strength brick masonry. *Journal of Building Engineering*, *17*, 23–31. https://doi.org/10.1016/j.jobe.2018.01.015

Showman Barua. (2020). *Salinity distribution through absorptive movement in bricks and mortar setup*. Khulna University of Engineering and Technology.

Stryszewska, T., & Kańka, S. (2017). The Effects of Salt Crystallization in Ceramic Bricks in Terms of Line Deformations. *Procedia Engineering*, *193*, 120–127. https://doi.org/10.1016/j.proeng.2017.06.194