Use of poulticing in desalination of masonry units – implications on salt deteriorated structures

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Abstract

Cellulose poulticing is a widespread method of desalination in practice for removal of salts from historic structures. Optimization of the process is essential, considering that poulticing/desalination is the prime step during the protection of existing structures in the coastal zone. Even though poulticing is widely used in European countries, it is not being commonly applied in Indian structures, because the principle and efficacy of the method have not been investigated so far for the masonry materials in the Indian historic structures with specific microstructure. The current study investigates the effect of cellulose poulticing in bricks considering the role of different pore sizes in the substrates and the removal of different types of salts depending upon the pore distribution. The process was found around 74% more efficient in removing Na_2SO_4 than NaCl, in materials with more micropores (pore size < 1 μm), as demonstrated from scanning electron microscopy (SEM) images and analysis of pore structure using mercury intrusion porosimetry (MIP) on brick samples. Interesting results on the unsuitability of cellulose poulticing in certain materials and the reasons behind them were obtained, which are based on the predominant transport mechanisms for salt removal. The study would be a reference for initiating cellulose poulticing as a desalination method effectively in the historic coastal structures of Southern India.

Keywords: Desalination, historic structures, protection, conservation, salt weathering

Introduction

Salt-induced degeneration is recognized as one of the most crucial causes of damage for masonry structures[1-3]. Salts introduced into the materials from external exposure can cause crystallization inside the material microstructure owing to the changes in temperature, humidity and depending upon the nature of salt. Repetitive dry-wet cycling increases the concentration of salts inside the pores, causing them to get supersaturated and causing crystallization pressure to the pore wall damaging the material. Hence, periodical removal of salts (desalination) is essential from porous masonry to prevent deterioration, and is also a must pre-repair/protection strategy while approaching salt-deteriorated structures with any kind of treatments. Desalination techniques have not been explored significantly in India, despite the ease of applicability and sustainable economic nature.

Background

Different desalination methods proposed/in use are broadly listed as diffusion (baths)[4], electro-migration, vacuum/water pressure extraction, using barium compounds to insolubilize the salts by intervening at room temperature,[5-7] and methods that use microbiological reaction or microwave ovens[8]. Among these, immersion in water is a generally accepted method for desalination in laboratory studies, but it is impractical for the existing structures. The use of absorbent poultices is one of the most commonly used and an easily adaptable salt removal technique for existing structures. Another solution to the problem of salt removal is the application of products modifying crystallization kinetics. It is reported that such modifiers can alter the supersaturation and permit migration of salts to the surface, by affecting the evaporation rate[9]. For the transport of salts in very fine porous materials where other techniques fail, electrochemical chloride extraction can be adopted. However, the electrical resistance of

the material and the varying tortuosity inside the pore system can adversely affect its efficiency, by causing an inhomogeneous flow of current inside a highly layered and tortuous material structure[10].

Poulticing is considered as the most accepted method of salt removal from existing structures[11,12]. A better understanding of the process with various desalination methods would provide guidelines for the engineers and conservators to efficiently select the poultice material according to the existing exposure condition at the site and the substrate material. The efficacy of the process depends on the transport phenomena in the material, which are indeed determined by the pore structure and pore size distribution. The capillary suction provided by the cellulose poultice to the substrate clearly depends on the size of pores in the substrate[9,13]. Nuclear Magnetic Resonance technology has been used in lab experiments to document the performance of various poultices in contact with common substrates and has demonstrated that the pore size of the substrate needs to be in proportion to that of the poultice for efficient desalination[14]. Different poulticing materials that have been tested in the past are clays, cellulose, minerals like diatomite, fume silica, rock wool and sacrificial mortars in the form of lime - among which clays and cellulose are the most frequently used ones[4,15,16]. Although clays are appreciated for their good adhesion with the substrates, difficulty to cleanly remove them makes their use restricted to objects without any heritage value[17]. Cellulose poulticing is practised well in the western countries and has demonstrated effectiveness in removing moisture as well as salt from structures, especially with high efficacy for brick masonry[18]. Cellulose compounds are easy to work with, have a neutral pH, high plasticity and water absorption, although the adhesiveness is poor (compared to clay) in vertical applications. Hydrophilic mineral wool has been studied for its potential to be utilized for poulticing in masonry materials as an alternative to cellulose, considering its advantages such as faster transport of moisture and salt, repetitive usage etc.[19] However, it could only be used for either

75 water transport (keeping the wool dry) or for salt transport (keeping the wool saturated) at a
76 time.

77 Optimizing the efficiency of poulticing in a particular material by designing the poultice with
78 new materials has been reported by Lubelli and Hees[11]. Besides the pore structure of the
79 substrate, the mechanism of advection by the poultice can differ largely based on the kind of
80 salt to be removed. The mechanism of salt deposition and further crystallization differs for each
81 salt based on the chemical characteristics[20-23]. Kumar and Singh have reported the difficulties
82 faced in the removal of salts from the Mahabalipuram Shore Temple made of granite in Tamil
83 Nadu[12]. Optimizing such situations requires experimental studies revealing the performance of
84 poulticing and its variation with respect to the controlling factors.

85 *Research significance*

86 The increasing risk of salt deterioration to historic structures due to the alarmingly changing
87 climatic conditions and floods has been reported worldwide[20]. Even though flooding is a short-
88 term exposure of salt loads, the resulting dry-wet cycles in the affected structures stay active
89 for years and can even activate deep accumulated salts within the material from various past
90 sources. Recent studies from Europe show that desalination is the most suitable conservation
91 technique, among which poulticing is found as a promising and convenient method for the
92 immobile objects – related to heritage, including historic buildings. However, the transport
93 mechanisms in poulticing systems are not experimentally reported, which is crucial in
94 evaluating the effectiveness and performance of such methods. Despite its very common
95 application in architectural conservation, the method has produced questionable results with
96 different types of poultices, salts and substrates[4,15]. No studies are reported to define the
97 variability in the efficiency of cellulose poulticing depending upon the combination of substrate
98 microstructure and type of salt. The present study addresses this issue, by experimentally

analysing the comparative efficacy of cellulose poulticing in masonry and correlating them to the possible transport mechanisms through microanalytical techniques – using bricks of different microstructures, exposed to different salts.

The current study investigates the effect of cellulose poulticing in bricks considering the factors of different pore sizes in substrates and removal of different salts. Sodium sulphate and sodium chloride are the salts considered in the study. Sodium sulphate is the most deleterious salt causing degeneration in masonry materials, especially in materials with pores less than 1 μm[23,25]. Sodium chloride was studied, considering the fact the most of the affected structures in India lie in the coastal zone where sodium chloride is the major prevailing salt, even though the damage of sodium chloride to the material is much lower compared to that of sodium sulphate, with respect to salt crystallization[24].

Materials and Methods

Properties of samples used

Since pore structure is a critical material property that affects the process of poultice desalination, 2 types of fired clay bricks depending upon their difference in pore structure were selected for the study, which are commercially available and sourced from Chennai, India. The first type of brick sample was denoted as HP – which was a “high porosity” brick, with large pores and low density. The second type was denoted in the study as LP – which represents “low porosity” brick, with more micropores and high density. 40 mm cube specimens were made out of both the brick types (by removing the external exposed surfaces with irregularities from all sides), each with variants of uncoated and coated with 2 different types of protective coatings – one was a silicone-based water repellent (SC), and the other was an acrylic-siloxane based water repellent (AS); these were reported as having entirely different mechanisms of

123 actions in the previous work by the authors[23]. The cubes were cut out of the whole bricks using
124 a diamond blade cutting machine, and by using water as a coolant to prevent any crack
125 formation during the process of cutting. The samples for the tests were thus denoted as HP,
126 HP-SC, HP-AS, LP, LP-SC and LP-AS, where SC and AC represent two different types of
127 water repellent coatings. 3 replicates of each variant of specimens were tested used for all the
128 tests. The physicomechanical and pore structure characteristics of the two brick types HP and
129 LP are given in Table 1. Compressive strength was measured as per IS 3945 (Part 1):1992 for
130 the bricks at a loading rate of 140 kg/cm^2/minute and water absorption was measured according
131 to IS 3945 (Part 2): 1992. UPV (Ultrasonic Pulse Velocity) test was done on whole bricks,
132 using direct transmission method, in accordance with IS 13311-1:1992. Each numerical value
133 in the table is an average of 3 tests on similar samples. Bulk density was measured by Helium
134 gas pycnometer, and porosity and critical pore size were measured by Mercury Intrusion
135 Porosimetry (MIP).

136 *Method of desalination*

137 Cellulose poulticing was used as the technique for desalination in the study. Cellulose powder
138 from Arbocel was used, which has a uniform pore size distribution around 10 μm (with a single
139 peak as critical pore diameter of 10 μm). Dry cellulose powder was mixed for 1 minute with
140 water in the ratio 1:6 (by weight) to form the cellulose pulp. The required water content to
141 provide the poultice with adequate workability depends on the nature and particle size of the
142 particular poultice material. Here, the poultice to water ratio was fixed by trial and error
143 method, with the aim of obtaining a consistency that allows the pulp to mix well, stick to
144 specimens and not flow. The wet poultice was then applied to the surface of the salt weathered
145 specimens with approximately 1 cm thickness on all sides and kept for drying at room
146 temperature (25 ℃) for 2 weeks, with polyvinylidene fluoride film covering for the initial 5
147 days to prevent evaporation. The moisture penetration depth of the cellulose poultice was

148 determined at 24 hours on a separate set of specimens with application of poultice on a single
149 face and was found to vary from 3 to 4 cm. The specimens were conditioned by drying at 40 C
150 until reaching constant mass and then cooling to room temperature before applying the
151 poultice. The moisture penetration was measured using a vernier callipers from the wet depth
152 from surface at mid-length on breaking each sample into two. The maximum drying shrinkage
153 of the poultice was measured as 5%. The poultice was removed on complete drying. The
154 specimens were then washed in water and dried to get desalinated specimens which were later
155 analyzed with microstructural characterization techniques. The process of preparation and
156 application of cellulose poultice on specimens was as shown in Figure 1. The cellulose powder
157 as such is shown, followed by the mixing of cellulose powder with water to form the pulp
158 (poultice) and then the samples covered by the prepared poultice.

159 *Microanalytical characterization techniques*

160 An Emcrafts GENESIS 2100 SEM (Scanning Electron Microscopy) equipment was deployed
161 to visualize the effect of cellulose desalination in the brick samples. Fractured surfaces of the
162 samples of size 5-8 mm were glued to the metallic stubs with carbon tape and were sputter-
163 coated with gold before viewing in the SEM. Secondary electron (SE) detector was used to
164 obtain SE images which showed the morphological features of pores opening up during the
165 desalination process.

166 Mercury Intrusion Porosimetry (MIP) was used to investigate the total open porosity and pore
167 size distribution at a microstructural level for the samples before and after desalination. The
168 instrument calculates the amount of mercury intruded under incremental pressures. Since the
169 pressure is inversely proportional to the pore size, the pore structure features can thus be
170 obtained from this experiment. Samples were first conditioned by drying at 40 ℃ until the
171 mass remains constant. Samples were then prepared as 4 similar small cubical pieces of 3 mm

size approximately from each brick, with a total mass in the range of 0.5-0.8 g. Hence, for a single test, the 4 brick pieces from the same brick are placed in the dilatometer so that the test result considers the average value of them. Using multiple pieces for the same test also ensures high exposed surface area and high accessibility for mercury intrusion. 140-440 Pascal porosimeter instrument from Thermo Scientific was used, which can measure pore sizes ranging from 100 µm to 3 nm, by increasing pressure from vacuum to 400 MPa. The mercury contact angle was assumed as 130º.

Results and discussions

Samples were subjected to accelerated salt crystallization weathering according to RILEM Test no. V 1.b, 1980 for 112 consecutive dry-wet cycles with both sodium sulphate and sodium chloride salts separately. The details of the weathering test methodology followed are given in Table 2. The different degree of damage and different amount of salts inside the samples were because of the pore size distribution of each sample[10,11]. Poulticing with cellulose pulp was applied on all the weathered samples to remove the salts, and the effect of desalination was examined using microanalytical tests like SEM (for qualitative and visual investigation) and MIP (for quantitative analysis).

Scanning Electron Microscopy

The effect of desalination on weathered samples was examined by capturing SEM images on samples before and after desalination. Cellulose poulticing was found effective in removing salts from the pores, for both sodium sulphate and sodium chloride salts, which is illustrated in the SEM images shown in Figure 2-4.

Figure 2 shows the interior of a weathered (with Na_2SO_4 exposure) LP-SC sample after desalination (sample was taken at a depth of 3-5 mm from the surface). Larger pores that opened up without any salts in them are observed in this figure – this is indicative of the

efficiency of cellulose poulticing in removing the sodium sulphate salts from the bricks. EDS spectrum was collected at the open pore observed in the SEM image in Figure 2 and is shown adjacently. It is seen that sulphur was not shown in the spectrum, which is indicative of the absence of sodium sulphate in the pores. The poulticing was also applied in samples subjected to NaCl weathering. Figure 3 shows the surface of a weathered sample (HP) with NaCl exposure, before and after desalination. EDS spectrum of the whole area of the SEM image in Figure 3b also shows the absence of NaCl in the surface from the mineral composition. The weathered surface before desalination (Figure 3 a) clearly exhibited larger NaCl crystals, almost completely covering the exposed area. The image of the sample surface after desalination showed that the NaCl crystals were completely removed from the surface, and in addition, new small pores were opened up from which salts would have possibly been removed. Figure 4 shows SEM images taken on desalinated samples collected 3-5 mm deep from the surface of a weathered uncoated LP sample (with NaCl). The large group of micropores observed shows that NaCl could deposit in pores of such small sizes, and poulticing could remove NaCl salts even from these small pores. However, SEM images are insufficient to quantify the efficiency of salt removal fully.

Porosity measurements

From the assurance that cellulose poulticing practically works for both Na_2SO_4 and NaCl salts, Mercury Intrusion Porosimetry was carried out in the desalinated samples to identify the actual pore structure and pore distribution on weathering, excluding the effect of possible salt deposition.

Total porosities were measured for each specimen - before weathering, after accelerated weathering and after desalination of accelerated weathered specimens, using MIP on samples

collected from 20 mm from the surface. Porosity changes were calculated from the data from MIP tests conducted on the same samples corresponding to the stages of 'before weathering, after weathering and after desalination'. The porosity values were then compared for each type of brick exposed to the various salt solutions (Na_2SO_4 and NaCl) to compare the efficiency of cellulose poulticing to remove salts, as shown in Figure 5. Comparing the change in porosities on desalination among sulphate weathered samples, and chloride weathered samples, a general observation that can be made is that cellulose poulticing is evidently more efficient in removing sodium sulphate salts than sodium chloride salts from the low porosity bricks. Due to the greater occurrence of macropores in the case of HP samples, sodium sulphate salt crystallization and deposition is not highly favoured. The reason is the dissolution-mediated phase transformation of sodium sulphate to reach supersaturations in smaller pores. This process occurs because of the transitions between the two significant stable phases of sodium sulphate called thenardite (Na_2SO_4) and mirabilite ($Na_2SO_4.10H_2O$). Thenardite to mirabilite conversion occurs by process of dissolution and recrystallization. As the relative humidity decreases and evaporation rate increases, an increase in the relative proportion of thenardite is observed. At equilibrium, thenardite is not expected to crystallize at temperatures less than 32.4 °C, but it occurs only at non-equilibrium condition in most porous materials. Below 32.4 °C, mirabilite ($Na_2SO_4.10H_2O$) is the stable phase. Mirabilite rapidly dehydrates at a relative humidity (RH) below 71% (20 °C) to form thenardite. Thenardite will rehydrate to mirabilite when the humidity exceeds 71%. So, a solution that is unsaturated with respect to thenardite may already be highly supersaturated with respect to mirabilite. Figure 6 shows the X-ray diffractograms of bricks affected by sodium sulphate (specimen LP is being shown) in which simultaneous presence of mirabilite and thenardite can be seen. This discussion provides clarity on the severity of damages associated with sodium sulphate salt. In the current case, this is evident from the observation of the negligible difference in total porosity values before and

after desalination in HP, HP-SC and HP-AS samples as seen from Figure 5 (a). LP, with its inherent micropores and newly formed micro-fissures on weathering, facilitated easy crystallization and precipitation of sodium sulphate salts, which were then removed on desalination. Whereas, the difference between total porosities before and after desalination in case of chloride affected samples are much higher (Figure 5 b). This is because NaCl salt does not face phase transitions, but gets precipitated and deposited on evaporation. Hence, a remarkable number of macropores in HP would get filled with NaCl salts. The accumulated NaCl salts from HP were then removed on desalination resulting in an increase of up to 13% total porosity.

In the case of LP, the exposure of sodium chloride solution resulted in the deposition of NaCl crystals in the larger portion of micropores which are abundant in the LP system. Smaller ionic size and easy mobility of NaCl aids its deposition in micropores. Much higher capillary action is required to remove these salts from the micropores - which would result in a decreased efficiency of desalination in LP bricks when affected with NaCl. No difference in trend was observed in case of the samples applied with the water-repellents in all the cases and the reason could be their sacrificial behaviour during the accelerated salt crystallization tests.

Figure 7 shows the differential intrusion curves for the samples at different conditions using the corresponding data derived from MIP test. The peak of each differential intrusion curve represents the critical pore size of the sample, which is the pore diameter corresponding to the maximum mercury intrusion, or it is similar to the most common pore size in the material. Figure 7 a shows the differential intrusion curves for the high porosity brick HP, where the nomenclature for reading the plots is as follows: HP is the curve corresponding to unweathered form of the HP sample, HP Cl is that for HP weathered with chloride salt, HP Cl-de is the desalinated form of HP Cl. This follows similarly for the low porosity brick LP also, in Figure

7 b. The upward shift of curves in the pre-peak region denotes the salt deposition in the pores of that regime. The reversal of this upward shift denotes the removal of salts from those pores. It can be seen from Figure 7 a that the critical pore size does not significantly change in the highly porous brick HP, before and after weathering or desalination. This is because of the inherent high salt weathering resistance of the HP brick due to larger pores in which salt damage is minimum. The salt deposition in the case of HP is evident with chloride and sulphate salts inside the pores, along with the effective removal of those salts (dotted lines), because of the ease of removal from the large pores. In the case of LP, the salt deposition is higher for sodium chloride (which can be seen from the larger area under the curve prior to peak); however, the corresponding salt removal is not very significant, because of the failure of capillary suction to transport salts from such smaller size, when the pore sizes in the poultice are larger than that of bricks. However, the removal of the precipitated sodium sulphate salts can be found more prominent in the case of LP. This is because sodium sulphate gets deposited in the larger pores in the brick matrix (larger than that of the pores in cellulose poultice). These observations are in support of the inferences out of the quantitative porosity analysis.

Figure 8 shows a schematic representation of the matrix of HP and LP bricks with large pores and micropores respectively, where selective deposition of sodium sulphate and sodium chloride crystals is shown. The figures are not drawn to scale. Figures 8 a and 8 b illustrate the sodium sulphate crystals being deposited in the large pores of HP and small pores of LP. In HP, the crystals are not facing any growth restraint; they are in equilibrium and do not cause any crystallization pressure on the pore walls. In LP, there are smaller pores of different size ranges. Sodium sulphate crystallizes and creates crystallization pressure on pores of size between 0.2 and 1 μm predominantly in such type of microporous brick material[23,26]. Pores smaller than 0.2 μm are difficult to access for sodium sulphate crystals to get precipitated. That is the reason why, in Figure 8 b, pores smaller than 0.2 μm remain empty, but salt crystals are

seen in the other pores. Figure 8 c and 8 d show the cases of HP and LP with NaCl precipitation in the pores. In Figure 8 d, because of the very small ionic size and high mobility associated with NaCl, the salt can get precipitated even in pores of size 0.01 μm[11,23]. However, the capillary force induced by the cellulose poultice due to the correlation between pore size distribution of the bricks and cellulose facilitates only salt absorption from pores larger than a particular size[4]. Hence, in Figure 8 d, NaCl crystals do not get removed from some of the pores of LP which are much smaller than that of the ability of cellulose poultice, thus decreasing the efficiency of the desalination process. This would be the possible reason for reduced desalination efficiency in removing NaCl from microporous material (LP) observed in the porosity quantification study presented in Figure 5 b.

The movement of salts can generally happen by the action of diffusion where the ions move owing to the difference in concentrations gradients between nearby areas (with the principle of Fick's laws), and advection where ions move in the direction of flow of water[27]. Diffusion is the more natural process which has been prominent in the case of the current study, between cellulose poultice and the bricks considered here (LP and HP). Advection can be predominant in case of poulticing, because of the moisture state and condition of substrate involved in the process. During the drying phase, when water evaporates out, salt can move along with the liquid and take advantage of the transport direction. Advection is a faster process; however, poultices should be specially designed with smaller pore sizes than that of substrate for facilitating the advective component[11]. The current study suggests that normal cellulose poulticing is not efficient in removing NaCl from the very small pores available in microporous dense materials like the LP bricks here, so process of advection may be further studied by adopting mix compositions for cellulose with materials such as sand, kaoline etc. that forms a pore structure denser than that of LP. If the poultice has a capillary pressure greater than that in the substrate, during the force of poultice drying, advection will govern to extract

salts[14,28,29]. Even when the Washburn's equation establishing the indirect relationship between pore size and the capillary force is valid, it is convenient that the pores in the poultice are not extremely small which slows down the process of salt transport. Hence, the current paper demonstrates the importance of choosing the cellulose poultice material based on the kind of salt and pore structure of substrate unit.

Considering the convenience and ease of using the poulticing technique for desalination, the results from the study can be used to optimize the choice of poulticing to any construction material such as concrete or any kind of stone depending upon their pore structure and the kind of salt to which the structure is exposed. The texture of different materials inside the pores may have an influence on the capillary action, which is not investigated in this study. Any masonry material with a microporous structure such as granite (normally with a critical pore size around 0.01 μm) or concrete (concrete with normal OPC or with blended cements typically has a critical pore size around 0.1 μm) can have NaCl deposition in the micropores if exposed to salt. NaCl is difficult to be removed by cellulose poulticing from the very fine micropores because of the high surface tension of the molecules and the necessity of very high capillary force. Whereas, sulphate exposure can deposit salts only in the available larger pores, which can be easily and effectively removed by cellulose poulticing. Hence the method is recommended for desalination in such materials (microporous) only if the exposure is predominantly to sodium sulphate - which is the most deleterious salt. However, in the case of materials with a large proportion of pores of size greater than 1 μm such as volcanic rocks (basalt, pumice stone), coral stones, perforated or air-entrained concrete etc., either chloride or sulphate salts would be seen precipitated in the large pores, and these can be effectively removed with cellulose poulticing technique. For the microporous materials such as granite or microporous bricks in the coastal areas, this paper emphasises the need for future studies for

desalination on techniques like electromigration, or poulticing combined with electromigration.

Conclusions

- SEM images showed that cellulose poulticing was found to be effective in removing both sodium sulphate and sodium chloride salts from the surface of any material. The requirement of capillary force by the poultice to deploy the suction of salts was found relevant only to the interior of the material where salts deposit inside the pores.

- On comparing the efficacy quantitatively by evaluating the total porosity using MIP on salt weathered samples before and after poulticing at the interior (depth of 20 mm from the surface), it was found that the process of desalination was around 74% more efficient in removing sodium sulphate salts than sodium chloride salts, in materials with more micropores (pore size < 1 μm). This is applicable in the case of any material irrespective of the chemical nature, like bricks, stones (e.g. granite), concrete or mortar that satisfies the prescribed pore size ranges.

- If the material is mostly comprised of macropores (pore size > 1 μm), desalination by cellulose poulticing is equally efficient to remove sulphate and chloride salts. This is valid for materials such as coral stone, volcanic stones like basalt, laterite, lightweight concrete etc.

- The study shows the inefficiency of cellulose poulticing for the complete removal of NaCl salts from more microporous system, where other advanced methods like advection by designing a poultice with finer pore system or electrokinetic desalination with migration component may be adopted as per the necessity.

Conflicts of interest

None

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468 **Tables**

469 Table 1. Physico-mechanical and pore structure properties of the samples

Characteristics	HP	LP
Dimensions (mm)	220x110x50	220x110x50
Image		
Compressive strength (MPa)	8.1	12.3
Bulk density (g/cc)	1.65	2.10
Water absorption (%)	18.4	10.3
UPV (m/s)	1400	1950
Porosity (% from MIP)	49	31
Critical pore size (µm from MIP)	11.1	6.1

470

471 Table 2. Particulars of the accelerated weathering test adopted

Solution concentration	For sulphate weathering test: 10% Na_2SO_4 anhydrate solution For chloride weathering test: 15.6% NaCl solution
Duration of 1 cycle	24 hours: 2 h immersion, 19 h drying at 60 ^oC, 3 h room cooling (~ 27 ^oC)
Sample size	40 mm cubes

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Figures Legend

Figure 1. Steps followed in the process of poulticing (a) cellulose powder in the dry form (b) mixing of cellulose powder with water to prepare the poultice (c) samples covered with the cellulose poultice left for drying

Figure 2. Interior of weathered (with Na_2SO_4) LP-1 sample after desalination

Figure 3. Surface of weathered (with NaCl) uncoated HP sample before and after desalination

Figure 4. Interior of weathered (with NaCl) uncoated LP sample after desalination

Figure 5. Comparison of total porosity values before and after desalination on (a) Samples weathered with sodium sulphate (b) Samples weathered with sodium chloride

Figure 6. X-ray diffractogram of sulphate weathered LP brick sample showing presence of mirabilite and thenardite

Figure 7. Differential Intrusion Curves of samples at different conditions (a) For the high porosity brick sample HP (b) For the low porosity brick sample LP

Figure 8. Schematic representation of matrix of different samples showing crystallization of salts in corresponding pores. (a) Sodium sulphate deposition in HP (b) Sodium sulphate deposition in LP (c) Sodium chloride deposition in HP (d) Sodium chloride deposition in LP

Figures

Figure 1. Steps followed in the process of poulticing (a) cellulose powder in the dry form (b) mixing of cellulose powder with water to prepare the poultice (c) samples covered with the cellulose poultice left for drying

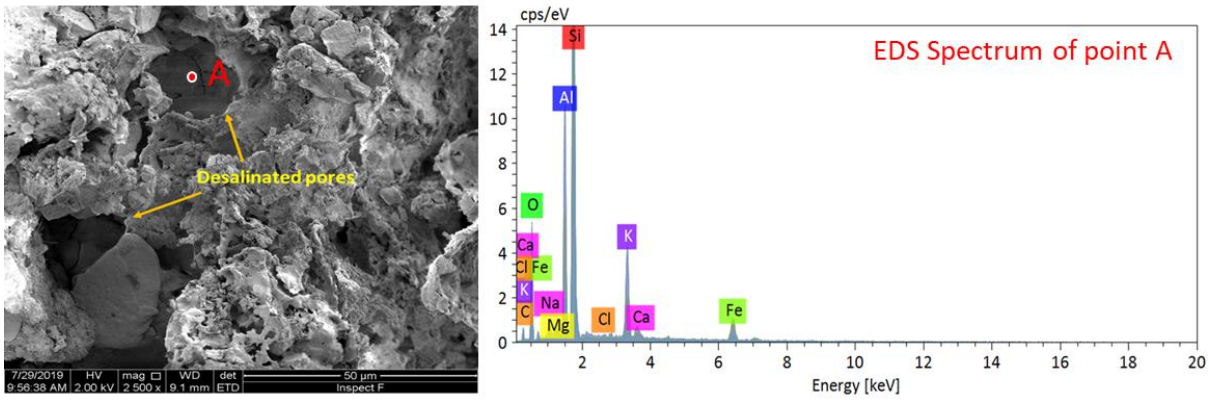
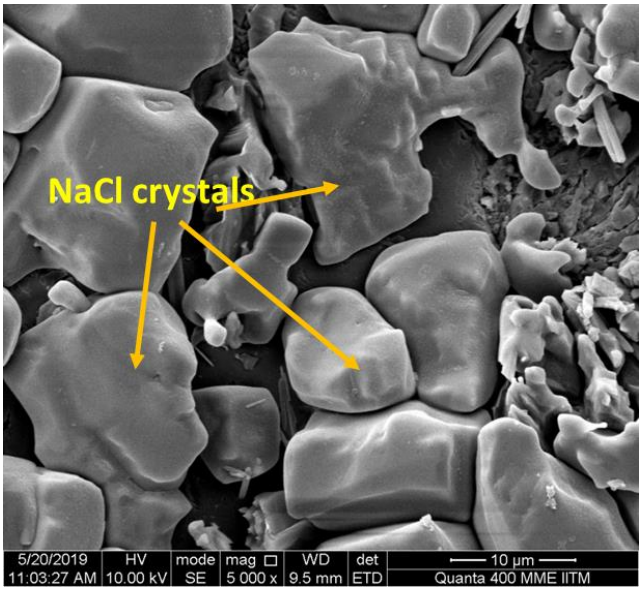
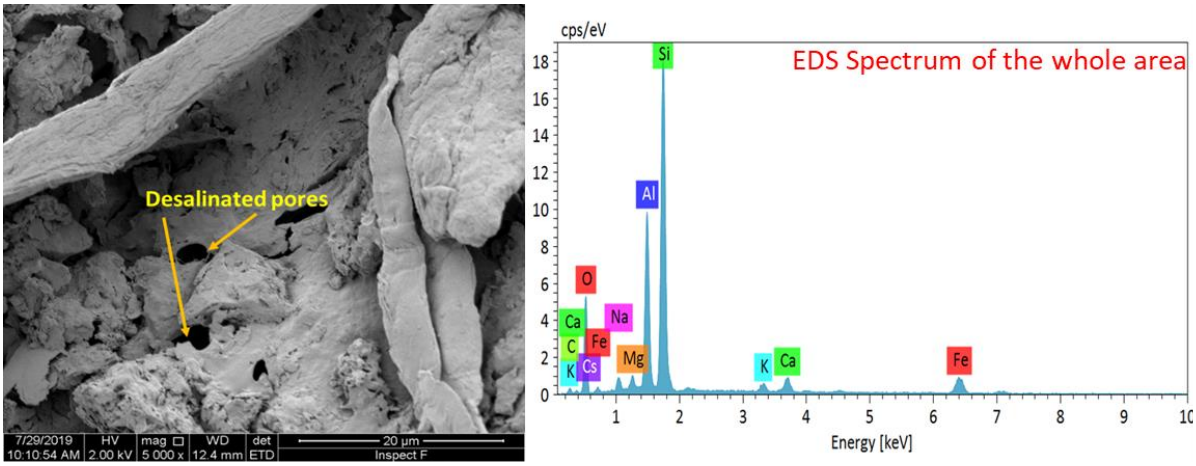


Figure 2. Interior of weathered (with Na_2SO_4) LP-SC sample after desalination, with the EDS



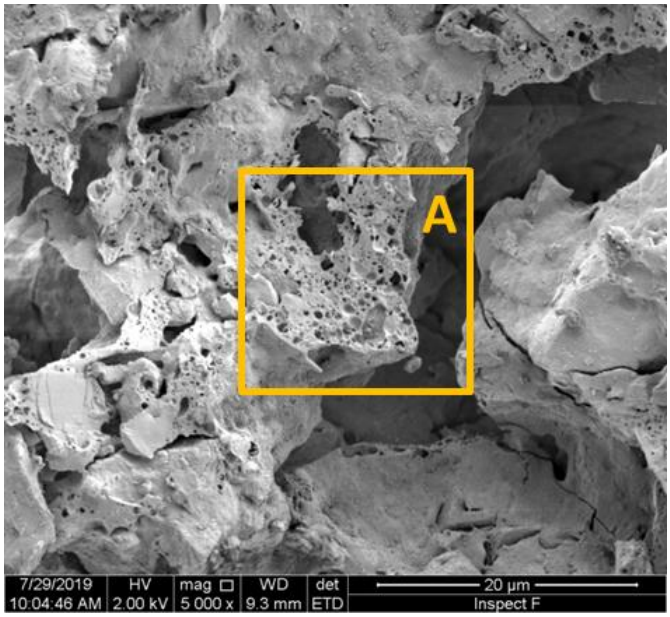
(a) Surface of a weathered uncoated HP sample showing NaCl crystals



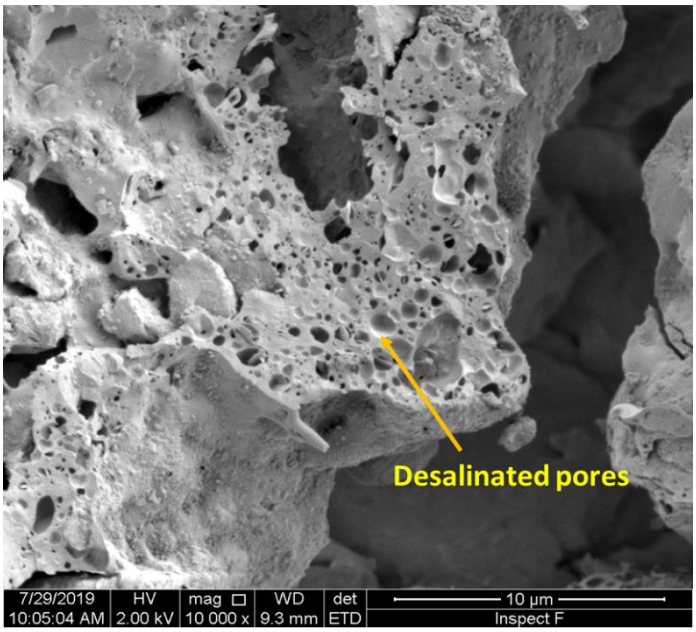
(b) Surface of the sample after desalination showing pores opened-up, with the EDS spectrum

501 Figure 3. Surface of weathered (with NaCl) uncoated HP sample before and after desalination

502



(a) Interior of the desalinated sample showing micropores



(b) Magnified view of 'A' marked in the previous figure

503 Figure 4. Interior of weathered (with NaCl) uncoated LP sample after desalination

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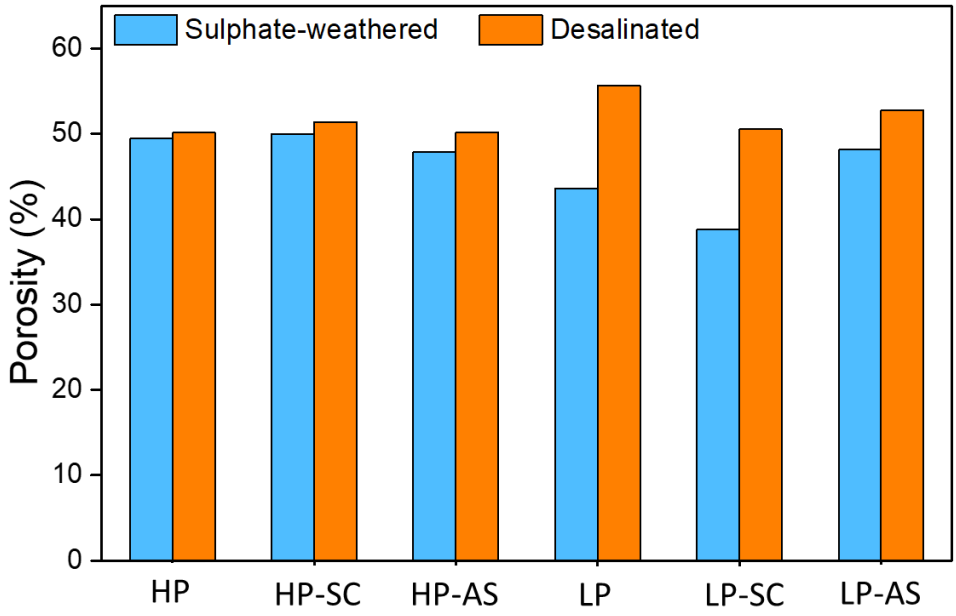
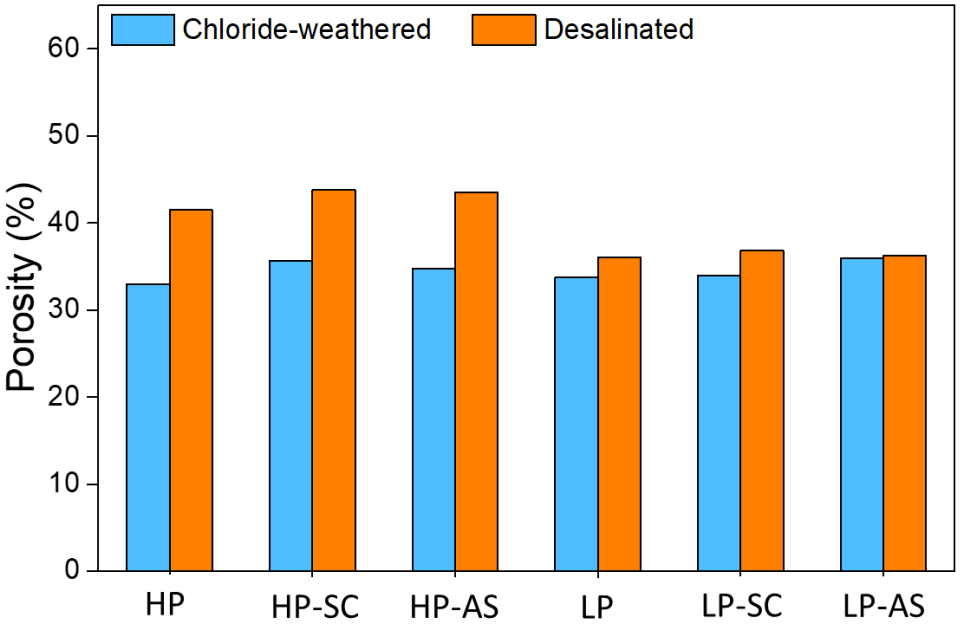


(a)



(b)

506 Figure 6. Comparison of total porosity values before and after desalination on (a) Samples

507 weathered with sodium sulphate (b) Samples weathered with sodium chloride

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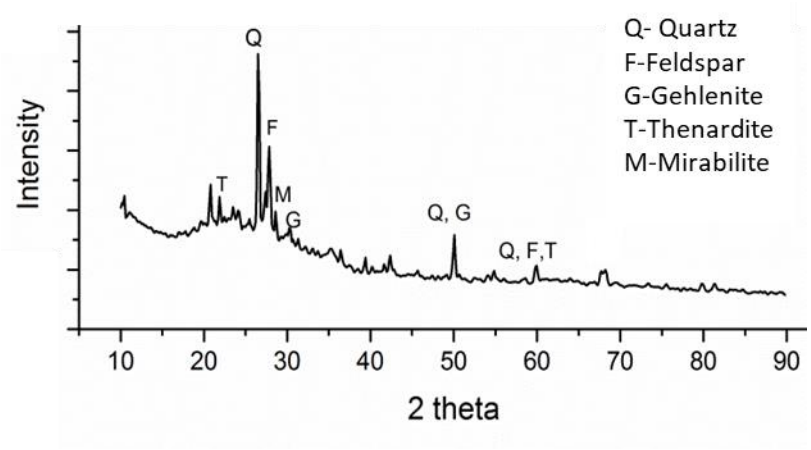

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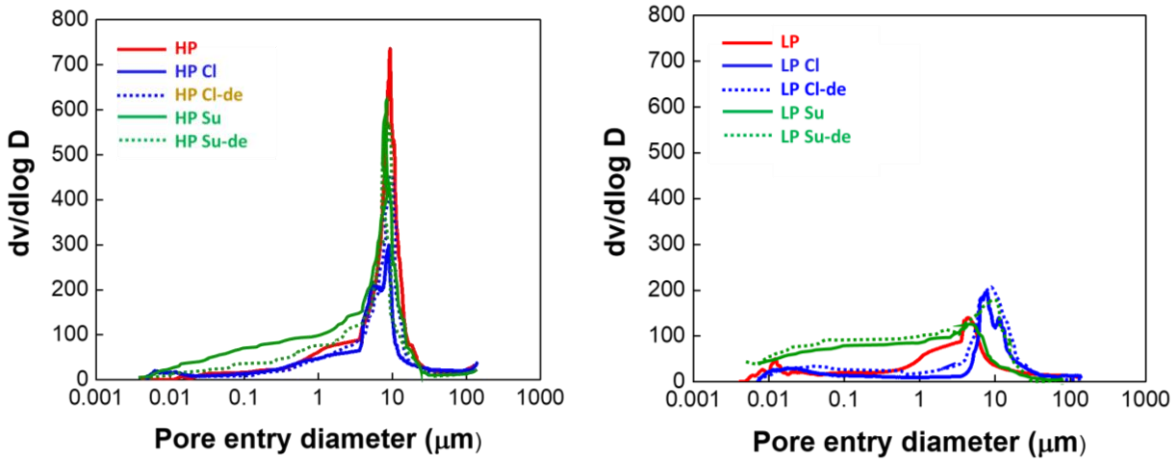
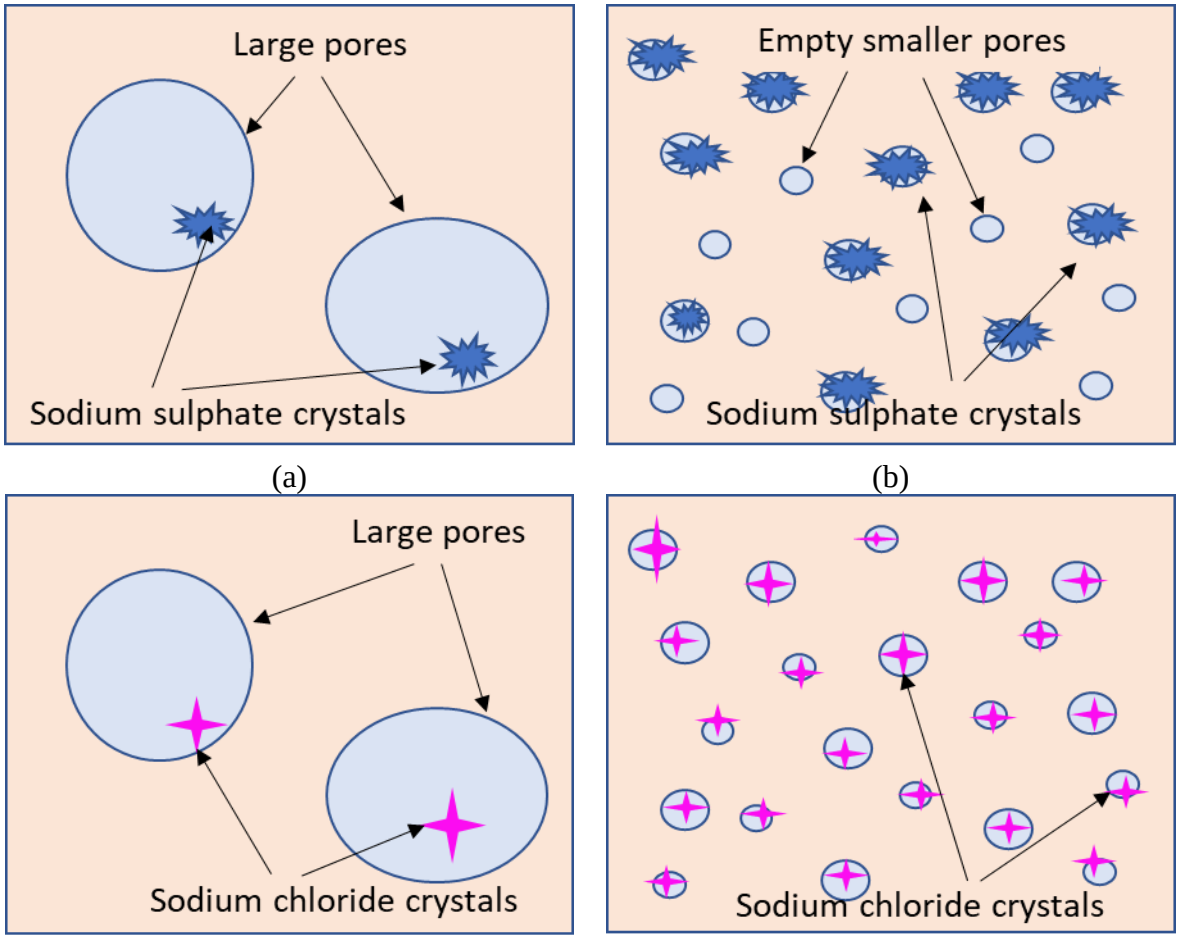


(a) (b)

Figure 7. Differential Intrusion Curves of samples at different conditions (a) For the high porosity brick sample HP (b) For the low porosity brick sample LP



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520 deposition in LP (c) Sodium chloride deposition in HP (d) Sodium chloride deposition in LP

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