ANALELE UNIVERSITĂȚII
“EFTIMIE MURGU” REȘIȚA
ANUL XXIV, NR. 1, 2017, ISSN 1453 - 7397

Appraisal of Salt Crystallisation and Rising Damp Problems in Building

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It should be pointed out that salt crystallisation and rising dampness are two separate but interconnected processes. Both of these damages must be understood if damage is to be minimized and if corrective measures are to be successful. However, the term rising damp has been usually used to cover both aspects, it tends to overlook the role of salt, and issues that will increasingly significant due to the buildings are getting older and as the soils are becoming more saline. Hence this paper will focus on background and an understanding of salt crystallisation and rising damp problems. Furthermore, the discussion also will include the indications, causes and effects of both damages.

Keywords*: salt crystallisation, rising damp, building defects, historical building, dampness*

1. Introduction.

Salt crystallisation is used to describe the damage caused by soluble salt crystallising within the pores of masonry materials. Salts are brought into the porous masonry in solution in water by a variety means included rising damp. During the dry period, when the moisture evaporates from the masonry wall, the salts will be left behind due to salts cannot be evaporated and the salt solution residue in the wall will become more and more concentrated as time goes by. More and more salt solution will be brought into the wall and accumulated, thus the wall become more and more concentrated. At some point where the solution is reaching a condition which is saturation, or super-saturation, crystals will begin to form in the wall [1].

When the evaporation rate from the wall surface is low, the evaporative front may be at or very the surface, in this case salt crystal will grow as long thin needles, extruding from the wall surfaces. These long thin needles made up by salt crystal are known as efflorescence and they are commonly seen as a relatively harmless white powder on the surface of wall.

In the case of greater evaporation rate, the evaporative front will be inside the wall and salts will be crystallising within the pores of the masonry which is known as sub-florescence. The force exerted by the sub-florescence is sufficient to disrupt the masonry material [2].

2. Salts

Salts consist of a combination of positively and negatively charged ions known as cations and anions. The cations commonly encountered in wall are Sodium (Na^+), Potassium (K^+), Magnesium (Mg^{2+}) and Calcium (Ca^{2+}). The anions commonly in wall are Chloride (Cl^-), Sulphate (SO_4^{2-}), Nitrate (NO_3^{2-}) and Carbonate (CO_3^{2-}). Salts may consist of a combination of any cation with any anion, provided there is a balance of positive and negative charges. Hence, sodium chloride which is known as table salt is written in NaCl. The combination of cation and anion which commonly can be found causing salt crystallisation in walls are sodium chloride, sodium sulphate and calcium sulphate. Calcium sulphate is also known as gypsum. Based on the basic salts chemistry, the chemical reaction of the ions can be pictured. When a salt is dissolved in water, it is dissociated into ions. For example,

$$NaCl + H_2O \rightarrow Na^+ + Cl^-$$

When the compounds formed by the crystallisation of a solution can be deriving from the reaction of an acid (eg. HCl) with a base (eg. NaOH).

$$HCl + NaOH \rightarrow H_2O + Na^+ + Cl^-$$

$$Na^+ + Cl^- \; H_2O - \textit{evaporation} \rightarrow NaCl \; \textit{(crystals)}$$

The ions are making up into these salts may be of purely natural origin or may be sourced from other compounds deliberately applied to roads or walls. They may come from the pollutants in the air or water. Alternatively, salts can also come from the masonry material itself. The reason salts incur a problem to masonry wall is due to they are soluble and can be dissolved and crystallized, often within the pores of the masonry at the point of evaporation [3]. Different salts has different solubility characteristic, and their effects to the masonry are different from others. Some are able to take up water from the air, and some can change structure as consequences of hydration and dehydration. The deterioration of the salt towards the masonry material has a relationship with the solubility of the salts. For example:

- *Practically insoluble* salts do not produce any dangerous or disruptive crystallisation. Despite of their poor solubility enable them to reach saturation in the material, the concentrations at saturation are minimal and they are insufficient to cause any destruction or damages.

- *Slightly soluble* salts are generally more dangerous as compared to practically insoluble salt. Due to their slightly soluble characteristic, they are able to crystallize just below the surface layer and cause bulging, detachment and loss of fragments. Among these, gypsum which is calcium sulphate is the predominant salt ($CaSO_4 \cdot 2H_2O$), which is susceptible to crystallize even in a humid climates. Thus, it has become the principal cause of deterioration.
- *Highly soluble* salts generally consist of the anions of chlorides (Cl^-) and nitrates (NO_3^{2-}). For instance, sodium chloride (NaCl), sodium
- nitrate ($NaNO_3$) and potassium nitrate (KNO_3). These salts can be accumulated and reached to a very high concentration of highly hygroscopic salts which therefore remain in solution in humid environments and thus, producing dark patches on the wall. In a drier condition, efflorescence appears when crystallization occurs. However, due to the highly soluble characteristic, crystallization requires strong evaporation that takes place.

The amount of salt required to cause damage will be varied. Basically, it depends on the type of salts involved, the nature and condition of the masonry including the pore structure such as the pore size and pore distribution and the cohesive strength of the material. Moreover, salt crystallisation does not happen in few days. It is the accumulation from day to day and year to year. Hence, salt crystallisation is not easy to be found in newly built buildings but an inheritance or heritage buildings [4].

Salts can be easily transported onto and into masonry in many ways, such as by capillary action from the groundwater and soil water, pollutants in the air or water, rainwater in rainfall and driving rain, in fog and dew, household cleaning detergents and other sources. Building receives salt from multiple sources, thus it is very susceptible to salt attack.

3. Indications of Salt Crystallisation

The presence of the salts within the masonry wall can be detected through the formation of the salt efflorescence on the surface of the wall. The white salt residues can be found on the affected walls and columns. It can be seen by naked eyes. Other symptoms of salt crystallisation include the presence of blistering and flaking of the plastering works. The plastering works can be spalling and crumbling. Hollow sounds on the plaster can also be the symptom of salt attack. Such loosening and detachment of surface flakes is consistent with the subsurface salt crystallisation and it is known as sub-florescence.

As mentioned earlier, salt crystallisation and rising damp are interrelated process. Thus, normally walls that are affected by the salt contamination are also susceptible damaged by rising damp problem. Rising damp occurs from the ground level and rise up to the wall. Hence, the area where salt contamination occurred can be spotted. Rising damp can easily be detected by using a non-destructive method which is moisture meter. Moisture meter can be placed at the area where it is suspected to be damaged by rising damp; the level of the moisture contained in the wall can be read from the reading of moisture meter. Figure 1 visualizes salt attack problem in bricks causing disruption and loss of the fireskin, the harder outer surface that develops during firing in the brick kiln [5].

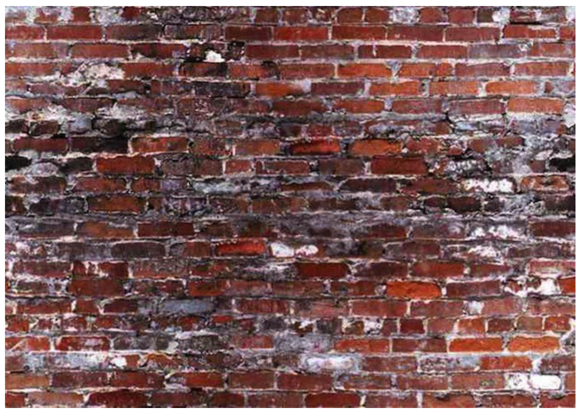

Figure 1. Salt attack problem in bricks causing disruption and loss of the fireskin, the harder outer surface that develops during firing in the brick kiln

4. Causes of Salt Crystallisation

In early 1900s, installation of Damp Proof Course (DPC) is not common in construction. Thus, the moisture from the ground is easily being soaked up through capillary action to the masonry walls. The moisture will dissolve the soluble salts from the ground and also dissolve the soluble salts from the building materials then carry them together upwards to the masonry wall. The moisture are easily be evaporated when the environment is hot and dry but the salt does not. During evaporation, moisture will be evaporated from the wall. However, the salt residues are decapitated on the wall. Cyclic of wetting and drying allows the salt residues in the wall to be accumulated. The possible sources of salts in the walls are

- saline soils and groundwater
- sea-spray for coastal sites
- air-borne salts
- air pollutants
- inorganic garden fertilizers
- biological sources such as pigeon droppings, micro-organisms, leaking sewers
- salt naturally occurring in the stone, brick clay, or mortar sand

- salty water used for pudding brick clay or mixing mortar
- cleaning compounds that contain or react to produce salts in walls

There are 2 types of salt contamination depending on the salt penetration. First one is the salt residue on the surface of the wall that will be shown as white powder on the plaster which is known as efflorescence. Efflorescence is considered harmless to the masonry wall this is due to the salt residue are inclined to come out from the wall apart from being unsightly. Second type of salt contamination is where the salt penetrates below the surface of the wall or in the wall. This phenomenon is known as sub-fluorescence [6]. This is a more serious case where the salt crystallization process in the building material might cause the building material to porous and thus crumble.

5. Effects of Salt Crystallisation

Salt crystallisation will lead to the destructive plastering work such as peeling, spalling and flaking of plastering works. The wall finishes such as paint will also be affected. Moreover, salt can affect the masonry through other processes such as corrosion of iron or any metal reinforcement. Timber structures will also being caused to decay and rot. Other than that, the salt contamination and rising damp area are susceptible to growth of fungi and mould. It would have unfavourable musty damp smell and the health of the occupant might be affected.
Over the time, salts migrate into porous masonry materials and start to clog pore spaces. Cyclic of crystallisation and hydration has lead the pores become filled. This process will lead to the imposition of considerable stress on the surrounding pore walls. An experimental work done by Professor Carlos Rodriguez-Navarro and Dr Eric Doehne published in 1999, showed that rapid evaporation caused highly supersaturated sodium sulphate solutions producing irregular sided (anhedral) crystals of mirabilite which were found to be highly damaging [7].

6. Rising Damp

Rising damp is one of the most common yet severe damage that leads to decay and deterioration of many buildings especially heritage buildings. When talking about rising damp, porosity of building material aspect cannot be neglected. It is a relevant aspect to rising damp. According to Young (2008), all masonry materials whether stone, brick, mortar, earth or concrete block, are to some degree porous: that is, they contain voids or pores. Porosity can be defined as the measure as a percentage of the volume of the material and ranges from 0.1% for fresh marbles to an extreme 50% for some limestones. Common porosities of sandstones, limestones, bricks and mortar used in traditional construction are range 10-30%. Dense materials such as granites, bluestone and slate have porosities around 1-5%.

Rising damp is the upward movement of moisture caused by the capillary action which draws the moisture from the ground or the soil through the network of pores in the permeable masonry material. Capillary suction becomes stronger as the pore size gets smaller. The moisture can be travelled up to many metres in a wall if the pore size is small enough, until the upward suction is balanced by the downward pull of gravity. The rate of evaporation is depending on the nature of the masonry, surface of coating, climate, season and geographic location. In countries where the climate is hotter and drier, the rate of evaporation of the moisture from the walls of the building is greater which has lead to the accumulation of soluble salt left behind in the masonry. This process has lead to salt crystallisation and rising damp. Figure 2 shows **s**ection through a solid wall showing the path of rising damp which is caused by the suction of porous masonry. The pores effectively form a network of capillaries which draw soil moisture against gravity. Damp rises in the wall and eventually evaporates from the wall surfaces. As well as damaging masonry materials, the dampness may lead to fungal rot and insects (borers and termites) in the floor timbers [8]. Today it is normal building practice to include a moisture barrier known as a damp-proof course (DPC) across the base of the wall below all floor timbers and at least 150 mm above ground level.

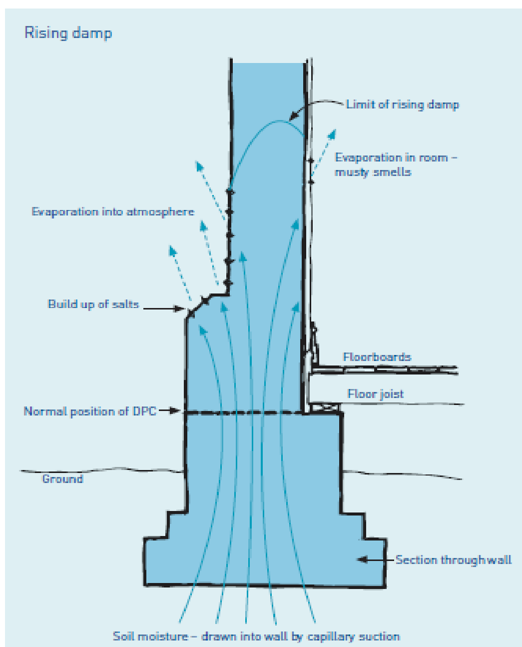

Figure 2. Section through a solid wall showing the path of rising damp which is caused by the suction of porous masonry

According to Young (2008), the process of evaporation is dynamic. More moisture is drawn from the ground when the moisture evaporates from the either side of the wall. There is often a continuous upward flow of moisture. However, the flow of moisture will become slow or even stop when the weather is dry and hot. The rate of flow of the moisture is depending on evaporation rate, the supply of moisture from the ground and the permeability of the building material.

7. Indications of Rising Damp

Rising damp is a very common problem for those heritage buildings which built in early 1900s due to the absence of Damp Proof Course (DPC). Severe rising damp problem can lead to the deterioration of the buildings. According to Tim Hutton (2012), when there has a long term problem with moisture penetration, evaporation at the edge of the damp area leads to a distinctive „tide mark☐ as a result of salt deposition. When this occurs at the base of a wall, the tide mark is often a typical diagnostic feature of rising damp. Moreover, there will be discolouration of the wall with general darkening and patchiness, growth of mould or fungi and loose or detaching paint and plaster. These symptoms of rising damp can be seen through naked eyes [9].

In order to verify the rising damp, non-destructive equipment can be used which is moisture meter. Moisture meter can be placed on the affected area thus the reading of the level of moisture content can be obtained. Another destructive test can be done by collecting the sample from the affected wall and undergo laboratory test. Figure 3 shows rising dampness on a painted brick wall.

Figure 3. Rising damp on a painted brick wall

8. Causes of Rising Damp

Rising damp refers to the moisture upward movement from the ground and soil. Thus, the common source of water that leads to rising damp problems in masonry wall is from the ground water and soil water itself. The severity of rising damp is depending on the water table underneath the soil. However, the water table is varied from one to another place depending on the geographic location and type of soil underneath. For instance, Penang Island is surrounded by sea water. As comparison, those buildings are close to the sea is susceptible to the rising damp problem than those buildings are away from the sea. Despite of the geographic location, the defects of the surface drainage and ground drainage also leakage plumbing system underground can be the factor to the rising damp problem. This can be the result of accumulation of water in the foundations and created a „reservoir" that contribute to the rising damp [3].

Increasing use of concrete or finishes around building without consideration of drainage slops which lead to failure of discharging water in the surface drainage also a common source contributed to rising damp. The accumulation of „moisture reservoir" in the foundation may also arise as the result of chronic plumbing leaks or floods from catastrophic plumbing or drainage defects.

Rising damp also can be occurred as a result of condensation. This occur when the warn moisture being cooled to a dew point which is the temperature which moisture condenses against a cold surface. Normally this happens in that particular room or area. This phenomenon is the main cause of damp in the base of walls rather than rising damp alone. Figure 4 shows the indication of rising dampness problem which exacerbated by hard cement render repairs.

Figure 4. Rising damp exacerbated by hard cement render repairs

9. Effects of Rising Damp

The rising damp in a building can lead to several problems. The moisture content in the masonry can be reached to a level where the decay organisms may grow, or the materials themselves may be adversely affected. Heritage buildings are susceptible to experience severe rising damp problem especially the timber structure which is widely use in the building structure include floor, roof, and wall and so on. For example, the timber skirting or built-in bonding timbers along the base of the wall may become infected and decayed by dry rot, wet rot, weevils or woodworm [7]. This is due to moisture condition is an optimum condition for the growth of insects, fungi and mould. In a very damp condition, the inorganic materials themselves may lose their structural strength in supporting the structure. This occur most spectacularly with walls made of cob (earth) soaked with water. Figure 5 shows the bridging the damp-proof course. Four examples of how changes to a building can create a path, or bridge, around an existing damp-proof course. Bridging by build-up of paving or garden beds is a common cause of rising damp problems

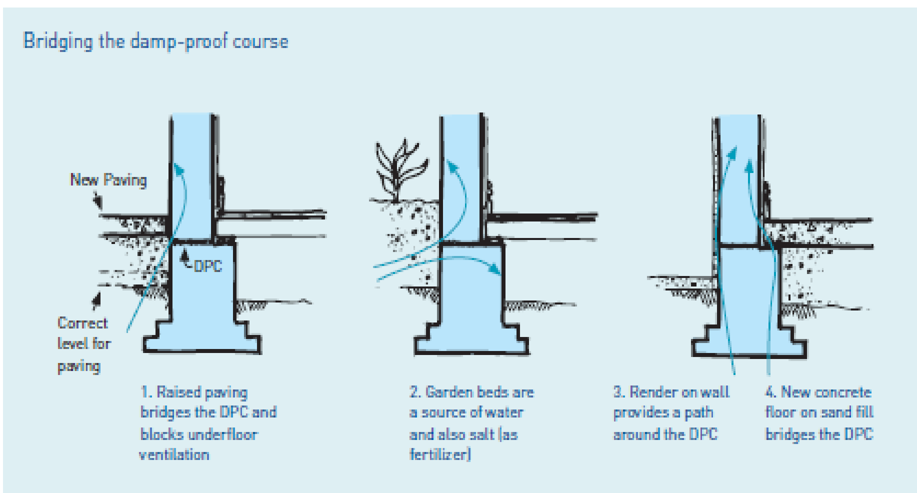

Figure 5: Bridging the damp-proof course

The rising damp affected wall allows the growth of the mould is aesthetically unacceptable. Moreover, the growth of mould can be a significant health hazard to the occupants. The finishes on the wall might be damaging. The plastering works and paints on the wall might be flaking and blistering [5]. Where evaporation takes place, the precipitation of the soluble salts on the surface of the wall and within the pores of the building materials can cause aesthetic and structural damages.

10. Summary

Rising damp and salt crystallisation are the most common problems yet the most severe phenomena that lead to the decay and deterioration of both old and new types of buildings. However, old buildings which are built in early 1900s are susceptible to rising damp and salt contamination due to lack of Damp Proof Course (DPC). Rising damp and salt crystallisation leads to unsightly and aesthetically unacceptable effect. Moreover, the structural strength and building material are being affected as well. The growth of mould and fungi can lead to the health of the occupants [8]. The problem of rising damp and salt crystallisation can be worsen if precise remedial and treatment are not taken. Thus, identifying predominant causes of the problems is critical to the search for appropriate treatment for the rising damp and salt contamination problem. Despite of solving the defect problems, the life span of the building can be extended with the precise treatment taken and proper maintenance.

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