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# Rising damp in masonry walls and the importance of mortar properties

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ABSTRACT

This paper briefly reviews the rising damp phenomenon with a discussion of the controlling mechanisms and contributing factors such as capillary effect, water absorption, evaporation and salt formation. It also presents the results of a study on rising damp based upon a practical year-long test. Measurements were made on rising damp on walls made from different mortars and the observations were compared with theoretical models. It was found that mortar characteristics would significantly affect the height of rising damp. It was also observed that there was a strong correlation between rising damp and the Sharp Front Model, and the rate of absorption of water into the mortar was a key factor in determining the height of the rising damp front. In addition, walls with rising damp treatment are warmer than their control counterparts due to a reduction in surface moisture evaporative cooling.

## 1. Introduction

Rising damp is a well known phenomenon around the world and occurs when groundwater flows into the base of a construction and is allowed to rise through the pore structure. The dampness causes damage to the fabric of the house and can make a room feel cold and inhospitable [1].

Water is an essential part of the process of brick and mortar manufacturing. In brick production, the wet clay is moulded and then fired to produce a hard, silicate bound structure with a network of pores. The pores are the residual volume that the evaporating water has left behind [2]. Likewise in cement mortar, a large volume of unreacted water evaporates in the mortar curing process and leaves a network of pores behind. Similar pore networks are found in many types of natural stone. Pores and voids are inherently present in these building materials. It is these networks that subsequently become the pathways through which groundwater can rise as shown in Fig. 1 [3].

Water has a strong affinity with the capillaries present in materials such as brick, mortar and stone [4]. This affinity brings about the rise of water into the structure through the force of capillarity. The capillary suction or capillarity is greatest for small capillaries and inversely proportional to the pore radius as Jurin's law describes [1]. The height of rise of water in a capillary ($h$) is governed by the following equation:

$$h = \frac{2\gamma\cos\theta}{r\rho g}$$

where $\gamma$ = surface tension, $\theta$ = contact angle, $r$ = capillary radius, $\rho$ = liquid density and $g$ = gravity.

The equation describes the relationship between pore size and height of rise. In the case of water, it has been found that when the pore size is 0.1 mm then the rise is 14 cm but when the size is 0.01 mm the rise can be 1.4 m. The pore size in bricks and mortar can be as small as 0.001 mm so there significant potential for rising damp [4]. Water rises in the structure of porous building materials through the process of capillarity. Further considerations are the rate of transport, which is influenced by the pore structure and viscous forces (see for example [5]), and subsequent removal by evaporation.

Evaporation is an important factor in rising damp. The surface of an affected wall contains moisture that has risen from the ground and this moisture is then subject to evaporation. The factors controlling evaporation include:

- Temperature
- Humidity
- Air movement
- Surface condition, for example has the masonry been painted

Mason developed a model for rising damp where capillary rise and evaporation coexist in balance [6]. A series of equations describe the flow processes through the capillary structure which

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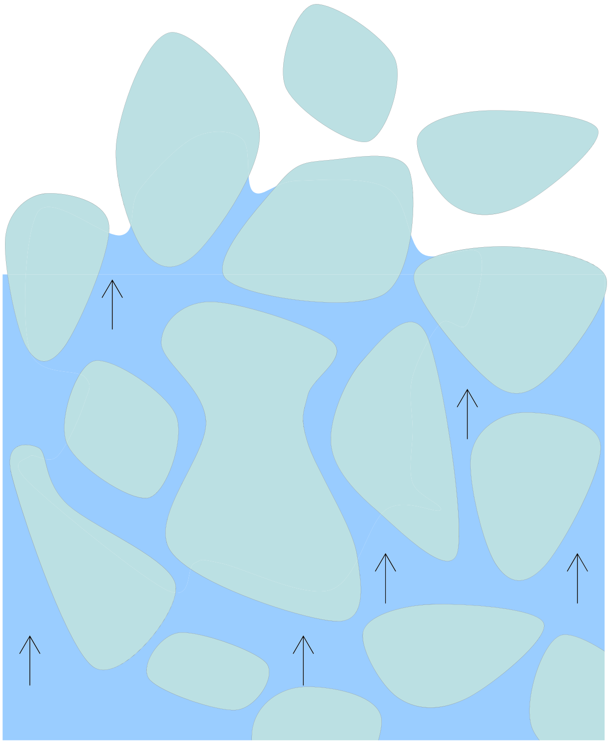

**Fig. 1.** Simple illustration of water flow through capillaries.

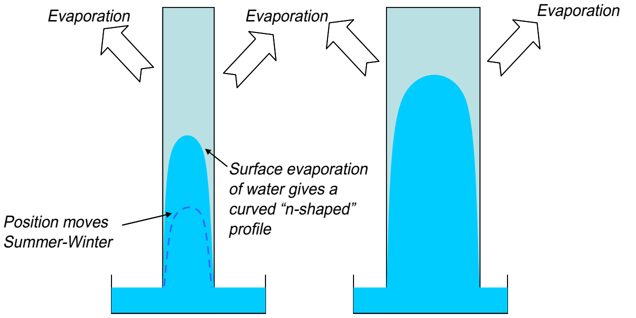

**Fig. 2.** Schematic diagram of a brick wall showing the equilibrium between capillary rise and evaporation.

form an equilibrium with evaporation. With evaporation introduced, the height of rise is governed by the factors relating to capillary pores, wall thickness and evaporation rate. In principle, evaporation equilibrium is an n-shaped profile of water distribution. The equilibrium between capillarity and surface evaporation is schematically shown in Fig. 2.

In a thin wall there is proportionally more evaporation than capillary rise which means that the height of the rising damp front is reduced. An increase in the evaporation rate, as may happen from greater surface temperatures in the summer months, will also result in a drop in the height of rise. Similarly, a reduction in the ground water level will also bring about a reduction in height of the rising damp front.

One problem highlighted by Mason is that the height of rise "increases by a factor of about seven between the first and perhaps the hundredth year of the lifetime of the wall" [6]. A tentative explanation is offered where slightly acidic water washes out free lime from the mortar to increase the flow process. Therefore, it is difficult to implement a test for rising damp with new mortars as these are not representative of the true situation in an older wall.

**Table 1**
Soluble chloride and nitrate contents in water of different sources in parts per million (after Kyte [8]).

| Source | Chloride | Nitrate |
|---|---|---|
| Groundwater (rising damp) | 12 | 50 |
| Tap water (Bucks) | 18 | 50 |
| Rainwater | <1 | 1 |
| Seawater | 18,000 | 10 |

More recently, Hall & Hoff have developed the Sharp Front Model for rising damp; it is so named because in the model the boundary between wet and dry parts of the wall is discrete or sharp [7]. This builds on the concept of balance between capillarity and evaporation. The equation which describes the height of rise is

$$H = S\left[\frac{b}{2e\theta}\right]^{1/2}$$

where $H$ = height of the rising damp front, $S$ = sorptivity (the suction of water into the mortar), $b$ = wall thickness, $e$ = rate of evaporation per unit area of the wetted surface, $\theta$ = moisture content of the wetted region (the volume of water per unit volume material).

The equation demonstrates that the sorptivity of water into the material has a strong influence on the height of the rising damp front. It can be measured by partial immersion of the test material in water and recording the weight increase with time. The equation also shows that the height of the rising damp front doubles by increasing the wall thickness by a factor of four.

The slow process of absorption of water into the structure with subsequent evaporation leads to the gradual deposit of salts in the wall. The masonry acts as a filter system for impure water as the various soluble salts are drawn into the wall and then left behind. Some figures of salt levels were reported by Kyte as shown in Table 1 [8].

In addition, the rising water can dissolve and redistribute the salts in the bricks and mortar allowing high concentrations of salt to build up. The consequences of the salt build-up are that;

(a) The salts can block the pores and capillaries through which the water evaporates and thereby push the rising damp front higher as also demonstrated in the above equation [9].
(b) Moisture content is increased in the mortar from the hygroscopic nature of the salts with the possibility of attracting further moisture into the wall. This contribution would be relatively small in comparison with capillary moisture.
(c) Damage to the structure from constant dissolution and recrystallisation of certain salts is incurred by humidity and temperature changes. Sodium sulphate salts deposited from groundwater can be particularly destructive to buildings and monuments [10].

## 2. Experimental

### *2.1. Wall construction*

Taking the comments by Mason into consideration that the permeability of the mortar appears to increase with age, two types of masonry wall were constructed. In the first wall, a low permeability mortar was used comprising ordinary Portland cement (CEM I) and building sand at a 1:5 ratio (volume) with a cement plasticiser. In the second wall, a more permeable mortar was made from a binder solution, powdered clay and building sand at 1:1:6 ratio (volume) respectively. This second mortar was considered to represent a permeable historic mortar where rising damp had occurred. A further paper in preparation aims