Diagnosis of capillary rise in heritage building

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Abstract. The Kota Tua area of Jakarta in Indonesia is known as an area with many heritage buildings. Most of the heritage buildings in Kota Tua are vulnerable to damage. One of the potential risks to the buildings is a capillary rise, which is known as a natural event. The capillary process may threaten the construction by the high dampness on the walls, caused by rising damp of water from the ground. Besides, the risk of salt attacks carried over the wall's surface will further cause more damage. All the physical condition degradation in heritage buildings makes the water rise quickly to wall building. This research is an observational study that measured the capillary rise level on the walls located in Jakarta's old city area. Cipta Niaga building was used as a sample in this case report study. The research has used exchange methods by using the Gravimetric (Oven drying) Method BRE Digest 245 to determine the destruction caused by capillarity. Based on our result, there was a particular dampness wall area caused by capillary rise and was proved by the percentage of Capillary Moisture Content (CMC) 2,94 % higher than its Hygroscopic Moisture Content (HMC) 2,06%.

1. Introduction
Most of the conditions of heritage buildings in the world have a problem of susceptibility to damage due to decreased quality of maintenance conditions. Besides, the development and utilization of cultural heritage buildings can also create conflicts of interest for various parties, thus threatening conditions for the preservation of cultural heritage, one of which is the physical building. The Kota Tua Jakarta in Indonesia area is one of the areas that still have many cultural heritage buildings. Some of the heritage buildings in the Kota Tua area of Jakarta was built in the Dutch colonial era. Located in the Kota Tua area, the Cipta Niaga Building is a building made in the 1910s. This building extends from west to east and faces directly to the Kali Besar Timur canal. The building has a Dutch colonial architectural style. The condition of the Cipta Niaga building was in a state of renovation. In general, the building's structural condition is still stable, but several parts are damaged. The damage can be seen on the exterior walls and interior walls of the building.

Capillary rise is often considered to be a threat to cultural heritage buildings because they are one of the causes of damage, including weathering of building components. Capillary rise happens because of the vertical movement of groundwater. Wall building components are one of the most vulnerable to capillaries because they are closely connected to the ground after the foundation. The response of the building wall material to the capillary might cause visually visible damage. This research will discuss the identification of capillary damage suspected to occur on the walls of the Cipta Niaga building.
2. Capillary Rise Damage in Heritage Building Construction

Capillarity in a building is defined as groundwater's vertical movement through a porous wall structure [1]. The capillary rise can cause the appearance of rising moisture into the structure. Water sources from the base that triggers capillarity include: soil conditions, environment (rain, sea, water vapor, etc.), possible leakage of wastewater, use of water for the production of building materials, interventions with the use of large amounts of water, hygroscopic salt [2]. The capillary rise can cause problems, including dampness and salt attack [3].

2.1. Dampness

Dampness is generally triggered by building elements or walls which are close to water sources, resulting in water penetration to the building elements. This condition can accelerate not only the damage to buildings but also harm building equipment. The capillary is one of the causes of generally causing dampness. Dampness can also be defined as extreme moisture and it can cause damage problems in historical buildings [4,5]. The factors that cause this rapid increase in dampness include [6]:

- Local climatic conditions (temperature and humidity values)
- Solar radiation received by the surface of the plane
- Soluble Salt
- Material pores
- Wall thickness
- Material layers

A considerable increase in humidity can be seen visually through wet walls, cracks, peeling, rot, and the growth of microorganisms such as moss to mold [7]. Microorganisms such as algae, fungi, and lichens will grow well at high dampness [8]. The wall is one part that is susceptible to dampness, both from the vertical and horizontal directions. It is known that bricks are the primary wall material in European colonial buildings in Indonesia. Based on literature studies, the type of wall construction of colonial buildings that were built in the early twentieth century used the limestone-sand brick. The brick is made from a mixture of lime cement and sand, which is molded into a brick by pressing it using a steam engine and weighed down to make it hard. The result is that the brick is light grey, heavy, and non-absorbent. Bricks are prone to weathering when compared to other building materials, due to their relatively high porosity between 11-40% in contemporary buildings and 30-38% in historical buildings [9]. The interconnected porosity can make it easier for water and other damaging substances to enter the brick matrix, making it easier to experience weathering or damage.

2.2. Salt attack

Salt attacks occur due to salt brought about by water penetration events into parts of the building such as capillaries, soil, leaks, and rainwater splash. 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 in the wall surfaces [10]. Apart from salt water, it can also come from the material itself, such as a mixture containing water, a series of alkalis that are owned by concrete, plaster, or brick. The accumulation of salt is formed from the moisture in the walls (water), which evaporates and leaves residual salt in brick, stone, or mortar pores. If the salt that accumulates, it can damage building components. The types of damage caused by salting include:

- The presence of efflorescence on the surface of walls, masonry, or mortar
- Porous on brick, stone or mortar
- Delamination or peeling of the plaster / paint / brick / stone front surface layer

The salt contained in the material may come from the raw material itself (soil) or during the production process. However, very often, this destructive salt comes from outside [8]. Essential elements are formed from positive and negative ionic chemical elements or called cations and anions [10]. The types of cations (+) and anions (-) that form salt elements, including (Table 1):
Table 1. The types of cations (+) and anions (-).

| Kation (+)      | Anion (-)      |
|-----------------|----------------|
| Sodium (Na⁺)    | Clorida (Cl⁻)  |
| Potassium (K⁺)  | Sulphate (SO₄²⁻)|
| Magnesium (Mg²⁺)| Nitrate (NO₃²⁻)|
| Calcium (Ca²⁺)  | Carbonate (CO₃²⁻)|

These ions are contained and react with water and material, which in turn will form chemical bonds with soluble salts (soluble salt). Types of soluble salts that can damage buildings include NaCl, Na₂SO₄, NaNO₃, MgSO₄·6H₂O [11]. Several studies have found that the salting reaction of white powder (efflorescence) on the walls is caused by the reaction of the alkaline content in Portland cement and soluble alkali in brick, which is naturally contained in those materials.

3. Diagnosing capillary rise

In this research, there are four steps have been carried out to determine the damage due to capillary action, which was:

- Visual Inspection and collecting building technical drawing data to map damage due to capillaries
- Measure wall humidity using a moisture meter
- Taking plaster and brick aggregate's to laboratory for gravimetric testing to determine the type of moisture that occurs on the wall
- Take a water laboratory sample test to determine the level of salt mineral content that causes damage from capillary events

3.1. Gravimetric methods

The gravimetric method (oven drying) is the most accurate identification method for determining material moisture content [2]. The gravimetric test could determine whether the moisture problem is caused by of capillary moisture or hygroscopic moisture [12]. The action is to take an aggregate sample, weigh it, dry it to constant weight in an oven at a suitable temperature (100 °C), then weigh it again. Moisture is expressed as the weight loss achieved by drying as a percentage of the material examined's oven-dry weight. Method – BRE Digest 245 has been carried out as a guideline to the gravimetric test. Procedure for the analysis are [12]:

- Samples to be examined must be taken from a wall on the floor or ground level at least 30 cm above the indicated dampness damage level.
- The sample should be taken by drilling, preferably in a mortar path around a 30 cm center, to the wall's center. It is recommended that the inner sample be separated from the sample originating from the plaster, as it is often desirable to analyze masonry and gypsum.
- The sample is obtained by drilling at low speed, drilling holes about 0.9 to 1.5 cm in diameter. The samples are collected in an airtight container. Details of sample positions should be noted.
- The collected sample is taken to the laboratory. Approximately 2g of the sample is weighed accurately (Ww) and then exposed in a container with a relative humidity of 75% for a minimum of 12 hours. After re-weighing (W75%RH), the sample is put in an oven at 100 °C until dry, then weighed again (Wd). Calculate the following:

For Hygroscopic moisture content at 75% RH (HMC) =

\[
\frac{W_{75} - W_d}{W_{75} - W_0} \times \text{wet weight} \quad (1)
\]
For Total Moisture Content of sample when found (TMC) =
\[
\frac{100 \cdot (W_w - W_d)}{W_w - W_0} \% \text{ wet weight}
\]  \hspace{1cm} (2)

For Capillary Moisture Content (CMC)
\[
\text{CMC} = \text{Total Moisture Content} - \text{Hygroscopic Moisture Content}
\]  \hspace{1cm} (3)

The interpretation of gravimetric method to determine the type of dampness, namely:
- If HMC > CMC, this is confirmed not rising damp or capillary rise
- If CMC > HMC, this is confirmed of rising damp or capillary rise

4. Case study
The condition of the Cipta Niaga building is in a state of renovation. In general, the building’s structural condition is still stable, but several parts of the roof have collapsed, and the floor has also fallen. Another damage was seen on the walls of the building. The facade of Cipta Niaga building can be seen in Figure 1.

![Figure 1. The facade of Cipta Niaga building.](image1)

The exterior walls show the layer of peeling paint. Meanwhile, inside the building interior, the building walls were found to be signs of damage due to moisture, including weathered paint, damaged plaster layers, and moldy walls. In this study, the documented damage cases focused on the damage predicted to be caused by capillary events.

![Figure 2. The locations sample for capillary rise identifications.](image2)

5. Results and discussion
Some of the damages found in the Cipta Niaga building indicated were damaged due to the capillary rise. Figure 2 shows the initial identification that was carried out. To find out the wall’s dampness level, it should be done by measuring the humidity with a moisture meter. Measuring points are made with a grid spacing 30 cm. Based on the results of the measurement, the value is 1.5 - 2.5%. The average values
can be interpreted as vulnerable to the moderate humidity level based on the tool's information. The dampness symptoms in the location of the samples can be seen in Figure 3.

![Sample images](image1.png)

**Figure 3.** The dampness symptoms in the location of the samples.

### Table 2. Interpretation of gravimetric testing.

| Number of Specimens | HMC (%) | TMC (%) | CMC (%) | Result |
|---------------------|---------|---------|---------|--------|
| Sample 1            | 4.48    | 4.48    | 0.00    | HMC = MCM Unknow |
| Sample 2            | 2.06    | 5.00    | 2.94    | CMC > HMC this is confirmed of rising damp or capillary rise |
| Sample 3            | 3.54    | 4.50    | 0.96    | HMC > CMC this is confirmed not rising damp or capillary rise |
| Sample 4            | 1.50    | 1.50    | 0.00    | HMC = MCM Unknow |
| Sample 5            | 1.90    | 1.50    | -0.49   | HMC > CMC this is confirmed not rising damp or capillary rise |

Based on the gravimetric test results (Table 2), the wall aggregate sample taken from sample location 2 shows that the humidity that occurs in the wall area is caused by a capillary event. The value of capillary moisture content was 2.94% higher than the hygroscopic moisture content value, was 2.06%—in the wall area. The damage caused by rising damp visually can be seen at the layers of paint the are peeling off [7]. There were unexpected test results on testing sample 1 and sample 4, that the humidity cannot be interpreted. Whereas for samples 3 and 4, the type of moisture that occurs can be interpreted caused by hygroscopic moisture. Hygroscopic moisture can be caused by penetration of water from rain or condensation of air [2].

The Cipta Niaga building is known to be located near one of the water sources, namely Kali Besar canal. To determine the effect of water on the level of damage due to capillary action, groundwater sources were tested for salt mineral content, to find the potential for salt content that could potentially be carried away by the capillary process [2]. The results of measuring the content of salt-forming ions in the water in the Cipta Niaga building obtained the following results in Figure 4.

![Figure 4](image2.png)

**Figure 4.** Result for salt mineral in the groundwater sample.
6. Conclusion

Identification using gravimetric to diagnose dampness due to capillary rise helps prove the existence of capillary rise in heritage buildings. Based on the research results on one of the heritage buildings located in the Kota Tua area of Jakarta, the Cipta Niaga building, humidity due to capillary increase occurs and shows moisture damage to the walls. The capillary rise in the Cipta Niaga building also causes dampness in the building wall area. The mineral content of groundwater in the Cipta Niaga building potentially can cause salt attack.

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