Salt attack and rising damp on house buildings at the tsunami-affected areas

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Abstract. Post tsunami 26 December 2004, rising damp and salt attack are two underestimated phenomena emerging on building construction on the tsunami-affected areas in Banda Aceh city, Aceh Province of Indonesia. The severity of building quality deterioration, particularly on the typical masonry walls, has never been observed by local inhabitants to have been escalated before the tsunami event. Such phenomena persistently present even after approaching the second decade of the post-tsunami event. The present study is the first attempt to explore the evidence of rising damp and salt attacks of the houses around the Banda Aceh city. Forty-five houses were purposively sampled based on their visual appearances being affected by the salt attack and rising damp, the heights of the rising damp, and also groundwater salinity in the vicinity of the sampled houses. The results show that the rising damp heights on the walls are relatively high in any location within the tsunami inundation boundary 500 m from the shoreline. However, a turning point where rising damp height reduced remarkably to less than 1 meter was identified as the distance of houses increased beyond 500 m from the shoreline. Overall, the high level of water salinity brought by tsunami inundation during the early post-tsunami has been an important controlling factor contributing to the salt attack and rising damp, regardless of the houses' distance to the shoreline, but may have been indirectly influenced those phenomena in the long run.

1 Introduction

Coastal properties exposed to both the ocean breeze and the shallow groundwater containing salt substance commonly result in salt attack and rising damp, particularly on concrete and masonry walls. Paint discoloration, peeling off paint and plaster, and also the presence of moss, the crystallization of salt along with the plaster to crumble on walls are the most common appearances of the walls infested with combined salt attack and rising damp. Factors that influence the height of capillary impact or rising damp on masonry walls depend on material properties (wall thickness and porous material composition). Evaporation is also an important factor in rising damp which include the factor that may control it, including the temperature, humidity, air movement and surface condition of the wall. If left untreated, they can cause extreme damage to the structure of buildings, particularly to both brick and mortar [1], [2]. Several studies on the effect of rising damp and salt attack have been conducted to investigate the strength decay of building structures, mostly for historic buildings located at the humid coastal areas [2], [3], [4].

Post tsunami 26 December 2004, salt attack and rising damp are two underestimate phenomena emerging on building construction on the tsunami-

affected areas in Banda Aceh city, Aceh Province of Indonesia, being one of the most devastated coastal areas affected by the tsunami. The severity of building quality deterioration, particularly on the typical masonry walls have never been observed before by the coastal inhabitants in the pre-tsunami era at the coastal areas of Banda Aceh city. Such phenomena persistently present even after approaching the second decade of the post-tsunami event.

The present study is the first attempt to explore the evidence of rising damp and salt attacks of the houses around the Banda Aceh city. The heights of rising damp and salt attack visually appear on the exterior walls of the sampled houses, and the distance of those houses from the shoreline are the two main factors being analyzed to capture the spatial distribution of the rising damp and salt attack phenomena affecting the houses at the coastal area. In addition, the correlation with the level of groundwater salinity was also examined. The results of the study ultimately contribute to a better understanding of the potential long-term and persistent problems for housing construction around the tsunami-affected coastal areas.

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1.1 Salt attack and rising damp

Salt attack and rising damp are two separate but interrelated processes [3],[5]. Rising damp is a phenomenon of groundwater pressure vertically transferred to building walls through capillary pressure. The capillaries draw water from the soils beneath a building against the force of gravity, leading to damp zones at the base of walls. Factors influencing the height of capillary impact, or rising damp, on wall is depending on material properties, i.e., wall thickness and porous material composition [6], [7].

When the groundwater or soil underlying a building foundation contains little or no salt concentration, the physical property of the water may induce damp walls in houses affected by rising damp. However, in most cases, the dampness will have salt associated with it, resulting in salt attack. The salt attack is the decay of masonry materials, such as stone, brick and mortar, by soluble salts forming crystals within the masonry pores [5]. The salt commonly comes from the soils beneath and is carried up into walls by rising damp. Evaporation is also an essential factor in rising damp which includes the factors that may control it, i.e., temperature, humidity, air movement and surface condition of the wall [7]. When the dampness evaporates from the walls, the salts are left behind and slowly accumulate to the point where they can cause damage. Repeated wetting and drying with seasonal changes lead to the cyclic precipitation of salts and the progressive decay of the masonry. If left untreated, the salt attack can cause extreme damage to the structure of properties.

1.2 Water salinity

A coastal aquifer is susceptible to anthropogenic activities, such as industry, household, and agriculture activities. On the other hand, the groundwater trapped within the aquifer layer is vulnerable to reduced quality and quantity by saline water intrusion, land subsidence, and water pollution [8], [9]. In general, topography, hydrostratigraphy, and the associated groundwater flow system determine the spatial distribution of saline land and water. Moreover, the redistribution of soluble salts accumulated in a catchment is evident mainly in topographically lower areas by terminal salt lakes, dry salinas, and regions of saline seeps and scalds [10].

In an extreme case, when a tsunami wave hits a coastal area, the waves inundated the low-lying coastal region. They deposited sediments and debris containing water-soluble salts in the soil, and there is no difference in chemical properties between tsunami deposits and the tsunami-inundated ground [11], [12]. Standing water, the thickness of tsunami sediment deposition and debris, and poor irrigation resulting salt traps in some locations. Moreover, the impact of tsunami inundation on groundwater salinity in the unconfined coastal aquifer not only increased acutely right after the period of inundation but is likely to persist over the years [8]. Such a condition causes a significant impact on the agricultural industry and requires special soil remediation treatment [13], [14]. In coastal aquifers,

salinity could cause premature concrete deterioration due to seawater intrusion and sulfate concentration [15].

2 Methods

Walkthrough fieldwork to identify houses affected by rising damp and salt attack was conducted in March 2021 over several villages in the region of Meuraxa and Kuta Raja subdistricts to identify and observe the visual appearance of houses infested with rising damp and salt attack over the coastal area of Banda Aceh.

Forty-five houses have been purposively sampled based on their visual appearances being affected by the rising damp and salt attack. Figure 1 reveals the typical wall conditions infested with rising damp and salt attack observed around the coastal area.

Fig. 1. Typical rising damp and salt attack appearances on houses' walls at Banda Aceh coastal region.

Apart from measuring the rising damp heights on the exterior walls of those houses, we conducted a water salinity survey from the dug-wells at each house or those found in the neighboring area. The salinity level of each sample was obtained from a simple refractometer that reads the salinity concentration of the sampled water. For the data analysis, we compared the results from the salinity concentration reading with the water salinity measurement obtained in the same coastal region in the early post-tsunami in 2005, performed by the Tsunarisque team of Laboratoire de Géographie Physique, Centre National de la Recherche Scientifique (LGP-UMR 8591 CNRS) in Meudon, France in collaboration with Gadjah Mada University. The purpose is to know the state of salinity level of the groundwater as one of the leading indicators of potential salt concentration contributes to the underlying soil of the sampled house buildings.

Another parameter being considered as necessary is the distance between the houses location and the shoreline. Here, the shoreline is defined as the landward-most relatively permanent water bodies at the seashore at present (post-tsunami), as a result of severe coastal erosion by the 2004's tsunami.

Fig. 2. Spatial distribution of houses sampling over Meuraxa and Kuta Raja Subdistrict of Banda Aceh city.

All the attribute data associated with the sampled houses are stored in a geodatabase in the GIS. We examined the spatial distribution of the house locations, the salinity concentration of the groundwater, the variability of rising damp heights and measured the distance of the house location from the post-tsunami shoreline. We subsequently examined the correlation between the height of the rising damp and salt attack of each house and their distances to the shoreline which are described in the Pearson's correlations.

3 Results

Salt attack and rising damp are problems related to both brick and mortar, particularly in the saline-prone locations such as coastal areas. All masonry materials are porous, including bricks. Bricks consist of voids or pores due to the nature of brick-making techniques. Bricks are permeable; water can pass through the pores via capillary action or a wicking effect. Therefore, salt attack and rising damp need to be tackled effectively and resolved by experts.

Most buildings in Indonesia are constructed by using reinforced concrete material and masonry structures. Bricks and mortar are the main materials for walls. This type of material is porous and it may increase the rate of water capillary and raising the moisture content of the wall. The durability of the building will be affected; thus, the building lifetime will be decreased [16]. It is therefore important to know how to control the rising damp, particularly the one instigating salt attack, to improve the sustainable building development and to increase the resistant capacity of building at the coastal areas prone to earthquake and tsunami.

The sampled houses of the present study are well-distributed within the tsunami-inundated zone over up to 5 km from the coastline of Banda Aceh (Fig. 2). The results of Pearson correlation show that there are strong positive correlations between the rising damp infested houses locations and their distance from the shoreline (0.60), and moderate correlation between the early post-tsunami water salinity level and the height of rising damp (0.49). On the other hand, weak positive correlation found between the rising damp infested houses with the 2021's water salinity (0.19).

We examined the distribution and variability of rising damp heights of the sampled houses relative to their distances from the shoreline, which depicted in Fig. 3. It shows high variability of rising damp heights on houses located at the nearest and up to 500 m from the shoreline (Fig. 3a and 3b). All the appearance of rising damp was associated with visible salt attack on the mortar; exposing bricks or corroded steel as a result (Fig. 1).

(a)

Fig. 3. Results of data analysis; (a) Distribution of rising damp heights at sampled houses relative to the distance of houses from the shoreline; (b) Distribution of rising damp height and water salinity early after the 2004 tsunami.; (c) Comparison between the early post-tsunami and the most recent water salinity condition.

It is noteworthy that out of 33 houses sampled within the area of less than 500 m from the shoreline, only three of those houses were built before the 2004 tsunami. On the other hand, out of 11 houses sampled on the area beyond 500 m from the shoreline, there were only 3 houses were built before the tsunami. This suggests that the salt attack induced by the rising damp has been persistent over the last 17 years since the tsunami event, regardless whether the building was constructed before or after the tsunami event.

Figure 3b reveals the distribution of the rising damp heights and the associated initial water salinity after the tsunami event. The rising damp heights averagely above 2 meters occurred at around the middle of the inundation area, around 400 m from the shoreline, while lower heights, but mostly well above 1 meter, were observed at those houses closer to the shoreline. This suggests that the rising damp heights on the walls are relatively high in any location within the tsunami inundation boundary within 500 m from the shoreline. However, a clear turning point where rising damp height reduced remarkably to less than 1 meter was identified as the distance of houses increased beyond 500 m from the shoreline (Fig.3a). Despite this, the effect of rising damp remains persistent until the present.

On the comparison between the water salinity levels of the early post-tsunami in 2005 and that of 2021 (Fig. 3c), it reveals that the water in 2021 has a significantly lower level of salinity, with an average of merely 0.69 ‰, compared to that of staggeringly high salinity level

in 2005. This suggests that the variability of rising damp on houses built post-tsunami remains persistent to affect the building quality, while the quality of groundwater has been recovered over the years.

Overall, the high-water salinity brought by tsunami inundation during the early post-tsunami has been an important controlling factor contributing to the salt attack and rising damp, regardless of the houses' distance to the shoreline, but may have been indirectly influencing the persistence of salt attack and rising damp in the long run. The high variability but persistent appearance of the rising damp on those houses closest to the shoreline may have been contributed by several other factors. The tsunami inundation and inland deposition are inherently brought about a high concentration of salt to the soil [11,16], in particular at the area where the tsunami deposit may have been trapped, such as on a depression, aquaculture ponds, or paddy fields with poor irrigation to release the salt by rainfall [13,14]. The enhanced capillary pressure of the salinated soil from the tsunami inundation deposition or the residual salinity contained in the entrapment of tsunami deposits underlying the buildings may have a direct influence on the persistence of salt attack and rising damp, which deserves an outlook for a further study. Some other factors that needed to be considered include the houses' age, the soil condition underlying the houses' foundation, and the quality of the construction material.

4 Conclusions

Rising damp and salt attack phenomena are typical problems to the coastal properties and have been studied in many coastal settings worldwide. However, such phenomena have never been thoroughly investigated for the case of tsunami-affected coastal areas. This study investigates the controlling factors causing the persistent and escalating rising damp and salt attack to the houses exist in the tsunami-inundated coastal regions. The tsunami inundation areal coverage and salt-substance inundation materials may have been the two main controlling factors causing the rising damp and salt attack phenomena in the tsunami-inundated coastal areas. Soil salinity distribution over both preserved tsunami deposits and non-tsunami deposits should be further investigated to support these preliminary findings of the rising damp and salt attack phenomena on house buildings in the post-tsunami coastal settings.

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