

Investigation on the Monitoring of Brick Structure in Yokosuka City

Risako FUKAMI,¹ Toshiya MATSUI,¹ Mayumi KAWAMOTO²

¹ World Heritage Studies, University of Tsukuba

² Board of Education, Yokosuka City

ABSTRACT

Brick structures in Yokosuka City are precious cultural properties to study on brick masonry, method of production at the time and its transition. These things and brilliance created by bricks prove that it has artistic, historic and archaeological value. However, many brick structures in Yokosuka City suffer from surface deterioration; for example, salt weathering and crack caused by environmental changes and changes in utilization. There is a possibility that the deterioration becomes harmful to keep them for next generation. The purpose of this investigation is to reveal progress and causes of deterioration in brick structures by monitoring. We measured that: 1) behavior of temperature and relative humidity in brick structures; 2) amount of collapsed brick at Sarushima, one of the islands as Tokyo Bay Fortress in Yokosuka City in June 2017. Moreover, brick debris which obtained monthly were analyzed by using XRD to identify salts in brick debris. As a result, amount of collapsed brick has increased at all spots in July that relative humidity was higher than June. Salt weathering is considered one of the factors to bring about the collapse of the brick because Calcite (CaCO_3) and Gypsum ($\text{CaCO}_4 \cdot 2\text{H}_2\text{O}$) were detected from brick debris. Finally, we consider the next step method of monitoring based on previous measurement results to find out the possibility of other causes of deterioration.

1. INTRODUCTION

The Many brick structures in Yokosuka City were made as Tokyo Bay Fortress in Meiji period to defend a capital and built a lot of batteries and coast-batteries there by Meiji government. Yokosuka City was the center of Tokyo Bay Fortress because it was at the entrance to the bay and thus a lot of sites of batteries and military facilities have survived as a national historical site in Yokosuka City. The production of bricks has started in Yokosuka City during the early Meiji period, therefore Yokosuka City has early Japanese bricks and it is one of the important places for history of Japanese bricks. For example, Sarushima is one of the islands as Tokyo Bay Fortress in Yokosuka City (Figure 1). It was built from 1881 to 1884. There are Flemish bond and Dutch bond in Sarushima, and it

show the changes of brick masonry in Japan. However, many brick structures in Sarushima suffer from surface deterioration; for example, salt weathering (Figure 2). Salt weathering brings about collapse of bricks. One of the drivers that cause salt weathering is environment in brick structures.

We investigate temperature and relative humidity in brick structures at Sarushima and analyze it what kind of salts exist in brick debris. Our result show that collapse of bricks is caused by some salts, environmental conditions such as temperature and relative humidity.



Figure 1: Brick structure in Sarushima

2. METHODS

Investigation on monitoring was carried out in 3 places such as d3 spot, f1-2 spot, and f1-3 spot from June 5 through June 29, and June 29 through August 2, 2017 in Sarushima (Figure 3). Behavior of temperature and humidity were measured by HOBO U23 Pro v2 Temperature/Relative Humidity data logger which was set to be measured every 30 minutes. Amount of collapsed brick was measured by tray containers set on brick walls and weighed it every one month. The number of trays which were set is 2 at d3 spot, 3 at f1-2 spot, and 1 at f1-3 spot. Brick debris which obtained monthly were analyzed by using X-ray diffractometer (Bruker AXS, NEW D8 ADVANCE) to identify salts in brick debris. The X-ray target was Cu, the tube voltage was 40 kV and the tube current was 40 mA.



Figure 2: Salt weathering

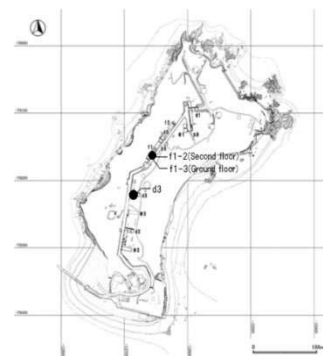


Figure 3: Measurement spots in Sarushima

3.RESULT AND DISCUSSION

Result of investigation on the monitoring over about 2 months, environment in the brick structures in Sarushima is very high humidity. The average of relative humidity at each spot is from 94% up to 100%. In addition, the average of relative humidity in July is higher than that in June at all spots (Table 1).

Table 1. Summary of the results of temperature and relative humidity from monitoring

	d3						f1-2						f1-3					
	Temperature(°C)			RH(%)			Temperature(°C)			RH(%)			Temperature(°C)			RH(%)		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
June	15.65	19.72	17.47±1.12	87.87	100	99.67±1.25	15.84	20.89	17.82±1.14	73.96	100	98.11±3.73	16.25	18.41	17.4±0.45	91.76	94.78	94.19±0.63
July	19.48	23.4	21.88±0.94	100	100	100	18.91	25.23	22.3±1.15	98.05	100	99.99±0.11	17.99	22.68	20.76±1.08	94.74	96.07	95.55±0.36

The environment in brick structures is high humidity, although amount of collapsed brick increase in July. Amount of collapsed brick of July 4 times larger than that of June at d3 spot, and 4.8 times larger than that of June at f1-3 spot (Figure 4).

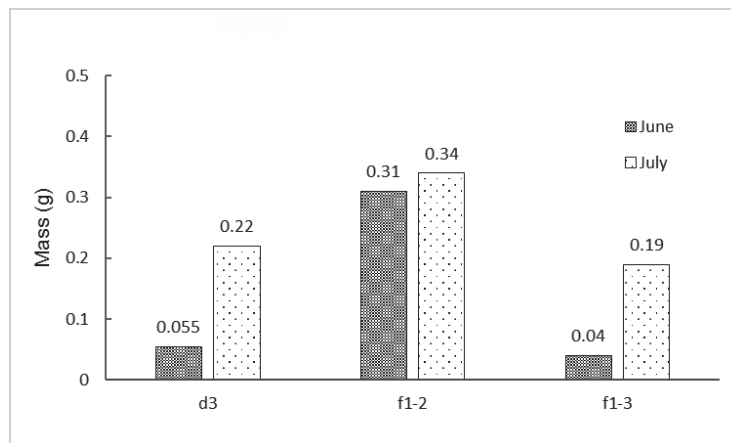


Figure 4: Monthly amount of collapsed brick

Results of XRD, Calcite (CaCO_3) was detected from brick debris at d3 spot, and Gypsum ($\text{CaCO}_4 \cdot 2\text{H}_2\text{O}$) was detected from brick debris at f1-2, and f1-3 spot. Both Calcite and Gypsum are poor solubility, and it is reported that these salts tend to form and separate in a high relative humidity environment. Moreover, it is reported that collapse of bricks is caused when humidity rises again, then salts in bricks deliquesce, because salts on the surface of bricks become heavy by absorbing moisture in the air, and it cause collapse of bricks. Therefore, amount of collapsed brick has increased even if Sarushima in July. Salt weathering is one of the drivers that induce the collapse of bricks, but amount in the f1-2 spot was larger than f1-3 spot despite Gypsum has been detected in f1-2 spot as well as f1-3 spot, thus it will be considered that the influence of vibration by tourists and the wind is other driver cause the collapse of bricks.

4. CONCLUSIONS

The surface of the bricks in Sarushima has been observed damage by salt weathering that cause collapse of the bricks. Investigation on monitoring has been carried out to ascertain relationship of environment and amount of collapsed brick in Sarushima. As a result, amount of collapsed brick has increased at all spots in July that relative humidity was higher than June. Salt weathering is considered one of the factors to bring about the collapse of the brick because Calcite (CaCO_3) and Gypsum ($\text{CaCO}_4 \cdot 2\text{H}_2\text{O}$) were detected from brick debris. It is necessary that the change of amount of collapsed brick with the change of temperature and relative humidity, and the change of kind of salts detect on the surface of the bricks are observed over a year. Moreover, it will be considered that not only salt weather, but also the influence of vibration by tourists and the wind is other driver cause the collapse of bricks. Therefore, investigation on monitoring relating to these cases is needed anew.

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