



6th International Building Physics Conference, IBPC 2015

Deterioration of the wall of a historic stone building in a cold region and measures to protect it

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Abstract

In the northern part of Japan, the air temperature decreases to -10 degrees Celsius in the winter. The outside walls of historic stone buildings deteriorate due to frost damage. We studied the deterioration of historic buildings and their environmental conditions in Otaru and Sapporo in Hokkaido. This paper reports on the observation of the deterioration of the building materials of an important cultural property, the *Nihon Yusen Building*. We also measured the temperature and humidity inside and outside the building as well as the water content of the wall surface. From these observations, it was revealed that the main cause of deterioration was damage to and rusting of the roof and chimney, which allowed rain water and snow-melt water to enter the rooms. The speed of deterioration is considered to be increasing. In particular, parts of the outside stone wall made of Otaru tuff under the roof on the north, west and south sides have deteriorated; this phenomenon was not observed at the time of the previous restoration. Rain water had penetrated into the stone mainly through the deteriorated part of the roof and rain water gutters as well as through the deteriorated part of the outside wall. Part of the water that had penetrated remained under the roof, on the borders previously mentioned, and between the stone blocks. The freeze and thaw cycles of the water in these areas caused the deterioration of the building materials in winter. As a protective measure, it is necessary to prevent the penetration of water into the building materials so as to avoid frost damage in the winter. It is also necessary to restore the roof, chimney and rain gutters immediately to prevent further damage to the building materials.

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Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL

Keywords: Historic stone building; Deterioration; Frost damage; Freeze and thaw cycle

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1. Introduction

A historic stone building, the Nihon Yusen Building, which was designated an important cultural property, is located in Otaru city in Japan (Fig. 1). Otaru city is in Hokkaido and is located in the northern part of Japan. Otaru city was an important port city during the Meiji period when many Japanese people came to Hokkaido to explore the wilderness. During this period, many stone buildings and storages were built by well-known architects using new technology. Construction of the Otaru Branch of the Nihon Yusen building was started in 1904 and completed in October 1906. It is a two-story building made of stone in the French Renaissance style with a zinc-plated iron roof. In September, 1906, a meeting was held in this building to determine the border between Russia and Japan on Sakhalin Island after the Russo-Japanese War. Seventy years after its construction, various parts of the building had deteriorated due to frost damage. Otaru city carried out restoration work for 33 months from October 1984 to June 1987 [1]. Twenty years after this restoration, the Otaru tuff building material had deteriorated under the roof on the north and south sides, and cracks were found at the borders between places where water repellent material had penetrated and where it had not. Wall paper, known as *kinkarakawakami*, had also deteriorated due to the penetration of rain water through the roof. In addition, fungi were found on the wall surface and color changes were observed on the ceiling.



Fig. 1 Nihon Yusen Building in Otaru

2. Deterioration of the building

2.1. Deterioration of the outside walls and ceilings

Fig. 2 shows the deteriorated condition of the walls facing north and east. The left photo was taken in June 2009 and the right photo was taken in October 2011. The white parts are places where the surface stone had peeled off or fallen. These pictures show that the surface area of the deteriorated parts rapidly increased in about 2 years.



Fig. 2 Deterioration of stone wall surface (left: June 2009, right: October 2011)

Fig. 3 shows the deterioration of the surface stone on the lower part of the column near the entrance. The right photo is an enlarged image of this part. The white part near the surface is where water repellent material penetrated, and the black part shows where it did not. On the surface of the upper part of this column, the trace of water fall is found. Water may penetrate into the stone through this deteriorated part, and the deterioration will continue due to the freeze and thaw cycles in the winter season [2].

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