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Analysis of wall exterior temperature and humidity data to characterise component aging conditions

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Abstract

The study of building materials durability and aging are essential to characterize new products, optimize the performance of buildings and adjust the building code for the climate found in Canada. To understand how the properties of a material change over the span of its service life, accelerated aging is often performed. The prerequisite to effective accelerated aging of building materials used in the building envelope is to have a thorough understanding of the aging conditions in the building envelope. To this effect, temperature and relative humidity data within the envelope of the Canadian Centre for Housing Technology (CCHT) at the National Research Council of Canada was examined. This is an instrumented house with brick cladding for which data was recorded on an hourly basis from 2004 to 2009. The data reported is for a south-facing and east-facing walls, and a south facing roof.

The temperature data for the south facing wall was used to determine fluctuations in the high-ends of the average monthly temperatures. The monthly temperatures varied from –25 °C to +45°C for the years 2004-2009, from which the normalized average temperature distribution was calculated. The results showed two distinct peaks one at about 0˚C and the other one at 20˚C (Figure 1). These two peaks suggest the bimodal distribution of data for the “hot” months (April to September) and “cold” months (October to March).

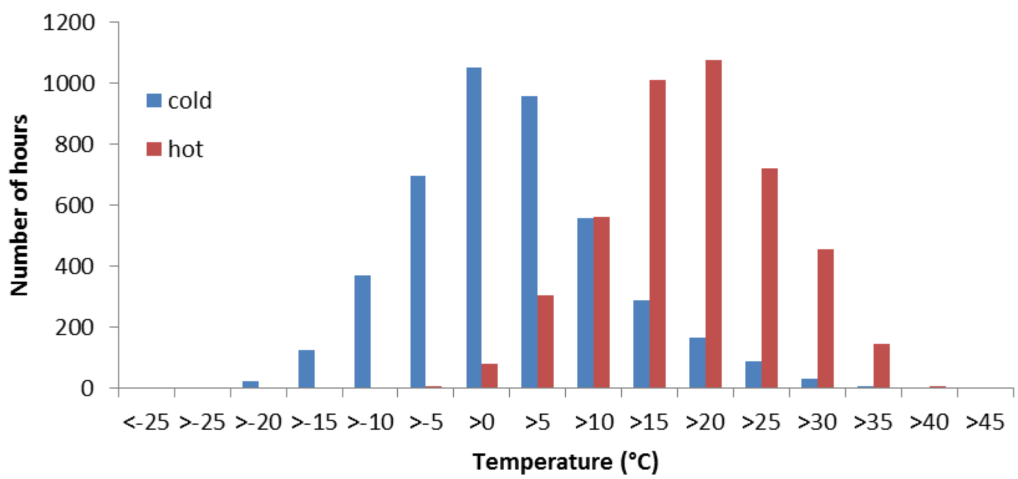

Figure 1: Temperature distribution in number of hours per temperature range for a south facing brick wall. The data is separated into hot and cold months showing bimodal distribution.

The temperature distribution for the wall was then compared to the outside temperature taken from the Ottawa Macdonald Cartier Airport data for the year 2007. The distribution of outdoor temperatures had the same bimodal distribution as the wall temperatures. This leads to the conclusion that the bimodality is not caused by the heating and cooling cycles of the house, and it is driven from the temperature changes in Ottawa. In other words, the temperature distribution in the wall is closely related to the distribution of outdoor temperatures. This bimodality, however, is not found in all climates. For example, analysis of temperature distribution in Vancouver showed a single peak with a very narrow range of temperatures.

The average monthly temperatures for the roof for the years 2004-2009 were also obtained. Then, the normalized average temperature distribution was calculated. The roof temperature data had a larger range compared to the wall temperature data. This can be attributed to the lack of air space between the shingles and the thermocouple in the roof. Similar to the wall results, the roof temperature distribution showed bimodality, related to the outside temperature in Ottawa.

Daily temperature profiles were used to find the maximum hourly rate of change for the temperature. This was done for both the wall and roof data. The maximum rate of change for the wall and the roof were calculated at 2.13°C/hr and 7.11°C/hr, respectively. These results clearly state that the rate of change for the roof is much higher than that of the wall. This is a key factor to be considered during the accelerated aging of the materials in the lab.

The absolute water content was calculated from the relative humidity (RH) and temperature values for an east facing wall during the years of 2004 to 2006. RH fluctuated from 40% to 90% on a typical year, with an average near 70%. From RH and temperature, the absolute water content in air was found to be 5 to 16 g/m^3 (grams water/m^3 of air) in the year, with high values of 10-16 g/m^3 between June and September. During half of the year, the absolute moisture content in the envelope was about 10 g/m^3. This is the basic moisture content to consider in accelerated aging methods.

The effects of air leakage on absolute humidity was also obtained, this time from secondary NRC test huts. This data offered insight into the effects of air leakage on the wall moisture content. The setup included a chamber on the inside of the wall to control the temperature, pressure, and relative humidity. Different size openings, 3 to 6 mm, were made in the wall sheeting to simulate different levels of air leakage. As expected, higher air leakage rates increased the water content within the wall.

Based on this work, more realistic accelerated aging conditions may be developed. The distribution and the limits of temperature and moisture variations, and their rates of change within the building envelope are all elements that will help to develop more realistic accelerated aging conditions to help estimate the durability of building envelope materials in typical Canadian dwellings.

Keywords: accelerated aging, building material humidity, material ageing, temperature