Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Building and Environment 40 (2005) 1450–1458
BUILDING AND ENVIRONMENT
www.elsevier.com/locate/buildenv

A driving rain exposure index for Norway

James P. Rydock[a,d,*], Kim Robert Lisø[b,d], Eirik J. Førland[c], Kristine Nore[a,d], Jan Vincent Thue[d]

[a]*Norwegian Building Research Institute (NBI), Høgskoleringen 7B, NO-7491 Trondheim, Norway*
[b]*Norwegian Building Research Institute (NBI), Forskningsveien 3b, P.O. Box 123 Blindern, NO-0314 Oslo, Norway*
[c]*Norwegian Meteorological Institute, P O. Box 43 Blindern, NO-0313 Oslo, Norway*
[d]*Department of Civil and Transport Engineering, Norwegian University of Science and Technology (NTNU), Høgskoleringen 7A, NO-7491 Trondheim, Norway*

Received 20 April 2004; accepted 22 November 2004

Abstract

Determination of driving rain exposure typically requires hourly values of rainfall and mean directional wind speed. Weather data at most observing stations in Norway are not recorded as hourly values and are therefore not amenable to this type of analysis. We present an alternative method for assessing driving rain exposures based on multi-year records of synoptic observations of present weather, wind speed and direction. Distributions of numbers of rain observations and wind speeds versus wind direction combined with average annual rainfall totals yield quantitative information about driving rain exposures at stations. Results from four weather stations in Norway are presented and discussed, using weather data from the period 1974–2003.

Keywords: Driving rain; Ventilated cladding; Building enclosure performance; Building stock; Weather observations; Norway

1. Introduction

Norway, by virtue of its location, is highly exposed to mid-latitude cyclones impacting Europe from the Atlantic Ocean. The topography of Norway is extremely varied, with a high percentage of mountainous terrain, many deep and narrow river valleys and fjords and a very long coastline extending from the Arctic Ocean in the north to the Norwegian Sea and open Atlantic Ocean to the west, to the North Sea to the south and finally to the relatively protected Skagerrak to the southeast. Not surprisingly, the nature and quantity of driving rain varies significantly across the country. There is, however, no practical tool currently available for assessing driving rain exposures in the planning and design of the built environment, and there has been little progress made during the past 50 years in the quantification and presentation of driving rain values at weather stations around the country. This is important because driving rain represents one of the greatest challenges in the design and construction of outer wall structures in Norway. In this paper, we present a new method for assessing driving rain exposures based on multi-year records of synoptic observations of present weather, wind speed and direction coupled with average annual rainfall totals.

2. Background

Direct measurement of driving rain (combined rain and wind, e.g. a measure of the amount of water passing through a vertical plane) would of course be the most natural means of quantifying driving rain loads at different locations. The equipment necessary to do this

*Corresponding author. Norwegian Building Research Institute (NBI), Høgskoleringen 7B, NO-7491 Trondheim, Norway. Fax: +47 73 59 33 80.
E-mail address: james.rydock@byggforsk.no (J.P. Rydock).

0360-1323/$ - see front matter
doi:10.1016/j.buildenv.2004.11.018

(a driving rain gauge), however, is not standard equipment for weather stations in Norway and consequently, driving rain is not routinely measured. Work on driving rain mapping, therefore, proceeded early on to investigating means of indirectly determining driving rain loads using ordinary wind and rain data. An overview of available Norwegian weather data and existing driving rain calculation methods are presented by Jelle and Lisø [1]. A driving rain map for Norway was developed as early as 1955 by Hoppestad [2]. The map separated average amounts of free wind-driven rain into four principal wind direction components (north, south, east and west). To acquire background data for the mapping, driving rain measurements (using driving rain gauges specially set up for this purpose) were made at four stations, every 12 h over a period of 3 years. For the same 3-year period, wind direction and velocity were recorded every 2 h at the same stations. The product of the wind component in each direction and the measured rain total (on a horizontal surface) was calculated for the period including the hour before and the hour after each wind observation during precipitation. These values were then summed for the 12-h periods corresponding to the driving rain measurements and a correlation coefficient between measured directional driving rain (from the north, south, east and west) and the product of directional wind and rain was determined. The coefficient was then applied to observational data from 1946 to 1950 where precipitation was measured twice daily and synoptic observations made three times daily to compute directional driving rain (in mm/yr) at each of these stations.

In order to accomplish this it was necessary to assume that precipitation events were uniform and started one-half of an observation interval before the first present-weather observation of rain and ended one-half of an interval after the last present-weather observation of rain in a continuous series of present-weather rain observations. A principal weakness in the practical application of this impressive work is that the directional dependence, with only four components, is not detailed enough to be much use in examining local topographical effects, which can be quite substantial over very short distances in Norway. Since the publication of Hoppestad's report, however, a period of almost 50 years, no further improvements have occurred in the area of driving rain mapping on a national level in Norway.

Currently, ISO 15927-3 [3] is available as a European pre-standard and provides two separate methods for calculating a driving rain wall index from wind and rain data. As defined in this document, a driving rain wall index is a measure of the quantity of wind driven rain impacting a point on a vertical wall. The first method detailed in the pre-standard, based on experience in Great Britain, requires hourly average wind speed and direction, as well as hourly rainfall amounts, for a period of at least 10 years (and preferably 20 or 30). Weather observations in Norway have not historically been recorded as hourly averages, and even today this is done at only a handful of stations at the largest airports in the country (though automated weather stations recording hourly wind and precipitation amounts are becoming increasingly common). A nationwide implementation of this method, therefore, is not practical at present.

The second method, which appears to be largely based on experience in France, does not require hourly wind and rainfall data. In this method, an index is introduced which is based on classification of the average weather conditions at a location for 12-h periods (or half-days), as moistening, drying or neutral. A moistening half-day is defined as a half-day with more than 4 mm of precipitation on a horizontal surface, with an average wind speed of greater than 2 m/s, with an average wind direction during the half-day within 60° of the perpendicular to the wall in question, and with the present weather code signifying some precipitation for at least three of the five observations during that half-day (The method assumes observations occur every three hours, so a 12-h period would include five observations, at 0, 3, 6, 9, and 12 h). A drying half-day, on the other hand, is a half-day with an average relative humidity less than 70%, with an average wind speed greater than 2 m/s, and with an average wind direction within 60° of the perpendicular to the wall direction in question. A neutral half-day is any half-day with conditions falling outside of the moistening and drying classifications. In this method, moistening days are given a value of $+1$, drying half-days -1 and neutral half-days 0. A cumulative sum is developed over a year, and an index is defined as the length in half-days of the longest moistening period (or 'spell', as used in the standard) in the year. At the time of writing of this paper, the definition of this index in the pre-standard is somewhat unclear.

Though observations at Norwegian weather stations are typically done only a maximum of three times during any half-day, there is nothing else about the nature of the meteorological observations in Norway that would necessarily preclude use of this second method detailed in ISO 15927-3. Twelve hour precipitation totals are available from most stations and average wind speed, wind direction and relative humidity for half-days could probably be reasonably approximated from the 3-a-day or 4-a-day synoptic observations that are the norm at weather stations in the country (see Section 3). The problem in this context is that the moistening/drying concept upon which the developed index is based is meant to be relevant for moisture transfer from the wetted exterior surface by capillarity into masonry-clad constructions. Masonry construction is deeply rooted in