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Mapping of maximum snow load values for the 50-year return period for Croatia

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A B S T R A C T

Snow load is an important climatic element that is, together with minimum and maximum temperatures and wind load, a part of the national annex of standards for the design of structures. In particular, the characteristic snow load, defined as the maximum snow load at the ground for the 50-year return period, has to be estimated and a map has to be supplied as part of the national annex. The method for the estimation of this parameter at the station locations is presented, followed by the geostatistical mapping procedure used to estimate this parameter for the whole territory of Croatia. Snow load is defined as a product of snow density, snow depth and gravitational acceleration. Although snow depths are measured at a large number of meteorological stations, snow loads are not easy to estimate because of very few snow density measurements. To overcome this, snow density was fitted to snow depth data using linear regression according to the daily pairs of values from 13 meteorological stations. Since snow density changes with elevations and seasons, the stations are divided into three subsets according to station elevation (lower than 600 m, 600–1000 m high and higher than 1000 m) and the regression equations are also built on a monthly basis. These modelling results allowed the estimation of the snow load at 96 low-elevation stations, eight higher elevation stations and one high-altitude station based on the monthly maximum snow depths and the model estimated snow densities. Based on the monthly maximum snow loads, the series of maximum annual snow loads can be calculated for 118 locations. These

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series of annual maximum snow loads are the basis for the estimation of the annual maximum snow load values for the 50-year return period, by means of an extreme value distribution.

Finally, the estimated annual maximum snow load values for the 50-year return period at 118 stations constitute the input for the geostatistical procedure of mapping this parameter for the territory of Croatia.

1. Introduction

Characteristic snow load is an important part of the national annex of standards for the design of structures, together with minimum and maximum temperatures and wind load. It is often considered to be the main action on certain kinds of structures. Hence, careful estimation of snow load values is important in order to avoid both unnecessary construction cost, but also the risk of structure failure (Luna et al., 2005). Designing the building to support a larger snow load would result in lower likelihood of damage, but also in a more expensive building (O'Rourke, 1997), while snow load underestimation can result in premature failure, high maintenance costs, resource damage and safety issues.

In the USA, the snow load standards for the design of structures differ depending on the importance of buildings (O'Rourke, 1997). They vary from:

(a) the snow load for the 25-year return period for buildings that represent a low risk to human life like agricultural facilities,
(b) 50-year return period for buildings of average importance like office buildings and shopping malls,
(c) and even a 100-year return period for essential facilities like police stations, emergency shelters and some health care facilities.

The Croatian Standards Institute publishes standards for the design of structures with national annexes. One of these contains characteristic snow load, s_k defined as the maximum snow load value for the 50-year return period. The existing standards for structural design from the year 2000 have to be updated according to the European standard EN 1991-1-3:2003, Eurocode 1: Actions on structures – Part 1–3: General actions – Snow load, with the new s_k map in the national annex. The details of the mapping procedure of the s_k, together with preparation and description of snow depth, snow density and snow load data are presented in this article.

Depending on the measuring tool, snow density is actually also calculated from snow depth and snow weight, or from snow depth and snow water content. Measuring this parameter is not standard at meteorological stations, so it is less frequently performed (Jonas et al., 2009; Sturm et al., 2010; Roebber et al., 2003), not only in Croatia. It is also time-consuming, since it is recommended that the procedure be repeated a few times to ensure the best accuracy. Sturm et al. (2010) estimate that measuring the snow water equivalent takes ∼20 times as long as measuring depth.

Estimation of snow density is not only a problem for snow load calculation, but is also important for the forecast of the snow depth from the quantitative precipitation forecast (Roebber et al., 2003). The simple, but inadequate, rule of 1:10 ratio, reflecting an assumed snow density of 100 kg m^{-3}, has been used in the USA and Canada to estimate snow depth. The neural networks algorithm has been proposed by Roebber et al. (2003) that predicts density based on monthly solar radiation, vertical profiles of temperature and humidity, and external compaction (surface wind speed and liquid equivalent precipitation).

Another application is by Sturm et al. (2010), who convert a large number of snow depth measurements into the snow water equivalent to be able to access worldwide snow water resources. The snow density model they developed used the day of the year, snow depth and climate classes to predict snow density.

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