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Towards new European snow load map

Support to policies and standards for sustainable construction

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Abstract

The Mandate M/515 of the European Commission to CEN requested the assessment of the climate change implications for the Eurocodes, the European standards for structural design. The European Commission Mandate M/526 requested the European Standards Organisations (ESOs) to contribute to building and maintaining a more climate resilient infrastructure throughout the EU in the three priority sectors: transport infrastructure, energy infrastructure, and buildings/construction. To proceed with the envisaged adaptation of the European standards to the implications of climate change, the expected changes in the climatic loading shall be assessed in terms of the Eurocodes concept for the characteristic values of the variable climatic actions.

The present report justifies the need of a European research project to develop an advanced procedure for deriving snow load on structures, taking into account climate change projections, and to set up a new European snow load map based on this procedure.

1. Rational and policy context

One of the conventional remarks about global warming is that as an obvious consequence of it, a reduction of snow load on the ground should be expected. In reality, it should be considered that the snow load on ground is often depending on local orographic situations that can determine increases of the height of local snow falls, even in case when the average snow height is reduced considering larger areas. In addition to that, the capacity of the atmosphere to hold moisture increases with the temperature, and this phenomenon may lead to an increase of both, the snow density and the occurrence of extreme snowfalls in regions where temperatures still may happen to be below freezing level during precipitation events.

Large snow loads on roofs during the winter season of 2005 - 2006 led to over 200 roof collapses in Central Europe. During the same winter season, two accidents with roofs of public buildings in Germany and Poland due to heavy snow loads led to 80 victims and more than 170 injured people. Hence, there is a need for re-evaluating the background for snow loads used in the design of buildings.

In view of the specific and wide ranging nature of climate change impacts on Europe, the European Union Strategy on adaptation to climate change (COM(2013) 216) envisages measures to be taken from local to regional and national levels. The Strategy emphasises the role of the European Union to fill both knowledge and action gaps to complement these efforts. Furthermore, it recognises the central role played by the technical standards in key vulnerable sectors like infrastructures and buildings, characterised by a long life span and high costs.

The Mandate M/515 of the European Commission to CEN requested assessment of the climate change implications for the Eurocodes, the European standards for structural design. The European Commission Mandate M/526 requested the European Standards Organisations (ESOs) to contribute to building and maintaining a more climate resilient infrastructure throughout the EU in the three priority sectors: transport infrastructure, energy infrastructure, and buildings/construction.

To proceed with the adaptation of the European standards for transport infrastructure, energy infrastructure, and buildings/construction to the implications of climate change, the expected changes in the climatic loading shall be assessed in terms of the Eurocodes concept for the characteristic values of the variable climatic actions. Such estimates will not be produced by the on-going European research projects on impact of extreme weather on the critical infrastructure (e.g. INTACT FP7 Project, RAIN FP7 Project). To this end there is need to set up European research projects which basing on state-of-the-art research will define procedures for derivation of climatic loading for structural design (snow, thermal, wind) from climate change projections and will produce harmonised European climatic design maps. The present paper justifies the urgent need of European research project on definition of a new European snow load map for structural design to take into account the implications of climate change.

2. Main findings

The IPCC Working Group 1 conclusions state that generally the snow cover extent will be reduced (IPCC, 2013). However, snow cover sensitivity to precipitation and temperature changes is highly related to topographic features such as elevation, aspect and terrain shading. Several literature studies based both, on regional climate models and on general calculation models (e.g. Krasting et al., 2013, Raisanen and Eklund, 2012, Lopez-Moreno et al., 2011) sustain the scientific evidence that in some areas of the world (even in Europe), the snowfall is expected to increase due to the climate change.

A reduction of snowfall is not directly linked to a reduction of snow load. In fact, the rain falling on snow can be stored within the snow pack, resulting in an increase in the total snow load (Strasser, 2008). In addition to that, the capacity of the atmosphere to hold moisture increases with the temperature, and this phenomenon may lead to an increase of both, the snow density and the occurrence of extreme snowfalls in regions where temperatures still may happen to be below freezing level during precipitation events.

The snow load was the reason for 216 roof collapses in Germany, Czech Republic and Poland in the winter of 2005 – 2006, as reported by Vasek (2006) and

Strasser (2008). Holicky and Sykora (2009) proved that the use of light-weight roof structures increases significance of snow load and an insufficient reliability level may be obtained by the partial safety factor design, as prescribed by the Eurocodes. In addition, the use of high-quality materials for heat insulation of roofs protects snow from melting and may cause its accumulation (often non-uniform). The study concludes that further refinement of the consideration of the snow loading in the design standards is needed.

Fig. A – The collapse of the Katowice Exhibition Hall in 2006 (source: http://www.szymborski.org/krajobraz-mtk/)

One of the main concepts of the Eurocodes is the design working life (DWL), which is defined as the period for which the structure shall be used with anticipated maintenance but without major repair. The structures designed in 2020 shall withstand climatic actions (snow, wind, thermal) and extreme events expected in 2070 (as for buildings), and in 2120 as regards bridges and monumental buildings. In the current version of the Eurocodes, the definition of snow loads on structures is largely based upon the results of the European Snow Load Research Project (ESLRP) (1998) and, in particular, on the European Ground Snow Load Map elaborated within that research. This map was the first snow load map derived at European scale with a strong scientific basis (ESLRP, 1998) and its elaboration started from the analysis of the basic snow data collected

across 18 European countries, which at that time were members of CEN. The produced snow load map is incorporated in Annex C of EN 1991-1-3 with the aim to help National Competent Authorities to redraft their national snow maps and to establish harmonised procedures to produce such maps.

CEN/TC 250 "Structural Eurocodes" has started the works on the evolution of the Eurocodes under the Mandate M/515, and the second generation of the Eurocodes is expected by 2020. The primary focus of the works related to climate change will be to define the way to incorporate possible climatic change events and actions in the design rules. No new maps of climatic actions taking into account the implications of climate change are planned under Mandate M/515.

The recent failures of roofs in Europe caused by considerable snow load, naturally call to estimate the expected snow load on structures taking into account the implications of the climate change. Only after having such an estimate it will be possible to proceed with further refinement of the definition of the snow load in the European design standards.

A pilot study by the University of Pisa supported by the JRC developed and validated procedure for derivation of snow load on ground from data on daily temperatures and precipitation (Macerini, 2015, Croce et al., 2016). This procedure allows to derive the characteristic snow loads from climate change projections and thus to evaluate the future trends of variation of snow loading. The procedure was used to compare the snow load on the ground in Italy according to the Eurocodes snow map ($Q_{k\ EN}$) and the one estimated from observed gridded data (E-OBS dataset for the period 1981-2010) $Q_{k\ EOBS\ corrected}$.

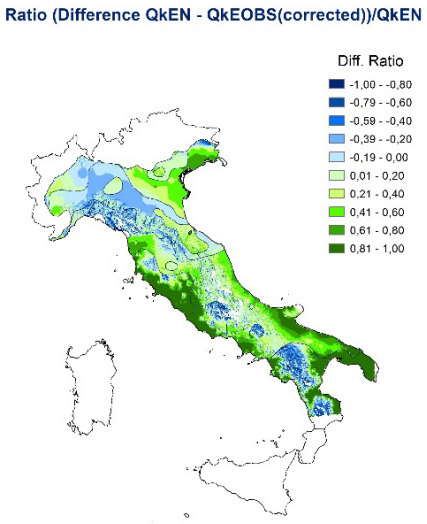

Fig. B. Comparison of snow loads at effective site altitude in Italy in terms of ratio between (Q_{kEN} – $Q_{k\ EOBS\ corrected}$) and $Q_{k\ EN}$

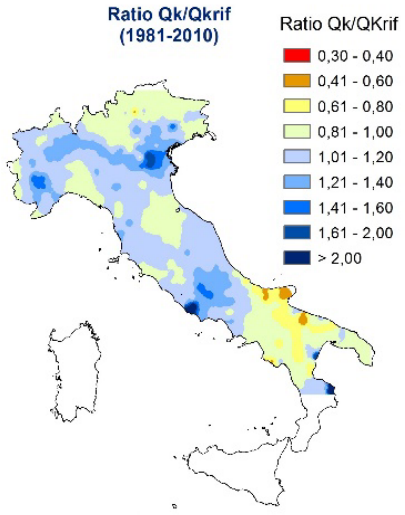

Fig. C. Ratio of snow load obtained from data for 1981-2010 (Q_k) and data for 1951-1980 ($Q_{k,rif}$)

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The results presented in Fig. B show that the current Italian snow map underestimates (up to 2 times) the ground snow load for northwest Italy and some regions in southwest Italy, and thus the map shall be updated.

Analysis of the trends in variation of the snow loads for the Italian territory (Croce et al., 2016) was performed with E-OBS data comparing the results for several time periods of thirty years, shifted by ten years, with those obtained for the reference period 1951-1980 ($Q_{k,rif}$). The results presented in Fig. C show increase of the snow loading (up to 2 times) in many regions in north and central Italy. The on-going research focuses also on comparing results obtained by observed point-source data (weather stations) and observed gridded data (E-OBS dataset) in order to set up a methodology to analyse gridded data which takes into account the effects of area average on the extreme values. Analysis of the trends for the Italian territory is performed using different regional climate models, general calculation models, and different representative concentration pathways scenarios.

3. Prospect for new European project on snow load map

The objective of the proposed research project will be to set up an advanced procedure for deriving snow load on structures taking into account the climate change projections, and basing on this procedure to derive European snow load map. The research project shall also consider snow redistribution (snow transport, Meløysund, 2010), as well as the occurrence of rain after a snowfall, which could contribute a substantial increase of the density of the snow layer. The pilot study on the implications of climate change on snow load provides a strong scientific background to the project.

Besides the use of the results of the project for further refinement of the definition of the snow load in the Eurocodes, the produced European snow load map can be used to update the existing snow load maps in Annex C of EN 1991-1-3 with the aim to help National Competent Authorities to redraft their National snow maps. The new load snow map should encompass all CEN Member countries and other European countries which are adopting now the Eurocodes, e.g. the Balkan countries which are not Member States of the European Union. The project on the snow load map shall be started as soon as possible, in order to have the results before finalizing the works on the second generation of the Eurocodes, which is expected in 2020.

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