Preparing a European standard for ice loads on structures

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Abstract— **The on-going work to prepare a new European standard for ice loads on structures is described.**

Keywords— ***Design standard, ice actions, ISO 12494, characteristic ice load, prEN 1991-1-9, ease of use.***

I. Introduction

In many countries, the standard ISO 12494 "Atmospheric icing of structures" [1] is used as the national standard for ice loads or, alternatively, the national codes refer to specific clauses of ISO 12494. Presently the Eurocodes EN 1993-3-1 (2006) and EN 1993-3-2 (2006) provide some basic guidance on how to consider ice loads in design of towers, masts and industrial chimneys, and for more detailed guidance they make reference to ISO 12494. For overhead power lines, the CENELEC standard EN 50341-1 (2012) should be applied. In some other countries, such as USA, there exist independent national standards for ice loads. This, somewhat coherent situation, is a result of historical developments and only partly justified by climatic factors.

In an effort to unify European standardization a new Eurocode for ice loads on structures is presently under preparation, funded by the European Commission under the Mandate M/515 to CEN. This task, monitored by the subcommittee CEN/TC 250/SC 1 "Structural Eurocodes - Actions on Structures", has been undertaken by the project team "SC1.T8: EN 1991-1-9 Atmospheric icing".

ISO 12494 will form the basis of this new Eurocode. However, rigorous attempts are made in order to simplify the determination of the design ice loads, and to enhance the ease of use. Moreover, updates based on research over the last two decades will be included, and the procedures will be adjusted to take into account local climate factors, yet minimizing, as far as possible, the need for national choices. Since the new document will be part of the Eurocode-system, harmonisation with other Parts of Eurocodes needs to be done appropriately. For example, the combined ice and wind load will only partly be included in the icing code. Combination rules for ice loads with wind on structures, recommended values of partial factors and combination factors ψ will be transferred to new Annex A.3 of EN 1990 for the basis of design of towers, masts and chimneys. It should be noted that for overhead power lines, different definitions of ice loads, wind actions and their combinations are recommended in EN 50341-1 in comparison to ISO 12494, see [24, 25].

This presentation explains the planned major changes as compared with ISO 12494, and discusses some issues of practical structural design in an icing environment. Section IV describes the data used and section V presents the results. A discussion is carried out in section VI.

II. PRINCIPAL CHANGES COMPARED TO ISO 12494

The scope of the new standard will be the same as that of ISO 12494. This means that it will cover ground-based structures, but not specifically power line cables or wind turbine blades. Formally, the new code will follow the general principles and the format of Eurocodes. There will be appropriate liaison with other Eurocodes, in particular with the ones related to wind actions on iced structures.

The main clauses are simplified to be better understandable and selected details are presented as notes. Many tables given in current ISO 12494 will be replaced by equations in an attempt to make the new standard more concise. There will be annexes, but they are focused on the practical use of the standard rather than providing extensive background information.

As to major technical changes, the principle of using a reference ice load (mass for rime and thickness for glaze) of ISO 12494 is maintained. However, the use of a characteristic load instead of an ice class may also be allowed as a national choice. The rime ice shape model for various structural components is considerably simplified. The modern methodology of using high-resolution atmospheric models in producing input for icing modelling [2] is promoted as an additional tool for estimating the ice classes and characteristic loads.

III. UPDATES AND SUPPORTING DATA

Since the release of ISO 12494 in 2001, there have been considerable developments in the science of icing as it relates to applications, such as determining design ice loads for structures. How these developments will be taken into account in the new Eurocode, is summarized below.

Perhaps, the most important studies regarding the new icing code are those related to verifying the methodology behind ISO 12494. Such verification for the overall methodology was made in reference [3], where it was shown that the ISO-method produces realistic ice load estimates on a lattice towers in a wide range of ice classes. The particular assumption that the rime ice mass on cylindrical objects is practically independent of their diameter has also been verified by numerical flow field modelling [4], as well as experimentally [5]. The very important issue of the height-dependence of rime ice loads on tall structures was studied in reference [5], finding very good correspondence between the ISO-equation, icing modelling based on high-resolution atmospheric hindcast, as well as direct observations. The wind drag coefficients for iced structures, adopted in ISO 12494, also seem to be quite appropriate, based on recent experimental studies [6].

In addition to the verification of the ISO-methodology, recent work includes information that can be used in updating the methodology. For example, a new method for estimating the height-dependence of glaze ice loads [7] is available, and will be adopted in the new Eurocode. Wet snow accumulation is also now better understood [8, 9, 10], and this understanding will be taken into account. The European Action COST 727 produced new theoretical [11, 12] and experimental [13, 14] approaches to icing which may be utilized in engineering work. In particular, theoretical icing modelling using, as input, meteorological data from high-resolution atmospheric models, was developed. This resulted in prospects to use historical meteorological data in determining characteristic ice loads for an icing map [9, 15], as well as for local sites [5, 16, 23].

As a part of preparing the code, the project team prepared a questionnaire that was sent for response to major designer companies of tall structures in Europe. The main question for the users was about requested improvements of ISO 12494. There were many useful comments that have been taken into account in the draft for the Eurocode.

IV. DISCUSSION

At the time of the IWAIS 2019 Workshop, the preparation of the new Eurocode is in a phase where a second draft has been submitted to CEN/TC 250/SC 1 for further comments. Those comments, as well as other possible comments, are then taken into account in the final version. For example, the shadowing effect of iced components of a lattice structure, that has been unclear to many users, may now be approached based on recent experimental data [17].

Some issues are under consideration and will be dealt with according to further comments from outside the SC1.T8: EN 1991-1-9 team. These include the modification of determining the design glaze ice thickness for objects of different shapes proposed in reference [18] and presently included in the American standard [19], and utilization of detailed studies on falling ice made in reference [20]. A further issue is to consider how the icing maps for the frequency of icing [15, 21, 22], developed for wind energy research, could be used in the design of structures in view of the extreme ice loads.

It is expected that basis for combination of icing with wind will be transfer from EN 1991-1-9 to EN 1990, Annex A.3. Level of structural reliability of towers and masts should be further verified for considered categories of consequence classes and values of partial factors and combination factors should be recommended.

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