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THE BACKGROUND DOCUMENT FOR SNOW LOADS

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Luca Sanpaolesi is involved in Structural Engineering studies, with particular regard to Actions. He has participated, since the beginning , to the development of the Eurocodes, in a first phase under EEC and in the second phase under CEN guide.
In EC1 works has been Convener of the Project Team on Snow Loads and member of the PT on Traffic Loads on road bridges. In Italy is involved in preparing codes on actions.

Summary

The Background Document treats about the most important, both technical and scientific arguments, regarding snow loads, showing the reasons of the choices, which has been made by the Project Team during the elaboration of the new Code for Snow Loads and also the open problems, proposing future research programs.

1. Introduction

The chapter dealing with rules on snow loads forms part of the Eurocode 1 - Basis of Design and Action on Structures. In 1990 a specific Project Team (PT) was formed and charged to carry out a research programme in order to produce this chapter. The PT was made up of: Luca Sanpaolesi (*University of Pisa - Italy*), Manfred Gränzer (*Landestelle für Bautechnik - Germany*), Haig Gulvanessian (*Building Research Establishment - United Kingdom*), Joel Raoul (*SETRA - France*), Rune Sandvick (*NBR, Norway*), Ulrich Stiefel (*Gruner AG, Switzerland*). In addition the following contributed to the research: John Tory (*Building Research Establishment - United Kingdom*), Diana Currie (*Building Research Establishment - United Kingdom*), Riccardo Del Corso (*University of Pisa - Italy*).
At the end of the works, in 1993, the PT decided to explain, in a volume, the fundamental principles which inspired the Code ENV-1991-2-3 itself. This volume has been written in 1994 and 1995, it is titled "New European Code for Snow Loads - Background Document" and a copy of it is now available for each participant to this Colloquium.
In carrying out its work, the PT studied and discussed many specific issues relevant to the various aspect involved in defining snow loads on constructions. The scientific criteria followed by the PT in defining the Code has been based on present state of the art, rather than specific reviews of existing codes. Nevertheless, during the actual drafting, particular attention has been provided for the ISO 4355 (1981), not to introduce its contents into the New Code,

but only to verify the research results with existing ones. On the contrary new draft of ISO 4355, dated 1993, has not been taken into account, being too much complicated to serve at an easy and practical definition of Snow Loads.
In this spite the aims envisioned by the PT in drafting the Background Document can be divided into three:

- illustrate the underlying rationale for and the choices made in EC1 - Snow Loads;
- provide information regarding the basic studies to the NCA;
- furnish broader guidelines and explanations to designers.

In the following the Background Document will be shortly illustrated with special regard to some of the most relevant problems.

2. Ground Snow Loads

2.1. Climatic data

The first problem encountered in studying snow loads regards climatic conditions and the need for quantitative definition of the ground snow loads. The problem is quite complex and depends on several factors, such as region's climate, altitude and topographic features, many of which causes consequences in the determination of snow loads which lead to the need of more detailed studies in the field.
The soundest basis for assessing characteristic snow loads are long term records of snow loads measured at a large number of stations. Such a solid basis is difficult to achieve because of the scarcity, both in frequency and in geographical density, of the available data, which have often been collected not with engineering objectives. Another problem consists in obtaining homogeneous measurements taken all over the European territory, existing different measurement techniques, such as weighing snow cover or evaluating the water equivalent values starting from the measure of the snow cover depth. The major frequency, up to date, of records giving snow depth, instead of weigh values, has lead to the need to describe, with empirical formulae, since no physical models exist which would permit this calculation, the correlation between snow depth and snow density, taking into account all the factor which affect the deposition of snow, such as wind, temperature, rain falling onto the snow and the nature of the snow layer. The snow cover, in fact, can be considered, for some regions, to be the result of multiple snow events, in climates where the snow accumulates over a relatively long period of time; on the other hand the snow cover can also be considered as the result of single snow events, in climates where the snow tends to melt completely between successive weather systems.

2.2. Statistical analysis of snow loads

Data records have to be treated with statistical procedures aiming at fixing a load value for design purposes.
Statistical analysis is first applied to the record made at a single station alone. The daily registered snow load values combine to give a record of the whole winter season. The values of particular interest to be found in records of daily registered values are the absolutely yearly maximum. These extreme values, one for each winter, have a statistical distribution, which may be approximated to one of the well-known extreme value distribution functions.

The reliability of statistical analysis depends on the length of maximum value records. It has been proved, thanks to a German investigation based on 94-years snow depth record, that the design value derived from samples of a floating period of 30 consecutive winters are not yet stable, but still influenced by exceptional years. Consequently, in the purpose for CEN Code, in which snow loads are given with a mean recurrence interval of 50 years, a record length of 40 to 50 years have been suggested for the statistical analysis of the collected data.
As already mentioned, the statistical analysis of the data consists in checking on distribution types to find the best fit to the sample data. It has been found that the choice of the probability function is influenced by the climatic condition of each site; for example, the Gumbel distribution seems to be preferable for regions whose maximum snow cover is usually build up trough accumulation of several snowfalls, while the lognormal distribution better suits regions where maximum amount of snow is caused by a single snow event.
Compared to the imposed or wind loads, snow loads may have a notably higher coefficient of variation. The smallest coefficient are found in mountainous regions where snow falls quite regularly and accumulate during the winter. In many areas, especially in coastal areas and in the southern part of Europe, snowfalls do not occur every year. Taking into account these zero values, if their number is quite important, in the statistical analysis should lead to unrealistic results. In this cases the analysis should be restricted to the non-zero values only, by operating an adjustment of the return period.
Another problem which has been encountered is represented by the "exceptional snow falls". These values are so high that clearly do not fit the distribution calculated when they are discounted. A study, carried out in France, has shown the great influence that these values would produce on the distribution function's parameter if taken into account (see fig. 1).

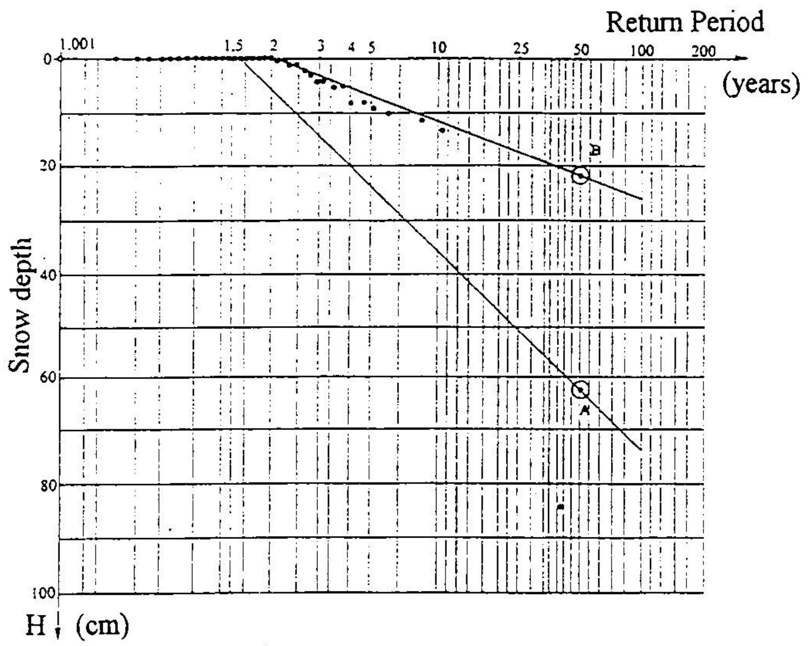

Fig. 1. Snow at Perpignan.

The purpose of the PT is to dealt with exceptional snow falls separately in order to determine the accidental value for the snowfall. A still open problem is the drawing of an European map where are defined all the areas where the exceptional snow falls have to be considered.

2.3. Characteristic snow load and return period

The characteristic snow load on the ground is based on annual probability of exceedance of 0.02 (1/50), that correspond to a mean recurrence interval of 50 years as recommended in the "Basis of Design". The choice of a 50 years return period, as already mentioned above, avoids inappropriate extrapolation from a data sample which generally cover several decades. It is to notice that it does not mean that it will necessary take 50 years after construction of a building for the characteristic snow load to be exceeded. From this point of view it is explained how much dangerous it is to reduce the design snow load taken from an extreme value distribution for a return period directly equal to the reduced expected lifetime of a temporary structure.

2.4. Regionalization

All the procedure and the problems encountered in what described above dealt with the analysis of records snow measurements at the single station, in order to find the characteristic ground snow load valid for each station. Now a procedure must be found to arrive at a geographic representation of the results, covering a whole region starting from the point values obtained at observation places.

The merely mathematical approach to this problem, trough one of the several existing methods, would give a continuos best fitting geographic distribution of the characteristic snow loads. Such an automatic procedure would completely ignores the knowledge and the experience of meteorologists and would furnish misleading results.

Sample data and the corresponding characteristic value obtained at a single station are influenced by several factors: orography, frontal waves, presence of great lakes, distance to the sea (macroscale effects); slope and contour of terrain, canopy and crop density (mesoscale effects); surface roughness presence of obstruction (microscale effects). All these parameters have to be taken into account for the extrapolation of a snow load map covering whole regions, making distinction between various homogeneous areas, in other words to carry out a regionalization.

It has been shown that very important parameters for local snow load variation are mainly: altitude, air temperature, orientation to solar radiation and wind exposure. In particular, it is often possible to arrive at a quite simple relationship between snow load and altitude alone, determining the "Altitude functions".

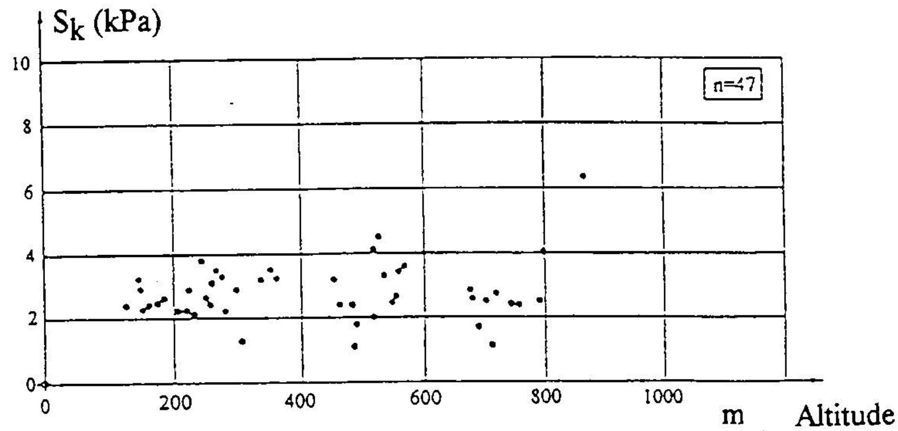

Fig. 2. Snow load; 50 year return period - County: Hedmark. Poor correlation between snow load and altitude.

Large European countries have used this method of zoning in their national codes. This simple procedure is not suitable for all European regions, as shown in a Norwegian study: there are areas where snow load does not increase with altitude following a more or less complex law (see figure 2).
The PT has always aimed at the definition of general rules, applicable in all CEN member states, in order to achieve a homogeneous framework for determination of design snow load.
In a first phase was attempted to collect existing snow load data from several European countries and to elaborate in a new European snow map. Since the differences in the criteria that each country have followed in measuring, collecting and elaborating that data, it was impossible to proceed in this direction; the PT went back to the national codes re-elaborating these ones to achieve a common level of safety. In this way arose conceptual inconsistencies and not acceptable differences at the borderlines between the countries. This inconvenience had to be accepted during the first phase of works.
What stated above leads to the need of a great research programme in order to determine a new European snow load map, elaborated with common and homogeneous techniques all over the European territory. This research would permit to update records of each country and to standardise and simplify the application of the Code.

3. Snow loads on structures

The roof snow load is normally calculated form the ground snow load by multiplying by conversion factors which account for the roof shape, thermal characteristics, exposure and, depending on the code, other influences that may increase or decrease roof snow loads.
The scientific basis underlying determination of the roof coefficients is rather limited and research work has been carried out especially in cold regions, thus these results are not directly applicable to all of Europe. It has been necessary to develop empirical formulae supported by experience and engineering judgement. In this field the comparison of the adopted criteria and parameters for the determination of snow loads on structures in the CEN Code and in the ISO 4355 one, has been very useful for testing results (see figure 3).

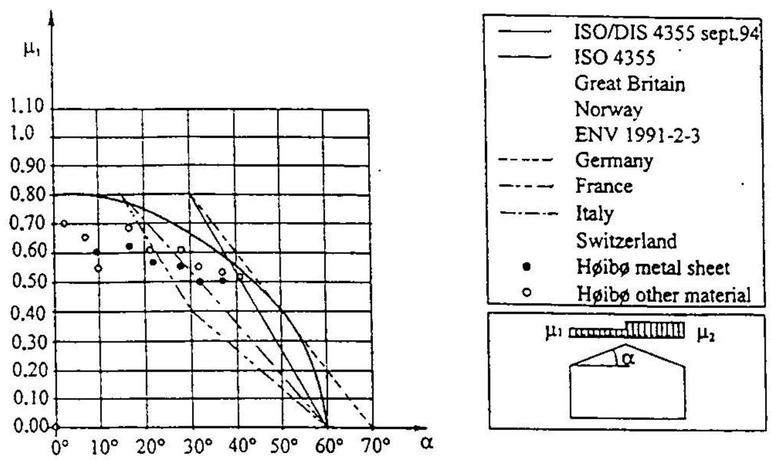

Fig. 3. Shape coefficient μ_1 for duo-pitched roofs.

In determining the conversion factors there are mainly three source of uncertainty: natural uncertainty, statistical and model uncertainty. Against natural uncertainties it can not be dealt with; on the other hand treatment of the uncertainties in the statistical and modelling procedures would follow lines similar to that for determining ground snow loads. It must be said that all the influences that affect ground snow loads determination also affect the roof snow load, to which are added the uncertainties in the other influences related to the roof itself.
The statistical uncertainties begin with data sampling due to difficulties of measuring directly the snow load on roof and to the enormous number of different types of roofs. Although the code attempts to standardise such types, the huge of existing roof shapes must be underscored. As for the ground snow loads, the problem of translating height into the load, until new practical techniques of measurement will be set up, also exists for the roof snow load. The probability distribution function, or the probability model for analysis of sampled data has been studied only rarely. It is necessary to develop simple models which permit calculation of the design load, in respect of the fixed levels of safety. Within a reasonable degree of uncertainty, the selection of two different loading types can be proved: a uniform and an unbalanced distribution of the snow layer.
The substantial lack of scientific knowledge on a probabilistic basis has emerged from elaboration of the shape coefficient within the EC1 work. Only further research will be able to reduce such uncertainties and therefore future efforts must be concentrated on this issue.
Herebelow are listed some of the specific arguments which could be object of this research:
- specific study about the definition of the values of the shape coefficients for the more frequent typologies of roof;
- probabilistic basis: only with such a prenormative research it will be possible to provide roof snow loads with a defined mean recurrence interval;
- shape coefficient for regions within single snowfalls.

4. Design situations

From the point of view of risk analysis it must be mentioned that the selection of relevant design situations is far more important than trying to develop "precise" partial factors. Therefore it is important to use good engineering judgement in selecting design situations that may occur and for which the design of the structure must be performed with reference to the SLS and ULS.
Special attention have to be used: in evaluating snow load on multi-level roofs with special dimensions such that cut drifts might result; in determining snow distribution model on roofs in those regions where, due to wind conditions, drifting predominates; in fixing snow loads in constructions without walls, for which high values of snow load, superimposed to horizontal wind action or horizontal earthquake acceleration may cause failures.
The combination factors between different action given in "Basis of Design" have been calibrated upon national codes values and general reflections. So far, no systematic calculation checks have been performed for snow loads combined with other actions and no investigation has been made in order to evaluate the modifications which may be required for different geographical regions.
In designing for serviceability, functioning and appearance of construction or its parts and comfort of people must be achieved by checking the structure in appropriate load combinations similar to the ultimate limit states ones. The corresponding representative values are obviously dependent on snow dispersion, but are also strongly influenced by the duration of the snow

cover on the ground, which depends on the region's climate. An important research work should be carried out, in the whole Europe, for the determination of the correction factors to be applied to snow load values, for serviceability checks, distinguishing between short-term value and long-term value. Such a research, performed for Switzerland only until now, would permit to execute serviceability verifications whit special reference to long term effects of great importance, for example, for timber structures.

5. Conclusions

The above illustrated "Background Document for Snow Loads" collects all the studies and the most significant issues encountered by the Project Team during the Code's elaboration. It is addressed to Engineers and to National Authorities charged to prepare national codes, in order to illustrate the underlying rational for and scientific basis of the choices made in Eurocode 1. Until now the still open problems are a lot and they regard all the fields of study.
There is no doubt that the ENV-1991-2-3 represents only a good base for the harmonization of the snow load on structures and are therefore necessary more detailed studies and researches in order to achieve a more faithful standardization.
Similar items arise in other codes on snow loads, such as ISO 4355 (ed. 1981 and ed. 1993), which do not solve the open problems mentioned above, especially for extremely non homogeneous regions such as Europe, extending from North Cape to Sicily, where climate conditions present widely varying features.
The "Background Document", in author's opinion, is an helpful publication and, supported by the research work that is to be developed, will lead to an improvement of the Code from the ENV phase towards the EN one.

References

The Background Document for Snow Loads presents, as already mentioned, an extremely wide bibliography, updated to 1994. Thus, for a complete bibliography list, it is made reference to the document itself.

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