Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 12 (1984)

Artikel: Damages due to snow loads

Autor: Johansson, Germund / Johannesson, Bengt

DOI: https://doi.org/10.5169/seals-12204

Damages Due to Snow Loads

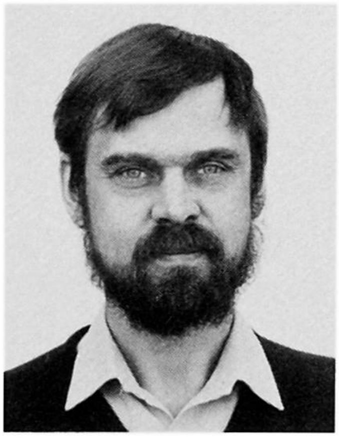
Dommages causés par des charges de neige

Durch Schneelast verursachte Bauschäden

Germund JOHANSSON
Tekn. lic., Lecturer
Chalmers Univ. Technol.
Göteborg, Sweden

Germund Johansson, born 1937, obtained his civil engineering degree at Chalmers Univ. of Technology in 1962. After some years at a consulting firm for geotechnical problems he joined the Dep. of Steel and Timber Structures at Chalmers Univ. of Technology. His research interests include steel structures, roofs, and structural damage due to snow, wind etc.

Bengt JOHANNESSON
Civ. Eng., Ph.D.
Chalmers Univ. Technol.
Göteborg, Sweden



Bengt Johannesson, born 1944, obtained his civil engineering degree at Chalmers Univ. of Technology, in 1972. For two years he worked as a designer in a glulam factory. After returning to CTH, Dept. of Steel and Timber Structures, he spent most of the time in research on structural timber. For some years he has also been working for the National Testing Institute in Sweden. He received his Ph.D. in 1983.

SUMMARY
Structural failures caused by snow loads are discussed. Nearly one hundred failures have been investigated and some examples are given. Nearly all of the structures involved were light-weight steel or timber structures. The failures are mostly due to mistakes in the design or manufacture.

RESUME
Cet article présente une étude de dommages causés à des structures par des charges de neige. Près de cent cas ont été examinés, et pratiquement tous concernent des structures légères en acier ou en bois. Ils sont apparus surtout à la suite d'erreurs dans la conception ou la fabrication. Quelques exemples ont été sélectionnés.

ZUSAMMENFASSUNG
Durch Schneelast verursachte Bauschäden werden behandelt. Fast einhundert Schäden sind untersucht worden, und einige Schadenfälle werden näher beschrieben. Die meisten beschädigten Konstruktionen sind leichte Konstruktionen aus Stahl oder Holz. Die Ursachen der Schäden sind gewöhnlicherweise Fehler beim Entwurf oder bei der Herstellung.

1. INTRODUCTION

During the winter 1976/77 heavy snow loads caused several structural failures in Sweden. Most of these failures occurred in the southern part of the country (Fig.1). The damages were of different types, ranging from failures in roof covering due to freezing water to completely collapsed buildings.

This investigation was concentrated on damaged structural members since failures of a member may often lead to complete failures of roofs or of buildings. In these cases there are great risks that people get hurt and the failures often lead to great losses in production etc. The aim of this investigation was to collect as much information as possible about the causes of the damages. Almost one hundred different damaged structures were studied.

During the winter the snow depth at different locations was measured by the Swedish Meteorological and Hydrological Institute (SMHI). Some of these measurements were compared with data from previous winters. It was found that in some cases the snow depth during the winter 76/77 considerably exceeded the 50 year Mean Recurrance Interval (MRI) ground snow depth, cf. table 1. However, this is not necessarily an extremely high value of the load.

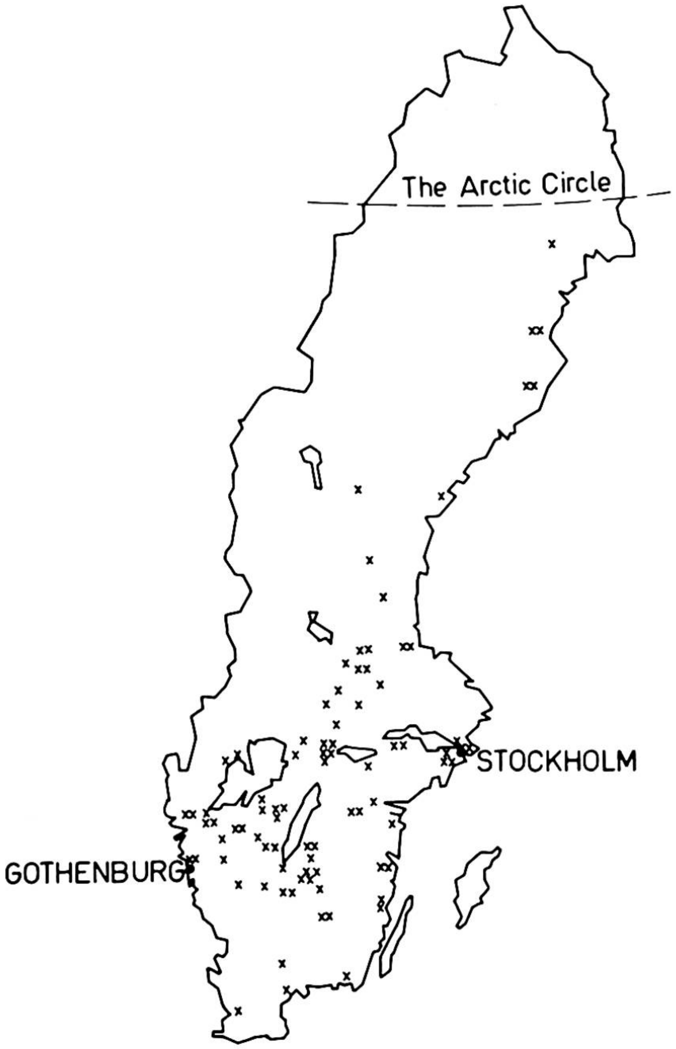


Fig.1 Map of Sweden with marked failure locations.

SMHI-Station	Measured snow depth m	50 year MRI m
Nyköping	0.75	0.66
Norrköping	0.74	0.51
Jönköping	0.69	0.38
Växjö	0.38	0.51
Ulricehamn	0.84	0.85
Skara	0.63	0.45
Falun	0.78	0.81

Table 1 Measured maximum snow depth and 50 year MRI ground snow depth.

2. COLLECTING INFORMATION

At first some information on damages was collected from notes in newspapers. In order to follow up these articles building approval authorities in all the 277 town and rural districts in Sweden were contacted and asked to report damages. The information obtained this way was of very varying quality. In addition to these "official" ways we got information through personal contacts with consulting engineers, contractors and insurance companies.

It was found that the first information either obtained by a letter or by phone was not always correct. A deeper study of a damage gave further details and revealed that the damage was not quite as firstly described and that the causes first assumed were not the proper ones. In roughly half of the cases studied we had to change our opinions. It is obviously necessary to treat first-hand informations with great care.

During the investigation of some failures it was apparent that some of the manufacturers were most unwilling to give any information about the building. They seemed to be afraid of getting a bad reputation.

3. CAUSES

The main reason for the structural failures has been the heavy snow loads causing the total load to exceed the load carrying capacity of the structure.

Table 2 shows a comparison of all the failures examined, with respect to both the cause of failure and the structural material. The table contains both small and big damages - ranging from buckling of steel sheets to total collapse of whole structures. The line in the table denoted *"Excessive snow load"* includes the cases where the amount of snow exceeded the snow load given by the Swedish Building Code and the cases with drift snow and sliding snow. *"Manufacturing faults"* includes all types of deviations from the prescribed design, both in the factory and at the building site. *"Underdesign"* means that mistakes were made either in the calculations or as an inappropriate design.

Estimated cause of failure	Steel %	Timber %	Aluminium %	Concrete %
Excessive snow load	23	15	1	1
Manufacturing faults	6	8	-	-
Underdesign	14	24	-	1
Other reasons	4	3	-	-
Total	47	50	1	2

Table 2 Examined failures, divided in causes of failure and structural material expressed as a percentage.

Often there have been many possible causes to the failure. The most probable cause in each case was counted in table 2, but sometimes alternative reasons might exist. Some failures were caused by a combination of reasons, e.g. damages on carports where sliding snow from an adjacent roof caused the structure to deflect horizontally; this structure was not designed for horizontal loads.

There are only a few measurements of the actual snow load on damaged buildings. This made it very difficult to decide in which cases excessive snow load was the prime cause of the failure. It is possible that we e.g. have stated "underdesign" or any "other reason" for a structure that also was exposed to excessive snow loads. Drift snow loads have caused nearly 25% of all the failures. This is a remarkably high figure, especially when considering the fact that drifted snow was included already in the Swedish code of 1950. Table 2 shows that the failures mostly are caused by mistakes in the design or in the manufacturing. These failures include 64 per cent of the timber structures, 43 per cent of the steel structures and one concrete structure. This concrete damage was caused by a combination of underdesign and overload.

4. SOME TYPICAL STRUCTURAL FAILURES

Bad gluing of wooden structures has caused failures in glulam beams and plywood webbed I-beams. The glulam beams were of an I-type where the gluing of the flanges to the web was badly done. Due to the thickness of the flanges it was probably impossible to achieve a proper pressure along the whole gluelines during the manufacturing. One of the basic conditions for a successful gluing is that the glued surfaces are plane enough to come in close contact and that the applied pressure is sufficiently high. Especially in the case of nail-gluing it is a necessity to use planed surfaces. The plywood beams failed due to badly planed flanges resulting in bad glue joints.

Timber connections with *nail plates* (punched metal plates) are sensitive to misplacements of the nail plates since the plate size often is small. Collapses of roof trusses were found to be due to too small nail plates at the heel joint. These small plates were placed so that cracks could develop in the rafter and then cause a collapse. When nail plates are used it is necessary not only to determine the minimum size of the plate but also to take into consideration the possibility for cracks to develop.

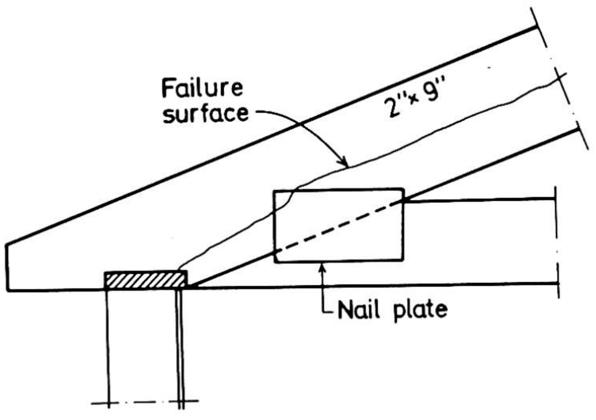


Fig.2 Heel joints with a too small nail plate.

Fig.3 Buckled Z-purlin.

Noninsulated buildings with light-weight steel trusses, covered with roofing membranes or corrugated steel sheets, have been involved in several failures. One of the reasons for this is that the buildings once were meant to be heated and thus designed for a low snow load, due to the absence of heat insulation. The use of the buildings has been changed and they were often used without heating. This of course means that snow accumulates on the roof in an unexpected extent. Some of these buildings were also badly designed, which was the primary cause of failure.

Steel columns have been involved in some cases due to improper design. In one case the building had no bracing so the buckling length was twice the column length. A similar thing happened in a building where an additional building was built and the old brick wall between the houses was taken away. In the original building the brick wall between the steel columns prevented lateral buckling. By the removal of the lateral support the buckling load for the column reduced drastically and the columns could not resist the snow load.

5. SPECIAL DAMAGES

5.1 Wood truss frame

This building was used as a cold storage. The primary structure was a three-hinged wooden truss frame. After about 20 years of service in one place the building was moved to another place. A drawing of one-half of the truss is shown in Fig.4. The flanges in the truss-beam were made of two 2"×5". When the building was moved the contractor cut the frames in the sections A-A (Fig.4). In these joints lap splices of 2"×5" were nailed with just a few nails to each part. The lengths of the lap splices were about 1 m.

The whole building collapsed due to failure in the joints A-A. Probably this was a progressive failure starting in one frame. At failure the snow load was estimated at 1.1 kN/m^2 based on in situ measurements. According to the Swedish Building Code the joint in the tension flange should have been nailed with about 130 nails. The estimated number of nails actually used in the joint correspond to an *allowable* load of 0. kN/m^2 which is less than the dead load .4 kN/m. 0.3 kN/m^2. The total load at failure was estimated at 1.4 kN/m^2.

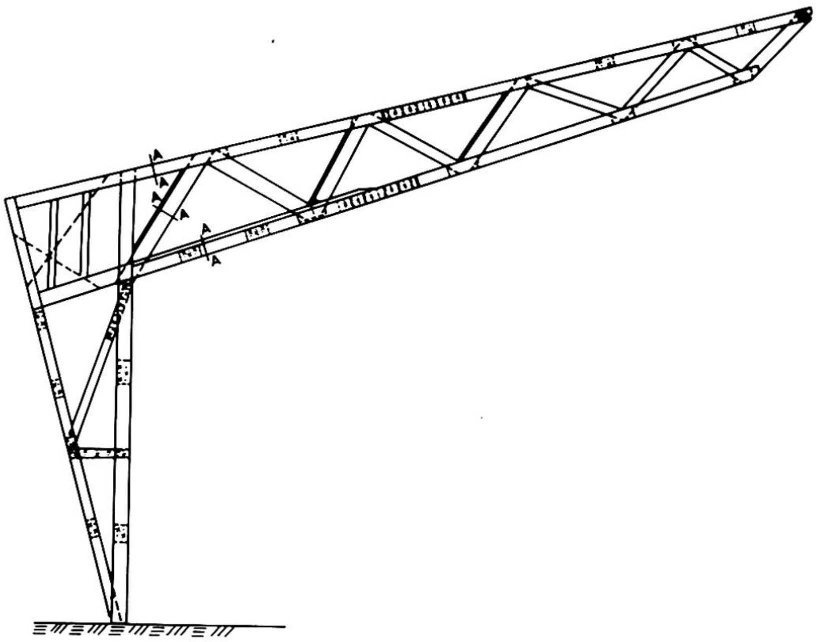


Fig.4 One half of a three-hinged truss frame, spanning 15.5 m, with joints at A-A.

5.2 Steel column

A storehouse 135×70 m^2 for sawn timber products was built in 1968. The height was approximately 9 meters. The structure was a flat roof made of crossed milled I-beams (beam depth ranging from 280 to 450 mm) resting on wide flange steel columns. The columns were placed in a square net, 14×15 m^2. The façace columns were HEB 180 and the others were HEB 200. The column length varied between 8 and 9.4 m. No diagonal bracing between roof and ground was used anywhere. At the ground the columns were fixed in cast concrete.

The whole structure collapsed due to overall column buckling (Fig.5). The roof snow depth was 0.55 m. The unit weight of snow varied between 2.6 and 2.9 kN/m^3 which means that the roof was subjected to a snow load of approximately 1.5 kN/m^2.

The column load caused by dead load and snow load was estimated at 360 kN. Assuming Eulers *first* buckling case the column buckling load is 105 kN and the slenderness ratio about 400. On the other hand the buckling load 360 kN corresponds to the buckling length 1.08 times the column length. That is very close to Eulers *second* buckling case. This means that the stiffness of the connections between the columns and the roof girders have a certain influence on the buckling load. It probably also means that the columns were bracing each other due to smaller differences in loads etc.

This case is an example of a poor design. With diagonal bracings the collapse should probably have been avoided.

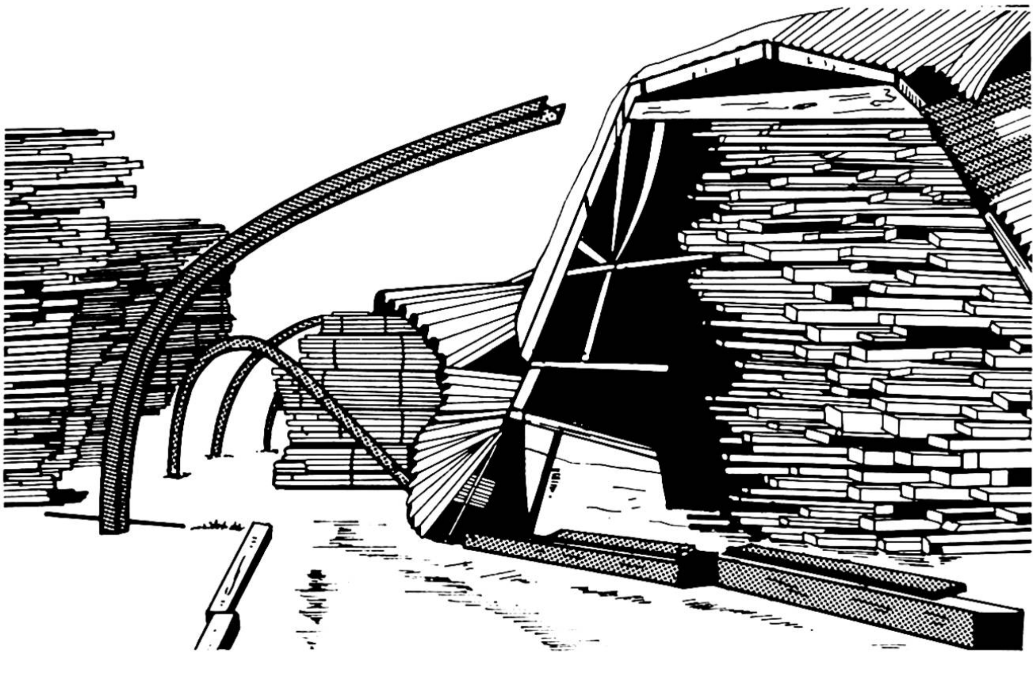


Fig.5 Buckled columns.

5.3 Concrete structure

The failure occurred in a prefabricated concrete structure as a shear failure at the supports of roof elements of a TT-type. The TT-element consisted of a thin concrete plate with two separate webs. The elements were 2.4 m wide with the span 15 m. The roof was divided in one higher and one lower part. Drift snow accumulated on the lower part. This snow drift corresponded to a maximum total load of about 9 kN/m^2 which was about 30 per cent higher than the prescribed design load.

At the support the shear reinforcement in the web consisted of one ribbed reinforcement bar Ø 16. The yield force in such a bar is about 80 kN. With a simple equilibrium model for the forces at the support it was found that this corresponds approximately to the load 7.9 kN/m^2 for the element in the worst position. The reinforcement bar was actually yielding.

6. CONCLUSIONS

The snow damages have mainly occurred in light-weight structures like steel and timber structures. These are often more sensitive to overload from live loads. The heavy concrete structures are mostly very insensitive to variations in live loads.

One reason for the damages is that drifted snow has not been properly considered. In nearly 25 per cent of the cases drift snow has been involved. Other causes are bad design and bad manufacturing of the structures which caused more than 50 per cent of the failures.

One experience from this study is that it is difficult to rely on the information you get. It is always necessary to cautiously use given information.

The failures investigated do not demand an increase of the design snow load. Most of the failures had occurred even with an increased value of the design snow load.

REFERENCES

JOHANNESSON, B., JOHANSSON, G., Snow damages during the winter 1976-77 (in Swedish). Statens råd för byggnadsforskning, Stockholm. Rapport R15:1979.

Leere Seite
Blank page
Page vide