EUROPEAN ROOFER'S EXPERIENCE AFTER THE 100 MPH WINDS OF JANUARY AND FEBRUARY 1990

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During the months of January and February 1990, two major storms swept across all northern European countries with winds in excess of 100 mph. These were the highest wind speeds ever recorded in many European countries.

There were more than two hundred fatalities. Extensive damage was caused to tile and slate roofs as well as flat roofs—not to mention buildings, trees, etc.

This paper will examine the particular damage caused to flat roofs in Holland and Belgium, what caused the damage, and what solutions must be envisaged for the future. It will also examine what were the building codes' requirements for wind uplift and should they be reconsidered and upgraded.

KEYWORDS

Benelux, European countries, roof damage, wind, wind speed.

INTRODUCTION

At the end of January and February 1990, two major storms swept across Europe, with wind speeds never before recorded. Exceptional wind speeds were recorded at over 160 km/hour (100 mph). Ireland, England, France, Belgium, Holland, Luxemburg, Germany and the Scandinavian countries were hit by the storms.

With more than 200 fatalities reported, these were the deadliest storms since 1940. The total damage costs are estimated at $7 billion (U.S.).

Many meteorologists believe that the frequency of such storms will increase in the future. It is vital, therefore, to analyze what happened during these storms, learn from the mistakes that have been made and, be better prepared to cope with future storms.

BENELUX

In this presentation, we will concentrate on the Benelux countries (Belgium, Nederland, Luxemburg).

Figure 1 shows all the storms recorded in Holland from 1940 to present. To be recorded, the storms had to be of at least 24.5m/sec. (88.2 km/h—54.8 mph) hourly average speed.

The wind speed is recorded at a height of 10 meters. The integration time of the gust speed measurement is 2 to 3 seconds. During those storms, there were several hundred gusts recorded with a speed above 10 Beaufort. It is also important to note that the speed measurements recorded over the Benelux countries varied considerably from one place to another. Measurements taken with the same equipment but 30 km apart gave different readings and wind speeds. The numbers in Figure 1 can only be considered as local measurements. Locations around the measurement areas may have sustained more or less damage by the storm.

Also, the dynamic pressure of the wind is proportional to the square of its speed. Therefore, the maximum gust speed measured with only a few km/h difference make a big difference in wind pressure.

Figure 1 shows that the frequency of the storms has increased in the last eight years.

Looking even further back, there is a certain regularity in the frequence of heavy storms. It seems indeed that every 50 years there is a period of 10 years during which heavy storms appear more frequently.

These storms caused the sea's level to rise more than 3.69 meters (12 ft.). Since a large portion of Holland and Belgium is under sea level, you can understand the seriousness of the situation. Fortunately, the dikes did resist the rise in the sea's level.

In the Benelux countries, more than 2,000,000 damage claims were recorded from the two storms in 1990. This is just over one claim per 12 inhabitants, which indicates almost everyone was hit by the storm and incurred some type of damage.

ROOF DAMAGE IN BENELUX

Tile and slate roofs suffered most from the storms, but flat roofs also had their share of problems and consequential damages due to roof blow-offs, can be enormous.

Building Codes

Several building codes existed—what were they requiring and was that sufficient?

Belgian standards for wind resistance were modified in 1988 after a proposal of "Bureau Seco." The new standards B03 002-1 are used in the Benelux countries.

These new standards take into consideration two types of decks. The standards give the designer minimum criteria to meet but they do not specify how to reach such criteria.

Every product, through official approvals, specifies their own way to meet the criteria. Every product, and/or manufacturer, may have its own way to design roofs.

Figure 2 is for flat roofs where the deck is not airtight and Figure 3 is for flat roofs where the deck is airtight.

For each figure, there are four distinctive areas of location (sea, rural, industrial, city). The height of the building and the fact that the building is or is not airtight is important.

The new standard explains how to determine the edge and corner area of the roof. Parapets and metal coping must pass the criteria set for the corner areas (see Figure 4).

During the January and February storms, the wind speeds were not regular, and many gusts and wind direction changes were recorded. This put a lot of extra pressure on all constructions. These new building codes are much stricter than the former ones because they include the extreme values of pressure on the surface of the building.

All buildings constructed following the new standards had no damage from the storms. These new standards, therefore, can be considered valid even under exceptional wind conditions.

One question to ask at this time is how many more storms a building will go through during its life. A building can be weakened by a storm and is never stronger after a storm. Time will tell if the new standards will remain valid after several storms.

SURVEYS OF STORM DAMAGE

After the storms, many organizations started surveys to learn more from the storms. The Vebidak Organization in Holland examined data, provided by its members, on 218 roofs covering a total of more than 2.5 million square feet of roofs. All roofs were flat with 25 percent mechanically fastened, 10 percent built-up roofing and 65 percent torched. Following are the results:

- 63 percent of the causes were based on bad construction of the roofing system as a whole—bad application, bad choice of a system, ageing of the system, perimeter attachment, etc.
- 75 percent were due to inadequate design and 25 percent were due to poor workmanship.
- 25 percent were due mainly to poor delamination strength of organic (cork) and inorganic insulation materials, such as, mineral wool, perlite and, in some specific cases, with foam insulation panels.

Buro Dakadvies, in Holland, investigated over 50 claims and came to the following conclusions:

- There was breakage at the perimeter—45 percent
  - Metal coping was not well attached.
  - No fasteners, or not enough fasteners, on the perimeter.
  - Perimeter pulled loose due to shrinking of the materials prior to the storms, which loosened the system. (Problems due to shrinking occured mainly with EPS boards, polyester-only reinforced membranes and single-ply sheets.)
- There was not enough adhesion to the surface—40 percent
  - Partially-adhered torched membrane through perforated base sheet (widely used in Holland).
  - Partially-adhered hot mopped system.
- There was delamination in the insulation material—20 percent
  - Mainly delamination between the facer and the insulation. Bad attachment or partial attachment of the facer on the board. Also, delamination in perlite boards and mineral wool boards.
- There was breakage in the under construction—10 percent
  - Adhesion of insulation to the deck.
- There was use of polyurethane adhesive—10 percent
  - Not enough quantity.
  - Not good adhesion or dusty surface.
- There was breakage in relation to the use of single-ply sheets—10 percent
  - Due to bad or no adhesion in corner areas.
  - Due to loosening of fasteners in the lightweight concrete.
- There were combined factors in may cases—40 percent

a + b : +/− 25 %	a + d : +/− 5 %
a + c : +/− 5 %	b + c : +/− 5 %

Many other extensive surveys were conducted in Belgium. Roofs that did not have any damage were surveyed as well as those with problems. The basic conclusions of these surveys were fairly similar and are summarized in below.

CONCLUSIONS

Buildings built following the new Belgian standards have sustained almost no damage.

The increased use of high performance, non-woven polyester mats as reinforcements in the roofing systems has an important impact on the extent of the damage to a roof blowoff. Indeed, weaker reinforcements used previously in roofing systems tear easily and therefore limit the damage to the torn area.

Non-woven polyester does not tear easily and in case of a blow-off, the whole surface often is blown away in one sheet, causing more extensive damage. But, non-woven polyester mats have a very high fastener resistance that can secure their attachment to the deck.

After several years of ageing, the adhesion characteristics of a roofing system is often weaker. When reroofing, always ensure that the new layer is properly secured to the deck.

When a new building is built as an extension to an existing one, a new calculation of wind load must be made for the whole building. Roof edge and corner areas where more attachment is required, may now be larger, even for the existing building.

It is very important to ensure that the flashing areas of the roof are as airtight as possible. All metal coping must be well designed to stop airflow, and securely attached to the structure of the building.

On insulation boards, all perimeter areas should always be securely fastened to the deck, whatever the method of application.

Many blow-offs were due to systems partially bonded through perforated base sheets or partially mopped.

Fatigue resistance of mechanically-fastened, polymeric sheets is lower than that of modified bitumen sheets, which are more rigid. After a heavy storm, some polymeric sheets could be severely damaged at the fastener by fatigue.

Very few blow-offs occurred with ballasted systems, although flying stones caused extensive damage.

Many blow offs occurred on old built-up roofs with the first layer mechanically fastened to a wooden deck—the fiberglass reinforced underlayer cannot take such wind pressure.

Note, most storms in Europe occur with an outside temperature of approximately 8°C (46°F). At that temperature, bitumen and other adhesives react differently to stress and shock than at room temperature. Thus, all wind uplift tests should be run at approximately 8°C (46°F).

Many other surveys are still in process. This paper can be updated to include these completed survey results/conclusions when available.

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Year	Date		Beaufort	Highest hourly average m/s	Highest hourly average km/h	Speed heaviest gust m/s	Speed heaviest gust km/h
1940	Nov	13-14	10	26	94	38	137
1943	April	7-8	11	31	112	35	126
1944	Sept	7	12	34	122	—	—
1949	March	1-2	11	29	104	39	—
1953	Jan 31-Feb 1		10	27	97	40	144
1960	Jan	20	10	26	94	41	148
1967	Oct	17	10	27	97	40	144
1972	Nov	13	11	29	104	42	151
1973	April	2	11	30	108	43	155
1976	Jan	2-3	11	30	108	41	148
1983	Feb	1	10	27	97	38	137
1983	Nov	27	10	27	97	40	144
1984	Jan	14	10	27	97	37	133
1987	Oct	16	10	27	97	41	148
1990	Jan	25	11	30	108	44	159
1990	Feb	26	10	26	94	41	148

The hourly averages have been recorded from 24.5 m/s (Beaufort 10). (*)Source: Centrale Weerdienst KNMI, Drs. B. Zwart.

Figure 1 Heavy storms since 1940 (*).

Zone	Sea			Rural				Industrial			Urban	
Height	8 m	14 m	20 m	5 m	8 m	14 m	20 m	10 m	14 m	20 m	14 m	20 m
Main roof area												
Airtight building (small openings)	1270	1420	1520	853	987	1156	1269	824	935	1057	823	863
Not airtight building (big openings)	1759	1966	2104	1132	1366	1600	1757	1141	1294	1463	1139	1195
Edge of the roof												
Airtight building	2247	2512	2689	1509	1746	2045	2245	1458	1654	1870	1456	1527
Not airtight	2736	3058	3273	1837	2125	2489	2733	1775	2013	2276	1772	1859
Angle of the roof												
Airtight building	2735	3058	3273	1837	2125	2489	2733	1775	2013	2276	1772	1859
Not airtight building	3224	3604	3858	2165	2505	2934	3221	12092	2373	2683	2089	2191

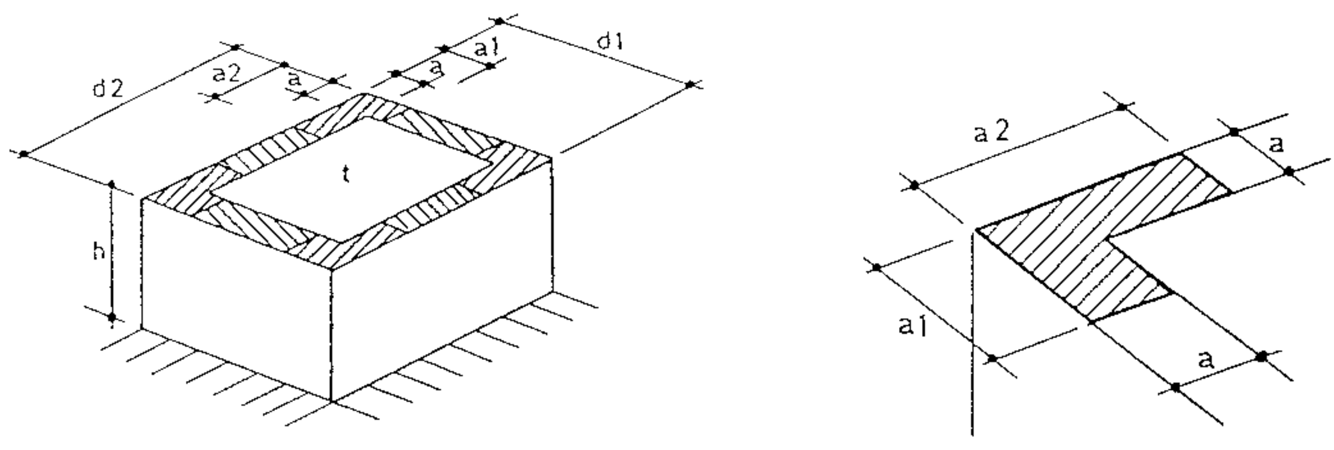
Valid on flat area with no high buildings around — length height (= low buildings)

Surface: 1 m² Source: Cours conference n°60 CSTC 1990. The numbers are Newton per square meter.

Figure 2 Action of the wind on flat roofs with deck—not airtight.

Zone	**Sea**				**Rural**			**Industrial**			**Urban**	
Height	**8 m**	**14 m**	**20 m**	**5 m**	**8 m**	**14 m**	**20 m**	**10 m**	**14 m**	**20 m**	**14 m**	**20 m**
Main roof area	489	546	585	328	380	445	488	317	360	1 407	317	332
Edge of the roof	1466	1638	1754	984	1139	1334	1464	951	1079	1220	950	996
Angle of the roof	1954	2184	2338	1312	1518	1778	1952	1268	1438	1626	1166	1328
Valid on flat area with no high buildings around — length % height (= low buildings)												
Source: Cours conference n°60 CSTC 1990.												

Figure 3 *Action of the wind on flat roofs with deck airtight.*



	if h ► d1 /3	if h ◄ d1 /3
return to the highest value	0.15 d1 1 m	0.45 h 0.04 d1 1 m
Determination of a1 and a2.		
if d2 % 1.5 d1	then a1 = a a2 − 0.5 d1	
if d1 ◄ d2 ◄ 1.5 d1 then a1 = 0.5 d1 (1.5 − d2/d1) + a (d2/d1 − 0.5) a2 = 0.5 d1 (d2/d1 0.5) | a (1.5 − d2/d1)		
Source: Cours conference n°60 CSTC 1990		

Figure 4 *Determination of the width of the edge areas a.*