Flat roof shatter damage in Germany in spring 2012
refurbishing the damage; requirements for the future

Wolfgang Ernst, President Europäische Vereinigung dauerhaft dichtes Dach e.V.

Flat roof shatter damage in 2012

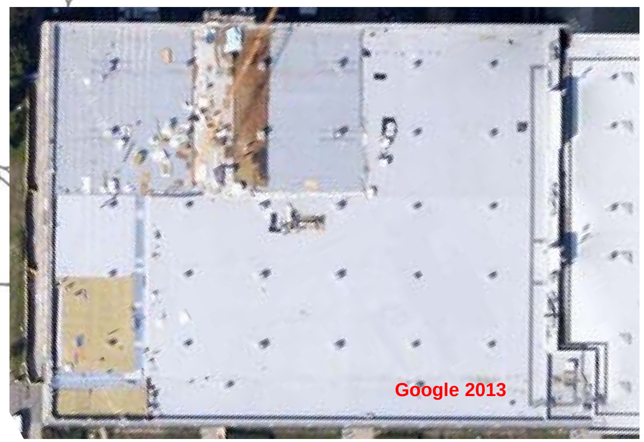
Vermessungsbüro Kaden, Dresden, 2012

The best known example in Germany:

EVA/PVC-sheet,
thickness 1,5 mm, unreinforced, with polyester fleece backing, mechanically fastened on mineral fibrous insulating material.

German standard specification: **Materialgroup EVA** acc. DIN 18531-2 / 4.3.4.4: limit value:

- EVA	min.	**25 M.%**
- PVC	max.	**50 M.%**
- Additives, Stabilizers, Pigments	max.	**30 M.%**



Europäische Vereinigung dauerhaft dichtes Dach ddD e.V.

European Association Durable Dense Roof

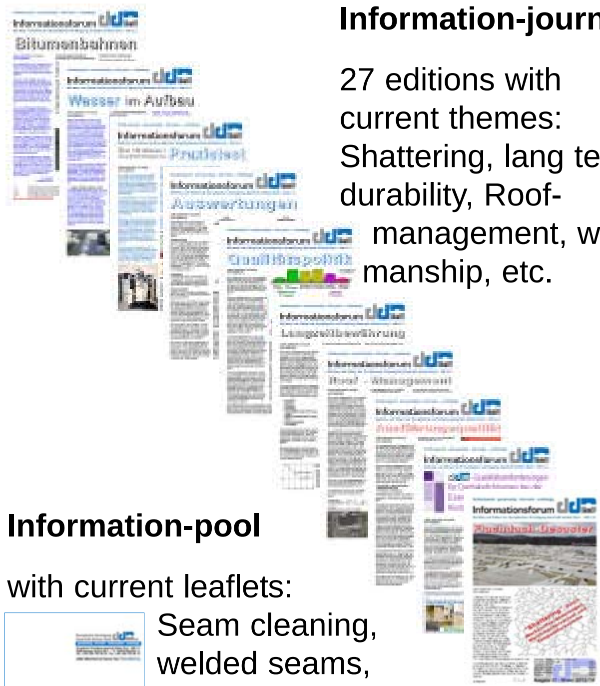
building better flat roofs

First a few words about our association:

The purpose of the organization is the promotion of consumer counseling and consumer protection at home and abroad about all aspects of a permanently tight roof. The association pursues exclusively and directly non-profit purposes and is (industry-) independent.

The purpose of the statutes is especially achieved through:

- preparation, promotion and publication of user-friendly and consumer-friendly images, specifications, inspection and test results of all materials and performances required for a permanently tight roof/part of a building.
- manufacturer-independent user-friendly and consumer-friendly consulting.
- Cooperation with other organisations and individuals at home and abroad which are close to these objectives of the association.



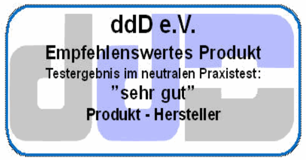
Information-journal

27 editions with current themes: Shattering, lang term durability, Roof-management, workmanship, etc.

Information-pool

with current leaflets:

Seam cleaning, welded seams, organisation faults, current jurisdiction etc..



Recommended requirements for all roofing an sealing sheets

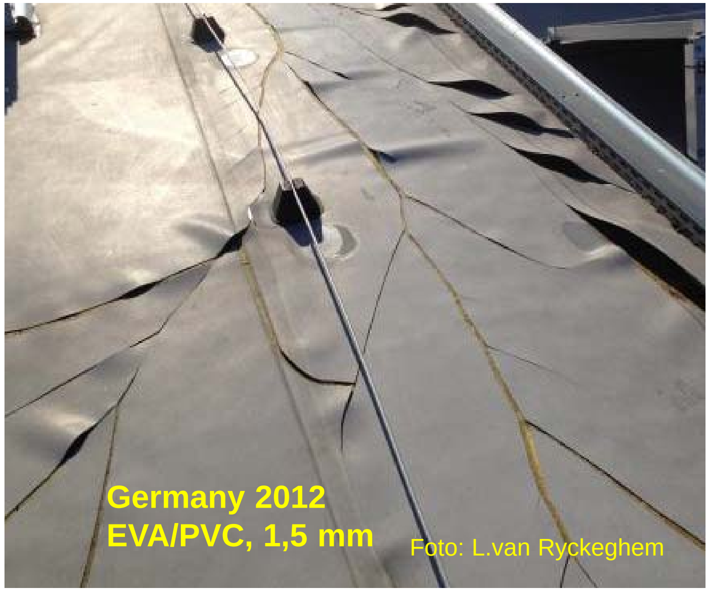
Quality label for good an excellent products.

Research Report: More than 100 roof membranes in comparativ quality test with valuations.

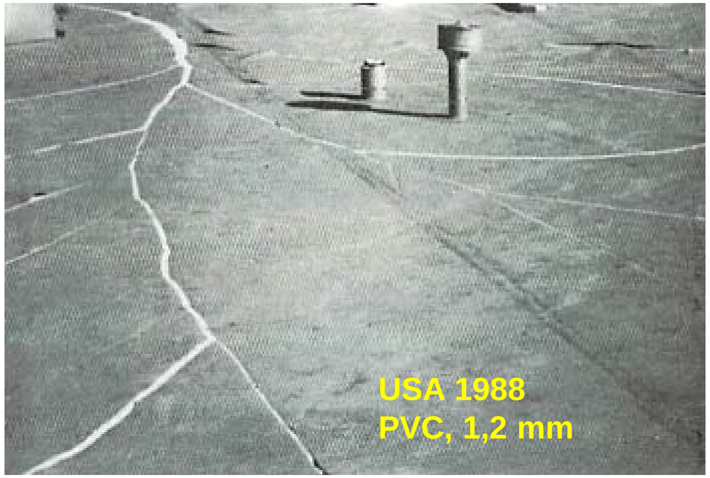
1. Introduction

Enormous damage did occur to plastic flat roof sealing in spring 2012 which in turn damaged the reputation of the flat roof. Surveys by the German Central Association of the Roofing Trade (ZVDH, 2012) show that damage did only occur to PVC plastic sheeting and plastic sheeting with a PVC content respectively. No damage was determined to roofs with for example: FPO/TPO-, EPDM-, ECB-sealing sheeting as well as liquid sealing and bitumen sealing. The susceptibility to damage was significant of homogenous PVC sheeting and sheeting with a PVC content respectively.

Result: The susceptibility to damage was significant of unreinforced PVC sheeting and sheeting with a PVC content respectively.
"68.72 % of all claims concerned sheeting with a thickness of ≤ 1.5 mm and without reinforcement/insert" (ZVDH, 2012).



Avoiding cold weather roofing failures,
DREGGER/KNATTERUD, Professional Roofing, November 1989



2. A review of the 80s

Damage is known from America since the beginning of the 80s to loosely laid, unreinforced PVC roof sheeting. Numerous damages to buildings of the US Army resulted in a 10-year field study by the USA-CERL (US Army - Construction Engineering Research Laboratory), as well as the publication of researches by scientists, associations, engineers and institutes between 1985 and 1995. The evaluation of the studies led to the assumption that sheeting with insert is less vulnerable. Furthermore, the technical reports dealt with the loss in plasticizer, among others, as cause of damage.

The cases of damage in the USA created a lively discussion about the material standardization. It was demanded that the ASTM D4434 - Standard Specification for Polyvinyl chloride (PVC) Sheet Roofing shall be construed stricter in order that it is possible to distinguish between sheeting with long and limited life span.

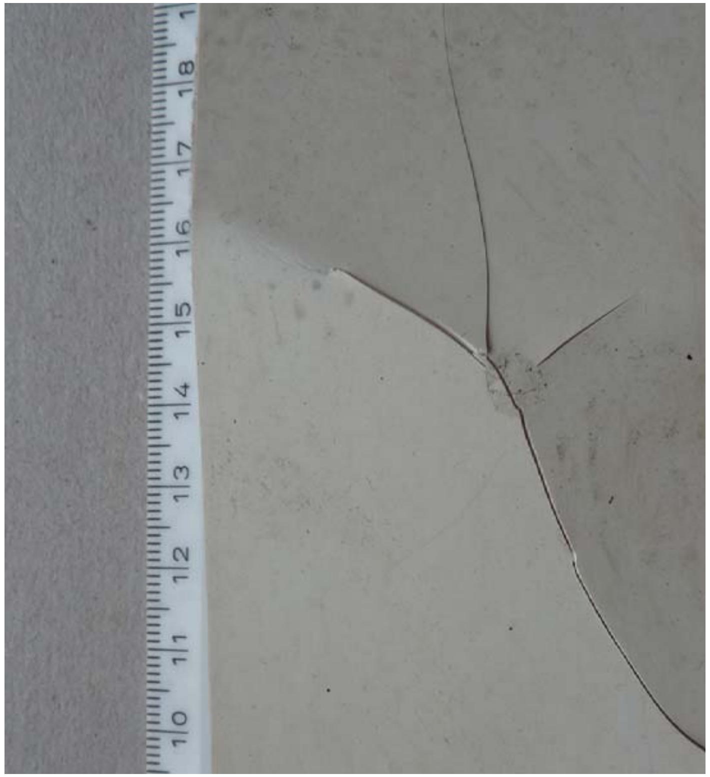
Only sheeting with insert/reinforcement was listed in the new ASTM D4434 at the beginning of the 90s which had positive effects on the market situation. An increase of the sheeting thickness could also be noted (PAROLI, 1993).

According to documents of our Association (ddDach e.V.), most damage did occur to sheeting made of EVA/PVC in spring 2012. Therefore, the following statements refer to the sheeting with the designation:

germán standard specification — single laying — characteristic — material group — compatible with bitumen — lamination — polyester fleece — thickness in mm

Product - DE/E1 EVA-BV-KPV-1,5

Samples of materials taken of damaged roof areas as well as available retention samples were tested in the laboratory.



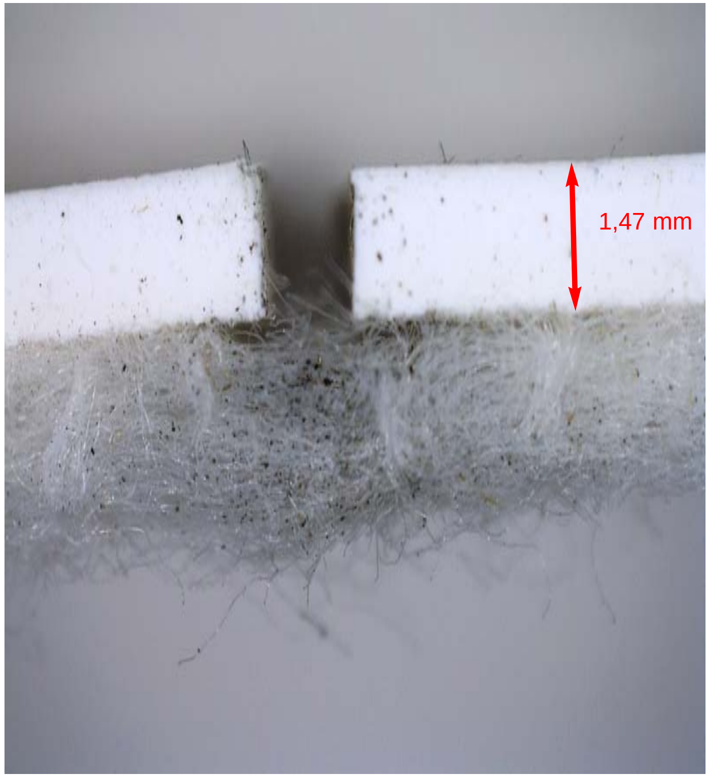
Shatter crack after determination of resistance to impact (acc. DIN EN 12 691 on **-10°C**
(2 years aged membrane, EVA/PVC, 1,5 mm).

3. Test methods (own laboratory)

- **Flexible sheets for waterproofing - Determination of tensile properties** acc. DIN EN 12311-2, method A, testing speed 100 mm/min,
- **Determination of tensile properties (E-Modul)** acc. DIN EN ISO 527-1 (DIN 16 726/5.6.2), elongation 1-2 %,
- **Cold contraction** acc. ERNST (1999),
- **Determination of resistance to impact** acc. DIN EN 12 691, at different minus temperatures, drop weight: 500 g, drop height: 500 mm, see picture.

and on Institute for Micro and Nanotechnology, MNT Buchs/Switzerland by Prof. Affolter

- **Infrared spectroscopy IRS** (Qualitative structural analysis of polymers and characterization of organic and inorganic constituents).
- **Differential scanning calorimetry (DSC)** Provides the melting temperature and melting heat, information on the material composition.
- **Scanning electron microscope energy-dispersive X-Ray spectroscopy (REM-EDX)** Provides high-resolution, element-sensitive information on the surface structure. Analysis of the elemental composition of the surface tested (semi-quantitative method).
- **Soxhlet extraction** For isolation and quantification of extractable additives. Analysis of the extracts by use of IR spectroscopy.
- **Dynamic scanning calorimetry in the oxidative induction time mode (DSC-OIT)** Provides information on oxidative damage.



Crack in a unreinforced EVA/PVC-membrane with polyester fleece backing.

4. Test results

4.1. Changes in property after laboratory stress

- Storage in hot water acc. DIN EN 1847, 50°C, Duration 112 d
  Changing: **27 %**
- Storage in limewash acc. DIN EN 1847, 50°C, Duration 112 d
  Changing: **41 %**
- Storage in acid solution acc. DIN EN 1847, 50°C, Duration 112 d
  Changing: **66 %**
- Hydrolytic resistance, Test acc. ERNST (1999), 90°C, 95 % RF, Duration 7 d,
  Changing: **43 %**

4.2. Changes in property after lay time of 2 years

When comparing the retention sample with the damaged sheeting after lay time of 2 years, the following changes in property could be detected:

- Change of the temperature at which damage can occur during resistance to shock-type loads (DIN EN 12 691), drop weight 500 g, drop height 500 mm:
  from -30 ºC to -10 ºC
- Increase of the cool contractile force compared to new material (kp/m) approx. **22 %**
- Significant increase of the modulus (E) MPa (embrittlement) compared to new material by approx. **50 %**
  (Test result ERNST,2008: > 200 kg/m)

	Value	reference sample 1998 new material	reference sample 2010 new material	changing in %
EVA	weight%	**28**	**31**	**+ 9,7**
PVC	weight%	**51**	**47,5**	**- 6,9**
additives ...	weight%	**21**	**21,5**	**-**
... therefrom **plasticizer**	weight%	**12,2**	**14,5**	**+ 18,9**

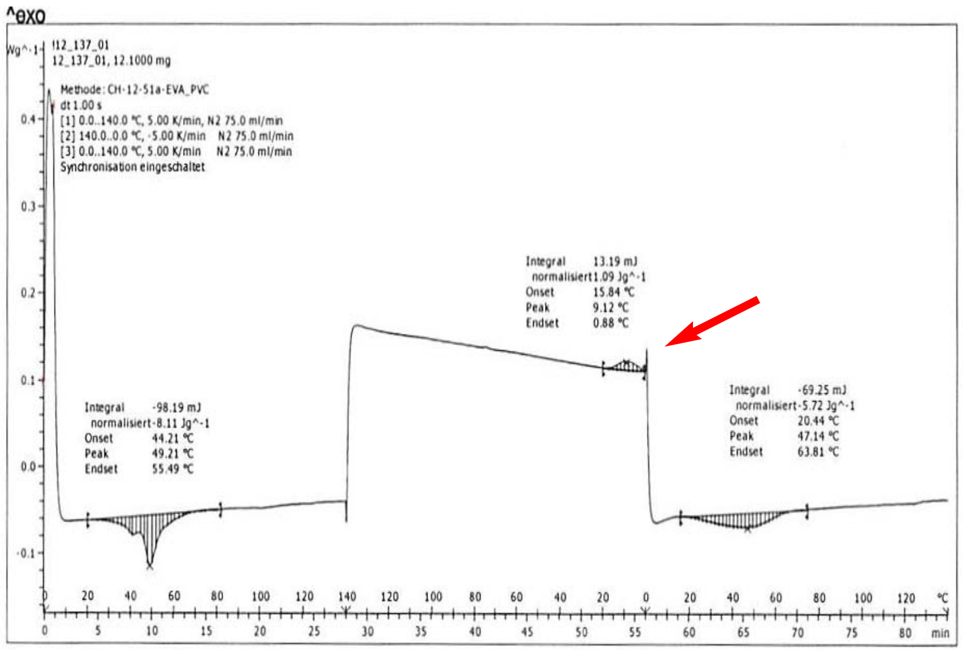
Table 1: Comparison between refernce sample 1998 und 2010 (new material).

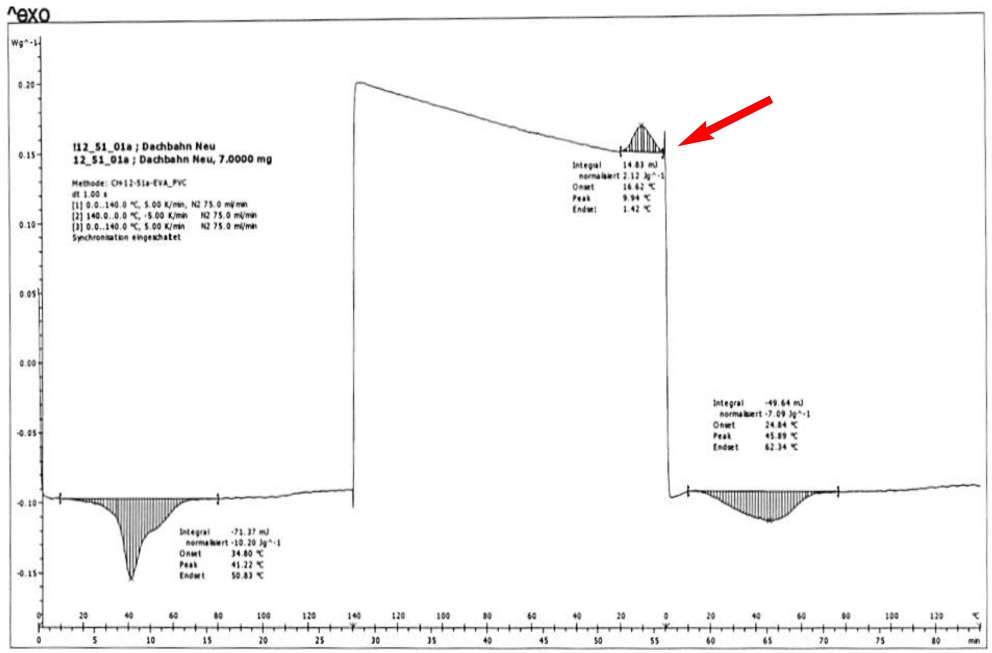
4.3 . Material changes 1998 - 2010

The comparison of new material from the years of production 1998 and 2010 (table 1) shows that the EVA content was increased. The PVC content was reduced with a simultaneous increase of the plasticizer content. In addition, talc (magnesium silicate) was replaced by aluminum hydroxide as flame retardant and filler.

Values measured by DSC (below) underline the significant changes. The **noticeable material change** of the sheeting is documented by the significantly deviating IR spectroscopies of both products (1998 - 2010).

DSC measure on reference sample **1998** **- 12 years difference-** DSC measure on reference sample **2010**





	Value	reference sample 2010 (new material)	damaged roof sheet after 2 years	changing in %
EVA	weight%	**31**	**24,5**	**- 21**
PVC	weight%	**47,5**	**47,3**	**-**
additives	weight%	**21,5**	**28,2**	**+ 24**
Total		100	100	

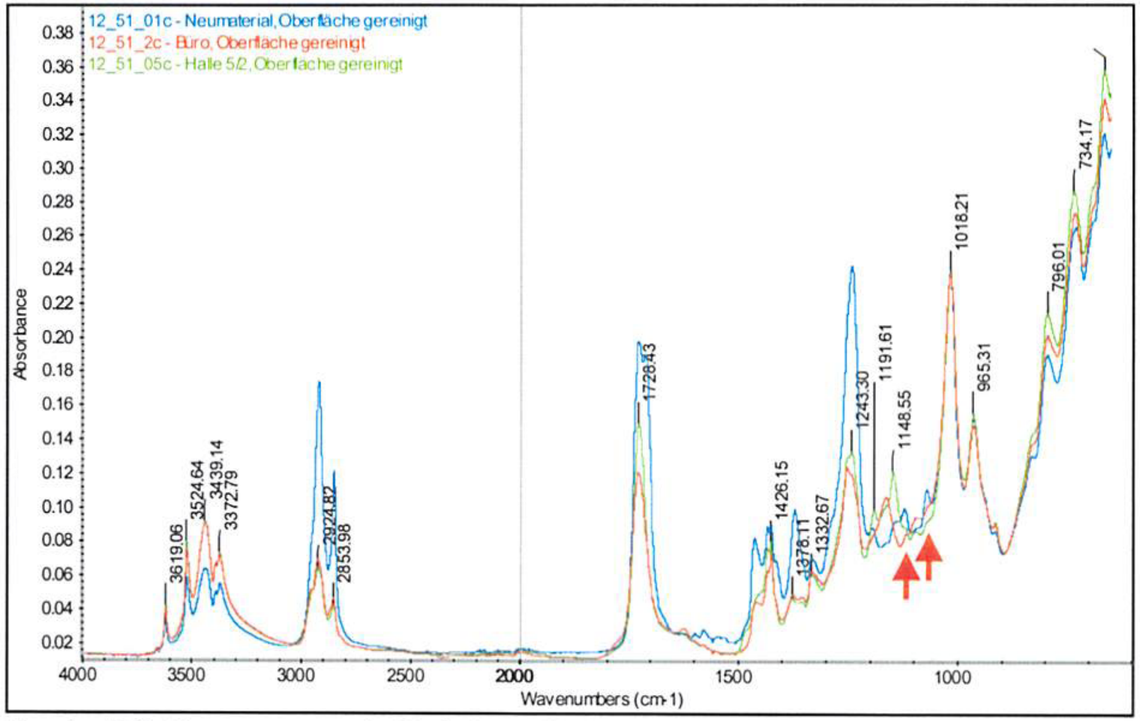
Table 2: Comparison between refernce sample and damaged sheet after 2 years.

IR-Spectre measurement on surface of the reference sample and on surface of the damaged sheet.

4.4. Material changes after lay time of 2 years until damage occurred

The (enormous) decrease of EVA and increase of additives can be presented and construed as follows:

The material change can be attributed to the hydrolysis susceptibility of the material EVA and the material changes under load to water, lime milk and acid solution of the sheeting respectively - there are clear indications from the test results presented above - Changes in property by standard load in the laboratory.



	Value	reference sample 2010	mean value damaged sheets 2012	changing in %
total proportion EVA + PVC	weight%	**78,5**	**72,4**	**-7,8%**
EVA-proportion on Polymers	weight%	**39,5**	**33,8**	**-14,4%**
Phathalat-proportion in PVC-P	weight%	**30,5**	**25,8**	**-15,4%**
Phathalat-proportion on 100 pure PVC	weight%	**43,9**	**34,8**	**-20,7%**

Table 3: changing of PVC, EVA and phatalat components in 2 years.

The following changes can be determined following further evaluation:

The decrease of polymer contents (EVA and PVC-P) as well as a comparatively **high loss of plasticizer is particularly significant** for the short lay time of the sheeting of approx. 2 years.

This indicates a change of the previous formula not tested yet and change of the components respectively.

5. Cause of damage

The damage to the sheeting made of the material EVA/PVC can be attributed to a material change of the polymer EVA, in particular, and a significant loss of phthalate plasticizer. This results in a:

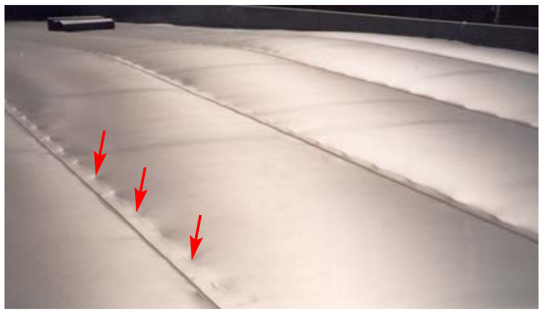
- contraction in volume

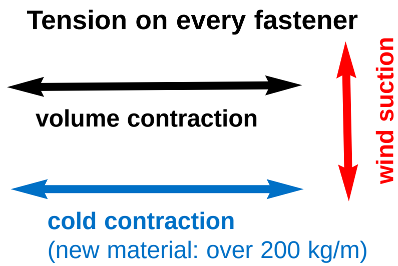
The total volume is below the amount of volume of the individual components - the total volume of the sheeting shrinks

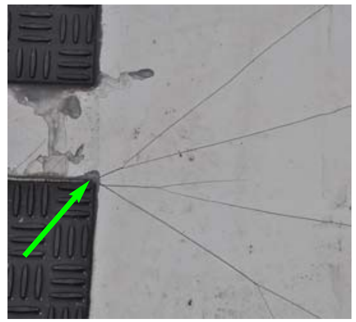
and a:

- reduction of the resistance to cold.

The external influence of cold (black frost with wind in January 2012) results in a contraction in volume based on the material-specific coefficient of expansion. In addition to the determined aging changes of the material and the contraction in volume due to loss of formula components such as EVA as well as phthalate plasticizer, this cold contraction results in tractive forces occurring increasingly which significantly stimulates crack formation already under the lowest mechanical stress.





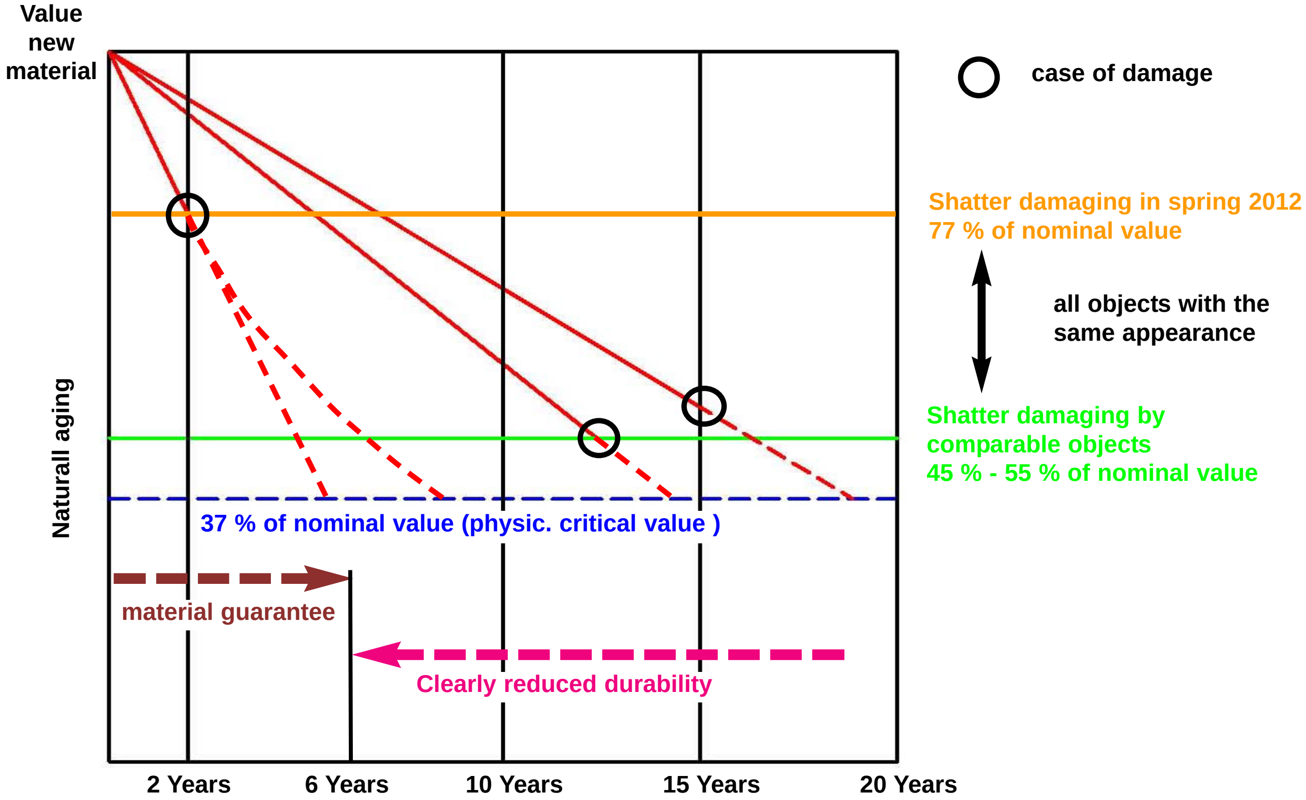


6. Forecasts

If one considers all test results of the previous years which are available in the laboratory of the signatory regarding the roof sheeting with the designation "DE/E1 EVA-BV-KPV-1.5" from different years of production and comparable objects, forecasts of the expected life span of the sheeting with natural aging behaviour can be presented in a simplified form (linear). The difference of the forecast of sheeting with an older (14 - 18 years) and younger (6 - 8 years) date of production becomes clearly noticeable in this Illustration.

The available test results are directly put in relation to 37 % of the reference value of new material. This reference value is defined as physical limit relevant literature at which the product benefit becomes questionable, e.g. the life span of the product is reached and renovation is necessary.

In addition, occurrences of damage are presented according to lay time and test results on the actual changes in property resulting in the occurrence of damage. The presentation is completed by the material guarantee period and the clearly reduced durability.



Illustation 1:
Simple diagram for lifetime with **abstract forecast.**
Clearly reduced durability between sheets from production-year 1998 to 2010.

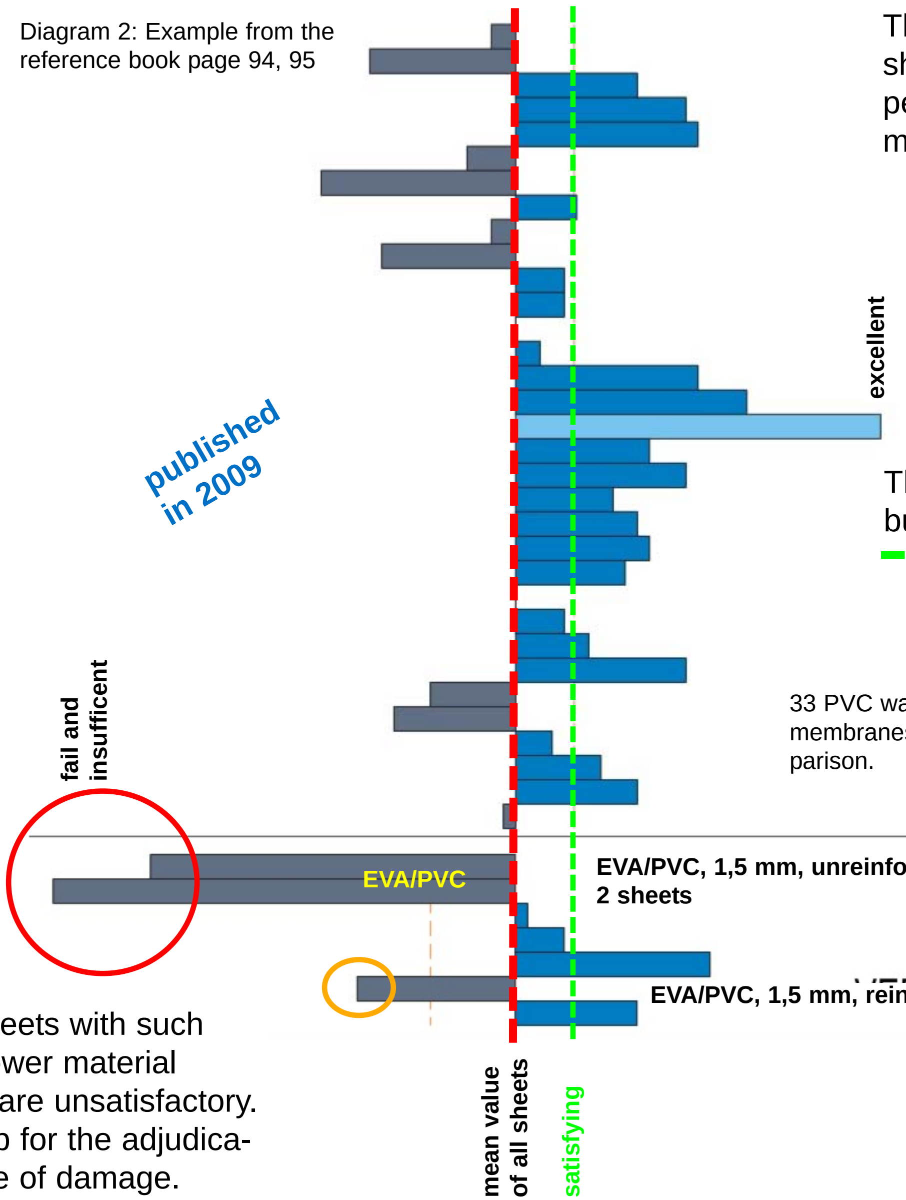
7. Current state of affairs

According to the current state of affairs presented at the expert conference 2013 of the ZVDH, field studies on temperature behaviour and fracture behaviour were supposedly carried out at producer level and formulas of individual sheeting were adjusted (?). Furthermore, the ZVDH sees a need for action at standardization level (ZENK, 2013).

However, this must be evaluated differently, because:

"The roof sealing standard (DIN 18531) in Germany, for example, assigns all plastic and elastomer sheeting to the same property category without exception even though practical experience has shown that this uniformly classified sheeting range has actually not the same performance capability. An independent contribution to solve this problem by the producers and their scientific advisers is unlikely.

Diagram 2: Example from the reference book page 94, 95



The mean value of all tested sheets illustrates the reference performance for all waterproof membranes.

The minimum requirements for building better flat roofs (ddD)

33 PVC waterproof membranes in comparison.

Roofing sheets with such provably lower material properties are unsatisfactory. This is a tip for the adjudication in case of damage.

The reference book "SEALINGS" is aviable for all delegates.

Flat roof shatter damage in Germany in spring 2012 refurbishing the damage; requirements for the future

Wolfgang Ernst, President Europäische Vereinigung dauerhaft dichtes Dach e.V.

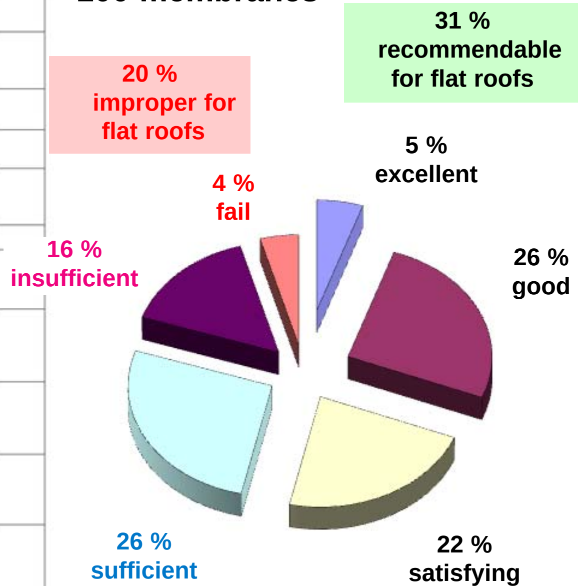
Users who appreciate reliable roofs should welcome tests more positively which contribute to the improvement of the information situation and provide a greater market transparency. Tests by ERNST (2009) supplement our picture of the behaviour of roof sealing under side/installation conditions and of the long-term behaviour by practical tests. They also reflect the partly extreme variations in properties within a product category ant thus demonstrate that a reasoned decision for a certain product can only be made on the basis of reasonable requirement profiles" (PROF. OSWALD, 2009).

Recommended requirements for all roofing and sealing sheets by ddDach© (2005)

	Roofing and sealing sheet: Materialgroup: __________, Thickness: ≥ ______mm, **with following material properties:**	required minimum value	Value of the sheet	perform yes/no
A.	**LOW TEMPERATURE FOLDING** acc. to **EN 495-5** Requirements: no rupturing or cracking at	- 30°C		
B.	**RESISTANCE TO IMPACT** acc. to **EN 12 691** Requirements: impenetrable, drop mass, weight: 500 g, method A = hard metall support. Height of fall:	≥ 700 mm		
C.	**HAIL RESISTANCE** acc. to **EN 13 583** Requirements: damaging velocity - hard/soft support	> 25 m/s		
D.	**ACTION OF CIGARETTE HEAT** acc. to **EN 1399** Requirements:	impenetrable		
E.	**STRAIGHTNESS AND FLATNESS** acc. to **EN 1848-2** Requirements: deviation of straightness(g) deviation of flattness (p)	< 30 mm < 10 mm		
F.	**HOT AIR WELDING** Welding window according to **ERNST** 1999 (attached):	yes/no		
G.	**BEHAVIOUR AFTER COATING WITH GREASE** acc. to **ERNST** (1992) Requirements: absolute elongation* acc. to **EN 12311-2** change elongation compared to new material	≥ 200 % ≤ 25 % relative*		
H.	**BEHAVIOUR AFTER STORAGE IN HOT WATER** acc. to **EN 1847** Hot water temperature: 50°C, Duration: 16 weeks, Requirements: absolute elongation* acc. to **EN 12311-2** change elongation compared to new material	≥ 200 % ≤ 25 % relative*		
I.	**BEHAVIOUR AFTER STORAGE IN LIMEWASH** acc. to **EN 1847** Hot water temperature: 50°C, Duration: 16 weeks, Requirements: absolute elongation* acc. to **EN 12311-2** change of elongation compared to new material	≥ 200 % ≤ 25 % relative*		
J.	**BEHAVIOUR AFTER STORAGE IN AN ACID SOLUTION** acc. to **EN 1847**, Hot water temperature: 50°C, Duration: 16 weeks, Requirements: absolute elongation* acc. to **EN 12311-2** change elongation compared to new material	≥ 200 % ≤ 25 % relative*		
K.	**RESITANCE AGAINST MICROORGANISMS** acc. to **EN-ISO 846**, pretreatment before biological test: acc. to EN 1847: Hot water: 50°C, time 14 days, soil-burial test: time 32 weeks, Requirements: Weight loss in contrast to new material	≤ 4 %		
L.	**HYDROLYTIC RESISTANCE** acc. to **ERNST** (1992) Requirements: change elongation to new material Weight loss compared to new material	≤ 25 % relative* < 3 %		
M.	**OZONE RESISTANCE** acc. to **EN 1844** Requirements: no cracks at 6 x magnification	no cracking		
N.	**LONG THERM ARTIFICAL AGEING** acc. to **EN 1296,** time 24 weeks, 70°C, Requirements: change of mass compared to new material change elongation to new material	≤ 5 % ≤ 25 % relative*		
O.	**ARTIFICAL AGEING BY L. TH. EXPOSURE TO UV RADIATION** acc. to EN **1297** Requirements: - unballasted membranes 5.000 h - ballasted membranes 3.000 change of mass: ballasted and unballasted membranes	Scale 0 Scale 0 ≤ 3 %		
P.	**FISHTEST** acc. to **OECD** »Fish Acute Toxity Test«, Procedure 203, **EEC** directive 92/69EEC, DIN 38 412 L 31, Description: ERNST(1999), Testfish: Poecilla reticulata (Guppy), Requirements:	> 24 h		
Q.	**COLD CONTRACTION** acc. to **ERNST** (1999), Requirements:	< 200 kg/m		
R.	**RESISTANCE TO ROOT PENETRATION** acc. to **FLL**-Test (1999): Requirements: resistance against root and rhizome penetration (attached):	yes/no		
S.	**DECLARATION ECOLOGICAL CHARACTERISTICS** acc. to **SIA 493** (att.):	yes/no		
	elongiation* absolute for unreinforced and bonded sheets and membranes with glass mesh reinforcement.			
In signing this document, the manufacturer confirms that the values given above can be verified by an officially recognized, public test laboratory or a testing institution in keeping with the international standards of quality management and quality systems (ISO 9001).				
Manu-facturer	The specified values apply to the product trade name/material: Product/Article: ______________________ / ____________ CE-mark according attached technical data sheet	Company stamp and sign: ______________________		

Copie from the reference book page 108

Result of the comparativ quality test of more than 100 membranes



Examples of two improper unreinforced membranes from the past

Europäische Vereinigung dauerhaft dichtes Dach e.V.

8. Future damage prevention

Considering the present test results, a controversial discussion is no longer needed. The facts are known. The weather conditions of the winter 2011/2012 can occur again at any time. Thus, there are the following references, recommendations and demands respectively by our association - ddDach e.V.:

- **Unreinforced PVC sheeting and homogenous sheeting with PVC content respectively do no longer belong on the freely exposed roof.**

- **All persons involved in the construction: principal, client, planner and worker take an incalculable risk with the decision for unreinforced PVC sheeting and sheeting with PVC content respectively.**

- **Planners who still tender this sheeting and workers who still lay this sheeting respectively are acting (grossly) negligent.**

- **The effective thickness of reinforced plastic sheeting should not be below 1.8 mm.**

- **The selection of sheeting should be made according to practical test criteria. They have already been published in 2006 (recommended requirements) by our association.**

Europäischen Vereinigung dauerhaft dichtes Dach e.V.
for Building Better Flat Roofs