Factors contributing to the life time performance of flat roofing with polymer membranes

General Preliminary Information for Participants (page 2 and 3):

- Building, design requirements,
- Flat roof market in Europe, polymer waterproofing membranes,
- Comparison tests (new materials), ageing behavior.

Factors contributing to the life time performance of flat roofing with polymer membranes

Experience and knowledge accumulated during more than 30 years (from 1985 until 2017) of conducting analyses on more than 200 construction projects.

- **Reduced life time** (case examples)
  - as a result of inadequate workmanship,
  - as a result of design errors, poor decisions,
    - lack of roof pitch, causing temporary water ponding,
    - unsuitable load (gravel)
  - unsuitable material,

- **Conclusion: prevention of lifetime-reducing factors**

- **feasible goal: life time >50 years**
  - two positive examples

leaky after 13 Years

diagnostic inspection after uncovering

leaky after 16 Years

General conditions and Selection criteria

1. Building

According to the definition in the "Guidelines for Sustainable Building", the useful life of buildings is around 50-100 years (Federal Ministry of Transport, Construction and Housing (BmVBW), 2001). The relevant legislation typically regards a useful life of 50 years as the normal case, and the statutory depreciation rates for buildings are likewise based on a lifetime of 50 years.

The logical consequence:
”A building needs to be permanently protected throughout the entire duration of its useful life by the building envelope - and specifically by the roof” (ERNST, 2002).

2. Design requirements

It is the architect's duty, as part of his or her design and planning services, to select precisely the right building materials for a particular building project and its unique circumstances. When faced with several alternatives, it is the architect fundamental duty to generally follow the "safest path", Ruling by the Berlin Appellate Court dated June 05, 2001 (Case No.: 7 U 6697/00).

"The architect's design of a building's weatherproofing, if professionally executed to good workmanship standards, must result in technically correct, complete, and permanent weatherproofing". Federal Court of Justice (BGH), Ruling of October 25, 1973 -VII ZR 181/72).

What follows from established case law are clear-cut and explicitly described requirements for planners when designing roof waterproofing.

3. Flat roof market

Flat roof market in Europe: Plastic membranes, approx. 113 m sqm p.a. approx. 72% PVC membranes and membranes with PVC share, approx. 20% TPO membranes and approx. 8% other.

4. Polymer waterproofing membranes

The numerous types of plastic membranes offered on the market are often difficult to distinguish by architects. It is true that the European materials standards for plastic membranes lay down a few minimum requirements which are further specified and supplemented by national application standards. Nevertheless, architects will be searching the rulebooks in vain for concrete decision-making criteria (e.g., specifications on functional life) to help them to find the right product most suitable for a specific application.

Manufacturers and their consultants can hardly be expected to provide solutions to the problem which are not colored by their own interests. That is why all users keen on permanently safe flat roof solutions should be all the happier about investigations aimed at improving the state of information (OSWALD, 2009).

5. Comparison tests (new materials)

In 2009, the **Europäische Vereinigung dauerhaft dichtes Dach - ddD e.V.**, a registered society, published the results of a direct quality comparison of more than 100 membranes and coatings in a research report.

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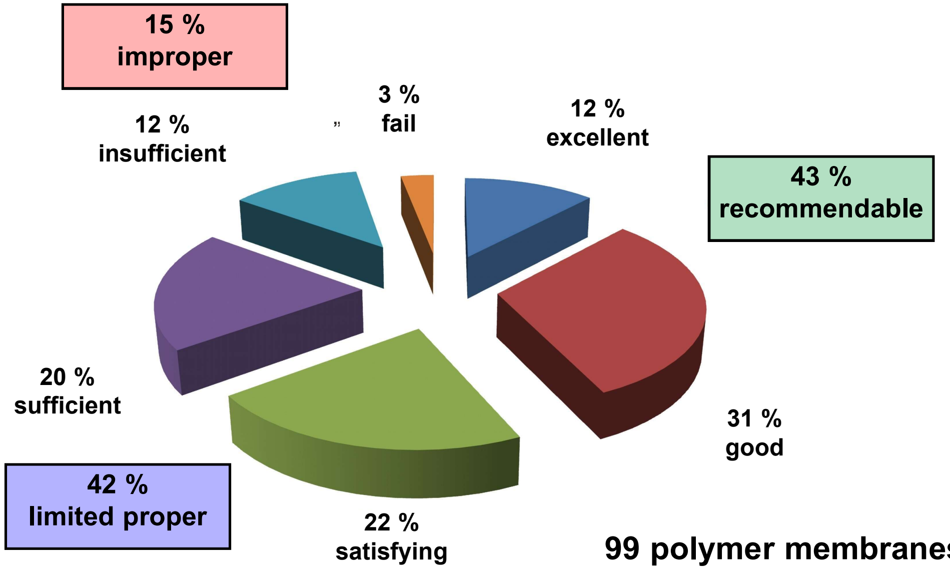


99 polymer membranes

82 thereof were plastic membranes of the following materials groups: ECB, EVA/PVC, VAE, PIB, PVC and FPO/TPO. Over the subsequent years, an additional 17 plastic membranes were tested and likewise graded by school grades following 14 practice-oriented, standards-adjusted tests, yielding an evaluation for a total of 99 marketable products. According to this evaluation, 43% of the polymer membranes are recommended, 42% are conditionally recommended, and 15% are considered unsuitable for permanent flat-roof solutions.

6. Ageing behavior

The ageing behavior of all plastic membranes is determined first and foremost by material quality and thickness, it being understood that the type and quality grade of the source materials and the manufacturing process play an essential role. Taking into account all environmental influences affecting a polymer membrane, whether openly exposed to the elements, graveled or planted, its ageing behavior, and hence its long-term functioning is determined by factors like extraction, migration, hydrolysis, saponification, volatility, resistance to microorganisms, weather conditions, and ozone.

7. Longitudinal studies

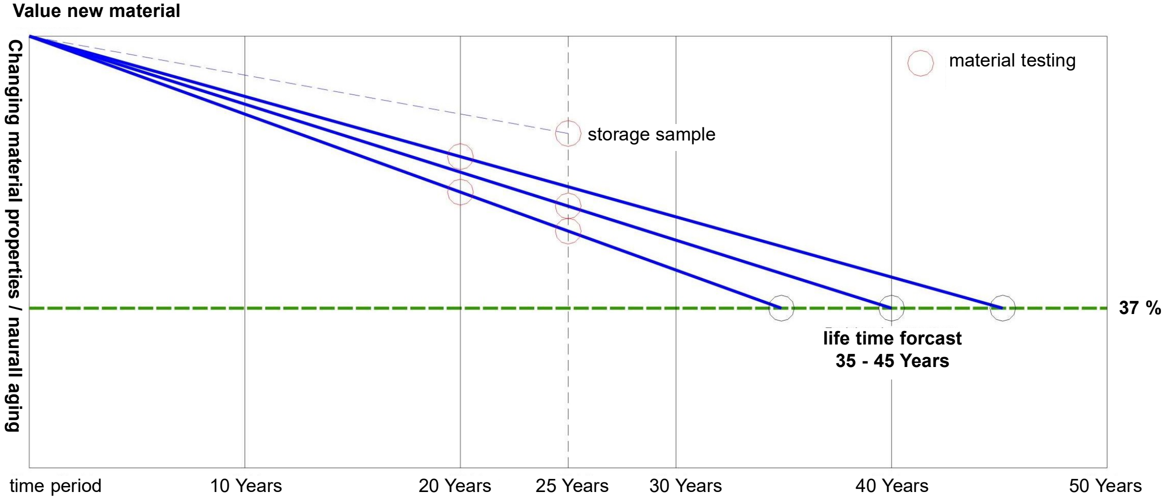
Over the past few years, numerous samples of installed plastic membranes were investigated to determine the changes in material properties after use under realistic conditions, compared with the available values for new materials. The numerous analyses performed suggest a clear trend. The changes in material properties caused by ageing correlate with the school grades following 14 practice-oriented test of new materials, which allows the following classifications.

Research Report 2009

Testergebnisse ddD e.V., 2009	**Prognosen** zur Lebensdauer	**Empfehlungen** des ddD e.V.
"excellent"	> 50 Years	recommendable for flat roofs
"good"	app. 30-50 Years	
"satisfying"	app. 30 Years	limited proper for flat roofs
"sufficient"	app. 20-30 Years	
"unsufficient"	< 20 Years	improper for flat roofs
"fail"	< 10 Years	

Analyses conducted on more than 200 construction projects

When putting the test results obtained for membranes after use under realistic conditions in relation to the available test values on new materials (100%), with due consideration of the exposure duration, a simplified diagram emerges. By adding to a product's lifetime as defined in physics until the setpoints have dropped to <37%, it is possible to forecast the time frame by which the product will no longer perform all of its intended functions, hence leading to a very high probability of uncontrolled damage. This is normally the point in time by which repair/refurbishment becomes indispensable.



Simplified diagram for determining the (remaining) live time of a PVC membrane, thickness: 1.5 mm, loosely laid, with protective layer and gravel load, investigated on 3 building projects located in the Rhine-Maine area.

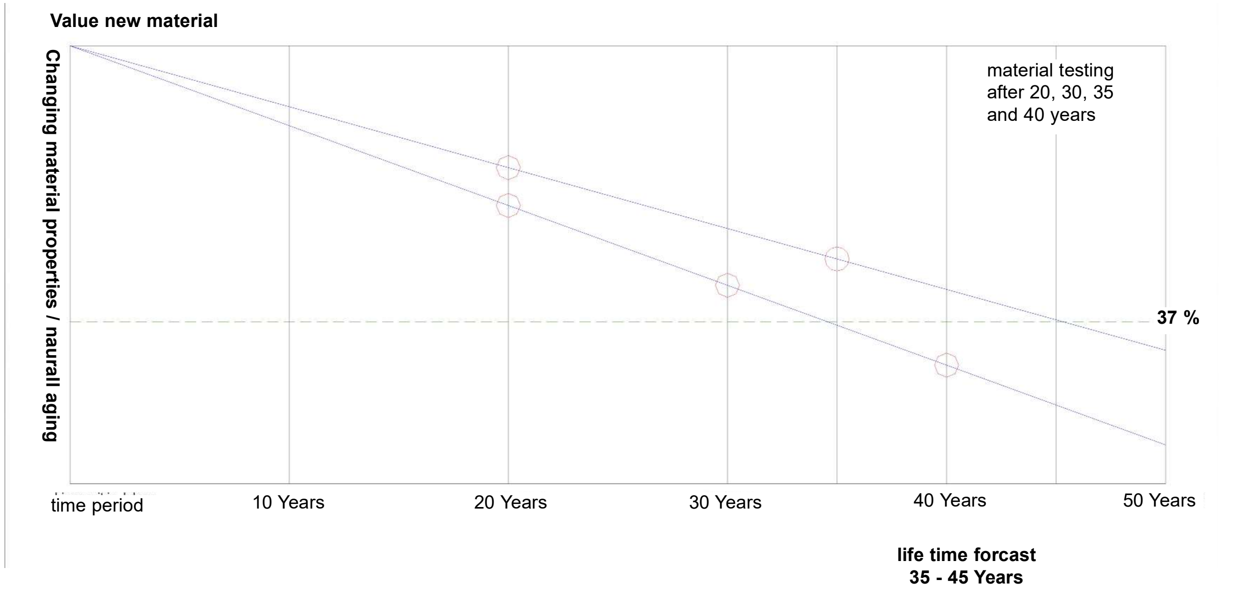
Samples were collected for laboratory testing after 20 and 25 years of exposure time, respectively. Rating of the membrane in ddD e.V. (2009): "Good".

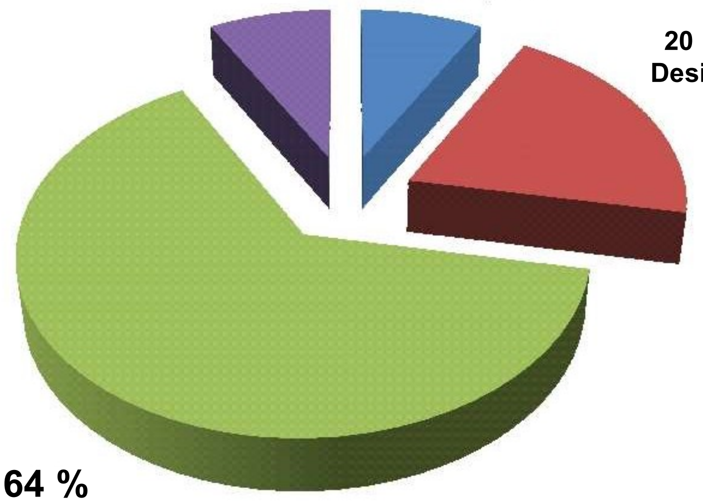
physical life time / functional life time

However, waterproofing can be used beyond its life time.

During that time, however, some of its features can no longer be guaranteed. The limitations are e.g.:

- mechanical exposure or walk on the roof by low temperature,
- no thunderstorm with hail.





Causes for a reduction in life time

According to the latest damage statistics (ddD e.V., 2017), 64% of the damages in flat roofs equipped with polymer membranes are attributable to prozessing defects in workmanship. This means that statistically speaking, approximately 2/3 of all flat roofs equipped with plastic membranes do not reach the end of their typical service life, but become prematurely leaky as a result of poor workmanship and damages during construction, thus requiring reworking and/or refurbishment after only a few years.

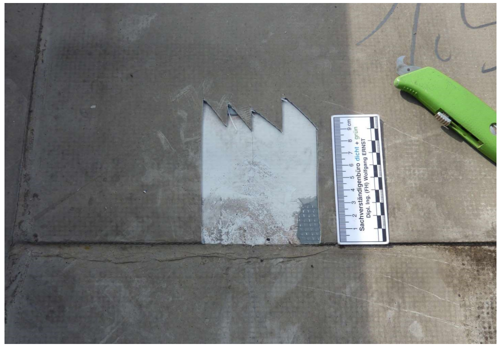
In the damage cases investigated to date, the main problem was leaks which started appearing after approximately 6-17 years, as a result of open welding seams in the joining seams made on site. It was found that these damages were in each case attributable to deficiencies in workmanship, as some of the seams had not been homogeneously welded. Joining seams which are only glued or inadequately welded will come open over the course of time.

The second most common cause for leaks was found to be damages which had occurred during construction. These damages had been caused either directly by the installer or by the following craftsmen of the various different trades.

Following a few case examples on:

1. **Quality of workmanship,
   Protection of the services provided,**
2. **Wrong decisions,
   Roof pitch design and detailed design,**
3. **Material quality.**

Reduced life time as a result of prozessing defects in workmanship during seam joining on site (typical examples)



Faulty manual weld at the end of the automatic weld.

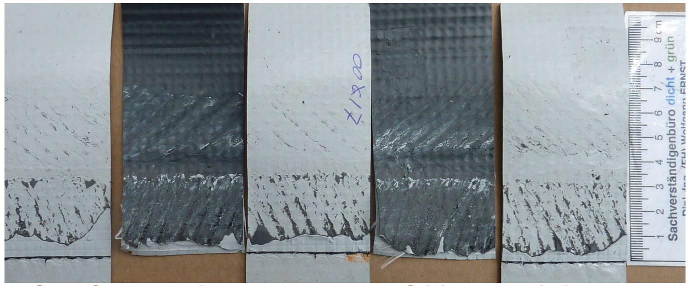
Rupture of the seam welding caused by withdrawal of the welding nozzle.

Interrupted automatic weld caused by carbon deposits from the welding nozzle.

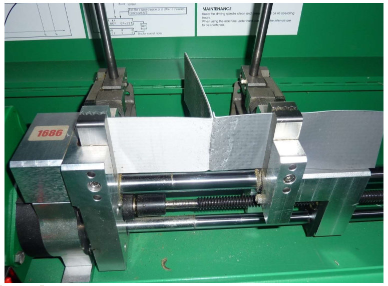
Faulty automatic weld caused by incorrect welding temperature or welding speed.

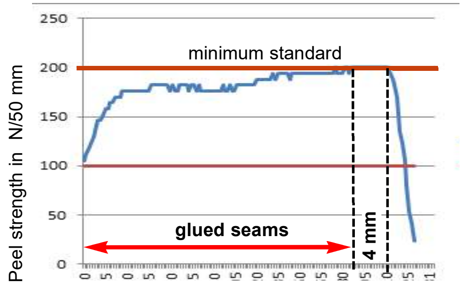
The actual welding seam quality can be assessed only by a peeling test, which has a destructive effect.
Using a test needle or vacuum testing using a suction cup will not yield the desired test results.

DIN EN 12316-2:2013-08: Flexible sheets for waterproofing - Determination of peel resistance of joints - Part 2



only a few mm homogeneous of 20 mm minimum standard





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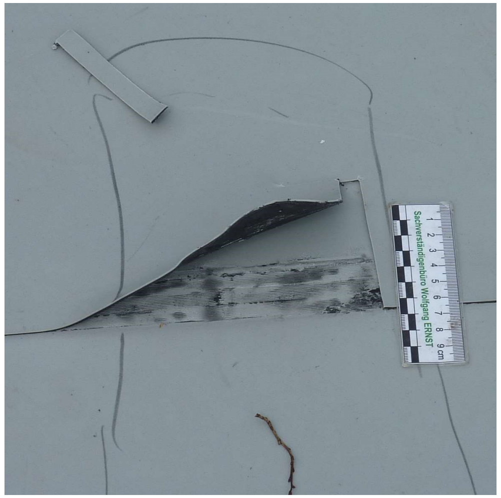
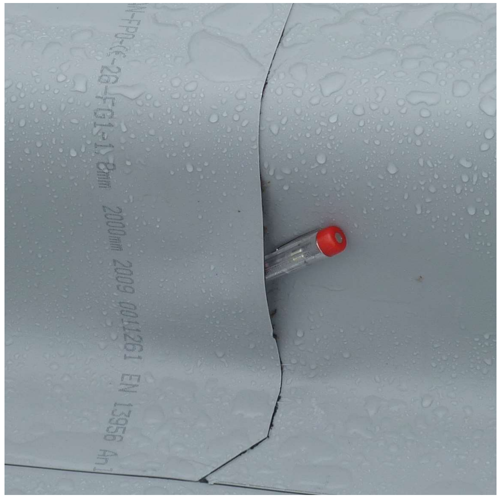
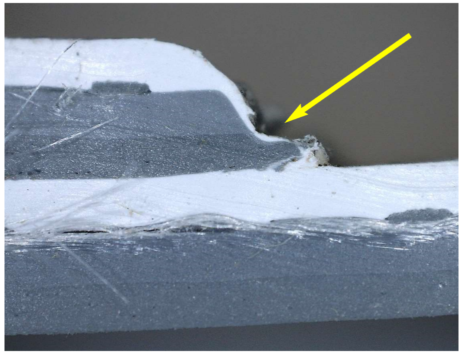




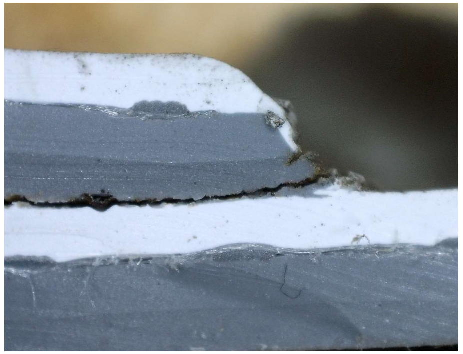
Any faulty seam welds found during quality testing/acceptance testing needs to be overlap-welded.

Non-homogeneously welded seams will come open after a few years.

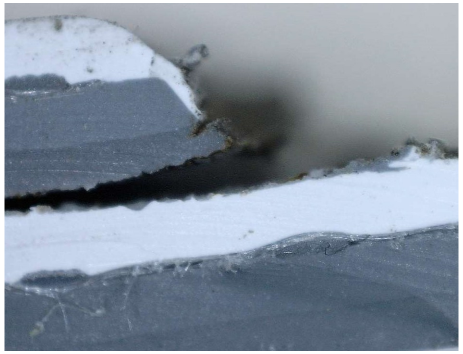
Glued seams have welding beads, which is why a test needle will not work.



Start of coming loose.



Open seam after only a few years of exposure time. The roof becomes leaky.



Leaky roof after 16 years of exposure time: complete refurbishment or repair?

Examples of open seams after 13 and 15 years of exposure time.

Comparative example of two virtually identical building structures after a period of 16 years:

A) Complete refurbishment as drastic solution. Resealing with bituminous sheeting. Decision made by an inexperienced architect, without the benefit of an inventory analysis. Construction costs: **€ 540.000,00**

B) Resource-conserving overhaul of the existing waterproofing. Recommendation by an expert with many years of experience, following an inventory analysis and functional forecast (see following page).
Construction costs: **€ 225.000,00**

Results:

- **cost savings approx. 60 %,**
- **no reduced life time of the flat roof with polymer membranes.**

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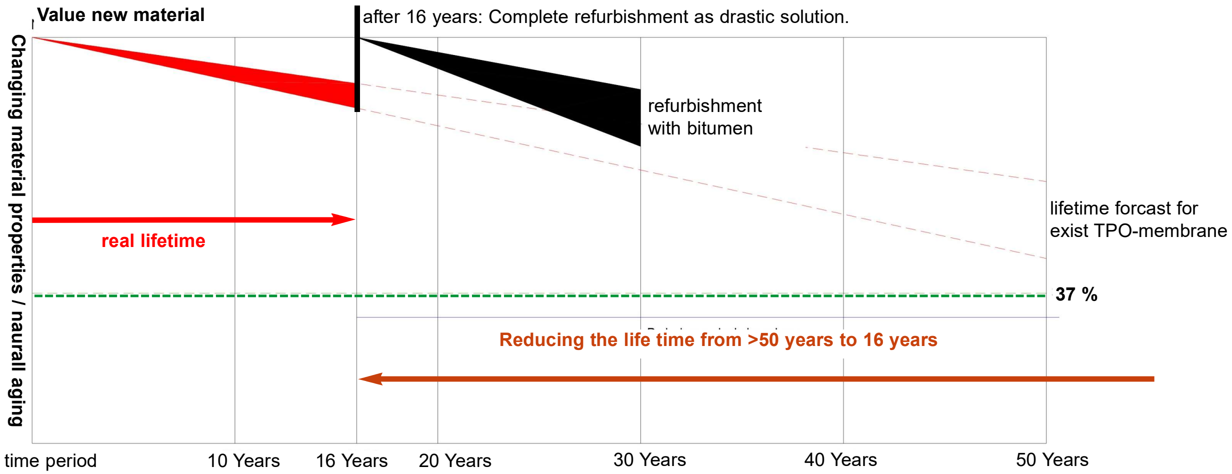
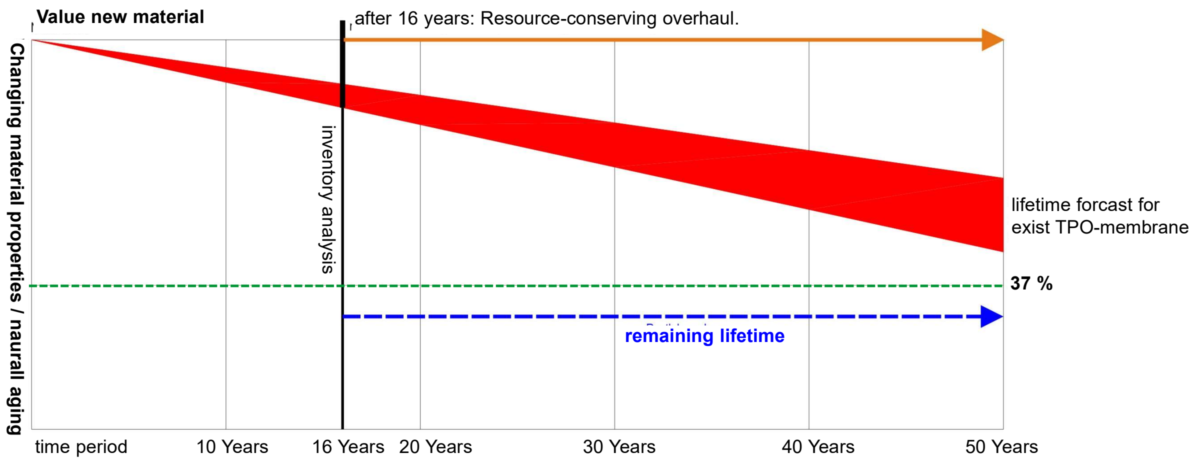


Architekt / Lifetime of the polymer membrane: 16 Years

Expert / Lifetime of the polymer membrane: >50 Jahre

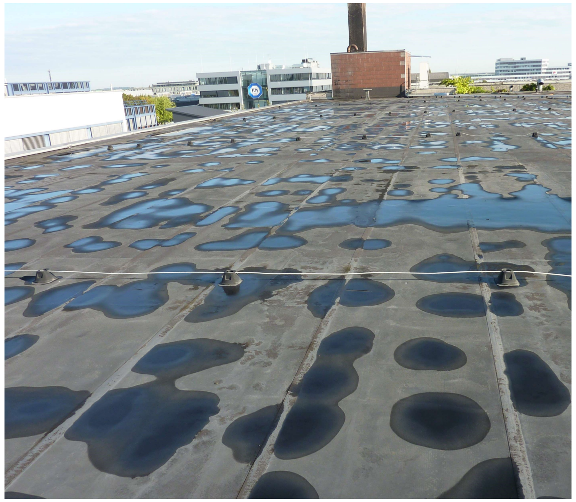


Reduced life time due to a wrong decision?

The most frequent reason given by clueless architects:

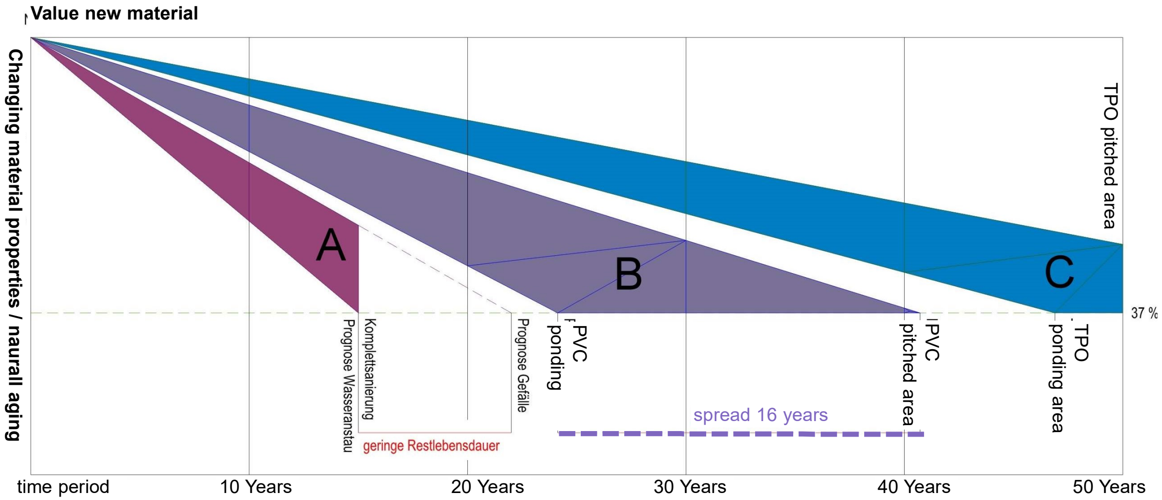
- **Polymer waterproofing membranes never last longer than 15 years anyway,**
- **moist insulating materials can no longer do their insulating job,**
- **bituminous sheeting is longer-lived.**

This translates into a **win-win-situation** for the:
- Architect: High construction costs = hefty fee,
- and the bitumen industry: Growth in sales.



Example of:
PVC-membrane, thickness 1.5 mm,
with temporary water ponding.

Example of:
TPO-membrane, thickness 1.8 mm,
with temporary water ponding.



Temporary water ponding

In roof surfaces openly exposed to the elements, significant differences were found between pitched areas and areas affected by temporary water ponding (dirt deposits, growth of algae). The differences in ageing behavior were particularly pronounced for PVC membranes and membranes with PVC share, whereas the differences for FPO/TPO membranes were less pronounced. This can be explained among other things by the fact that pure olefinic-based membranes are more hydrolysis and microbe resistant thanks to the material.

Comparative examples for differences between the different materials groups when exposed to roof pitch and water ponding:

A) Membrane with PVC share, 1.2 mm thickness, material failure in the water ponding area, complete refurbishment due to short remaining life.

B) PVC membrane, 1.5 mm thickness, significantly reduced life time as a result of accelerated ageing behavior.

C) FPO/TPO membrane, 1.8 mm thickness,

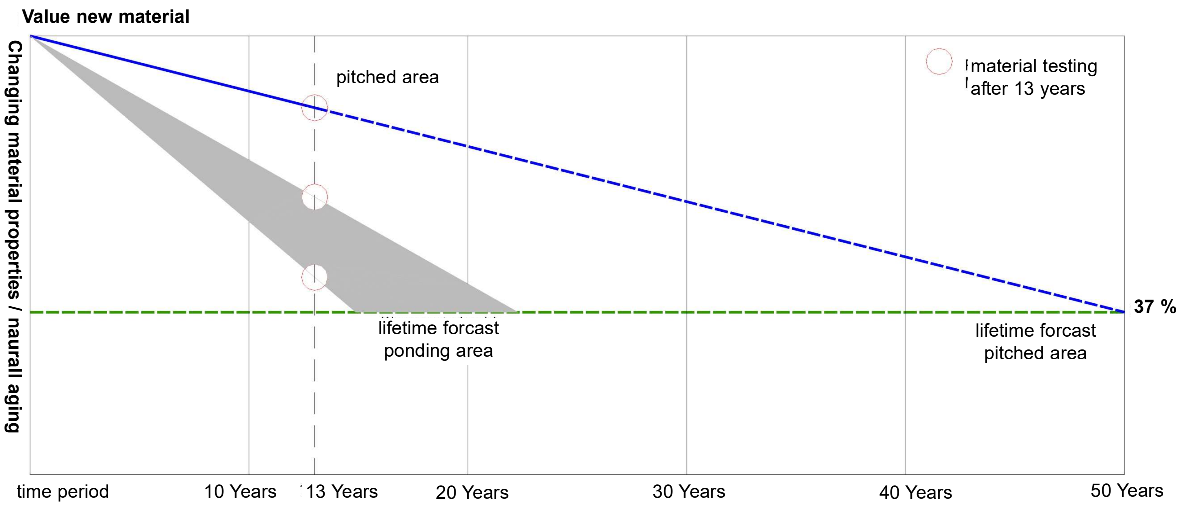
Example of partial refurbishment of the roof edge

Thanks to the positive material properties of the PVC membrane in the pitched area, with an appropriate service life forecast, an approximately 2 meter wide strip was refurbished along the roof parapet after 13 years exposure time (approx. **10% of the total surface**).

Thanks to the adequate height of the roof parapet, it was possible, with the aid of insulating wedges, to create a 2% cross slope to the run-offs in the roof parapet valley. After cleaning the seams, it was possible to weld the old membrane material to the new membrane material without any problems.

Results:

No overall refurbishment.
No reduction of the polymer waterproofing membrane's life time.



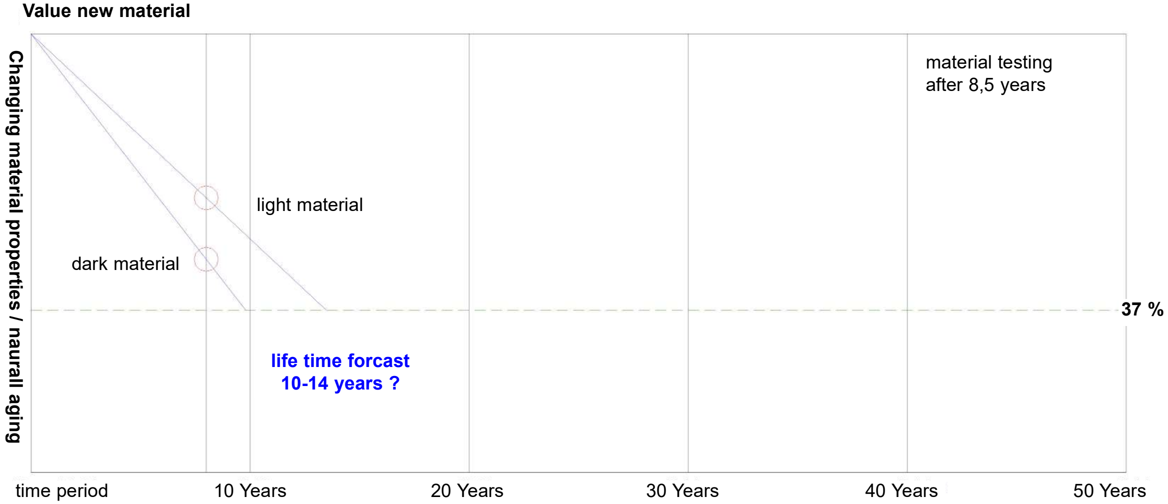
Reduction in life time caused by unsuitable gravel load

Gravel roofs without an additional protective layer (PE membrane) on the waterproofing layer show accelerated ageing behavior. The dirt deposits accumulating on the waterproofing layer are an ideal breeding ground e.g. for microorganisms.

Extensive planting systems, by contrast, provide optimum protection for the waterproofing layer, as demonstrated by the example.

Life time forecast for an PVC roof sheeting membrane, 2.0 mm thickness, E: GV, loosely laid, either under extensive roof planting or under gravel (material analysis after 17 years of exposure time).

From the point of view of overall roof life time with polymer membranes, the negligible extra costs for a protective extensive planting system are never wasted.



Limited life time as a result of accelerated ageing behavior

Roof surface featuring two different TPO membranes of 1.8 mm thickness by a single manufacturer:

Both membranes feature the same type designation (brand name) on the consignment note completed by hand (?).

According to the manufacturer's specifications:
- the light membranes are calendared,
- the dark membranes are extruded.

In comparison to the reference sample from the 2008 production, significant changes in material properties were found after approximately 8.5 years of exposure time, as clearly evident from the functional life diagram.

One can only hope that this is an isolated, exceptional case.

Conclusion

In this day and age, the culprits to be blamed for the bad reputation of roofs containing plastic waterproofing membranes - with a few exceptions - are no longer the manufacturers, but first and foremost those who install them, and who turn predominantly good polymer membranes into bad building components which start leaking after only a few years.
This situation is exacerbated to a considerable extent by clueless architects, design and planning faults, wrong decisions, and inadequate site supervision.

Prevention of lifetime-reducing factors in polymer waterproofing membranes

Material selection: e.g., plastic membranes rated as "Good" or "Very Good" according to the recommendations by ddD e.V., or bearing a quality label,

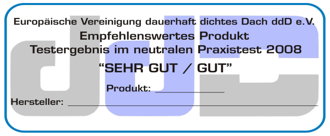
Planning design: Material-specific planning with a distinct roof pitch, or use of demonstrably hydrolysis-resistant polymer membranes,

Execution: Execution by qualified companies employing skilled staff, and quality assurance through documented self-monitoring and external monitoring (e.g.: quality label for execution, since 2017),

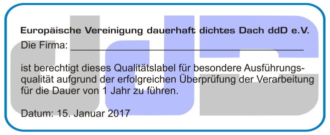
Acceptance testing: Technically qualified acceptance testing by experienced experts as quality-assuring final inspection,

Maintenance: The conclusion of maintenance contracts is mandatory.

Contribution by ddD e.V.


Europäische Vereinigung dauerhaft dichtes Dach ddD e.V.
Empfehlenswertes Produkt
Testergebnis im neutralen Praxistest 2008
"SEHR GUT / GUT"
Produkt:
Hersteller:


more than 30 field reports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Die Firma:
ist berechtigt dieses Qualitätslabel für besondere Ausführungsqualität aufgrund der erfolgreichen Überprüfung der Verarbeitung für die Dauer von 1 Jahr zu führen.
Datum: 15. Januar 2017


Information sheet: Roofing experts (with technical equipment)

End-to-end quality assurance

with material-specific and feasible objectives.

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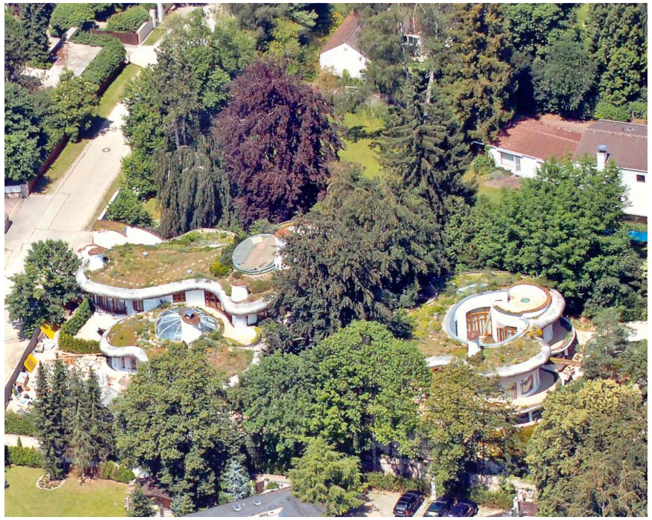
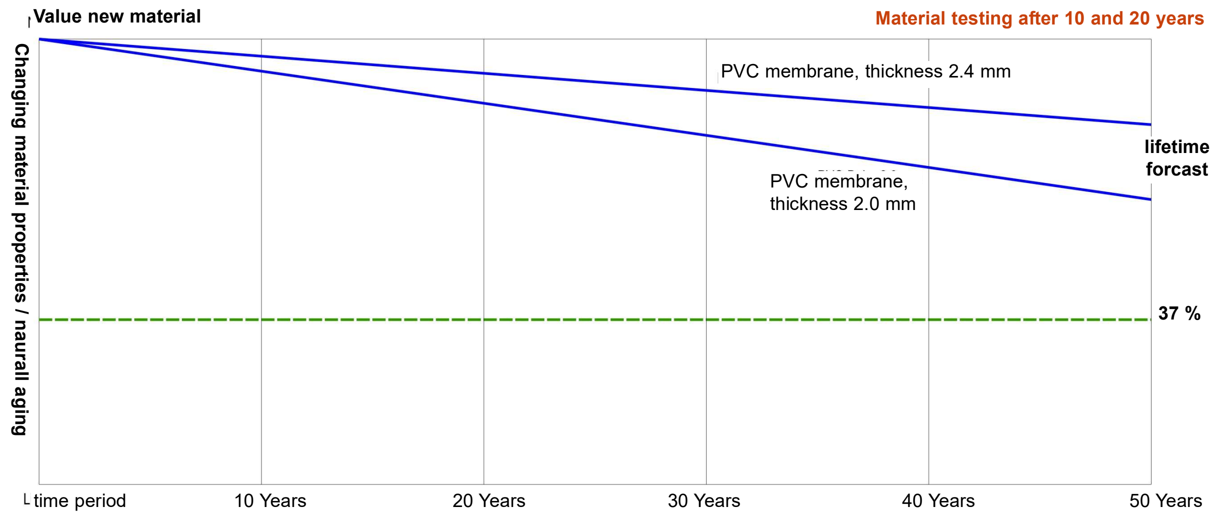
Object example, year of construction **1987**, (now 30 Years), PVC-membrane, thickness: 2,4 mm,



Object example, year of construction **1989** (now 28 Years) PVC-membrane, thickness: 2,0 mm, (both PVC-membranes from the same manufacturer).



Life time >50 years two positive examples

The two building examples (28 and 30 years old) clearly illustrate that roofs equipped with plastic waterproofing membranes can reach a service life >50 years, provided there is consistent quality assurance:

- high-quality product (thickness >1,8 mm),
- material-appropriate planning and tendering,
- material-specific execution by a specialist company employing skilled staff,
- technical acceptance testing of the services rendered by qualified experts, as final quality control,
- (and additional protection of the polymer waterproofing membranes by a planting system).

These objectives should be aspired for all roof types equipped with polymer membranes (worldwide).

Europäischen Vereinigung dauerhaft dichtes Dach e.V.
building better roofs with polymer membranes