Development of environmentally friendly lead-free flashing

Development of material and mounting process for an alternative to lead for flashing applications on roofs

A Danish version of this report dated September 2002 is available on the website of the Danish National Agency of Environmental Protection.

In the English version of the report dated 15 April 2003 the designation of the material ”pem-komposit” has been replaced by the product name “Perform”.

Poul-E Meier ApS

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Synopsis

In Denmark flashing with lead is abandoned from 1 December 2002. It is indeed a great challenge to replace a flashing material like lead, which has been dominating the market thoroughly.

For centuries lead has been used for flashing on all kinds of roofs, probably because lead technically has been the best material and the easiest one to handle for the craftsman.

Alternatives have existed for many years but they have not gained significant market share compared to lead. This is mainly due to the fact that the plumbing industry has not found the quality satisfying.

Therefore, we have been working on developing a material with properties that could entirely satisfy the plumbing industry. Technically, I thought that this was a huge challenge, but from the start my goal was in fact to invent an even better material.

The biggest companies and associations in the plumbing industry concurrently state that the newly developed Perform apparently is as good as lead for flashing – or even better

During the development of Perform, significant measures have been taken to ensure a clean and healthy environment and also an equally clean workspace for the persons involved in manufacturing the material.

1. Danish EPA abandons the use of lead

Lead is a toxic material, which, for example, can lead to reduced intelligence among children.

In Denmark, 17,000 tons of lead is used every year. Of these, 3,000 tons is used for flashing. Part of these 3,000 tons will eventually harm the environment as lead will be washed down from the roofs down into the earth around houses. Additionally, at demolition of houses or when roofs are replaced or renewed, much lead is simply thrown away.

Therefore, the Danish Environmental Protection Agency (Danish EPA) has abandoned a range of products containing lead. In 1999, when the development of PERFORM started, a draft of the executive order on lead was already ready, but the time of the prohibition against lead was not fixed.

Additionally, the work with lead, both handling and soldering, can lead to a harmful working environment, depending on the particular kind of process and working method. This indeed becomes evident when studying rules and regulations about soldering and handling lead.

The executive order on lead resulted in investments in the development of alternative flashing materials that could replace lead.

Several companies of the Danish plumbing industry contacted the ‘Danish Technological Partnership’ of the Danish Technological Institute in 1999. They were all looking for an alternative to lead as no competent alternatives were available at that time.

At the same time, I got an idea in my summer cottage!

2. The first part of innovation is to look …..

After having installed a chimney and the flashing, what you really need is a bath!

In the spring of 1999 I had just installed a stove and chimney in my girlfriend's and my summer cottage in Vendsyssel in Denmark.

I was really amazed at the technical and environmental properties of lead. The huge weight of lead was indeed a positive aspect due to the strong wind of the Danish west coast. But as a flexible craftsman, I do have demands when it comes to mounting, construction and material.
Thus, I was not satisfied as I had to be so careful with, for example, the soldering process. As a 'glue and adhesives advisor' I often refer to the construction of an aircraft wing as an example of how light materials can be used to design structures with great strength.
When using this example as my starting point, I could only see lead as a technically poor and old-fashioned material.
The next parameter was the sheet work – the way the flat material is handled so that it shapes just like the profile of the roofs.
Even with the greatest care, I did not succeed in shaping the lead and at the same time obtaining a nice surface finish. I could probably learn it if I had the time, but for me the lead still had bumps around areas where the material was stretched. It was not pretty! I thought: This can definitely be done in a better way!

3. The relation between needs and innovation

Later the same year, an introduction from 'Technological Partnership' was published stating that an alternative to lead for flashing applications was wanted.

Now, this was a challenge and I announced that I was working with initial ideas aimed at developing a brand new composite material for this application.

Measurement of deformation pressure and (return) springiness

The first companies were only interested in buying an existing product and they did not find my ideas and initial construction samples interesting.
However, the company Exhausto A/S, which produces complete ventilation systems and matching roof bushings, showed interest and agreed to take part in a development project. The aim of this project was to define demands and wishes to the product and subsequently to carry out practical tests of the material.

After initial meetings where all demands to the properties of the product were defined, I started developing a flexible material that could easily be shaped.

Lead and an initial sample of Perform with sand as top surface layer (September 1999)

4. Financial support

Alongside the collaboration with Exhausto, I imagined that alternatives to lead had to be interesting on a more general basis. Therefore, I contacted the Danish EPA, which showed great interest but also demanded that the project was well planned and that I could show them a budget.

Thorough planning, detailed plans and a budget all turned out to be helpful tools in the control and execution of the project.

From the 'Cleaner Products Scheme' support of up to DKK 800000 (approx. 115000 USD / 107000 Euro) was promised. The budget indicated a need of DKK 577,000 (approx. 82000 USD / 77000 Euro). Thus, the foundation was ideal for serious and positive collaboration.

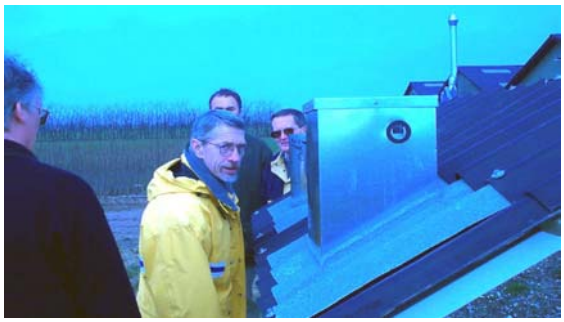
Now, after a supported period which has been extended from 2 to 2¼ years, the project has received support of all together DKK 600,000 (86000 USD / 80000 Euro). Without this support from the Danish EPA the project could not have been carried out

I have been working more than full-time on this project and apart from minimal personal expenses, I have also spent the support money on counselling, material, tools, travelling. Furthermore, I have spent money on non-supported related expenses in order to patent my invention. A significant advantage of this is that I have been able to just buy the necessary materials and thereby have not been dependent on free samples etc., which would all lead to a slower development process and in general lacking independence.

I had to find suppliers who were on the leading edge when it comes to both the technical and the environmental side. Additionally, it was essential that my suppliers had a high service level and an organisation that was able to support me as a developer and inventor. At this point, I experienced much difference in the ability to deliver materials, which could meet my specific and numerous demands. One demand was, for example, willingness to deliver special assignments or prototypes in small quantities and in easy-to-handle packaging.

5. Organising the development phase

The Danish EPA, Office for Cleaner Products, suggested the following way to organise the project:
Project leader / inventor: Poul-E Meier
Partner of collaboration, especially with focus on testing: Exhausto A/S
Support group: Henri Heron, Chairman of Danish EPA, Henning Holm Sørensen, Exhausto A/S, Jacob Maag, COWI A/S and myself Poul-E Meier.



Good advice from the support group

The collaboration with Exhausto was really going well and after establishment of the support group, the project benefited from broader evaluation of ideas and generally helpful feedback to me as an inventor and developer.

Earlier, I have been working for 7 years as an advisor and it was indeed of great value again to be in contact and to collaborate with a very competent group of experts.

My product was already on the ‘apply-state’ and developed to a partly usable product so the initial concept had turned out to be of high quality.

However, I was still far from the goal as much work had to be done with optimisation of the product and examination of many different conditions all related to the product.

6. The need for personal counselling

As the project proceeded, I felt a great need for counselling or a kind of board to help managing my project.

At this point I found valuable help in Carl Otto Klingberg from the TIC Centre in Hillerød, Denmark who is very experienced and has been a valuable and positive support.

Patents:

I had done some research into patents in general and handed in my own patent applications. However, I did consider involving a professional patent agency and via the TIC Centre I was advised to contact the patent agency Chas. Hude.

7. The development work

The development work did proceed as planned and the quality of my prototypes did improve step by step and to my satisfaction, the time schedule and budget certainly corresponded satisfyingly with the reality.

The demands and wishes of the Danish EPA were in fact a great support during the planning phase.

So now was the time to look for possible manufacturers of the product. This phase turned out to be surprisingly difficult and time demanding.

From my work at Brüel & Kjær, Denmark I knew by experience that you would normally expect an equal amount of resources to be spent on development, production and sales.

I did realise that development and production were demanding, but I had never expected to spend so much energy on establishing contacts and on sales in general.

During the work with the project, I have had inspiring collaboration with persons from two big companies, both being possible manufacturers of the product. The first one was Sven Harder from Icopal and later Thor Due from Roulunds Fabrikker (and the sister company Polymax Roulunds). The year-long collaboration ended due to internal changes in the big companies such as new ownership and decisions not to take any financial risks on their own

I learned much from this collaboration and Roulunds advised me to carry out thorough market research.

8. It took time to find a manufacturer

The project support and I, who are all technically educated and project-focused persons, did not imaging that it would take years to find a manufacturer and at this point the project was exceeding both the budget and the time schedule.

At a 'Profession-Development' seminar held by Socialistic Adult Education Association (the Danish SFOF) I presented my project. At the same time I got in contact with permanent under-secretary and lecturer Jørgen Rosted from the Danish Ministry of Business Affairs and he advised me to contact the Danish Technological Institute, department of Inventions and Creativity. This turned out to be a good idea as the project received support from Rasmus B. Offersen to help this new and time demanding promotion phase.

In January 2002 a presentation meeting was held at the Danish Technological Institute for the 15 biggest customers in Denmark, an interested company from the Netherlands and a possible manufacturer, which was Roulunds. The thorough market research which had been carried out at this stage contributed significantly to the positive outcome of this meeting. The quality and the properties of the material were evaluated by the participants and the conclusion was very positive.

One participant was Anders Kjær Jørgensen, who is second generation from Juelsminde Aluminium Industry A/S, which produces accessories for roofs. Speaking with Anders Jørgensen was very positive as he was both the person to make the decisions but also the specialist who was able to evaluate the properties and thus, the possibilities of the material.

During the next few months a licence contract was signed allowing Anders Jørgensen and his Partner Jess Robert to establish a company and to manufacture the material that was given the name Perform.

The name of the company is Robert & Kjaer ApS.

9. Great interest from the plumbing industry

’A product has been created which apparently can be used for flashing on all kinds of roofs’
This expression was in fact mentioned for the first time by the potential manufacturer Icopal and this ability apparently is very essential in the Danish plumbing industry.

In the workshop! A flashing from the factory should ideally be as small as possible during transportation and preferably be as light as possible so that it is easy to carry up on to the roof.

Already before the first square meters were manufactured, Danish divisions / departments of foreign companies have shown great interest in using the product both in Denmark but also outside Denmark.

The first presentation outside Denmark has taken place and collaboration has been established in order to carry out preliminary tests and material optimisation. As the following assembly probably has to be carried out on big sophisticated machines, it is essential to establish collaboration as early as possible in order to be able to modify both material and machinery to suit the ideal manufacturing process.

At the moment Robert & Kjaer ApS is working intensely on developing and optimising the manufacturing facilities in Juelsminde, Denmark.

It should be mentioned that this is the first time that Rasmus B. Offersen, the Danish Technological Institute has been involved in an invention and development phase where production facilities did not exist at the start of the project.

10. Test of material parameters

Testing can be divided into many categories and here are a few examples of how the material is tested, typically in comparison with lead and existing alternatives to lead.

Test of Perform's flexibility in comparison with soft Zinc and lead
The tools used to shape the materials were a plastic hammer and a special sand hammer which is a kind of a sock coated with MS polymer and filled with sand. The sand hammer had the advantage of transferring the force from the hammer to the flashing material in a very uniform way.

- The ability of the material to stay in the shape it has been given – both when it comes to bending, extension and contraction
- The force needed to extend and bend the material
- Elongation at break and the force needed, both within the normal deformation zone and at the point of break
- Bending at temperatures below -40° C
- Heating up to temperatures significantly above the recommended 90° C
- Perforation and measurement of penetration force
- Number of bending cycles before break
- Water tightness after break
- UV light influence in extended condition – with or without an extra top surface layer, for example consisting of slate
- Assembly with typical materials used in the building industry
- Proposals on how easily to construct solid joints
- Mounting in the workshop and on the roof
- Curing times in different conditions

11. Comparison of aims and results of the project

The following 10 aims and objectives of the project are taken directly from the application sent to the Danish EPA in 1999. Each of these 10 points is commented and the rate of success is assessed.

The overall objective of the project was to develop a product which can replace lead in all flashing applications on buildings. Apart from this, the aim has been to optimise certain parameters, so that the material could fulfil the following:

- Working environment during manufacturing, processing and installation

The materials that are part of Perform are aluminium and MS Polymer.
MS, which is a so-called silian-modified polymer, is typically used as flexible glue or sealer. After curing it has rubber-like properties

MS polymer has a MAL code: 00-1 or 0-1. This is the same code often used for indoor water-based painting.

- The used materials should not be harmful to nature during use or by the end of the product life cycle. Additionally, the energy spent during manufacturing should be kept as low as possible

Perform is scrapped just like normal building refuse and, apparently, the aluminium can be separated from the polymer. Aluminium does demand relatively much energy during extraction and manufacture. Therefore, recycling of this material is interesting.

- Fire resistance

It is not an objective that the material should not be able to burn. However, the supplier of the polymer is trying to find out if the fire resistance of the polymer could be improved.

- Strength, tightness and durability related to UV-light, freezing water, changing temperatures, wind conditions and, finally, mechanical strength and flexibility

Installation test carried out at Exhausto A/S.
The drawn mesh is used to assess how the material is extended and shortened after it has been shaped to fit the roof profile.
Note that a traditional tool is used, which is a specially shaped piece of lead.

These properties have been tested since 1999, especially at Exhausto A/S.
At Exhausto A/S a test-house was build, which has both round and square bushings.
During a summer period, the jointed sheets have been put into a large freezer. No changes to the material or the joints were evident and the material remained flexible even at very low temperatures.
The stability when exposed to wind pressure has been tested in practice at the test house and on the factory buildings of Exhausto A/S.

An impartial test at the Danish Building and Urban Research is being developed.

- Design of the material - shape, colour and structure

PERFORM can be shaped just like lead. Besides from this, compression is possible without any bumps, which is the case when lead is compressed.

Maximum and recommended deformations are shown at the top. At the bottom, a self-adhesive multi-flexible installation flange is shown.

The material can be glued with the same type of silian-modified polymer to itself and to other construction materials. The quality and strength of the joints does indeed qualify for use in building constructions.
The glue has unchanged flexibility at temperatures between -40 to +90° C. Thus, the glue does not have thermoplastic properties, which could soften the glue due to heat from the sun.

Many combinations of materials are possible

This leads to many new design and installation possibilities. This is mainly down to the fact that Perform can be jointed with non-solderable surfaces like, for example, glass, aluminium and painted surfaces.
However, porous materials like bricks and concrete do need to be primed before gluing.
Additionally, the mechanical strength of Perform, makes it possible to joint the material using screws and rivets.
The colour-range is at the moment black and ‘lead-grey’ but the possibilities of introducing more colours are being assessed. An obvious additional colour could be ‘tile-red’.
It is technically possible to apply a top surface layer of, for example, ’mini-slate’ or a similar material.

- Design-related possibilities so that individual demands can be met – all based on the same base material

It is possible to paint the material, which is being tested at the moment. Experiments are also being carried out on how to coat PERFORM with a coloured MS-polymer layer, slate and other kinds of top surface layers. PERFORM can as a flexible construction material be jointed with 'itself' or other materials in a way so that the material remains totally stable.

- Possible special editions for use at extreme temperatures

Experiments have been carried out with a high-temperature polymer at temperatures up to 350° C. Apparently, this is possible and this forms the basis of alternative applications for Perform besides from flashing on roofs.

- Flexibility compared to lead in order to be able to rationalise manufacturing of pre-fabricated roof elements like, for example, bushings

Perform is apparently more flexible than lead. To what extend this should be exploited is up to the manufacturer of the pre-fabricated products. Extra flexibility is obtainable if the rest of the construction is carefully designed to be fitted with Perform. During my work with flashing materials, I have seen different tiles with an adjustable angle. A solution like this is preferable as it prevents the material from being stressed.

A tile with adjustable angle makes it easy to compensate for the angle of the roof.

- Price should be competitive

There are strong indications that Perform will be a more expensive material than lead. On the other hand, the installation time and, thus, the installation price is expected to be lower. Installation time and prices are, however, individual depending on type of construction, size, rate of automation etc.

Perform provides several of opportunities, for example, more freedom when the other construction materials are chosen. This can lead to savings and improvements.
The material price itself is, therefore, difficult to assess but the plumbing industry has shown great interest and many people are very excited about Perform and the new possibilities provided.

- Optimisation of the product aimed at simple manufacturing methods

Apparently, the product is easy to manufacture in smaller pieces manually. Many manufacturing methods and processes have been considered. Especially the way the material is 'built up', the material thickness and the surface finish have been thoroughly assessed. Preliminary tests have been carried out by means of simple methods but conclusions have all had mass production as a starting point.
Now during the manufacturing this process continues in order always to choose the right ways of manufacturing and the right tools.

Bosch adjustable roof tile fitted with Perform

12. Environmental influence

The fact that lead is prohibited and widespread use of Perform will lead to less lead being washed down from roofs. This tendency is possible to carry through to other European Union (EU) countries and also in countries outside the EU.

Also, when it comes to the working environment, Perform will be a step forward as the gluing process replaces the soldering process with lead. Perform is patented in Denmark and an international PTC patent application has been handed in. 13. Communication of results

Danish EPA

- An early edition of Perform is mentioned in 'Miljøprojekt nr. 593, 2000'. This report is made by COWI A/S and is available on the Danish EPA website.

Technical periodicals with articles about Perform:

- 'VVS & El Horisont, nr. 6. april 2002'. On 3 pages Morten Sinding-Jensen describes the history behind the project. The article describes the progress of the project and refers to the earlier mentioned report by COWI A/S by Jacob Maag and to comments from Benny Wielandt from 'FagHøjskolen', and to engineer Jens Christian Poulsen from the solar heat company Batec A/S.
- 'Dansk VVS, april 2002'. Two pages where the possibilities of PERFORM are described in very favourable terms.
- 'Bygge-& Anlægsavisen, nr. 1. maj 2002'. A whole newspaper page with descriptions and pictures.
- 'Miljø Horisont, nr. 3. marts 2002'. One third of a page with introduction to the 'DanMiljø' exhibition.

'Danmarks Radio (DR)' (Radio Denmark):

- On the DR Homepage a 10 minutes long report (from the radio).

'DanMiljø' Herning Exhibition Centre 2003

Nominated in the category: Environmentally friendly inventions

the Danish Technological Institute:

- Technological Partnership became the starting point of a new pioneer invention.

- One page describing the invention and the Technological Partnership
- 'Opfindelser & Kreativitet'. Article is on the way and will be published in September.

Danish Building and Urban Research

- 'By og Byg anvisning 201'. Perform is described under the headline: "Formstabil polymerinddækning med metalforstærkning" (Stable flexible reinforced polymer flashing material) among other lead-free alternatives.

Farum, 15 April 2003
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