Survey results of corroding problems at biological treatment plants, Stage II
Protection of concrete
State of the Art

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Waste Refinery

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Summary

A pilot study on the degradation and corrosion of concrete in biological treatment plants was conducted in 2009/2010 in a Waste Refinery Project WR-27 "Survey results of corroding problems at biological treatment plants". The results showed that the concrete does not have sufficient resistance in the current aggressive plant environment. Furthermore, it is stated that some form of surface protection system is needed to ensure the good performance of concrete constructions, and that the system must withstand the aggressive environment and the traffic that occurs on site. Consequently, a new study was proposed in order to develop specifications for surface protection of concrete in aggressive food waste environments. Results from that study are presented in this report.

The report includes various types of waterproofing/protection coating for concrete in biological treatment plants. A number of proposals from the industry are presented in the light of results from project WR-27, i.e., the materials must, among other things, withstand the aggressive leachate from waste food at temperatures up to 70 °C, and some degree of wear.

Some systems are compared in terms of technical material properties as reported by the manufacturer. It turns out that different testing methods were used, and the test results are thus generally not directly comparable.

A proposal for a test program has been developed, focusing on chemical resistance and wear resistance. A test solution corresponding to leachate is specified. Laboratory tests for verification of the proposed methodology and future requirements are proposed, as well as test sites and follow-up in the field.

Keywords: composting, digeste, corrosion, food waste, concrete, sealing coat, leachate, polyurea, epoxy, MMA, mastic asphalt

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Content

Bilagor

BILAGOR A – G: PRODUKTINFORMATION

1 Introduction

The aim of the project has been to formulate a number of general technical requirements for waterproofing, or waterproofing systems, used for the protection of concrete in biological treatment plants (biogas and compost/food waste plants). Appropriate testing program to verify those requirements has also been proposed, including test methodology according mainly to European standard. The requirements specification can hopefully serve as a basis for the selection of appropriate waterproofing system for these concrete structures, and facilitate a comparison of different systems. It also makes it easier for manufacturers and contractors to present the expected functional properties. Chemical resistance (to leachate) is a crucial property that has been studied especially and in the light of results from Waste Refinery Project WR-27.

Possible waterproofing and coating products for concrete in biological treatment plants are different types of thermosets and/or bitumen-based materials. It is in this context to be mentioned that the experience of liquid/spray-applied waterproofing systems for concrete in Sweden is limited. Benefits of such a system are primarily (provided the application work is carried out in sufficient thickness and without any problems):

- No joints or edges.

Drawbacks are:
- Results of the waterproofing work is generally very weather dependent. The risk of blistering is great in less favorable conditions (moisture, heat, poor surfaces);
- The product is "manufactured" on site, which makes great demands on the precise mixing and application techniques (difficult to quality control);
- The work may require special security measures and shall be conducted by specially trained personnel.

1.1 Limitations

The project is essentially based on results and experience obtained through a preliminary study [Boubitsa et al. 2010].

The requirements specification is related to prefabricated waterproofing membranes or membranes sprayed or otherwise applied in liquid form on the concrete. Possible materials or material combinations include epoxy, acrylate, polyurethane, polyurea and/or bitumen-based products of various kinds.

A preliminary technical assessment of materials has been carried out for a number of different waterproofing systems designed for biological treatment plants. The assessment is based on the reported testing by the manufacturer. The reported properties have been compared against relevant corresponding testing and specifications for similar types of systems used for other types of concrete structures.

No laboratory testing is part of the project.

2 Background

Problems concerning leachate and corrosion of concrete in biogas and composting plants have in recent years been reported to the Swedish Waste Management (the Swedish stakeholder and trade association in the field of waste management and recycling). This has occurred as the collection and composting volumes increase around the country. A pilot study "Survey results of corroding problems at biological treatment plants" was carried out in 2009/2010 within a Waste Refinery project WR-27. Four different treatment plants were investigated, involving analysis of leachate, concrete and reinforcement. The results showed that concrete does not have enough resistance to the aggressive environment in such treatment plants (see Figure 1). Furthermore, the report states that some form of protection coating is needed to ensure the function of the concrete structure, and that the coating must withstand the aggressive environment as well as the traffic that occurs on site. A new study was therefore suggested for developing specifications for protection systems on concrete in aggressive food waste environments. Results from that study are presented in this report

Figure 1. *Corrosion damage on tank in biogas plant [Boubitsas 2010]*

In Sweden, there are today some twenty biogas plants for waste, and about hundred or more composting facilities for waste from parks and gardens and/or food waste. Another couple of biogas plants are planned. Many existing plants must also rebuild and repair their constructions due to concrete damage and corrosion. Biological treatment is also increasing in other parts of Europe, and an increasing number of treatment plants are built. In Germany, there are about 800 plants and in Italy 240 [Barth 2010]. However, there seems to be no particular standard, either for concrete or for protection coatings used on concrete in these facilities. But obviously, it is important that the concrete is protected with waterproofing and coating systems that work under the present circumstances.

2.1 About concrete

Concrete is the material used most in the construction industry today. It consists mainly of rock (aggregate) bound together by cement paste (cement and water). Its properties are determined mainly by water-cement ratio (w/c) or water-binder ratio. (Definition according to EN 206-1 for concrete reads: "material formed by mixing cement, coarse and fine aggregates and water, with or without the incorporation of admixtures or additions, which develops its properties by hydration of the cement. ")

Strength and durability are important properties. The strength is determined mainly by the w/c, but also cement type and ballast characteristics and composition influence, as well as particle size distribution of aggregate. On surfaces where fast drying and high density are required, most often high-performance concrete with low w/c is used.

The compressive strength of concrete is much higher than its tensile strength and therefore concrete structures are reinforced in zones exposed to tensile stresses. The reinforcement is typically made of steel having a very good tensile strength. The compressive strength of concrete is normally stated after 28 days, but improved in general over time (several years).

Concrete is a strong and relatively inexpensive building material. However, in some applications concrete needs protection. The reason for this may be limited resistance to chemicals or, for various applications, its porosity/permeability. The preparation of a concrete surface is in this context very important. Depending on the surface quality, various types of cleaning and/or adjustment are required, such as grinding, milling, blasting, repairing cracks, filling, etc. Laitance and curing membranes must always be removed from new concrete surfaces [Abbott 2010]. (Laitance is the thin, weak, brittle layer of cement and aggregate fines formed on a concrete top surface. Membrane curing agent is used to protect the newly cast concrete and keep it moist for a longer time.)

There are a variety of grades and uses of concrete. In recent decades, the development of additives and admixtures made possible entirely new types of concrete. One such example is SCB (self-compacting concrete) of various kinds, containing flow improver/super plasticizer as an important component. With silica fume (micro silica), it is possible to produce very special concrete with very high strength. Extremely dense and hard floors can be manufactured by so-called powder concrete [Lagerblad 2006]. Despite major improvements in concrete quality, the penetration of chemicals cannot completely be avoided, as some cracking always occurs in the concrete.

On the concrete surface, with acceptable macro-structure, is then applied a primer to ensure the adhesion between the concrete and the protective membrane or coating. Compatibility between primer and membrane is also very important. The primer is included along with the waterproofing in the waterproofing system to serve as protection for the concrete construction. Primer products are discussed in more detail in Chapter 5.

2.1.1 Degradation of concrete

Concrete structures are affected by the surrounding environment, and its resistance can be compromised by interaction with aggressive properties of the external environment. Examples of aggressive environments are, salt exposure in marine environments and salted roads, temperature changes (freezing/thawing) and exposure to various chemicals such as different acids. Environmental impact, however, could in some respects also be positive (mainly hydration of cement grains and self-healing of cracks and other defects) [Concrete Handbook 1994]. According to the Concrete Handbook, the largest durability problems in Sweden are frost attack and reinforcement corrosion. Reinforcement corrosion does not only reduce the concrete structure bearing capacity. Also, the concrete around the corroding reinforcement will rapture due to reinforcement increased volume (corrosion products require space). Furthermore, a number of other attacks that are considered of minor importance are listed: sulfate attack, sea water attack, salt attack, leaching and cement aggregate reaction. In Chapter 23 of the Handbook is a comprehensive overview and list of substances having a degrading effect on concrete. Regarding degrading effect by acids, this is usually based on pH value, and strong influence can be expected by acids with pH below 4. But not only the pH is important, but also the ability of aggressive ions to get around in the concrete matters.

Degradation of concrete can also occur in contact with hydrogen sulfide. Biological sulfide is formed during microbial degradation of organic matter, and can occur naturally in for instance groundwater. In organic waste, hydrogen sulfide is converted to sulfuric acid, among other things, in the presence of bacteria, fungi and mold in a damp environment. The sulfuric acid reacts with available lime (calcium hydroxide, calcium aluminates, etc.) in the concrete and new minerals such as ettringite and thaumasite are formed. These minerals are more porous and require a greater volume in the concrete resulting in cracking and disintegration. For sewer pipes made of concrete, this is considered especially problematic.

Concerning exposure classes related to environmental actions, according to EN 206-1, eighteen different classes within six different types of exposure are defined:

1. No risk of corrosion or attack (X0)
2. Corrosion induced by carbonation (XC1, XC2, XC3 and XC4)
3. Corrosion induced by chlorides other than for sea water (XD1, XD2 and XD3 (such as parts of bridges, pavements and car park slabs))
4. Corrosion induced by sea water (XS1, XS2 and XS3)
5. Freeze/thaw attack with or without de-icing agents (XF1, XF2, XF3 and XF4 (such as roads and bridge decks exposed to rain and freezing))
6. Chemical attack (XA1, XA2 and XA3)

Exposure 6 is related to chemical attack only in soil and ground water areas, at temperatures between 5 and 25 °C. Specified limit values for exposure class XA3 (ground water) are listed in Table 1 below. XA3 is described as highly aggressive chemical environment in the table (XA stands for chemical **A**ttack). The most onerous value for any single chemical characteristic determines the class.

Table 1: Limit values for exposure class XA3 (according to SS EN 206-1, Table 2)

Chemical characteristic	Limit values
Sulfate, $SO4^{2-}$ (mg/l)	> 3000 and ≤ 6000
pH-value	< 4,5 and ≥ 4,0
Carbon dioxide, CO_2 (mg/l)	> 100 up to saturation
Ammonium, NH^{4+} (mg/l)	> 60 and ≤ 100
Magnesium, Mg^{2+} (mg/l)	> 3000 up to saturation

Recommended limits for concrete composition and properties of concrete under different exposure classes are listed in EN 206-1, Appendix F. For XA3 is recommended: highest w/c 0.45, minimum compressive strength class C35/45, minimum cement content 360 kg/m^3 and sulfate resistant cement. As a complement to EN 206 is used in Sweden, however, SS 137003, which describes additional Swedish requirements and recommendations as required or permitted. (This includes the testing methodology and some Swedish applications.) The corresponding recommendation for limits in SS 137003 are: highest w/c 0.40, lowest cement content 200 kg/m^3 and strength class ≥ 42.5. Cement content is determined in each case, as well as maximum allowed amount of additives. For guidance on exposure classes, Concrete Report 11 is referred to.

In the pilot study of this project, chlorides, organic as well as inorganic acids, ammonia and ammonium ions were identified as aggressive to concrete [Boubitsa et al. 2010].

Examples of different areas of use for concrete in aggressive environment are bridges, garages and parking decks, animal stables and biological treatment plants. In bridge structures, the concrete is exposed to traffic (load, vibrations, mechanical impact, etc.) and climate (eg, large temperature variations), but also for a variety of degradation processes in the presence of water, road salt and air pollution. Degradation processes are of mechanical or chemical nature and result in concrete damage and reinforcement corrosion.

Garages and car parks belong to perhaps the most exposed type of concrete structures in terms of reinforcement corrosion [Johansson et al. 2010]. The corrosion is caused by chlorides from de-icing road salt carried in by cars entering the facility during the winter. During dry weather the water dries off, while the chlorides remain and chloride concentrations in the concrete thereby increase each season. For parking decks, abrasion and loss of adhesion are the biggest problems. Concrete damage in a garage may look like in Figure 2.

Figure 2. *Concrete damage in a garage*

In livestock buildings, concrete is the predominant flooring material. The concrete is also here damaged by mechanical abrasion and chemical attack. Mechanical wear and tear are caused by animal hooves and equipment for the removal of dung. The chemical attack partly comes from animal urine which is alkaline and will affect the cement binding of grains, and partly from some feeds, such as whey, which form acids [Sällvik 2005]. This calls for special engineering requirements for waterproofing, protection against rot and corrosion. The materials used must therefore be able to withstand mechanical impact and attack from chemically aggressive substances like urine, detergent, animal feed, lactic acid, etc. [Dolby et al. 1989].

Biological treatment plants for food waste is another example of concrete structures in need of special construction materials and technical specifications in order to avoid degradation of the concrete and reinforcement corrosion due to chemical attack. Leachate from waste food contains relatively high concentrations of various salts and organic acids (mainly acetic acid), and is generally quite acidic with a pH value around 4 [Boubitsa et al. 2010]. It is, as already mentioned, known that organic acids, such as acetic acid, have a strong corrosive effect on the cement paste in concrete. The leachate contains also other harmful components such as ammonium ions that can further damage the concrete. As for the temperatures expected in the leachate and substrate surfaces, it may be up to 70 °C in waste piles during the decomposition process. In Borlänge composting plant, an air temperature of 66 °C was measured two meters above the floor of one of the eight composting boxes. Recent temperature measurements in one of the boxes at Atleverken show maximum 52 °C. Three sensors were placed along the middle of the box (at ¼ of the length, in half and three quarters into the box). An approximately 15 cm thick layer of wood chips were then placed on the sensors, followed by compost, which had already been processed a few weeks in another box. The compost had on this occasion, a core temperature of 70 °C. At this compost plant, a layer of chips is used in the compost to ensure proper oxygenation in the compost. However, there are no chips under the food waste in the reception hall.

Box at Atleverken is shown in Figure 3.

Figure 3. *Box for a temperature recording at Atleverket*

In a recent Norwegian study on various kinds of material problems in Norwegian waste treatment plants, experience from six different plants was documented [Jentoft 2008]. The report includes descriptions of various microorganisms and their effects on the chemical environment of the plant. Damage, not only on concrete, but also on metal, bio-filters, air ducts, rubber components, electrical equipment, etc. is dealt with. For concrete and protective coatings on concrete, the following is concluded in the report:

- Experience with "acid resistant" concrete is good in composting boxes, and reception boxes for food waste should be built in "acid resistant" concrete;
- Stainless steel can withstand the environment in biological treatment plants, but is expensive;
- Asphalt concrete paved surfaces soften under load from collecting vehicles.

Some good experience of protective coating with fiberglass and epoxy is referenced to for one of the plants. Either acrylate, polyurea, polyurethane or asphalt is mentioned in the report.

As far as possible, it is important to avoid building structures with high humidity, high content of organic acids, and cold upper surfaces (roofs and walls). This can be achieved through more open composting plants, or compost plants where the air can be sucked out of compost piles.

3 Method

The project was carried out within the three sections described below.

3.1 Knowledge collection

Contacts were made with a wide range of manufacturers, experts and entrepreneurs concerning potential products for waterproofing/waterproofing systems on concrete in biological treatment plants. Current technologies are based on epoxy, polyurethane, polyurea, acrylate and/or bitumen (asphalt)-based materials. Review of the literature as well as specifications and methodology for similar applications are included. In particular, the study focuses on chemical resistance and wear resistance, which are considered to be unique for these plants. Test solution for chemical resistance was proposed.

A number of manufacturers were asked about appropriate protection systems in the light of the results of project Waste Refinery 27 (leachate, high temperature and possibly wear). Product data sheets were required. Eight different systems were recommended by five different manufacturers/experts (Nils Malmgren AB, Zel-Aaren, Elmico, Stirling Lloyd and The Hanson Group LLC).

3.2 Comparison of technical material properties

The material technical assessment/comparison referred to involves three systems used or considered for biological treatment plants in the recent past, but before the implementation of project Waste Refinery 27. The assessment is based on reported properties and testing according to the manufacturer, and compared with relevant corresponding testing and properties for similar types of waterproofing such as bridges. The intention has been to see how well it is possible to compare different products, for the same application, based on current specifications.

The comparison was carried out in collaboration with the respective product supplier (DAB Domiflex AB, Arma Coatings and Chesterton).

3.3 Proposal for a testing program

A draft test program/specification has been proposed. The program is designed in accordance with the corresponding specification for bridges, but adapted to the specific circumstances of biological treatment plants. In particular, this applies to the aggressive leachate environment, and where appropriate, wear.

4 Different types of waterproofing/protection coating on concrete

Knowledge of materials is required for all constructors, contractors and/or clients.

In this chapter, a number of different types of waterproofing material that may perform well as protection of the concrete in biological treatment plants are dealt with. The intention is to provide some knowledge regarding the performance, advantages and disadvantages for different applications. Products covered are epoxy, polyurethane, polyurea, acrylic and bitumen-based materials. For all technologies, so-called chemically resistant products exist on the market.

4.1 Epoxy products

The type of epoxy resin that is used today in a variety of areas, ie, epoxy resin of epichlorohydrin (diglycidyl ether) and bisphenol A, was first produced in the late 1930's. The honor for discovery is shared between the Swiss Dr. Pierre Castan and American Dr. SO Greenlee. The goal of the development of epoxy resins was originally to find a binder that could be used in coatings to make them resistant to alkali [Augustsson 2004].

4.1.1 Chemical and physical properties

Epoxy resin thus is produced from epichlorohydrin and bisphenol A, and the resin molecular weight (or rather, the average molecular weight) depends on the relationship between these two components. Figure 4 shows the final chemical reaction formula for the manufacture of epoxy.

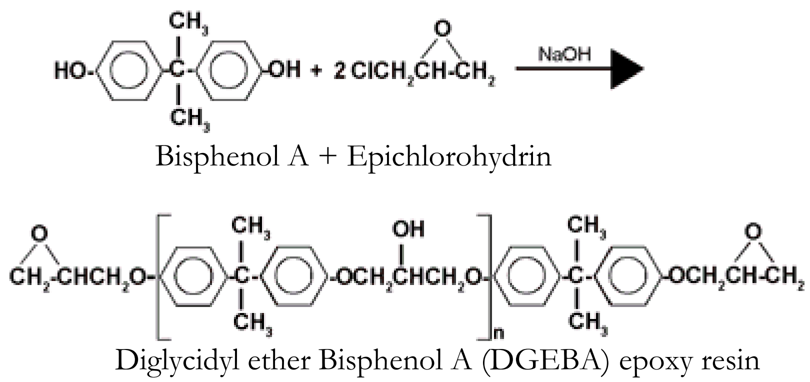


Figure 4. *Chemical formulas for production of epoxy resin [Augustsson 2004].*

Moreover, it is mainly the molecular weight that determines what the epoxy resin can be used for. Low molecular weight resins can be handled without the addition of solvents, and are primarily used for casting, thick coatings, etc. The higher molecular weight resins, however, normally are dissolved in organic solvent, and used for paint and varnish.

To convert the epoxy resin to epoxy, a suitable curing agent (hardener) is added. There are a number of such substances, but for hardening around room temperature, amines (especially di-and polyamines) or amides are used as a rule. The reaction between epoxy resin and hardener is an exothermic irreversible polyaddition, and the type of hardener is essential for the reaction rate, or so-called pot life of the product. As a rule of thumb, epoxy that cures at room temperature needs about 7 days at +20 °C in order to achieve maximum properties.

There are some fifty epoxy resins and hundreds of different hardeners which, in various combinations, can result in a very large number of epoxy products with various properties [Augustsson 2004]. Epoxy may additionally be modified by using a diluent (for lower viscosity). These can be non-reactive (such as xylene, toluene, alcohol, etc.) or reactive (containing one or more epoxy groups). There are, however, a number of risks associated with the addition of diluents. Primarily, this applies to non-reactive diluents which can cause severe blistering [Augustsson 2004]. Also, high-molecular isocyanates are used for modification of epoxy, as well as pigments (metal oxides) and filler.

Epoxy is perhaps best characterized by its ability to act as very strong glue to different types of surfaces. Other positive properties are water resistance, chemical resistance and excellent adhesion properties. The crack bridging ability, however, generally is small and usually is pointed out as a disadvantage for epoxy.

Unfortunately, epoxy is highly allergenic and skin contact should therefore be avoided and protection for hands, eyes, etc. used while handling. The risk for allergy when handling epoxy is due to molecular size. For epoxy resins with low molecular weight content, the risk is higher than for epoxy resins without low molecular weight content.

4.1.2 Use on concrete

Epoxy is often used as a coating on concrete floors in order to protect against dust and chemicals, and make the floor more "easy to work" in terms of cleaning. The simplest protection treatment consists of impregnating or sealing, and is carried out with low viscosity epoxy systems. Thin-layer coatings normally contain fillers, for increased durability, and can vary in thickness up to perhaps 1 mm. There are also self-leveling coatings, epoxy concrete, concrete, insulation, epoxy for bonding new concrete to old concrete, epoxy for repair and epoxy injection in concrete cracks. A typical self-leveling epoxy coating for floors, that must withstand high mechanical and chemical stress, should be at least 3 mm thick and consist of epoxy binder (35 %), quartz sand and pigments [Augustsson 2004]. Epoxy concrete contains less adhesive than epoxy coating, for avoiding any stresses in the boundary layer to concrete at temperature changes.

4.2 Polyurethane and polyurea

Urethane coatings can be chemically divided into three categories. These are polyurethane (PU), polyurea (PUA) and mixing combinations of these (PU PUA hybrids), all depending on type of isocyanate reaction. The systems can all be aliphatic, aromatic, or both aliphatic and aromatic. Pigments, fillers, solvents and/or additive can be added.

Polyurethanes are formed by polyaddition of di- or polyisocyanate with a di- or polyfunctional alcohol (polyol). Most polyurethanes are made from three starting components: long-chain polyols, diisocyanate and chain extender. Polyurethane made from these materials has a segmented structure, meaning a block co-polymer. There is a soft segment of polyols with weak forces in the chain, and there is a hard segment formed by the reaction of diols and diisocyanate. The hard segments have strong forces in the molecular chain, such as hydrogen bonds and dipoles, due to the large amount of polar groups. As for spray polyurethane products, the end result must not contain any urea groups. Catalysts are usually needed.

On the other hand, polyurea coating is obtained when the isocyanate reacts with polyamines. Isocyanates can be monomer baserad, consist of a so-called prepolymer, a polymer or a mixture thereof. Prepolymers may contain both amine and/or hydroxyl groups, whereas the second component (polyamine) may only contain amine groups. The A component is always the part that contains the isocyanate, and the B component is the amine-based part. A hybrid of polyurethane and polyurea in the same product is obtained by reaction between a polyisocyanate component and a blend component that can contain both hydroxyl and/or amine groups. One or more catalysts are also included.

Figure 5 shows the chemical formulas for polyurethane and polyurea. Polyurethanes, however, are of limited use as waterproofing due to its moisture sensitivity, and should not be used if the moisture content of the substrate exceeds 5 % and/or in wet weather [Broekaert 2002, 2004]. In the following sections only polyurea are therefore discussed.

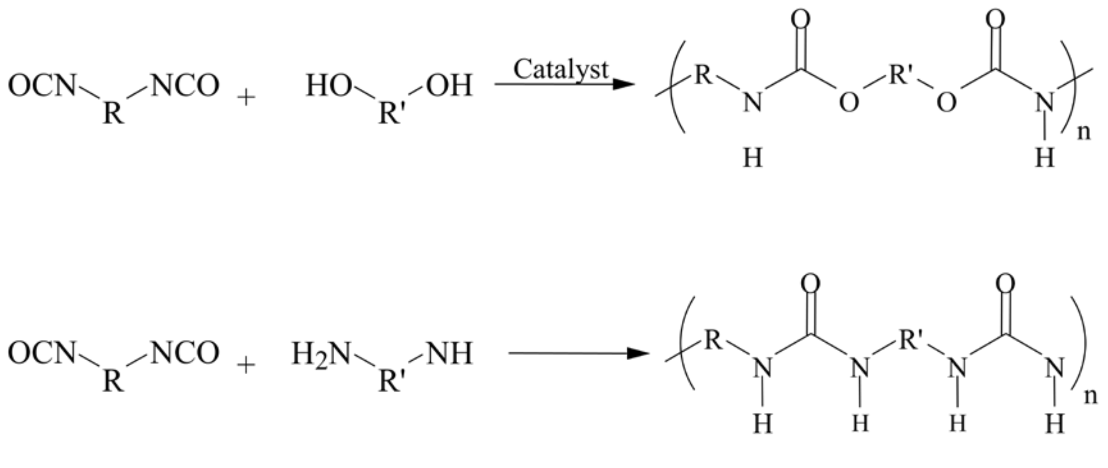


Figure 5. *Chemical formulas for production of polyurethane (top) and polyurea (bottom)*

Polyurea spray technology was introduced in the late 1980's and first used commercially in 1988 [Flanagan et al. 2010]. Initially, polyurea was used as protective layer on polyurethane insulation foam for roofs, but later mainly for injection (RIM, which stands for Reaction Injection Moulding) and spray coating [Broekaert 2002, 2004]. PDA (Polyurea Development Association) is the polyurea industry's trade association representing polyurea industry worldwide. It was formed in 2000. Its counterpart in Europe is called PDAE and was registered in June 2007 [Hohberg 2009].

The cost of polyure systems has been seen as a problem because raw material prices are high, and expensive initial investment in equipment also required [Broekaert 2004]. An example of use in Sweden is the new Botnia railway.

4.2.1 Chemical and physical properties

As already mentioned, polyurea is the result of a reaction between isocyanate and polyamine. Standard products of polyurea generally are expressed as tough and flexible, with a high melting point and good resistance to degradation of various types, chemical attack and oxidation. However, acid resistance is sometimes listed as a weakness for polyurea [Scott 2010]. The product cures rapidly even at very low temperatures, and are not moisture sensitive. As reactive diluents for polyurea, propylene carbonate can be added, however not if water is present [Broekaert 2002, 2004].

Typical physical properties that can be expected for a polyurea product according to specification are listed in Table 2.

Table 2: Typical physical properties for polyurea according to specification [Broekaert 2004]

Property	Specification	Result
Gel time (s)		1-20
Tack free time (s)		3-120
Hardness, Shore A	DIN 53505	50-100
Hardness, Shore D	DIN 53505	10-75
Tensile strength (N/mm^2)	DIN 53504	10-30
Elongation (%)	DIN 53504	20-800
Angle tear (N/mm)	DIN 53515	50-125
Trouser tear (N/mm)	DIN 53507	20-60
Abrasion (mg)	ASTM D4060-90	150-500
Cold impact resistance (kJ/m^2)	ISO 180	50-100 at -20 °C
Flexural bending modulus (N/mm^2)	ASTM D790	50-600

Raw materials that affect polyurea properties are:

- type of isocyanate (MDI, TDI, HDI, IPDI)
- type of amine (polyether amines, primary diamines, secondary diamines)
- chain extenders
- additives (UV stabilizers, flow aids, pigments)

An isocyanate is a molecule equipped with a functional, ie reactive, group consisting of nitrogen, carbon and oxygen (NCO). This group reacts with other molecules such as amines, water, hydroxyl and carboxyl groups. Isocyanates can, as already mentioned earlier in this chapter, be aromatic or aliphatic, and are mostly already partly reacted. Aromatic isocyanates are generally cheaper and more versatile. Aliphatic isocyanates are used for UV stability, but are more expensive, react more slowly and are potentially more toxic than the aromatic isocyanates. The most common isocyanate is MDI (diphenylmethane diisocyanate) which is aromatic and used in standard products of polyurea. The NCO content varies depending on desired characteristics of the end product (such as viscosity). Isocyanate type TDI (toluene diisocyanate) products are also aromatic, while the HDI (hexamethylene diisocyanate) and IPDI (isophorone diisocyanate) are aliphatic. Figure 6 shows the various types of isocyanate.

Concerning different types of amines, polyether amines are used for elongation and softness, and secondary amines used for longer gel time, better adhesion and flow [Hanson 2010]. DETDA (diethyl toluenediamine) is the standard chain extender used in aromatic polyurea spray coatings. The chain extender contributes to the stiffness and heat resistance of cured polyurea coatings. In addition, there are a great number of chain extenders for different needs and special products.

The mixing process is of utmost importance for spray applied polyurea. Since the mixing time is short and the curing speed very high, mixing must be carried out under pressure (between 150 and 250 bar), and the viscosity must be low enough (below 100 mPa s) at application temperature [Broekaert 2002, 2004]. The development of application equipment for polyurea is continuously evolving and there are a number of different machines depending on type of application. Skilled personnel wearing adequate protective equipment is a must in this context [Hearon 2010].

For further information on polyurea, a State of the Art report is referred to [Hohberg 2009].

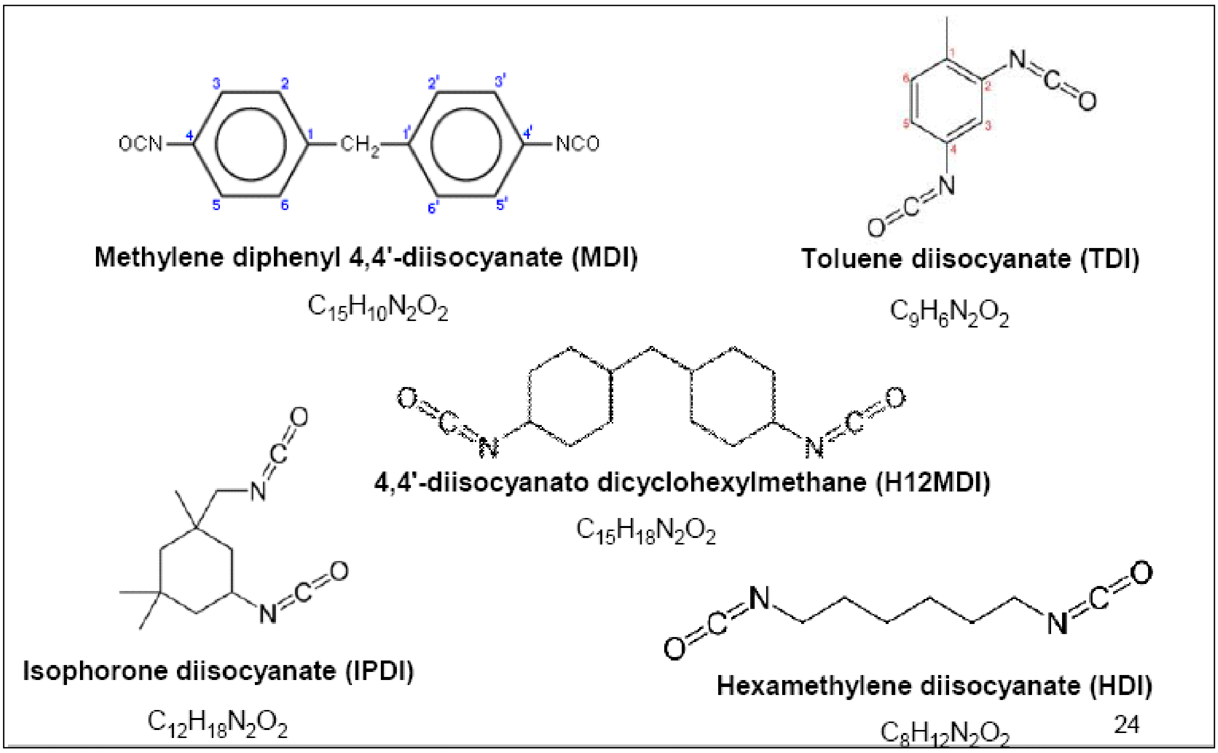


Figure 6. *Different types of isocyanate building blocks [Dries 2010]*

4.2.2 Use on concrete

Suitable primer products under polyurea on dry concrete could be acrylic, epoxy or polyurethane, while acrylate-based primer has shown to work best on damp concrete [Broekaert 2004].

4.3 Acrylate based products

One use of methyl methacrylate (MMA) is for surface protection and impregnation of various kinds when color stability, wear resistance and fast curing time is of great importance. MMA was first produced in the mid 1930's with the help of technology using acetone and hydrogen cyanide. Today, there are also a number of less difficult MMA processes. For instance, MMA can be produced from methyl propionate and formaldehyde or from ethylene, methanol and carbon monoxide. Maximum use is still to polymethyl methacrylate (PMMA, product name Plexiglas). Another major application is in house paint.

4.3.1 Chemical and physical properties

MMA is a colorless, volatile and flammable liquid with a strong odor that can be very irritating to the eyes, nose and throat. The chemical formula of this monomer is:

$CH_2{=}C(CH_3)COOCH_3$

Advantages for the product include: high abrasion resistance, fast curing and excellent color stability. Weaker sides usually considered are: strong smell, sensitivity to high temperatures and humidity and the risk of shrink stresses.

The MMA product cures by the addition of a peroxide, which induces a so-called radical reaction. In pure form, the acrylate then forms only carbon dioxide and water.

Elastic acrylates can contain polyurethane as an additive. The curing time is short but the reaction can be inhibited by moisture and air. Since the flash point is low (below 23 °C), the product is considered flammable during application. Heating and flame must therefore be completely avoided.

4.3.2 Use on concrete

Suitable primer product for MMA coatings are usually MMA. Recommended application temperature can vary between 0 and 50 °C.

4.4 Bitumen based products

In this chapter, two types of bitumen based waterproofing products are dealt with, bitumen sheets and mastic asphalt. For concrete bridges and parking decks in Sweden, mainly polymer modified products are used, ie, the bituminous binder (bitumen) forming part of the products is modified with polymers, usually of SBS (Styrene Butadiene Styrene) type. The waterproofing can be covered with an asphalt concrete layer. Different types of binder and wearing courses are selected, depending on traffic load.

Bitumen is described very briefly in the section below.

4.4.1 Bitumen

Bitumen is the black adhesive that binds flexible pavements on roads and airfields together. Bitumen is also used in other areas of application such as waterproofing, flooring and joint materials. Almost all bitumen is produced from crude oil. Depending on the age and origin of the crude oil its composition may vary, and not all crude oils are suitable for bitumen production. The heavy crude oils usually contain a lot of bitumen, while light crude oils contain a lot of fuel. Naphthenic-based crude oils generally provide a high yield of bitumen, often of good quality. Figure 7 shows the different types of crude oil.

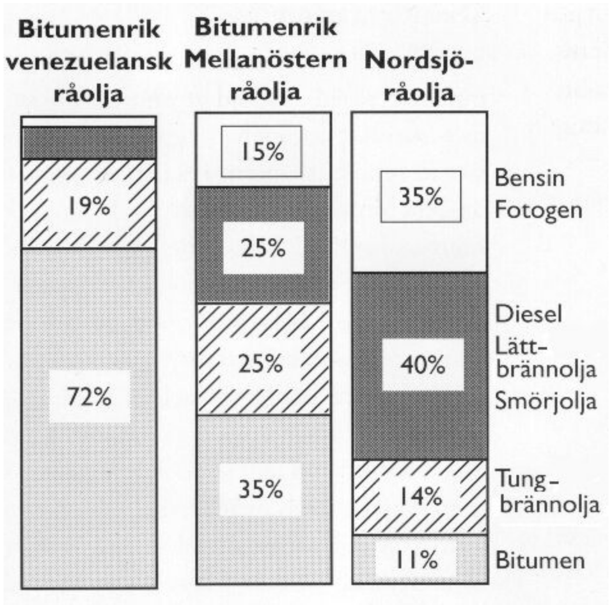


Figure 7. *Different types of crude oil (in Swedish)*

From a chemical point of view, bitumen is a highly complex system consisting of mainly carbon and hydrogen (90-95 %). The remaining 5-10 % consists of heteroatoms (nitrogen, oxygen and sulfur). Traces of metals (vanadium, nickel, iron, magnesium and calcium) also occur in the form of eg inorganic salts and oxides. Quantity and type of heteroatoms in bitumen reflect the original crude oil (oils) as well as bitumen ageing status. Hetero atoms (especially sulfur) play an important role in bitumen ageing, as they are more chemically reactive than the remaining hydrocarbons. Functional groups such as $C = O$ (carbonyl), $S = O$ (sulfonyl), $N - H$ (amide) and COOR (carboxyl) are part of the bitumen molecular system.

Bitumen does not react chemically with water at room temperature, however, absorbs very small amounts of water (0.001 to 0.01 wt %). This is probably caused by small amounts of water soluble inorganic salts or fillers in the material. Plain bitumen is also resistant to mild chemicals, but reacts with aggressive chemicals such as concentrated sulfuric acid, nitric acid and hydrochloric acid. Diluted acids can sometimes cause hardening of the bitumen, while diluted bases, sometimes cause emulsification of bitumen as a result of the reaction with naphthenic acids. Elemental sulfur reacts with bitumen at higher temperatures (above 150 °C) during the formation of hydrogen sulfide. In contrast, sulfur bound in bitumen molecules are so tightly bound that much higher temperatures are required for hydrogen sulfide to be formed (more than 280 °C). Bitumen is completely soluble in some aromatic and chlorinated solvents such as toluene and methylene chloride. Most commonly, however, bitumen is only partially soluble as is the case with most organic solvents. Bitumen is insoluble in water, formamide, glycerin and diethylene glycol. Sensitivity to organic solvents may be of great practical importance in the case bitumen is exposed to such spillage of fuel or oil from vehicles or aircraft. Chemical resistance of bituminous pavement materials (eg mastic asphalt) can be improved considerably by polymer modified binder, acid resistant aggregate and protective granules on the top surface of the pavement. Bituminous pavement coatings shall not normally be protected with thermosetting plastics as polyurea or polyurethane as the risk of adhesion loss between the materials is great.

4.4.2 Waterproofing sheet and mastic asphalt

The waterproofing flexible sheet usually consists of a core/reinforcement with polymer bitumen on both sides. The reinforcement is often made of polyester and impregnated with impregnating bitumen. According to the Transport Administration requirements specification (see Chapter 7), the reinforcement may be placed in the upper part of the sheet, because the sheet is torch-welded to the concrete surface. The polymer bitumen often contains filler for better stability. Figure 8 shows the torch-welding application of a waterproofing sheet system on a concrete bridge deck (the Öresund Bridge).

Waterproofing with mastic asphalt consists, according to Swedish specifications, of polymer modified bitumen, filler, and sand, and is applied 10 mm thick on gas ventilating glass fiber net.

For bridges and parking decks, the sheet or mastic asphalt is covered with coarse aggregate mastic asphalt or asphalt concrete.

Figure 8. Torch-welding of bitumen sheet

4.4.3 Use on concrete

Sealing with epoxy has been recommended as the safest way to avoid blistering in connection with the application of bituminous waterproofing systems on concrete. The Transport Administration recommends, however, today primer treatment with diffusion tight primer. MMA (methyl methacrylate) is preferred to epoxy.

5 About pretreatment of concrete surfaces

The importance of a good concrete surface for the application of a waterproofing or waterproofing system can not be overemphasized. The adhesion to concrete can never be better than its own surface tensile strength, and pretreatment work is therefore crucial. Pretreatment includes cleaning. All contaminants (such as dust, oil, grease and chemicals) must be removed as well as any laitance and curing membrane. This may be accomplished by grinding, milling and/or blasting. Vacuuming or water flushing may be necessary to get a really clean concrete surface with a good possibility for a primer product to penetrate the concrete. In some cases, washing with diluted hydrochloric acid may be used to remove laitance, but this is a risky process that requires great accuracy in several respects. Also repairing damage in the concrete is problematic and must be performed with great precision and appropriate repair products. One way could be by using a specially composed epoxy and new repair concrete product.

The concrete surface must also be strong enough for the waterproofing coating, so that not any tensions that may arise at the interface between coating and concrete give rise to adhesion loss, and the coating thus becomes detached from the concrete. Surface tensile strength of the concrete shall be determined on site.

Surface temperature and moisture conditions are other important factors to consider for achieving good results. The surface temperature can often be crucial to the curing time of a thermoset material. In the case of primer products, epoxy usually is most sensitive to temperature and acrylates least sensitive. To avoid the risk of moisture forming on a concrete surface during outdoors work, the surface temperature should be at least 3 °C above the dew point (the temperature at which air is saturated with moisture and moisture thus condenses as water).

To provide a concrete surface with a protective coating in many cases can be expensive and it is therefore important to get it right from the start.

5.1 Why primer?

Concrete shall normally always be primed/sealed before protection coating of any kind can be installed. The treatment is performed to increase adhesion between the concrete surface and coating. The primer is expected to penetrate into the concrete and wet the surface (low viscosity), have a certain moisture-resistant and dust-binding effect, and possibly also be able to reduce blistering in the application process [Abbott 2010]. Primer and protective coating must be compatible and form a fully tested system depending on type of object and application.

There are a number of different types of primer products for protective treatment of concrete, such as epoxy, urethane primer and acrylate based primer. Also bitumen based primer products are used for bituminous waterproofing systems.

Epoxy primer is usually a two-component system. The primer product may be solvent free, contain solvent or be water emulsified. There are advantages and drawbacks for all variants. Generally, in the case epoxy, however, the curing time is strongly dependent on temperature which should be at least about 10 °C. For water dispersed epoxy, carbonation is usually not a problem, but the curing time can be long and the treatment may have to be repeated several times. If epoxy is used in combination with a coating layer of polyurea, the epoxy is often formulated so that it is chemically reactive with polyurea, in order to increase adhesion [Abbott 2010].

Urethane primer may consist of one or two components and, like epoxy, be solvent free, contain solvents or be water emulsified. The primer cures, unlike epoxy, well even at low temperatures, but is still heavily dependent on both moisture and temperature.

Acrylate primer consists of one component and can be either solvent or water based. It dries very quickly but usually has lower adhesion than epoxy as well as urethane primer. It is less expensive than epoxy or urethane.

Bitumen primer has long been used in combination with bituminous sheets or mastic asphalt. Bitumen primers are usually composed of polymer modified bitumen, solvent and adhesives. The primer has recently been criticized by the National Road Administration (now Transport Administration) in connection with blistering problems on bridges. A bitumen primer may indeed be chemically compatible with a bituminous waterproofing coating system, but problems can occur anyway [Edwards 2010].

6 Products proposed by manufacturers

This chapter briefly describes a number of products/coating systems that, on request from the project, were proposed by the industry for use in food waste plants. The proposed systems were selected by the manufacturer with knowledge of the results and analysis reported in the pilote study [Boubitsa 2010]. Product data were requested and are attached to this report.

In each case, the manufacturer recommends specific testing in leachate water before use in these plants.

6.1 Epoxy systems

6.1.1 Epoxy - NM Silo 556

The system is a so-called NM Tank System which is used for protection of concrete in for instance tanks for pig feed.

The following is proposed for food waste plants [Augustsson 2010]:

- Primer treatment with NM Primer Super BP50 in three layers. The primer is reported diffusion open (and is not sand treated). Alternatively, a water-free product can be developed.
- Epoxy coating, NM Shiloh 556/H40.
- Reinforcement of glass fiber net to prevent cracking. For the floor, the use of two layers of glass fibre net is recommended.
- Epoxy coating, NM Shiloh 556/H40 in an additional layer.

After curing, the system should be checked for the appearance of pores. If the number of detected pores exceeds a certain number, an additional layer of epoxy is applied. Local additions can also be made.

The hardener H40 is reported to be aliphatic and cycloaliphatic. It replaces an earlier used hardener containing aromatics (Diamino Diphenyl Methane, DDM). With DDM as curing agent, epoxies are more resistant than with the current hardener. But DDM was abondoned because of labeling problems, as it is considered more dangerous. It may however be used also in the future for specific cases, but then special permission is required.

Product data sheets are in Appendix A.

6.1.2 Epoxiy- Con Seal

Con-Seal is a system that, among other things, is used to protect the concrete slab facilities for parking of aircrafts (refueling and charging). For example, the product is used at Kallax F21 and Arlanda airports for the protection against the de-icing chemicals used there. The system is also recommended for food waste plants [Linde 2010].

Product data sheet is in Annex B.

6.1.3 Epoxy polysulphide – Permare EP

Permare EP is a two-component system with high wear resistance and good resistance to different types of chemicals. Ratings after exposure in a number of chemicals (short time at room temperature) are given for the product. However, acetic acid is not part of the chemicals used. The product is proposed by Stirling Lloyd.

Product data sheets are in Appendix C.

6.2 Polyurea system

6.2.1 Micorea S3

The system is a polyurea standard system which, among other things, was used for railway bridges along the Bothnia railway line in Sweden.

For food waste plants, the following is proposed [Michelson 2010]:

- Primer treatment with Micopox P plus treatment with dry clean sand, 0.4 to 0.8 mm.
- Polyurea layer of Micorea S3, 3-4 mm, depending on wear.

The polyurea is applied using special equipment, and it is very important that the coating is free of pores. Micorea is considered to be a highly elastic membrane.

Product data sheets and job descriptions are in Appendix D.

6.3 Acrylate systems

A total of four systems based on MMA-technology were proposed by Stirling Lloyd [Birley 2010]. These are Safetrack SC Decseal, Safetrack HW and Bridge Master. Chemical resistance to acid attack is not addressed in the respective product data sheet. Generally, however, Stirling Lloyd methyl methacrylate products (according to testing by the manufacturer) provide excellent protection against spills and leaks of acids and bases. When tested, the test specimens are stored four weeks at 23 °C in each medium, after which the tensile strength is tested and compared against the original value. The tensile strength may not differ by more than 20 %. According to this test, methyl methacrylate coatings are partially resistant to 10 % formic acid (but not resistant to 30 % formic acid), and resistant to 10 % acetic acid (and partially resistant to 30 % acetic acid). Product data sheets are in Appendix E.

6.3.1 Safetrack SC and Safetrack HW

Safetrack SC is a fast-curing three component system with high wear resistance and good friction properties. The system is used for paving car parks, footpaths and cycleways. The product is described as being resistant to motor oil, diesel fuel and deicing chemicals. The effect of acid is not mentioned among product properties.

Safetrack HW includes aggregates, and the wear resistance is higher than for Safetrack SC. It is also used for high-traffic pavements.

6.3.2 Decseal

Decseal is a combined waterproofing and pavement systems, intended for applications such as parking decks and bridges. A wearing course (Decseal Wearing Course) may also be included.

6.3.3 Bridge master

The system is applied in one layer including sand treatment and sealing. The thickness is adjusted depending on traffic load, from foot traffic to vehicular traffic. Chemical resistance is not included among the reported properties.

6.4 Bitumen based systems

Among bitumen based systems, GAFS (the Swedish mastic asphalt association) recommends waterproofing sheet with coarse aggregate mastic asphalt (PGJA) for floor application [Kinnmark 2010]:

- Primer treatment with a suitable epoxy or MMA primer
- Torch-welded waterproofing sheet (5 mm) according to Transport Administration specification for concrete bridges, VVTBT (see Section 7.1)
- Polymer modified coarse aggregate mastic asphalt with acid-resistant aggregates

The waterproofing sheet is sealed against the wall surface using a thixotropic epoxy sealing product that meets the requirements according to VVTBT (Annex B, Tables 1-3 and 5).

Product data sheet for acid-resistant coarse aggregate mastic asphalt is available in Appendix F.

6.5 Other systems

In connection with the PDA Conference in Orlando in spring 2010, and discussions there about suitable products for food waste plants, the proposed product described in the next section was added to the report.

In connection with the PDAE conference in Sitges, later that year, came other proposals of polyurea products. These are not discussed in this report.

6.5.1 Warrior 260

The product is considered to belong to the next generation of phenolic-based products, and is described as being extremely chemically resistant and durable. The product is compared in the product data sheet (Annex G), with a typical polyurea. The product has been used for many years and is patented. The technology is owned by The Hanson Group LLC, and manufacturing takes place in Georgia, USA.

7 Specifications and requirements for protection coatings on concrete

There are a series of European standards relating to products and systems for the protection and repair of concrete structures (EN 1504, Part 1-10). In one of the parts (EN 1504-9), general principles for selection of products and systems are dealt with. For protection against chemical treatment (Principle 6 of the standard), EN 1504-2 Surface protection systems for concrete is referred to. In EN 1504-2, a variety of standards for characterization of different types of systems are referred to, many of which can be attributed to production control. However, there are also various traffic load classes, as well as different classes of vapor permeability, adhesion, crack bridging ability and impact resistance. For chemical resistance, EN 13 529 is referred to and for wear resistance the Taber abraser, according to SS EN ISO 5470-1 for coatings. The chemical resistance and wear are discussed in more detail in Section 7.4 and 7.5.

There are also a number of specifications for waterproofing and/or protective coating on concrete in various more specific areas of use. Relevant specifications available in this context concern waterproofing for road bridges and railway bridges. Specifications for parking deck is missing in the strict sense, but bituminous systems similar to those for bridges can be used.

7.1 Specifications for Swedish road bridges

In the former SRA, mainly two types of waterproofing were used on concrete bridges, namely polymer modified mastic asphalt and polymer bitumen sheets. In a system with polymer modified coarse aggregate mastic asphalt (PGJA) on mastic asphalt or sheet, also the PGJA is included as waterproofing.

According to VVTBT Waterproofing of bridges 2009 (previously BRO 2004), a mastic asphalt waterproofing system consists of a 10 mm thick layer of polymer modified mastic asphalt on gas ventilating glass fiber net. Requirements regarding composition and design of the mastic asphalt are given. The mastic asphalt shall conform to EN 12970 (which, however, faces revision and harmonization). Problems with waterproofing by mastic asphalt may occur if the glass fiber net is embedded in the mastic asphalt or if gas outflows are tight and therefore do not have the intended ventilating effect.

For a sheet waterproofing system, the sheet shall consist of a reinforcing core with polymer bitumen on both sides. Requirements regarding composition and properties are given. Polymer modified bituminous sheets and related specifications were introduced in Sweden with Bronorm 88, as a result of an extensive research project between the National Road Administration and VTI (National Road and Transport Research Institute) during 1985-1988. All of SRA currently accepted sheets are high quality 5 mm thick SBS-modified bituminous sheets that are torch-welded in one layer to the primed surface. Problems with blistering may occur between sheet and concrete. Concrete quality, large variations in vapor pressure in the concrete just below the waterproofing, the weather situation, and application quality are all parameters of importance and impact on the formation of blisters between the waterproofing and concrete. The primer is of critical importance (see Chapter 5). According to BRO 2004, pre-treatment of concrete was carried out using a bituminous primer. Sealing with epoxy in two layers provides significantly less risk of blistering, but has recently been abandoned because of health and environmental reasons. Starting in April 2010, a methyl methacrylate primer shall be used in contracts containing performance agreements.

Liquid-applied waterproofing systems are not normally used on road bridges of concrete in Sweden. This is based partly on the negative experience from test sites (such as one spray-applied polyurethane system that was used on SJ-bridge F529 at Sävsjö in 1988 [Colldin 1990]), but also to the fact that no relevant technical specifications exist (like the one used for waterproofing sheets). For the test bridge mentioned above, severe blistering occurred due to water absorption in the polyurethane layer. Furthermore, the measured thickness varied significantly and so did adhesion values.

On steel bridge decks, however, epoxy, acrylate, or sheet waterproofing systems can be used. No actual specifications exist for acrylate polyurethane or polyurea based products.

7.2 Specifications for Swedish railway bridges

The technical specification for spray applied waterproofing systems on railway bridges, used by the former Railway Administration, was for many years only formulated in general terms about a number of functional requirements that should be met through testing according to "acceptable" methods, making it difficult to evaluate the suitability of different products. Different test methods could therefore be used by manufacturers of various systems, and reported test results were generally not directly comparable.

A new specification was formulated later on, containing essentially the same functional requirements. For liquid/spray-applied systems, a completely new specification was developed, while the SRA requirements specifications were applied for other types of waterproofing on railway bridges. The new specification for liquid applied elastic waterproofing systems was included as Appendix 6-1 BV of BV Bro, edition 9.

In the new Transport Administration, specifications for road bridges and rail bridges will be coordinated.

7.3 ETAG 033

Both CEN (Comité Européen de Normalisation) and EOTA (European Organisation for Technical Approvals) are involved in efforts to harmonize specifications and testing methods in the field of bridge deck waterproofing on concrete. A so-called ETA (European Technical Approval) can be developed for a given product if no relevant harmonized EN standard exists or is planned for the product in question. The difference between EOTA and CEN, regarding waterproofing of bridges, is that EOTA treats liquid systems while CEN deals with sheet systems.

ETAG 033 is such a framework/guideline which was drafted by EOTA for liquid systems that are sprayed or spread onto the bridge deck, in one or more layers, providing a continuous watertight membrane. Normally, the waterproofing membrane is not expected to be subjected to direct traffic or ballast. The guidelines are based on relevant existing knowledge and testing experience for this type of product. Existing EN methods from CEN TC 254 WG6 (Flexible sheets for waterproofing of concrete bridge decks and other concrete surfaces trafficable by vehicles) are used to the greatest possible extent, but other EN - or ISO methods have been included. A number of technical reports (EOTA TR) were prepared as a support and reference documents to the guidelines. The waterproofing service life adopted by EOTA is at least 25 years, based on what we know today, but can be much longer.

A seventh draft of ETAG 033 has been circulated for comments and was recently established.

Systems used under ballast are not included, although the systems may include protective layers, reinforcement (such as fabrics) and other essential products (e.g. priming coats, tack coats). Kits considered relevant in this context are based on one or more of the following chemistries:

- Acrylics
- Epoxies
- Polyesters
- Polyureas
- Polyurethanes

The systems are divided into three different categories of use:

- A, with overlay of bituminous pavement layer (three kinds) or a non-bituminous layer, and in all cases intended for vehicular traffic;
- B, Without overlay (exposed) and intended to receive only pedestrian or cycle traffic
- C, Without overlay (exposed) and un-trafficked (including special case of un-ballasted rail bridges.

The range of operational temperatures of the waterproofing layer during use is -40°C to +60°C.

Concerning the risk of slipperiness, EN 13036-4 (friction pendulum) is referred to, but for wear resistance no specific test method is mentioned.

For chemical resistance to oil, gasoline, diesel fuel, deicing, etc., the manufacturer must simply declare that the system retains its properties after exposure.

Overall, this Guideline is very general and is therefore somewhat difficult to use.

7.4 Chemical resistance

The most chemically aggressive environments for concrete floors are in the food, beverage and pharmaceutical industries [Bayne 2006]. Biological treatment plants may also fall into this category of very chemically aggressive environments where special protection of concrete is required. In order to specify the right type of product(s) for these environments, exposure conditions clearly must be given careful consideration. For biological treatment plants, the worst chemical exposure is that of the aggressive leachate at temperatures up to 70 °C. The leachate from Swedish plants has, as mentioned earlier, low pH value and contains relatively high concentrations of various salts and organic acids (mainly acetic acid). In a specification for products to be used for protection of concrete against leachate water from food waste, it should be clear that the protection must be chemically resistant to leachate in particular, and how this is tested and evaluated.

7.4.1 Requirements and test methods

Resistance to chemical attack may, depending on the type of material, be determined in different ways. For waterproofing of thermoset products, testing of chemical resistance as a rule, means immersing test specimens in the test medium at room temperature for a defined period. After immersion, the test specimens are inspected visually or tested with respect to properties such as change in hardness. (cf. Section 6.3.)

There is a need to develop performance related criteria for evaluation of protective coatings on concrete, and guidelines/rules for the selection of coatings suitable for various exposure conditions [Aguiar et al. 2008]. The following sections discuss the method according to EN 13 529 for protective treatment of concrete.

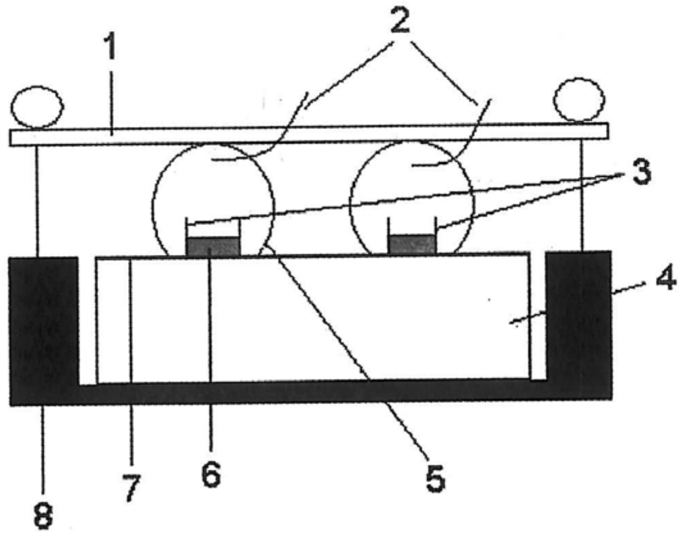
SS-EN 13529

The method is for products and systems for the protection and repair of concrete structures. Specified test slabs of concrete are provided with protective coating and exposed locally to the testing liquid for a certain period (typically 1-90 days depending on the field of application, specified in EN 1504-2). After exposure, the test surface is examined for blistering, peeling, cracking, optical changes, and (if possible) also hardness and adhesion. Finally penetration of the testing liquid through the protective layer is examined. A long series of test liquids are listed in an annex. For corrosion resistance to the group of organic acids (except formic acid), a mixture of acetic acid and propionic acid (50/50) is suggested. The test can be performed with or without pressure (1 bar).

In a recent comparative study, testing according to EN 13529, with sulfuric acid and ammonium hydroxide (20 % in both cases), were used for the evaluation of epoxy resin coatings and acrylic coatings on concrete. The storage time was 28 days. The sulfuric acid was found to cause severe blistering of both systems, as well as a lot of cracking of the epoxy system. The acrylic based system came off, unlike the epoxy system, entirely from the surface. The study concluded that sulfuric acid has a significant impact on both types of systems, but the ammonium hydroxide effect is negligible [Aguiar 2008].

EN 1504-2 specifies three different classes with respect to chemical resistance. The exposure is carried out according to EN 13529, using relevant liquids (or as agreed between parties). For Class III (best class) the exposure is carried out for 28 days under pressure. The hardness is determined before and after testing, either in accordance with EN ISO 2815 (Buchholz method) or according to EN ISO 868 (Shore). Measured hardness, after the exposure, shall be at least 50 % of the original value. A sketch of the test set is shown in Figure 9.

Examples of other tests of chemical resistance are: EN 2812 (for paint and varnish) and SS 923 518 (for floor coverings). These are, however, less suitable for biological treatment plants.



1 : fixation base (used in pressure test);
2 : air compressed tube (pressure test);
3 : bonded tubes;
4 : concrete specimen;
5 : chamber (pressure test);
6 : test liquid;
7 : painting;

Figure 9. *Sketch of test equipment according to SS EN 13529*

7.5 Wear resistance/abrasion

Abrasion with Taber Abraser is included in a long series of standards for many different types of materials. Different loads, wheel types and number of cycles/rotations can be used. For reasonably durable coating layers of thermoset materials, the test is normally carried out with wheel type CS-17, load 1000 g and 1000 rotations. The result is expressed in mg per total number of cycles. Using these parameters, the test is described as medium to high and designed to simulate some traffic load. No tearing or scraping impact is included. Wheel type C-10 provides less impact and H-22 considerably higher (used for rubber, linoleum, leather etc.), according to specification of the wheels. The equipment is shown in Figure 10 below.

According to specification in EN 1504-2 (Table 5 - Performance requirements for coatings), testing is carried out according to EN ISO 5470-1 (Taber test) and the wear shall be less than 3,000 mg using wheel type H-22, 1000 cycles and 1000 grams of load. Also testing according to EN 13 813, which deals with properties and requirements for flooring, however, is accepted. Three different methods for wear resistance (EN 13892-3, EN 13892-4 and EN 13892-5) are included in EN 13813. These are considerably more aggressive than the Taber test. For example, a steel wheel load of 2000 N is used in EN 13892-5. Flooring materials are divided into different classes depending on wear and selected methodology.

Figure 10. Taber Abraser

Tougher testing for the simulation of studded tires are used for road surfaces (cf. Section 8.4).

8 Technical assessment of materials

An attempt was made to technically evaluate three different membrane systems used or considered for biological treatment plants in Sweden in recent years. The intended use of the systems was primarily as protective coating on floors in plants with certain traffic.

Selected systems are:

- Matacryl, acrylate based coating from DAB www.dab-domiflex.com
- MS 901, polyurea from Arma coatings www.armacoatings.com
- FCS 304, epoxy coating from Chesterton www.chesterton.com

Physical material properties of the products/systems are reported in Table 3A.

The assessment was based on reported properties and testing according to the manufacturer's product data sheet. Reported properties are compared against relevant corresponding tests and specifications (and additional information on request) for similar types of waterproofing for concrete to other types of concrete structures. The comparison is based, as far as possible, on the following materials and functional characteristics:

- Thickness
- Watertightness, water absorption
- Resistance to water, oil, leachate/chemicals, alkali, UV (if the waterproofing is exposed to sunlight)
- Compatibility with bitumen (if the waterproofing will be combined with a bituminous upper layer)
- Corrosivity to steel
- Tensile bond to concrete surface
- Elasticity /tensile strength and elongation
- Low temperature performance, crack bridging ability
- Resistance to impact/dynamic impact and wear. Hardness
- Hardening
- Resistance to high temperatures (depending on type of plant and if the waterproofing will be covered with eg coarse aggregate mastic asphalt having an application temperature of approximately 200 °C or more). Expected service temperatures?
- Resistance to flow at higher temperatures (if the waterproofing will be applied on not horizontal surfaces)
- Resistance to ageing, properties not changed
- Harmful to humans and the environment
- Risk of slipping
- Application
- References(objects)

Tear resistance has not been taken in to account.

A similar evaluation of coating systems including bitumen-based waterproofing sheet and coarse aggregate mastic asphalt is also included in this chapter.

Table 3A: List of material characteristics for surface protection in biological treatment plants. Given by the producer.

Properties **Testing**	**Matacryl** **DAB, Domiflex AB**	**MS 901** **Arma coatings**	**FCS 304** **Chesterton**
Thickness	Membrane 2-5 mm in two layers Wearing layer 3-7 mm	3-5 mm in one layer, depending on wear	Applied in one layer, from 6 mm Can be covered with another layer (ie FCS 201)
Watertightness	ETAG 005 TR 003 EOTA (0.1 bar 24 h, tight) EN 1928 B (3 bar 24 h, tight) Neg. Water pressure (2.5 bar, tight, full adhesion) testing on 2-3 mm	Reported to be watertight	Watertight from experience
Resistance to water, oil, leachate/ chemicals, alkali, UV	Reported to be highly chemical resistant Testing is missing	Methodology missing Absorbs 0.7% water No visible changes after 15 days in calcium hydroxide or after 15 days in salt solution (3%)	Resistant to chemicals at 21 °C, reported Will resist short/intermittent immersion in acetic acid (5%)
Compatibility with bitumen	Reported to withstand asphalt concrete up to 250 °C Testing is missing	Report/testing is missing	Report/testing is missing
Not corrosive to steel	Used also for steel bridges	Used also for steel bridges	Report/testing is missing
Tensile bond to concrete surface	NFP 98 282* (>3.4 MPa)	Methodology is missing (≥ 2.6 MPa)	Methodology is missing (> 28 kg/cm^2 = 2.8 MPa)
Elasticity /Tensile strength and Elongation	NFP 98283 (9.1 MPa 145% (25 °C)) ISO 527 (24 MPa 107% (-20 °C)) (E-modulus 2.3 and 4.2 MPa at 100 and 300% elongation, resp.) Rebound resislience DIN 53512 (23, 3%, thickness 12 mm)	ASTM D412 3000-3500 psi 550% (3000psi=20.7 MPa)	ASTM C307 (tensile strength: 52 kg/cm^2) ASTM C580 (Flexural strength:152 kg/cm^2) (Modulus of elasticity 1.7x10^5 kg/cm^2)
Low temperature performance, Crackbridging ability	Dynamic crackbridging ability, BPG (0 °C 6.5 mm/thickness 2.1 mm; -20 °C 8.8 mm/thickness 2.7 mm	Reported to be crackbridging down to -40 °C.	ASTM C884 (Thermally compatible with concrte according to test)

Table 3A: List of material characteristics for surface protection in biological treatment plants. Given by the producer. Continuation.

Properties **Testing**	**Matacryl** **DAB, Domiflex AB**	**MS 901** **Arma coatings**	**FCS 304** **Chesterton**
Resistance to impact/dynamic impact and wear. Hardness	Resistance to perforation of macadam, SNCF (not perforated, thickness 3.2-3.4 mm) Static point load ETAG 005 TR 006 EOTA (L4 of max L4 thickness 2.5 mm) Dynamic point load ETAG 005 TR 006 EOTA (I 4 of max I 4; 2.5 mm) Hardness Shore 85 A Hardness Shore 55 D	Hardness Shore 50-55D	ASTM C 579 Compressive strength 478 kg/cm^2 ASTM D 4272 Impact toughness better than concrete according to test
Resistance to wear (abrasion)	Abrasion Taber, ISO 7784-2, 1000 g CS 10 56 g/500 r; 64 g/1000 r	Abrasion Taber, ASTM D4060, 1000g CS 17 17 mg/1000 r Alt. ASTM D3489 231 mg	Abrasion Taber, ASTM D4060, C 17/500g/ 500 r: max 0.75mg
Curing time	Reported to cure quickly	Dry after 5 s at 25 °C Cured after 24 h at 22 °C	Pedestrians after 10 h at 16 °C…. Cured after 72 h at 16 °C…
Resistance to high temperatures	Reported to withstand asphalt concrete up to 250 °C	From -50 to approximately +250 °C according to thermogravimetric analysis Reported	ASTM C884 (Thermally compatible with concrete according to test) Methodology is missing (Max temp.resistance at immersion in liquid: 60 °C)
Resistance to flow	Reported to cure quickly	Reported to dry quickly	Only for horizonlal surfaces
Resistance to ageing	Reported to have a long and cost effective life Testing missing	Reporetd to have a long life	Report/testing is missing
Not harmful to humans and the environment	See safety data sheet	See safety data sheet	See safety data sheet
Application	Reported to be possible to apply all year round Manually or with special spray equipment	To be spray applied	16-32 °C Storing at 10-32 °C
References	References are missing	References are missing	Fågelmyra composting plant, Borlänge

*NFP=French standard

8.1 Matacryl

The product is based on fast-curing acrylic resin and is available for various applications, such as waterproofing, wearing course or as a combined waterproofing and pavement system. The product can be spray applied or manually applied. Primer is applied to approximately 0.2 to 0.35 kg/m^2, depending on surface and texture.

Matacryl has recently been applied to the walls of the digestion tank at Falköping biogas plant where corrosion problems have occurred.

8.2 MS 901

Selected product system from Arma Coatings is a spray applied polyurea product with very short curing time.

8.3 FCS 304

Selected product system from Chesterton is a polymer/silica composite coating where the base material is composed of epoxy resin, which has reacted with a modified amine curing agent. The material has been used in parts of the Fågelmyra plant in Borlange. It is applied with a trowel and can not be vertically applied. For walls and ceilings, products such as CS4 are recommended.

8.4 Waterproofing and coarse aggregate mastic asphalt

Acid resistant coarse aggregate mastic asphalt is a product that has long been used for flooring, especially in facilities exposed to chemicals such animal feed, fertilizer, battery acid, etc. Mastic asphalt floors are therefore used within the galvanizing industry, in dairies, in the paper industry and in different types of stables. Reconstruction is usually needed after 10-20 years of use [Bergman, 2010]. As a rule, the acid-resistant mastic asphalt differs in formula from conventional polymer-modified mastic asphalt only with respect to the type of filler that is replaced from limestone to quartz. Other aggregate fractions, from Swedish quarries, are considered acid-resistant and need not be replaced. The polymer binder (Pmb 32 from Nynäs) in a polymer modified mastic asphalt (PGJA) contains about 4 % SBS. The mastic asphalt is placed 30 mm thick on a suitable membrane which must withstand the high asphalt application temperature of 200° C or more. Maximum aggregate size is 8-11 mm. The mastic asphalt as such is regarded as waterproof (air void free) with high bitumen content.

Acid-resistant mastic asphalt was popular in stables for many years, but is no longer used because of damage to the animals' delicate hooves caused by the sharp aggregates wearing up after some time [Oostra 2006, Bergman 2010].

Acid-resistant mastic asphalt from NCC/Binab was used as flooring in the reception hall of a biogas plant in Västerås, where extensive damage to the concrete had occurred after only a couple of years in full operation [Boubitsa 2010]. The plant was built in 2005. The mastic asphalt (25-40 mm) was placed on gas ventilating fiberglass after the concrete had been repaired and treated with a bitumen solution primer (June 2008). The present mastic asphalt contains: polymer bitumen Pmb 32, filler, feldspar, natural sand and macadam of quartzite. The upper surface was not sanded. According to a follow-up by NCC/Binab in December 2010, at the request of this project, it was noted that there was some mechanical damage on the asphalt as a result of heavy machinery, but no repairs were required. No chemical attack was observed. However, in this reception hall is also used another type of protective coating of epoxy (2-5 mm). Also this coating was damaged by wear and tear. The epoxy is damaged down to the concrete, and repairs are urgently required to prevent damage to the concrete and reinforcement. No adhesion problems, however, could be detected.

Specified properties for waterproofing sheets according to requirements by the Transport Administration are shown in Table 3B. Some typical properties for coarse aggregate mastic asphalt are listed below. Requirements for PGJA are specified in VVTBT Bituminous layers.

- Hardness. Indentation value for mastic asphalt PGJA is between 1 and 6 mm (load test at 40 °C). Testing according to SS-EN 12697-20. Change in dimension must not be more than 8 mm (24 hours at 80 °C). Testing according to SS-EN 12 970, Annex B.
- Wear resistance. Mastic asphalt shows very good wear resistance with a Prall value of 11-12 grams according to EN 12697-16. Corresponding requirements for cores from an asphalt pavement of type ABS 11 with ADT> 7000 is ≤ 24 grams according to Transport Administration specifications.
- Chemical resistance. Normal bitumen reacts with aggressive chemicals (see section 4.4). According to product data sheet for acid resistant mastic asphalt Daboleum SK , this product is resistant to for instance acetic acid (25 % at >30 °C) but not butyric acid or phenol. Exposure procedure and tested properties are not described.

Figure 11. *Abrasion test according to Prall using steel balls*

Table 3B: Requirements for torch-welded polymer modified bitumen sheets, according VVTBT

Sheet	Requirement	Method
1. Thickness - concrete-, wood-aluminum surfaces - steel surfaces	≥ 5,0 mm 3.5 – 4.0 mm The individual values may deviate by ± 0.5 mm from the nominal required value. (Without granules.)	SS-EN 1849-1
2. Mass per unit area	Measured values shall be advertised and may deviate by ± 10% from nominal value. For sheets with granules by ± 15 %.	SS-EN 1849-1
3. Tensile strength and Elongation	≥ 800 N ≥ 40 %	SS-EN 12311-1
4. Flexibility at low temperature, weldable bitumen side -after heat ageing	-20 °C	SS-EN 1109
	-10 °C	SS-EN 1109 SS-EN 1296, storage 24 weeks
5.Dimensional stability	Shrinkage ≤ 0.50 % Elongation ≤ 0.30 %	SS-EN 1107-1
-at higher temperature	Srinkage ≤ 1,0 % Elongation ≤ 0,6%	SS-EN 1107-1, after 1 hour at 160 °C.
6.Flow temperature	≥ 115 °C	SS-EN 1110
7.Water absorption	≤ 1.0 % (without granules)	SS-EN 14223
8. Resistance to indentation and dynamic waterpressure	No leakage .	SS-EN 14694 Granules are removed.

Weldable bitumen	Requirement	Method
9. Softening point -after heat ageing	≥ 120 °C	SS-EN 1427
	≥ 100 °C	SS-EN 1427 SS-EN 1296, storage 24 weeks

Table 3B: Requirements for torch-welded polymer modified bitumen sheets, according VVTBT. Continuation.

Performance	Requirement	Method
10. tensile bond (23±2 °C) to - Concrete, test specimen type 1	≥ 0.8 N/mm²	SS-EN 13596, SS-EN 13375 test area diameter: 50 mm
- Asphalt concrete, test specimen type 2 - Mastic asphalt, test specimen type 2	≥ 0.6 N/mm² ≥ 0.8 N/mm²	
11. Shear resistance (23±2 °C) with - Aspalt concrete - Mastic asphalt 12. Compatibility by heat conditioning, shear resistance value	≥ 0.3 N/mm² ≥ 0.3 N/mm² ≥ 0.3 N/mm²	SS-EN 13653, SS-EN 13375 SS-EN 14691
13. Crackbridging ability, at –20 °C, test specimen type 1	No cracks or evident loss of bonding after 1000 pulses.	SS-EN 14224
14. Resistance to compaction of an asphalt layer,	No leakage	SS-EN 14692, metod 2
15. Behaviour during application of mastic asphalt	To be reported	SS-EN 14693

8.5 Comment

As shown in Table 3A above, different test methods are used by the manufacturer of the respective systems, and reported test results are not usually directly comparable.

For the resistance to chemicals is concluded from the table that products in the table are said to be chemical resistant, but no relevant testing exists in reality. FCS 304 (epoxy based) is reported to resist short-term/intermittent immersion in acetic acid (5%).

For wear resistance is referred to ISO 7784-2 (Maracryl) or ASTM 4060 (MS 901 and FCS 304). In both cases, testing is carried out with Taber Abraser (see Figure 10) and current test parameters must be specified, ie type of wheel, load on the wheel and number of cycles. These vary in the comparison as shown in Table 3, but Matacryl seems less durable (may be due to errors in the product data sheet). For thermosetting resins, wheel types according to Table 4 below are used. Most common is CS 10, and a good epoxy coating for flooring according to The Paint Research Association (PRA) is not worn more than 60 mg after 500 cycles, and not more than 120 mg after 1000 cycles.

Table 4: Types of wheel for testing surface coating products in Taber Abraser

Type of surface protection to be tested	Wheel type
All types of surface, general handling	CS 10
Flooring with pedestrian traffic	CS 17
Flooring with vehicular traffic	H 22

9 Proposal for a test program

9.1 Product properties

Properties, testing and requirements fall into two categories, one for the membrane (exposed test pieces) and another for functional testing of the system. Suitable parts can be selected depending on the type of protective coating and the environment.

For bituminous waterproofing sheets (under asphalt in a system) also the Transport Administration requirements specification is referred to for the membrane as such.

9.1.1 Waterproofing membrane (free films)

Thickness
The membrane is normally applied in one or two layers. The manufacturer shall specify the applied amount per unit area required to obtain a dry membrane of a given thickness, nominal film thickness and the deviation from the nominal value. The thickness shall be verified in connection with the manufacture of specimens for laboratory testing, and continuously monitored during application of the concrete substrate.

The thickness of the manufactured test specimens can be measured according to suitable parts in ISO 2808 (paint and varnish), EN 1849-1 (waterproofing sheet) or equivalent. The result must be within the declared tolerance of the manufacturer's declared value.

Hardness
There are a variety of different hardness scales and techniques to measure the hardness of different types of coating layer (rubber, elastomers, etc.). Hardness is specified in Shore units (with durometer) or IRHD (International Rubber Hardness Degrees).

For current products, the hardness can be determined according to suitable parts in ISO 48 (IRHD) or by Shore (ISO 868, DIN 53 505, ASTM D2240, etc.). The hardness is determined at 70 °C, +23 °C and -20 °C, and the results must be within the declared tolerance of the manufacturer´s declared value.

Tensile properties
Tensile strength and elongation are determined according to suitable parts in ISO 527-3 (test specimen type 1b) at +23 °C and -20 °C. The results shall shall lie within the declared tolerance of the manufacturer's declared value.

Flexibility at low temperature
Flexibility at low temperature shall be determined according to EN 1109. The result shall be less than or equal to the manufacturer's limiting value.

Water absorption och resistance to water
The content of water absorbed shall be determined in accordance with suitable parts in EN 14223., but with sealed test specimen edges The water absorption shall be less than or equal to the manufacturer's limiting value and should not exceed 3 % by weight. No visible changes may appear.

The hardness is determined at +23 °C according to ISO 48 (method M) before and after storage in water. The results are reported.

Watertightness
Watertightness of the membrane is verified by testing according to EN 1928, method B. Testing shall be carried out on free films of the applied membrane. The result shall show if the membrane has leaked or not during water pressure testing.

Chemical resistancet
Chemical data are reported, showing that the product is not affected by products prodiced in the food waste process. Tensile strength or hardness can for instance be reported after exposure. Exposure is carried out for 28 days at 70 °C.

Proposal for specified test liquid:

> acetic acid 2 %
> pH ≤ 4
> chlorides 0,5 %
> phosphate 0,2 %
> ammonium ions/ammonia 0,2 %
> hardness 20

For testing of the complete system on concrete, see section 9.1.2 Performance related characteristics for waterproofing system below.

Compatibility with bitumen
Here is referred to material ment to be combined with an asphalt overlay. Testing can be performed as follows:

> Two specimens (approximately 120 mm x 60 mm) are stored in bitumen 50/70 for 84 days in an oven at 70±2 °C. After storage, the bitumen is removed. The hardness is determined before and after storage according to ISO 48 (method M).

The metod is taken from EOTA ETAG 033 for Liquid Applied Bridge Deck Waterproofing Kits.

Resistance to thermal ageing
In order to verify the thermal ageing behaviour of the product, a number of characteristics shall be determined before and after heat exposure for 24 weeks at 70 °C. The thermal ageing can be carried out in accordance with suitable parts in EN 1296 or EOTA TR 011. Relevant characteristics to be determined before and after exposure are hardness and tensile properties.

Hardness is determined at +23 °C in accordance with ISO 48 (method M) and tensile strength and elongation in accordance with ISO 527-3, at the same temperature. In each case, the result shall lie within the declared tolerance of the manufacturer's declared value.

9.1.2 Performance related characteristics for waterproofing system

Bond strength
Bond strength between waterproofing and concrete support, and if relevant also to overlay asphalt concrete or mastic asphalt, is tested in accordance with EN 13596. The results shall be greater than or equal to the manufacturer's limiting value.

Test specimens are prepared in accordance with suitable parts in EN 13375, referring to EN 1766 and specified reference concrete of type MC (0.45). The following modifications/additions concerning application of the waterproofing (Section 6 in EN 13375) and storage time apply:

> The liquid waterproofing product and primer are applied to the concrete support (specified in EN 13375) according to manufacturer's instructions and current thickness. The waterproofing is applied at normal temperature and relative humidity (appr. 23±2 °C and 50±10 % RH) and is allowed to cure under controlled conditions for maximum 28 days. The waterproofing thickness shall be checked in a suitable manner and testing performed within 3 months after completed curing time.

Bond strength to concrete is tested at 23±2 °C, before and after 20 freeze-thaw-cycles in accordance with EN 13687-3. Mode of failure shall be reported.

Shear strength
Shear strength to concrete support as well as overlay shall be tested in accordance with EN 13653. The results shall be greater than or equal to the manufacturer's limiting value.

Test specimens of type 3 are prepared in accordance with suitable parts in EN 13375, with the modifications/additions concerning application of the waterproofing and asphalt overlay (Section 6 and 7 in EN 13375) and storage time:

> The liquid waterproofing product and primer are applied to the concrete support (specified in EN 13375) according to manufacturer's instructions and current thickness. The waterproofing is applied at normal temperature and relative humidity (appr. 23±2 °C and 50±10 % RH) and is allowed to cure under controlled conditions for maximum 28 days. The waterproofing thickness shall be checked in a suitable manner and the asphalt layer placed after suitable curing time according to manufacturer's instructions. Testing shall then be performed within 3 months.

Shear strength is tested at 23±2 °C, before and after thermal ageing in accordance with EN 14691. Mode of failure shall be reported.

Crack bridging ability
The ability of bridging cracks in a concrete support shall be tested in accordance with EN 14224.

Test specimens of type 1 are prepared in accordance with suitable parts in EN 13375, with the following modifications/additions concerning application of the waterproofing (Section 6 in EN 13375) and storage time:

> The liquid waterproofing product and primer are applied to the concrete support (specified in EN 13375) according to manufacturer's instructions and current thickness. The waterproofing is applied at normal temperature and relative humidity (appr. 23±2 °C and 50±10 % RH) and is allowed to cure under controlled conditions for maximum 28 days. The waterproofing thickness shall be checked in a suitable manner and testing performed within 3 months after completed curing time.

Testing is performed at -30 °C, -20 °C, -10 °C or 0 °C, before and after thermal ageing 28 days at 70 °C (in accordance with EN 1296 or EOTA TR 011). The test temperature is chosen by the manufacturer. The method is facing revision.

Chemical resistance (applied on concrete)
Chemical resistance is tested in accordance with EN 13529, with the following modifications/additions concerning application of the waterproofing (Section 6 in EN 13375) and storage time:

The liquid waterproofing product and primer are applied to the concrete support (specified in EN 13375) according to manufacturer's instructions and current thickness. The waterproofing is applied at normal temperature and relative humidity (appr. 23±2 °C and 50±10 % RH) and is allowed to cure under controlled conditions for maximum 28 days. The waterproofing thickness shall be checked in a suitable manner and testing performed within 3 months after completed curing time.

The chemical exposure is carried out with specified test liquid in accordance with proposal below, 28 days at 70 °C:

> acetic acid 2 %
> pH ≤ 4
> chlorides 0,5 %
> phosphate 0,2 %
> ammonium ions/ammonia 0,2 %
> hardness 20

After exposure, the test areas are visually examined and the bond strength to the concrete is tested at 23±2 °C in accordance with EN 13596 . Failure mode shall be reported. The concrete under the waterproofing is analysed for chemicals from the test liquid.

Resistance to flow at higher temperatures (for application on not horizontal surfaces)
Resistance to flow can be tested in accordance with method specified in EOTA ETAG 033 for Liquid Applied Bridge Deck Waterproofing Kits (Annex E).

Resistance to compaction of an asphalt layer
The test is carried out in accordance with suitable parts in EN 14692 (method 2) for waterproofing intended to be combined with an asphalt overlay. The compaction is performed in accordance with EN 12697-33.

Slipperiness
If the waterproofing is intended for use under pedestrian traffic, sufficient friction coefficient must be verified for avoiding accident owing to slippery conditions. The friction coefficient is determined in accordance with EN 13036-4, using 4S sliding rubber.

Wear resistance
Testing is performed in accordance with SS EN ISO 5470-1 (ASTM 4060 Taber test) with choice of testing parameters (wheel, load and number of cycles) depending on type of application. For high wear resistance, testing is performed with wheel H 22 or method in accordance with SS EN 13892.

Table 5: Requirements for liquid applied surface coatings on concrete in biological treatment plants **The waterproofing membrane** (free films are produced according to instructions by the producer)

Characteristic/ Testing	**Method**	**Requirement**	**Comment**
Thickness	SS EN ISO 2808, SS EN 1849-1 or similar	Reported	
Hardness	SS ISO 48 (method M) SS EN ISO 868 (Shore)	Reported	Determined at +70, +23 and -20 °C
Tensile properties	SS EN ISO 5273	Tensile strength and elongation are reported	Determined at +23 and -20 °C
Flexibility at low temperature	SS EN 1109	Less than or equal to the manufacturer's limiting value	Determined at ≤ -20 °C
Water absorption and resistance to water	SS EN 14223, with sealed test specimen edges SS ISO 48 (method M)	Max change in weight 3.0 % and no visible changes	28 days of storage in water at room temperature Hardness is determined before and after storage
Chemical resistance (leachate)	Specified test liquid according to proposal	Reported	28 days of storage at 70 °C Tensile properties are determined before and after storage
Compatibility with bitumen (if the waterproofing will be combined with an asphalt overlay)	EOTA Draft ETAG 033 SS ISO 48 (method M)	Reported if relevant	84 days of storage in bitumen at 70 °C Hardness is determined before and after storage
Resistance to thermal ageing	SS EN 1296 or EOTA TR 011 SS ISO 48 (method M), SS EN ISO 5273	Reported	24 weeks at 70 °C Hardness and tensile properties are determined before and after storage
Watertightness	SS EN 14694 (without fpre-treatment)	Reported No leakage	0,5 N/mm^2 (50 m); 1000 pulses
Resistance to UV (if the waterproofing will be exposed to sunlight)	EOTA TR 010 SS ISO 48 (Method B) SS EN ISO 5273	Reported if relevant	5000 h, condition S and UV-A, at 70 °C BST Hardness and tensile properties are determined before and after storage

Table 5: Requirements for liquid applied surface coatings on concrete in biological treatment plants

Functional testing (test specimens are prepared on concrete according to instructions by the producer, or as free films)

Characteristic/ Testing	Method	Requirement	Comment
Bond strength to -Concrete -Mastic asphalt	 SS EN 13596 SS EN 13596	 ≥1.0 N/mm^2 ≥1.0 N/mm^2 Reported if relevant	Performed before and after freeze-thaw-cycles SS-EN 13687-3 Increase in tensile force: 0.15 N/s mm^2 Test area diam: 50 mm or area: (50x50) mm^2
Shear strength	SS EN 13653 SS EN 14691		Performed before and after thermal ageing 91 days at 50 °C
Crack bridging ability at low temperature	SS EN 14224 SS EN 1296 el. EOTA TR 011	Shall pass the test at –20 °C without cracks in the waterproofing, if relevant	Performed before and after thermal ageing 28 days at 70 °C Ampl: 0,20 mm Frequency: 1Hz No of cycles: 1000
Resistance to flow at higher temperature	Annex E in EOTA ETAG 033	Reported if relevant	For application on not horizontal surfaces
Slipperiness	SS EN 130364	Reported if relevant	4 S rubber is used
Wear/abrasion	SS EN ISO 5470-1 (ASTM 4060 Taber test) SS EN 13892-5	Reported	

9.2 Checking on site

The thickness shall be checked regularly during application work and documented. Bond strength testing between membrane and concrete substrate must be carried out in accordance with the methodology described in SS EN 13596. Testing shall be conducted (as agreed between client and contractor) to any particular started number of m^2 membrane. Each test will consist of three over the surface evenly spread individual tests that, regardless of the temperature, shall be at least 0.5 N/mm^2. Any blisters (pin/blowholes) shall be addressed.

9.3 Field testing

Test sites and follow-up in the field are suggested before using any system in full application work. This can be carried out for selected systems following laboratory testing. A number of plants can be experimentally provided with protection coating.

10 Comment and conclusions

The initial study of weathering and corrosion of concrete in biological treatment plants, which was conducted in 2009 [Boubitsa 2010], showed that the concrete does not have sufficient strength in the current aggressive plant environment. It was concluded that some form of waterproofing is needed in order to ensure the good function of the concrete structure. Furthermore, the waterproofing must withstand the aggressive environment and the traffic that occurs on site.

In Waste Refinery Project WR-34, various types of waterproofing/protective coating for concrete in biological treatment plants are discussed. A number of proposals from industry are presented in the light of results from project WR-27, ie, the materials must, among other things, withstand the aggressive leachate from food waste at temperatures up to 70 °C, and some degree of wear. Some different systems are compared with regard to material technical characteristics reported by the manufacturer. A proposal for a test program has been developed, focusing on special chemical resistance and resistance to wear. A test liquid corresponding to leachate has been specified. Laboratory testing for verification of the proposed methodology and data for requirement levels are proposed, as well as field testing and follow-up. The following conclusions can be drawn:

- There are a variety of technologies, materials and systems on the market that according to manufacturer/contractor are expected to perform well as a waterproofing and protective coating for concrete in biological treatment plants. Relevant testing is missing, however, and also corresponding reference objects. Various test methods have generally been used for various systems, and test results/performance are therefore not directly comparable.
- Chemical resistance, or in this context mainly resistance to leachate from food waste, is especially important. Relevant tests are not available for all products/systems treated in the project. Such testing is proposed in the report.
- Wear resistance is especially important for the protective coating on concrete floors in the reception hall where food waste is received. Testing with Taber Abraser has generally been carried out with this kind of materials, but the parameters vary (type of wheel, load and number of cycles). For the protective coating on concrete floors in the reception halls with heavier traffic, testing according to more aggressive methods is needed. Such testing is proposed in the report.

10.1 Future work

The following future work is suggested based on results so far in the report:

- Laboratory studies and tests to verify the proposed method for resistance to leachate
- Laboratory studies and tests to verify the proposed method for resistance to wear
- Field testing and follow-up of selected systems (on renovated and new objects)

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ASTM C580 *Standard Test Method for Flexural Strength and Modulus of Elasticity of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes.*

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Appendix A

Utg: 1994-10-06
Ers: 1998-08-06
Rev: 2004-11-19

Datablad NM Silo556 / Härdare 40

NM Silo 556 / NM Härdare 40 är en lösningsmedelsfri och lätt tixotroperad två-komponent epoxi med mycket god kemikalie och vattenresistens. Systemet används till uppbyggnad av invändig beläggning i tankar och kar för kemikalier.

Se arbetsbeskrivning NM Tanksystem

Användningsområden:

- Invändig beläggning i tankar och kar för kemikalier.
- Ytskikt och laminering.

Tekniska data

Bas:
NM Silo 556
Härdare:
NM Härdare 40
Blandningsförhörhållande:
Bas-Härdare 100-48 viktdelar

Densitet - Bas:	1142 kg/m^3
Densitet - Härdare:	1057 kg/m^3
Densitet - Blandning.:	1114 kg/m^3
Viskositet.:	1100 mPa·s
Potlife 100g 20°C:	25 min
Tryckhållfasthet DIN 53457:	60 MPa
Draghållfasthet DIN 53455:	35 MPa
Kemikaliebeständighet:	Se tabell
Satsstorlek:	5.0+2.4= 7.4 kg

Verktyg rengörs i aceton.

NILS MALMGREN AB
Box 2039
S-442 02 YTTERBY
Tel: 0303-936 10
Telefax: 0303-928 55
E-post: info@nilsmalmgren.se
Hemsida: www. nilsmalmgren.se

Arbetsbeskrivning **NM Tanksystem för epoxibeläggning i betongcisterner** **Nils Malmgren AB**

1. Konstruktionsprincip

NM Tanksystem utförs som invändig beläggning i betongcisterner.
Beläggningen är utformad så att den kan överbrygga befintliga eller uppkommande sprickor i betongen.

2. Rengöring av betongen

Är ytan förorenad av oljor, fett eller dylikt skall den behandlas med ytaktivt medel (ev. kausticsoda NaOH) och avspolas med vatten. Betongen skall sedan torka före vidare behandling.

Är ytan förorenad av färg, asfalt eller dylikt, avlägsnas detta i möjligaste mån genom skrapning eller försiktig mejsling. Därefter kan resterna avlägsnas genom sandblästring.

Där betongen endast är svagt förorenad eller om cementhud finns, sandblästras ytorna.

När anslutningar skall göras till ingjutningsgods skall ytorna vara metallrena dvs blästrade.

Betongens fuktförhållande kan vara avgörande för resultatet. Det är därför viktigt att detta kontrolleras.
Enklast utförs detta med hjälp av en hygrometer som fästes mot betongen och övertäckes med ett stycke plastfolie. Om vatten vandrar kapillärt och avdunstar från betongytan, kommer den relativa fuktigheten snabbt att öka under plastfolien.
Se kapitel **Ytpreparering** i NM Epoxihandbok angående betongens fuktighetsgrad.

3. Hålkäl

Alla övergångar mellan vägg, golv och ingjutningsgods skall förses med hålkäl (minsta radie 20 mm).

4. Primerskikt

Om betongen är torr utförs primering med ett skikt av **NM Grundering BP 50 Super / NM Härdare 50**.Harts och härdare blandas med hjälp av en långsamtgående borrmaskin och visp. Materialen skall vara tempererade till ca 20°C. Primeringen utföres med hjälp av målarrulle på skaft. Åtgång ca 150 g/m^2. Primeringen skall härda över natt, före nästa skikt. Betongens temperatur skall vara minst +10°C och relativa fuktigheten får ej överstiga 80%. Luftväxling är nödvändig.

Om fuktvandring pågår enl. punkt 2 skall betongen primeras med **NM Grundering BP50 Super** i tre skikt, med en dags mellanrum. Åtgång ca 3 x 150 g/m^2.

5. Elastiskt skikt

Det elastiska skiktet har till uppgift att fördela de spänningar som uppstår i tätskiktet över en spricka till ett vidare område på båda sidor av sprickan. Det elastiska skiktet utgörs av **NM Spackel Elastic 705 Flex / NM Härdare 701**. Detta påförs så jämnt som möjligt till en mängd av 1 liter/ m^2 (1.35 kg).

Se baksidan för ytterligare information.

Beläggningskrav:
Ythållfasthet: >1.5 MPa
Yttemperatur: >10°C
Max RF i luft: 80%

Blandningsförhållanden på ingående komponenter. (Bas - Härdare)

NM Spackel Elastic 705 Flex
NM Härdare 701
100 - 23 viktdelar

NM Spackel Elastic 705
NM Härdare 706
100 - 15 viktdelar

NM Silo 556
NM Härdare 40
100 - 48 viktdelar

NM Silo 556
NM Härdare 29
100 - 60 viktdelar

NM Grundering BP 50 Super
NM Härdare 50
100 - 200 viktdelar

Denna arbetsbeskrivning är ett förslag på hur produkten skall läggas för bästa slutresultat. Alla omnämnda produkter är en blandning mellan en bas och en härdare om inte annat anges. För blandningsförhållanden och övriga data hänvisas till aktuellt datablad eller etikett. Vid frågor, kontakta inköpsställe eller Nils Malmgren AB

Nils Malmgren AB
Box 2039, S-442 02 YTTERBY Tel: 0303-936 10 Fax: 0303-928 55

Appendix B

Con-Seal

Data A komponent

Epoxiharts 100 %

Densitet 1,16 kg/m3

Löslighet i vatten : ej löslig

Svagt gulaktig trögflytande vätska

Data B komponent

Cykloalifatiska polyaminer

Densitet 0,99 kg/m3

Delvis löslig i vatten

Ph värde dispergerad 50:50 i vatten ca:11

Viskositet 20-35 mPs vid 25°C

Svagt gulaktig vätska

Data blandad vara

Geltid (arbetstid) vid 20°C 15-20min.

Härdtid 20°C ca 6 tim. (fullt uthärdad 24 tim.)

Lägsta rek. Härdtemperatur +10°C

Användningsområde och egenskaper hos Con-Seal

Con-Seal är framtagen för att verka som spricköverbyggande coating och frostskyddande yta för utomhus liggande betong ytor.

Con-Seal härdar till en hård men samtidigt seg yta som tränger in och tätar ytan av betongen och förseglar mindre sprickor (2-3mm.)

Con-Seal är alkalibeständig, en förutsättning för en bestående vidhäftning mot betong som är relativt starkt alkalisk.

Bruksanvisning.

Betongytan rengöres med t.ex. högtrycks tvätt ytan får därefter torka.
Con-Seal A+B blandas noggrant i A komp. burken. tills en homogen lösning erhållits.

Lösningen slås portions vis ut och avjämnas med en gummiraka , ytan avsandas (mättas)med 1mm sand medan lösningen är våt.
Ytan får härda och därefter uppsuges överskottet av sand.

Hälsoaspekterna vid hantering av epoxi skall iaktas.
Upplysningar genom Varu informations blad Con-Seal.

Mer upplysningar kan fås genom
Zel-Aaren Innovation AB
Frälsegårdsgat. 31
504 94 Borås

Tel 033 257640 Fax 033 25 41 76
e-mail sune.linde@zel-aaren.se

Appendix C

stirling lloyd
THE TECHNOLOGY OF PROTECTION

CHEMICAL RESISTANCE

permare® ep
CHEMICAL RESISTANCE

INTRODUCTION

The data in this chart summarises the short-term effects of a wide range of fluids on the Permare EP Epoxy polysulphide elastomeric coating. This data should only be used as a guide. It is advisable to test the material under actual, or at minimum, simulated service conditions, before specification and use. The following ratings are based on short-term laboratory immersion tests conducted at 21°C on free (unsupported) cured films.

RATING KEY

1 = Fluid has little or no effect
2 = Fluid has minor or moderate effect
3 = Fluid has moderate effect
4 = Fluid has severe effect

CHEMICAL RESISTANCE

CHEMICAL	DAYS			
	1	3	7	30
1. Water				
Chlorinated Water 1ppm	1	1	1	1
Chlorinated Water 10ppm	1	1	1	1
Chlorinated Water 100ppm	1	1	1	1
2. Alkalis				
Potassium Hydroxide (Caustic Potash) 15%	1	1	1	1
Sodium Hydroxide 50%	1	1	1	1
3. Acids (Aqueous)				
Benzoic Acid 5%	1	1	1	1
Boric Acid 20%	1	1	1	1
Citric Acid 50%	1	1	1	2
Nitric Acid 30%	4	-	-	-
Oxalic Acid 20%	1	1	1	1
Sulphuric Acid 20%	1	4	-	-
Tartaric Acid 50%	1	1	1	2
Hydrochloric Acid 1M	1	1	1	1
4. Salt Solutions (Aqueous)				
Aluminium Sulphate 50%	1	1	1	1
Ammonium Chloride 50%	1	1	1	1
Ammonium Perchlorate 50%	1	1	1	1
Ammonium Polyphosphate	1	1	1	1
Ammonium Sulphate 30%	1	1	1	1
Barium Hydroxide 10%	1	1	1	1
Calcium Chloride 50%	1	1	1	1
Calcium Hydroxide 50%	1	1	1	1
Copper Sulphate 20%	1	1	1	1
Ferric Chloride 50%	1	1	1	1
Ferrous Sulphate 10%	1	1	1	1
Magnesium Chloride 20%	1	1	1	1

CHEMICAL	DAYS			
	1	3	7	30
Magnesium Hydroxide 30%	1	1	1	1
Potassium Carbonate	1	1	1	1
Potassium Bicarbonate	1	1	1	1
Potassium Permanganate 6%	4	-	-	-
Sodium Carbonate 40%	1	1	1	1
Sodium Cyanide 5%	1	1	1	1
Zinc Chloride 10%	1	1	1	1
Zinc Nitrate 17%	1	1	1	1
5. Petrochemicals				
Benzene	4	-	-	-
Fuel Oil	1	1	1	1
Diesel Fuel	1	1	1	1
Kerosene	1	1	1	1
Mineral Spirits	1	1	1	1
Motor Oil 10W/40	1	1	1	1
Naphtha VM & P	1	1	1	1
6. Solvents/Chemicals*				
Acetone	4	-	-	-
Acrylonitrile	4	-	-	-
1.4 Butanediol	1	1	1	1
Butyl Cellosolve	4	-	-	-
Butyl Oxitol	4	-	-	-
Carbon Disulphide	4	-	-	-
Chlorobenzene	4	-	-	-
Cyclohexane	1	1	1	1
Ethyl Acetate	4	-	-	-
Ethyl Acrylate	4	-	-	-
Ethyl Alcohol	1	1	4	-
Ethyl Hexyl Acrylate	1	1	1	1
Ethylene Dichloride	4	-	-	-
Heptane	1	1	1	1
Hexane	1	1	1	1
Hexylene Glycol	1	1	1	1
Isobutanol/Isobutyl Alcohol	1	1	1	2
Isopropanol	1	1	1	2
Isopropyl Amine	4	-	-	-
Linseed Oil	1	1	1	1
2-Mercaptoethanol	4	-	-	-
Methanol	4	-	-	-
Methyl Acrylate	4	-	-	-
Methylated Spirit	4	-	-	-
Methyl Carbitol	4	-	-	-
Methyl Cellosolve Acetate	4	-	-	-
Methyl Methacrylate	4	-	-	-
Methyl Ethyl Ketone	4	-	-	-
Methylene Chloride	4	-	-	-
Butyl Acrylate	4	-	-	-
Butanol/Butyl Alcohol	1	1	1	2
Propylene Glycol	1	1	1	1

* Where the coating is not resistant to a volatile solvent this will, in many cases, be reversed by a drying period to allow solvent evaporation after the exposure.

MA290 Permare EP Chemical Resistance Issue 3
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stirling lloyd
THE TECHNOLOGY OF PROTECTION

CI/SfB | | | Vn6 |

PRODUCT DATASHEET

permare® ep

PRIMARY & SECONDARY CONTAINMENT MEMBRANE

DESCRIPTION

Permare® EP is a two component, seamless liquid system which combines the features of both epoxies and polysulphides to produce a coating with outstanding physical properties. The material cures to produce a tough, flexible coating especially suited to applications where abrasion and chemical resistance is required.

USES

Permare® EP is designed to retain, exclude or protect structures from water, oils, fuels and many aggressive chemicals. Typical applications include:

- Storage tanks and silos
- Secondary containment - bund lining or earthen containment bunds (using a fabric carrier for the coating)
- Petrochemical Industry
- Concrete, masonry, asphalt or steel substrates requiring a chemical and/or abrasion resistant coating
- Car park kerbs and areas where high abrasion resistance is essential
- Floor protection in industrial environments (the addition of an aggregate overscatter provides a slip resistant finish)
- Silage units
- Canals and culverts
- Sewage, sludge tanks and manholes
- Above or below ground applications

FEATURES

- Excellent chemical, abrasion and impact resistance
- Good low temperature flexibility
- Low gas permeability
- Excellent UV and weather resistance
- Does not contain solvents
- Easy to apply
- Liquid applied - providing a seamless coating with no vulnerable joints
- Can accommodate difficult surface profiles and shapes
- High bond strength to substrate
- Two component, colour coded system to ensure homogeneous mixing on site
- Long and effective life
- On site quality assurance programme
- Applied only by authorised and trained contractors

TECHNICAL DATA

PROPERTY	VALUE
Application Temperature Range [1]	5 – 50°C
Maximum Humidity During Application	85%
Working Life (Typical)[2] (Material Temperature)	
@ 50°C	15-25 mins
@ 40°C	20-30 mins
@ 30°C	30-40 mins
@ 20°C	60-70 mins
@10°C	75-85 mins
Minimum Overcoating Time[3] (Ambient Temperature)	
@ 50°C	4 hrs
@ 40°C	8 hrs
@ 30°C	16 hrs
@ 20°C	21 hrs
@ 10°C	29 hrs
@ 5°C	33 hrs
Typical Tensile Strength (BS903: A2:1995) @ 23°C	6.5 MPa
Typical Elongation at Break (BS903: A2:1995) @ 23°C	35%
Adhesion to Substrate (BS EN ISO 4624: 2003)	
Steel	> 2 MPa
Concrete	> 1 MPa
Hardness (Shore D) (BS2782: Pt 3: Method 365B: 1992 ISO 868: 1985)	55
Water Vapour Transmission Rate (1mm coating. ASTM E96-80)	0.8-1.3/m^2/day
Water Vapour Resistivity ($x10^5$MNs/g) (ASTM E96-80)	1.6 - 2.6
Petrol Transmission Rate (ASTM E96-80)	Zero
Abrasion Resistance: (ASTM D1044-85, CS-17 wheel, 500g load)	
100 cycles	30 - 35 mg
500 cycles	80 - 95 mg
1000 cycles (1000g load)	94 mg
Low Temperature Flexibility (0.25 mm coating) (ASTM D3111-88)	Pass at -26°C

[1] For temperatures outside this application range please contact our Customer Services Department.

SURFACE PREPARATION

It should be stressed that the success of any waterproofing system is dependent on the thoroughness of the surface preparation.

Concrete
New concrete substrates should be a minimum of seven days old. The substrate must be clean, dry and structurally sound. It

[2] Permare EP may be applied when the ambient temperature is below 10°C though the material may require heating to facilitate good mixing and ease of application. For further information please contact our Customer Services Department.

[3] Minimum overcoating time is based on good air circulation. This may increase in enclosed situations.

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Appendix D

ARBEIDSPROSEDYRE

Prosjekt:	Biogass anlegg Micorea S3	Rev.:	Sider: 3
Prosess:	Vanntetting med polyurea	Datum: 21.06.2010	

Utarbeidet av: Elisabet N Michelson
Godkjent av: Svein Kjennerud

Denne prosess beskriver utførelse av priming med Micopox P avstrødd med tørr ren sand til metning, 0,4 – 0,8 mm, og påsprøyting av et høyelastiskt vanntett membran av polyurea, Micorea S3.

1.0 KRAV TIL BETONGEN - UNDERLAGET

1.1 Betongen skal være fri for gammel maling og forurensninger som fett, olje og støv. Ved belegging av nystøpte betong, skal sement huden fjernes.

1.2 Betongen skal være tørr før belegging starter og min 28 døgn. Fuktvandringen kan kontrolleres med 1 m² plastfolie som festes ved hjelp av teip på betongoverflaten. Hvis det ikke betongen mørkner eller at fukt ikke er synlig etter et døgn, er betongen tørr nok til belegging. Alternativt kan prober støpes inn for å måle fuktinnholdet i betongen. For å oppnå en vanntettende effekt er det viktig at membranen blir påført på den siden der vannkilden kommer ifra. Hvis det er muligheter for vann inntrengning, vil et tett belegg magasinere ev innsig av vann og forårsake stor skade. Hvis konstruksjonen blir utsatt for lave temperaturer, kan det være fare for frostsprengning.

1.3 Eventuell membranherder må fjernes. Dette kan enkelt kontrolleres ved å påføre en vanndråpe. Hvis vanndråpen ikke trenger ned i overflaten, er det trolig membranherder som må fjernes før belegging.

1.4 Anbefalt temperatur på betong ved utførelse bør være min 5 °C. Temperaturen på overflaten skal være minimum 3 grader over dugg punktet ved utførelsen.

2.0 FORBEHANDLING

2.1 Sementhuden fjernes ved sliping, slyngrensing.

2.2 Eventuelle sår, riss og ujevnheter utbedres med epoxy sparkel, Micopox P sparkel, alternativt epoxy mørtel, Micopox P blandet med sand. Ved større skader kan sementbaserte spesialmørtler limt med Micopox L brukes.

2.3 Betongen skal støvsuges eller blåses ren før belegging.

3.0 DETALJER

3.1 Beleggs avslutninger, anslutning til renner og sluk, samt hulkil og sokler utføres i henhold til egen arbeidsbeskrivelse. Kanter og hjørner bør avrundes om mulig.

3.2 Hvis et nytt lag Micorea skal påføres på et Micorea membran som er eldre enn 2 dager, bør en primer, Micopox WP brukes for å sikre mellomstrøks adhesjon. Temperaturen på overflaten skal være minimum 3 grader over dugg punktet ved utførelsen.

4.0 PÅFØRING

4.1 Påføringen bør skje ved mest mulig stabil temperatur eller ved fallende temperatur for å redusere faren for porer i belegget.

4.2 Priming utføres med Micopox P. Epoxyen avstrøs umiddelbart med sand, 0,4 – 0,8 mm, for hånd eller blåses på. All overskudds sand fjernes etter at primeren herdet.

Forbruk:	Micopox P	ca 0,3 kg/m²
	Sand, 0,4 – 0,8 mm	ca 1 kg/m2

4.3 Membran av Micorea S3 påsprøytes med en spesialsprøyte med ca 180 bars trykk og ca 80 C temperatur. Micorea blir støvtørr på noen sekunder og man kan gå på membranen umiddelbart etter belegging, men vi anbefaler at membranen ikke belastes mekanisk før etter 1 døgn.

Forbruk: Micorea S3 ca 3,5 kg/m² pr strøk ved beleggstykkelse på 3 mm, alt 5 kg/m2 for en tykkelse på 4- 4,5 mm.

4.4 Micorea S3 gulner ved sollys. For å unngå dette kan en vannbasert epoxy, Micopox W, påføres i ønsket farge.

Forbruk: Micopox W ca 0,2 kg/m2

5.0 KONTROLL

5.1 Betongen kontrolleres for eventuell fukt, slam og støv og eventuelt andre forurensninger.

5.2 Temperatur sjekkes mot kravene, se punkt 1.4.

5.3 Primerens heft til underbetongen sjekkes eventuelt med avtrekksprøve.

5.4 Forbruket kontrolleres og noteres.

5.5 Visuell kontroll etter utførelsen skal bekrefte at belegget har tilfredsstillende overflate.

6.0 ANSVAR

6.1 Entreprenøren har ansvaret for å følge denne arbeidsprosedyren og for å notere all nødvendig dokumentasjon under arbeidet, så som batch nummer, materialforbruk, temperaturer, tidsforbruk etc. se vedlegg 1.

Prosjekt Futurum
KONTROLL SKJEMA **Vedlegg 1**

Daglig kontroll

Prosjekt	Prosjekt nr:	Hovedentreprenør:
Sted/lokal		Kontakt person:
Tid:	Ansvarlig for utførelsen:	Signatur:

KONTROLL AV	**Utført Ja**	**Utført Nej**	**Datum**	**Kommentarer**
1. Underlag	☐	☐		
1.1 Temperatur i omgivelsen	☐	☐		
1.2 Fukt(RH) i omgivelsen	☐	☐		
1.3 Temp. I underlaget	☐	☐		
1.4 Fukt I underlaget	☐	☐		
1.5 Avvik	☐	☐		
1.6 Renner til sluk	☐	☐		
1.7 Avbrudd	☐	☐		

2. Utførd forbehandling	**Area**	**Datum**	**Kommentarer**	**OK**
2.1 Metod				

UTFØRT ARBEID/ KONTROLL	**Mengde Area**	**Datum**	**Kommentarer**	**OK**
3. Priming Micopox P, forbruk	m² kg			
4. Kontroll av heftfasthet	Ja ☐ Nej ☐			
5. Batch nr				
7. Membran Micorea	m² kg			
8. Batch nr				
11. Detalj arbeid				
11.1 Hullrum, ujevnheter	lm			
11.2 Sprekker riss		lm		
11.3 Sluk, renner			lm	
11.4 hulkil, sokler				
11.5 Avsluttninger				

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Datasheet 1008 N
Date 22.09.2003

MICOPOX P

PRODUKTBESKRIVELSE: Micopox P er en to komponent lavviskøs klar epoxy uten løsningsmidler.

ANVENDELSESOMRÅDE: Micopox P er velegnet som primer,bindemiddel til kompakt gulv, mørtelbelegg eller som bindemiddel til belegninger med kvartssand Micopox P er ikke egnet som topplakk. I slike tilfeller benyttes Micopox 300.

EGENSKAPER: Micopox P er en lavviskøs epoxy med god inntregningsevne i betong.

FORBEHANDLING: Avrettning/fresning eller slyngrensning og omhyggelig støvsuging. Overflaten skal være ren og tørr før påføring.

BLANDING: Komponentene A + B blandes med drill og visp i minimum 3 minutter, til en homogen masse.

PRIMING: Den klargjorte betongoverflaten påføres med Micopox P ved hjelp av kost eller malerull. Videre belegning skal utføres innen 24 timer. Forbruket er avhengig av underlag og temperatur.

PÅFØRING: Micopox P påføres med kost eller malerull, eventuelt med tannet sparkel.

RENGJØRING: Verktøy reingjøres med Micorens.

MILJØ OG SIKKERHET: Se HMS datablad.

DRIFT OG VEDLIKEHOLD: Se eget datablad.

TEKNISKE DATA:

Komponent A 6 kg Komponent B 3 kg Sett A+B 9 kg	Sp.vekt 1,08 kg/l Tørrstoffinhold 100 % Viskositet 400 cP	Potlife +20 oC 35 min. Forbruk ca. 0,25kg/^{2}m Laveste herdetemp +5 °C	Blandingsforhold 2 : 1 Lagring: Oppbevares tørt og frostfritt. Beskyttes mot direkte sollys. Holdbarhet: minimum 12 mnd.

Spesielle opplysninger: MALKODE: 00-5 (1993) PRODUKTNR: COMP A: Produktet er anmeldt PRODUKTNR: COMP B: 1608721.
Opplysningene i dette datablad er basert på vår nåværende viten og erfaring og må kun betraktes som retningsgivende og være gjenstand for vurdering i hvert enkelt tilfelle.

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Datasheet 1004 N
Date 12.01.2003

MICOPOX WP

PRODUKTBESKRIVELSE: Micopox WP er en to komponent vannemulgerbar transparent epoxy.

ANVENDELSESOMRÅDE: Micopox WP anvendes som støvbinder på betong og primer for herdeplastbelegg, som f.eks. Micopox W, Micopox C, Micopox SL-3, Micopur LS og Micopur G.

EGENSKAPER: Micopox WP har meget god inntrengningsevne og heftegenskaper til betong.

FORBEHANDLING: Avfetting og sliping eller slyngrensing, samt omhyggelig støvsuging. Overflaten skal være ren og tørr før påføring.

BLANDING: Komponentene A + B blandes med elektrisk drill og visp i minimum 3 minutter, til en homogen masse.

PRIMING: Micopox WP kan tynnes med 5 til 10% vann.

PÅFØRING: Påføres med kost eller malerull.

RENGJØRING: Verktøy reingjøres med vann, eventuelt tilsatt såpe.

MILJØ OG SIKKERHET: Se HMS Datablad.

DRIFT OG VEDLIKEHOLD: Se eget vedlikeholdsdatablad.

TEKNISKE DATA

Komponent A 2 kg Komponent B 8 kg Sett A + B 10 kg	Sp.v. 1,02 Tørrstoffinnhold 33 %	Potlife +20 C° 45 min. Forbruk ca. 0,2 kg på m^2 Laveste herde- og overflatetemperatur 10 C°	Blandingsforhold i vekt: 8 : 2 Lagring: Oppbevares tørt og frostfritt og beskyttet mot direkte sollys. Holdbarhet: Minimum 12 mdr.

Spesielle opplysninger: Malkode: 00-5 (1993) Produktnr.: Comp A: 1567384. Produktnr. Comp B:1567405.
Opplysningene i dette datablad er basert på vår nåværende viten og erfaring og må kun betraktes som retningsgivende og være gjenstand for vurdering i hvert enkelt tilfelle.

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Datasheet 1015 N	
Date	13.08.2008

MICOREA S2/S3/S4

PRODUKTBESKRIVELSE: Micorea er et tokomponent polyurea system for spray applikasjoner med to komponents spesialsprøyte. Produktene kan fås i flere varianter,bla S2,S3 og S4. Micorea herdner på noen sekunder. Spesialsprøyteutstyret må bestå av oppvarmede slanger og sprayes under høyt trykk.

ANVENDELSESOMRÅDE: Micorea er velegnet som høyelastisk membran under støpeasfalt eller fliser eller som belegg i hardt belastede miljøer som P-hus, lager og produksjonslokaler og katastrofebassenger. Micorea også benyttes på stål.

EGENSKAPER: Micorea er et elastisk system med sprekkoverbyggende egenskaper. De ulike variantene S2,S3 og S4 har ulike egenskaper mhp elastisitet og andre tekniske egenskaper.

FORBEHANDLING: Avfetning og sliping/fresing eller slyngrensing, samt omhyggelig støvsuging. Stål sandblåses til SA 2 ½.

BLANDING: Komponentene A + B blandes i pistolmunnstykket.

PRIMING: Betongoverflater påføres Micopox WP (ca. 0,2 kg/m^2), Micorea påføres deretter innen 24 timer.

PÅFØRING: Påføres med egnet sprøyteutstyr av spesialentreprenør i ønsket tykkelse. For vanntetting anbefales en tykkelse på min 2 mm.

RENGJØRING: Verktøy rengjøres med aceton eller Micorens.

MILJØ OG SIKKERHET: Se HMS datablad.

TEKNISKE DATA:

Micorea	**Micorea**	**S2**	**S4**	**S3**
Leveres i 200 kg fat	Strekkfasthet, MPa 23C	25,5	20	25
Blandingsforhod(A : B) 1:1	-20 C	32,5		37
Tørrstoffinnhold 100 %	Bruddforlengelse, %, 23C	440	300	380
Lagring: Oppbevares tørt og frost-	-20 C	155		154
Fritt og beskyttet mot direkte sollys.	Rivfasthet, N/mm, 23 C	60	100	75
Holdbarhet: Min. 12 mdr.	-20 C	122		
	Shore A	93	97	92
	Shore D	45	60	45
	Gel tid, s	10	2	3
	Klebefri etter, s	18	5	7

Spesielle opplysninger: Malkode: 00-3 (1993) Produktnr. Comp A: Produktnr. Comp B:
Opplysningene I dette datablad er basert på våre nåværende kunnskaper og erfaring og må betraktes som retningsgivende og gjenstand for Vurdering I hvert enkelt tilfelle.

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Appendix E

stirling lloyd
THE TECHNOLOGY OF PROTECTION

CI/SfB

PRODUCT DATASHEET

stirling lloyd mma resins

CHEMICAL RESISTANCE OF MMA SURFACE COATINGS

Surface coatings made from Stirling Lloyd's Methyl Methacrylate (MMA) resins are highly resistant to attack from a wide range of chemicals. They provide excellent protection against spills and leakages of organic and mineral acids as well as alkalis.

Our test procedure involves the immersion of an unfilled, polymerised specimen in the test medium at 23°C. After 4 weeks of storage its tensile strength is tested. The rating 'resistant' stipulates that the tensile strength readings may not deviate by more than 20% from those of a control sample stored in air at 23°C.

The ratings given should be considered as general guidelines only. The resistance properties of a finished coating are influenced both by pigments and fillers used and by fluctuations in temperature. Furthermore, it may be affected more severely if exposed simultaneously to two or more chemicals.

Rating:
+ Resistant
o Partly resistant
- Not resistant

1	**Water**		
	Distilled water		+
	Salt water		+
2	**Alkalis**		
	Ammonia	10%	+
		30%	o
	Caustic Soda	10%	+
		30%	+
		50%	+
	Potassium Hydroxide	10%	+
		30%	+
		50%	+
3	**Acids**		
	Acetic Acid	10%	+
		30%	o
		80%	-
		conc.	-
	Chromic Acid	10%	+
		20%	+
		40%	-
	Citric Acid	10%	+
		30%	+
	Formic Acid	10%	o
		30%	-
	Hydrochloric Acid	10%	+
		30%	+
		conc.	+
	Lactic Acid	10%	+
		30%	+
	Nitric Acid	10%	+
		30%	o
		conc.	-
	Oxalic Acid	10%	+
	Phosphoric Acid	10%	+
		40%	+
		conc.	o
	Sulphuric Acid	10%	+
		30%	+
		50%	o
		conc.	-
4	**Salt Solutions (saturated)**		
	Ammonium Chloride		+
	Ammonium Sulphate		+
	Calcium Chloride		+
	Potassium Chloride		+
	Sodium Carbonate		+
	Sodium Chloride		+
	Sodium Hypochlorite	15%	+
	Sodium Sulphate		+
5	**Petrochemicals**		
	Crude Oil		+
	Diesel Fuel		+
	Gasoline, high octane		o
	Gasoline, normal octane		o
	Kerosene		+
	Mineral Oil		+
	Paraffin Oil		+
	Petroleum		+
	White Spirit		+
6	**Solvents**		
	Acetone		-
	Benzene		-
	Butanol		-
	Butyl Acetate		-
	Butyl Ether		-
	Carbon Tetrachloride		-
	Chloroform		-
	Cyclohexane		+
	Ethanol		-
	Ethanol	30%	+
	Ethyl Acetate		-
	n-Heptane		+
	n-Hexane		+
	Isopropyl Alcohol		-
	Cresol		-
	Methyl Ethyl Ketone		-
	Perchloroethylene		o
	Phenols		o
	n-Propyl Acetate		-
	n-Propyl Alcohol		-
	Styrene		o
	Turpentine		+
	Toluene		-
	Trichloroethylene		-
	Xylene		-
7	**Natural Oils & Fats**		
	Animal Fats		+
	Castor Oil		+
	Linseed Oil		+
	Olive Oil		+
	Vegetable Fats		+
8	**Disinfectants & Cleansers**		
	Calcium Chloride		+

MA216 Chemical Resistance of MMA Surface Coatings Issue 3
Page 1 of 2

Appendix F

Utgåva 070505

7.1

Daboleum SF

Syrabeständiga gjutasfaltgolv

Användnings-område:	Lokaler där syror förekommer t.ex. ackumulator och eloxerings fabriker, mottagningshallar för mjölk och boskap, stall, hund-gårdar m.m.
Utseende:	**Daboleums** utséende är mörkgrå.
Miljö:	Vattentätt, ljuddämpande, dammfritt, lättstädat, slitstarkt, hygieniskt samt behagligt att gå och stå på.
Materialval:	**Daboleum SF**: Syrabeständig gjutasfalt 18-25 mm alt. 2*18-25 mm. **Beta S-fog** : Polymermodifierad asfaltfogmassa. **Beta Broprimer**: Kallasfaltprimer. **Betaspackel**: Polymermodifierad asfaltmassa för avjämning.
Utförande:	Primering utföres med **Beta Broprimer** längs väggliv, runt samtliga genomföringar, brunnar o.dyl. Primerad yta strykes flödigt med **Beta S-fog**. Beläggning utföres med 18-25 mm alt. 2*18-25 mm **Daboleum SF** på glasfiberfilt, ytan rives med sand alternativt valsas blank, eventuella skarvar brännes ihop.
Läggning:	**Daboleum SF** utlägges vid en temperatur av 220-250 C.
Underlag:	**Daboleum SF** kan läggas på alla solida underlag. Större ojämnheter justeras med betong, mindre (max. 20 mm) justeras med **Daboleum** alt. **Betaspackel**.
Tjocklek & Vikt:	18-25 mm / lager. 50-65 kg/m2 och lager.
Resistens:	**Daboleum SF** är resistent mot de flesta syror med vissa undantag (se resistenslista 7.1.3.).
Hårdhet:	**Daboleum-**massans hårdhet anpassas till objektets och verksam-hetens art och testas med stämpelbelastningsprov enl. DIN 1996.
Övrigt:	**Daboleum SF** utlägges med ca. 400 m2 / dag och kan med fördel utföras över en helg. Eftersom massan formas på plats kan man lägga runt maskiner och andra fast monterade detaljer. I lokaler med kraftig trafik alt. starka syror utlägges två lager med förskjutna skarvar för att undvika att syra och fukt tränger ner i underlaget.

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Appendix G

Warrior™ 260
Fast Cure Spray Elastomer System

The Hanson Group, LLC
900 McFarland 400 Blvd
Alpharetta, GA 30004
770.667.6111 (phone)

PRODUCT DESCRIPTION

Warrior™ 260 is the next generation phenolic. Superior physical properties, 100% solids, highly chemical resistant, extremely abrasion resistant, tough, two part elastomeric spray coating giving rapid and consistent cure in applications ranging from -20°F to over 400°F.

INTENDED USES

Warrior™ 260 is specifically designed to be used in demanding installations requiring an elastomeric coating with superior physical properties and very high durability in harsh chemical environments. Applications can normally be reopened to traffic and service in minutes.

-Secondary Containment Areas
-Waster Water Linings
-Mechanical Rooms
-Fertilizer Plants
-Pipe Line Coating
-Petroleum Prod. & Storage
-Refineries
-Tank Linings
-Digester Linings
-Pulp & Paper Mills
-Petrochemical facilities
-Cooling Tower Lining
-Oil & Gas Transmission

PRACTICAL INFORMATION

Advantages: Superior resistance to solvents, acids and bases | 100% solids, no VOC's | Flexible, 260% elongation | Excellent thermal stability | Shock resistant | Abrasion resistant | Low perm rate | Cures -20°F to 400°F | Return to service in 60 min. | High strength | Bridges moving gaps up to 1/16" W | Waterproofs | Accepts vehicular traffic

Physical Properties	Test Method	Value
Tensile Strength (psi)	D-638	5350
Elongation (%)	D-638	260
Tear Strength (pli)	D-624	730
Shore Hardness ("D" scale)	D-2240	62
Moisture Vapor Transmission	E-96	(perm. In.) 0.015
Abrasion Resistance (wt. Loss-mg.)		
H-18, 1000g, 1000 rev.	D-6040	43
CS-17, 1000g, 1000 rev.	D-6040	< 2
Flash Point, components (°F)		>200
Coefficient of Thermal Expansion (in/in/°C)		approx. 4 X 1- ^{4}
Gel Time / Tack Free		6 sec. / 30 sec.
Flame Spread	E-108	Class A (Comparable to UL 790)
Flexibility Test		
Gardner Impact, in.-lbs. (on 1/32" steel panels) Direct and Indirect	D-2749	
Mandrel Bend:		
Conical Bend (on 1/32" steel)	D-522	pass
1/4" Mandrel, 25°C (free film, 35-50 mils)	D-1737	pass
1/4" Mandrel, -20°C (free film, 35-50 mils)	D-1737	pass

CHEMICAL RESISTANCE COMPARISON
Warrior™ 260 vs. Polyurea

This chart compares the suitability of Warrior™ 260 with polyurea for use in secondary containment applications.

LEGEND

R: Recommended (no danger) C: Caution (some swelling, discoloration, cracking) R-8: Recommended with eight hour washdown
R-1: Recommended with one hour washdown N: Not Recommended

CHEMICAL	Warrior 260	Typical Polyurea	CHEMICAL	Warrior 260	Typical Polyurea
Acetic Acid, 10%	R	R	Methyl Ethyl Ketone	R-1	N
Acetone	R-8	N	Mineral Spirits	R	R
Ammonium Hydroxide, 20%	R	R	Motor Oil	R	R
Ammonium Nitrate	R	R	Nitric Acid, 10%, 20%	R	N
Ammonium Phosphate	R	R	Nitric Acid, 40%	R-8	N
Antifreeze (50% Ethylene Glycol)	R	N	Nitric Acid, 50%	R-1	N
			Phosphoric Acid, 10%	R	R
Battery Acid (Sulfuric Acid)	R	N	Phosphoric Acid, 25%, 50%, 85% (conc.)	R	N
Benzene	R-8	N			
Brine (saturated 130,000 ppm)	R	R	Potassium Hydroxide, 10%	R	R
Brake Fluid	R-1	N	Potassium Hydroxide, 20%, 50%	R	N
Chlorine (2,000 ppm in H_2O)	R	R	Propylene Carbonate	R	C
Citric Acid	R	R	Skydrol (aircraft hydraulic oil)	R-1	N
Copper Chromate Arsenic (4% working sol'n)	R	R	Sodium Chloride	R	R
			Sodium Hydroxide, 5%, 10% 25%	R	R
Diesel Fuel	R	R	Sodium Hydroxide, 50% (conc.)	R	C
Dimethyl Formamide	R-1	N	Sodium Hypochlorite (household bleach)	R	C
Gasoline - unleaded	R	C			
Hexane	R	R	Stearic Acid	R	R
Hydrochloric Acid, 5%, 10%	R	R	Sulfuric Acid, 5%, 10%, 20%	R	R
Hydrochloric Acid, 25%	R	N	Sulfuric Acid, 25%, 50%	R	N
Hydrofloric Acid	N	N	Sulfuric Acid, 98% (conc.)	R-1	N
Hydraulic Oil	R	C	Toluene	R-8	C
Isopropyl Alcohol	R	C	1,1,1 Trichloroethane	R-8	C
Lactic Acid	R	R	Trisodium Phosphate	R	R
Liquid Nitrogen Fertilizer (28-0-0)	R	R	Vinegar, (5% Acetic Acid)	R	R
			Water	R	R
Liquid Urea Fertilizer	R	R	Xylene	R	R
Methanol	R	C			

APPLICATION

Warrior™ 260 is a plural component, fast cure, spray phenolic co-polymer system. Equal volumes of parts "A" and "B" are proportioned and dispensed through high pressure, high temperature spray environment. Consult The Hanson Group for correct machine conditions.

Gel time 6 sec. Tack-free time 30 sec. Open to light traffic 60 sec. Open to chemical exposure 8 hr.

Bond Strength	(ASTM D-4541)	(primed substrate)
Concrete:	350-400 psi	(concrete failure)
Steel:	exceed 1200 psi	
Wood:	200-250 psi	(wood failure)

Color Availability: Black, Light gray, Dark gray and Beige. See standard color chart. Custom colors available at additional chare. See remarks on color retention.

Waste Refinery

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