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Chemical Resistance and Wear for Concrete Protection Systems to be used in Biological Treatment Plants – Laboratory Testing and Results

Ylva Edwards[1], Leif Fjällberg[1*]

[1]*Swedish Cement & Concrete Research Inst., Sweden*
[*]*Drottning Kristinas väg 26 SE – 100 44 Stockholm,*
ylva.edwards@cbi.se, *leif.fjallberg@cbi.se*

ABSTRACT

This paper describes a project regarding degradation and corrosion problems for concrete at biological treatment plants in Sweden. An initial study shows that concrete used in such plants cannot resist attack by leachate from food waste, and therefore needs surface protection. In a second project part, requirements specification was developed trying to ensure the function of such protection products and systems, together with concrete, in different parts of a plant. The third part of the project involves laboratory testing of different types of products possibly suitable for the protection of concrete in biological treatment plants. Performance parameters studied and tested in the laboratory are chemical resistance and resistance to wear. Chemical resistance concerns acidic leachate water at temperatures up to 70°C. The laboratory study involves epoxy, polyurea, polyurethane, methyl methacrylate, vinyl ester, bituminous products and silica. Results and experience are reported, showing significant differences between types of material.

Keywords. Composting, corrosion, food waste, concrete, leachate

INTRODUCTION

A study on the degradation and corrosion of concrete in biogas and composting plants was conducted in 2009/2010 (Boubitsa, 2010). Results clearly show that concrete in such plants cannot resist attack by leachate from food waste in particular. Leachate test samples from a number of treatment plants were analyzed in the laboratory and found to be acidic, containing several aggressive chemical components with devastating impact on concrete. Furthermore, the temperature during food waste treatment will increase to around 70°C in the process. Mechanical abrasion from heavy vehicles in receiving halls also has to be considered.

Following this initial study, a State of the Art was produced (Edwards, 2010). Several manufacturers, experts and contractors were contacted in the project concerning possible products and technologies for the protection of concrete in such plants. Literature was reviewed as well as specifications and testing methods for similar fields of application. In particular, chemical resistance and wear resistance were focused on. Test liquid, corresponding to leachate, and test procedures were proposed. Furthermore, a number of systems were recommended by manufacturers in the project. Possible technologies are based on bituminous materials, epoxy, polyurethane, polyurea and acrylates (MMA). Three systems, already used in Swedish biological treatment plants, were compared regarding reported characteristics, performance and testing by the producer. Finally, test program and specification were proposed. Laboratory testing of chemical resistance and resistance to wear, specifically for the environment in these plants, was suggested as well. However, test methodology had to be evaluated and verified in yet another study (Edwards, 2012).

Consequently, the aim of the laboratory study was to evaluate and validate the proposed testing methodology based on laboratory tests on selected products and systems. The methods concern resistance to leachate, in combination with high temperature, and resistance to wear. Testing was carried out in collaboration with manufacturers and contractors. The specification shall apply specifically for surface protection systems used on concrete in biological treatment plants, and be used as a basis for the selection of appropriate materials as well as to facilitate a comparison of different systems. It also makes it easier for manufacturers and contractors to report the expected properties for a certain area of use. The project is expected to be followed by field testing at one or several appropriate plants. With the right products and protection of concrete in biological treatment plants, the plant life will be significantly prolonged, and costly concrete repairs avoided.

Damaged floor in reception hall for food waste is shown in Figure 1.

Concrete degradation. Concrete is a strong, durable and comparably cheap building material. Within certain areas of use, it may, however, need protection. Reasons for this could be limited resistance to chemicals, or its porosity/permeability. Pre-treatment of the concrete surface is very important prior to applying any surface coating. Depending on concrete surface quality, different types of cleaning or adjustment may be necessary, such as grinding, milling, blasting, crack sealing etc. Laitance and curing compounds must always be removed from fresh concrete surfaces.

There are a variety of grades and fields of application for concrete. In recent decades, the development of new additives and materials made possible entirely new types of concrete. Self-compacting concrete (SCC) is such an example, using flow improvers/super plasticizers as a very important component. In spite of great improvements of concrete quality, the penetration of certain chemicals cannot entirely be avoided, as all concrete has a tendency to crack, and it is not possible to produce a completely crack-free concrete surface.

Concerning exposure classification and risk of corrosion, eighteen different classes within six different types of exposure are defined in EN 206-1:

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 from sea water (XD1, XD2 and XD3)
4. Corrosion induced by chlorides from seawater (XS1, XS2 and XS3)
5. Freeze/thaw attack with or without de-icing agents (XF1, XF2, XF3 and XF4)
6. Chemical attack (XA1, XA2 and XA3)

In the case of exposure 6, chemical attack in soil and ground water at temperatures between 5 and 25 °C is referred to. XA3 is described as highly aggressive chemical environment according to some specified conditions, and the most onerous value for a single chemical component determines the class. Fields of application for concrete in aggressive chemical environment are bridges, garages and parking decks, animal stables and biological treatment plants.

In the initial study of the project, chlorides, organic as well as inorganic acids, ammonia, and ammonium ions were identified in leachate from food waste. They are all aggressive to concrete.

Figure 1. Damaged floor in reception hall for food waste (photo: Mattias Persson, Atleverken)

EXPERIMENTAL

Protection products and systems used in the laboratory study (Edwards, 2012) are listed in Table 1. In addition, a special acid resistant concrete (AB) was tested as well, and a silica product (SI) used for the protection and strengthening of concrete.

Table 1 – Products used in the laboratory study

Id	Type of product	Intended Use	Measured thickness (mm)
1G	Bitumen sheet and Mastic asphalt (PGJA)	Floor	25
2G	Bitumen sheet and Mastic asphalt (PGJA)	Floor	25
3G	Polyurea	Floor	8
4G	Vinyl ester	Floor	8
5G	Polyurethane	Floor	5
6G	Epoxy	Floor	3
8VT	Polyurea	Wall/Ceiling	7
9VT	Polyurea	Wall/Ceiling	3
10VT	Vinyl ester	Wall/Ceiling	1
11VT	Polyurea	Wall/Ceiling	2
12VT	Epoxy	Wall/Ceiling	1
13VT	MMA	Wall/Ceiling	4

Chemical resistance was tested using methodology based on EN 1504-2 and EN 13529. A pilot study was performed in order to find the suitable equipment and procedure for this specific type of exposure. Suggested and used test liquid, corresponding to leachate from food waste, is composed as follows:

- Acetic acid 2.0 %
- Chlorides 0.5 %
- Phosphates 0.2 %
- Ammonia/ammonium ions 0.2 %
- Calcium 0.8 % (for hardness ca 20)
- pH 4.0

Test slabs (surface protection applied on specified concrete slabs) were exposed at 70°C for 28 days. Surface tensile bond testing was performed after the exposure, and compared to test results for not exposed test slabs.

Resistance to wear was tested according to EN ISO 5470-1 (ASTM 4060 Taber Abraser test) and methodology according to EN-13892-5 (Rolling Wheel Abrasion, RWA).

Adhesion to concrete varied significantly for the different types of systems. For not exposed systems, adhesion values were between 0.6 and 3.8 MPa. After exposure, these values generally decreased. Best results were measured for systems 5G, 6G and 12VT. Test slabs with system 5G are shown in Figure 2.

Figure 2. Test slabs with system 5G after pull-off testing, without exposure (left hand picture) and after exposure (right hand picture)

Wear resistance varied as well. Best RWA results (low wear and no visible kneading effects) were shown for products 3G and 6G. For PGJA systems and 4G, this test method seems less suitable, due to kneading effects, and therefore may have to be discussed further. Best Taber Abraser results (low wear) recorded in the study are shown for products 8VT and 9VT. Test slab of mastic asphalt (PGJA) before and after testing is shown in Figure 3.

Figure 3. Test slab of PGJA before and after testing according to EN 13892-5

All test results are shown in Table 2. For different reasons (not relevant or not possible), testing was not performed in all cases. Ranking of products is not part of this study.

Table 2 – Test results for chemical resistance and wear

	Adhesion (MPa), Mean		Abrasion, Mean	
Id	Original	After exposure	Taber (mg/100 cycles)	RWA (cm^3)
Ref*	3.7	Not exposed	Not performed	Not performed
1G/2G	0.6	0.5	Not performed	Kneading effects
3G	2.0	0.6	Not performed	-2
4G	1.7	0.5	Not performed	-52
5G	3.2	2.5	95	90
6G	3.5	2.6	69	8
8VT	2.8	2.0	25	Not performed
9VT	0.8	0.7	18	Not performed
10VT	2.6	Cracked and loose	97	Not performed
11VT	2.9	1.0	(ca 10 acc to producer)	Not performed
12VT	3.8	3.5	(ca 12 acc to producer)	Not performed
13VT	2.0	1.3	56	Not performed
AB	4.1	3.6	Not performed	128
SI	4.6	3.4	Not performed	Not performed

* Reference concrete slabs without surface protection

CONCLUSIONS

Methodology for testing the resistance to leachate and wear, respectively, has been evaluated by laboratory testing of a number of products and systems intended for floors or walls and ceilings in biological treatment plants. The study has resulted in the following:

- New methodology for the resistance to leachate based on SS EN 13529.
- Proposal of existing methods (SS EN ISO 5470-1 and SS EN 13892-5) for the determination of wear resistance has been presented, with accompanying selection of appropriate test parameters depending on the intended use in a waste treatment plant. Gaps and needs for further studies in terms of wear resistance and methodology for determining this have been identified.
- New specification for waterproofing and protection coatings on concrete in biological treatment plants and associated methods has been proposed.
- New knowledge and experience about the product properties and test methods have been developed within the project. Knowledge transfer between different operators and industries has been carried out through fruitful discussions, meetings, reports and seminar.
- Suitable products and protection of concrete in biological treatment plants are expected to contribute to a more sustainable facility with a longer lifetime without costly concrete repairs, less damage, less maintenance, less costly interruptions and less exchange losses.

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