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The Recent Progress of Protecting Engineering for Cement Concrete

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ABSTRACT

One of key factors with concrete durability is environments resistance.

To protect concrete from environments penetration from the surface side to inside of concrete, glass flakes blocking technology has been studied and tried to apply concrete in lining films. It is expected that this system will perform effectively in sewage facilities where corrosion is a key issue.

Keywords. Vinyl Ester, Glass Flake Lining, Heavy Duty Lining, Sewage Works, Crude-oil Stock Tanks

Introduction

Today, a large number of cement concrete buildings have been built to be held them durable as valuable social properties. Substantially, cement concrete are alkaline and easy to be attacked by acids. Accordingly, protecting materials should be chemically resistant to both alkaline and acidic environments. From this point of view, two kinds of resins are selected, one is epoxy resin and the other is epoxy methacrylate resin or vinyl ester resin. With these resins, the authors at Plastics Lining Association, developed “heavy duty anticorrosion plastic lining” for concrete constructions.

In actual those processing methods are coating, resin mortaring. FRP lining and flake lining, of which performance of heavy duty are specially designated and applied. The heavy duty performance is much widely required in the fields of electric power stations, steel works, nonferrous metal industries, metal surface treatments, chemical industries, oil, paper-pulp and so forth as well as public enterprises.

The authors will report about their technology, what heavy duty performance is, how to make it and for which equipment and facilities this technology and engineering are suitable. The most suitable facilities are waste water treating unites and sewage plants.

Metal surface treating plants need heavy duty anti-corrosion floors in protecting their cement concrete layers from corrosive environments. In terms of this, plant floors need similar protecting linings. Tank yards are other applications where not only chemical resistance but also weather ability is necessary.

As conclusion, cement concrete protection with plastic linings have made a good progress in technologies and engineering. The authors will touch their future prospects.

Methodology ― the problems and their solutions.

As mentioned above, this paper reports focusing on the case of waste water treating unites and sewage plants.

To respond to the requirement of longer service life with sewage systems, studies from both theoretical and practical are helpful to strategic solution for finding work.

To realize a satisfactory solution in corrosion, first, we have to touch about what corrosion control is.

The definition for anti-corrosion (corrosion control) with lining

Historically, indeed, the issue has been discussed and its result has found a sort of trade-off relationships between “affordable cost” and “length of service life”. However, we need to clarify more what is real and ideal anti‐corrosion control from view point of product reliability.

Anti‐corrosion lining layers are a sort of barriers to chemicals, environments and so on. The illustration is shown in Figure1 where you can see comparison of anti‐corrosion to water proofing.

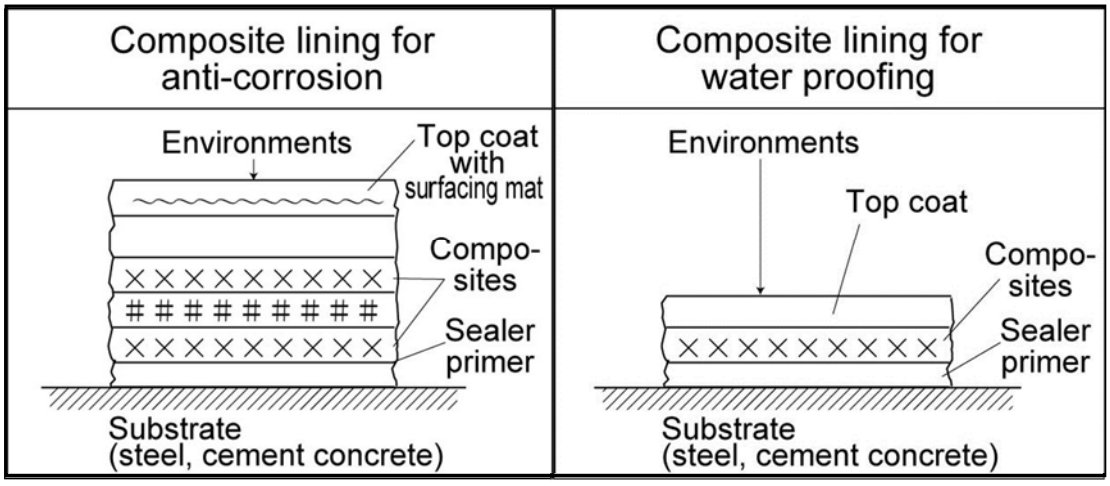

Figure 1. Composite linings for anti-corrosion and water proofing

Additionally, as you see in Table 1, this ASTM says the difference between water proofing and anti-corrosion, even though, a definition for lining can't be found in it.

Therefore, the authors are thinking that there is no limitation of film or sheet thickness about lining. The role of anti‐corrosion must be a perfect barrier layer not to let environments penetrate into the deeper layer close to the surface of substrate.

Table 1. Degrees of their duties in performance,

Terms for degrees	Definitions of service environments
1. Mild Service (Regular coating)	Indoor or protected out door areas not subjected to rain, dew or corrosive elements, or both.
2. Moderate Service (Water proofing)	Areas subject to weather away from costal or corrosive industrial environments or both.
3. Severe service (Anti‐corrosion)	Corrosive/erosive environments including coastal salt laden atmosphere, industrial atmosphere, and high intensity sunlight.
4. Immersion service (Anti‐corrosion)	Wetted surface of tanks, containers, pits, etc. and surfaces that are normally wet by condensation or exposed to other corrosive environments.

ASTM D5161-96: Standard Guide for Specifying Inspection Requirements for Coating and Lining work (Metal Substrates) Annual Book of ASTM Standards 2004 (Vol.06.02).

Corrosion control and Quality standards

JSWA (Japan Sewage Works Agency) has tried to define those corrosion problems evaluating and grating into several degrees such as class A to Class D as shown in Table 2 (JSWA, 2007).

Table 2. Class A to Class D

Classes	Definitions
A	Relatively richer H_2S gas, but not so corrosive
B	H_2S gas little remains and not so strongly corrosive
C	H_2S gas much remains and strongly corrosive
D	In C Class environment, the facilities / Parts harder to make maintenance work such as repairing.

Table 3. The quality standards for coating type lining process

Quality Standard / Items	Class A	Class B	Class C	Class D_1
Lining appearance	No wrinkling, inconsistency, delaminating and cracking	(The same as shown in left)	(The same as shown in left)	(The same as shown in left)
Adhesion with concrete	Standard state ＞ 1.5 MPa Wetting state ＞ 1.2 MPa	(The same as shown in left)	(The same as shown in left)	(The same as shown in left)
Acid resistance with lining	No swelling, cracking, softening and solution after 30 days immersion in pH 3 H_2SO_4	No swelling, cracking, softening and solution after 30 days immersion in pH 1 H_2SO_4	No swelling, cracking, softening and solution after 45 days immersion in 10% H_2SO_4 solution	No swelling, cracking, softening and solution after 60 days immersion in 10% H_2SO_4 solution
Sulfur penetrating depth	————	————	The depth must be less than 10% to designed thickness and less than 200μm after 120 days immersion in 10% H_2SO_4 solution	The depth must be less than 5% to designed thickness and less than 100μm after 120 days Immersion in 10% H_2SO_4 solution
Alkali resistance	No swelling, cracking, softening and solution after 30 days immersion in saturated $Ca(OH)_2$ solution	(The same as shown in left)	No swelling, cracking, softening and solution after 45 days immersion in saturated $Ca(OH)_2$ solution	No swelling, cracking, softening and solution after 60 days immersion in saturated $Ca(OH)_2$ solution
Moisture permeability	＜ 0.30 g	＜ 0.25 g	＜ 0.20 g	＜ 0.15 g

[Source : Japan Sewage Works Agency, Guide and Manual.]

Table 4. The quality standard for sheet type lining process

Items \ Quality Standard		D_2
Lining appearance		No wrinkling, inconsistency, delamination and cracking.
Fixing with concrete		＞ 0.24 MPa
Acid resistance		No blistering, cracking, softening and solution after 60 days immersion in 10% H_2SO_4 solution.
Sulfur penetrating depth	Sheet portion	The depth must be less than 1% to the designed thickness after 120 days immersion in 10% H_2SO_4 solution.
	Joint portion	The depth must be less than 5% to the designed thickness and less than 100μm after 120 days immersion in 10% H_2SO_4 solution.
Alkali resistance		No blistering, cracking, softening and solution after 60 days immersion in saturated $Ca(OH)_2$ solution.
Moisture permeability		＜ 0.15g

[Source : Japan Sewage Works Agency, Guide and Manual.]

Heavy duty performance in corrosion control

As seen in the case D_1 (Table 3), a protective lining must have almost no penetrating depth against H_2SO_4 solution. Hopefully, for this purpose, "Glass flakes vinyl ester resin lining films" (JIS K 6940, 1998) has established (PLA-R-501-93, 1993). This JIS K 6940 is a fundamental standard on which applied practices can be developed.

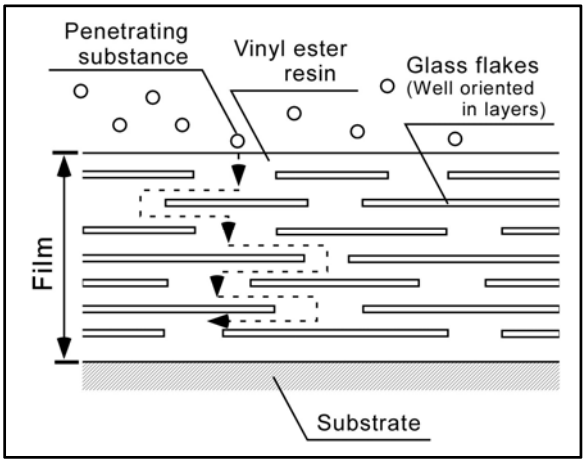

Figure 2. A schematic section view of glass flakes film (flakes oriented)

The principle can be described as follows: (1) Vinyl ester resin (liquid) which has an excellent anti-corrosion performance, (2) glass flakes (very small glass films in size and thickness like fish flakes) and (3) small amount of some additives are mixed to be a compound which are coated on substrates and cured on them (Figure 2). When coating, those glass flakes get so well oriented as to be effective barriers against penetrating environments such as H_2SO_4 (Sulfuric acid).

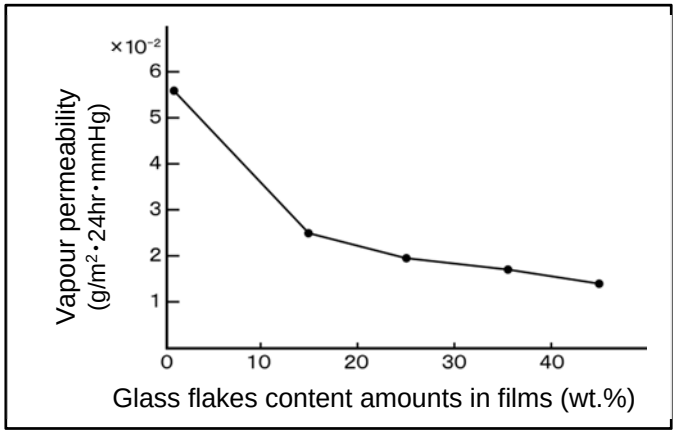

Figure 3. The relationships between "Glass flakes content amounts in films" and "Vapor permeability"

Based on this principle, two types of heavy duty lining have been developed as shown in Table 5.

Table 5. Two types of glass flakes vinyl ester resin lining films

Items / Types		Film thickness	Environmental temperature applicable	Applications mostly used
Type 1		2.0 mm	＜90℃ (Liquid phase)	FGD, Towers/Tanks for flue
			＜130℃ (Gas phase)	Towers/Tanks for water treatment and acid/alkali
Type 2	A	600 μm	＜60℃	Oil tanks, Sea water tanks, Water tanks
	B	400 μm	＜40℃	

Concrete protection

In case of most serious condition like D_1 with "coating by hand", in general, an usually recommendable specification is shown in Figure 4 (Nomaguchi, 2005, 2009).

This design concept is relatively conventional that chemical resistance performance and film thickness are taken into account on. So, for long period of time, the environment could

penetrate and permeate into the film deeply to another side of surface where concrete faces against.

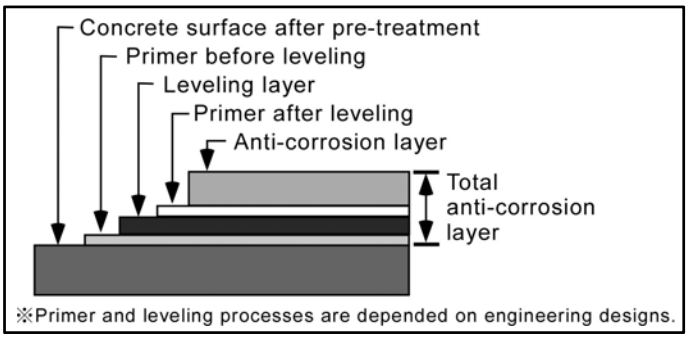

Figure 4. A schematic section view of currently applied Protecting lining in general (a sample case)

To solve the problem of permeation of environments, glass flakes blocking technology has been chosen and tried to apply for anti-corrosion layer for concrete. This technology has been successful in applying to metal substrates and studied by Dr. Masatoshi Kubouchi at TIT (Kubouchi, 2012). The authors have been trying to develop it as heavy duty anti-corrosion lining technology for concrete and it is going on.

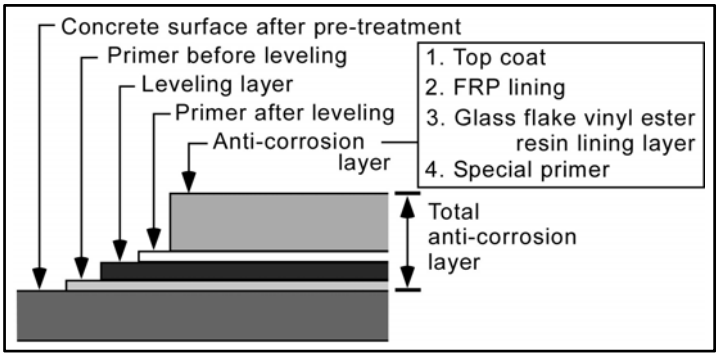

Figure 5. Heavy duty anti-corrosion lining for sewage (Applied with glass flakes vinyl ester resin lining film in it, under studying)

Discussion and Perspectives

The word of "lining" suggests its film is much thick enough not to be permeated through the film to another side surface, while, in case of "coating", it might happen. Blocking with "glass flakes" is strengthening the performance of lining. The authors are studying to develop these technologies and engineering improving processes.

Conclusion

Cement concrete protection with plastics lining have been made a good progress in technologies and engineering.

(1) Glass flakes vinyl ester resin lining film technologies are helpful to protect concrete structures from corrosive environments by "blocking effect".

(2) To get sufficient effects with glass flakes, skill on making well-oriented flakes is necessary from their blocking performance point of view.

(3) To promote concrete durability, lining systems including (a) pre-treating on concrete surface, (b) primer, (c) leveling, (d) primer after levering and anti-corrosion layer of glass flakes vinyl ester resin are importantly designed.

(4) Top coating is also key technological issues in corrosion control engineering.

Acknowledgement

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