CORROSION AND REHABILITATION OF CONCRETE ACCESS CHAMBERS

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ABSTRACT

Concrete pipes and structures are an integral part of all sewerage systems. They are however susceptible to corrosion which, if not addressed, can ultimately lead to a failure of the system.

Concrete Access/Inspection Chambers are some of the assets where corrosion can occur, however it has also been observed within concrete pipes, sewerage pumping stations and sewerage treatment plants. These assets represent considerable financial investment by those in the water industry and need to be well maintained to obtain maximum operational life.

Since 1995 Barwon Water has employed various techniques to restore corroded Access/Inspection Chambers. This paper discusses the corrosion process and briefly outlines the various products/processes used at Barwon Water to undertake the rehabilitation of Concrete Access/Inspection Chambers.

KEYWORDS

Access/Inspection Chambers, Rehabilitation, Sewerage, Corrosion, Concrete, Reticulation, Hydrogen Sulphide, Sewerage Treatment Plants (S.T.P).

1.0 INTRODUCTION

The construction of reticulated sewerage systems has generally involved the utilisation of concrete pipes and Access/Inspection Chambers, both "cast in situ" and pre-cast types, of various sizes. The Access/Inspection Chambers, or more commonly called manholes (M.H), have been installed at different locations within a reticulated system to provide access to the sewerage system.

In most cases inspections have found that Access/Inspection Chambers at Barwon Water are in good structural condition and have not deteriorated noticeably. There are however, silent but effective agents acting within a reticulated sewerage system that can adversely effect these structures. In some cases the speed and degree of deterioration, to a point of failure, can be a fraction of the normal life expectancy of the concrete.

It has been identified that some concrete chambers have been adversely effected by corrosion very quickly. For example, some new pre cast "sulfide resistant" Access/Inspection Chambers installed in April 1993, had by June 1997, corroded to a depth of more than 45 mm, i.e. greater than 50% of their original wall thickness.

This paper deals with the types of corrosion generally occurring in a sewerage system and those rehabilitation operations, materials and methods that have been utilized within Barwon Water's area of operation.

The rehabilitation works have been undertaken within both the reticulation and trunk sewerage system and at some sewerage treatment plants (S.T.Ps).

2.0 CORROSION

Corrosion is a result of a chemical reaction between a material (structure) and the surrounding environment, which leads to the deterioration of the mechanical properties of the structure. (Larfarge Fondu International – Circa 1995). The types of corrosion in concrete structures usually encountered in a sewerage system are described below.

2.1 Corrosion by sulphates - Calcium Sulphate Corrosion.

The corrosion of concrete by sulphates ($SO_4^{2\text{-ion}}$) is generally well known and documented.
Sulphates occur mainly in clay soils but can be present in "mud-stones" and in sulphated ground. The attack can be further aggravated by the additional presence of chloride ions.

Some examples of the principal minerals found are:

- Naturally occurring: $CaSO_4$. 2 H2O (Gypsum).
- In an industrial environment: (NH_4)2 SO_4, $CuSO_4$, $ZnSO_4$, $Al_2(SO_4)_3$, etc.

The difference between this type of reaction and those indicated in 2.2 & 2.3 is that the reaction is with the less stable minerals cement paste, notably $Ca(OH)_2$.

2.2 Acid Attack - Chemical attack by an acidic effluent, eg sulphuric acid (H_2SO_4)

The acid solutions in a sewerage system are often associated with industrial waste and effluent. It is therefore important to have an effective trade waste monitoring and regulation system in place as part of an overall strategy.

The equation below shows how the cement, lime with high pH, reacts with the acid to form salt and water. (Larfarge Fondu International – Circa 1995).

H_2SO_4	+	$Ca(OH)_2$	→	$CaSO_4$	+	$2H_20$
Sulphuric Acid		Hydrated Lime		Calcium Sulphate		Water
ACID	+	BASE	→	SALT	+	WATER

The salts produced can in some cases often protect the rest of the structure from further degradation, however this is dependent upon various factors including the nature of the effluent and flow characteristics of the system.

2.3 Bacterial Acid Corrosion - due to atmospheres rich in Hydrogen Sulphide (H_2S)

In general a sewerage system carries various inorganic and organic materials which can release sulphur. The sewerage contains sulphates, which are used by anaerobic bacteria in the slime layer to form sulfide in the form of hydrogen sulphide (H_2S) and is released through turbulence, eg. downstream of sewerage rising mains. When released the H_2S can either:

- Dissolve in water to form sulfurous acid or
- Oxidise to sulphur which is used as a feedstock by the bacteria to form sulphuric acid (H_2SO_4). It is this H_2SO_4 which attacks the concrete.

Although there may appear to be some similarities between the reactions that take place in an Acid Attack (2.2.2) and this H_2SO_4 type corrosion some of the differences are indicated below. (Larfarge Fondu International – Circa 1995).

- The H_2SO_4 acid produced is on damp surfaces of concrete and not in an acid solution.
- The amount of acid present is dependent upon the bacterial activity.
- The acid is produced at a microscopic scale. Corrosion is therefore extremely localised with concentration of acid and salts varying greatly from area to area.

3.0 CORROSION PREVENTION

3.1 Design Stage

If the potential for corrosion is known at the design stage and the concrete is to be exposed to this corrosion then appropriate protection should be provided. An example of this type of protection is the installation of "plastiline" on concrete surfaces at S.T.Ps.

3.2 Operational Level

Generally in most new sewerage systems it is unknown at the design stage what type of waste is to be discharged, particularly in those areas/estates that are targeted for industrial development.

Thus an inspection and monitoring program must be undertaken in those areas where there is a likely source of corrosion. This will then assist in identifying and allow priorities to be assigned.

As mentioned (2.2) another strategy is establishing trade waste agreements with industry prior to them being built and/or arranging with existing industries to comply with particular guidelines that, among other criteria, minimise those factors contributing to corrosion.

It may also be necessary to have special installations where chemicals, or other special agents, are added to the system to reduce those factors contributing to corrosion, eg. direct oxygen injection.

3.3 Replacement or Rehabilitation?

When a concrete structure has been identified as being severely attacked by corrosion the two (2) alternatives generally available to avoid complete failure are either replacement or rehabilitation.
In most cases replacement may not be an option due to operational or cost factors. Another important factor to consider however is when replacing the item, including material selection, the replacement item still needs to include protection against attack by corrosion.

Early detection of any deterioration of a structure requiring rehabilitation or protection can be advantageous in many ways. In particular, the early detection allows more options to be considered and rehabilitation can usually be undertaken with minimal impact on operation. Also, when the deterioration is detected and addressed early, the existing structure can often be utilised as a foundation for the rehabilitation process.

4.0 REHABILITATION METHODS AND MATERIALS.

Although there are many products and processes on the market it has become apparent that with the limited availability of "in house" resources there is a need for a different approach for any rehabilitation works undertaken at Barwon Water.

Some of the matters to be considered include what processes are available, what procedure is the most effective for a particular application, if cleaning is undertaken how it is achieved, if a coating is used how it is to be applied and tested. With this in mind contacts, were made with Melbourne Water and on site inspections of the rehabilitation works undertaken in the Spotswood area were held.

Initially it was agreed that Barwon Water would manage and coordinate on site trials and assist in the evaluation of a particular technique and/or contractor. In recent works undertaken, the approach has been that a contractor manages all the particular factors associated with the rehabilitation project to a particular procedure/specification and Barwon Water audits the works undertaken.
The concrete rehabilitation projects, excluding main replacement projects, that Barwon Water have undertaken since 1995 have been predominantly associated with concrete Access/Inspection Chambers within the reticulation and trunk sewerage system. There have however been some works undertaken at Barwon Water's sewerage treatment plants.

A summary of the rehabilitation works undertaken to date is shown in Table 1.

Table 1 : ***Rehabilitation Works Completed*.**

Location	Qty.	Product/System Used	Contractors/Applicator
Geelong Urban Reticulated System.	27	Epoxy "Super Epoc" Coating (18), PVC Lining (1), MacIntosh IM 10/8 coating (3), Incatec SL 98 coating (4), Lafarge "Sewpercoat" (1).	Enetech Streamline, Vic Pits, Incatec, GripSeal, Phil Morell.
Main Outfall between Geelong & Black Rock S.T.P.	43*	Epoxy "Super Epoc" Coating.	Enetech Streamline
Queenscliff/Pt Lonsdale	21#	Epoxy "Super Epoc" Coating (20). Lafarge "Sewpercoat" (1), Incatec SL 98 coating	Enetech Streamline, Incatec, GunForm.
Trunk Sewer between Drysdale/Clifton Springs and Leopold	34	PVC Lining (3), PolyPit 1100 mm I.D. poly manhole modules (16), Sealed Off (11), Inspection type (4)	Vic Pits, PolyPit.
Torquay Reticulation	7	Epoxy "Super Epoc" Coating.	Enetech Streamline
Black Rock Treatment Plant.	1	Epoxy "Super Epoc" Coating.	Enetech Streamline
Portarlington Treatment Plant.	1	Epoxy "Super Epoc" Coating.	Enetech Streamline
Anglesea Treatment Plant.	1	Epoxy "Super Epoc" Coating.	Enetech Streamline
Total	135		

* There are another 31 chambers to be rehabilitated using Epoxy "Super Epoc" Coating between March & December 2000.

\# There are another 12 chambers to be rehabilitated using either a "750 mm poly liner" or Incatec SL 98 between March & June 2000.

4.1 Lafarge Aluminates "Sewpercoat" Mortars.

The Access/Inspection Chambers where this type of coating was undertaken were on a joint project basis between the supplier of the product, Lafarge Aluminates Australia Pty Ltd, and Barwon Water.

The chamber selected was constructed in 1971 and is 4.5 metres deep on 300 mm diameter gravity main, 623 metres downstream of a 913 metre long rising main.

This chamber was not only severely corroded but also located in an area where traditional replacement options were very costly, and would have caused disruption and inconvenience to Barwon Water's customers.
The Lafarge product selected, "Sewpercoat" mortar lining, is designed to act as sacrificial lining but the benefits are that it slows down the corrosion process and can be used in situations where the structure integrity is at risk. Since completing the initial application in June 1995 the chamber has been inspected several times, including April 2000, and the coating appears to be performing as expected, ie. has deteriorated to a depth of 10 to 15 mm.

It has been estimated that the cost of the works was approximately $12,000. Due to the unique site conditions, eg. possibility of ground water, flow control measures, proximity of buildings, roads etc. that to excavate and replace this chamber would have cost in excess of $25,000.

In May this year another chamber was rehabilitated using this product and it is expected that the final costs will be less than $4000, whereas conventional excavation methods would have cost in excess of $10,000. In this project the coating was trowelled on which increased the labour costs. It is possible, however, that the product could be applied using spray on equipment but this equipment is not presently readily available.

4.2 PVC Lining

This method was initially undertaken in November 1997 on a trial basis as a joint project between Barwon Water and Vic Pits to a 3.4 metre deep chamber on a 2757 long, 375 mm dia gravity section of a trunk main. This main conveys sewerage from Drysdale/Clifton Springs to Leopold and this trunk main is downstream of a 7711 metre long, 375mm dia, rising main from Drysdale/Clifton Springs.

The pre-cast asset/inspection chambers on this line were installed in 1987 and approximately 8 years later inspections found many chambers to have suffered severe corrosion. It was found that some chambers had portions of concrete that had been completely corroded away.

Following investigations as to possible replacement and/or rehabilitation methods and associated costing it was decided to trial a PVC liner inside one of the 1200 diameter chambers. The liner was rolled into shape from PVC sheet and welded together to form the required shape/length. When the corroded concrete was removed using a portable water pressure cleaner, the PVC liner was inserted, and then held in place by a steel reinforced cage while a concrete grout was poured between the liner and the existing chamber. When set, the support cage was removed and a new lid installed.

To date there have been three (3) chambers rehabilitated on the above trunk main and one (1) on a gravity main in East Geelong. The benefits of this system are that it can be fabricated to suit almost any shape/depth chamber and is generally easy and cost effective to install.

To date the average cost of this type of work has been $3800 each, however it should be noted that there were high establishment costs associated with this method.

4.3 Moulded Polyethylene Lining.

- ***Standard Manhole Modules of 1100 mm I.D. from "PolyPit".***

These standard items are currently available from "PolyPit Pty Ltd" and the chambers rehabilitated to date have shown that these items provide a very practical solution.

This method has been employed on the Drysdale/Clifton Springs line, see above, where as mentioned the structural integrity of the chambers was questionable. In this case, after cleaning and modifications to the benching a standard poly chamber is inserted within the chamber.
The advantages of this method are that there is no need for a support cage, the lid is an integral component and the new chamber is ready made, easy to assemble and has its own structural integrity.

Following an initial trial, to date a total of 16 chambers have been rehabilitated using this method. It has been found that as a cost effective solution, this method is limited to those structures where the dimensions of the chamber allows a prefabricated relining product to be inserted. It could however be utilised in those situations where the chamber can be easily demolished and a completely new poly chamber installed in its place.

The 16 chambers rehabilitated using this method have been done at an average cost of $3200 each. This is less than the $5000 each it was estimated for replacement, however, no allowance has been made for any protection.

- ***Standard 750 mm Dia Ribbed poly Chamber - from "PolyPit".***

To date their have only been four (4) of these type of systems installed.

The concept of this method is again similar to that used in standard manhole modules. However, in this process a standard 750 mm diameter poly pipe is inserted into the chamber. One end of the pipe is modified to suit the standard poly access/inspection chamber lid/surround.

This system has the advantage that it can be used on chambers where structural integrity is required and other rehabilitation methods are not cost effective.

It can also be utilised on those chambers where future access is only intended for cleaning and/or inspection equipment.

4.4 Epoxy "Super Epoxy" Protective Coating.

Initially this method was undertaken on a chamber built in 1971 at Queenscliff, ie. immediately downstream of the chamber referred to in Larfarge Aluminates "Supercoat" Morters.

As demonstrated in Table 1, this method has been the most widely used protection system within Barwon Water's area of operation. The main reasons for this is that it is a spray on application and the contractor can offer both a product, application process and manage the works, ie. a "total system" approach. Also the product used has been shown to have performed well in other applications, ie. structures at Melbourne Water eg. the Spotswood S.P.S drop structure.

This high build spray on coating has been used on a wide range of chambers from those within the reticulation system to those on Barwon Water's outfall sewer. The quantity and scale of works have varied so a cost of this process has been difficult to determine. Generally the average cost of works has been in the range of $3000 each for reticulation chambers, to $7000 each for the larger outfall sewer chambers.

4.5 Incatec Polymer Cement Coating

This product was initially trialed on a reticulation chamber where the corrosion had only mildly effected the concrete. The spray on product has since been applied to other chambers and a white pigment added where corrosion is likely to occur ie. chambers at the end of rising mains.

To date the product appears to be performing satisfactorily. In order to test this product further it is intended to undertake further works on structures that have been adversely effected by corrosion. The average cost of the work undertaken to date has been $1500 each.

4.6 MacIntosh IM 10/8 Coating

This spray on product was initially trialed on reticulation chambers where the corrosion was in its early stages and/or had the potential to be effected by corrosion.

To date the product appears to be performing satisfactorily. The average cost of the work undertaken to date has been $1100 each.

5.0 CONCLUSIONS

There are various products and or methods available to assist in the rehabilitation of concrete access/inspection chambers. If applied correctly they can have an important impact on protecting the concrete structures that may be exposed to the effects of corrosion.

If using a coating type product, the preparation/cleaning process is fundamental to the success of the coating product. In particular, it is vital that all corroded material has been removed before applying any coating material to ensure that there is adhesion/bonding between the parent and coating materials.

When selecting a product/process allowance should be made for the extent of the corrosion, ie. the structural strength remaining following the removal of the corroded material.

Consideration should be given to how the product/process, particularly a coating type product, is to be tested/measured to ensure that when completed the success of the application can be quantified.

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