

THE STRUCTURAL REHABILITATION OF THE FISH WATER FLATS WASTEWATER TREATMENT WORKS IN NELSON MANDELA BAY MUNICIPALITY

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ABSTRACT

Service providers often operate facilities to provide water and sanitation services without an understanding for the need to perform integrity evaluations. Service providers can only achieve maximum service life from its assets, if proper maintenance rehabilitation strategies are followed.

The Fish Water Flats Waste Water Treatment Works (WWTW) situated in the Nelson Mandela Bay Municipality treats in excess of 100 ML/d of domestic and industrial wastewater. The facility is subject to a severely corrosive environment and the reinforced concrete structures have deteriorated significantly. This paper provides an overview of the condition assessment, rehabilitation strategy for the structures and a case study of the rehabilitation works undertaken.

INTRODUCTION

The Fish Water Flats WWTW, situated in the Nelson Mandela Bay Municipality is a conventional activated sludge treatment works originally commissioned in 1976 to treat 80 ML/day of domestic sewage and 32 ML/day of industrial wastewater. In 1997 extensions were constructed to increase the capacity of the industrial stream to 52 ML/day.

The original activated sludge reactors were upgraded to include biological nitrate removal in 2001-2002.

Concrete deterioration was noted to the aerator platform bridges in 1998 and the first extensive concrete rehabilitation works was undertaken simultaneously with the upgrade of the activated sludge reactors in 2002.



Figure 1: Typical severe concrete deterioration to an aerator platform recorded in 1998. Rehabilitation works to the structures were undertaken in 2001.

The plant will undergo future extensions to increase its capacity to 170 ML/day.

The scale and complexity of the works is demonstrated in Table 1 which summarises the principal process units and the total number of



Figure 2: Locality and layout of Fish Water Flats WWTW. The works are located within 350m of the Indian Ocean.

90 reinforced concrete structures currently provided for at the works:

The plant is a strategic facility for the Nelson Mandela Bay Municipality as it treats 70% of its waste water and will be a future strategic

Table 1: Summary of Processes and Structures at Fish Water Flats WWTW

Structure	No. of Structures	Structure	No. of Structures
Industrial Contact Tank	1	Thickener Pump House	1
Chlorination Control Room	1	Mixing Tower	1
Digester Pump Station	1	Heat Treatment & Pump House	2
Industrial Secondary Clarifiers	2	Oil Storage	1
Domestic Secondary Clarifiers	4	Consolidation Tanks	3
Sludge Return Pump House	3	FS Building	1
Storm Tank	1	Chemical Storage	1
Effluent Reservoir	1	Filtrate Tank (external)	1
Sub Station	7	Concentrated Sludge	1
Reticulation Pump House	1	Toilet Block	1
Workshop and			
Admin Building	1	Filter Building	1
Change Rooms	1	Hypochlorite Tank & Chlorination Building	2

Domestic Primary Clarifier	4	Domestic Contact Tank	1
Industrial Primary Clarifier	2	Chlorination Sample Room	1
Industrial Distribution Bell	1	Pump Station	4
Domestic Distribution Bell	1	Raw Sludge & RAS Pump Stations	2
Primary Sludge Pump House	1	Clarifiers	3
Valve & Gas meter Stations	2	Transfer & Digester Pump Stations	3
Distribution Channels	1	Gas Holder (external)	1
Sewerage Inlet Pump Station	1	Boiler House & New Structure	2
Screens, Stone Traps and Coneysors	3	Well	1
Detritors	1	Aeration Basins	7
DAF Units and			
Pump Station	3	Grit Hopper	1
Sludge Thickener	4		
TOTAL			90

thereby reducing the ability of the steel to form and maintain a passive insoluble oxide layer resistant to corrosion. Combined with moisture, carbon dioxide can produce carbonic acid which causes aggressive corrosion of metallic equipment and piping.

Chlorides

The Fish Water Flats WWTW is also situated along the coast line where salt laden sea spray results in concentration of chloride salts within the cover concrete to the reinforcing steel, thereby increasing the corrosive aggressiveness of the environment.

Depending on the localised concentration, treatment chemicals such as ferric chloride, sodium/calcium hypochlorite, aluminium sulphate, ferrous sulphate and sulphuric acid can cause further corrosion of concrete or ferrous metals.

Durable Concrete Design and Specification

The importance of low permeability concrete in combination with sufficient cover to reinforcing steel for a durable concrete, has become more evident during research performed during the period 1970 to 1990. Before this period, the focus for concrete quality control was more towards achieving strength combined with additional cover for aggressive environments.

Low permeability is an essential requirement to reduce ingress of aggressive substances (chlorides and carbonation), as well as moisture

and oxygen (both required to promulgate local corrosion cells on steel reinforcement). Permeability of concrete should not be confused with porosity. Both these measures are expressed as in terms of the hydrated cement paste (HCP).

Porosity of HCP = Voids / Solids Ratio

28% voids in HCP equates to Porosity = $28 / 72 = 0.4 = 40\%$

Whereas, Permeability is the degree of interconnectivity between capillary pores (not gel pores) within the HCP. When the cement hydration process is supported to completion with sufficient water curing, a discontinuous pore system is formed.

Durability Index Tests (28 days age) were developed in 1999 for South African construction industry by researchers Alexander, Mackechnie & Ballim:

- Oxygen permeability test – for permeation (Correlates to rate of carbonation)
 - Water sorptivity test – for absorption (Correlates to rate of Chloride ingress)
 - Chloride conductivity test – for diffusion (Correlates to rate of Chloride ingress)
- Typically, concrete specifications for durable design will focus on the following aspects –
- Minimising water/cement ratios
 - Moist curing for minimum 5 days (eliminating the use of curing compounds)
 - Cement replacement by fly ash (70% Cement/ 30% fly ash ratios is common)
 - Minimum cover to reinforcing steel 40mm (50mm for aggressive environments)

Time to Repair

The time to repair a structure is related to the time for corrosion initiation and the time for corrosion damage to reach a point at which the concrete becomes deteriorated where repairs are needed.

This is indicated schematically in Figure 3 based on a conceptual model by Weyers and Tuuti (from Bentur et al.) There is initial damage during construction which is repaired. Later on, corrosive elements migrate into the concrete for several years. When the corrosive element reaches a critical level for depassivation of the steel to occur, pitting corrosion is initiated. It takes several more years for corrosion damage to cause further concrete distress.

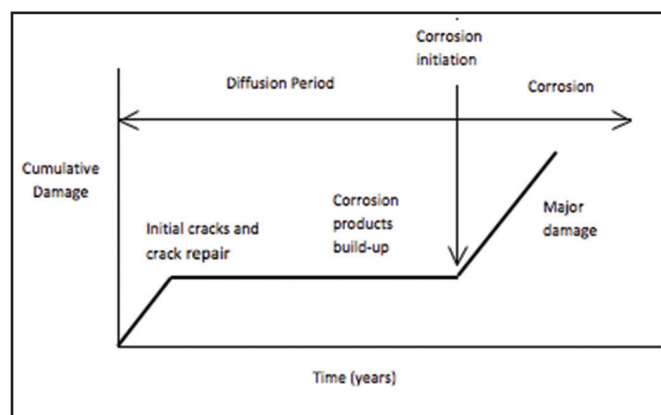


Figure 3: Schematic description of the corrosion process after Weyers and Tuuti.

The above concept illustrates that corrosion is not a linear progression but will dramatically accelerate once it is visually detected. It has been shown through case studies that the most economical strategy is to

Table 2: Durability Indexing as developed by Alexander et al.1999.

Durability Class (28 days)	O ₂ Permeability Index (log scale)	Sorptivity (mm/ hr0.5)	Conductivity (mS/cm)
Excellent	> 10	< 6	< 0,75
Good	9,5 – 10	6 – 10	0,75 – 1,50
Poor	9,0 – 9,5	10 – 15	1,50 – 2,50
Very Poor	< 9,0	> 15	> 2,50

prevent corrosion from occurring through adequate maintenance, timely detection and application of protection systems before major damage occurs.



Figure 4: Illustration of corrosion damage to roof parapet walls to Heat Treatment Building (2009).

Figure 4 illustrates the extent to which corrosion of reinforcing, once it has been allowed to promulgate far enough, will cause concrete structural damage.

Concrete rehabilitation is a labour intensive process which, in combination with the costs for access onto structures and the application of well researched proprietary materials, results in expensive repair projects. Figure 5 shows that the longer a structure is allowed to degrade, the repair costs escalates exponentially in terms of total rehabilitation costs per square meter of surface to be treated.

Figure 5: Graphic illustration of increasing costs associated with structural deterioration (2012).

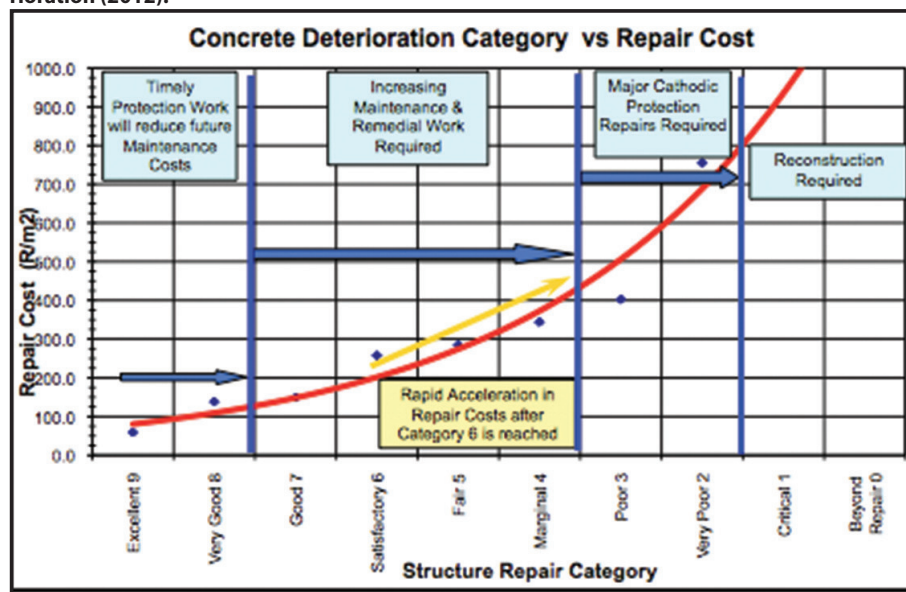



Table 3: Example of a record sheet for visual inspection conducted in 2008

A 48: Sludge Thickener No. 2		
	Defect	Photographic Plate No.
	Severe spalling to the external wall with exposed corroded rebar.	A48:1
	Spalling to the west side external wall. (failed patch repairs).	A48:2
	Spalling to the external wall. (failed patch repairs).	A48:3
	Cracking to roof slab.	A48:4

REHABILITATION STRATEGY

The primary goals of rehabilitation are returning the structure or equipment to its original; degree of integrity and installing a durable form of protective lining or coating system requiring minimal maintenance. In 1998, when severe concrete spalling and corrosion was first noted to the bridge structures supporting the aerators to the aerator basins, a report of the findings was compiled and the rehabilitation strategy adopted the following steps:

- Condition Assessment
- Design and Implementation

After the first concrete rehabilitation works was completed in 2002, the Municipality compiled a detailed condition assessment in 2008 for the planning of further rehabilitation works to the entire plant.

Further rehabilitation works were implemented in 2011 and 2013.

Condition Assessment

The condition assessment is a "health report" of the concrete infrastructure and determines the severity of any deterioration. Delaying or ignoring deterioration can have serious financial and operational impacts for the wastewater treatment works.

The condition assessment comprised of three main activities namely:

- Visual Assessment
- Diagnostic Testing
- Detailed Assessment

Visual Assessment

Visual inspections were carried out and all defects are recorded against photographic records. An example of such a visual inspection record for the sludge thickener no.2 is presented in Table 3.

Diagnostic Testing

Detailed diagnostic testing to the reinforced concrete structures was undertaken to determine the cause and extent of the concrete spalling and to quantify the risk of corrosion to the various structural elements.

The diagnostic testing included the following:

- More detailed visual inspections to the structural elements (including construction and expansion joints) and hammer sounding.
- Photographic records of those aspects considered necessary for comment.

- Diamond core sample extraction and determination of the carbonation level to the structural elements (where considered appropriate)
- Diamond core sample extraction and determination of the chloride concentration profile of the concrete.
- Cover meter surveys to the reinforcement to structural elements in limited areas randomly selected

Detailed Assessment

The detailed assessment report included the following:

- The annotation of the diagnostic test results to determine the cause of the concrete spalling, the levels of contamination and risk to the structures.
- Recommending the appropriate remedial strategy for the rehabilitation of each structure.

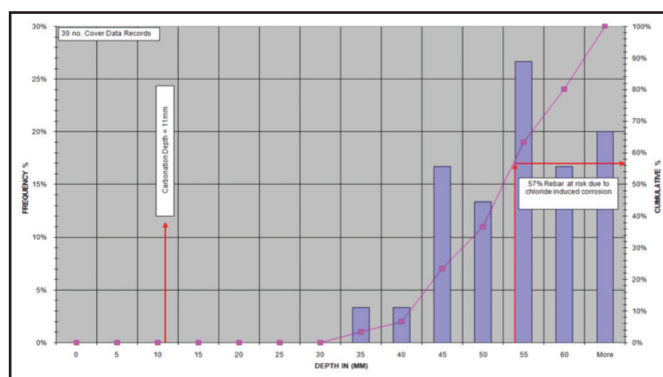


Figure 6: Typical statistical presentation of reinforcing steel cover survey overlaid with carbonation and chloride risk of corrosion.

A prioritised phased rehabilitation work programme totalling ZAR 29 500 000 was prepared in 2008 as outlined in Table 4.

Phase 1: 2008-2009	ZAR 9 000 000
Phase 2: 2009-2010	ZAR 7 000 000
Phase 3: 2010-2011	ZAR 7 500 000
Phase 4: 2011-2012	ZAR 6 000 000
Total	ZAR 29 500 000

Table 4: Proposed phased rehabilitation capital programme

Design and Implementation

Initial works

After the first structural assessment carried out in 1998, a rehabilitation contract was awarded by the Municipality in 2002 to implement urgent repairs to the aerator platforms. The cost of these works was ZAR 7.0 million and the scope of work included:

- Extensive cutting and breaking out of spalled and contaminated concrete
- Spall repairs with proprietary repair mortars
- Local thickening of the support columns in the aeration zone offering additional protection
- Installation of sacrificial zinc anodes
- Cementitious protective coating to the concrete surface.



Figure 7: Left: Rehabilitation underway in 2002. Right: Completed rehabilitation.

Phase 1 Works

Following the condition assessment completed in 2008, a contract for phase 1 rehabilitation works was awarded and completed in 2011 at a cost of ZAR 4.5 million. The contract comprised of repairs and maintenance work to:

- Heat Treatment Building
- Inlet Building
- Hypochlorite Tank (demolished)
- Thickener Pump House
- Substation No. 5
- Storm Tank

The works primarily comprised of:

- Surface Preparation (concrete surfaces) – high pressure water jet cleaning
- Spall Repairs – cutting and removal of delaminated reinforced concrete areas, preparing steel surfaces, application of repair mortars and crack injection chemicals,

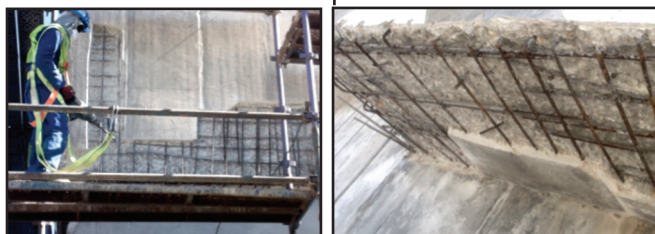


Figure 8: Cutting, breaking and preparing reinforcing steel for repair mortar application

- Apply migrating corrosion inhibitor which adsorbs onto reinforcing steel to protect against corrosion
- All concrete tiles and vertical concrete surfaces to receive a penetrating water repellent impregnation
- Apply protective coatings and decorative coatings both to external and internal walls.
- Sealing of floor and wall joints on storm tank using a flexible bandage joint sealing system.



Figure 9: Substation No. 5 building before and after rehabilitation



Figure 10: Thickener Pump House before and after rehabilitation



Figure 11: FS building before and after rehabilitation

Phase 2 Works

Phase 2 works were completed in February 2013 at a total cost of ZAR 6.5 million to the following structures

- Chlorination Sample Room
- Sludge Thickeners 1 to 4
- No 7 sub-station
- DAF pump station
- Primary sludge pump house
- Various other buildings

CONCLUSIONS

A wastewater treatment works is exposed to an aggressive corrosive environment from naturally occurring corrosive elements in the effluent and atmospheric environment. The corrosive environment leads to extensive degradation of its concrete and steel structures.

Timely condition assessments and maintenance are essential to intervene against future major structural damage and costly rehabilitation works.

The Fish Water Flats WWTW constructed in 1976, requires in excess of ZAR 40 million structural repair works which started in 2002 and resumed in 2011 to 2013. The works are not complete due to budget constraints preventing the maintenance backlog from being completed.

Plant owners need to recognise the need for asset management of structures to ensure that timely assessment, maintenance and rehabilitation are undertaken.

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