LODEMANN

EST. 2015

Consulting Engineers | Project Managers | Construction Managers

CONTRACT NO.: TNPA 722

PROFESSIONAL SERVICES TO UNDERTAKE THE INSPECTION OF BERTH 4 OF ISLAND VIEW FOR THE PORT OF DURBAN

ENGINEERING REVIEW REPORT

TRANSNET

national ports authority

LODEMANN

EST. 2015

REG. NO.: 2015 440 459 07 **VAT NO.:** 4400 2784 06 **CSD NO.:** MAAA 03566

HEAD OFFICE:
Suite 301 Wheeler House, 112 Mathews Meyiwa Road, Morningside, Durban, 4001
T: 031 826 9850 **F:** 0864 1616 48 **E:** info@lodemann.co.za

SATELLITE OFFICES:
- Midrand, Gauteng
- Nelspruit, Mpumalanga
- Cape Town, Western Cape

Approvals Table:

Name	Role	Signature	Date
Mhlengi Madiba (PrCPM. No: D/2404/2017)	**Project Manager**	[signature]	12/12/2018
Bazi Dukhan (Pr. No: 20070210)	**Structural Engineer**	[signature]	12/12/2018

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

SECTION 1

1. BACKGROUND AND CONTEXT

Berth 4 at the Island View Precinct is a chemical berth and was constructed by the joining of two mooring dolphins (built in the 1950's) via a pile supported concrete deck structure (built in 1986). The overall structure is thus over 65years old and is exhibiting some signs of deterioration (refer figure 1 and figure 2 below) on both the founding and deck structures. The impact of this deterioration on the structural integrity of the overall structure has not been assessed and hence, Transnet National Ports Authority (TNPA) have procured the services of a *Consultant* (Lodemann Holdings) to undertake a structural condition assessment of the structure.

Figure 1: Spalling of concrete on quay wall

Figure 2: Underdeck concrete spalling

2. INTRODUCTION

TNPA have procured the services of Lodemann Holdings, a professional engineering and project management services provider, to undertake the structural condition assessment of Berth 4 at the Island View facility. In order to conclude a professional opinion on the structural integrity of the berth, Lodemann undertook the following activities:

- Visual inspection of the above water concrete structures
- Diving inspection of the underwater concrete structures
- Surface diving inspection of concrete structures in the splash zone
- Extraction of concrete cores on the deck and pile structures, laboratory testing of cores and analysis of test results

3. SITE LOCATION

The site is located within the Island View facility at the chemical berth, Berth 4.

Figure 3: Arial view of Berth 4 within Island View facility

Berth 4 is located west of Berth 3 and East of Berth 5 in the inner entrance channel along the Bluff south walls within the Island View Channel and turning basin. It is surrounded by quay walls and sea walls from Island view berths 1 to 9 and along the Navy boundary adjacent to Island View. Figure *3* shows the aerial view of Berth 4. Figure *4* is a close up view of Berth 4 which shows the berth and the surrounding infrastructure.

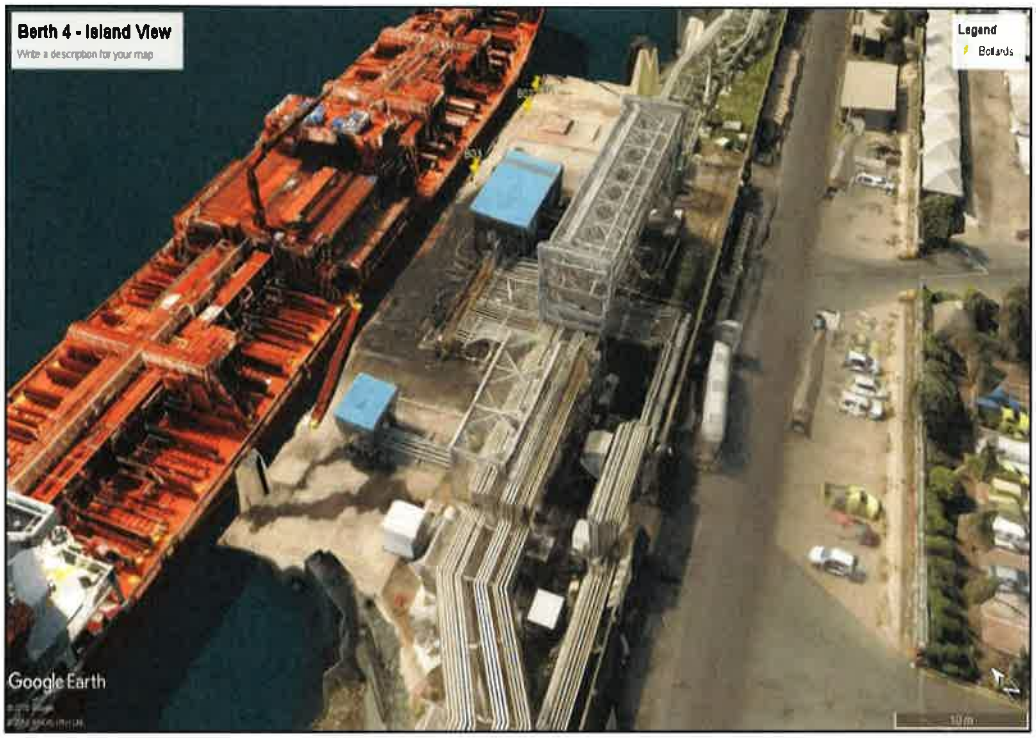

Figure 4: Berth 4 and surrounding infrastructure

A steel pipe rack is located to the south of the berth. This runs parallel to Wharfside Road. The revetment sea walls on either side of the berth consists of gabion walls that have overturned resulting in the hand stone being dislodged from the gabion baskets. A canopy structure houses a series of discharge manifolds supplying various chemicals to the ships docking at Berth 4. The structure is located more towards the western side of the concrete deck.

4. PREVAILING SITE CONDITIONS

- Altitude: At sea level
- Ambient temperature: 15-25 °C
- Relative humidity: Frequently 100%
- Air Quality: heavily saline; industrial and locomotive fumes;
- General wind velocities: Up to 60 km/h
- Storm wind velocities: Up to 180 km/h

5. APPLICABLE STANDARDS

The latest editions and/or revisions of the following are applicable:

- BS: British Standards
- ISO: International Standards Organisation
- SANS: South African National Standards

6. CODES

The latest editions and/or revisions of the following are applicable:

- BS 8007 – Water Retaining Structures
- SANS 1200 A – General
- SANS 1200 AH – General (Structural)
- SANS 1200 G – Concrete
- SANS 1200 H – Structural Steel
- SANS 2001-CC1 – Construction works – Part CC1: Concrete Works (Structural)
- SANS 2001-CS1 – Construction works – Part CS1: Structural Steelwork
- SANS 10100-1 – The structural use of concrete Part 1: Design
- SANS 10100-2 – The structural use of concrete Part 2: Materials and execution of work
- SANS 10144 – Detailing of steel reinforcement for concrete
- SANS 10160 – Basis of structural design and actions for buildings and industrial structures
- SANS 10162-1 – The structural use of steel Part 1: Limit-states design of hot-rolled steelwork
- SANS 10162-2 – The structural use of steel Part 2: Cold-formed steel structures
- SANS 10400 – The application of the National Building Regulations

7. OBJECTIVES OF STRUCTURAL ASSESSMENTS

Structural assessment is initiated, when there has been a change in resistance, such as structural deterioration due to time-depending processes (e.g. corrosion, fatigue) or structural damage by accidental actions. Also when there will be a change in loading or an extension of the design working life. In general, structural assessment is a process to determine, how reliable the existing structure is able to carry current and future loads and to fulfil its task for a given time period.

There are two main objectives when conducting assessments of existing structures:

- Assurance of structural safety and serviceability – The main task of the structural safety assessment is to ensure that the structure or parts of the structure do not fail under loading. A reduction of serviceability may lead to a limitation of use.
- Minimisation of costs – Systems for managing structures have been developed for minimising the overall cost by optimising inspection, maintenance and repair work.

8. METHODS OF DATA AQUISITION

While a wide range of methods exist, they vary in respect of expense and accuracy. TNPA have specified the following methods:

- Study of existing data and documentation related to the structure}
- Inspections
- Material testing

8.1. Study of existing data and documentation related to the structure

This method involves the review of documents from design and construction processes as well as inspection and maintenance reports and is in general the quickest way of gathering data about the structure to be assessed. It has to be assured that the reviewed documents are correct.

The Berth 4 original design loads were stipulated on the original drawings supplied by TNPA and have been reproduced in **14.1** below. Resistance properties like material and structural properties and dimension can be obtained from codes, drawings and other design specifications (e.g. static calculations, subsoil condition report), from construction documents (e.g. material delivery documentation) and from reports of earlier inspection and maintenance.

At the project kick-off Lodemann requested to be supplied with all existing reports and drawings for the structure. TNPA advised that it was not in possession of any previous reports but it did supply a few drawings of the structure.

8.2. Inspections

Inspections are usually conducted as one of the means to estimate the in-situ investigation of load and resistance parameters. There are a large variety of methods, starting with simple visual inspection and ending with several high-end non-destructive techniques. Inspections are especially important for the detection and investigation of deterioration processes like corrosion and fatigue and for detection of changes in the structural systems. Therefore, it is necessary to conduct inspections, especially simple visual inspections, regularly. Visual inspections are usually used to identify surface defects such as reinforced concrete cracks, spalling and corrosion.

Lodemann conducted site visual assessments as required by TNPA.

8.3. Material Testing

Material tests are sometimes done for determining strength parameters of the reinforced concrete material. The tests can be destructive and non-destructive. They are usually conducted in a controlled laboratory environment.

Parameters to be investigated and corresponding investigation methods are:

- Cross sectional and longitudinal geometry changes (damages) from overloading (e.g. cracks, ruptures) and from deterioration processes (e.g. corrosion, spalling, fatigue cracks) using laser, ultrasonic devices, slide gauge, electronic gauges, etc.
- structural integrity (e.g. for hidden damage or inhomogeneity) using for instance impact echo testing
- material strength using tension and compression tests on samples, sclerometer method, pull-out tests, pull-off tests, etc.
- parameter, influencing the dead load and the superimposed dead load
- duration influencing parameters of the structure (e.g. environmental conditions, carbonation and chloride content of concrete) using pH-test, phenolphthalein test, quantitative chloride analysis on samples, etc.

Lodemann procured the services of a SANAS approved materials testing laboratory to conduct the specific tests required by TNPA.

9. TYPES OF CONCRETE DEFECTS

9.1. Spalling

Spalling is a term used to describe areas of concrete which have cracked and delaminated from the substrate. There are a number of reasons why spalling occurs including freeze thaw cycling, the expansive effects of Alkali Silica Reaction or exposure to fire. However, the most common cause of spalling is the corrosion of embedded steel reinforcement bars or steel sections. Corroding steel can expand up to ten times its original volume, exerting stress on the surrounding concrete.

When steel is cast into concrete, the naturally high alkalinity helps to protect the embedded steel from corrosion. However, the protection afforded by high alkalinity can be compromised by the ingress of acidic atmospheric gases, a process normally referred to as carbonation, or by the presence of salts in the concrete, typically from marine environments. Combine these contaminants with oxygen and water and we have the key ingredients for corrosion. The reason some concrete structures exhibit widespread spalling whilst others appear to be in a sound condition is down to a combination of age, maintenance, concrete quality, the depth of concrete cover and local environmental conditions.

If left unchecked spalling tends to accelerate and spread to an extent that results in the instability of the structure.

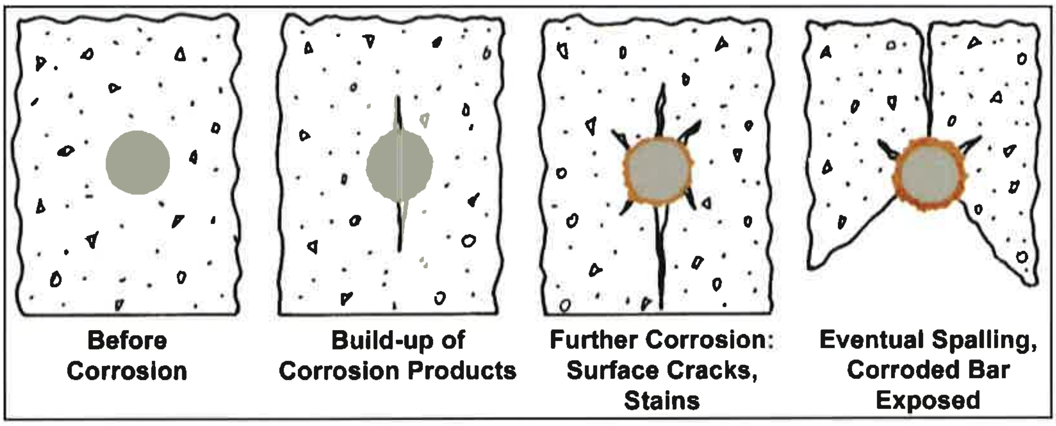

Figure 5: Progression to spalled concrete

Figure 6: Example of a spalled concrete structure

9.2. Abrasion by Wave Actions

Marine concrete is subject to some of the harshest conditions on the planet, usually in the most critical of applications. Not only does the concrete face chemical attack from seawater but it is also affected by continual impact from waves and the abrasive action of wave born sand and shingle with the ebb and flow of the tide. This impact and abrasion can be very severe leading to spalling of the concrete and corrosion of conventional reinforcement such as steel.

Figure 7: Abrasive damage to concrete structure by wave actions

9.3. Cracking

There are several causes of cracks in concrete. Cracks caused before hardening are due to constructional movement, settlement shrinkage, and setting shrinkage. Cracks caused after hardening are due to chemical reactions, physical movement, thermal changes, stress concentrations, structural design, and accidents. Many elements in a concrete mix can greatly influence the concrete's vulnerability to cracking. Water is one of the most significant. It has been found that the more water used, the greater the cracking tendency. This is due to the increase in shrinkage and resulting decrease in strength that is caused by the water content in a mix. The amount of cement is also important; in general, the richer concretes crack more. The mineral composition, shape, surface texture, and grading of aggregate variously affect the required proportions, thermal coefficient, drying shrinkage, stiffness, creep, and strength of concrete. Some admixtures may also affect cracking because of their effects on such contributory factors as rate of hardening, shrinkage, and creep.

9.4. Honeycombing

Honeycombing is the term used to describe areas of the surface that are coarse and stony. It may be caused by insufficient fine material in the mix, perhaps due to incorrect aggregate grading or poor mixing. This can be corrected by increasing the sand and cement content of the mix and by proper mixing, placing and compaction. Alternatively, honeycombing may be caused by leakage of grout or mortar fraction from the concrete at construction or formwork joints. The obvious solution here is to ensure that joints are well sealed and leak-free.

Small, shallow areas of honeycombing are cosmetic. However, deeper areas will lead to a local reduction in the protection to the reinforcement from the concrete cover and hence resulting in durability problems.

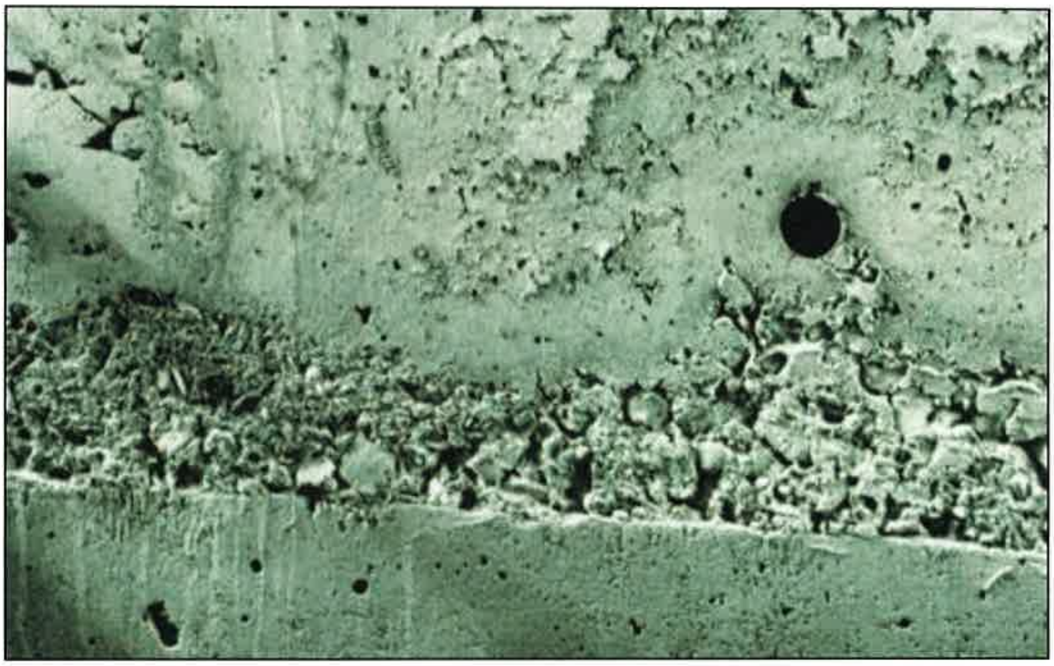

Figure 8: Example of honeycombing in concrete structure

10. DURABILITY OF CONCRETE

Durability is the ability to last a long time without significant deterioration. A durable material helps the environment by conserving resources and reducing wastes and the environmental impacts of repair and replacement. The production of replacement building materials depletes natural resources and can produce air and water pollution.

Concrete resists weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Different concretes require different degrees of durability depending on the exposure environment and the properties desired. Concrete ingredients, their proportioning, interactions between them, placing and curing practices, and the service environment determine the ultimate durability and life of the concrete.

Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Different concretes require different degrees of durability depending on the exposure environment and properties desired. For example, concrete exposed to tidal seawater will have different requirements than an indoor concrete floor.

Concrete has been used in seawater exposures for decades with excellent performance. However, special care in mix design and material selection is necessary for these severe environments. A structure exposed to seawater or seawater spray is most vulnerable in the tidal or splash zone where there are repeated cycles of wetting and drying and/or freezing and thawing. Sulphates and chlorides in seawater require the use of low permeability concrete to minimize steel corrosion and sulphate attack. A cement resistant to sulphate exposure is helpful. Proper concrete cover over reinforcing steel must be provided, and the water-cementitious ratio should not exceed 0.40

Chlorides present in plain concrete (that which does not contain reinforcing steel) is generally not a durability concern. In reinforced concrete, the paste protects embedded steel from corrosion through its highly alkaline nature. The high pH environment in concrete (usually (greater than 12.5) causes a passive protective oxide film to form on steel. However, the presence of chloride ions from seawater can destroy or penetrate the film. Once the chloride corrosion threshold is reached, an electrochemical current is formed along the steel or between steel bars and the process of corrosion begins.

Concrete has a high resistance to chloride, however, for severe environments it can be increased by using a low water-cement ratio of approximately 0.40. Increasing the concrete cover over the steel also helps slow down the migration of chlorides. Other methods of reducing steel corrosion include the use of corrosion inhibiting admixtures, epoxy-coated reinforcing steel, surface treatments, concrete overlays, and cathodic protection.

11. DURABILITY INDEX TESTING

The South African Durability Index (DI) tests comprise oxygen permeability, chloride conductivity and water sorptivity tests. The durability indices obtained with these test methods have been related empirically to service life prediction models. Index value, test results can be used as the input parameters of service life models, together with other variables such as steel cover and environmental class, in order to determine rational design life. Limiting index values can be used in construction specifications to provide the necessary concrete quality for a required life and environment. Thus, a framework has been put in place for a performance-based approach to both design and specification.

The test specimens considered in this method are circular discs prepared from the cores extracted from the deck at above water conditions and from the piles at underwater conditions. The cores for the upper deck were 90 mm in diameter by 300 mm in length. The cores retrieved from the piles were 70 mm in diameter by 152 mm in length. Figure 2 shows the cores retrieved from the site.

Figure 9: Concrete core samples retrieved from the berth's deck and piles

The details of preparation of the cores retrieved from the site structural elements is shown in the figure 10 below.

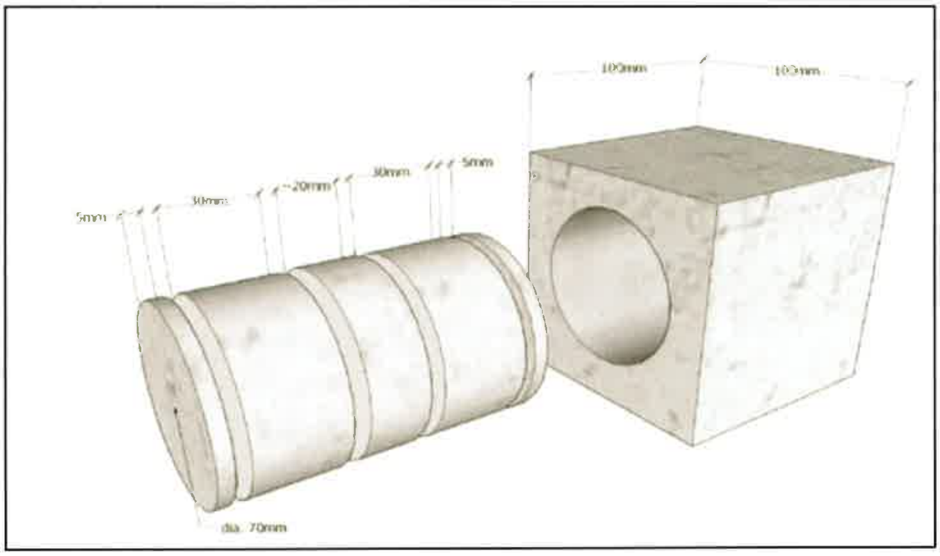

Figure 10: Preparation of samples retrieved from the site structural elements

11.1. Oxygen Permeability Test

Permeation is the process of movement of fluids or gases through the concrete pore structure under an externally applied pressure whilst the pores are saturated with the particular fluid or gas. Permeability is therefore a measure of the capacity for concrete to transfer fluids or gases by permeation. The permeability of concrete is dependent on microstructure, moisture condition of the material, and characteristics of the permeating agent. For the testing of concrete properties, permeation characteristics are commonly identified measuring gaseous flow through a specimen under an externally applied pressure gradient. In terms of durability specifications, gas permeability characteristics are used in predicting the ingress of carbon dioxide into concrete members.

The South African Oxygen Permeability Index (OPI) test method comprises measuring the pressure decay of oxygen passed through a concrete disk (typically 68 mm diameter by 25 mm thick) placed in a falling head permeameter. A pressure gradient is applied across the test specimen and subsequently the pressure decay in the pressure cell is monitored over time (figure 9). Prior to testing, samples are preconditioned by oven drying at 50 °C for a period of seven days.

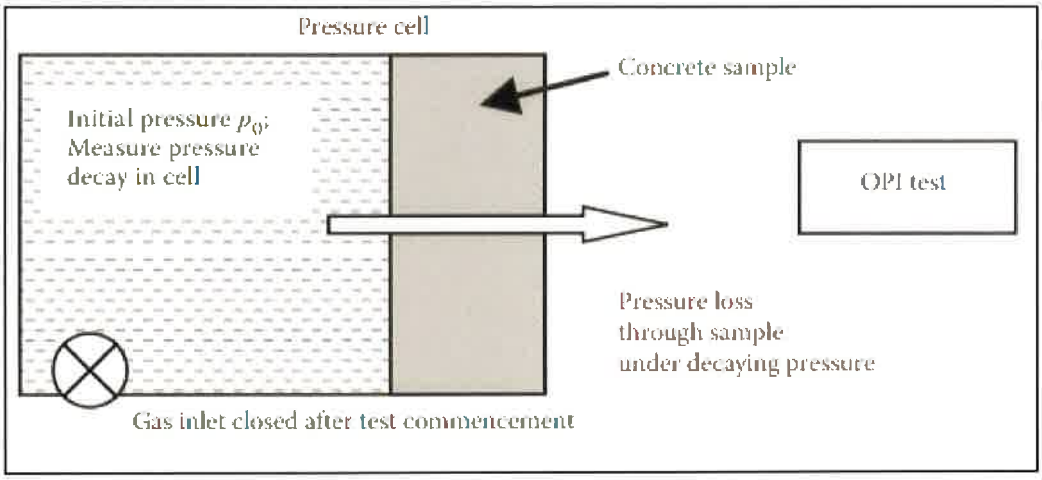

Figure 11: Schematic of Oxygen Permeability test

11.2. Chloride Conductivity Test

Chlorides are able to enter the concrete microstructure in three main ways, namely capillary absorption, permeation, and diffusion. Of these, diffusion is the primary means of ingress and might easily allow ions to reach the level of the reinforcing steel within the life span of the structure. Diffusion is the process by which liquid, gas or ions move through a porous material under the action of a concentration gradient. It occurs in partially or fully saturated concrete and is an important internal transport mechanism for most concrete structures exposed to salts, for example in the marine environment. High surface salt concentrations are initially developed by absorption, and the salt migrates by diffusion towards the low concentrations of the internal material. This salt migration process can be seen as diffusion of chloride ions. As diffusion is a slow process, rapid chloride tests have been developed to accelerate the diffusion process. Most of these methods rely on electrical acceleration of the ions.

The South African Chloride Conductivity test involves the measurement of a sample's electric conductivity. A concrete specimen (typically 68 mm diameter by 25 mm thick) is dried in an oven and vacuum pre-saturated with a 5 M NaCl solution. A conduction cell is used, in which the sample is placed between two cells containing 5 M NaCl solution. A potential difference is applied across the sample, causing a movement of chloride ions, the corresponding current is used to calculate the concrete's conductivity, which in turn can be related to the concrete's resistance to chloride ingress. This procedure gives an instant reading.

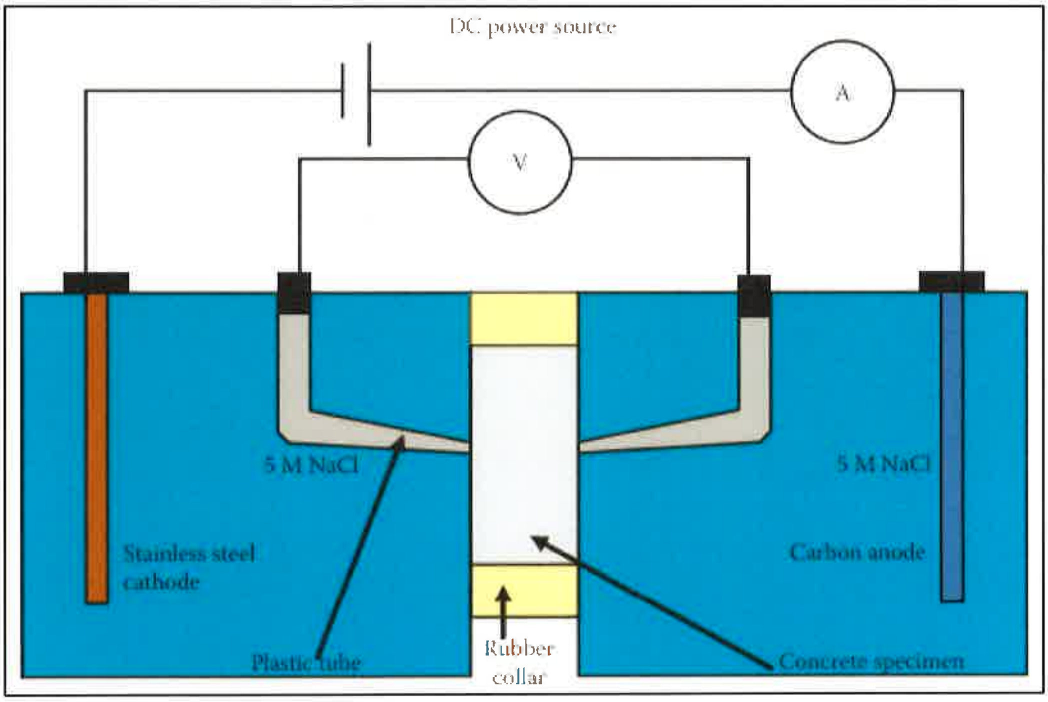

Figure 12: Schematic of Chloride Conductivity test

11.3. Water Penetration / Sorptivity Test

Absorption is the process whereby fluid is drawn into a porous, unsaturated material under the action of capillary forces. Water absorption caused by wetting and drying at the concrete surface is an important transport mechanism in near-surface regions. The rate of movement of a wetting front through a porous material under the action of capillary forces is defined as sorptivity.

The South African Water Sorptivity Index test is based on measuring the unidirectional ingress of water into a preconditioned concrete sample. For this, the concrete samples are sealed on the circumferential surfaces and exposed to a few millimetres of water with the test surface facing downwards. This method measures the mass change of the specimens over time, determining the amount of water absorbed into the concrete.

In the water sorptivity index method, the porosity of the sample is considered in the analysis to establish the rate of water sorption, that is, the speed at which water is absorbed into a certain depth of the member, resulting in the unit (mm/√h). The South African test effectively normalises the results for porosity, and at the same time provides a useful measure of concrete porosity.

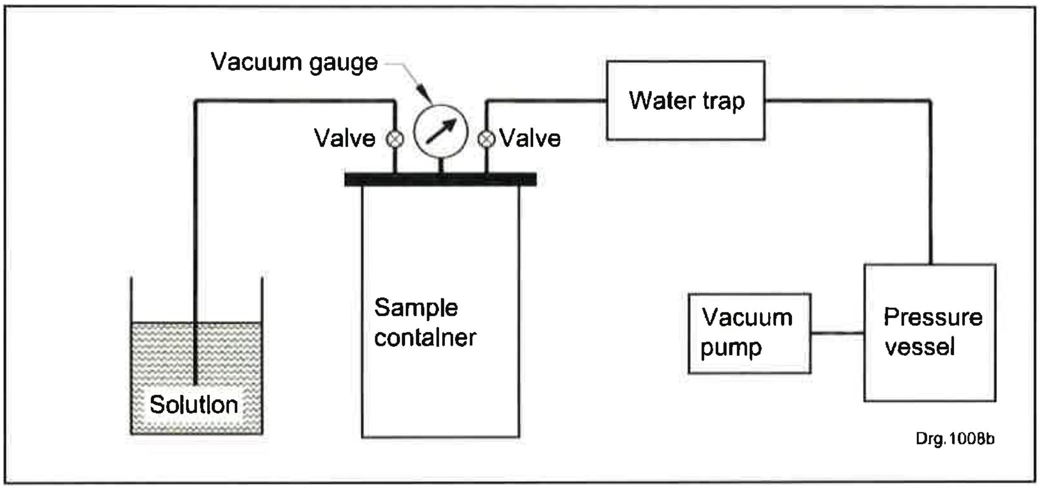

Figure 13: Water Sorptivity test schematic

12. COMPRESSIVE STRENGTH TESTING

Compressive strength testing on drilled concrete cores is required to determine the strength of hardened concrete in structure. The results achieved via testing are then compared with expected normative values. Large discrepancies between the strength test results and expected values may thus point to inherent defects within the concrete.

13. STRUCTURAL DETERIORATION IN MARINE ENVIRONMENTS

The transformation of materials into a successful marine structure is a multidisciplinary endeavour (Figure 14) that includes a design stage and a manufacturing stage.

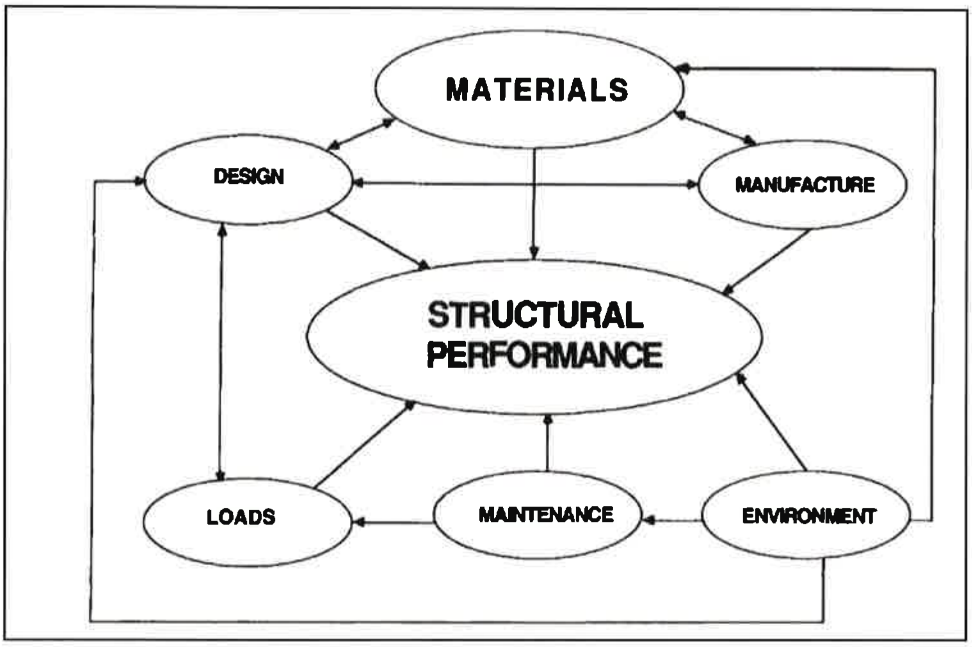

Figure 14: Parameters affecting concrete in a marine environment

In the design stage, the usual engineering goal is to plan a structure which when fabricated will function in the manner intended, be economical to produce and maintain, be durable, and be reliable. The main design functions to assure these characteristics involve determining overall structural configuration, operating stress levels, local stress levels and stress concentrations, material selection, and selection of fabrication processes and finishes.

The use of modern numerical methods for calculating static and dynamic stresses and the development of fracture mechanics for subcritical crack growth in fatigue, corrosion fatigue, and stress corrosion cracking (SCC) provide a means to evaluate and design for defect tolerance. The materials selected for fabrication and the processes used to convert the mill products into the structure during fabrication play a significant role in the success of the structure. This is especially true for marine structures because of the strong effects of the marine environment on the performance of materials. Such factors as chemistry, microstructure, heat treatment, effects of welding, surface finish, and protective finish are important parameters. All of these factors relate in an interactive way to the performance of the structure in the physical and loading environments imposed on the structure during its lifetime.

13.1. Chemical Composition of Sea Water

The salinity of sea water is generally about 3.5% of inorganic salts, the principal compounds being sodium chloride and magnesium sulphate.

The concentration of dissolved oxygen in sea water varies with temperature, depth and turbulence of the sea. It is approximately 10 ppm at the surface, decreasing to about 3 ppm at 100 m depth. In comparison, the oxygen concentration in air is about 210 ppm.

13.2. Temperature of Sea Water

The temperature of sea water has an important influence on the durability of concrete; high temperatures generally accelerate the deterioration process, not only owing to their direct influence, but also to faster drying and salt accumulation caused by rapid evaporation in the splash zone. In cold oceans, such as the Arctic, surface temperatures of the sea water can be reduced due to atmospheric temperatures of below -50 °C, whereas water below the ice line remains at around 0 °C. In temperate climates such as the North Sea, temperatures vary from about 16 °C near the surface in late summer to 6 °C in winter. In deeper water, below 50 m, the temperature variation is much smaller, in the range 6-9 °C for all seasons. Warm oceans in the tropics can reach temperatures of nearly 30 °C in the surface zones, the temperature decreasing with depth to about 12 °C at 200 m depth.

13.3. Exposure Zones

Concrete in a marine environment undergoes different deterioration processes depending on its position with respect to the tidal levels. From this standpoint, the marine environment can be divided into three principal zones as shown in Figure 15.

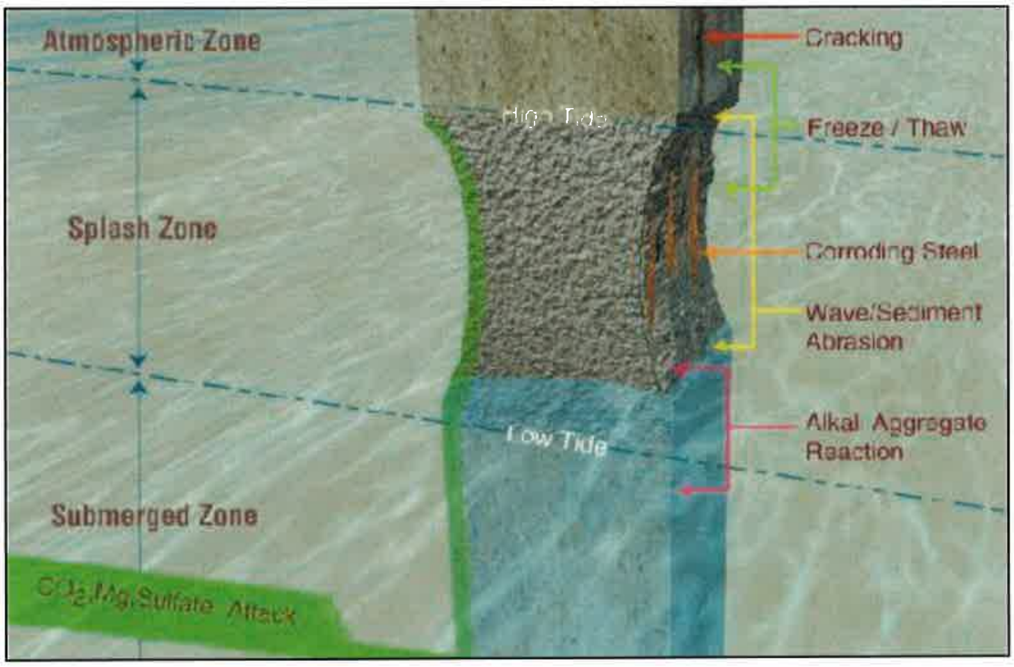

Figure 15: Marine exposure zones of concrete structures

Atmospheric Zone

Deposition of sea mist and sea salt occurs on materials exposed in marine atmospheres. The salts are deleterious to most common alloys, promoting localized attack; their hygroscopic nature and sea mist provide an electrolyte that is necessary for the attack to occur, while the anions in the salt promote film breakdown on passive metal surfaces. The mere presence of the deposits also may promote the formation of differential aeration cells.

The salt deposition process is a function of many variables, including wind and wave conditions, height above the sea, distance from the shore, panel orientation, degree of sheltering, and the amount of rain and distribution during a given time period. In general, those factors which promote salt build-up and prevent rainfall from removing the salt promote the most severe corrosion. Thus, the bottom sides of panels or those panels which are sheltered from the rain are generally more severely attacked.

Fungi and mould also may deposit on metal surfaces in marine atmospheres. These organisms may promote corrosion by the formation of differential aeration cells and by holding moisture on the metal surface.

Splash Zone

The zone exposed to the atmosphere above high tide level. The concrete is exposed to salt spray and cycles of wetting and drying. This zone is most prone to chloride-induced reinforcement corrosion resulting in cracking and spalling of the concrete cover.

Tidal Zone

This is the zone between the low and high tide levels. The concrete undergoes wet and dry cycles of sea water exposure. Chloride induced corrosion of reinforcement can cause cracking and spalling. Mechanical action of the waves with sand and gravel causes abrasion, resulting in loss of material. Chemical decomposition of Portland cement hydrate is also likely in this zone.

Submerged Zone

The part of the structure below the low tide level, which is always submerged in sea water, is primarily vulnerable to chemical attack by the salts in sea water on the products of hydration of Portland cement. This can result in strength reduction and loss of material. Sea water in this zone lacks dissolved oxygen to fuel corrosion of reinforcement and frost attack is also not a problem in this zone. The hydrostatic pressure caused by the depth of sea water, however, is likely to result in rapid diffusion of chloride into concrete.

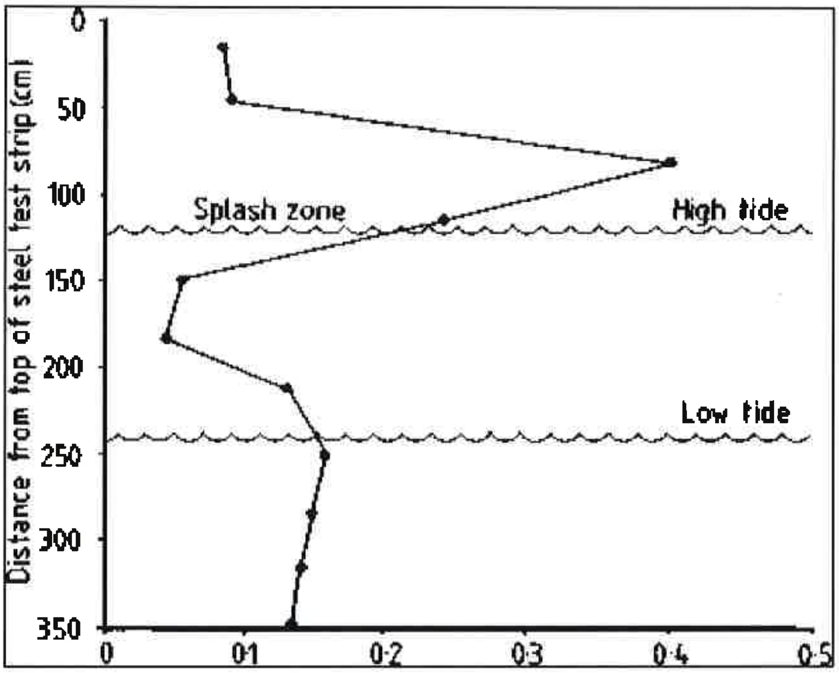

Figure 16: Corrosion rates of steel in marine exposure zones

13.4. Marine Fouling

Concrete structures in a marine environment are normally covered with marine growth, the constitution and thickness of which depend on sea water composition, temperature and depth. Marine fouling causes degradation of the concrete surface and impedes subsequent repairs to the structure. Marine organisms can be characterized into two broad categories, namely soft and hard fouling organisms. Examples of soft organisms are sponges, sea squirts and sea weed. Hard fouling organisms include barnacles, mussels and tube worms. Growth of these organisms is influenced by light intensity, water temperature, dissolved oxygen concentration, depth, age of structural installation in the sea, geographical location, season, current velocities and surface characteristics of structures.

The effect of marine growth on concrete durability appears to be insignificant. In fact, the sealing of the concrete surface by marine growth may act as a barrier to the diffusion of oxygen and chemical ions through the concrete cover, thereby preventing deterioration.

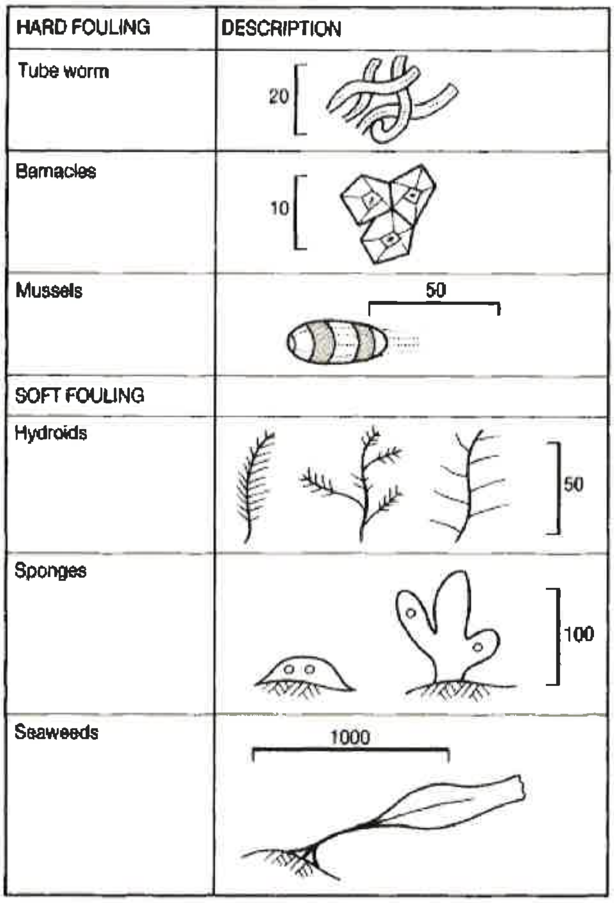

Figure 17: Types of Marine Growth

13.5. Chemical Attack

A reinforced concrete structure in the submerged zone of the marine environment is vulnerable to chemical reactions between sea water and the products of hydration of cement, which can result in material loss and strength reduction. Deterioration is also likely due to impact, abrasion and scour caused by floating ice and waves containing sand and gravel particles. The main products of hydration of Portland cement are vulnerable to decomposition by the aggressive components of sea water such as $C0_2$, $MgCl_2$ and $MgS0_4$. These products are formed by hydration of the dicalcium silicate (C_2S) and tricalcium silicate (C_3S) compounds of Portland cement which produce the two crystalline hydrates calcium hydroxide,

13.6. Damages Attributable to Operations

These can be attributed to the following factors: ship impact forces exceeding design values, effects of cargo handling and hauling systems, ship propeller induced scour which may threaten to undermine the berth structure, or a combination of all of these. Physical damage to the berth structure caused by a vessel can be generally categorized as either accidental or attributed to the method of ship handling. Accidental loadings by their very nature are a short-duration, one-time event. These loadings can generate stresses higher than the strength of the structure, resulting in localized or general failure. Determination of whether accidental loading caused damage to a structure requires knowledge of the events preceding discovery of the damage. Usually, damage due to accidental loading is easy to diagnose.

Visual examination will usually show damaged steel and spalling or cracking of concrete that has been subjected to accidental loadings.

Accidental loadings by their very nature cannot be prevented. The accidental damage to the berth structure is usually attributed to ship mechanical problems such as power loss or poor weather conditions. At times poor coordination of berthing/unberthing operations creates an accidental situation when a ship approaches or leaves the berth at an unacceptable angle or with unacceptable velocity.

Ship-structure collision under these conditions sometimes results in damage to the structure or its elements such as the fender system, piling, and others, and/or to the ship.

At times quite substantial damages to the berth structure caused by power failure, mechanical problems, or by errors in berthing of ships literally of all sizes, but mainly by large vessels with bulbous bows, have been reported. A bulbous bow is ideal for piercing holes in sheet pile bulkheads and in thin-walled concrete structures, damaging gravity type vertical walls and catching the piling under piled platforms and all types of piled dolphins. Experience indicates that the damage to the structure caused by bulbous bows usually occurs in the outer row of piles nearest the face of the wharf. Very often these piles were centred as close as 0.3 to 0.5 m from the face of the berth. In some incidents other support piling, and the second row in particular, were damaged but not to the extent or frequency of the outer row.

The damage to the structure usually occurred when the vessel had been approaching the wharf at an angle that exceeded 10 to 15° and/or with an unacceptable velocity from the fender system energy absorbing capacity point of view. Hard docking may be affected by weather conditions, for example, heavy wind or high waves. On occasion additional tugs may be required to combat the force of the winds to ensure safe docking of a ship with a large sailing area. Hard docking, absence of, or inadequate fendering may result in greater wear and tear on dock walls. Lack of a proper fender system and errors in berthing may also result in removal of mooring bollards and hand rails by flared bows. Flared bows have been responsible in a number of accidents involving cargo handling equipment, for example, container cranes.

14. STRUCTURAL CONFIGURATION OF BERTH 4

Several historical drawings for the berth structure comprising the deck and the mooring piled dolphins were received from TNPA. These drawings are relevant for Berth 2 and Berth 3. Many of the drawings are not legible due to the microfilming process.

14.1. Berth Design Criteria

The design criteria for the berth is shown in drawing no. 62 214/402.

LOAD DESCRIPTION	VALUE	UNIT
Lateral fender load	**100**	**kN**
Lateral bollard load	**100**	**kN**
Lateral load caused by vessel impact while berthing	**100**	**kN**
Imposed distributed load on the deck	**10**	**kN**
Wind loading	**0.6**	**kN/m^2**

14.2. New Portion of Berth 4 (1986)

Drawing No. 62 214/401 shows that the berth was 51,810 m in length, which implies that the older portion of the deck is less than or equal to 40,69 m. From the diving footage, the configuration of this newer deck is slightly different from the older piles and pile caps.

The figure below is based on site measurements and agreement with the appointed Divers from Katlantic. The approximate position of the "infill" deck constructed during 1986 is reproduced.

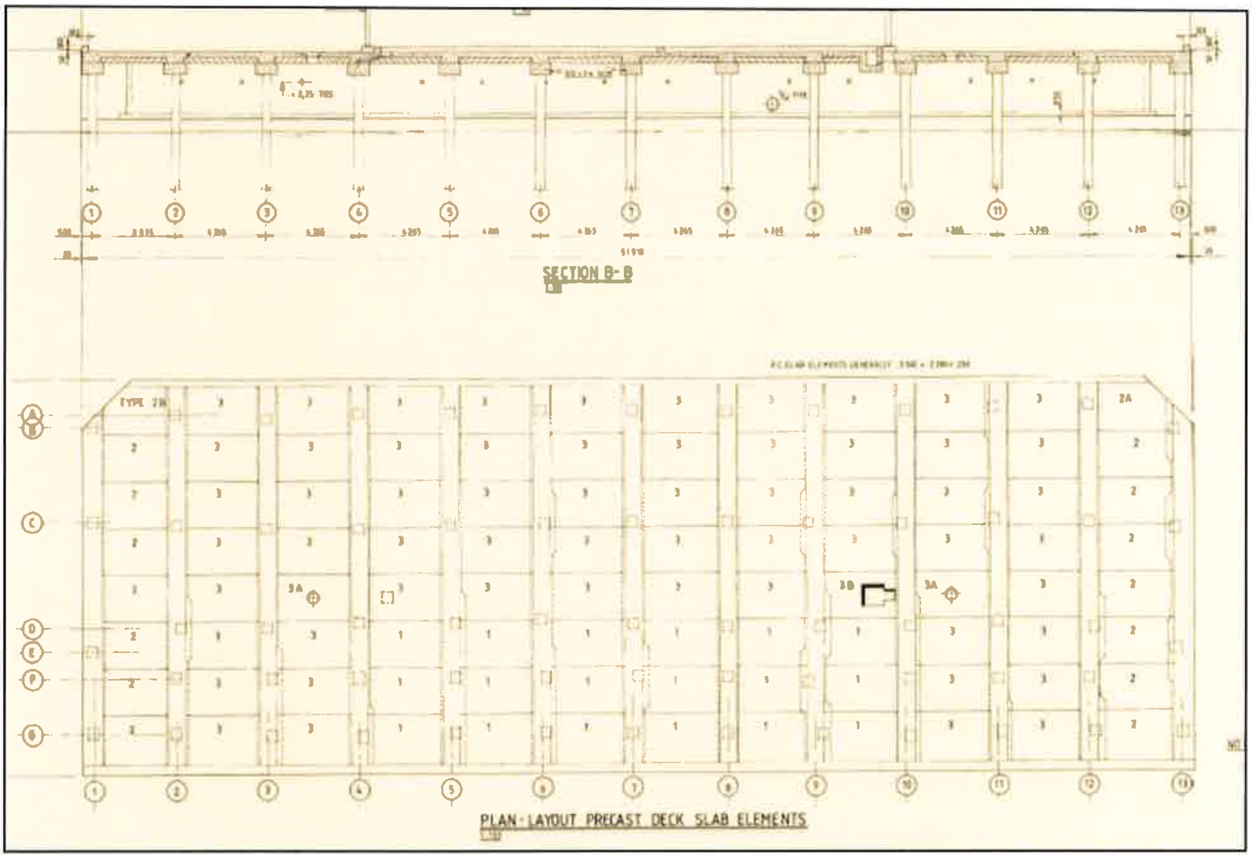

Figure 18: Precast deck slab elements in plan and section through the deck

The majority of the precast piles are spaced equally at 4.265 m with the exception of the end piles which are spaced at 3,895 m.

The precast piles used for this section are shown in drawing 62 214/402. The precast square piles are 450 mm square and reinforced with 4 no. Y25 rebar and 4 no. Y12 main reinforcing bars. The pile shaft lengths are typically 15 m, 17 m or 19 m. The lower and upper 1,5m of the piled shaft is reinforced with secondary R8 helical links with a pitch of 75 mm with the central portion typically with a pitch of 150 mm. The lifting positions were typically 0.21 L from either ends.

The concrete cube strength for the precast piles were 45 MPa at 28 days. Cover to reinforcement for piles was specified as a minimum of 60 mm.

The figure below shows a section through the new section of the deck and piles and the approximate Cope level. The Quay Wall, 80 ton bollards and tyre fenders located on site are illustrated in the forthcoming figures.

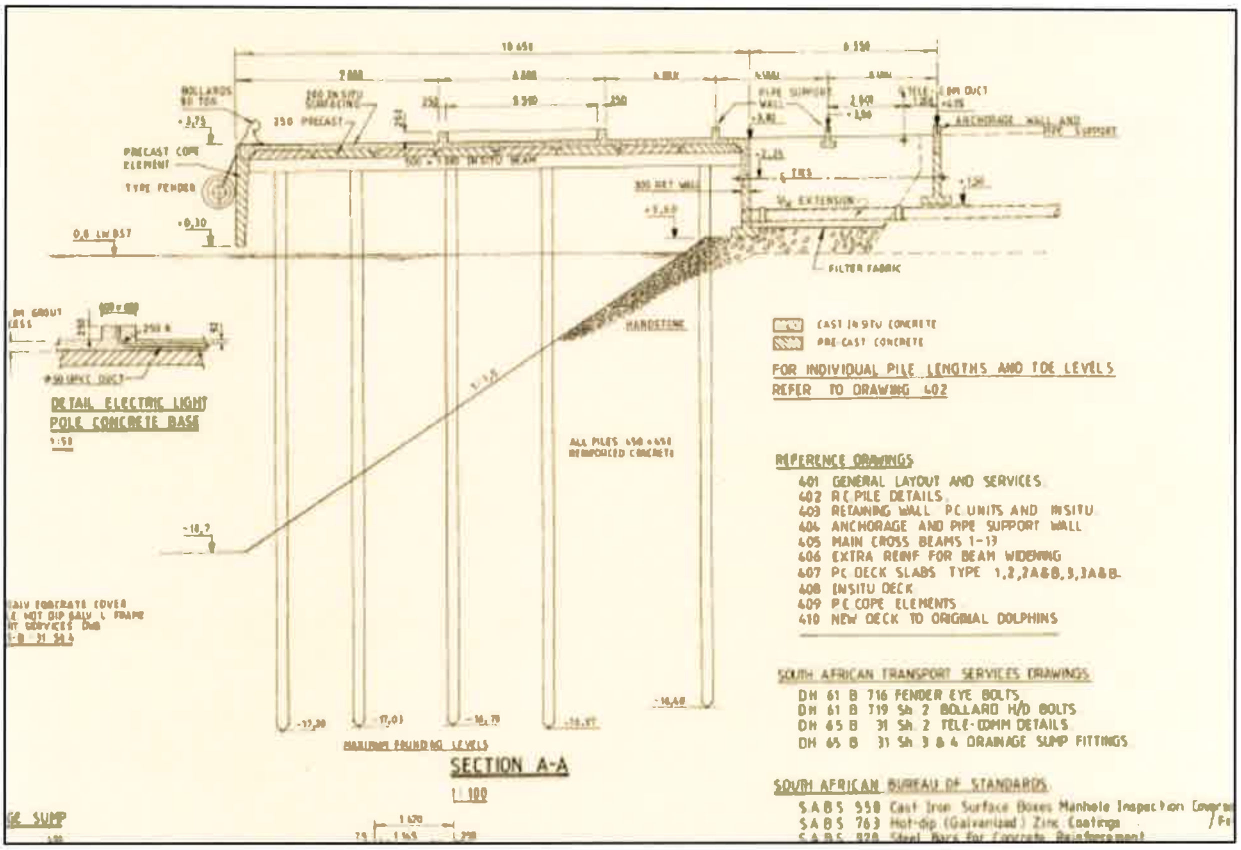

Figure 19: Section AA through the berth and piled dolphins

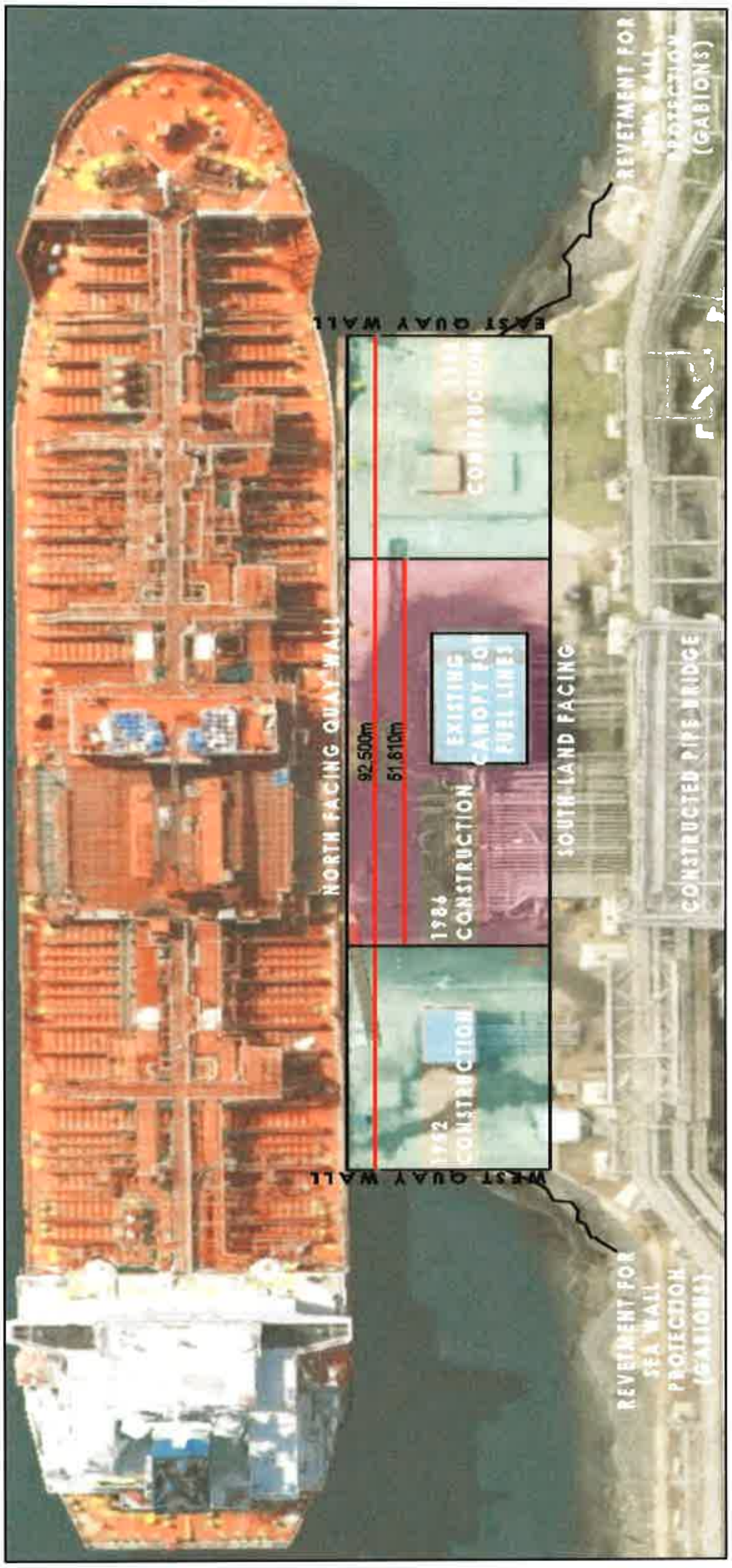

Figure 20: Arial view showing old and new portions of the berth

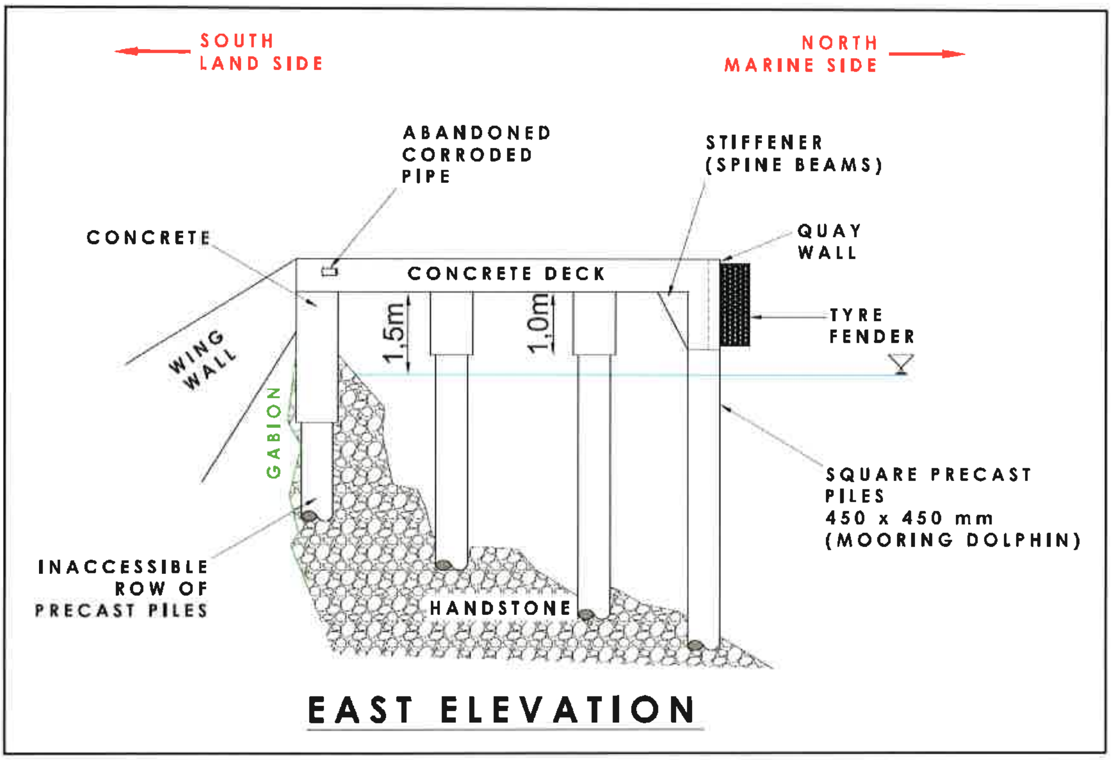

Figure 21: East elevation

15. SCOPE OF WORKS

15.1. Site Investigation and Methodology

An above water and under-water dive inspection was undertaken in order to assess the existing condition of the berth's concrete structures.

The durability of concrete is a vital factor influencing the in-service life of any reinforced concrete structure. Elements of a marine structure that interface with water are subject to a wide range of aggressive environmental conditions. This generally leads to accelerated deterioration, and consequentially maintenance becomes an important factor in the service life of the structure.

As structures age, the construction materials will degenerate and this, combined with external factors, such as overloading and impact damage, will further detract from the integrity of the structure, leading to a possible downgrading of the facility. Above the waterline, deterioration is readily apparent and remedial measures can be taken to protect the structure. As is the case of the Berth 4 deck and piles, the structure is partially submerged and therefore deterioration or damage is not immediately apparent. More often than not the problem is not detected until the structure has reached an advanced state of distress. Underwater inspection is therefore of great importance.

In order to assist with the underwater and above-water visual inspections below the deck, the Professional Structural Engineer, PR Eng., accompanied the team of Specialist Divers from Katlantic.

An 8 m Rigid Hull Inflatable boat with trailer was used to facilitate the diving operations. Agreement with regard to the notation and recording information was discussed between the Structural Engineer and the Diving Manager prior to diving operations.

The initial above water structural visual survey was used to identify the six pile cores to be extracted above and below the tidal /splash zones.

The CCTV visual survey was undertaken using an SSDE system 4251 high resolution camera. This provided high quality footage for the underwater mooring dolphin piles at depth. Audio Commentary was also included in the final footage received from Subtech Group.

Other equipment used included a hydraulic power pack, a 100 m Hydraulic line, a 100 m water line hose and a core drill.

The strategy for the inspection comprised of the following combined staged programme:

- Preliminary Inspection (Identification of problem areas)
- Detailed inspection (to quantify deterioration)
- Appraisal of the situation
- Repair
- Monitoring

The preliminary inspection comprised of the above water and under-water visual survey aimed at recording anomalies and identification of problem areas for detailed inspection. The detailed inspection comprised of the extraction of cores at selected positions on the piles and deck. The subsequent sections of this report will discuss the evaluation of the results and recommend methods of repair and monitoring.

15.2. Sampling

The preliminary underwater and above water survey conducted by the diving crew formed the most important stage in the programme as it allowed for a subsequent detailed inspection to be undertaken and the selection of the cores to be made. Figure 22 shows the piles that were labelled according to the agreed grids.

A total of 132 piles were visually inspected. Based on the drawings for the piles constructed during 1986, there are 63 No piles in this area. The remaining 68 No piles are piles constructed in 1952.

Table 1 below is a summary of the piles in the different areas.

Table 1: Pile location summary

SECTION	AREA EAST	AREA NEW	AREA WEST
NO OF PILES	38	63	31
YEAR OF CONSTRUCTION	1952	1986	1952

Figure 22: Pile differentiation by colour coding

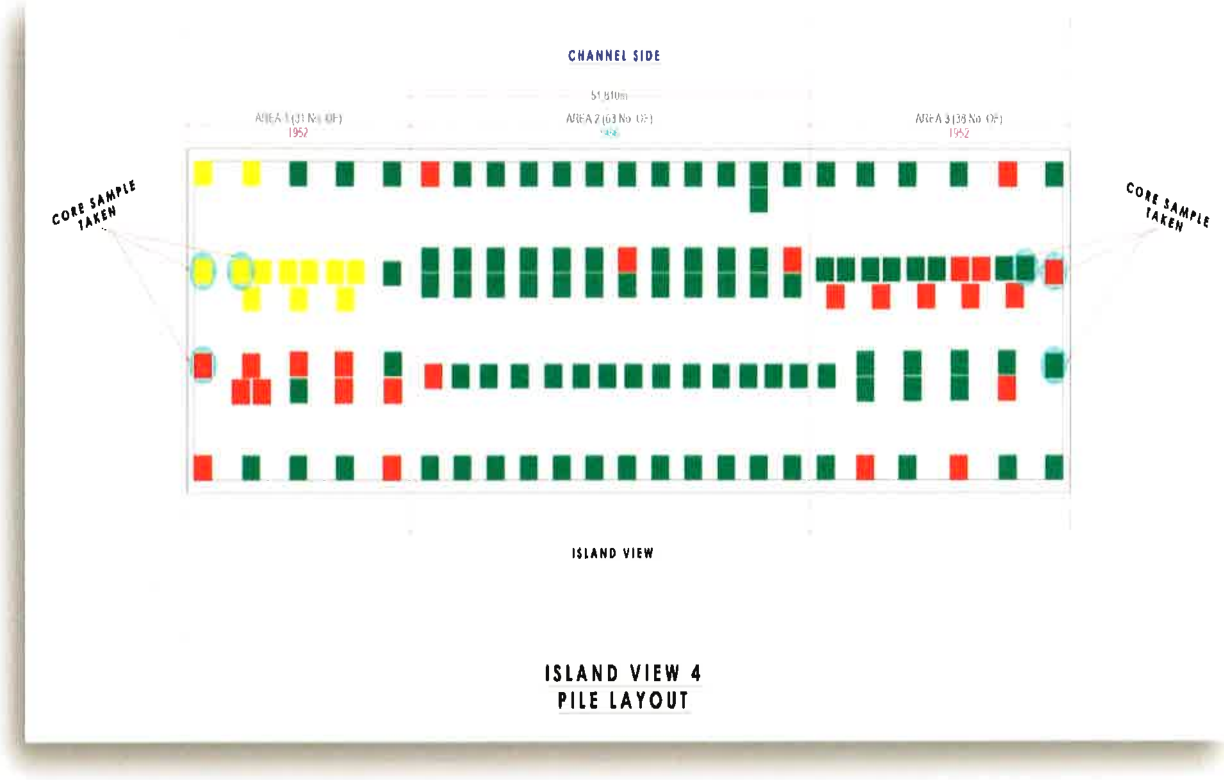

Figure 23: Plan view showing old and new portions of the berth as well as the precast pile inspected

Defects were noted on 6 of the 132 piles that were inspected. The cores for the piles have been selected as follows:

- On the East side (piles constructed in 1952)
- C-0 taken at tidal and facing North
- B-0 piles taken 5m below water surface
- B-2 – sample taken at tidal

All cores taken from piles were 75 mm in diameter and approximately 152 mm in height. These cores were tested for mechanical and chemical properties.

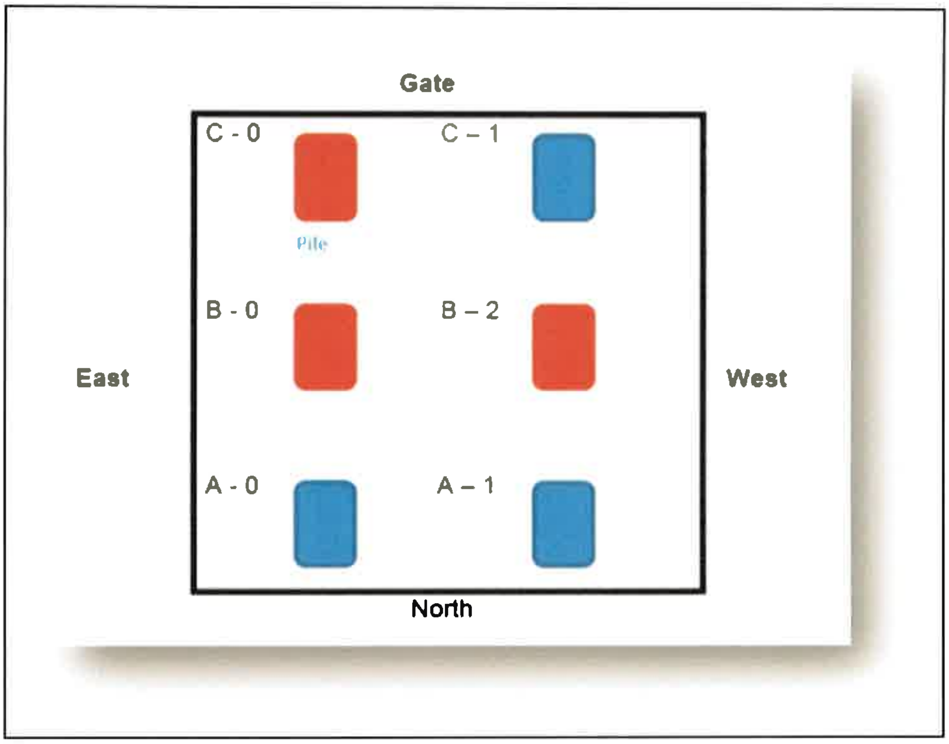

Figure 24: Positions of the cores taken from the precast piles

16. PRELIMINARY FINDINGS FROM VISUAL INSPECTIONS AND ANALYSIS OF DIVE FOOTAGE

Figures 15 and 16 will be used when referring to the various components of the marine structural elements (viz Deck (Berth), Piles (mooring dolphins) and the stiffeners/web beams). Although the requested assessment was predominantly for the deck and piles, we have requested the divers to comment on the stiffeners or "concrete spine" beams wherever they were encountered and to note any major cracks on the surface.

#NOTE: Figure 25 below is a summary of the deterioration on the piles, deck and spine beams that were discussed with the divers and reassessed in structural deterioration terminology related to concrete structures.

Gridline	Pile No	Spine Beam	Slab underside	Pile	Pile depth	Severity of defect	Description	Comment
A	1	surface crack , minor/cosmetic	no defects	No structural defects	N/A	Minor cosmetic	Minor	
A	17	no defects	no defects	Minor overspill	7m and 4m	Minor overspill		
B	0,1	no defects	Honeycombing under slab	Cap impact damage	assumed at interface		650mm L x80mmD south	740mmLx115mm D North
B	1,1	no defects	no defects	spalling	4m		545mmx65mm North	660mmx85mm West
B	1,2	no defects	Honeycombing /spalling of concrete	No structural defects		spalling between B&C 4-2m	area of 1,5m x 2m	
B	1,3	no defects	Defects on slabs	spalling between B line		spalling between B3 and	area of 6m x 2m	
B	2,1	no defects	Honeycombing	No structural defects				
B	2,2	no defects	Honeycombing	No structural defects				
B	2,3	no defects	Honeycombing	No structural defects				
B	3,1	no defects	Honeycombing	No structural defects				
B	4,1	no defects	minor delamination	No structural defects				
B	5,1	no defects	crack line - unknown	No structural defects				
B	6,2	no defects	Honeycombing	No structural defects				
B	7,1	no defects	crack line - unknown	No structural defects				
B	11,2	no defects	crack line - unknown	crack line - unknown depth				
C	1,1	surface crack , minor/cosmetic	no defects	No structural defects				
C	2,2	no defects	Spalling and exposure of	No structural defects				
C	19,1	no defects	Minor spalling	spalling due to corrosion of				
C	20,1	no defects	Minor spalling	No structural defects				
C	21,1	no defects	Minor spalling	No structural defects				
	21,2	no defects	Minor spalling	No structural defects				
	22,2	no defects	Minor spalling	No structural defects				
	23,1	no defects	Minor honeycombing	Base of pile	no infrasructure top and bottom of			
	23,2	no defects	Minor honeycombing	minor spalling	possible replacement pile			
	24,1	no defects	no defects	minor spalling				

Figure 25: Summary defects table

16.1. Topside of Concrete Deck

No photographs were allowed as per the rules of the facility. However, the concrete structure was generally found to be in good condition with no major structural defects noted. Minor cracks caused by operational wear and tear were found in some areas. These are mainly cosmetic in nature and can be easily addressed on site with a repair contractor and the engineer. Some broken concrete was found around the bollards, these are cosmetic damages and do not have any effect on the load bearing capacity of the bollard i.e. the bollards are still firmly anchored in their original foundations.

16.2. Underside of the Concrete Deck

Based on the visual inspection of particularly the soffit of the deck supported by the 1952 piles on the eastern and portions of the western side, severe concrete spalling with exposed corrosion. *Figure* 26 shows a typical section where major spalling was noted. The "Green cells" in the table above show those areas that were areas of the underside of the deck.

It should be noted that the Subtech report shows the affected deck area within the vicinity of the referenced pile number.

Based on Condition Index for all underdeck deterioration a CI of 40 to 54 is given for Zone 2 i.e. Fair: Moderate deterioration. Function is still adequate. Severity levels of corrosion of reinforcement is 5 where loss of section >20% was noted. Spalling of concrete has a severity level of 3 with spalling 1/3d to 1/2d in depth, where d is concrete cover.

Figure 26: Typical spalling below soffit of old section (1952). Major spalling of concrete and depassivation of reinforcement

Concrete cover to exposed rebar was in the order of 30mm which is not suitable for aggressive exposure conditions according to SANS101

00.

16.3. Piles (Mooring Dolphin)

Refer to "Summary Defects Table" figure 22 above.

Figure 27: Typical precast deck supported by primary 1000x500 insitu downstand beams

Table 2 below provides a summary of the identified piles distributed along sections.

Table 2: Piles distributed along sections

SECTION	AREA EAST	AREA NEW	AREA WEST
NO OF PILES	38	63	31
YEAR OF CONSTRUCTION	1952	1986	1952
AFFECTED IDENTIFIED PILES	2	1	3

Pile C23.1 was completely detached from the pile cap and a replacement pile was noted by the divers.

16.4. Concrete Quay Wall and Spine Beams

Two precast concrete Quay walls were damaged due to impact load from berthing forces of a 1000 Ton ship. There is extensive exposure of reinforcement and concrete damage as shown in figure 28 below.

Figure 28: Impact damage on Quay Wall

To undertake further evaluation, the Durability Index Testing is undertaken in accordance with SANS 3001-CO3-1:2015, SANS 3001-CO3-2:2015 and SANS 3001-CO3-3:2015. The cores have been sent to the laboratory for testing. As soon as this becomes available, we will report on it and update the assessment.

17. RESULTS AND INTERPRETATION OF CORE SAMPLE TESTS

Concrete core samples were extracted on the berth's deck and pile structures as per TNPA's requirements. The cores were subjected to Durability Index tests viz; Water Sorptivity, Chloride Conductivity and Oxygen Permeability and crushing tests to determine the concrete strengths. All testing was undertaken at ROADLAB, a SANAS approved Civil Engineering and Material Sciences laboratory.

17.1. Compressive Strength

The table below is a summary of the test results received from the labs. Laboratory sample no C0169 and C0173 were extracted from the precast concrete piles. The remaining cores were extracted from the concrete deck.

ROADLAB
Civil Engineering Materials Testing Laboratory
(PTY) LTD • 1965/000000/07 • VAT No. 4660115884
Established 1965

HEAD OFFICE
207 Rietfontein Rd Primrose Germiston 1401
P O Box 1476 Germiston 1400
Tel: 011 828 0279 Fax: 011 828 0273
E-mail: info@roadlab.co.za
www.roadlab.co.za

Lodemans Holdings (Pty) Ltd
KZN
33 Gordon View, 33 donbel
Morningside, Durban
4001

Mr. Rishaan Chabilal

Date:	14/09/2018
Report No.	94/02/0020/18

Compressive Strength of Cores - SANS 5865:1994

ATTENTION:	Mr. Rishaan Chabilal	DATE RECEIVED:	10/09/2018
CONTRACT / PROJECT:	KZN	DATE IN WATER:	43382
TYPE OF TEST DONE:	Compressive Strength On Concrete Cores	OUR TRACK NO:	33571
SPECIFIED STRENGTH:	N/A	PRESS SERIAL NUMBER:	210/1
SOURCE OF SAMPLE:	Concrete Cores	BALANCE SERIAL NUMBER:	6e/152
TYPE OF SAMPLE:	Concrete Cylinders	LAB TESTER:	Andrew Chitsine
SAMPLED BY:	Client	SAMPLE METHOD:	SANS 5865-1994

Laboratory Ref	Client Ref	Date Cast	Date Tested	Age Days	Length Drilled (mm)	Diameter (mm)	Length Cut (mm)	Length Capped (mm)	Mass (g)	Load (kn)	Area mm²	Core Strength (Mpa)	Voids Factor	Adjustment for voids	Adjustment for reinforcement
C0169	1	-	12/09/2018	-	191	93,22	93,41	93,21	1560	294	6826	43.00	1,13	48,6	None
C0170	2	-	12/09/2018	-	280	93.16	93,12	93,21	1566	339	6817	49.50	1,13	55,9	None
C0171	3	-	12/09/2018	-	325	93.31	93.13	93.27	1546	515	6839	75.50	1,13	85,3	None
C0172	4	-	12/09/2018	-	385	93,25	93,10	93,22	1540	312	6827	45,50	1,04	47,3	None
C0173	5	-	12/09/2018	-	198	93.09	93,08	93,24	1570	287	6807	42,00	1,13	47,5	None
C0174	6	-	12/09/2018	-	221	93,11	93,06	93,20	1547	402	6810	59,00	1,04	61,4	None
				Average (Rounded to 0.05MPa)						358	-	52,50	-	57,66	-
				Standard Deviation											-

Acceptance Criteria SANS 10100 Part 2

14.4.3.1 If the average core strength is at least 80% of the specified strength and no single core strength is less than 70% of the specified strength the concrete will be accepted.

14.4.3.2 If an individual core strength is less than 70% of the specified strength, re-core to investigate

Voids Content	Correction Factor		
0% = 1.0	1.5% = 1.13	3% = 1.28	4.5% = 1.45
0.5% = 1.04	2% = 1.18	3.5% = 1.33	5% = 1.51
1% = 1.08	2.5% = 1.23	4% = 1.39	

Comment:

REMARKS:
1. Opinions & interpretations are not included in our schedule of Accreditation.
2. SANAS accredited Laboratory No. T 0296.
3. The samples were subjected to analysis according to SANS method 5865.
4. The results reported relate only to the samples tested.
5. Further use of the above information is not the responsibility or liability of Roadlab.
6. Documents may only be reproduced or published in their full context.

sanas testing laboratory

Mr Joe Rooplal
Technical Signatory

Figure 29: Compressive Strength results

17.1.1. Analysis

The concrete cube strength specified at 28 days for the precast concrete piles was 45 MPa. (Drawing No. 62214/401 dated 7/10 1985.). The specified concrete cube strength at 28 days for the concrete deck was 40 MPa. Although the specified target strengths were given for the 1986 portion of the berth structure, the same concrete cube strengths were specified for the older 1952 sections of the berth structure.

The test method for the cores was as follows: (SANS 5865-1994)

1. The cores were immediately tested after it was removed from the water whilst still wet. Cores with cracked or loose caps were disregarded. Surface water, grit and projecting fins was removed, and for each core under test, the length of the ground core or of the capped core was determined to the nearest 1 mm,
2. The compression plates were wiped clean and positioned so that the core in the machine and axis of the core was aligned with the centre of thrust of the spherically seated platen.
3. The compression load was applied without shock and was increased at a uniform rate of 0,3 MPa/s until the specimen fails. The load at failure P, in Newtons was thus reported

The figure below plots the compressive strength data for the concrete deck.

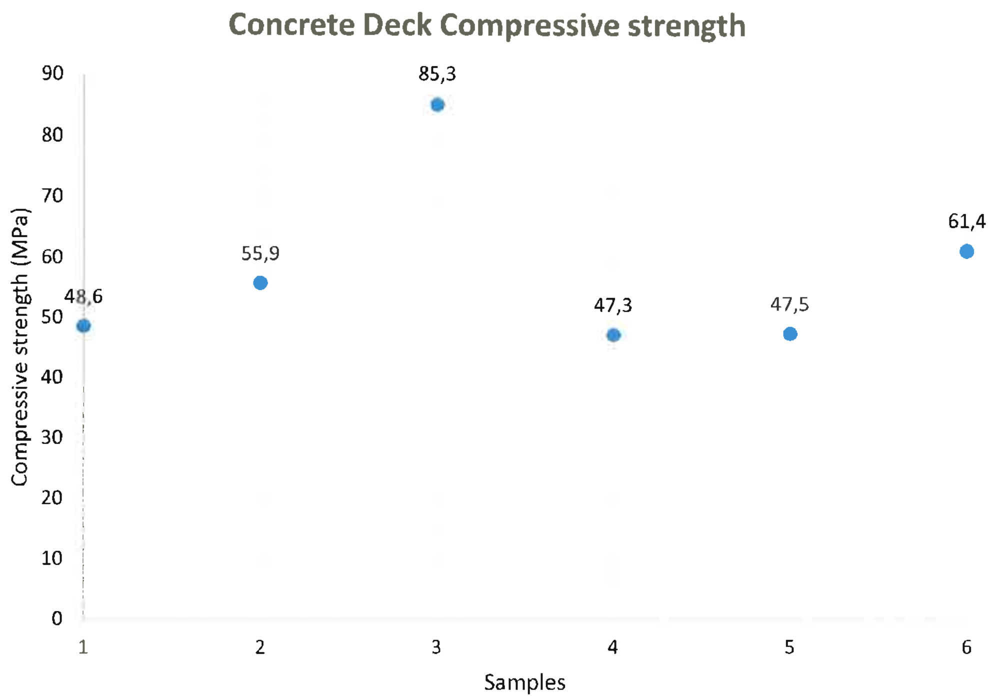

Figure 30: Graph of core sample compressive strength

The mean value for the compressive strength is 62.525 MPa. The standard deviation is 16.22 MPa. The concrete cube strength at 28 days for the concrete deck was 40 MPa. The results are higher than the specified strength for the concrete deck and is acceptable.

The cores (C0169 and C0173) have a compressive strength of 48.6 MPa and 47.5 MPa which are greater than the concrete cube strength at 28 days for the precast concrete piles which were 45 MPa. These results are thus acceptable.

17.2. Durability Index (DI) Testing

17.2.1. Water Sorptivity and Oxygen Permeability Testing Result

In the figures that follow, the laboratory results received for the Water Sorptivity and Oxygen Permeability tests are given.

ROADLAB
Civil Engineering Materials Testing Laboratory
Established 1965

HEAD OFFICE
Tel 011 ... Fax ...
E-mail: info@roadlab.co.za
www.roadlab.co.za

YOUR REF : LOD002 OUR REF : 96-ROA027-09-0003-18 DATE : 20/09/2019

Lodemann Holdings (Pty) Ltd
33 Gordon View
93 Clarlue
Morningside , 4001

TEST REPORT : CONCRETE DURABILITY TESTING

ATTENTION :

Dear Sir

Please find below test results as tested by Roadlab (Pty) Ltd.

STRUCTURE	: BERTH 4 / ISLAND VIEW	DATE CAST	N/S	:
ELEMENT	: CONCRETE CORES	DATE TESTED	18&19092018	:
SUPPLIER	N/S	AGE AT TESTING:	N/S	:
MIX DESIGN	: N/S	DRILLING	N/S	:
SAMPLE TYPE	CORES	TESTED BY	Andrew	:

SAMPLE DETAILS		DISC 1	DISC 2	DISC 3	DISC 4	MEAN
ORIGIN / CURING	UNIT					
CORES	OXYGEN PERMEABILITY	9,58	9,38	9,44	9,40	9,45
CORES	WATER SORPTIVITY					

Comments :

Kind Regards

Mr Joe Roopial
Technical Signatory

Page 1 of 1

ROADLAB
Civil Engineering Materials Testing Laboratory
Established [illegible]

HEAD OFFICE
[illegible]
E-mail: info@roadlab.co.za
www.roadlab.co.za

YOUR REF : LOD002 **OUR REF** : 06-ROA027-09-0001-18 **DATE** : 20/09/2019

Lodemann Holdings (Pty) Ltd
33 Gordon View
93 Clenbel
Morningside, 4001

TEST REPORT : CONCRETE DURABILITY TESTING

ATTENTION :

Dear Sir,

Please find below test results as tested by Roadlab (Pty) Ltd.

STRUCTURE	: BERTH 4 / ISLAND VIEW	DATE CAST	N/S	:
ELEMENT	: CONCRETE CORES	DATE TESTED	18&19092018	:
SUPPLIER	N/S	AGE AT TESTING	N/S	:
MIX DESIGN	: N/S	DRILLING	N/S	:
SAMPLE TYPE	CORES	TESTED BY	Andrew	:

SAMPLE DETAILS		DISC 1	DISC 2	DISC 3	DISC 4	MEAN
ORIGIN / CURING	UNIT					
CORES	OXYGEN PERMEABILITY	10,46	10,57	10,48	10,49	10,50
CORES	WATER SORPTIVITY	5,81	4,71	6,59	3,70	5,2

Comments :

Kind Regards

Mr Joe Roopiall
Technical Signatory

RVCCCS/[illegible] Page 1 of 1 [illegible]

ROADLAB
Civil Engineering Materials Testing Laboratory
Established 1968

HEAD OFFICE
[illegible] Rd Primrose Germiston 1401
P O Box 1176 Germiston 1400
Tel: 011 [illegible] Fax: 011 [illegible]
E-mail: info@roadlab.co.za
www.roadlab.co.za

YOUR REF : LOD002 OUR REF : 96-ROA027-03-0002-8A DATE : 20/09/2019

Lodemann Holdings (Pty) Ltd
33 Gordon View
93 Cleibel
Morningside , 4001

TEST REPORT : CONCRETE DURABILITY TESTING

ATTENTION :

Dear Sir,

Please find below test results as tested by Roadlab (Pty) Ltd.

STRUCTURE	: BERTH 4 / ISLAND VIEW	DATE CAST	N/S	:
ELEMENT	: CONCRETE CORES	DATE TESTED	18&19092018	:
SUPPLIER	N/S	AGE AT TESTING:	N/S	:
MIX DESIGN	: N/S	DRILLING	N/S	:
SAMPLE TYPE	CORES	TESTED BY	Andrew	:

SAMPLE DETAILS		DISC 1	DISC 2	DISC 3	DISC 4	MEAN
ORIGIN / CURING	UNIT					
CORES	OXYGEN PERMEABILITY	10,43	10,58	10,61	10,59	10,55
CORES	WATER SORPTIVITY	5,87	6,12	7,75	7,16	6,8

Comments :

Kind Regards

Mr Joe Roopial
Technical Signatory

Remarks:
[illegible]

MY DOCS/RWD Page 1 of 1 [illegible]

Figure 31: Water Sorptivity and Oxygen Permeability laboratory test results

17.2.2. Analysis – Oxygen Permeability Tests

Table 3: Sample 1 OPI - Result

Disk Number	k(m/s)	OPI
1	3,71535E-11	10,43
2	2,63027E-11	10,58
3	2,45471E-11	10,61
4	2,5704E-11	10,59
Mean	**2,84268E-11**	**10,56**
S.D.	**5,86326E-12**	**0.083**

Table 4: Sample 2 OPI – Result

Disk Number	k(m/s)	OPI
1	2,63027E-10	9,58
2	4,16869E-10	9,38
3	3,63078E-10	9,44
4	3,98107E-10	9,4
Mean	**3,6027E-10**	**9,45**
S.D.	**6,85548E-11**	**0,09**

Table 5: Sample 3 OPI – Result

Disk Number	k(m/s)	OPI
1	3,71535E-11	10,46
2	2,63027E-11	10,57
3	2,45471E-11	10,48
4	2,5704E-11	10,49
Mean	**2,84268E-11**	**10,50**
S.D.	**5,86326E-12**	**0,083**

OPI- calculated oxygen permeability of the specimen

k-coefficient of permeability of the test specimen in meters per second (m/s)

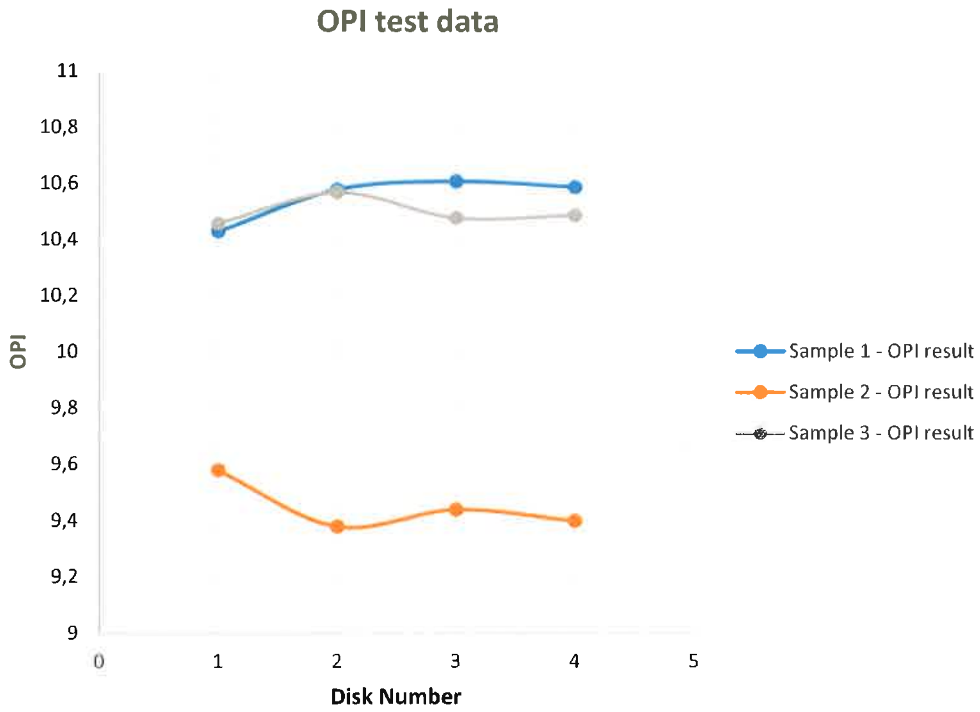

Figure 32: Graph of OPI results

Based on the Plot of the OPI values that were plotted on a log scale from the laboratory results on the Cores from the piles and deck, all core specimens tested fall within the accepted range >9.4 in figure 33. The minimum value is 9.38 which is the Conditional Acceptance range of 9.0 to 9.4. A maximum value of 10.61 was attained. This OPI value is greater than 9.4 and a full acceptance criterion of this range is given as in figure 33 below.

Based on the above values for the concrete durability indexes, the concrete has thus withstood the service conditions that the open berth structure was designed for.

The OPI is evaluated according to the following Durability class:

Acceptance Criterion		OPI (log scale)	Sorptivity (mm/√h)	Conductivity (mS/cm)
Laboratory concrete		> 10	< 6	< 0.75
As-built Structures	Full acceptance	> 9.4	< 9	< 1.00
	Conditional acceptance	9.0 to 9.4	9 to 12	1.00 to 1.50
	Remedial measures	8.75 to 9.0	12 to 15	1.50 to 2.50
	Rejection	< 8.75	> 15	> 2.50

Figure 33: Durability Index Acceptance Criterion

Based on the results analysed for the OPI, it is concluded that the Acceptance Criterion is Full Acceptance on As-built structures

17.2.3. Analysis – Water Sorptivity Tests

Table 6: Sample 1 Water Sorptivity – Result

Disk Number	Sorptivity ($mm/hr^{0.5}$)
1	5.81
2	4.71
3	6.59
4	3.70
Mean	**5.2**
S.D.	**1.26**

Table 7: Sample 2 Water Sorptivity – Result

Disk Number	Sorptivity (mm/hr$^{0.5}$)
1	5.87
2	6.42
3	7.75
4	7.18
Mean	**6.8**
S.D.	**0.82**

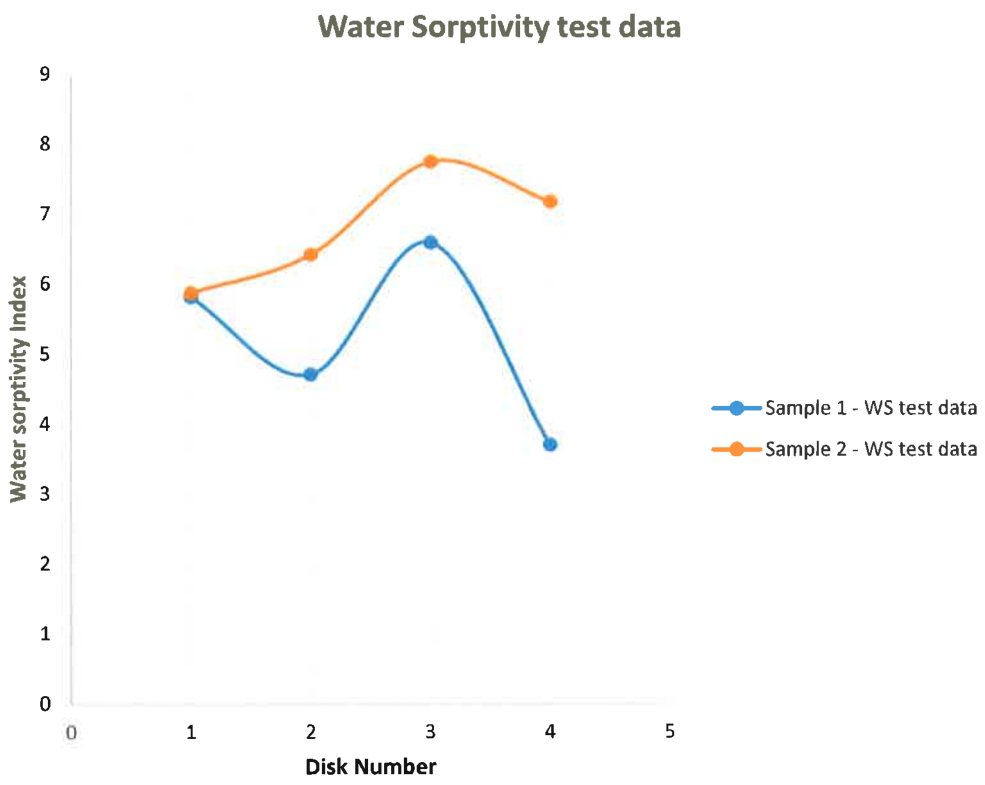

Figure 34: Graph of Water Sorptivity results

Based on the Plot of the Water sorptivity values that were plotted on a log scale from the laboratory results on the cores from the piles and deck, all core specimens tested fall within the accepted range of less than 9 in figure 33. The minimum value is 3.7 and the maximum value is 7.75.

The water sorptivity value is less than 9 and the Acceptance criterion is Full Acceptance. Based on the above values for the concrete durability indexes, the concrete has thus withstood the service conditions that the open berth structure was designed for over the prolonged periods.

17.3.1. Chloride Conductivity Testing Result

Below are the laboratory results received for the Chloride Conductivity tests.

Centre of Product Excellence Laboratory - Roodepoort

AfriSam

Test Results for Chloride Conductivity Test

Project: ROADLAB

Sample Reference ID No.: JOB 1157-18-A

Date of Test: 27-Sep-18

Test Operator: Linda

Chloride conductivity: 0.20 mS/cm

EAST-B-E-0-50		EAST-C-0-52		WEST-TIDALC-LINE-54		WEST-B-LINE-56	
Diameter (mm)	67.13	Diameter (mm)	67.94	Diameter (mm)	68.00	Diameter (mm)	67.53
Diameter (mm)	67.17	Diameter (mm)	67.92	Diameter (mm)	68.04	Diameter (mm)	67.51
Ave Diameter (mm)	67.15	Diameter (mm)	67.93	Diameter (mm)	68.02	Diameter (mm)	67.52
Thickness (mm)	31.06	Thickness (mm)	30.30	Thickness (mm)	30.82	Thickness (mm)	29.82
Thickness (mm)	29.37	Thickness (mm)	30.16	Thickness (mm)	31.45	Thickness (mm)	29.96
Thickness (mm)	30.47	Thickness (mm)	31.04	Thickness (mm)	32.05	Thickness (mm)	29.79
Thickness (mm)	31.34	Thickness (mm)	30.36	Thickness (mm)	31.43	Thickness (mm)	29.54
Ave Diameter (mm)	30.56	Thickness (mm)	30.47	Thickness (mm)	31.44	Thickness (mm)	29.78
Area	35.4177	Area	36.21304		36.34112	Area	35.7772
Volts	7.39	Volts	7.58	Volts	7.62	Volts	6.96
Amps	14.2000	Amps	18.0000	Amps	19.6000	Amps	18.5000
Conductivity	0.165797	Conductivity	0.199774	Conductivity	0.222511	Conductivity	0.22123

Average Conductivity Value: 0.2023 mS/cm

All testing was conducted at Afrisam Centre of Product Excellence Laboratory and carried out in accordance with test procedure as laid out by Research Monograph No 4. Collaborative research by the University of Cape Town and the University of the Witwatersrand

Manager Centre of Product Excellence: **M. McDonald**

Afrisam Roodepoort - Tel: 011- 758 6000 & Fax 011- 758 6091

Centre of Product Excellence Laboratory - Roodepoort

AfriSam

Test Results for Chloride Conductivity Test

Project: ROADLAB

Sample Reference ID No.: JOB 1157-18-8

Date of Test: 27-Sep-18

Test Operator: Linda

Chloride conductivity: 0.19 mS/cm

WEST-TIDAL-B-LINE-G#2-58		N1-E-152mm-60		N2-155mm-64		N3-70	
Diameter (mm)	68.10	Diameter (mm)	68.09	Diameter (mm)	68.17	Diameter (mm)	65.87
Diameter (mm)	68.10	Diameter (mm)	68.09	Diameter (mm)	68.19	Diameter (mm)	65.84
Ave Diameter (mm)	68.10	Diameter (mm)	68.09	Diameter (mm)	68.18	Diameter (mm)	65.86
Thickness (mm)	30.92	Thickness (mm)	33.62	Thickness (mm)	30.35	Thickness (mm)	29.62
Thickness (mm)	30.64	Thickness (mm)	32.97	Thickness (mm)	29.99	Thickness (mm)	30.87
Thickness (mm)	30.52	Thickness (mm)	32.43	Thickness (mm)	29.71	Thickness (mm)	31.86
Thickness (mm)	30.95	Thickness (mm)	33.11	Thickness (mm)	29.64	Thickness (mm)	29.84
Ave Diameter (mm)	30.76	Thickness (mm)	33.03	Thickness (mm)	29.92	Thickness (mm)	30.55
Area	36.40524	Area	36.39455		36.50153	Area	34.029
Volts	7.72	Volts	7.17	Volts	5.94	Volts	7.21
Amps	16.5000	Amps	17.8000	Amps	14.7000	Amps	12.5000
Conductivity	0.180573	Conductivity	0.225323	Conductivity	0.20287	Conductivity	0.15563

Average Conductivity Value: 0.1911 mS/cm

All testing was conducted at Afrisam Centre of Product Excellence Laboratory and carried out in accordance with test procedure as laid out by Research Monograph No 4. Collaborative research by the University of Cape Town and the University of the Witwatersrand

Manager Centre of Product Excellence: **M. McDonald**

Afrisam Roodepoort - Tel: 011- 758 6000 & Fax 011- 758 6091

Figure 35: Laboratory results for Chloride Conductivity tests

17.3.2. Analysis

Table 8: Chloride Conductivity - Test Results - Disk 1-4

Disk Number	Conductivity (mS/cm)
1	0,181
2	0,225
3	0,202
4	0,156
Mean	**0,1909075**
S.D.	0,029597312

Table 9: Chloride Conductivity - Test Results - Disks 5-8

Disk Number	Conductivity (mS/cm)
5	0.166
6	0,199
7	0,223
8	0,221
Mean	**0,214333333**
S.D.	0,01331666

The tabular results are summarised in the graph below.

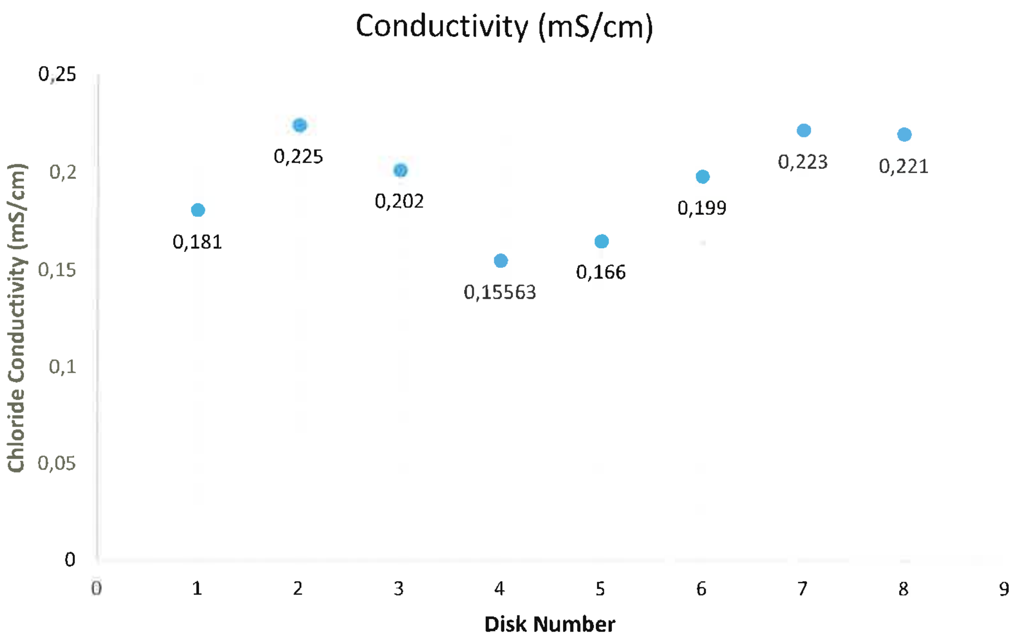

Figure 36: Graph of Chloride Conductivity results

Based on the graphical Plot of the Chloride Conductivity values on the Cores from the piles and deck, all core specimens tested fall within the accepted range of less than 1 in Table 2. The minimum value is 0.15563 mS/cm and the maximum value is 0.225 mS/cm and the Acceptance Criteria (figure 33) for as-built structures is "Full acceptance".

Based on the above values for the concrete conductivity results, the concrete has thus withstood the service conditions that the open berth structure was designed for. Chlorite attack is not the direct underlying contributing factor to the corrosion of reinforcement noted.

18. PROPOSED REMEDIAL WORKS OPTIONS AVAILABLE TO TNPA

Based on the results/outcomes of the detailed inspections and testing undertaken on Berth 4 Island View, Lodemann proposes the following three options for the Works:

18.1. Option 1 – Do Nothing

This option involves maintenance of the current status quo. It is however clear from the inspections completed, that the berth structure is beginning to show localised deterioration.

As much as the deterioration noted in this study remains largely cosmetic in nature and does not pose a major structural risk to the berth, if left unattended the localised deterioration shall progressively worsen to the point of affecting the berth's structural capacity. Repairs that may possibly be carried out at some stage in the future (on the premise that no remedial actions are taken now) will likely be much more significant in respect of longer time for completion, complexity of the repairs and the consequentially negative effects to berth operations.

18.2. Option 2 – Repairs

The visual inspection and laboratory testing results mesh well with each other and point to the existence of localised deterioration and defects that require localised repairs. It appears that the timing of the assessment was fortuitous, as the damage noted has not progressed to levels where they are having an effect on the structural integrity of the berth. With suitable repairs, the berth deterioration can be acceptably addressed.

18.3. Option 3 – Rebuild

Considering the extents of the defects noted, it is unlikely that a rebuild of the deck shall be necessary.

19. MULTI-CRITERIA ANALYSIS

The three options described in Section 18 above were consolidated into a matrix structure to allow for their comparison against predefined associative criteria. Weighted numerical scores were applied, with the summation of the individual scores resulting in the preferred option.

The critical project factors are described below as follows:

- **Effect on Operations** – means how significantly will the option impact the daily operations of the berth
- **Duration for Completion of the Works** – means how long (in months) will it take to complete the full scope of the work
- **Expected Lifespan Following the Completion of the Works** – means how long is the berth structure expected to last without experiencing a major structural failure
- **Constructability** – is a measure of the complexity associated with completing the works to a satisfactory level of fabrication quality
- **Maintenance Costs Within the First 10 years Following Completion of the Works** – means how much will the expected maintenance costs be

- **Cost of the Works** – means how much will the works cost to complete

IV4 Multi-Criteria Analysis

1. Effect on berth operations
0=Total shut down of Berth operations; 3= Partial Shutdown; 5= No effect on Berth operations

2. Duration for completion of the work
0= >12months; 1= 9-12months; 2= 6-9month; 3= 4-6months; 4= 1-3months; 5= 0months

3. Expected lifespan following completion of works
0=<5years; 1= 5-10years; 2= 10-20years, 3= 20-30years, 4= 30-50years; 5= >50years

4. Constructability

0= Highly complex construction incorporating very specialised construction techniques ; 5= Low complexity with standard construction techniques

5. Maintenance costs within the first 10 years following completion of the works
0=>20mil; 1=10-20mil; 2= 5-10mil; 3= 2-5mil; 4= 1-2mil; 5= 0-1mil

6. Cost of Works
0= 100-300mil; 1= 50-100mil; 2= 20-50mil; 3= 10-20mil; 4= 0-10mil; 5= 0mil

Note: In the table below, the highest total represents the preferred option

OPTIONS	CRITERIA						TOTAL
	Effect on berth operations	Duration for completion of the work	Expected lifespan following completion of works	Constructability	Maintenance costs within the first 10 years following completion of the works	Cost of Works	
1. Do Nothing	5	5	1	5	1	5	22
2. Repairs	3	3	3	5	3	3	20
3. Demolish and Rebuild	0	0	5	0	5	0	10

Figure 37: Multi-criteria analysis

19.1. Analysis of the Multi-Criteria Analysis

Though the **'Do Nothing'** option scored the highest, it is not a reasonable option as the berth has already been found to be in a deteriorating condition. This deterioration is certainly time dependant with the structure constantly subjected to the abrasive actions of the tidal movements meaning that the current deteriorated state shall only worsen over time. Areas where spalling and honeycombing were found will also deteriorate further due to chloride and sulphate attacks. Though the deterioration of the structure is currently considered primarily cosmetic, it is a certainty that doing nothing will eventually affect the

Serviceability and Ultimate Limit States of the structure. This is likely to result in diminished structural load bearing capacity which will negatively impact future berthing operations.

As mentioned in the previous paragraph, the structural deterioration currently noted on the berth structures is classified as cosmetic and having no major impact on the structural capacity of the berth. Hence, the **'Demolition and Rebuild'** of the berth is not considered to be necessary. For parity however, this option has had the critical project factors applied to it, in order to give an indication of the effect on operations, time, cost and complexity that would be associated with this option.

The findings of the various assessment techniques employed to establish the structural condition of the berth have been found to be largely congruous, with the outcomes pointing to structurally repairable defects at different locations on the berth structure. Through the application of the various critical project factors to the **'Repair'** option, repairs have been found to be both a logical and viable option.

20. RECOMMENDATIONS

The visual inspection survey both above water, in the splash zone and below water revealed only isolated areas of damage to the berth's reinforced concrete structures. In all instances, the classification of the damages fell into the typical ranges of reinforced concrete deterioration classes i.e. cracks, spalling, abrasion and honeycombing. The extent of the damages identified, at their current stage of inspection, is largely classified as 'cosmetic' type deterioration which means that the ultimate limit state of the structure has not been affected. Further, due to the intact Ultimate Limit State of the structure, it remains in a 'Fit for Purpose' operational condition. The results of the laboratory testing i.e. Compressive Strength Testing and Durability Index Testing of the concrete cores extracted from varied locations on the berth structure corroborates the findings of the visual assessments.

The reinforced concrete cores that were crushed all revealed breaking/crushing strengths exceeding 40 MPa, meaning that the original concrete mix design was adequate and suited to the application. This resulted in concrete that has suitably cured in its marine environment since it was first installed.

The results of the individual tests that comprise Durability Index testing i.e.: Water Sorptivity, Oxygen Permeability and Chloride Conductivity all produced results classified as 'Full Acceptance', meaning that the concrete at a microstructure level has not been compromised or significantly affected by the saline, high chloride marine environment.

We have thus concluded that the specific structural defects noted in the condition assessment are repairable, the repairs must follow the applicable specification rigidly.

Repairs to all affected concrete structures comprising the berth, as per the specifications and requirements as discussed in Sections 21, 22, 23 and 24 below, are thus recommended.

21. SPECIFICATION FOR REPAIRS TO UNDERWATER REINFORCED CONCRETE STRUCTURES

Repairs or remediation to the underwater concrete structures shall be in accordance with the following specifications:

- Completely remove all loose, delaminated and weak concrete, oil, grease, laitance and other contaminants. Prepare concrete using acceptable mechanical means and concrete cleaners or degreasers as necessary to obtain clean, sound and rough concrete surfaces exposing coarse aggregate.
- Where surfaces are not underwater or are in tidal zones, pre-soak concrete surfaces thoroughly for a minimum of eight hours with potable water. Concrete shall be saturated and free of standing water at time of placement.
- Where reinforcement is exposed, mechanically prepare surfaces to remove all rust, scaling, oxidation, marine growth and other contaminants. Where a delay in grouting may occur, coat reinforcement with a suitable corrosion inhibitor or coating.

Figure 38: Rotary pneumatic grinder used to prepare underwater concrete and steel surfaces for repairs

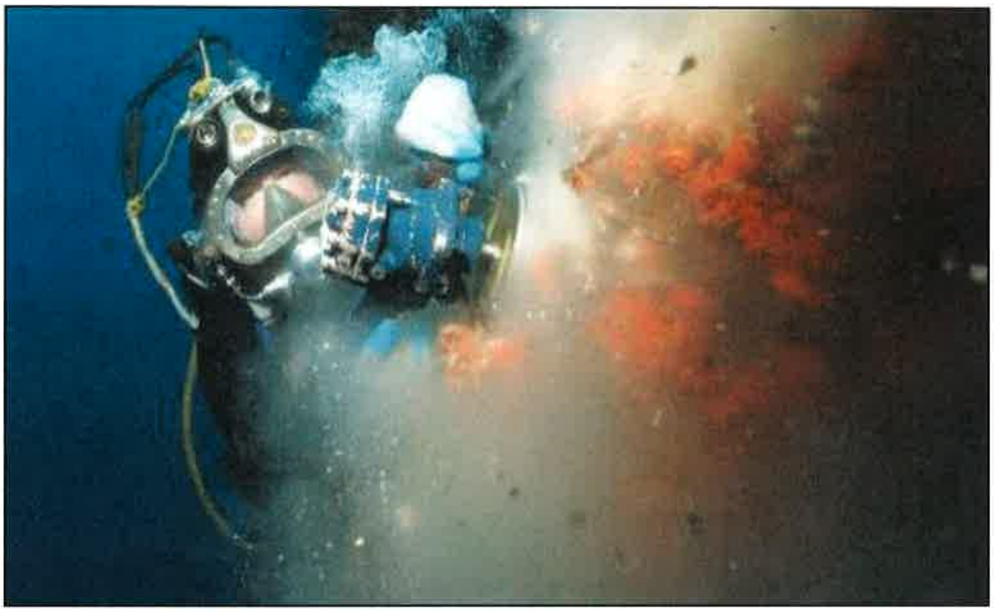

Figure 39: Preparation of underwater concrete structure

- All repair / grouting should be done at a minimum 25 mm thick to a maximum of 150 mm. Larger/deeper placements may be accomplished by extending grout with a clean washed coarse aggregate to Engineers specification.
- We recommend that all underwater grouting be dry-packed. It must be noted that dry-pack placement should be limited to small application areas. However, should we discover excessive structural damage after the dredging process alternative methods like underwater pouring or pumping should be adopted where it is not practical for dry-pack placement.
- A dry-pack consistency is achieved when the mixed grout can be squeezed into a ball by hand without crumbling. Only enough water should come to the surface to moisten the hands.
- Use a ram with a square cut end and hammer to evenly compact the grout against solidly braced backing boards, combining each layer (approximately 12mm thick) to the previously placed layer over its entire surface.
- Each placed layer shall be visually inspected for placement uniformity.
- Striking force should be sufficient for compaction of the grout without affecting plate alignment.
- Placement shall be continuous until grouting is complete.

- The contractor must follow all processes specified on the material data sheets when preparing the repair areas.
- The applicator must apply the repair mortar to the repair area as per the requirements of the supplier's material data sheet.

22. SPECIFICATION FOR REPAIRS TO ABOVE WATER REINFORCED CONCRETE STRUCTURES

22.1. Spalled Concrete

Spalled concrete that is visible on some concrete elements must be repaired in following way:

20.1.1. Surface Preparation

Mark out all of the defective areas of concrete to be removed. These shall be agreed with the Supervisor and recorded before proceeding with the repair works.

The concrete surfaces to be repaired must be free from dust, loose or friable materials, surface contaminants and any other materials which could reduce the bond of the repair materials.

All delaminated, weak, damaged and deteriorated concrete and where necessary sound concrete, shall be removed by suitable mechanical means or very high pressure water techniques (Up to 110 MPa). Tie-wire fragments, nails and any other metal debris embedded in the concrete must also be removed.

The edges of areas where concrete is removed shall be cut to an angle of more than 90° to avoid undercutting but not more than 135° to reduce the possibility of shrinkage / debonding / cracking at the adjacent sound concrete interface. These areas shall be roughened sufficiently to provide a mechanical key between the original concrete and the repair mortar.

Where the repair depth corresponds to the depth of concrete cover and the concrete removal exposes steel reinforcement; the breaking out shall continue to expose the full circumference of the steel, plus a further 20 mm behind the bars. Breaking out shall continue along the reinforcement until non-corroded steel is reached. Care must be taken to ensure that any reinforcement exposed is not cut or damaged.

20.1.2. Steel Reinforcement

Rust, millscale, mortar, concrete, dust and other loose and deleterious material which could reduce bond, or contribute to corrosion, shall be removed. The steel surfaces shall be prepared to a minimum standard equivalent to SA 2 ½ according to ISO 8501-1. The steel surfaces shall be prepared using abrasive blast cleaning or high pressure water techniques (Up to 60 MPa). Where exposed reinforcement is contaminated with chlorides or other materials which could cause corrosion, the reinforcement shall also be cleaned by low pressure water jetting techniques (Up to 18 MPa).

20.1.3. Corrosion Protection

Apply the anti-corrosion protective coating by brush or by spray onto the prepared reinforcement. Care must be taken to ensure complete application behind the reinforcement. Two coats must be applied and sufficient time must be allowed for first coat to harden before applying the second coat.

20.1.4. Bonding Primer

Apply the bonding primer into the substrate with a stiff brush, filling all of the profile. The subsequent application of the repair mortar shall then be done 'wet on wet'.

20.1.5. Repair Mortar

The repair work can either be hand placed or can be poured with a free-flowing structural repair concrete whichever is the most practical.

Ensure that the bonding primer is still 'tacky' when the repair material is applied using 'wet on wet' techniques.

Hand Placement – Apply a wet sprayed / hand placed fibre reinforced repair mortar or high build repair and profiling mortar depending on depth by hand using traditional techniques, or mechanically using 'wet' spray equipment. When the repair depth exceeds the maximum allowable thickness of the repair material, it shall be applied in several layers. The previous layer must have hardened sufficiently, so as not to be disturbed by the subsequent application. The first layer must not be smoothened in order to provide a mechanical key and ensure a good mechanical bond for the subsequent layer.

Repair Grout – Fix the formwork prior to the mixing of the material and seal grout tight. Different ways of grouting are applicable, such as pouring from the top as well as pumping from the bottom. Care must be taken that air can escape. The use of a rod will assist in releasing entrapped air. Slight knocking on the formwork might be of help to avoid air pockets. Place the free-flowing structural repair concrete directly after mixing ensuring that any displaced air is not allowed to escape. A sufficient hydrostatic head must be maintained to keep the product flowing. The repaired area must be protected from rain until initial set has been achieved. The repair grout must be cured by keeping wet to avoid rapid loss of water. Normal curing practices should be applied as for any other cementitious material.

20.1.6. Corrosion Inhibiting Impregnation Paint

Apply 3 coats of the corrosion inhibiting impregnation paint to saturation by brush, roller, low pressure or airless spray equipment.

After the application of the last coat, as soon as the surface becomes mat, do a low pressure water cleaning (water hose).

The day after application, the treated surfaces shall be cleaned by pressure washing (10 MPa) to remove any traces of soluble salts that may have deposited at the surface.

20.1.7. Silane Based Water Repellent Impregnation Cream

Apply one coat of the Silane Based Water Repellent Impregnation Cream using a brush, roller or airless spray.

22.2. Crack Repairs

The surface over the entire length of the crack should be wire brushed to remove laitance from the concrete. If the surface of the concrete is unsound chase a "V" cut at least 10 mm deep and 20 mm wide into the crack. All debris should be removed.

Drill into the crack using the 6 mm bit. Drill at least 50 mm deep. Ensure that the crack lies within the sides of the hole.

Using a fine stiff wire, scratch out the debris/dust that may block the crack in the sides of the hole.

Holes should be between 250 mm and 300 mm centres, the finer the crack the less the centre spacing.

Seal the grease nipples into the holes with a collar of a two-component repair epoxy mortar. Cover the head of the nipple with a short length of rubber or plastic tubing to ensure the inlet is kept free of epoxy. Also ensure that the outlet is kept free of epoxy.

Having sealed the nipples into the crack, seal the entire face of the crack applying about 3 mm thick and approximately 50 mm wide. Where the crack is chased out the chase should be filled and finished flush with the concrete surface.

Allow to cure overnight.

After curing (24hrs), open the non-return ball valves of the nipples by forcing in pins.

Fill the injection gun with correctly mixed low viscosity injection liquid.

Starting at the lowest point of the crack or at one end, if the crack runs horizontally, pump in liquid resin. Continue pumping until resin exudes from the next nipple. Remove pin and carry on pumping for a few more strokes of the gun.

Disconnect gun from inlet and attach it to the nipple from which resin exuded.

Continue this sequence working either up or along the crack. After about 30 minutes return to the first nipple that was filled, re-open the ball valves with pins and try to pump in further resin. This can usually be done as the resin may have seeped away into finer cracks or pockets of honeycomb. If foamy resin extrudes continue filling until clear resin is evident.

Once injection of crack has commenced, work must continue until the crack has been filled.

Before injection work starts, a rough calculation should be made as to the amount of resin that will be needed to fill the crack. This need to be approved by the Supervisor before the contractor continues with the work.

Twenty-four hours after injection, the surface seal and protruding nipples may be cut off with a grinding wheel.

22.3. Minor Honeycombing

The concrete surface should be sound, clean, properly cured, free from oils, grease or surface contaminants. All loose materials and surface laitance must be removed by high pressure jet blasting or similar mechanical means. The prepared surface should be thoroughly soaked with clean water until uniformly saturated, leaving no standing water.

Apply the cementitious pore sealer and levelling mortar by trowel to the pre-wetted substrate. As soon as the mortar has started to set, it can be rubbed down with a wooden or plastic float or sponge finished. Extra water should not be added to improve workability once setting has started.

23. METHOD STATEMENT FOR CONCRETE REPAIRS REQUIRING DIVING WORKS

23.1. Introduction

This method describes how underwater repairs to berth's reinforced concrete structures will be executed by a commercial diving entity.

23.2. Equipment Used

The following equipment will be used:

- Surface Supply System
  - Video camera and recorder
  - 2-way communication system from diver to surface
  - One-way and Non-return valves
  - Gauges
  - Main gas supply system
  - HP back up gas
  - Kirby-Morgan dive helmets
- Hydraulic Equipment
  - Hydraulic Power pack, piping and valves
  - Hydraulic Grinder
  - Hydraulic Breaker
- BROCO Oxy-Arc Underwater Cutting Equipment
- Support Vessels
- Support Vehicles

23.3. Establishing Operational Readiness of the Equipment

Surface Supply System

- The video camera and recorder will be tested
- 2-way communication between diver and surface will be tested
- The non-return valves will be tested
- The one way valves will be tested
- The gauges will be tested
- The main gas will be tested
  - LP compressor
  - Oil level will be checked
  - Pig will be visually inspected
  - Water will be drained out of pig

- The air quality of the main gas will be tested
- The HP backup gas will be tested
- The Kirby Morgan diving helmets will be tested

Hydraulic Equipment

- Check that the hydraulic power pack has got oil in the motor
- Check that the hydraulic power pack has got fuel in the tank
- Start the hydraulic power pack see if there is any leaks
- Test the hydraulic pipes by connecting them up to the hydraulic power pack and to each other complicating a loop
- Run the motor and stop see what the hydraulic oil level is if low top it up
- Testing the grinder
  - See firstly if the blade is secure
  - See if the guard is in place and if it does not interfere with the cutting end
  - Test the power handle and see whether it gets stuck, the ease of use if too much force needed to operate, then see whether it can be adjusted but also on no force
  - See whether the blade has any play on it
  - Test the grinder and see whether it rotates at the correct speed
  - Test the grinder on a piece of steel in the workshop

BROCO Oxy-Arc Underwater Cutting Equipment

- Get the BROCO cutter tested to make sure there are no leaks in the pipes from the oxygen cylinder
- Test the welder that will power it and see that the welder is in working order
- Invert polarity on DC welder, making positive terminal the earth.
- Test the clamp
- Test the stick
- See if the O-rings in the stick are still in good working order if not replace them
- Test the knife switch
  - It should open and close with ease

- If it gets stuck in any way replace the knife switch

Support Vessels

- Check that the fuel tank is full or has ample fuel for the journey
- Check that the motors start
- Check that the vessel has a capsized container
- Check that the vessel has got electrical power to all the instruments (VHF, GPS, Depth sounder)
- Check that the bungs are in.
- Check that the fire extinguishers are in date and have got the correct pressure reading
- Check that all emergency equipment is board
    - 2 rocket flares
    - 2 hand held flares
    - 1 orange smoke grenade
    - First aid kit
    - 2 space blankets
    - 1 sound signaling device
    - 1 orange sheet 2m-2m
    - 1 waterproof torch + spare battery's and bulb
    - Check that the steering magnetic compass
    - Check that the grab lines are secure
    - Check that the tiller arm is on board
    - Check that the vessel has six life jackets that are marked and in working condition
    - Check that the vessel has spare parts and tools if emergency repairs are needed to be made
    - Check that the vessel has 1 litre of clean drinking water per person on board
    - Check that the pontoons are inflated
    - Check that there is an air bellow pump on board and also a pontoon repair kit
    - Check that the vessel has got no deformities or abnormalities

- Check the paper work for the vessel:
    - The LGSC
    - The Radio station license
    - Skippers COC
    - Radio Operator COC
    - Buoyancy certificate
    - Proof of induction

Support Vehicles Check

- License disk in date
- Road worthy
- Maintenance schedule
- Daily inspection list
- Spare wheel
- Tyre pressure
- Jack

23.4. Composition of the Dive Team

- 1 x commercial diving supervisor
- 4 x commercial divers/line tenders
- 1 x first aider
- 1 x skipper
- 1 x deck hand

23.5. Site Establishment Requirements

- Site office container

23.6. Execution

23.6.1. Demolish Defective Under Deck Areas

A small mobile pontoon based floating platform will be towed to the site using the work boat. It will be equipped to accommodate up to 3 divers. It will have a draft requirement of 300mm or less which will minimise the impact of tidal variance.

On low tide it will be pulled under the deck allowing divers to work from. Once the defective areas are marked the divers will use the hydraulic / pneumatic breakers to demolish the weathered concrete till sound concrete is obtained.

Figure 40: Dive platform

23.6.2. Demolition of Defective Pile Areas

The defective pile areas will be identified and marked. The diver, using a hydraulic drill, will install pigtails on either side of each repair area. The pigtails will be used for the diver to attach a nylon safety harness enabling a secure anchoring point for the diver to tie himself to.

Once the diver is secure he will commence with demolishing the defective area using a hydraulic / pneumatic breaker. All weathered concrete will be removed till sound concrete is obtained.

23.6.3. Reinforcing

The corroded steel reinforcing will be cut away using the hydraulic grinder or BROCO in restricted spaces. New bars will be chemically dowelled as required into the demolished area for reinstatement.

Figure 41: Underwater cutting of corroded rebar

23.6.4. Grouting

Refer Section 24 for repair products.

23.6.5. Completion Polish

After the grout is given time to set the diver will polish the repaired surfaces using the hydraulic grinder with a stone sand cup.

23.7. Safety

23.7.1. Land Safety

- All personnel are to fulfil PPE requirements
- All personnel to be certified medically fit for duty

23.7.2. Assessment of Significant Risks for Tasks

- Daily safety checklists will be completed, including hazard identification
- Daily Toolbox talks to be completed, highlighting safety concerns
- Method Statements will be read and explained to the pertinent operatives
- Risk Assessment to be discussed with workers
- Safety talks to take place daily before work commences
- Foreman/supervisor to fill out Daily HIRA highlighting job specific hazards, all employees to sign @ the back of form
- All employees and operators must be medically fit and be inducted
- Operators to fill out daily checklist on machinery

23.7.3. Personal Protective Equipment

- All personnel will wear safety boots, hard hats, reflective vests, safety glasses, overalls and gloves

23.7.4. Emergency Protocol

- The site designated first aiders will administer first aid treatment.
- Emergency evacuation procedures will be on display.
- All relevant signage will be displayed
- All certification will be on hand.
- Toolbox Talks will be conducted daily prior to work.
- Emergency Contact Numbers will be distributed and displayed on notice boards

24. RECOMMENDED REPAIR PRODUCT – REINFORCED CONCRETE STRUCTURES BELOW WATER

24.1. Introduction

Where there are identified areas displaying damage to below water concrete structures, the following product is used:

- Repair Mortar

As the presence of atmospheric oxygen is mostly diminished below water, damaged areas of the structure can be repaired by the direct application of cementitious mortars.

24.2. Data Sheet – Rapid Setting Cementitious Mortar for Underwater Applications

Below is given the data sheet for a repair mortar for use in marine environments. The product should be applied directly to the damaged areas.

BASF

We create chemistry

MasterEmaco® S 902

Rapid setting cementitious repair mortar for underwater applications

DESCRIPTION

MasterEmaco S 902 is a ready to use, fast setting, cement based marine mortar. It was specifically developed for underwater repair and restoration work.

RECOMMENDED USES

- Repairing eroded concrete or timber piles, sea walls, wharves
- Repairing leaks or joints in marine structures, concrete reservoirs, swimming pools, pipelines, well etc.

FEATURES AND BENEFITS

- **Rapid setting** - Quick, efficient repairs to areas exposed to wave and tide action
- **Excellent adhesion** - High bond strength to clean concrete and timber surfaces
- **Easy to use** – applied by hand
- **Dense anti wash out mortar** - resistant to wave action during placing
- **Suitable for constant immersion** - resistant to sulphurous ground waters
- **Waterproof** - provides a watertight seal when used to repair leaks or seal joints

PERFORMANCE DATA

Compressive strength of 50mm cubes of **MasterEmaco S 902** placed at 21°C are:

Age	Compressive Strength
1 day	10 MPa
3 days	18 MPa
28 days	27 MPa

APPLICATION

Preparation

All unsound material, dust, dirt, etc. must be removed from surfaces to be restored. Pre-dampen dry surfaces to eliminate suction.

Mixing

Mix **MasterEmaco S 902** with fresh water only. Water requirements vary depending on temperature and humidity, but in most cases three volumes of **MasterEmaco S 902** require approximately one volume of water.

Place **MasterEmaco S 902** into container and add half the water, mix quickly with a short handled trowel, add extra water as required. (Mix only small batches at one time, **MasterEmaco S 902** must be placed within 5 minutes of mixing).

Promptly add the remainder of the water and mix thoroughly until no white streaks are present. The mix is ready for use.

For hand application **MasterEmaco S 902** should be made into a putty-like consistency and shaped quickly into balls of about cricket ball size.

Do not retemper material which has begun to stiffen - discard material which has lost its plasticity.

Application

When applying **MasterEmaco S 902** to eroded piles, all or part of **MasterEmaco S 902** "ball" should be centred in the cavity firmly, and quickly smoothed out from the centre to the sides with both hands, using "forward and sideways" pressure, moulding to appropriate shape and thickness.

When applying underwater, place freshly-mixed "balls" of **MasterEmaco S 902** into a wire basket and lower steadily to diver. Where there is wave action or turbulence in the water, it is advisable to press the **MasterEmaco S 902** firmly in place for a moment or so before smoothing it out to shape.

Spray application can be used for the repair of piles above the water-line and in the wave wash water-line.

Timber pile restoration

1. Remove marine growth and unsound timber by square cutting into sound wood above and below to the depth of furthermost deterioration and then remove the unsound section by hand or with air hammers.
2. In cases of deep deterioration, make up a reinforcing cage by using eight No. 12mm diameter rods 20% shorter than the height of the cutout. Drive these rods into counter-bored holes in the top and bottom of the cut surfaces at four equidistant points and splice adjacent rods. Wrap 8-gauge galvanised wire spirally around the cage at 100mm centrelines.

MASTER® BUILDERS SOLUTIONS

BASF
We create chemistry

MasterEmaco® S 902

3. Below water, apply **MasterEmaco S 902** by hand after mixing with water to a putty-like consistency. This operation must be carried out quickly as **MasterEmaco S 902** takes its initial set within 5 minutes. Above water, apply either by hand or pneumatic gun.
4. In cases of shallow deterioration only, 20-gauge galvanised chicken wire should be lashed and stapled to the pile and a 2mm thick coat of **MasterEmaco S 902** is built up in stages.

Concrete pile restoration, honeycombed concrete repair.

1. Remove deteriorated concrete, rust and scale from reinforcing steel by chipping and/or sand-blasting.
2. Care should be take to square up or, preferably, under-cut or "dovetail" the edges of those sections where deteriorated concrete has been removed.
3. If reinforcing steel is extensively exposed, where possible wrap 8-gauge galvanised wire spirally around exposed longitudinals at 100mm centrelines.
4. Apply **MasterEmaco S 902** under water by hand, and above water either by hand or by pneumatic gun, until adequate covering thickness is built up or restored.

When repairing cracks or holes in leaking tanks open up the crack or hole to at least 15mm wide and 15mm deep and divert water if necessary with a plastic tube. Mix and ball up mortar, ramming in and holding until initial set. Tie off water diversion.

ESTIMATING DATA

20kg of MasterEmaco S 902 mixed in accordance with recommended application directions will yield 11.2L (0.0112m³) of mortar.

PACKAGING

MasterEmaco S 902 is packaged in 20kg moisture resistant bags.

SHELF LIFE

MasterEmaco S 902 has a shelf life of 12 months. Store out of direct sunlight, clear of the ground on pallets protected from rainfall.

PRECAUTIONS

For the full health and safety hazard information and how to safely handle and use this product, please make sure that you obtain a copy of the BASF Material Safety Data Sheet (MSDS) from our office or our website.

25. RECOMMENDED REPAIR PRODUCTS – REINFORCED CONCRETE STRUCTURES LOCATED ABOVE WATER AND IN THE TIDAL ZONE

25.1. Introduction

Where there are identified areas displaying damage to the above water and tidal zone based concrete structures, a combination of the following three products is used:

- Zinc based primer
- Repair mortar
- Silane based corrosion inhibitor

These products are required in combination due the presence and effect of atmospheric oxygen on the reinforced concrete structure above water and falling within the tidal zone.

25.2. Data Sheet – Zinc Primer

Below is given the data sheet for a zinc based primer specific for use in marine environments. The product should be applied directly to the freshly blasted steel rebar.

BASF
We create chemistry

MasterEmaco® 8100 AP

Single component epoxy based zinc rich primer for steel

DESCRIPTION

MasterEmaco® 8100 AP is a single component, solvent borne zinc rich epoxy primer, providing active galvanic protection to steel. It is a thick grey liquid of paint-like consistency, recommended for use where chloride induced attack on steel and concrete is involved.

PRIMARY USES

- As a protective coating to steel reinforcing bars in concrete.
- As a touch-up primer for damaged galvanised metal.
- As a primer for steel substrates prior to suitable top coating.

ADVANTAGES

- Provides positive protection of steel components against corrosion.
- Excellent adhesion to steel.
- Easy to use single component material.
- No pot-life restrictions or wastage.
- Short overcoating time.

PACKAGING

MasterEmaco® 8100 AP is a single component system, supplied in 1 litre units.

TYPICAL PROPERTIES*

Appearance:	thick grey liquid
Specific gravity:	2.20 at 25°C
Tack free time: (approximate)	20 mins at 25°C 5 mins at 40°C
Recoat time :	5 hours at 25°C 2 hours at 40°C
T.Z.C. in DFT	>90%
D.F.T. per coat	>50 microns
Application temperature:	min. 10°C max. 40°C

STANDARDS

MasterEmaco® 8100 AP is formulated to meet the scope of BS 4652, 1995 Type 2.

APPLICATION PROCEDURE

SURFACE PREPARATION:

The steel surfaces should be grit blasted or wire brushed to remove all traces of corrosion. Ensure no oil, grease or dust is present. Surfaces should be dry.

Apply **MasterEmaco® 8100 AP** immediately after completion of preparation to prevent any contamination. Do not leave blasted or prepared steel uncoated.

MIXING:

MasterEmaco® 8100 AP should be thoroughly mixed prior to application.

APPLICATION:

Brush the **MasterEmaco® 8100 AP** onto the prepared substrate, ensuring uniform and full coverage, particularly on the back face of reinforcement. Repair mortars can be applied as soon as the **MasterEmaco® 8100 AP** is dry.

LONG TERM EXPOSURE

MasterEmaco® 8100 AP is not designed as a finished coating. Although protection to the steel will be provided for some time, overcoating should be carried out as soon as possible, particularly in aggressive environments.

COVERAGE

When used for coating steel 1 litre of **MasterEmaco® 8100 AP** will cover 165 linear metres of 16mm diameter bar per coat and pro rata or 7.5m²/litre/coat.

EQUIPMENT CARE

Tools should be cleaned with Methyl Ethyl Ketone immediately after use.

MASTER® BUILDERS SOLUTIONS

BASF

We create chemistry

MasterEmaco® 8100 AP

STORAGE

Store under cover out of direct sunlight and protect from extremes of temperature. In tropical climates the product must be stored in an air-conditioned environment. Shelf life is at least 12 months from date of manufacture when stored as above.

Failure to comply with the recommended storage conditions may result in premature deterioration of the product or packaging. For specific storage advice consult BASF's Technical Services Department.

SAFETY PRECAUTIONS

As with all chemical products, care should be taken during use and storage to avoid contact with eyes, mouth, skin and foodstuffs. Treat splashes to eyes and skin immediately. If accidentally ingested, seek immediate medical attention. Reseal containers after use.

NOTE

Field service, where provided, does not constitute supervisory responsibility. For additional information contact your local BASF representative. BASF shall not be liable for technical advice provided.

BASF reserves the right to have the true cause of any difficulty determined by accepted test methods. Undertaking such tests is not, and shall not be deemed to be, an admission of liability or an assumption of any risk, loss, damage or liability.

QUALITY AND RESPONSIBLE CARE

All products originating from BASF Construction Chemicals South Africa are manufactured under a management system independently certified to conform to the requirements of the quality (ISO 9001), environmental and occupational health & safety standards.

* Properties listed are based on laboratory controlled tests.

® = Registered trademark of the BASF-Group in many countries

STATEMENT OF RESPONSIBILITY	The technical information and application advice given in this BASF publication are based on the present state of our best scientific and practical knowledge. As the information herein is of a general nature, no assumption can be made as to a product's suitability for a particular use or application and no warranty as to its accuracy, reliability or completeness either expressed or implied is given other than those required by law. The user is responsible for checking the suitability of products for their intended use.
NOTE	Field service where provided does not constitute supervisory responsibility. Suggestions made by BASF either orally or in writing may be followed, modified or rejected by the owner, engineer or contractor since they, and not BASF, are responsible for carrying out procedures appropriate to a specific application.

BASF Construction Chemicals South Africa (Pty) Ltd

852 Sixteenth Road, Midrand

PO Box 2803, Halfway House, 1685

Tel: +27 11 203 2405 Fax: +27 11 203 2679

www.master-builders-solutions.basf.co.za

Revision Date: 25/04/2017

25.3. Data Sheet – Repair Mortar

Below is given the data sheet for a high strength, rapid setting, shrinkage compensated, fibre reinforced, structural repair mortar with an active corrosion inhibitor specific for use in marine environments. The product should be applied on top of the previously blasted and primed structural rebar embedded in the concrete structures.

BASF

We create chemistry

MasterEmaco® S 5410 CI

High-strength, rapid setting, shrinkage compensated, fibre reinforced, structural repair mortar with active corrosion inhibition

DESCRIPTION

MasterEmaco® S 5410 CI is a single component, extra high-strength, high modulus, shrinkage compensated structural repair mortar that meets the requirements of the new European Norm EN 1504-3 class R4. MasterEmaco S 5410 CI contains Portland cement, graded sands, selected polymer fibres and special additives to significantly reduce the risk and incidence of shrinkage cracking. When mixed with water, it forms a highly thixotropic mortar that can easily be spray or trowel applied.

RECOMMENDED USES

MasterEmaco® S 5410 CI is used for the structural repair of concrete elements such as:

- Columns, piers and cross beams of all bridges
- Cooling towers and chimneys and other industrial environments
- Tunnels, pipes, outfalls and all below ground construction especially in harsh ground conditions

FEATURES AND BENEFITS

- **Versatile** – Can be applied in extreme environments where active corrosion inhibition is required.
- **Shrinkage compensation systems and fibre reinforcement** – Minimize crack tendency.
- **Highly thixotropic** – Can be applied up to 50 mm without the need of secondary reinforcement.
- **High early and ultimate strengths** – Matches high strength concrete found in structures.
- **Outstanding workability** – Easy placing and finishing for applicators.
- **High modulus and excellent adhesion** – Ensuring load transfer in structural repair.
- **No primer required** – Allows rapid application at reduced cost.
- **Very low permeability to water and chlorides** - Protection of reinforcing steel.

TYPICAL PROPERTIES*

Typical properties when tested at 2.8l water/20kg powder

Appearance	Grey powder
Application thickness Overhead Max	10-50 mm /layer Not more than 30mm/layer
Density	Approx. 2.2 g/cm3
Mixing water per 20kg bag	Approx. 2.4 – 2.8 litres
Working time	Approx. 30 minutes
Application Temperature (support and material)	Between +5 and +35°C
Compressive strength EN 12190 - after 3 hours - after 1 day - after 7 days - after 28 days	 ≥15 MPa ≥15-30 MPa ≥ 40 MPa ≥ 60 MPa
E-Modulus (28 days) EN1504-3	≥ 20 GPa
Adhesion (28 days) EN 1504-3	≥ 2 MPa
Adhesion after Freeze/Thaw EN 1504-3	≥ 2 MPa
Adhesion after Thunder/Shower EN 1504-3	≥ 2 MPa
Adhesion after Adhesion after dry cycling EN 1504-3	≥ 2 MPa
Capillary absorption – EN 13057	≤ 0.5 kg/m²h$^{0.5}$
Rapid chloride permeability ASTM C 1202 2012	Approx. 300 coulombs (very low)

APPLICATION

Surface preparation - Concrete must be fully cured with a minimum direct tensile strength of 1.5 MPa. All loose traces of concrete or mortar, dust, grease oil, etc. must be removed. Damaged or contaminated concrete shall be removed to obtain a keyed aggregate exposed surface. Non-impact / vibrating cleaning methods, e.g. grit or high pressure water blasting are recommended. Cut the edges of the repair vertically to a minimum depth of 10 mm. Clean all exposed reinforcement to a bright steel condition and apply MasterEmaco 8100 AP zinc rich primer to exposed cleaned steel and allow to dry. Ensure concrete substrate is free of dust and pre-saturated for a minimum of 4 hours prior to commencing with the installation.

MASTER® BUILDERS SOLUTIONS

BASF
We create chemistry

MasterEmaco® S 5410 CI

Mixing - Only full bags are mixed. Damaged or opened bags should not be used. Mix MasterEmaco® S 5410 CI in a forced action pan mixer, or with a helical paddle attached to a low speed (300-600rpm) mixer for 3 minutes until a lump free, plastic consistency is achieved. Only use clean water. Mixing water needed: 2.4 to 2.8 litres per 20kg bag depending upon consistency required. Allow the mortar to rest for 2 - 3 minutes and then remix briefly, adjusting the consistency when required, without exceeding the maximum water demand.

Priming Concrete - No special primer is required. Thoroughly saturate the surface of the concrete to provide a saturated surface dry condition. Poor quality concrete may require soaking for a significant length of time. Any surface water should be removed using an oil free compressed airiest.

Mortar application - The minimum temperatures must be maintained during application and for at least 24 hours thereafter for optimum curing of the product. The prepared substrate should be pre-soaked, preferably for 24 hours, but at least 2 hours before applying MasterEmaco® S 5410 CI. The surface must be saturated surface dry, but without standing water. MasterEmaco® S 5410 CI can be spray or hand applied. Apply mixed product directly to the prepared damp substrate. Spraying the material with the necessary pressure will ensure good adhesion of the material. A thin scraper coat or contact layer before building up to the required thickness, wet on wet, will improve adhesion especially in case of hand application. Apply to the desired layer thickness of 10 to max 50 mm and level using a screeding bar, trowel or wooden board. Can be applied in thicker layers in smaller patches or where additional reinforcement is present. Smoothing with a trowel or finishing by float or sponge can be done as soon as the mortar has begun to stiffen.

CURING

The following curing methods are advised: Polyethylene film, damp cloths, MasterKure® curing agents.

ESTIMATING DATA

One 20kg bag will yield approximately 10 litres of mortar. Approx. 2.2 kg of mixed product per m^2 per mm layer thickness. This consumption is theoretical and depends on the roughness of the support amount of rebar, wastage etc, for which reason it should be verified in each particular job by means of "in situ" tests.

PACKAGING

MasterEmaco® S 5410 CI is available in 20kg bags.

SHELF-LIFE

Store in cool and dry warehouse conditions. Shelf life in these conditions is 12 months from date of manufacture in unopened original bags.

PRECAUTIONS

For the full health and safety hazard information and how to safely handle and use this product, please make sure that you obtain a copy of the BASF Material Safety Data Sheet (MSDS) from our office.

MASTER® BUILDERS SOLUTIONS

25.4. Data Sheet – Corrosion Inhibitor

Below is given the data sheet for a Silane based corrosion inhibitor specific for use in marine environments. The product should be applied on top of the repair mortar that had previously been applied to the damaged concrete areas.

BASF
We create chemistry

MasterProtect® 8000 CI

Advanced Organo functional Silane based Corrosion Inhibitor

DESCRIPTION

MasterProtect® 8000 CI is a single component, ready to use, low viscosity, clear liquid which combines the proven effectiveness of penetrative silane treatments for the control of moisture and Chloride ion ingress with advanced organo functional corrosion inhibition.

FIELDS OF APPLICATION

MasterProtect® 8000 CI is sprayed directly onto the surface of steel reinforced concrete structures and buildings.

It is equally suited to cast in situ, precast, post tensioned, prestressed, GFRC, or other steel reinforced concrete.

It is particularly suited for the protection of:

- Bridge decks, piers columns and beams
- Multi-Storey Car Parks, building facades and balconies
- Marine jetties and structures

MasterProtect® 8000 CI can be used as part of an overall repair strategy using **MasterEmaco®** Concrete Repair Systems to mitigate corrosion rates within the balance of the structure and significantly reduce the possibility of "ring anode" induced spalling at a later date.

Equally **MasterProtect® 8000 CI** can be used as a cost effective preventative measure before the onset of corrosion induced problems occur.

Contact the Technical Department of your local BASF Construction Chemicals for further information.

FEATURES AND BENEFITS

- Reduces chloride induced corrosion of concrete steel reinforcement.
- Reduces corrosion in carbonated reinforced concrete.
- Works at the molecular level to effectively inhibit macrocell (rebar to rebar) and microcell (on the same rebar) corrosion.
- Proven long term effectiveness in laboratory and field trials >10 years & proven performance in aggressive environment subject to deicing salts and vehicular traffic.
- Equally effective in high humidity conditions.
- Chemically bonds to steel, cement paste and other siliceous material – will not wash or leach out during wetting / drying cycles, ensuring extended active life.
- Simple and easy to use.
- Does not discolour or change appearance of concrete.
- Breathable vapour permeable treatment.
- Repels further ingress by chlorides and water.

PACKAGING

MasterProtect® 8000 CI is supplied in 20 litre containers.

TYPICAL PROPERTIES*

Appearance	Clear Liquid
Density	0,88g/cm³
pH	7 to 8
Flash Point	63°C
Viscosity	0,95 mPas

PERFORMANCE DATA

U.S. Federal Highways Administration Test protocol for cracked Beam Concrete

TEST METHOD

MasterProtect® 8000 CI was sprayed at the approved application rate onto standard test specimens where the concrete (W/C ratio 0,47) had been deliberately cracked along the length of the reinforcing steel to simulate real life experiences of transverse bridge deck cracking. Some specimens showed existing corrosion before application whereas others did not.

The specimens were then subject to the following rigorous conditions:
48 weeks cyclic salt water ponding (15% salt solution)
High Relative Humidities: 70–80%
Elevated temperatures: 37°C

MASTER® BUILDERS

BASF
We create chemistry

MasterProtect® 8000 CI

CORROSION INHIBITION

Specimen conditioning	Observed results compared with untreated control specimens
Cracked concrete: NO preexisting	99% reduction in corrosion
Cracked concrete WITH existing corrosion	92% reduction in corrosion

REDUCTION IN CHLORIDE INGRESS

Tests according to ASTM 1152 at depths of 12,5mm, 32mm, 50mm and 69 mm.

Control			MasterProtect® 8000 CI treated		
12 weeks	24 weeks	48 weeks	12 weeks	24 weeks	48 weeks
0,703*	0,861	1,020	<0.007	0,010	<0.007
0.321	0,628	0,645	<0.007	<0.007	<0.007
0.032	0,386	0,0386	<0.007	<0.007	<0.007
<0.007	0,040	0,040	<0.007	<0.007	<0.007

* Chlorides measured according to ASTM 1152

APPLICATION PROCEDURE

Preparation of Substrate

Concrete surfaces must be dry and cleaned to remove all traces of mould oil, curing compounds, dirt, dust, efflorescence, mould, algae, grease, oil asphalt, paint, lacquers, or other coatings or any other materials that would prevent penetration.

Acceptable cleaning methods include shotblasting, high pressure water blasting, or grinding.

All delaminated, loose or spalled concrete must be removed and repaired with an approved product from the **MasterEmaco®** or other approved Concrete Repair range.

MasterProtect® 8000 CI can, as an additional protective measure, be applied directly to exposed rebar before repair work commences.

Non moving shallow shrinkage cracks with no structural significance are simply treated with multiple coats or ponding of **MasterProtect® 8000 CI** .

Other cracks or failed joint sealants should be routed clean and treated with **MasterProtect® 8000CI** before being filled with suitable joint sealant from the **MasterSeal®** range or similar approved.

Apply **MasterProtect® 8000 CI** to the entire surface to be protected, including any repaired areas, using low pressure spray equipment with a suitable fan nozzle.

A total application of 600ml/m² is usually required applied in two or three separate applications (e.g. Horizontal applications 2 x 300ml while vertical and overhead 3 x 200ml) . Allow a minimum of 15 minutes between coats (or until visibly dry).

APPLICATION WATCHPOINTS

In cases where the temperature is below 5°C and above 35°C, please contact BASF Technical Services for guidance. The concrete surfaces should be surface dry after heavy rain or cleaning with water before applying **MasterProtect® 8000 CI.**

Do not apply if rain is expected within 4 hours.

Do not alter or dilute the material as supplied.

COVERAGE

600ml/m² applied in two or three coats *Horizontal surfaces:* 2 coats @ 300ml/m² *Vertical or overhead surfaces:* 3 coats @ 200ml/m²

MASTER® BUILDERS

BASF

We create chemistry

MasterProtect® 8000 CI

STORAGE

MasterProtect® 8000 CI should be stored under normal warehouse conditions between – 15°C and 50°C.

Keep containers closed when not in use and away from naked flames, heat sources and sparks.

SHELF LIFE

MasterProtect® 8000 CI has a shelf life of 12 months from date of manufacture when stored in undamaged, unopened containers.

NOTE

Technical support, where provided, does not constitute supervisory responsibility. For additional information contact your local BASF representative. BASF shall not be liable for technical advice provided.

BASF reserves the right to have the true cause of any difficulty determined by accepted test methods. Undertaking such tests is not, and shall not be deemed to be, an admission of liability or an assumption of any risk, loss, damage or liability.

QUALITY AND RESPONSIBLE CARE

All products originating from BASF Construction Chemicals South Africa are manufactured under a management system independently certified to conform to the requirements of the quality (ISO 9001), environmental and occupational health & safety standards.

* Properties listed are based on laboratory controlled tests.

® = Registered trademark of the BASF-Group in many countries.

26. CONCLUSION

Berth 4 is located within the Island View Precinct, a National Key Point, and is of significant operational and strategic significance to TNPA as well as the greater shipping industry and the South African economy. Due to the criticality of the berth operations, it is required that the berth be continuously available. This justifies the regular planned maintenance of the berth.

Unfortunately, this condition assessment, while a step in the right direction in respect of 'Asset Care' has revealed some evidence of the application of constrained maintenance, at best, being applied to the berth. It is fortuitous, that this assessment was undertaken as the damage and deterioration noted was found to still be at a fully repairable state, with no damages noted that provide evidence of a potential structural failure state. However, the damages that have been highlighted during this condition assessment, if not addressed immediately, certainly possess the potential to affect the Ultimate Limit State of the structure and hence its structural load bearing capacity.

As outcomes from the condition assessment, Lodemann has proposed three possible remedial options available to TNPA.

Lodemann has recommended the **'Repairs'** option.

TNPA must choose amongst the proposed options.

27. REFERENCES

a. Tsinker G. Handbook Of Port And Harbor Engineering. 1997.
b. Carl A. Thoresen (Institution of Civil Engineers I. Port Designer's Handbook. 2014.
c. Alexander S. Durability Index Testing Procedure Manual. 2018;2018(April).
d. Gouws ASM, Alexander MG, Maritz G. Use of Durability Index Tests for the Assessment and Control of Concrete Quality on Site USE OF DURABILITY INDEX TESTS FOR THE ASSESSMENT AND CONTROL OF. 2001;98(April):5–16.

28. ANNEXURES

28.1. Dive Survey Report