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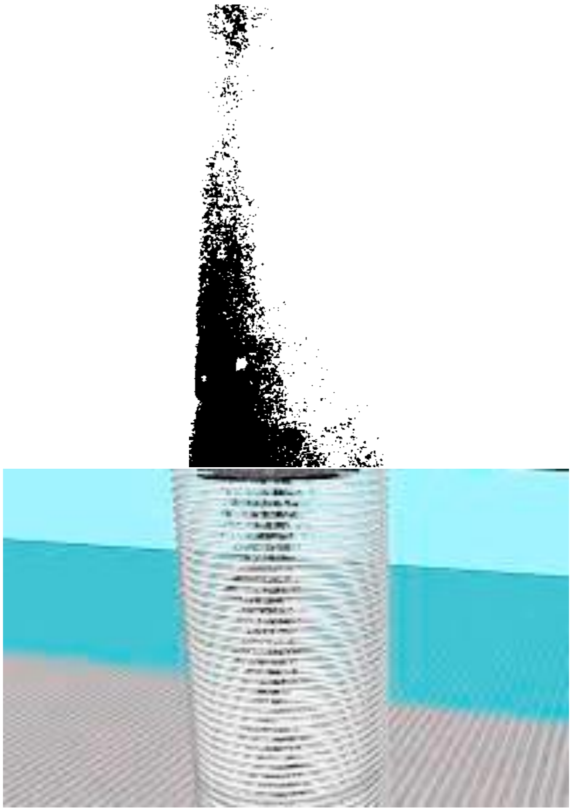

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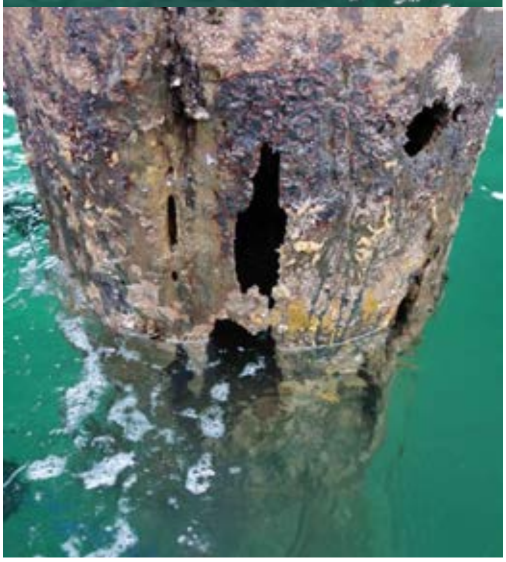

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Timber Pile Rehabilitation – FRP Sleeving – Completion Report

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Preface

Marina assets such as timber piles and their life cycle management represent major planning and engineering efforts; especially those subjected to harsh marine environmental conditions. For Companies and or Government Authorities to obtain the maximum working life and return on their initial investment from assets in a marine environment it is important that they be maintained to an acceptable and safe working standard. To ensure the quality assurance of their asset it is necessary to complete infrastructure surveys, programmed maintenance, and subsequent to inspection findings; remedial works.

When marina installations and their ancillary components come into service, it is hoped that they're free of all significant faults. This of course depends on the professional standards of the quality assurance of the numerous involved Parties in design, fabrication, construction, and installation.
To ensure a continuous working life for any marine asset, it is necessary to maintain an adequate inspection programme. Such a programme must be capable of detecting potential problems at an early stage. This allows the designers and engineers time to analyse the inspection information and suggest remedial action if required.

Experience has shown that the vast majority of all faults; damage / defects / deterioration found in marine structures have been done so visually. Visual information is of utmost importance both in programmed visual survey inspection, condition assessment, and general diver observation.
Throughout the progression of these survey inspections personnel observe and record data on numerous components in varying condition states.
The consequences of failure of what initially may only be a single component, especially sudden failure, can be catastrophic and very expensive, both in terms of repairs, lost business, and risks to health, safety and the environment.
Programmed survey inspections / condition assessment / asset management audits are completed to ensure the continuing operational function and safe condition of the marina is maintained. Providing the Asset Owner, its operators, and subsequently the users with an assurance of reliability and ensuring the integrity of the components that collectively are the marina.

Condition assessment is an important step in the life cycle management process of Marine Assets and their ancillary components.
One of UCL's major facets of work and experience is in the inspections, condition assessment and reporting on numerous 'in-water' structures throughout New Zealand and Offshore. It is a facet of our work that we can derive immense satisfaction from; when being able to detect potential problems at an early stage, then work in partnership with Clients towards achieving common goals and economic solutions. Thus minimising risk and therefore maintaining the Clients valuable asset in safe and efficient working condition – "fit for purpose".

Asset Management

Asset management is a strategic, long-term approach which provides a foundation for improved operational performance and a sustainable business model.
The key benefits of Asset Management Planning are:

- Manage an asset throughout its lifetime and improve performance.
- Consider risks associated with costs and performance in all decisions.
- Help to improve organisational performance and achieve sustainable business objectives.
- Achieve tangible profits over time with optimised return on investment and / or growth.
- Be able to demonstrate to stakeholders, sensible utilisation of assets and associated risks and costs.
- Improve corporate reputation and credibility.

Asset Maintenance

"It needs to be recognised; to have an effective Asset Management Plan; you're required to have an effective Asset Maintenance Programme".

Over the past few decades, the desire of extending the useful service life of infrastructures has become of paramount significance. Where the ageing infrastructure is a serious problem faced by countries across the world, the premature deterioration has also emerged as the major problem that results in reduced service life of structures.
Structural elements are constantly subjected to multiple risk factors that result in deterioration over the course of their service lives.
Structural failure may be defined as the inability of a structure to serve its intended function with the desired levels of safety and serviceability.
Failure of a structure may be attributed to a number of independent and interrelated factors.

Asset condition assessments combine the processes of periodic inspection and testing and the assessment and interpretation of the resultant data to provide an indication of the current condition of a specific asset as to the determination of the requirement for remedial action.
Asset condition assessments determine the physical state of an asset that may affect the performance of the asset and the ability of the asset to provide the required level of service.

The benefits of knowing the current condition of an asset are:

- The ability to plan and manage the delivery of the required level of service of the asset.
- Avoiding premature asset failure by providing the option of cost effective remediation.
- Providing an accurate estimate of future expenditure that is required.
- Determination and refinement of maintenance and rehabilitation strategies.

Asset maintenance to be undertaken over the balance of structure service life is a major challenge to provide reliable and sustainable facility operation. Operating ageing facilities efficiently and safely requires an asset maintenance cycle to include inspection diagnosis, evaluation and implementation of remediation processes.
It is a critical part of asset management to determine the remaining lifecycle of an asset and the capability of the asset to meet the designed performance and level of service requirements.
In today's environment, the preventative maintenance of ageing structures is much better than the cost of construction of new structures once original design lives have been exceeded. Asset Condition Assessment gathered information assists the determination of the remaining service life of an asset, the scheduling of remediation requirements that are required to reinstate the level of service that is provided by the asset to the desired standard.

Being unaware of the current condition of an asset may lead to the premature failure of the asset leaving limited options to the facility owner with replacement being the most expensive option. Unforeseen failure of an asset provides major consequences that constitute a risk to business operations or potential loss to the organisation. The benefits of knowing the current condition of an asset are the ability to plan and manage the delivery of the required level of service of the asset, avoiding premature asset failure providing the option of cost effective remediation, providing an accurate estimate of future expenditure that is required and the determination and refinement of maintenance and rehabilitation strategies.

Assessment of damaged or deteriorated structures should only be made by qualified and experienced people and the process of should always include the aspects of the condition of the structure including all visible, non-visible and potential damage and defects, a review of the past, current and future service functions / requirements.

With most damaged or deteriorated structures, the facility owner has a number of options which will effectively decide the appropriate remediation strategy that will meet the future service requirements of the structure. These options will include doing nothing, downgrading the capacity or functioning of the structure, preventing or reducing further damage without repair, improving, strengthening or refurbishing the structure, reconstructing all or part of the structure or demolishing the structure.

Proper remediation methodology begins with inspection and testing to identify the type and extent of defects and degradation mechanisms and the overall condition and quality of the structure. Remediation projects are prone to increasing in volume and costs once work has commenced – investing in comprehensive and accurate Asset Condition Assessments before remediation begins has proven cost effective in the long term.

Often there is limited information on “as built” with drawings and construction records being partial at best and more than often incorrect.
An understanding of structures is critical in being able to provide comprehensive reporting on all aspects of the construction envelope. Prior to diagnosing the causes of defects or failure within a structure it is important to understand that defects result from several factors: design, construction practices, materials, the environment, and loading applied to the structure.

The Asset Condition Assessment is intended to form the foundation for short-term maintenance strategies in which structural elements of the facility are prioritised aligned with the degree of deterioration and loss of function.

General and Overview

The timber piles at Chaffers Marina are predominantly H6 CCA treated *Pinus Radiata*, however a small percentage of piles (ex-Fender piles from the OPT) are Hardwood.
The major cause of pile deterioration within Chaffers Marina results from marine borer infestation of the timbers; predominantly from the ‘Sea Gribble – *Limnoria*’; and to a lesser extent ‘Ships Worm – Teredo’.
Burrowing of molluscan and crustacean organisms, that are found in abundance in Wellington harbour waters, are responsible for the most severe damage to piles in the marine environment.

Timber has long been an accepted and extensively used material in marine construction. In New Zealand ‘*Pinus Radiata’* is a commonly used timber for marine piling and construction.
To allow this timber to be used in a marine environment, impregnation with a suitable preservative treatment is necessary. The object of any preservative treatment is the protection of the timber so it will remain sound without maintenance under severe conditions of use.

The accepted standard for timber preservation treatment in a marine environment is H6 CCA treatment.

H6 treatment uses copper-chrome-arsenate (CCA). Several variations of treatment technique and strength are available, but consist mainly of immersing suitably seasoned timber within a solution inside a pressure vessel. The solution is forced into the timber until the required degree of impregnation has been attained.
A pressure of 1400 kPa is satisfactory for total penetration of sapwood, but for useful impregnation of heartwood 7 Mpa is required.
Therefore adequate treatment penetration into the heartwood seldom occurs.

Figure 1: *'Pinus Radiata'* timber pile exhibits clear evidence of *'Limnoria*' borer damage

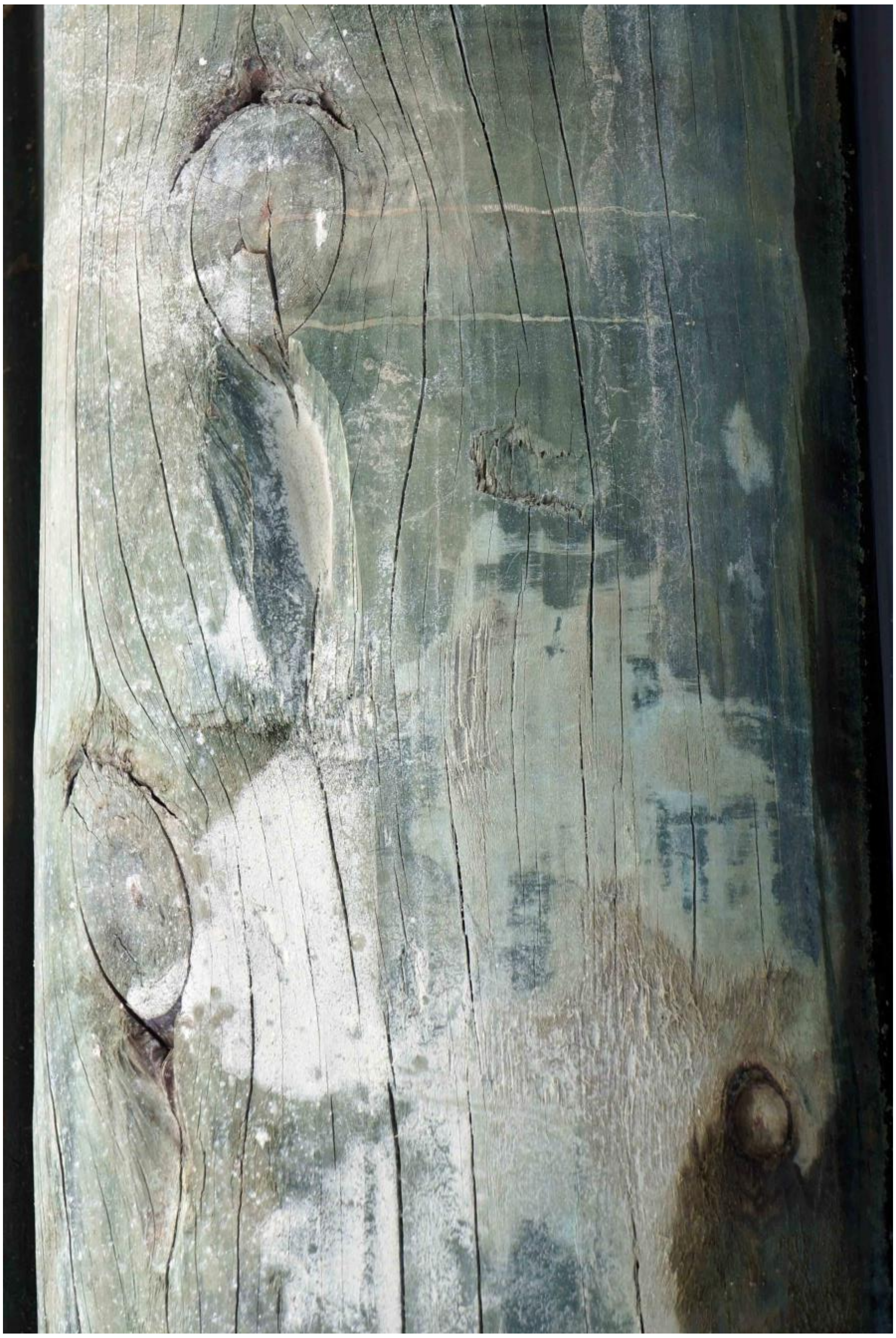

Figure 2: Typical of the 2nd grade piles widely used throughout Chaffers Marina

The use of 2nd grade low density *Pinus Radiata* timber piles in marine construction holds potentially serious and costly ramifications: where an abundance of knots and defects due to poor selection specifications and rough handling processes exist in piles, the timber becomes easily accessible to marine borer infestation.

Over the past few decades an increasing emphasis has been placed upon rehabilitation of marine constructions rather than more costly option of renewal.
One such internationally accepted and widely proven rehabilitation process within the marine industry is pile rehabilitation by engaging in the process of installation of Fibre Reinforced Plastic jacketing (FRP).
When used on deteriorated timber piles, this process returns the integrity of the pile to the desired levels of strength and serviceability.

Summary of Works Process

In 2019 following Timber Pile condition assessment and reporting; acceptance of a rehabilitation option; approval of the rehabilitation specification and methodology: FRP sleeve installations were completed on a number of designated piles requiring strengthening, both within the general Marina berth positions and also under the Boatlift structure.
The seabed position was targeted as priority for timber pile rehabilitation by FRP process for piles within the berth areas; and at the Boatlift, timber pile deterioration was most prevalent and therefore a priority for FRP jacketing within the tidal zone.

- ## FRP Pile Jacket Specification

SCOPE
This section covers the design, supply, fabrication and installation of the fibre reinforced polymer (FRP) pile jackets and related items necessary to complete the work indicated on the Drawings (provided).

RELATED DOCUMENTS
This specification shall be read in conjunction with the FRP designer and manufacturers written instructions and specifications. This specification will take precedence where there is ambiguity.

MATERIALS
FRP jackets shall be manufactured from quality materials, suitable for permanent immersion in seawater, and resistant against long-term exposure to ultra-violet light.

QUALITY ASSURANCE

i. **General**
The Contractor's quality assurance procedures should encompass all aspects of the FRP pile jacket construction; including, but not necessarily limited to:

a) Structural design
b) Compliance for materials with relevant codes
c) Fabrication procedures
d) Installation procedures

The structural design of the FRP jackets shall be carried out by Composite Design Group Professional Engineer equivalent in standing to a Chartered Professional Engineer.

The Contractor shall nominate a representative who is trained and experienced in FRP application, to be responsible for the quality control of the FRP pile jacket construction.

The nominated representative will be required to complete and sign a written quality control checklist for each major component after FRP manufacture and installation. All completed checklists and other quality records supplied by the nominated representative shall be collected by the Contractor, who will keep a filed record.

Quality records shall be kept up to date and be available for audit by the Engineer at all times during the project.

ii. **Submittals**
The Contractor shall supply the following information to the Principal's representative:

a) Details of the proposed proprietary FRP system with technical data sheets.
b) Shop Drawings.
c) Technical specifications.
d) Methodology for fabrication and installation.
e) Structural design calculations.

iii. **Guarantee**
The Contractor shall supply a guarantee for the materials and workmanship for the FRP pile jacket offered. The guarantee must cover full replacement of a defective item, and be for 10 years from the date of installation.

REPAIR TYPES

i. **Standard Repair –** Intertidal to Seabed
A Standard repair is required where a pile has a reduced cross-sectional area, but retains partial structural integrity and remains intact.

The Contractor shall prepare the surface of the pile and fit the FRP jacket around the pile. The length of the FRP jacket shall be determined by the length of the deteriorated pile plus sufficient top and bottom development length back onto the undamaged pile section.

The FRP jacket shall be grouted with high strength grout (Sika 212 or equivalent).

ii. **Stump Repair**
A stump repair is required where a pile is completely broken. A stump repair may also be required when a pile has lost a significant proportion of cross sectional area, there is evidence of severe hollowing or the pile has sustained significant damage resulting in a reduced design life.

The old pile shall be cut at a position where the original pile diameter contains sound timber, and the upper section removed.

The Contractor shall install a suitable replacement pile section. Fixing the lower end of the replacement section to the end of the existing pile with a central dowel pin.

The Contractor shall prepare the surface of the pile and fit the FRP jacket around the pile centred on the pile splice joint. The minimum length of the FRP jacket shall be 2.5 metres.

The FRP jacket shall be grouted with high strength grout (Sika 212 or equivalent).

DESIGN REQUIREMENTS

i. **Structural Capacity of Standard Repair**
The design and construction of the FRP split jackets for the pile repair shall provide sufficient strength to assist the pile to carry axial loads, and all construction and installation forces (such as from grouting).

ii. **Structural Capacity of Stump Repairs**

The design and construction of the FRP jacket for the pile stumping repairs shall provide for the following ultimate strengths once installed:

- Moment: 50 kNm
- Shear: 125 kN

Design parameter values for FRP shall be the guaranteed minimum value, not the mean value.

iii. **Service Life**

All materials and construction shall provide for a service life of 25 years minimum in an exposed marine environment.

WORKMANSHIP AND MATERIALS

All materials and fabricated jackets shall be suitable for installation, constructed for permanent immersion in seawater, and exposed to sunlight.

All materials shall be long-term UV resistant or protected from UV by a barrier system.

INSTALLATION

i. **Existing Pile**

The Contractor shall ensure at all times during the pile repair works that the pile is adequately restrained and supported by a temporary support (if required) to maintain its position and stability until the repair has reached its design strength.

ii. **Surface Preparation**

The surface of the timber pile shall be cleaned of all loose and damaged timber, marine life and other deleterious material.

iii. **Tolerances**

The FRP pile jackets should be installed to within a tolerance of not more than 25mm, or less as per Manufacturers requirements.

iv. **Grouting**

The annulus between the jacket and the pile shall be grouted with a non-shrink Cement based grout of 50 Mpa or better that is designed for underwater applications. The grout shall be installed from the bottom of the jacket to displace any water.

The methodology for grouting shall ensure that no grout is lost into the water.

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(FRP Jacket Design Calculations)

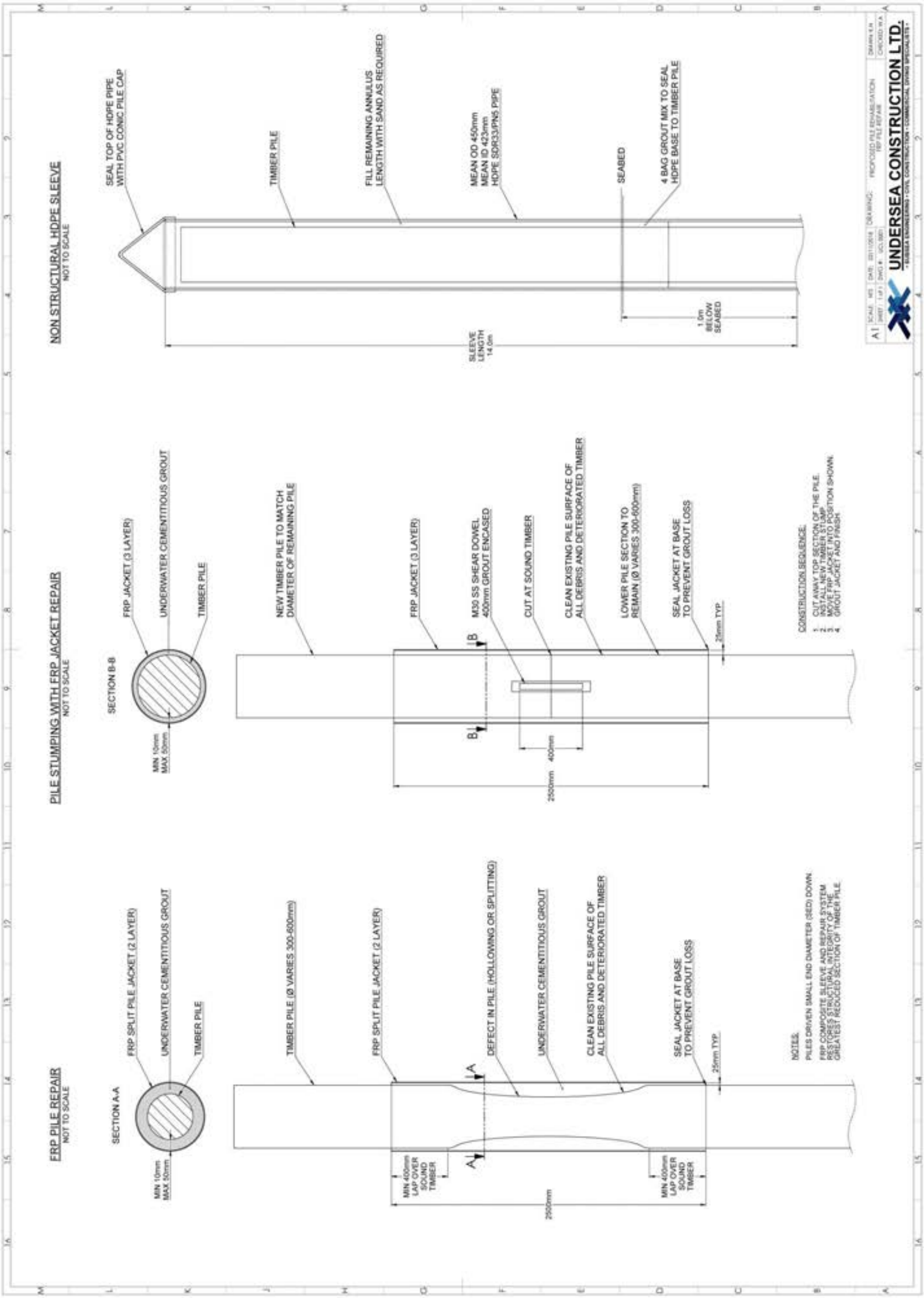

Figure 3: Drawing – pile rehabilitation – FRP jacketing

The USA company; Composite Designs Group (CDG), Duane Gee – Professional Engineer and Principal Consultant is responsible for product development of the FRP jackets, and analyses all of the site specific data parameters presented prior to any jacket production.
Francis O'Riley is the Structural Engineer representative for the NZ licence holder for the FRP jackets. From the data presented to him Francis completes the above attached Calculation Sheet; ensuring the suitability of both the timber piles and the FRP jackets to perform their intended function.

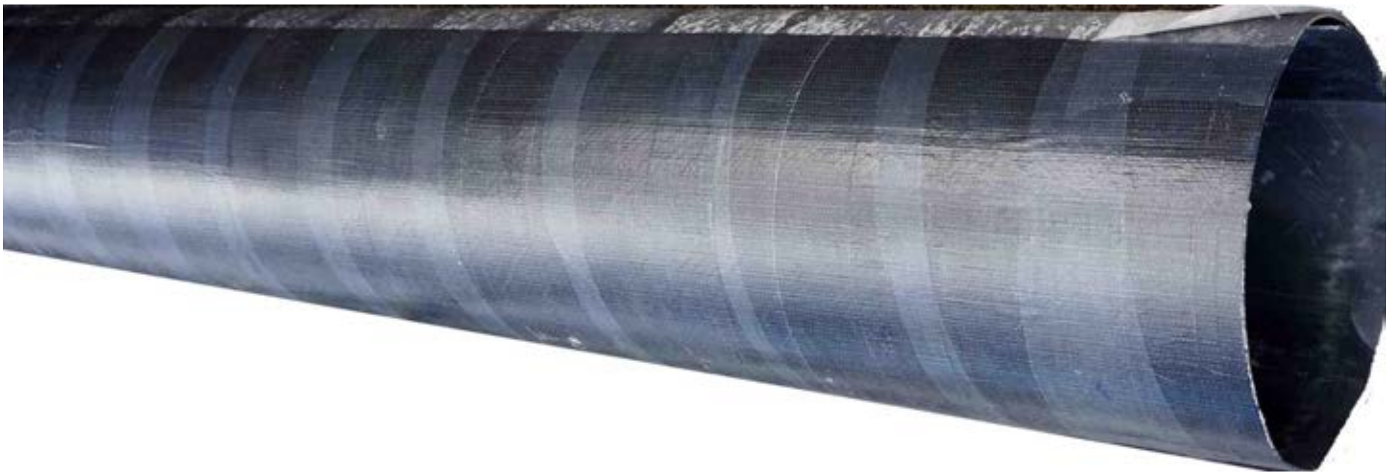

Figure 4: Fibre (carbon fibre) Reinforced Plastic (FRP) sleeve

Figure 5:
FRP jacketing of Boatlift structure timber pile

Figure 6: FRP jacketing of deteriorated timber pile – seabed installation – marina general berth position

Figure 7: FRP jacketing of deteriorated timber pile – seabed installation – marina general berth position

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