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IN SITU PROTECTION OF SPLASH ZONES – 30 YEARS ON

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ABSTRACT

The corrosion rate in the splash zone of marine piles is severe. Coatings for application in situ must provide protection even when applied to contaminated or immersed surfaces. Petrolatum tapes have been used for this application for 30 years and such systems are well established.

Developments of this type of coating have been evaluated by laboratory tests and case histories and confirm that petrolatum tape systems with suitable outer coverings maintain long term corrosion protection of splash zones and are unaffected by sulfate reducing bacteria (SRB).

INTRODUCTION

Corrosion of steel structures in marine environments is a problem that has to be considered during both design and maintenance. The problems with corrosion control are probably best illustrated by jetty piles and wharf piling. Vertical piles pass through the whole range of marine environments from the mud line through total immersion, tidal zone, splash zone and marine atmosphere. Not only are corrosion rates high but they vary according to the conditions in each zone. See Fig. 1. The most severe corrosion occurs in the splash zone where corrosion rates are generally more than twice those in the immersed portion.

Above the splash zone protection can be maintained by a range of coatings applied to a substantially dry and well-prepared surface. The immersed areas can be protected by cathodic protection. Maintenance of effective corrosion control is more difficult in the splash and inter-tidal zones.

There are more options for new work such as increasing the thickness of the steel to give a corrosion allowance, metallic coatings such as flame sprayed aluminium and various heavy-duty coatings applied before installation. The methods described in this paper are for the protection of piles and other structures in situ.

A paper by W D Parker and W H Yeigh[1] published in Materials Performance in 1972 described test programs and field experience with petrolatum tapes for splash zone protection. Over the 30 years since, the systems have been further developed and installed worldwide and several papers have been published on the subject[2,3,4,5]. Such systems are now well established where in situ application is required but questions concerning the level of protection, effects of bacteria and expected service life still arise.

THE PROBLEM

Corrosion rates for the various zones on marine piles are well published in various forms. Table 1 gives results from various sources for the maximum corrosion rate in the splash zone and immersed zone for a range of locations. These show the maximum corrosion rates for the splash zone in the range 150-500 µm/y compared to the immersed zone at 60-140 µm/y.

In a paper to NACE 2001 Rolf Lye[6] referred to requirements for a corrosion allowance of 400 µm/y for design.

Use of cathodic protection would normally reduce the corrosion rate in the immersed zone to <25 µm/y. Clearly, effective corrosion control measures are required at the splash zone to ensure that design parameters are not exceeded. In practice the area protected needs to extend from below low water level to just above the splash zone. Such measures are required where use of the structure is to be extended beyond the originally intended life.

If such work is to be carried out in situ a coating system is required that can be installed reliably both above and below water and tolerate seawater contaminated surfaces. For rehabilitation work it would also need to accommodate existing surface pitting.

REQUIREMENTS OF THE COATING SYSTEM

A successful coating for in-situ application shall:

- Allow application above and below water.
- Displace water from the metal substrate.
- Be surface tolerant.
- Fill pits and surface irregularities.
- Resist displacement by water.
- Be water resistant and resist saponification or emulsification.
- Resist microbiological action.
- Resist damage.
- Have long term weather resistance.
- Prevent corrosion or reduce it to a very low level.

PETROLATUM TAPE SYSTEMS

Petrolatum tapes have been used for the protection of buried, immersed or exposed steel structures since 1929. The widening range of uses led to a series of long term exposure tests and investigations in the 1960's. Much of this work, including marine exposures in the tidal/splash zones has been reported elsewhere[2,3,5]. This formed the basis for developing a protective system for marine piles using petrolatum tape and a protective outer covering. See Fig. 2. Development of a robust outer cover or jacket which could be applied to a pile in situ was considered essential for successful performance of the system. Initially jackets were preformed FRP half shells but these have been superseded by more user friendly and effective wraparound jackets. Various types are used to suit the range of environments.

Since the 1970's the use of petrolatum tape systems on coastal jetties, harbors and moorings has been widespread involving a wide range of climates and sea conditions and protection for over 300,000m² of piles has been provided worldwide by the authors' company. This has required continuous innovation and development of the system and verification of performance.

Development of a petrolatum tape that could be applied underwater without use of a primer considerably simplified application and this has been widely used for over 15 years. This tape can accommodate pit depths up to 2mm (80 mil) without use of a primer or filler. The dewatering agent, inhibitor and biocide system in the tape promote adhesion to the metal and minimize the effects of any water or contaminants trapped under the tape.

TESTING

During the development of this type of tape laboratory tests were carried out by applying tapes to steel pipes under 3wt% sodium chloride solution and leaving them immersed for 3 years. The new tape without primer performed at least as well as the previous tape and primer system and considerably better than conventional petrolatum tapes used without primer. This was subsequently confirmed by field testing.

A more recent series of tests confirms this.

Immersion in Aerated Salt Water.

60mm (2.36in) OD steel pipes were blast cleaned and wrapped dry and with the surface wetted with 1wt% sodium chloride solution. The wrapped pipes were immersed in 1wt% sodium chloride solution and air bubbled through the solution using a fish tank aerator. After 100 days the pipes were unwrapped and examined with the followings results.

	Wrapped Dry	Wrapped Wet
Standard Petrolatum Tape	Nil corrosion	20% of area with heavy dark staining
Petrolatum Tape with Dewatering Additive	Nil corrosion	7% of area with light staining

Specific Electrical Resistance

This test was carried out to assess whether incorporation of dewatering and other additives would reduce water resistance as measured by a loss of electrical resistance.

The tests were carried out according to BS EN 12068 (Annex J). Wrapped 60mm OD steel pipes were immersed in 0.1 mol/litre (0.585wt%) sodium chloride solution. The electrical resistance of each specimen was measured at 50V DC at intervals over 100 days.

The results in Table 2 show that the electrical resistance of the standard petrolatum tape changed from 10^9 to 10^8 ohm.m² over the period whereas the petrolatum tape with dewatering additive remained unchanged at 10^8 ohm.m² confirming the water resistance of the wrapping. The results for both types of tape easily exceed the specified requirements for petrolatum tape of 10^6 ohm.m²

MICROBIOLOGICAL RESISTANCE

Concern is often expressed that sulfate reducing bacteria (SRB) or other marine bacteria could cause deterioration of the protective coating and consequent corrosion of the steel piles. This question was raised following a routine inspection of the 6 year old protective system on round steel piles of a cargo handling jetty in Australia. SRB are known to be a problem at this site enhanced by contamination by fertilizers being unloaded.

In spite of 20 years experience with this system without problems and the knowledge that SRB only metabolize sulfates and cannot utilize hydrocarbons or other organic materials it was opportune to use this site for a reassessment of this aspect by an independent laboratory using natural seawater. This was preferable to a laboratory based assessment as seawater from the site could be used and bacterial cultures taken from the actual materials taken from site.

During the assessment samples of seawater and corrosion product from the steel piles were examined. The examination showed

Seawater:		
SRB	Positive	10^4 per ml
Hydrocarbon utilising bacteria	Positive	<1 per ml
Iron depositing bacteria	Positive	<10 per ml
Corrosion Product from pile:		
SRB	Positive	10^5 per ml

Biological Activity of the Petrolatum Protective Layer

Fresh petrolatum tape and primer were smeared onto the inner surface of sterile plastics containers. The containers were filled with seawater from the site and stored for 7 days. The total bacterial count for SRB and aerobic bacteria was measured at the start and end of the test period and compared with the control test without petrolatum samples. The bacterial counts showed no significant difference between the test samples and the control indicating that the petrolatum protective coating does not enhance bacterial growth.

Similarly there was no loss or change in nature of the petrolatum products after exposure to the seawater.

Corrosion Rate

Tests were carried out to establish the effectiveness of the petrolatum based protective system in preventing corrosion in natural seawater containing high levels of SRB.

Twelve mild steel test coupons, 55mm x 20mm x 1.6mm (2.2in x 0.8in x 0.06in) were grit blasted and accurately weighed. Two were left uncoated as controls. The remainder were coated with petrolatum based primer and tape. These were assembled in a test chamber through which seawater could be circulated from a 10 litre reservoir (Fig. 3).

The seawater was taken from the jetty site. SRB were cultured from the surface of a sample of tape taken from site and added to the water along with Postgate's medium as a nutrient. The water was circulated using a peristaltic pump at a rate of 30ml/minute to allow free flow around the specimens.

The first series was run for 46 days and the second series for 28 days. On several occasions the pump was stopped overnight allowing the test chamber to drain and aerate to simulate tidal action. At the end of the test period the cells were drained and the specimens removed.

Results

At the end of the test the seawater had a dirty black color and odor of hydrogen sulfide. SRB had colonized the outer surface of all specimens.

Bacterial counts were:

Seawater in Test Chamber	SRB	10^5 per ml
Outside of wrapped coupon	SRB	$>10^4$ per ml
Surface of coupon after unwrapping	SRB	Nil

After removal of the tape wrapping the coupons were cleaned and reweighed. The corrosion rate was calculated.

	Corrosion Rate (µm/y)	
	Mean	Range
Wrapped coupons	4	3-6
Uncoated coupons (controls)	216	144-288

There was no visible corrosion on the wrapped specimens. The rate of corrosion for the bare coupons, 216 µm/y, agrees well with observed corrosion rates of steel piles in the splash zone shown in Table 1. The SRB count was higher in the laboratory test than normally encountered in service on the pile. The corrosion rate of the wrapped specimens was just 1% of the 400 µm/y corrosion allowance used for design of offshore structures[6] and agrees well with the maximum corrosion rate of 8-9 µm/y at LaGuardia airport reported by Chaker and Lindemuth[4].

PROTECTIVE OUTER COVERING

To complete the protective system the petrolatum anti-corrosion layer must have an outer covering or jacket to ensure that it is not damaged or displaced by wave action, boats, floating debris or marine fouling. The outer covering or jacket must be applied in close contact with the petrolatum tape to prevent water moving up and down inside the jacket with tidal movement. Such action could replenish oxygen, corrosive materials and nutrients for bacteria or marine organisms. To achieve this the outer covering is commonly fabricated from 1.5-3.0mm (60-120 mil) UV protected high density polyethylene (HDPE) or similar material. This can be secured around the pile by use of strapping at regular intervals or by using a fastener or bolted system. The bolted system provides effective hoop tension, ease of application and increased service life. It was particularly developed for areas having severe wave or tidal action. The choice of outer covering depends largely on the site conditions.

CASE HISTORIES

Product development means taking an existing product, studying its performance and making improvements. Improvements must be confirmed by testing. The reliability of the testing is confirmed by studying the performance in use. The following case histories are given to support laboratory test data.

Groote Island, Northern Territory, Australia

This jetty was constructed for the loading of bulk manganese ore. In 1978 the original coating on the 400 HP2 hexagonal piles had failed. It was replaced by a petrolatum tape system using a heavy duty laminate tape as the outer covering. In 2001, after 23 years, inspections were carried out to assess the need for future maintenance and reinstatement. Corrosion protection was still effective and damaged areas due to flotsam etc will be replaced with the same system that was installed 23 years earlier.

Port Of Tyne, UK

The berthing for a roll on-roll off ferry service was constructed in 1965. In 1982 42 Rendhex 3, 16” (405mm) piles were protected with a petrolatum tape system with an outer covering of heavy duty laminate tape. Inspection in 2001 after 19 years service confirmed that the coating system was still intact and corrosion protection was still being maintained.

Raynes Quarry, UK

When this aggregate loading jetty in North Wales was constructed in 1984 the engineers were concerned that the impact and abrasion by sand and aggregate and a moving beach level would damage the aluminium coating on the piles. A petrolatum tape system with polypropylene jackets was installed on the piles in 1985. Inspections every 3 years have confirmed that the abrasion and corrosion protection continues after 18 years in a harsh environment.

Abbott Point, Queensland, Australia

This project was carried out in 1988 and involved the protection of 14500m^2 (156000 ft^2) of pile surface. 550 steel piles x 1200mm (48 inch) diameter support a coal handling jetty extending 3.9km (2.4 miles) out to sea. Protection of 7m of each pile was provided by a petrolatum tape system with FRP jackets consisting of half shells bolted together with marine brass bolts. The jetty has survived four cyclones. Regular inspections by the owners confirm that protection continues after 13 years service.

Teppco Crude Pipeline, Texas, USA

The splash zone areas of 16” (405mm), 18” (455mm), 24” (610mm) and 30” (760mm) steel dock piles were protected in 1990 using a petrolatum tape system and 2.5mm (100 mil) high density polyethylene (HDPE) jacket covering 1.8m (6ft) section of each pile. An area of over 950m^2 was protected. During inspection in September 2001 the outer covering and petrolatum wrapping were removed from an 18” pile. The outer covering showed no signs of deterioration and there was no active corrosion on the pile after 11 years in service. The pile was rewrapped with petrolatum tape and the same outer jacket reinstalled.

La Guardia Airport, New York, USA

In 1991 a petrolatum tape system with 2.5mm (100 mil) HDPE jackets was installed for splash zone protection to replace an epoxy coating which was no longer effective. The project called for protection for 2000 x 18 inch (455mm) diameter steel piles which support the airport runways over the East River.

Selection of the corrosion protection system followed a stringent assessment program in 1988/89 in which several alternative splash zone protective systems were evaluated[4]. The petrolatum tape system with HDPE jackets gave excellent results and was chosen as one of the systems to be installed in 1991. During an inspection in 1999, after 8 years service, the outer jackets and petrolatum tape were removed and ultrasonic thickness tests carried out on the steel substrate. There was no metal loss and no active corrosion. The piles were rewrapped and the same jackets reinstalled.

CONCLUSIONS

1. The severity of corrosion of marine steel structures in the splash zone is well established with typical corrosion rates of 150-400 µm/y or 3-8mm (0.12-0.31in) after 20 years.

2. The use of a thick petrolatum based coating with a protective outer covering has become accepted as an effective system for the in situ protection of the splash zone of marine piles.

3. In situ application requires a coating that can accommodate surface irregularities and pitting and tolerate salt and microbial contamination

4. Conventional petrolatum tapes require a water displacing primer to ensure corrosion protection when applied to wet or immersed surfaces. Laboratory and field testing confirm that modification of the petrolatum tape to displace water and promote adhesion allows application underwater without use of a primer whilst maintaining water resistance and long term corrosion protection.

5. Recent test programs have confirmed that the petrolatum system is resistant to microbiological attack and will maintain protection against the corrosive effects of SRB.

6. Case histories spanning 23 years confirm that use of a petrolatum tape system with a suitable outer covering will provide effective long term corrosion protection

ACKNOWLEDGEMENTS

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TABLE 1

CORROSION RATES

mil/year (mpy) = 25.4 µm/y (microns/year)
(CP) = with cathodic protection.

LOCATION	MAXIMUM CORROSION RATE µm/y	
	SPLASH ZONE	IMMERSED ZONE
1970 UK ESTUARY	195	80
1977 TOKYO BAY	500	10 (CP)
1983 UK PORTS	180	140
1983 NETHERLANDS	180	60
1983 CYPRUS	210	110
1983 UAE	220	120
1989 LA GUARDIA AIRPORT[4]	150	25 (CP)
AVERAGE	230	100
RANGE	150-500	60-120

TABLE 2

SPECIFIC ELECTRICAL RESISTANCE TESTS

TIME IMMERSED	SPECIFIC ELECTRICAL RESISTANCE (ohm.m²)	
Days	Standard Petrolatum Tape	Petrolatum Tape with Dewatering Additive
2	3.7×10^9	3.8×10^8
20	2.2×10^9	5.2×10^8
40	1.2×10^9	5.0×10^8
60	8.6×10^8	5.0×10^8
80	8.6×10^8	5.0×10^8
100	5.8×10^8	4.4×10^8

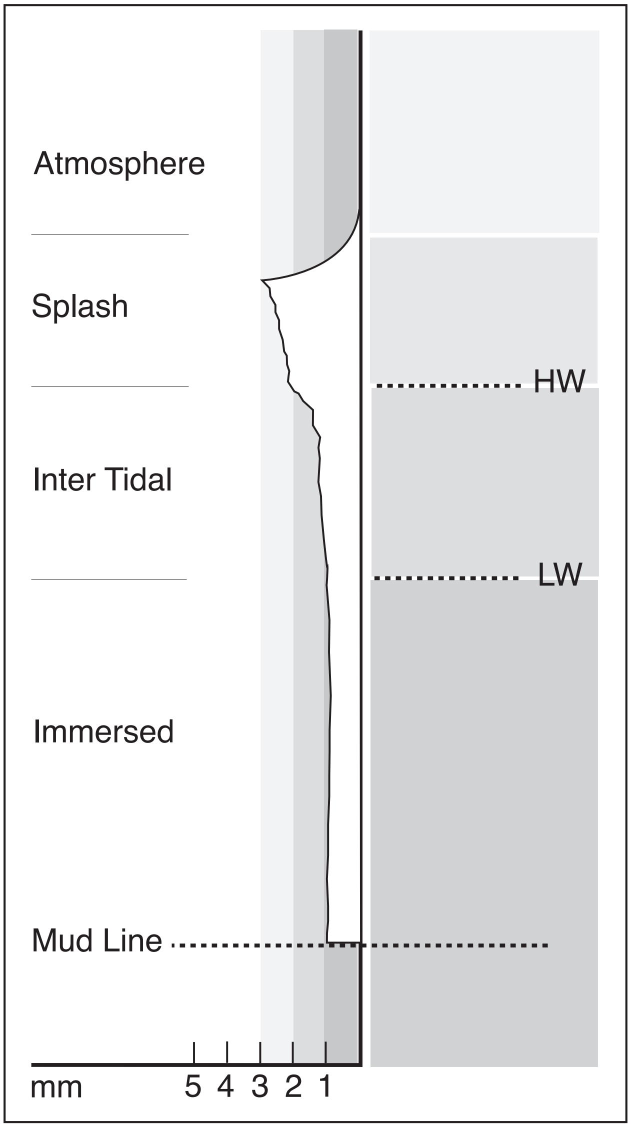

FIGURE 1 - Corrosion rate profile after 10 years.

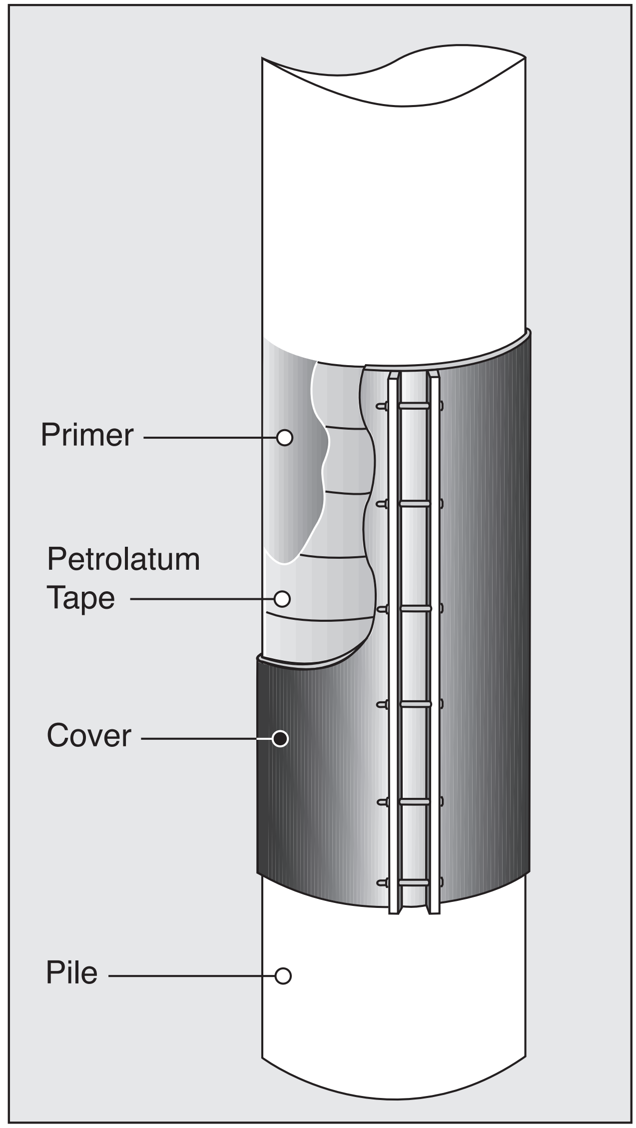

FIGURE 2 - Petrolatum tape system with outer cover.

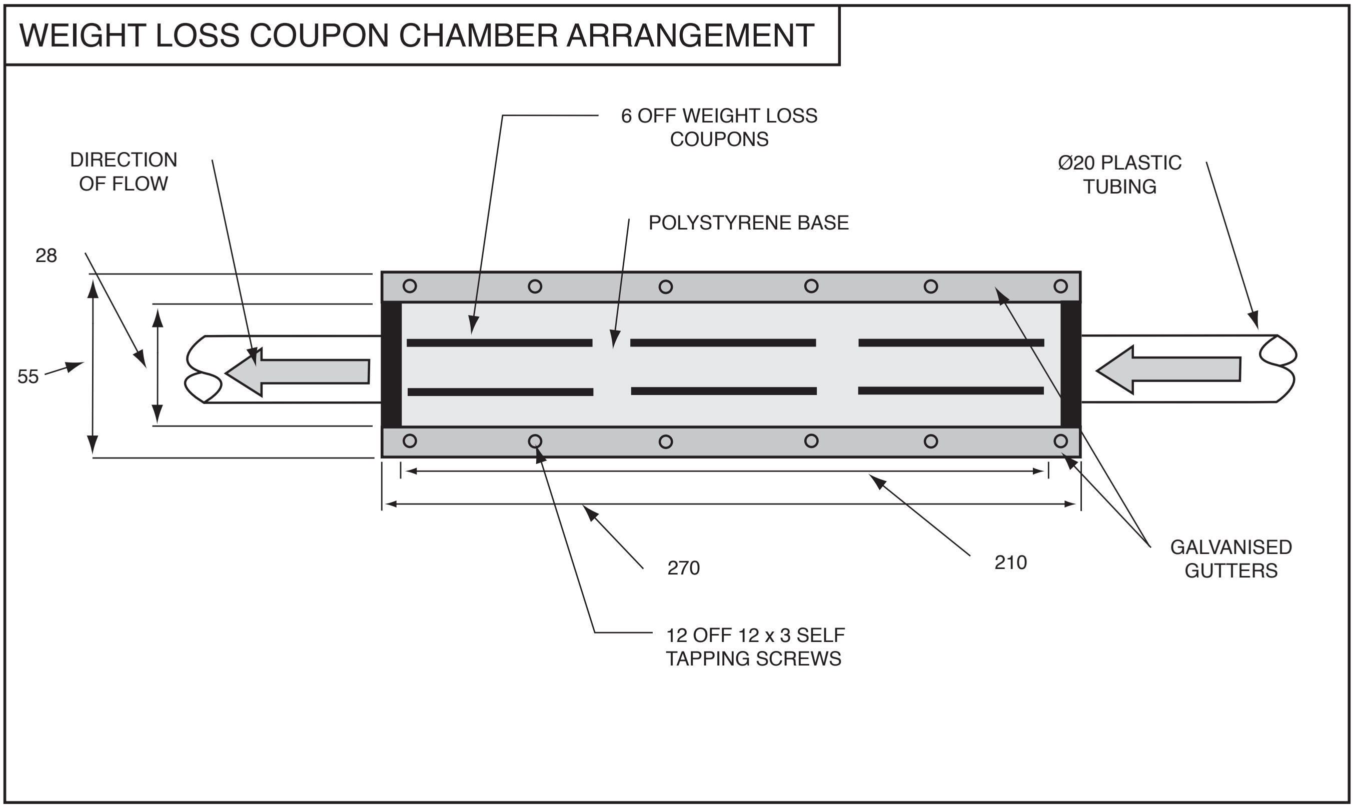

FIGURE 3 - (Drawing courtesy of EXTRIN Consultants, Perth, Australia).