Study on Epoxy Mastic Coating of Submerge Structure

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CERTIFICATION OF APPROVAL

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Approved by,

(Mr. Kamal Arif Bin Zainal Abidin)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(MOHAMAD HUSAINI BIN ABDUL WAHAB)

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ABSTRACT

This report basically discusses the research done and basic understanding of the chosen topic, which is Study on Epoxy Mastic Coating of Submerge Structure (Jackets, Buoy, and Ballast Tank). The objective of the project is to study the performance the chosen coating with different surface roughness and the corrosion properties of the sample. This study also includes the effect of barnacle to the coating system especially in the marine environment. Submerge structure e.g. jackets of offshore platform, buoy, and also ballast tank will fail when painting or coating failure. When coating fail, seawater corrosion, oxygen corrosion and microbiologically induced corrosion (MIC) will contribute and lead to the mass failure. Corrosion is the main threat in the oil and gas industries and millions of dollar has been expense by oil and gas company to study the corrosion behavior so that they can encounter corrosion and prevent it before corrosion attacks the piping, equipments and other steels attached. In order to achieve optimum performance of the coating system, the right choosing of coating specification, surface preparation and application technique is very important. Coating can fail if inappropriate surface preparation is chosen since this criteria are important to the adhesion of the coating itself and the respective substrate surface. At the end of the project, we will know the result expected on epoxy coating adhesion, corrosion properties and also it barnacle effects.

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ABBREVIATION AND NOMENCLATURES

UTP – Universiti Teknologi PETRONAS

MIC – Microbiological Induced Corrosion

GF – Glass Flake

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

This project is mainly executed to study epoxy mastic coating on submerge structure. Submerge structure can be ballast tank, buoy or also internal compartment of substructure platform. Epoxy mastic coating is studied because it has potential to replace the existing coating which is polyester whereby polyester is bad to environment and relatively more expensive.

In short, this study is to analyze the adhesion properties of the coating for different surface roughness, corrosion properties and also barnacle effects. Mild steel will be used throughout this study and coated by the author itself.

The adhesion study applied commercial and user –friendly equipment at level 2 Block 17 Mechanical Engineering Department called REVETEST, Scratch Tester, by CSM Instruments. There are few equipment used to help this study and it will discuss in the following section.

1.1.1. Coating

Coating is a thin layer that is applied to the surface of an object usually referred to as substrate e.g. carbon steel plate or stainless steel plate. In many cases, coating is applied to improve the surface properties of the substrate such as appearance, corrosion resistant, wear resistant, scratch resistant, and antifouling. Coating can be categorized into organic coating or inorganic coating. Different coating has different function and it can only be applied to certain substrate only.

Coating has been design to use for specific purpose that act as barrier between the metal (substrate) and its environment. Coating is highly used to prevent corrosion in many industries from food processing to oil and gas industry. By using coating, the control the corrosion rate by controlling the metal elements.

There are many types of coating which is organic coating, metallic coating, inorganic coating and also conversion coating.

Coating need to be applied for specific purpose. Wrong application of coating will not provide protection to the metal surface but may also contribute to the corrosion.

1.1.2. Epoxy Mastic

Epoxy or polyepoxide is a thermosetting polymer produced by reaction of epoxide resin with polyamine. Epoxy commonly used as adhesive and marine coating since it has special properties which is high adhesiveness, chemical and heat resistance, good electrical insulator. Epoxy can be modified by adding additive to ensure it has certain properties required. For marine coating, epoxy is reinforced with glass flake to ensure that oxygen and water cannot penetrate through coating to the metal surface.

1.1.3. Corrosion Problems.

Corrosion specifically refers to any process involving the deterioration or degradation of metal components [3]. The best known case is that of the rusting of steel. Corrosion processes are usually electrochemical in nature, having the essential features of a battery. Corrosion also can be defined as electrochemical oxidation of metals in reaction with an oxidant such as oxygen [4]. Formation of an oxide of iron due to oxidation of the iron atoms in solid solution is a well-known example of electrochemical corrosion, commonly known as rusting.

According to ISO 8044 standard, corrosion is defined as "Physicochemical interaction (usually of an electrochemical nature) between a metal and its environment which results in changes in the properties of the metal and which may often lead to impairment of the function of metal, the environment, or technical system of which these form a part" [5].

There are eight unique form of corrosion and there are some interrelated [6]. The eight are:

1. *Uniform* ,or general attack
2. *Galvanic*, or two metal corrosion
3. *Crevice corrosion*
4. *Pitting*
5. *Intergranular corrosion*
6. *Selective leaching* ,or parting
7. *Erosion corrosion*
8. *Stress corrosion*

Corrosion attacks every stage in the life of every oil and gas field. From drilling campaign, production time and abandonment. To prevent corrosion is quite impossible but engineer can always control corrosion by controlling corrosion rate because it is most economical solution for time being. Coating is the common method that being used to prevent corrosion but coating also has some defect and need to be enhanced to encounter corrosion with minimal cost.

1.1.4. Effects of corrosion

Corrosion is the main concern to the engineers and designer. Engineer need to design structure or equipment that can resist corrosion and can prolong the lifetime of the equipment itself. There are many effects of corrosion and it varies according to the type of corrosion and the location the corrosion occurs.

When corrosion happen, safety precaution should be taken since corrosion change the material properties and it will lead to the mass failure. Steel that has corroded usually are more brittle and has less hardness.

In economical aspect, there was study in 2002 by US Federal Highway Administration entitle *Corrosion Costs and Preventive Strategies in the United States* on the direct costs associated with metallic corrosion. The study show that the total annual estimated direct cost of corrosion was approximately $276 billion (approximately 3.2% of the US gross domestic product) in 1998 [28].

1.1.5. Common Corrosion Prevention Methods

In order to prevent corrosion to occurs, we need to know the basic principle of corrosion which is the condition and element that need to present in order for corrosion to occur.

There are four basic elements for metallic corrosion to occurs which is [9].

1. An anode
2. A cathode
3. An electrical connection between anode and cathode
4. Electrolyte that in contact with anode and cathode

If one of the elements is not presence, the corrosion is impossible to happen. So, to prevent corrosion, one of the elements needs to be absent. One way to do that is by retarding either anodic or cathodic reaction. Engineer need to choose the best method according to the prevent corrosion at specific location. Not all corrosion can be prevent by the same method since all method has the advantage and disadvantage.

The concept is simple. Engineers need to reduce the corrosion rate by controlling the metal, environment and also electrochemical reaction.

Protective coating has been chosen as the most the effective way to control corrosion. It is the easiest and most common method used in the oil and gas industry to protect the surface of equipment and structure.

1.2. PROBLEM STATEMENT

The existing coating nowadays which is Polyester Glass Flake Coating is relatively more expensive and not economical. Besides, it was also bad to our health and also our environment. Epoxy Mastic with reinforced Glass Flake is the best alternative to replace the existing coating for submerge structure since epoxy coating is versatile coating that can be modified to obtain certain properties desired.

1.3. OBJECTIVE

Objectives of this project are:

1. To study the effect of different surface condition to the adhesion properties of the coating on metal surface.
2. To study the corrosion properties of the coating on the metal surface.
3. To investigate to effect of barnacle on coating properties.

1.4. SCOPE OF STUDIES

The material that will be used for this study is mild steel material. Mild steel material is used as constant variable throughout this study. This is because mild steel is easier to get and more affordable than the commonly used carbon steel material. Besides, mild steel material commonly used to construct offshore platform structure, jacket, pressure vessel, separator, buoy and also ballast tank of ships.

Coating that will be used for this studies is Jotamastic 87 GF from Jotun. This coating is most affordable and can be obtained easily and also easy to handle in its class.

Only three (3) tests will be conducted for this studies which is adhesion testing and corrosion testing due to UTP laboratory facilities and equipment. The immersion test will be done at the beach in Lumut, Perak. The equipment for both tests are already provided in UTP. If the study is completed earlier and the results are satisfied, the other test will be conducted to improve the result obtained but it depends on the time constraint.

CHAPTER 2
LITERATURE REVIEW

Literature review section was done by author throughout the two semester's project period which is form August 2010 to August 2011. This section was important to the author in order to perform the studies on the chosen topic since literature review provides essential and accurate information to the author regarding the project. This will also enhanced the author knowledge in the field of studies and it will provide strong foundation throughout the project period.

Coating is the commonly used by engineers and designers to protect submerge structure from corrosion since coating cover all the metal surface and act like barrier to oxygen and water from surfaces. However, wrong choices of coating application and improper surface preparation can lead to coating failure and this will lead to major loss in term of operation, economy and also hazard to the workers.

Scratch adhesion test has been widely used to quantitatively measure coating adhesion to base material. Therefore in this study, to be able to study the epoxy coating adhesion properties, **Revetest** Scratch Tester will be utilized.

2.1 Coating Failures

The premature failing of a coating system in the submerge structure though can have major engineering and financial problems. The coating also called immersed coating has to provide a long lasting barrier between the steel and seawater. The ability of the coating to provide this barrier is called m-value. M-value is dimensionless and calculates from the water vapor permeability and is independent of the dry film thickness. A high M-value indicates that low water vapor permeability and better barrier function.

Coating failure also dependant on the thickness of the coating itself. Too low thickness results in premature rusting and extra costs for the secondary pretreatment. But, if too high thickness, it increases the risk of formation of pinholes in topcoats because of escaping entrapped air in some porous shop primers and the slowing down of welding operation

Coating failure can happen to offshore structure even though a good material chosen for coated is high quality. Some of the example shows basic reasons for the poor performance of coatings. According to a research done by Wasco Energy Company in the two production platform in Gulf of Mexico, there are six cause of coating failure which is [1]:

1. Poor surface preparation (especially surface cleanliness).
    - The substrate surface is not adequately prepared for the coating. This may include cleaning, chemical pretreatment or surface roughening.
2. Poor coating application.
    - This can be a problem with either shop-applied or field applied coatings, and occurs when the required specifications or parameters for the application are not met.
3. Poor or inadequate inspection.
4. Poor specification (both construction and coating).
5. Poor component design.
6. Murphy's Law

Some are easy to deal with and others require much effort to repair. Mostly, it is one or more of these cause working together to produce the end result. Beside the six cause above, the timing and ambient condition also need to be considered. The above six cause are not the only cause of coating failure. According to George T. Bayer, Ph.D. and Mehrooz Zamanzadeh, Ph.D. in their thesis, there are a lot of reason why coating and painting failure such as [2]:

1. Improper coating selection

- Either the paint or coating selected is not suitable for the intended service environment, or it is not compatible with the substrate surface.

2. Improper drying, curing and over coating times
    - Again, this problem relates to a lack of conformance to the required specifications or parameters.
3. Lack of protection against water and aqueous systems
    - This is a particularly serious problem with aqueous systems containing corrosive compounds such as chlorides.
4. Mechanical damage
    - This results from improper handling of the painted or coated substrate, resulting in a breach in the paint or coating.

2.2 Jotamastic 87 GF

Jotamastic 87 GF is a two pack surface tolerant with glass flake reinforced, abrasion resistant, high solids epoxy mastic coating which may be applied in high film thickness produced by Jotun. It can be use alone or in combination with various systems of primers and topcoats and it also gives excellent corrosion protection in salt and fresh water. Glass flake was reinforced to improve abrasion resistant and general wear and tear characteristics. The detail of Jotamastic 87 GF by Jotun is shown Appendix A1.

Figure1: Illustration on how glass flake help improve coating performance

2.3 Mild steel

Mild steel is the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. It is widely known as structural steels and is predominantly hot-rolled steels. Mild steel contains approximately 0.16–0.29% carbon (usually 0.25%); therefore, it is neither brittle nor ductile. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing [29].

Common coding for mild steel available in AISI (American Iron and Steel Institute), SAE (Society for Automotive Engineering) and ASTM (American Standard for Testing and Material). In AISI, they were coded from 1020 – 1541 and it depend in their heat composition range and limits. Mild steels are unresponsive to heat treatment intended to form *martensite*, and strengthening is accomplished by cold work. Mild steel are relatively soft and weak but have outstanding ductility and toughness. Due to that, there are machinable, weldable and another special characteristics. The microstructures are prominently ferrite and pearlite [19].

It is often used when large quantities of steel are needed. The density of mild steel is approximately 7.85 g/cm^3 (7850 kg/m^3 or 0.284 lb/in^3) and the Young's modulus is 210,000 MPa (30,000,000 psi) [29].

2.4 Surface Preparation before Coated

Surface preparation involves surface roughening to obtain mechanical bonding ("teeth") as well as removal of dirt, rust, mill scale, oil, grease, welding flux, crayon marks, wax, and other impurities [9]. There are many way to prepare the surface like grit blasting or sandblasting, pickling, scraping, wire brushing flame cleaning other chemical treatment. Table below show the estimated costs for surface preparation for various condition.

Sandblasting	Blasting rate, (100 psi 5/16-in. nozzle)		Cost ($/ft²)
SSPC	Ideal	Condition 6	
SP- 5 White metal	100ft² / hr	83 ft² / hr	0.75 – 1.50
Sp- 6 Commercial blast	150	125	0.50 – 1.00

Table 1: Sandblasting Estimation Cost

Condition of steel	Rate of cleaning				Cost ($ /ft²)
	Structural steel		Tanks		
	ft² / hr	ft² / 8hr	ft² / hr	ft² / 8hr	
1	150	1200	187.5	1500	-
2	75	600	125	1000	0.25 - 0.50
3	50	400	62.5	500	0.75
4	125	1000	500	4000	Do not paint
5	87.5	700	137.5	1100	0.25
6	25	200	62.5	500	0.5 – 0.75
7	12.5	100	31.25	250	100

Table 2: Hand Cleaning Estimation Cost

Application rate, ft² / coat / man-hour					
Flat surfaces		Medium structural steel (250 ft² / ton)			
		Oil based	Chlorinated rubber	Epoxy	Vinyl
Spray	300 - 600	210 – 240	180 – 210	160 – 195	145 – 180
Roller	200 – 400	150 – 180	125 – 150	10 – 125	100 – 125
Brush	100 – 200	70 - 80	65 - 70	60- 65	60 - 65

Table 3: Estimation Cost for Paint Application

In this study, to study coating adhesion, the author has differentiated 3 surface roughnesses before the coated process. Three (3) samples will be used in this process and it was prepare to have three (3) different surface roughnesses which are sandblasting, polishing, and also bare metal. All the sample can be easily be distinguish by visual inspection since we can feel the different between smooth and coarse surfaces by using our finger.

However, visual inspection can be very subjectively and it also depends to the knowledge and experience of the person who inspect it. To get exact surface roughness, we use surface profiling machine. Thanks to technology that we can know the exact degree of roughness and smoothness the surfaces are. With surface profiling machine, we can get the exact graph of the smoothness the surfaces are. The dimension applied for the surface are very small and being expressed in micrometer, 5 µm. From the machine, we can know which parameter we need for example Ra, Rx, Ry,Rv, Rp, Rt, Rsk, Rku or Rz.

For this project, the author use Ra or Roughness Average as the parameter. Ra or arithmetic average (AA) of absolute value is derived from [30];

$$Ra = \frac{1}{n}\sum_{i=1}^{n}[yi]$$

Ra is value over one sampling length represent the average roughness. The effect of a single spurious, non-typical peak or valley will be averaged out and relatively have the small effect on the value given. It was chosen as parameter because it is the most effective surface roughness measures commonly adopted in general engineering practice. It also descripts the height variation in the surface.

The length of the surface measured is call traverse length, *Lt* play the important role because it affected the graph resulted from the measurement. The graph can be obtained from the software called Surpak by MITUTOYO. Traverse length is the total length of surface traverse by the stylus during the measurement.

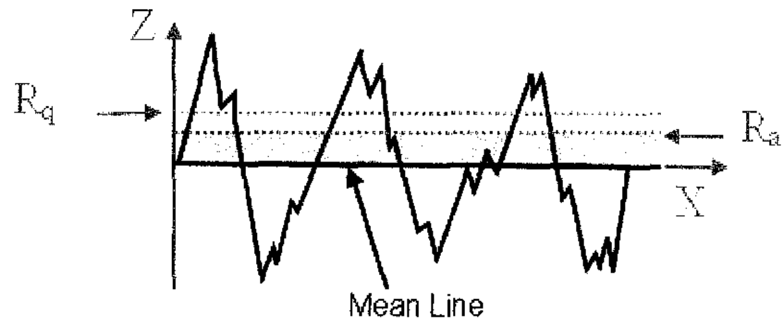


Figure 2: Example of the graph after surface roughness measured.

2.5 Adhesion

Adhesive bonding is a method by which materials can be joined to generated assemblies and it is alternative to more traditional mechanical methods of joining materials such as nails, rivet or screw [11]. According to Sina Ebnesajjad, adhesion is something very hard to defined and entirely satisfactory definition. Wu has proposed the following definition which is "Adhesion refers to the state in which two dissimilar bodies are held together by intimate interfacial contact such that mechanical force or work can be transferred across the interface. The interfacial forces holding the two phases together may rise from van der Walls forces, chemical bonding, or electrostatic attraction. Mechanical strength of the system is determined not only by the interfacial forces, but also by the mechanical properties of the interfacial zone and the two bulk phases" [10]. An assemblies by the use of an adhesive is called *adhesive joint* or an *adhesive bond.*

There are two types of adhesive bonding can be categorized according to Sina which is structural and non-structural. Adhesiveness is important since it function to join parts together by transmitting stresses from one member to another in a manner that distribute the stresses much more uniformly than can be achieved by mechanical fastener.

Adhesive is not new because it has been used since Egypt and Greek empire long time ago. Adhesive can be classified and sub divided according to the figure below [12].

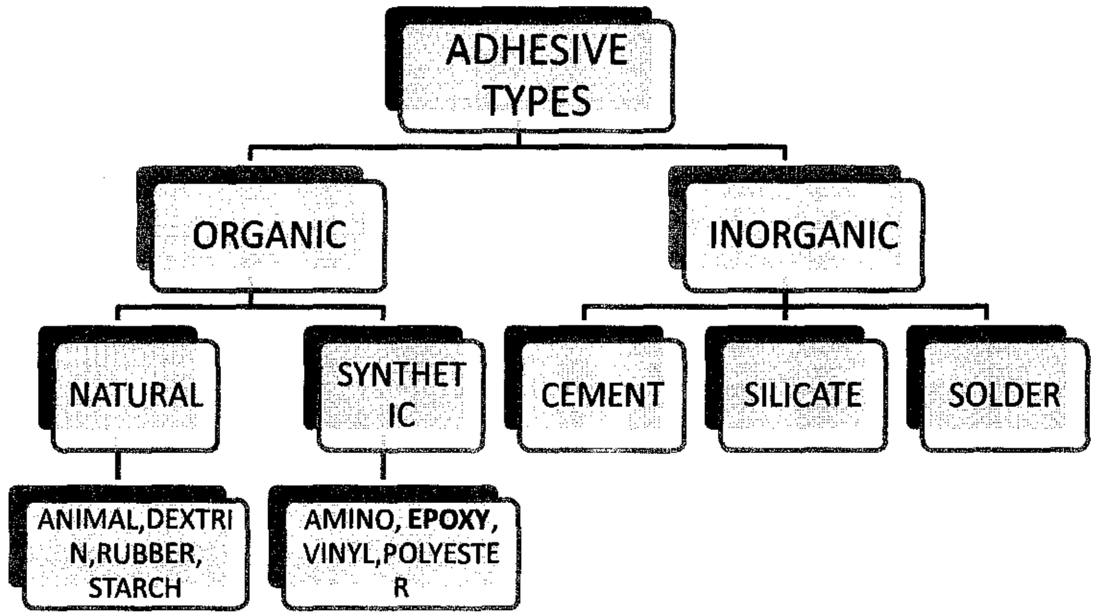


Figure 3: The relationship of the principal adhesives

Only God make something perfect. What human invented are not perfect and always has pro and con. Same goes to adhesion. There are advantage and disadvantage of adhesives that the author can list out.

<u>Advantages</u>

1. Uniform distribution of stress and larger stress-bearing area
2. Join thin or thick materials of any shape
3. Join similar or dissimilar material.
4. Resist fatigue and cyclic loads.
5. Minimize or prevent electrochemical (galvanic) corrosion between dissimilar materials
6. Seal joints against a variety of environment.

7. Insulate against heat transfer and electrical conduct.

Disadvantages

1. The bond does not permit visual examination of the bond area
2. Careful surface preparation is required to obtain durable bonds, often with corrosive chemicals.
3. Long cure times may be needed, particularly where high cure temperature are not used.
4. The useful life of the adhesive joint depends on the environment to which it is exposed.
5. Rigid process control, including emphasis on cleanliness is required for most adhesives.
6. Natural or vegetable-origin adhesives are subject to attack by bacteria, mold, rodents, or vermin.
7. Exposure to solvents used in cleaning or solvent cementing may present health problems.

2.6 Epoxy Bonding and Epoxy Resin

Epoxy adhesiveness are chemical compound used to joint components by providing a bond between two surfaces. It was initially introduced commercially in 1946 in many applications and believed to be most versatile family of adhesives because they bond well to many substrates. They also can be modified to certain properties to suit their roles in industry application [13]. Epoxy adhesive offer a high degree of adhesion to all substrates except for some low surface energy, untreated plastics and elastomer. Epoxy resin commercially composed of an epoxy resin and a curing agent. Both of this need to be mixed according to certain ratio to achieve good bonding. Epoxy resin exhibit certain properties including

- Low cure shrinkage
- No volatiles given off during cure
- Compatibility with a great number of materials

- Strength and durability
- **Adhesion**
- Corrosion and chemical resistance
- Electrical insulation

One of the significant advantages of epoxy is that they generally allow easy incorporation of additive chemically and it result a formulation to the epoxy itself. Due to that, it can easily adapted to many manufactured process such as [13]

- Pultrusion
- Lamination
- Filament winding
- Molding
- Casting and potting
- **Coating**
- Adhesive bonding

2.7 Scratch Test for Adhesion Testing.

Scratch test can be thought as an extension of the indentation test with the added featured that the indenter is translated along the sample surface as well as into the coating. A typical scratch test can be used to estimated the hardness of a coating and a surface tribological properties like coefficient of friction.

This test involves generating a forced controlled scratch with a diamond tip on the sample under test bed. The tip, either a Rockwell C diamond or others sharp metal tip is drawn across the coated surface under either constant load or progressive load. At a certain critical load Lc, the coating will start to fail. The critical load can be detected by mean acoustic sensor attached the load arm together with built in video microscope. The critical load data will be used to quantify the adhesive properties of the thin film. We can also measure the penetration depth of the tip thru coating, friction force, normal load and also acoustic emission while doing scratch testing.

Lc is the critical load which is the minimum load at which the coating starts to crack/peel off. By practice, the point where the crack/break started is determined by inspection through microscope but due to advancement of computer technology and application of acoustic emission, the Lc is accurately determined easily and take relatively short time. However, microscopic examination still be used as supportive data to ascertain the critical point within the scratch length. With the support data from microscope examination, we can see the chevron-like shape at where the point start to fail.

This test also helped by software called *Scratch 3.0* that come with the REVETEST machine. This software will analyze and provide data in graph mode when the scratch process started. When the scratch test started, we can see the penetration depth, acoustic emission, and also the critical load from the graph.

As usual, scratch test also has some goodness and flaw. Below are some of the advantages and disadvantages of the test [14].

<u>Advantages</u>

- The stylus can be act as indenter, so coating hardness and elastic properties can be determined.
- Can give valuable information on surface topography, mechanical properties, and modes of deformation and delamination.
- Semi quantitative information can be obtained by recording the stylus load at failure; thus scratch testing can be used to rank the durability of a series of coating formulations.
- In some cases, fully quantitative estimate of the fracture energy of the coating/substrate interface can be obtained provided all relevant

mechanical properties and fracture mechanics calculation are measured carefully.

Disadvantages

- The test limited to hard brittle coatings even some exception such as brittle epoxy coatings.
- The softer polymer coatings tend to viscoplastically flow and deform around the scratch stylus causing mounding at the edges of the scratch track and pile up at the stylus.
- Scratch test is mechanically complex. The act of pushing the stylus into the coating gives rises to very high stresses and deformations in both coating and substrate, thus bringing into play the full range of highly nonlinear viscoplastic material behavior.

2.8 Corrosion Test

The salt spray test is a standardized test method used to check corrosion resistance of coated samples. Salt spray test is an accelerated corrosion test that produces a corrosive attack to the coated samples in order to predict its suitability in use as a protective finish. The appearance of corrosion products (oxides) is evaluated after a period of time. Test duration depends on the corrosion resistance of the coating; the more corrosion resistant the coating is, the longer the period in testing without showing signs of corrosion.

According to **ASTM B117 - 09** (Standard Practice for Operating Salt Spray (Fog) Apparatus), salt spray test provides a controlled corrosive environment which has been utilized to produce relative corrosion resistance information for specimens of metals and coated metals exposed in a given test chamber. Prediction of performance in natural environments has seldom been correlated with salt spray results when used as standalone data.

Correlation and extrapolation of corrosion performance based on exposure to the test environment provided by this practice are not always predictable. Correlation and extrapolation should be considered only in cases where appropriate corroborating long-term atmospheric exposures have been conducted.

The reproducibility of results in the salt spray exposure is highly dependent on the type of specimens tested and the evaluation criteria selected, as well as the control of the operating variables. In any testing program, sufficient replicates should be included to establish the variability of the results. Variability has been observed when similar specimens are tested in different fog chambers even though the testing conditions are nominally similar and within the ranges specified in this practice.

CHAPTER 3
METHODOLOGY / PROJECT WORK

This section was used to describe and explain the basic procedure and method for all mechanical testing done and sample preparation prior to coating. The purpose of this section also elaborated the methodology for this final year project for future reference. There are few apparatus and high technology equipments will be used throughout this project to ensure that the results obtain is accurate.

3.1 SAMPLE PREPARATION

3.1.1 Material acquisition

For all the test that will be done, mild steel has been chosen as the substrate. The sample which is mild steel was obtained from manufacturing lab at Block 21, Mechanical Engineering Department of UTP. Mild steel properties that have been used for the test are discussed in the section above.

3.1.2 Sample's dimension

Mild steel come from the manufacturer in the dimension of 150mm (length) x 100mm (width) x 5mm (thick). As for this experiment, we need only:

1. 70mm (length) x 20mm (width) x 3mm (thick) for adhesion properties test
2. 150mm (length) x 100mm (width) x 5mm (thick) for corrosion test
3. 150mm (length) x 100mm (width) x 5mm (thick) for barnacle effect test

The detail and technical drawing of the sample are mentioned in the Appendix A2.

3.1.3 Cutting

The sample need to be cut according to the dimension that the author specified based on the journal from previous research. To cut the mild steel, mechanical steel cutter has been used located at Block 21, Mechanical Engineering Department of UTP.

3.1.4 Grinding / Polishing

In this project, the effect of surface roughness and surface smoothness of the substrates to the adhesion (epoxy mastic) is studied. Polishing is one of the methods chosen to produce necessary surface roughness before coating was applied.

Polishing was done at Block 21, Mechanical Engineering Department using mechanical polisher. Polishing is the process of creating a smooth and shiny surface by rubbing it sand paper. The process start with coarse one and it will graduates to fines ones.

Polishing will remove all the oxides (black surface) on the sample's surface so that the shiny metal surface will appears. Polish also make the surface of the sample smooth and shiny. All six of the sample surface need to be polished until all the surface are meet the required standard.

Figure 4: Mechanical Polisher.

3.1.5 Sandblasting

Sandblasting is another method chosen to ensure that the surface roughness is different from other sample that been used other method which is polishing.

Sandblasting was done at block 17, Mechanical Department by using sandblasting machine. Even though the machine was design for experiment purpose and not industrial purpose, the result was obtained and meet the expectation. The sandblasting process takes a few hours to obtain a good result since the machine has small capacity compare to the industrial sandblasting machine.

Figure 5: Sandblasting machine

Figure 6: Sandblasting machine

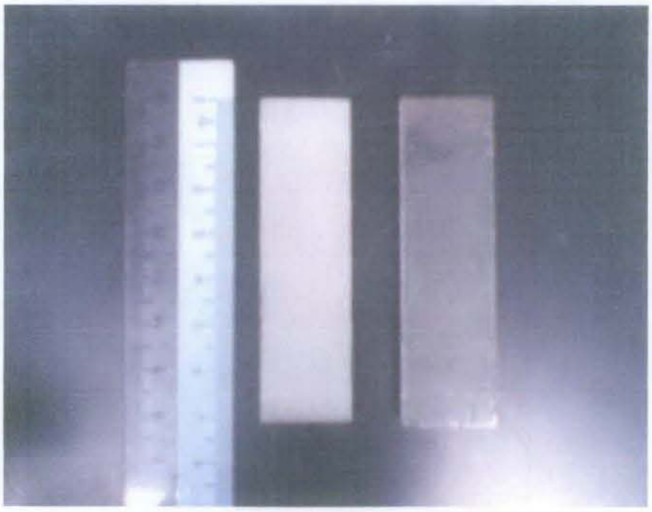


Figure 7: Comparison between after sandblasting process (left) and ~~after~~ before sandblasting (right) on sample.

3.1.6 Weighing

Weight is done to the sample to know their exact weight. This is essential since we need to know the corrosion rate of the samples. Weighing is done at Block 17, Mechanical Engineering Department of UTP. Electronic digital balance is used to weight the sample since it is very accurate for sample that is less than 600 gram.

Figure 8: The sample weight is being measure by digital balance to acquire the exact weight.

3.1.7 Surface Profiling

Surface profiling is the process where the sample surface's smoothness or roughness was measured. Surface profiling machine was used in this process. The stylus will touch the surface roughness and transverse along the sample. Using the surface profiling machine combine with *Surpak software*, the machine will plot the graph and the roughness will be measured. The detail about the principle of surface profiling was discussed in the literature review section in the surface roughness subsection.

Below are some of the graphs or result obtained from the surface profiling process for sand blasting, polishing and bare metal.

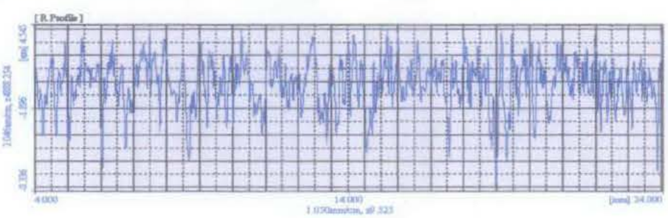


Figure 9: Sandblasting

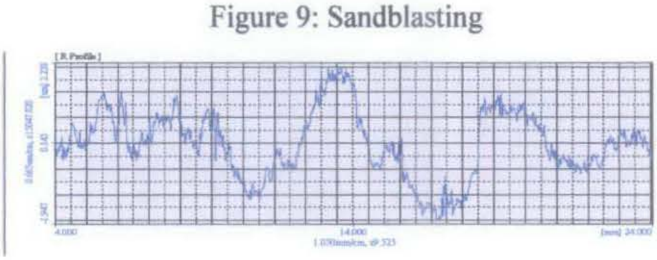


Figure 10: Polishing

Figure11: Bare Metal

3.1.8 Visual Inspection

Visual inspection is done by visually inspect the sample from any defect and flaw. The sample dimension is measured using vernier caliper to ensure that the dimension is meet the required standard. Any sample that has defect will be rejected and will be change with another sample.

Visual Inspection process also was done at Block 21, Mechanical Engineering Department. Visual inspection also was done after coating was applied. This is to ensure that all the sample's surfaces are coated and no holiday was detected.

This precaution must be taken to ensure out test will not adversely affected by the surface imperfection. Furthermore, the basis of metal (mild steel) must be ensured is free from dirt, grease, oil, and oxides.

3.1.9 Coating Process

Jotamastic 87 GF was used as we discussed at the section above. Roller and brush was used in order to get good surface finishing. Coating process need to be done properly since the coating need to have same thickness for all surface. The force that applied to the roller and brush need to be maintained for all sample.

Coating also need to be mixed according to the ratio provided. If ratio was not right, the coating will become either liquefied or too concentrate and it will affect the result of the experiment.

For good coating, drying and curing time need to be as long enough so that all the coating molecules are bond together with the substrate. Curing time is the period after coating has been dried and when it was ready to be used.

Drying times are generally related to circulation, temperature, film thickness, and number of coats, and will be affected correspondingly. Good ventilation is needed when coating process to ensure the samples are properly coated.

Figure 12: Jotamastic 87 GF by Jotun. Below is Part A and upper is Part B

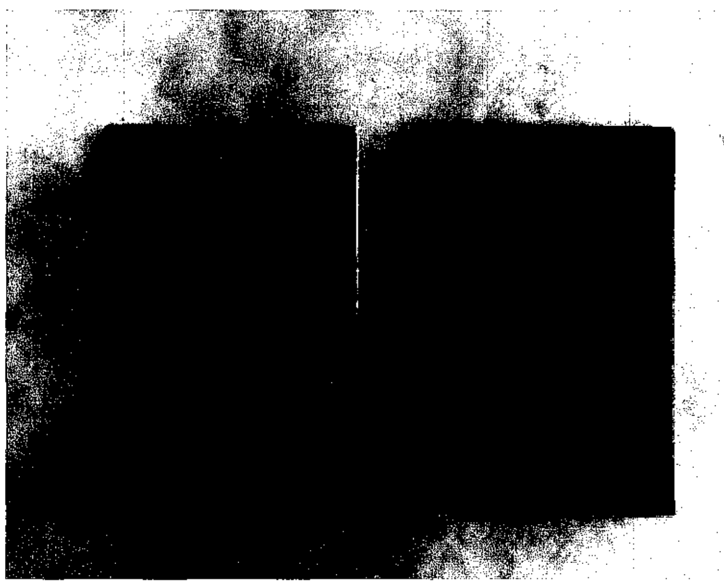


Figure 13: Difference between surface that already being coated (right) and not being coated (left)

3.2 MECHANICAL TESTING

3.2.1 Scratch Test

Scratch test is a test used to measure adhesion of the coating. It was performed by using commercial scratch tester fitted with a Rockwell C diamond stylus. For this experiment, 2 scratches have been made. The first one is constant load and the second is progressive load. The constant load scratch was performed just to know the maximum load that the coating can sustain before the stylus or so called indenter reached the base metal / substrates. The progressive load the test that the result of coating failure will obtained.

Firstly, constant load of 10N was used to ensure how deep the indenter can penetrates. However after few scratches, the author finally pick 50kN as the maximum load since after 50N scratch has been done, we can see the bare metal.

For the test, scratches were performed using progressive load for a transfer length of 10mm. Initial load was set to be 10N and ended at 50N. The REVETEST Scratch tester machine was equipped with acoustic emission monitoring device that can detect acoustic emission within the vicinity of 100 kHz to determine the failure. The same machine also has built in microscopic examination capability that help the author to look for failure in microscopic mood. The magnification can be 5x and 20x and the high of the sample can be adjust manually.

Below are the test parameters that the author applied throughout the studies

Linear Scratch	
Type	Progressive
Begin Load (N)	10
End Load (N)	50
Loading rate (N/min)	2.52

Speed (mm/min)	0.63
Length (mm)	10
Position X (mm)	16.358
AE Sensitivity	1
Indenter Type	Rockwell
Serial number	S / O -258
Material	Diamond
Radius (μm)	200

Table 4: Parameters of Scratch Test.

Next, the author will briefly explain the step taken to do scratch test.

1. Firstly, the sample that already coated is cleaned by tissue to ensure that the surface is free from contaminant that can affect the result
2. Then the sample is placed on the scratch table and clamped tightly. This is to ensure the sample is not move when the scratch in process.
3. Open Scratch software which is SCRATCH 3.0 and then fill the test information including the detail of coated sample.
4. Next, at the software interface, click "new scratch test" and choose simple scratch when the other window prompted.
5. Then, user need to enter all the desired test parameter. For this test, all the parameter as stated in the box above are key in. (progressive load, initial load and end load)
6. Adjust the distance between the sample surface and the indenter to be closed enough but not touching.
7. As prompted, "start automatic indenter touch"
8. Then adjust DZ range by rotate it either clockwise or anticlockwise (as mention in the window prompted) just before the test begin.
9. Click Run test and the test will start automatically.

10. After the scratch test completely executed, a prompt window will asked to initiate optical analysis. (A study of failure mode of coating i.e. flaking need to study and understand first before we can analyze the result)
11. After optical analysis is closed, more critical loads, acoustic emission and depth of penetration were marked on the scratch test graph.
12. The sample will moved to the origin position and procedure (2) to (11) will be repeatedly by other sample.
13. The scratch sample will be analyze by visual inspection and helped with optical microscope or 3D non contact equipment.

3.2.2 Corrosion Test

Corrosion test that will apply in this study is salt spray test ASTM B117-90 by using corrosion chamber. Corrosion test will be done in the corrosion chamber located at Advance Material Laboratory, ground floor at Block 17, Mechanical Engineering Department.

The parameters of the test are as below:

Concentration of salt solution	: 5% NaCl
pH of salt solution	: 7
Air supply pressure	: 20 psi
Chamber temperature	: 30 °C
Period of exposure	: 312 hours (13 days)

For this test, the apparatus used in the salt spray test shall include the following:

1. Exposure chamber with racks or fixtures for supporting specimens.
2. Salt solution reservoir with means for monitoring an adequate level of solution.

3. Means for atomizing the salt solution, including suitable nozzles and compressed air supply.
4. Chamber heating means and controls
5. Mean for humidifying the air at a temperature above the chamber temperature.

Next, the author will briefly explain the process taken to run this test.

1. Firstly, ensure that the corrosion chamber is not leak. If the tank is leakage, the solution need to be added frequently and this is not economical and wastage.
2. Ensure all the apparatus in good condition
3. Mix solution to make salt solution (5% NaCl) and add the solution to the salt solution reservoir (tank) just beside the chamber.
4. Salt solution should be make enough to support the chamber for the whole duration of the test
5. Place sample at the designated location in the chamber.
6. Close the chamber's cover
7. With help of laboratory technician, key in all the parameter desired as shown above and turn on the switch.
8. Visit the corrosion chamber frequently to check the sample condition.
9. After the test, turn off the switch and check sample and measure sample weight. Visual inspection also should be done at this stage
10. Do housekeeping after the test.

After exposure about 13 days, the sample were carefully removed from the rack and gently washed in water to remove salt deposits from their surface. Figure 14 and 15 the photograph of the samples before and after the exposure to salt spray.

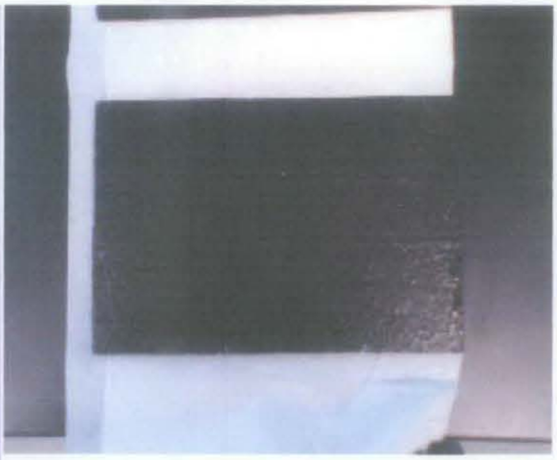


Figure 14: Coated sample before test.

Figure 15 : Coated sample after test

Uncoated sample that were exposed to bare metal were cleaned with brush to remove all the corrosion products. The photograph is shown in figure 16 and the result are summarize in Section 4.

Figure 16: Uncoated sample after test.

3.3 OTHER TEST

3.3.1 Immersion Test

Immersion test was a test to study barnacle effect to the epoxy mastic coating. By its name, it was clearly that the sample was submerge to seawater. The sample is put in the splash zone. This is to study whether the barnacle or another fouling microorganism will growth at the sample. Marine fouling organism such as algae or slime will adhere, colonize, and grow rapidly if not controlled through the use of antifouling coatings.

Two samples already have been submerge into the seawater environment. One is coated with coating and another is bare mild steel. The location of the test is at beach near Lumut, Perak Darul Ridzuan. The samples are left there for 3 months to see whether the barnacle will stick to it or not.

Another sample also was submerge in the lab using seawater sample taken from the same beach where the other sample was submerge. Until this minute, there is no existence of barnacle.

Figure 17: Two samples that being submerge in the seawater. Barnacle can be seen in the surface of the rock near the samples.

3.4 TESTING PRINCPLE

3.4.1 Scratch Test to study adhesion of epoxy coating

During scratch test, at a certain load we can clearly see the coating is separated and start to crack. This load is the load that needs to consider as critical load on order to measure coating adhesion. From the scratch graph obtained, all the data need to be studied carefully so that the adhesion can be measured.

The technique is based on the realization on a scratch on a sample by a moving point. This point which is diamond indenter as specified in a section above is placed in contact with the coated surface under certain range of progressive load (10N-50N). The change of the deposit can be observed optically under a certain critical load value. The optical analysis is correlated with information from various sensors positioned on the system i.e. acoustic emission sensor and penetration depth sensor. There additional diagnostic deliver a unique signature of the adhesive properties of the coating.

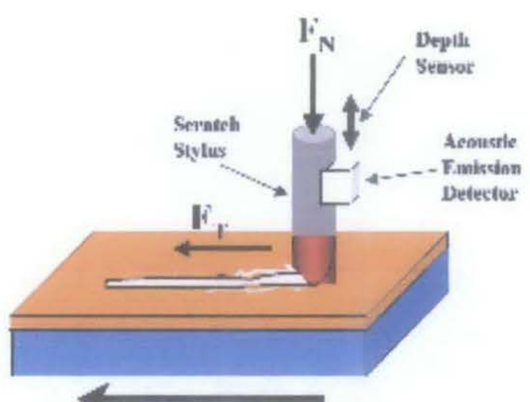


Figure 18: Illustration of scratch testing

Stress is introduced at the surface of coating by applied force Fx perpendicular to the surface. This can be accomplish by pressing diamond indenter stylus in the sample surface at certain load specified. As the sample move at constant speed depending on the rate of penetration, the stress applied will result flaking, cracking of the coating. The smallest load at which specified failure event is recorded and called critical load (Lc) is automatically recorded via *scratch test software* discussed in the above section.

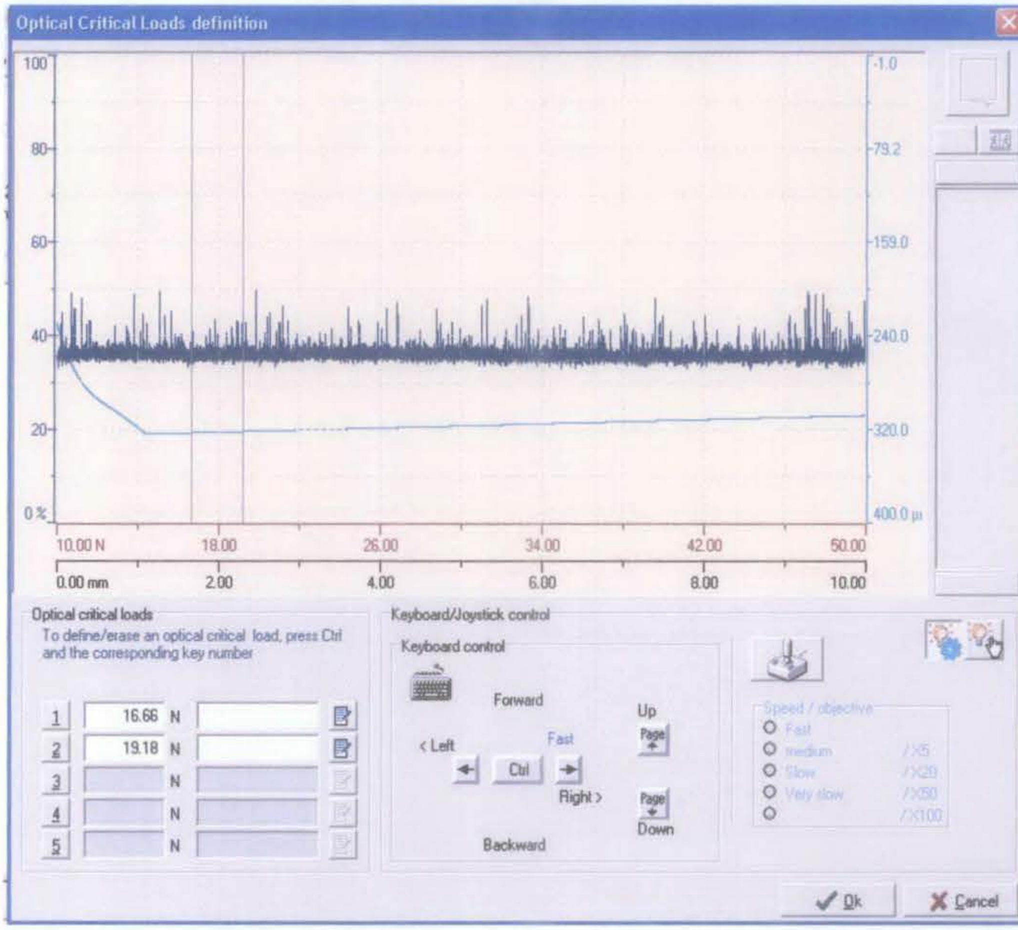


Figure 19: Determination of Lc by using Scratch 3.0 software.

3.4.2 Corrosion test

The salt spray test is a test in which the samples are subjected to a fine mist of salt solution. This test has several useful purposes when utilize with full recognition of its deficiencies and limitations. The purpose of this test is as an accelerated laboratory corrosion test simulating the effects of seacoast or marine atmosphere on metal with or without protective coating. Some idea of the relative service life and behavior of different samples of the same protective coating in marine or exposed seacoast location can be gained by means of the salt atmosphere test provided accumulated data from correlated field service tests and laboratory salt atmosphere tests show that such relationship does exist.

The salt spray test is very helpful as a screening test for revealing particularly inferior coatings.

3.4.3 Immersion test

This test basically just immerses the sample to the seawater. According the marine biologist, if the sample was submerge or put at splash zone, the barnacle or other marine fouling organism will growth rapidly. This is because the zone is full of oxygen and the seawater itself has properties that can make them growth well. Certain parameter like pH, salinity, and % NaCl play major role for the barnacle to growth.

3.5 PROPOSED APPARATUS

3.5.1 CSM Revetest Scratch Tester (RST)

CSM Revetest Scratch Tester (RST) is a product by CSM Instrument and it was supplied to UTP by ST Equipment Supply & Services Sdn.Bhd which operates in Selangor Darul Ehsan. This machine is equipped with Scratch Software version 3.0 that can be used with the popular Microsoft interface and its general features are identical to window application.

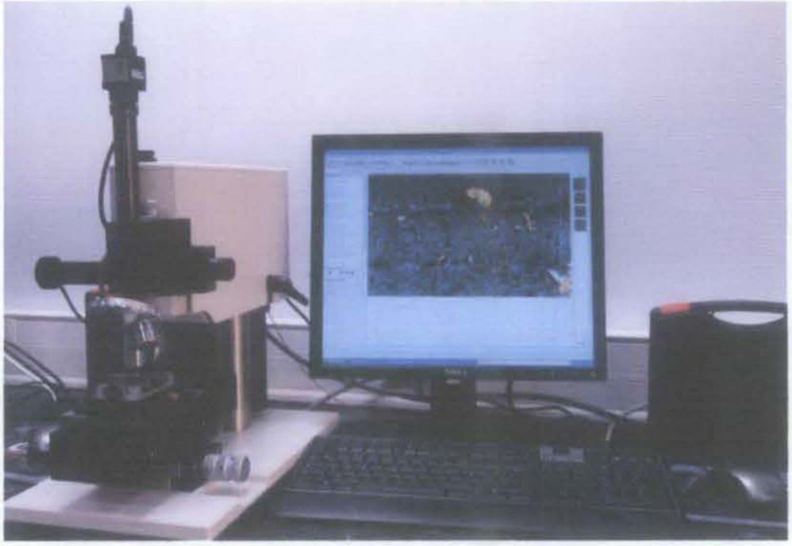


Figure 20: REVETEST Scratch Tester (RST) with built in microscope and equipped with Scratch Software 3.0.

Figure 21: The sample is clamped to the work bench just before test started.

3.5.2 Mahr Perthometer Surface Profile

This equipment is available at metrology laboratory at Block 17 Mechanical Department of UTP. Mahr Perthometer Surface Profiler Is used to access surface roughness of the coated materials prior to adhesion test. The surface roughness information obtain is very useful data in understanding the effect of the surface characteristic to the adhesion properties.

This machine also equipped with software called SURpak that come together with the package. This software will help to analyze the surface roughness and determine the roughness parameter desired. The stylus in the machine is very important feature in the machine. This stylus play main role in determining the surface roughness. The stylus wills transverse along the desire line on the surface of the sample and sends the data to the computer for analyzing.

Figure 22: The exact same model of Mahr Perthometer Surface Profiler at Metrology laboratory at Block 17.

Figure 23: This stylus play important role to determine the surface roughness of sample. It also very sensitive.

3.5.3 3D Non Contact Machine

3D non contact machine was located at Block 17. This machine is very useful to measure any sample even in microscopic size. It also help researcher in many ways since it can calculate and determine coordinate of the sample in micrometer. It also equipped with microscope that can magnify until 5000x. Throughout this study, the author use this machine to analyze the coating failure by using the microscope and calculate the distance from test started to the point where it started to fail.

Figure 24: Above is the exact same model of 3D non contact machine at Block 17. At the right the measurement machine with microscope and at the left is the computer equipped with software that helps to analyze the sample.

3.5.4 Cyclic Corrosion Cabinet Model SF / 450 / CCT

Figure 25: The exact same model of cyclic corrosion chamber at Block 17

Photo above is the exact model of cyclic corrosion chamber at Block 17. This chamber is very useful to simulate and accelerate the marine or seacoast environment to study corrosion. However, good cleaning and maintenance should be done regularly since the chamber is very fragile easy to broke. The pipe that connect from salt solution always leakage and clogged with salt particle.

3.6 PROJECT FLOW CHART

3.6.1 Adhesion Properties

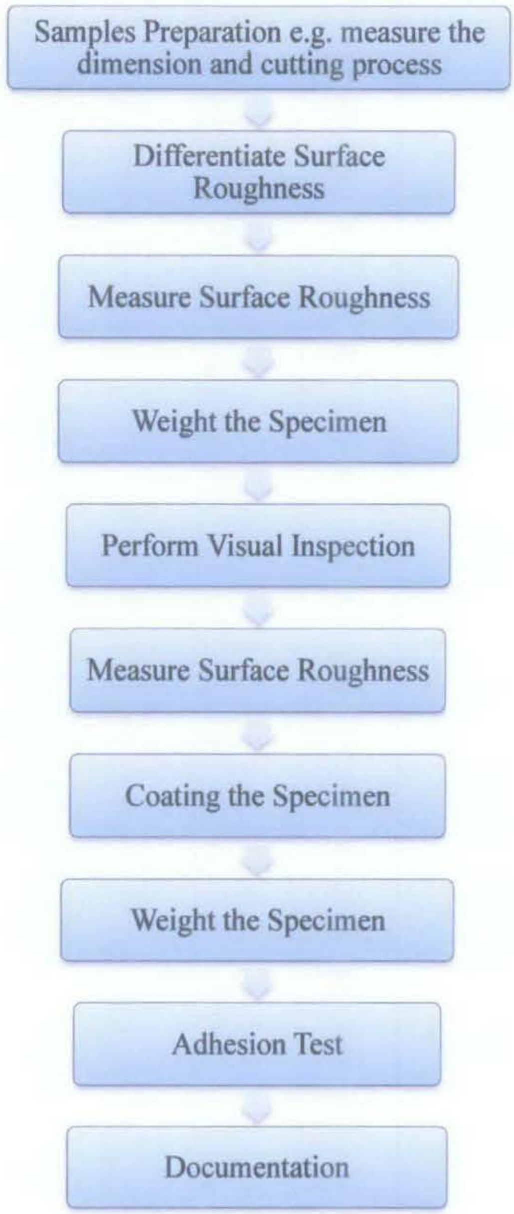


Figure 26: Project flow chart for adhesion properties test.

3.6.2 Corrosion Properties

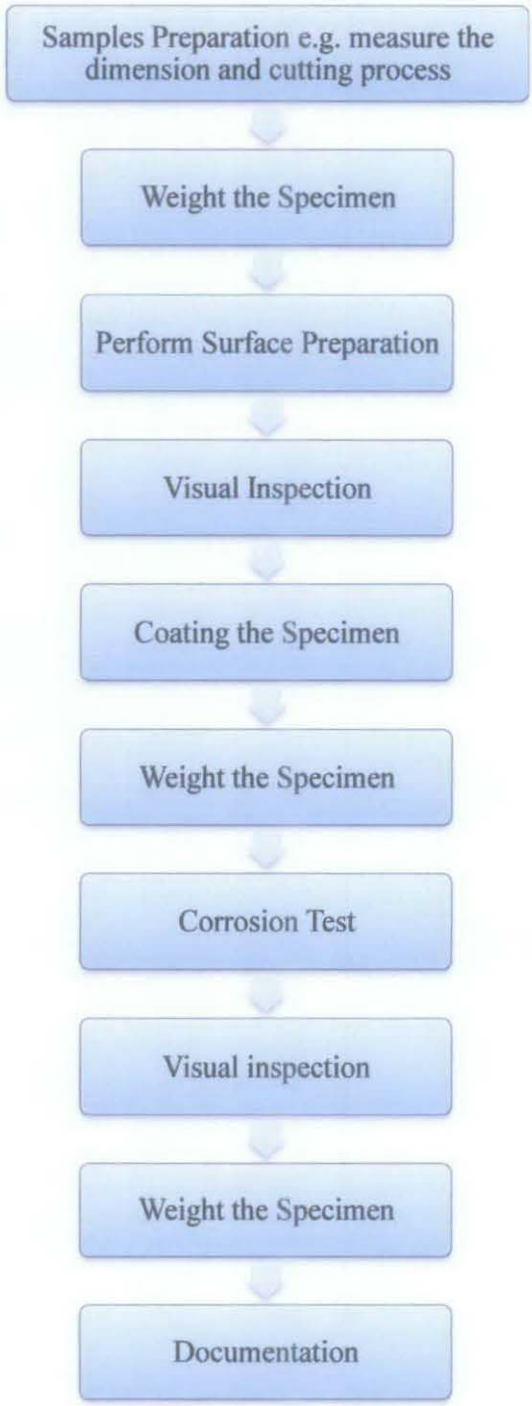


Figure 27: Project flow chart for testing of corrosion properties

3.6.3 Barnacle Effects

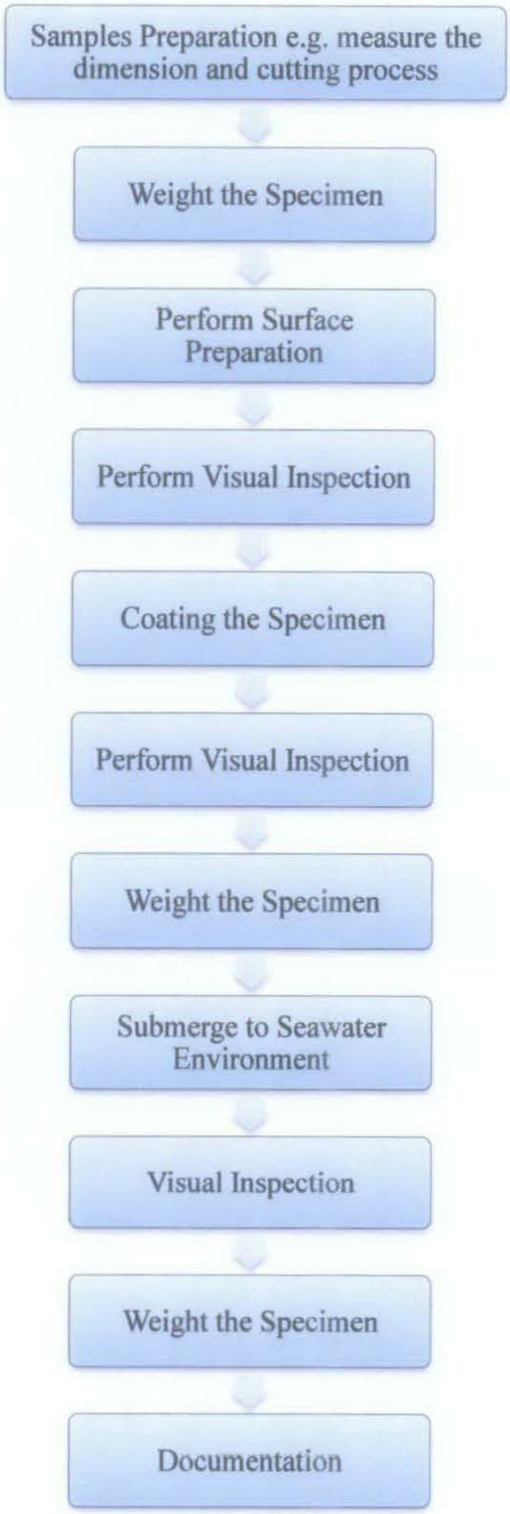


Figure 28: Project flow chart for barnacle effect studies.

3.7 GANTT CHART

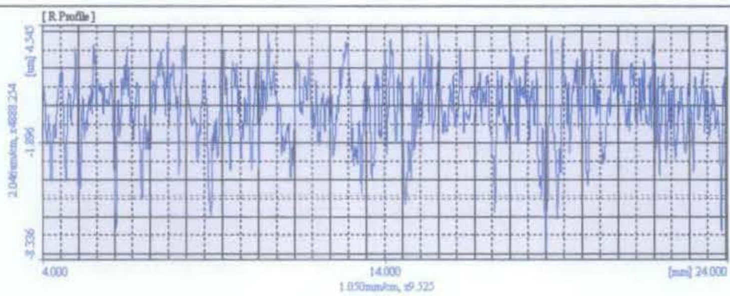
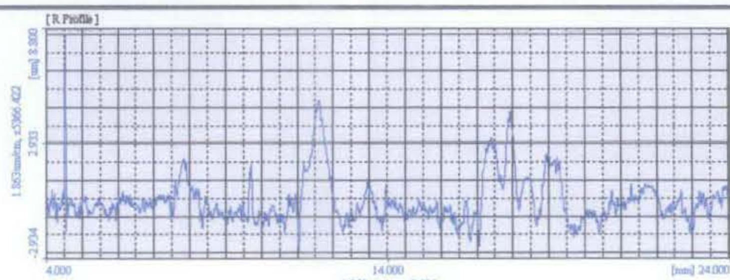
Gantt Chart for this study is shown in Appendix A3.

CHAPTER 4
RESULT AND DISCUSSION

4.1 EXPERIMENTAL RESULT

<u>Surface Profiling</u>

Three (3) different surface roughness samples was measure with surface profiling machine to calculate the respective data which is surface roughness. This comparison was made to study surface roughness on the adhesion properties of epoxy mastic coating which is organic coating. The graph and values was obtained during the measuring process. The results are tabulated as below:

Type of Surface	Roughness Value (Ra)	Graph
Sandblasting	1.497 µm	
Bare metal	0.817 µm	

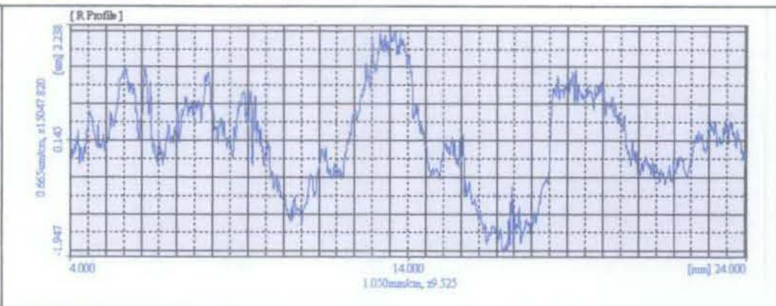
Polishing	0.677 µm	

Table 5: Result of the Surface Roughness Test.

From the graph, we can expect the adhesion of the coating especially primer to the surface of substrate.

<u>Salt Spray Test</u>

Sample	Description	Weight Initial (gram)	Weight after exposure (gram)	Weight after cleaning (gram)	Remarks
A	Coated	259.2	259.0	259.5	No weight loss
B	Coated	248.9	249.1	248.6	No weight loss
E	Uncoated	245.5	252.2	239.5	Weight loss 5.5 gram
G	Coated	255.0	256.1	255.0	No weight loss

Table 6: Result of weight loss of the sample after 13 days

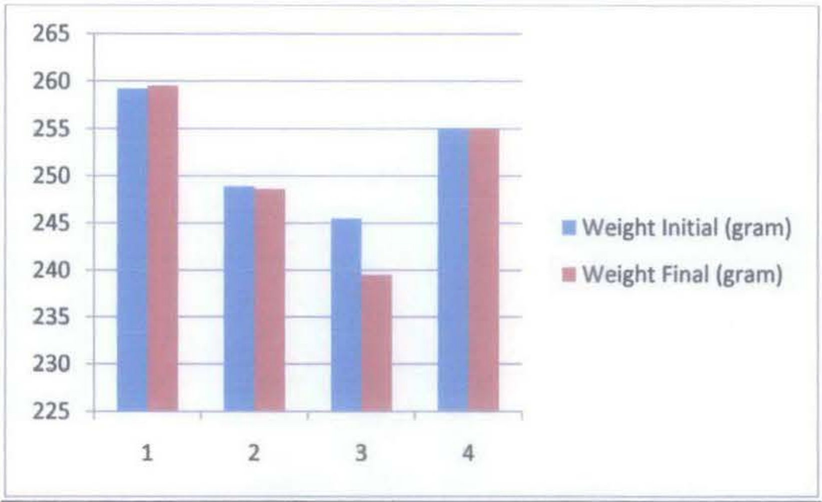


Figure 29: Bar chart show the different weight before and after the test.

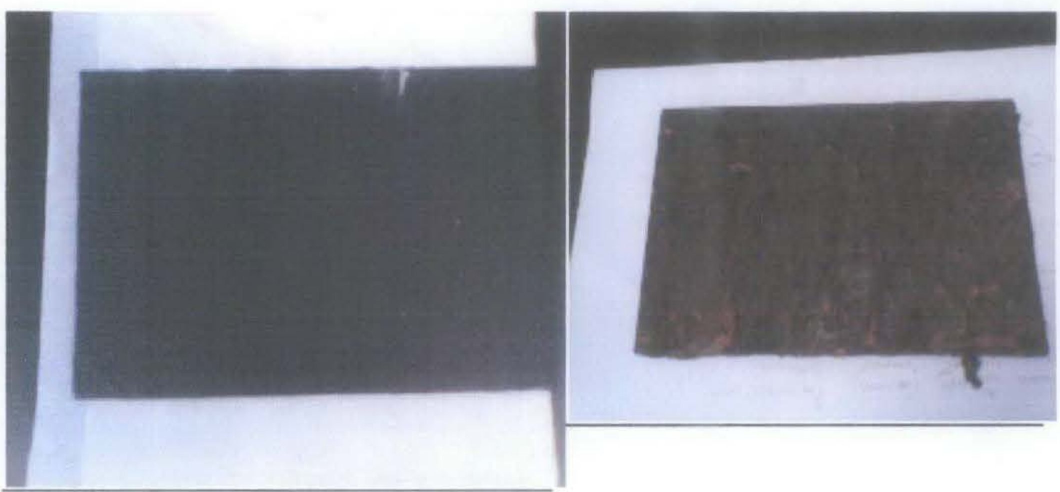


Figure 30: Two sample after the salt spray test

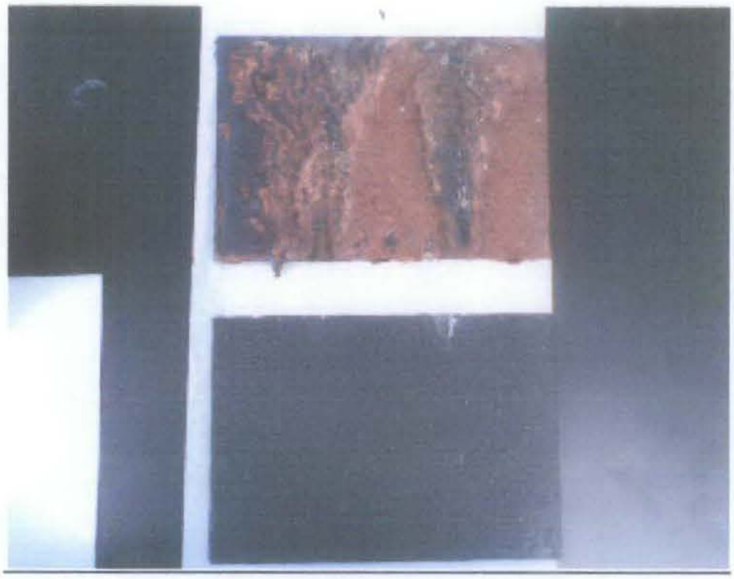


Figure 31: Another comparison of sample after salt spray test

Corrosion rates are expressed in mils per year (mpy).This expression is readily from the weight loss of the metal specimen during the corrosion test by formula given below [9]:

$$\text{mpy} = \frac{534W}{DAT}$$

where , W = Weight loss, mg

D = Density of specimen, g / cm³

A = Area of specimen, sq.in

T = Exposure time, hr

So from this test, we can calculate the corrosion rate by each sample by using the equation above. The result of corrosion rate can be tabulated as table below.

Sample	Description	Weight Initial (gram)	Weight after cleaning (gram)	Weight loss	Corrosion Rate (mpy)
A	Coated	259.2	259.5	No weight	0

				loss	
B	Coated	248.9	248.6	No weight loss	0
E	Uncoated	245.5	239.5	Weight loss 5.5 gram	49.460
G	Coated	255.0	255.0	No weight loss	0

Table 7: Result of corrosion rate after 13 days of exposure

The result of uncoated sample was obtained by

$$\text{mpy} = \frac{534(5500mg)}{\left(\frac{8.1667g}{cm^3}\right)(23.305\ sq\ in)(312\ hr)}$$

$$\text{mpy} = 49.460$$

For coated sample, there was no weight loss, hence no corrosion rate obtained.

<u>Scratch Test</u>

In order to evaluate the scratch results, it is necessary to understand what occur during the test. It is also necessary to separate the effects of appearing stress states, mechanisms of failure and aspects of damage.

The results are evaluated when the data is obtained. Basically, there are two basic results available which is by looking at cracks and delamination via optical microscope after the test and on the other hand is via recorded signals of tangential force and acoustic emission during scratching. Cracks and delamination are very difficult to detect. The result for each scratch is very unique and also their critical load.

Below are result to measure adhesion of coating from sandblasting's surface.

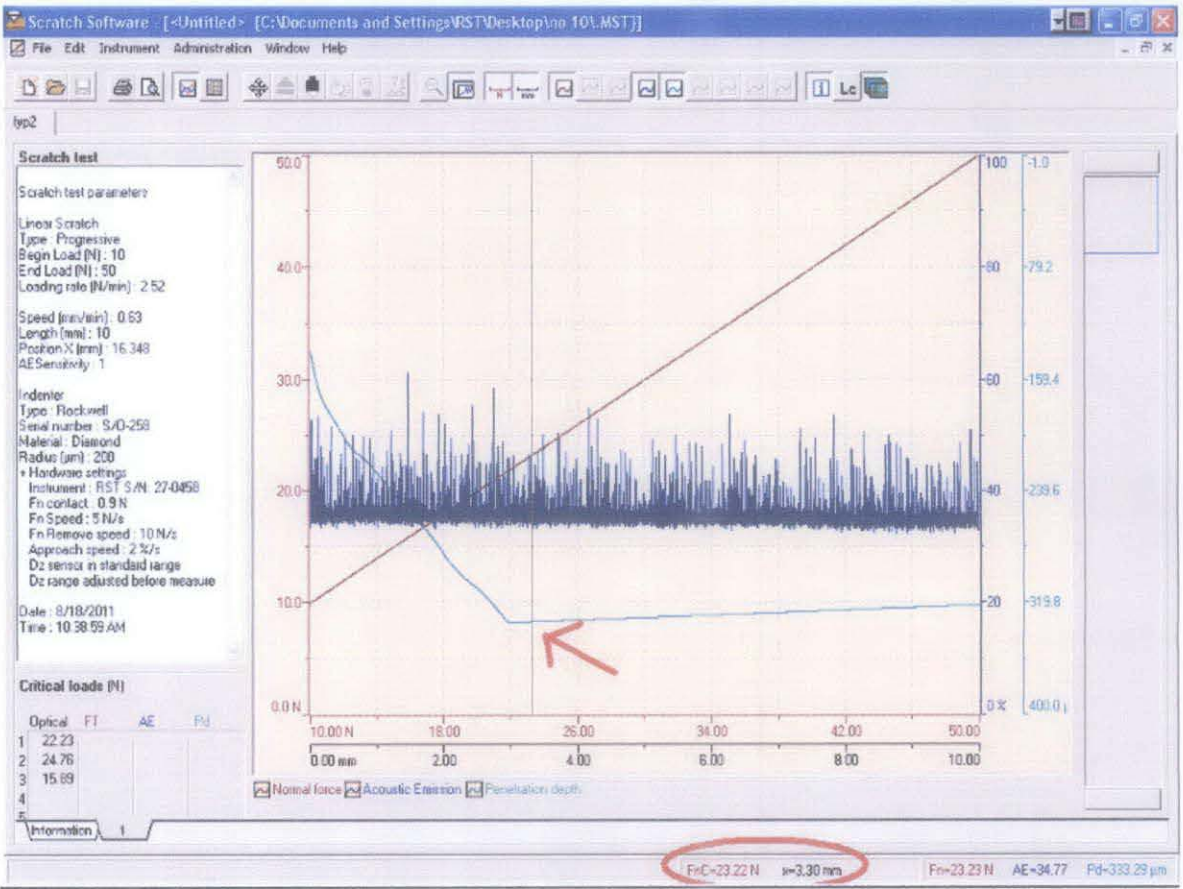


Figure 32: Graph of critical load of sandblasting surface

From the graph, we get the critical load when the coating started to fail is 23.22 N and at the 3.30 mm after scratch. At this coordinate, the coating is failing and that's the reason why the penetration depth can reach anymore and started to increasing. By using very high technology 3D non- contact machine, we can see what happen at that particular coordinate in microscopic view.

For this test, the starting point is at 5.50 mm. So, by adding 3.30mm to 5.50 we obtain 8.80 mm. Using 3D non- contact machine, the author located 8.80 mm from x-coordinates and the scratch can view as the photo below.

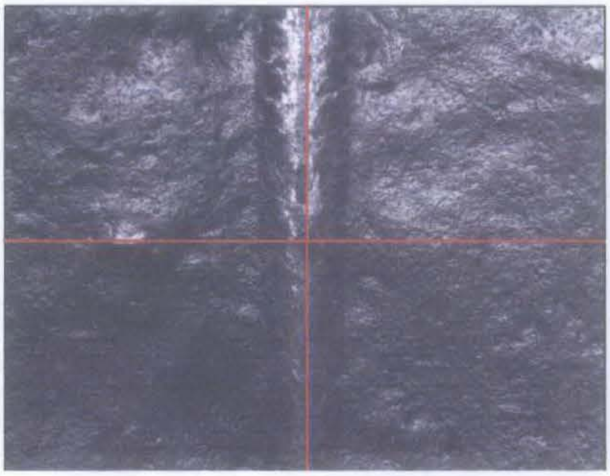


Figure 33 : 8.80 mm from x-coordinates (1000 magnification)

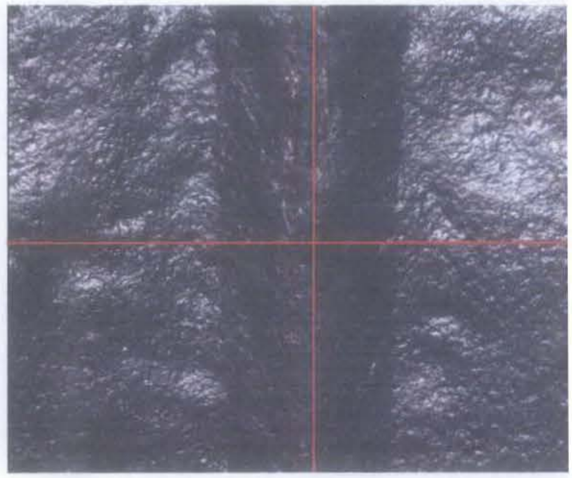


Figure 34 : 8.80 mm from x-coordinates (2 magnification)

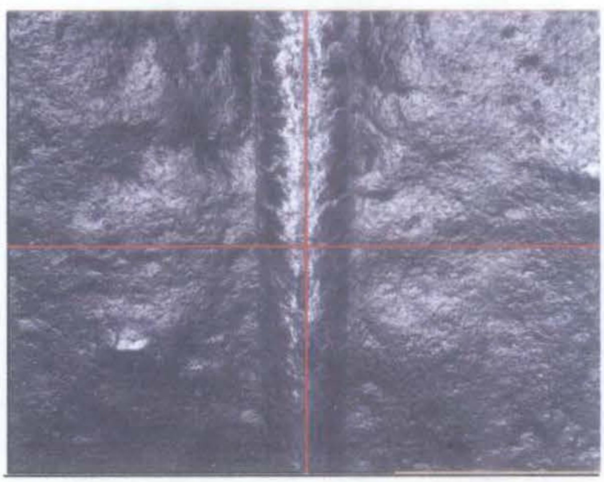


Figure 35: 9.81 mm from x-coordinates (1000 magnification)

From the photo, we can see clearly that coating start to failure at 8.80mm from X coordinate. At the 2nd photo with 2000 magnification, we can see clearly chevron-shape start to show up.

At the 3rd photo from 9.81 mm from x coordinate just 1.00 mm from the 8.8 mm location, we can see the area where the coating fail and show the substrate surface (white layer).

Below are results to measure adhesion of coating from bare metal's surface.

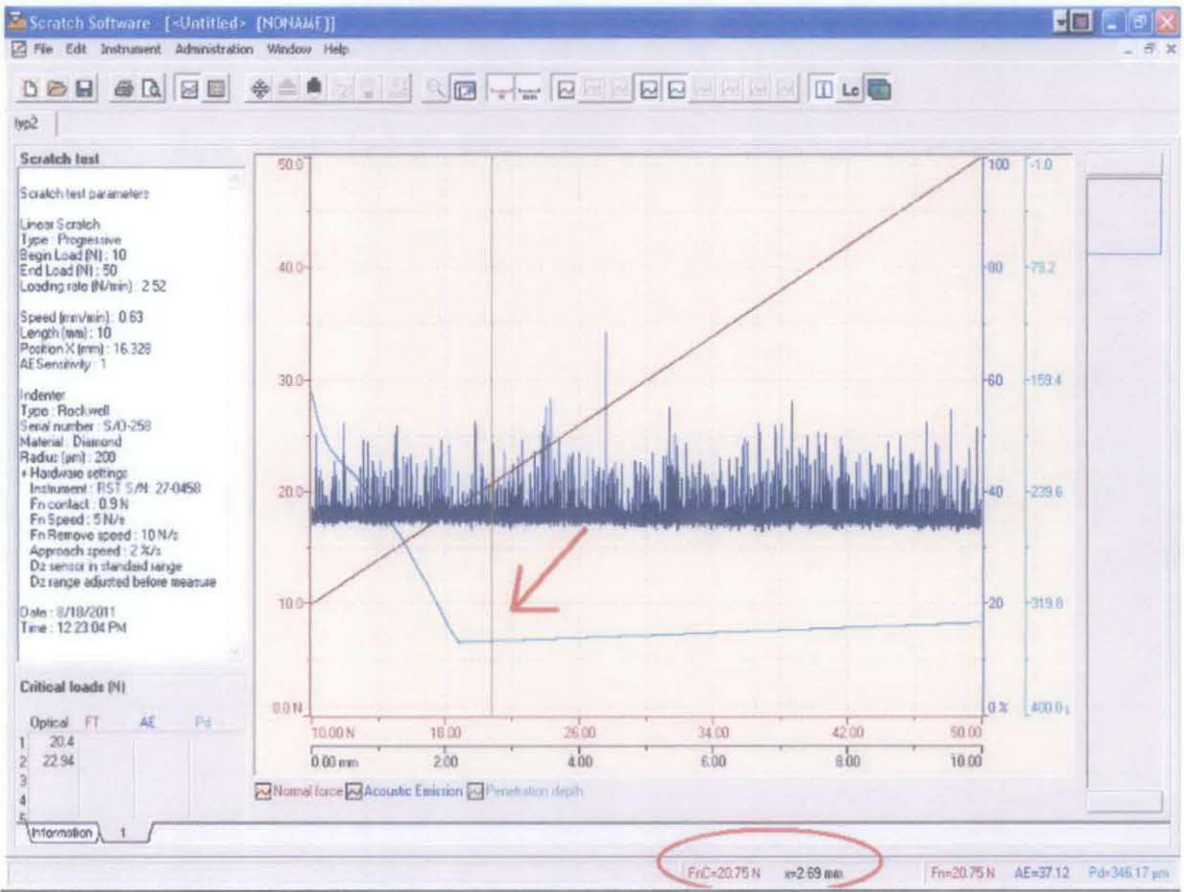


Figure 36: Graph of critical load of bare metal surface

From the graph, we get the critical load when the coating started to fail is 20.75 N and at the 2.69 mm after scratch. At this coordinate, the coating is failing and that's the reason why the penetration depth can reach anymore and started to increasing. By using very high technology 3D non- contact machine, we can see what happen at that particular coordinate in microscopic view.

For this test, the starting point is at 3.20 mm. So, by adding 2.69 mm to 3.20 we obtain 5.89 mm. Using 3D non- contact machine, the author located 5.89 mm from x-coordinates and the scratch can view as the photo below.

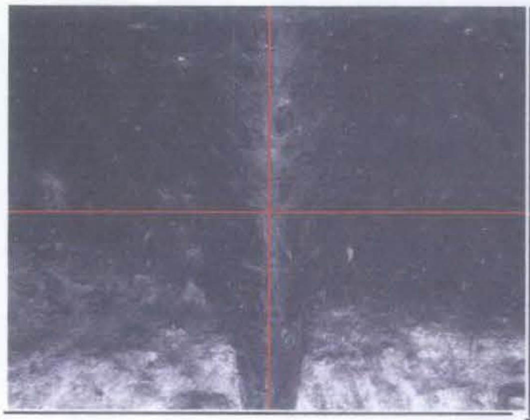


Figure 37 : 5.89 mm from x-coordinates (1000 magnification)

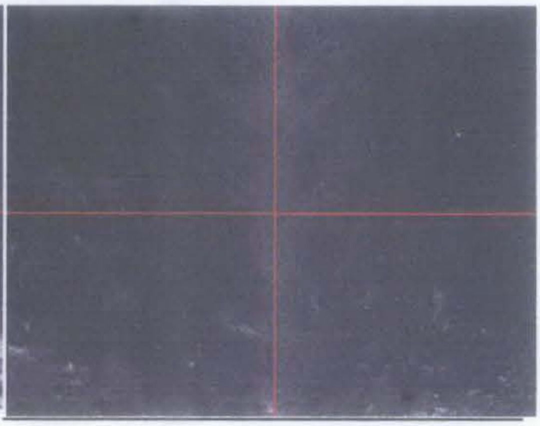


Figure 38: 5.89 mm from x-coordinates (2000 magnification)

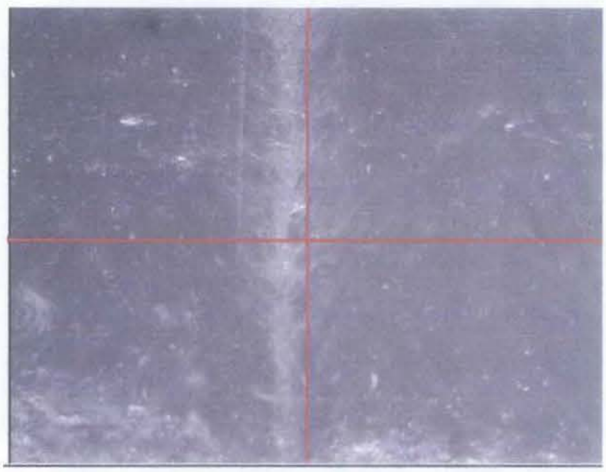


Figure 39: 6.89 mm from x-coordinates (1000 magnification)

From the photo, we can see clearly that coating start to failure at 5.89 mm from X coordinate. At the 2nd photo with 2000 magnification, we can see clearly chevron-shape start to show up.

At the 3rd photo from 6.89 mm from x coordinate just 1.00 mm from the 5.89 mm location, we can see the area where the coating fail and show the substrate surface (white layer).

Below are results to measure adhesion of coating from polishing surface.

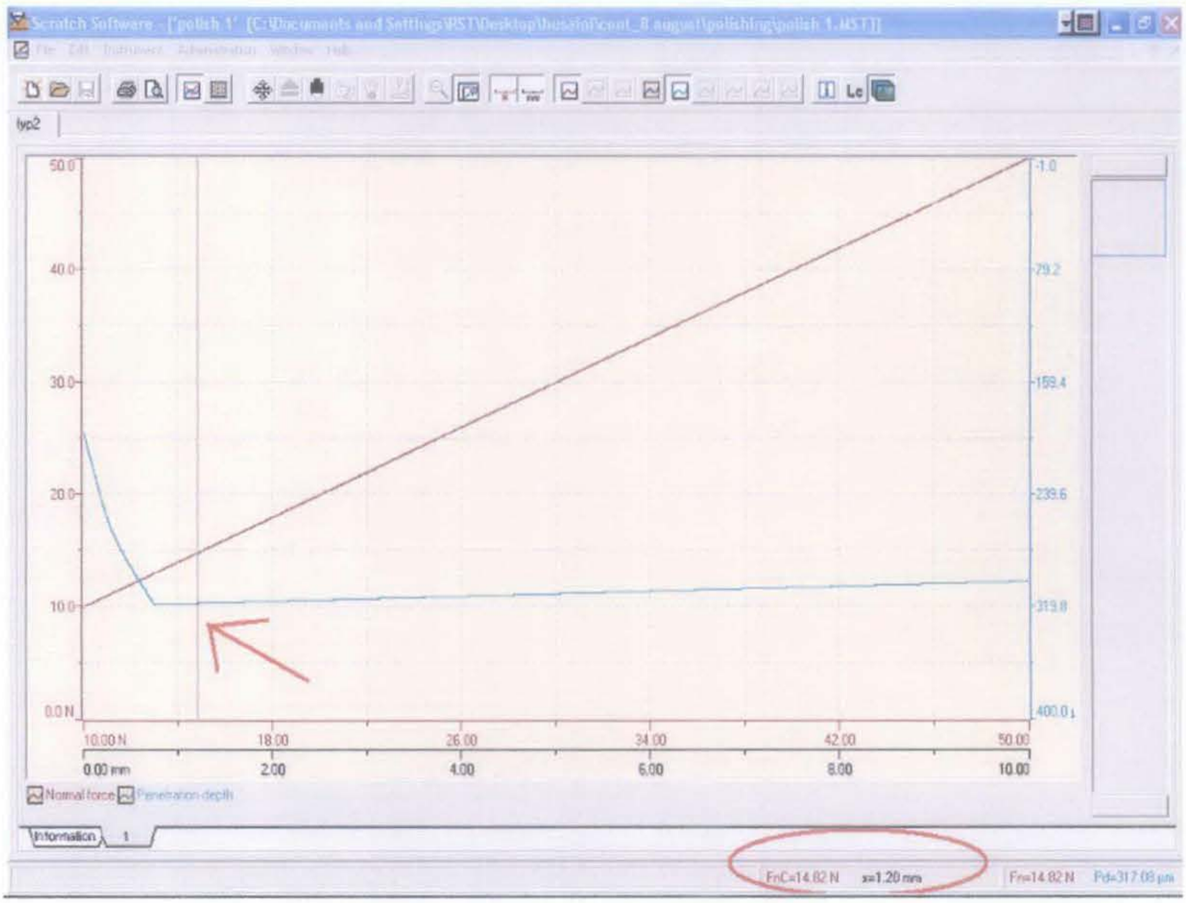


Figure 40: Graph of critical load of polish surface

From the graph, we get the critical load when the coating started to fail is 14.82 N and at the 1.20 mm after scratch started. At this coordinate, the coating is failing and that's the reason why the penetration depth can reach anymore and started to increasing along the scratch line. By using very high technology 3D non- contact machine, we can see what happen at that particular coordinate in microscopic view. By visual inspection, the polish surface sample produced significant amount of small debris when the indenter moved along the surface.

For this test, the starting point is at 2.20 mm. So, by adding 1.20 mm to 2.20 we obtain 3.40 mm. using 3D non- contact machine, the author located 3.40 mm from x-coordinates and the scratch can view as the photo below.

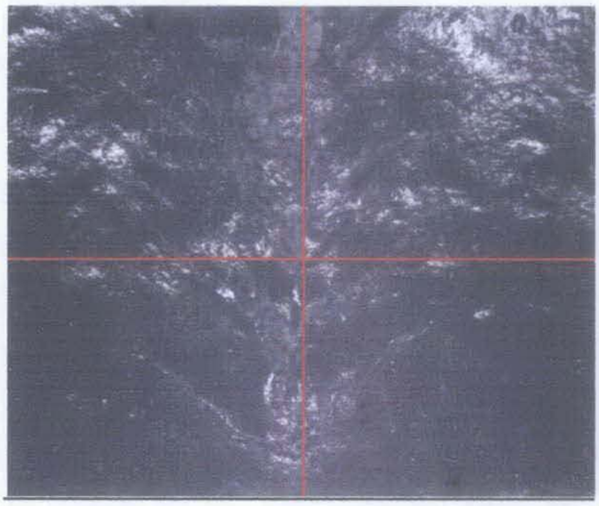


Figure 41: Photo show that the chevron-shape near the starting point of scratch test.

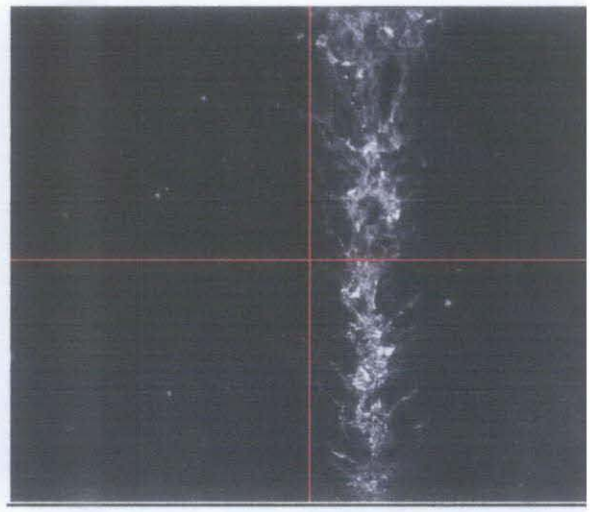


Figure 42: Photo show that the chevron-shape started near the starting point of scratch test and start to crack and propagate at 1000x magnification.

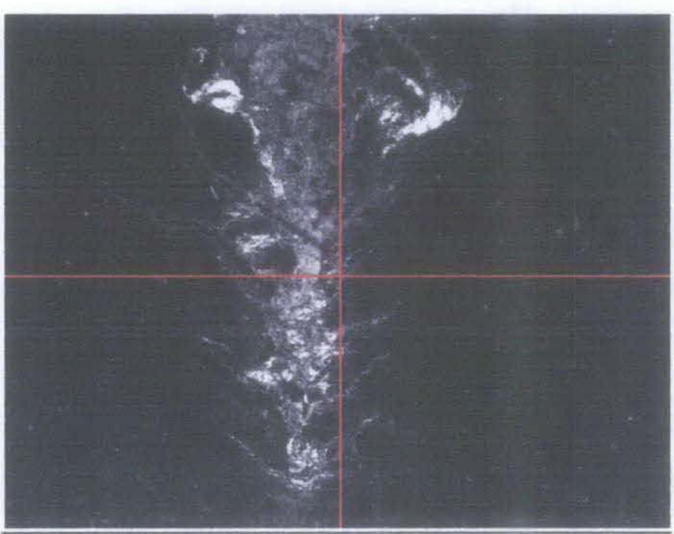


Figure 43: Photo show that the chevron-shape started near the starting point of scratch test and start to crack and propagate at 2000x magnification.

For polish surface, we can see clearly that the coating started to fail just after the scratch started. From microscopic view, chevron-shape like are very clear compare to sandblast and bare metal surface. From visual inspection, coating started to flaking and peel off just after the scratch test is over.

So the result for all the surface can be conclude in the table below.

Surface Preparation	Critical Load, Lc	Distance Scratch Start
Sandblasting	23.22 N	3.30 mm
Bare Metal	20.75 N	2.69 mm
Polish	14.82 N	1.20 mm

Table 8: Scratch Test Result.

Immersion Test to study barnacle growth.

The sample that the author submerges at the splash zone at Lumut Perak shows no sign of barnacle or other potential organism.

The same are conduct at the lab to study the barnacle effect to the coating. The water is taken from the same location which is at Lumut. The same result obtains at the sample in the lab and the sample at the splash zone which is no sign of barnacle growth or other potential organism.

4.2 DISCUSSION

The effect of surface roughness on the adhesion of the coating is analyzed after the scratch test completed. The test is done repeatedly to ensure that the result obtain is satisfied. Sandblasting surface is the best surface for coating since sandblasting process is free from contaminant and grease. It also best choice since it has so called "teeth" that will help the adhesion of the coating (primer). From the graph obtained from surface profiler machine, we can see that the graph was stable with high and low peak. The polish on the other way around is very bad surface to applied epoxy mastic coating. The "too smooth" surface is very bad to adhesion especially organic coating. The bare metal is not recommended surface since usually bare metal has a lot of contaminant and scale mill. Beside, the bare metal contain thin oxide layer that can affected coating adhesion performance. In scratch test, the thickness of the coating is same for all samples.

Coating adhesion test by scratch test is also affected by the hardness of base metal due to the dependence of the critical load on the coating thickness is not linearly dependence and it varies with the basic material hardness. So, by restricting the sample to only mild steel substrate, the effect is neglected. Scratch test should be performed in the constant temperature and humidity since the variation of this parameter may affect the result.

The salt spray test helps the author a lot to study corrosion properties of the epoxy coating. The salt solution need to be mix accordingly and follow the percentage of NaCl needed. The wrong percentage of NaCl can lead to the wrong interpretation of the result obtained. The salt solution reservoir need to inspect regularly to ensure the volume of salt solution is not below the minimum volume. The sample coated with epoxy mastic does not corrode after exposed in the corrosion chamber after period of time. However, the uncoated sample is badly corroded. Form the result, we can see that epoxy mastic coating is survive if expose to marine environment. No weight loss is reported and no single corrosion product is produce. The test may not be directly related to the intended services but are sometimes incorporated in specification as acceptance test.

As for immersion testing, we can conclude that epoxy mastic coating can survive form barnacle growth or other potential microorganism. The samples were inspected from time to time and there is no barnacle present.

All the step taken from sample preparation until coating need to be done continuously in order to ensure that the oxides are not form at the sample surface after sandblasting and polishing process. Oxide can form in 24 hours if the surface of samples is not protected. Oil or grease can be used to protect the surface from oxides formation. For this testing, cooking oil is used to protect the surface of sample temporarily before the coating process. Cooking oil is just like other oil that can provide surface barrier between the metal substrate and the environment. Besides, the samples also need to be kept at safe location. Sample cannot be exposed to direct sunlight since it will change the properties of the sample. Sample also cannot be expose to high temperature such as flame and other chemical that hazardous.

All testing need to be done under supervision of lab technician. Proper handling of chemical and heavy machinery need to have permission from lab technician and also project supervisor. All rules and regulation in the laboratory need to be obeyed in order to avoid any potential accident occurs.

Seawater sample that has been taken from Lumut, Perak Darul Ridzuan need to be kept in the refrigerator in order to preserve all algae and other microorganism from die. The temperature need to be kept as low as 15 °C. This is to ensure that the algae and microorganism in the seawater will produce barnacle in the laboratory.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

As a conclusion, the study on epoxy mastic coating of submerge structure is success and follow the schedule. The coating used is Jotamastic 87 GF produce by Jotun.

It is recommended that further study on the adhesion of epoxy mastic coating since adhesion is very interesting and unique properties. More testing should be done like pull off test, blister test, bend test, burnishing test, peel test, push test, file test, impact test scribe-grid test, draw test, chisel knife test, heat quenched test and grind saw test.

It is also recommended that the sample is coated by professional and coated at designated coating lab. This is because the coating in this study is coated by amateur at the common room. The sample should be coated via air spray and at the controlled temperature and humidity room since the parameters can affect the strength of coating. Formation of bubbles is one of the examples if the coating process is done at common room. These bubbles can affect the result for scratch test and if this happen, another scratch test need to be performed. Due to that, a lot of time and effort is wastage and this will affect the schedule and progress of the project.

For test to study barnacle effect on coating the sample should be immerse for long period of time to ensure that barnacle or marine fouling organism can growth. With that then we can study their effect to coating and fine a way to prevent it.

Coating color also play important role in this studies. Black coating is very difficult to analyze since we can see clearly the surface and scratch line by using microscope. Bright color light white or yellow are most recommended since they can provide clear microscopic view for analyzing the scratch. Hence, we can see the flaking, crack, chevron- shape clearly and conclude the result confidently.

The project goals are to study the epoxy mastic and only focus on adhesion properties, corrosion properties and barnacle effect only. For adhesion properties, the author only focused on the relationship between surface preparation and the adhesion of coating. With the application of appropriate tests and laboratory exercise as mention in Methodology sections, the relationship of surface preparation and adhesion level of coating is established. Revetest scratch tester has been proven to be very useful for this study. Other machines are also very useful and help a lot. Correct interpretation and guidance from is very critical to analyze the scratch test.

Upon the completion of the project, this research and experiment based project has definitely added more information pertaining epoxy mastic coating and hence be the reference to industrial practitioners and future studies.

Finally, it can be concluded that the epoxy mastic coating is a versatile coating that can exploited and modified to desired properties. Sandblasting is the best method for surface preparation and sample that were sandblasted are relatively has high adhesion compare to bare metal and polish sample. Epoxy mastic also can sustain corrosion even at marine and seacoast environment make it more practical to apply in the industry. Besides, it also free form barnacle growth and other potential microorganism.

To recap back, this project is about to study on epoxy mastic coating of submerge structure (jackets, buoy and ballast tank) and effect of barnacle top the coating system.

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APPENDICES

A1. Jotamastic 87 GF Technical Datasheet

A2. Technical Drawing of the Sample

A3. Gantt chart

Technical Data
Jotamastic 87 GF

Jotun Protects Property

Product description

Jotamastic 87 GF is a two-pack surface-tolerant, abrasion resistant, high solids epoxy-based primer/topcoat reinforced with glass flakes, which may be applied in high film thickness. Two hardeners (comp.B) are available, according to temperature conditions. Cures down to 23°F (-5°C) by using cold climate comp. B. This product is a part of a complete system which is certified not to spread surface flames.

Recommended use

Anticorrosive primer with improved abrasion resistance for steel structures, cures down to 23°F (-5°C) by using cold climate comp. B. Useful on steel where blast cleaning may not be possible, and on hydrojetted surfaces still being moist where gloss retention is of minor importance

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Film thickness and spreading rate

Standard climate hardener	Minimum	Maximum	Typical
Film thickness, dry mils (µm)	8,0(200)	14,0(350)	10,0(250)
Film thickness, wet mils (µm)	10,0(250)	17,6(440)	12,6(315)
Theoretical spreading rate ft²/gl (m²/l)	160(4)	92(2,3)	128(3,2)

Cold climate hardener	Minimum	Maximum	Typical
Film thickness, dry mils (µm)	8,0(200)	12,0(300)	10,0(250)
Film thickness, wet mils (µm)	11,4(285)	17,2(430)	14,4(360)
Theoretical spreading rate ft²/gl (m²/l)	140(3,5)	92(2,3)	112(2,8)

Comments

Hong Kong rules: Category of paints - Other vessel coatings; VOC 250 gms/ltr HK EPD method (Ready to use); Exempt compound - N/A; Specific gravity: 1.41 (A+B);
Both VOC and Specific gravity values provided are typical values, subject to changes when different color involved.

Physical properties

Color	Grey, Red, White
Solids (vol %)*	80 ± 2 Standard climate hardener 70 ± 2 Cold climate hardener
Flash point	**Standard hardener:** 95°F ± 4 (35°C ± 2) (Setaflash) **Cold Climate hardener:** 88°F ± 4 (31°C ± 2) (Setaflash)
VOC	2,09 lbs/gal (250 gms./ltr.) USA-EPA Method 24 170 gms/ltr UK-PG6/23(97). Appendix 3
Gloss	Semigloss
Gloss retention	Fair
Water resistance	Very good
Abrasion resistance	Excellent
Solvent resistance	Good
Chemical resistance	Very good
Flexibility	Good

*Measured according to ISO 3233:1998 (E)

Surface preparation

All surfaces should be clean and free from contamination. The surface should be assessed and treated in accordance with ISO 8504.

Bare steel
Cleanliness: Power tool cleaning to min. SSPC-SP2 "Hand Tool Clean" or St 2, mill scale free (ISO 8501-1:1988). Improved surface treatment (blast cleaning to SSPC-SP10 "Near White Blast" or Sa 2½) will improve the performance. In case of hydrojetting the flash rust degree shall not exceed moderate in SSPC and NACE standards for water prepared surfaces.

Shopprimed steel
Clean, dry and undamaged approved shopprimer.

Coated surfaces
Clean, dry and undamaged compatible primer. Contact your local Jotun office for more information. For maintenance UHPWJ to WJ2 (NACE No.5/SSPC-SP 12) or Power tool cleaning to min. SSPC-SP2 "Hand Tool Clean" or St 2 for rusted areas

Other surfaces
The coating may be used on other substrates. Please contact your local Jotun office for more information.

Condition during application

The temperature of the substrate should be minimum 50°F (10°C) (Std), 23°F (-5°C) in CC and at least 5°F (3°C) above the dew point of the air, temperature and relative humidity measured in the vicinity of the substrate. Good ventilation is required in confined areas to ensure proper drying.

Hydrojetting of steel surface makes a wet surface. The surrounding air must have a relative humidity not exceeding 85 %. Before painting the surface shall not be glossy with moisture, but can have a patchy apperance.

Application methods

Spray	Use airless spray
Brush	Recommended for stripe coating and small areas, care must be taken to achieve the specified dry film thickness.
Roller	May be used for small areas but not recommended for first primer coat, however when using roller application care must be taken to apply sufficient material in order to achieve the specified dry film thickness.

Application data

Mixing ratio (volume)	**Standard hardener:** 6 parts Comp. A (base) to be mixed thoroughly with 1 part Standard Comp. B (curing agent) **Cold Climate hardener:** 4 parts Comp. A (base) to be mixed thoroughly with 1 part Cold Climate Comp. B. (curing agent)
Induction time	10 minutes.
Pot life 73°F (23°C)	**Standard hardener** 10C: 4 hours, 23C: 2 hours, 40C: 1 hour **Cold Climate hardener:** 1 hour
Thinner/Cleaner	Jotun Thinner No. 17
Guiding data airless spray	
Pressure at nozzle	15 MPa (150 kp/cm², 2100 psi).
Nozzle tip	0.63 - 1.09 mm (0.025-0.043")
Spray angle	40 - 80°
Filter	Filters to be removed prior to spraying.

Drying time

Drying times are generally related to air circulation, temperature, film thickness and number of coats, and will be affected correspondingly. The figures given in the table are typical with:

* Good ventilation (Outdoor exposure or free circulation of air)
* Typical film thickness
* One coat on top of inert substrate

Standard hardener

Substrate temperature	**50°F(10°C)**	**73°F(23°C)**	**104°F(40°C)**
Surface dry	8 h	4 h	2 h
Through dry	24 h	10 h	4 h
Cured	14 d	7 d	2 d
Dry to recoat, minimum	24 h	10 h	4 h
Dry to recoat, maximum [1]	-	-	-

Cold climate hardener

Substrate temperature	**23°F(-5°C)**	**32°F(0°C)**	**41°F(5°C)**	**50°F(10°C)**	**73°F(23°C)**
Surface dry	24 h	18 h	12 h	6 h	2,5 h
Through dry	48 h	26 h	18 h	12 h	5 h
Cured	21 d	14 d	7 d	3 d	2 d
Dry to recoat, minimum	48 h	26 h	18 h	12 h	5 h
Dry to recoat, maximum [1]	-	-	-	-	-

1. Provided the surface is free from chalking and other contamination prior to application, there is normally no overcoating time limit. Best intercoat adhesion occurs, however, when the subsequent coat is applied before preceding coat has cured. If the coating has been exposed to direct sunlight for some time, special attention must be paid to surface cleaning and mattening/removal of the surface layer in order to obtain good adhesion.

The given data must be considered as guidelines only. The actual drying time/times before recoating may be shorter or longer, depending on film thickness, ventilation, humidity, underlying paint system, requirement for early handling and mechanical strength etc. A complete system can be described on a system sheet, where all parameters and special conditions could be included.

Typical paint system

Jotamastic 87 GF	**2 x 10 mils (250 µm)**	**(Dry Film Thickness)**
Hardtop II	1 x 2 mils (50 µm)	(Dry Film Thickness)

Other systems may be specified, depending on area of use

Storage

The product must be stored in accordance with national regulations. Storage conditions are to keep the containers in a dry, cool, well ventilated space and away from source of heat and ignition. Containers must be kept tightly closed.

Handling

Handle with care. Stir well before use.

Packing size

20 liter unit with Standard hardener: 16 liters (4.23 gallons) Comp. A (base) in a 20 liter container and 2.7 liters (0.67 gallons) Comp. B (curing agent) in a 3 liter container and
20 liter unit with Cold Climate hardener: 16 liters (4.23 gallons) Comp. A (base) in a 20 liter container and 4 liters (1.06 gallons) Cold Climate Comp. B (curing agent) in a 5 liter container.

Health and safety

Please observe the precautionary notices displayed on the container. Use under well ventilated conditions. Do not breathe or inhale mist. Avoid skin contact. Spillage on the skin should immediately be removed with suitable cleanser, soap and water. Eyes should be well flushed with water and medical attention sought immediately.

For detailed information on the health and safety hazards and precautions for use of this product, we refer to the Material Safety Data Sheet.

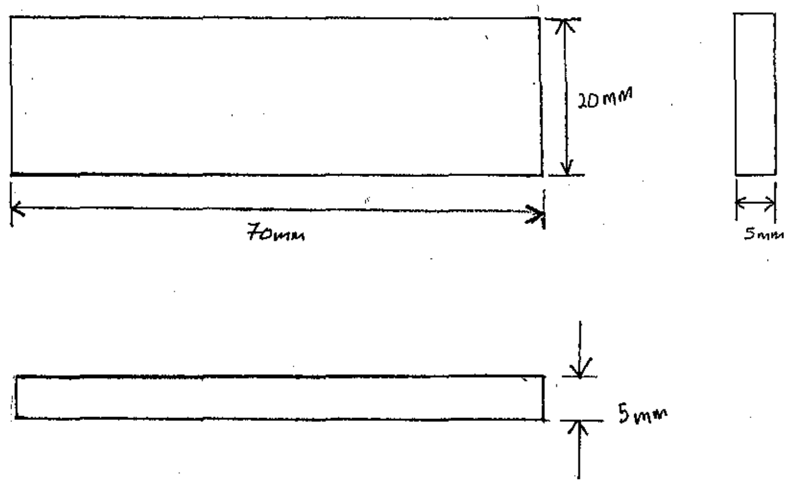
DISCLAIMER
The information in this data sheet is given to the best of our knowledge based on laboratory testing and practical experience. However, as the product can be used under conditions beyond our control, we can only guarantee the quality of the product itself. We also reserve the right to change the given data without notice. Minor product variations may be implemented in order to comply with local requirements.
If there is any inconsistency in the text the English (UK) version will prevail.

Jotun is a World Wide company with factories, sales offices and stocks in more than 50 countries. For your nearest local Jotun address please contact the nearest regional office or visit our website at www.jotun.com

ISSUED 26 NOVEMBER 2010 BY JOTUN
THIS DATA SHEET SUPERSEDES THOSE PREVIOUSLY ISSUED

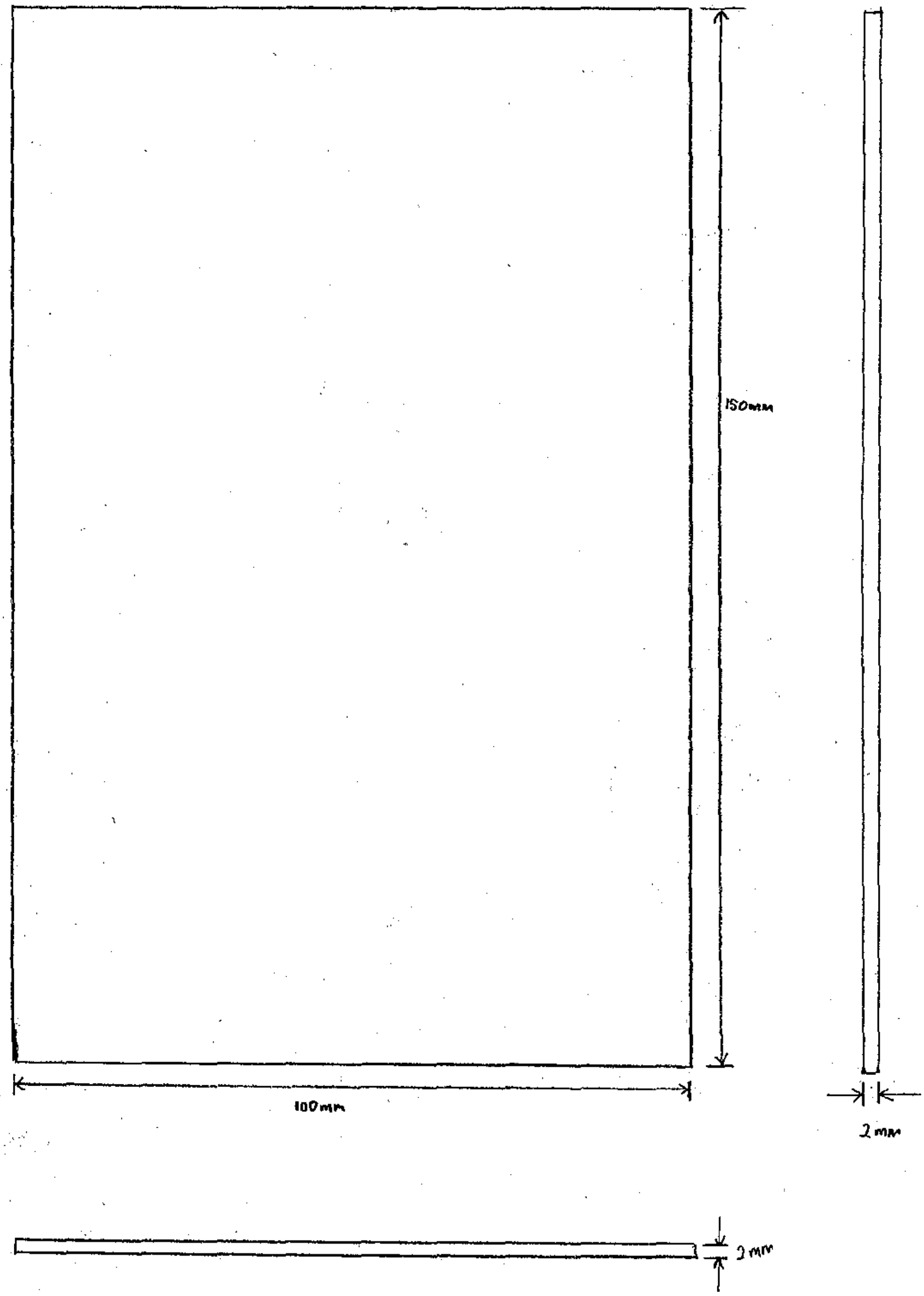
TECHNICAL DRAWING OF THE SAMPLE.

SAMPLE'S ACTUAL DIMENSION FOR ADHESION TEST



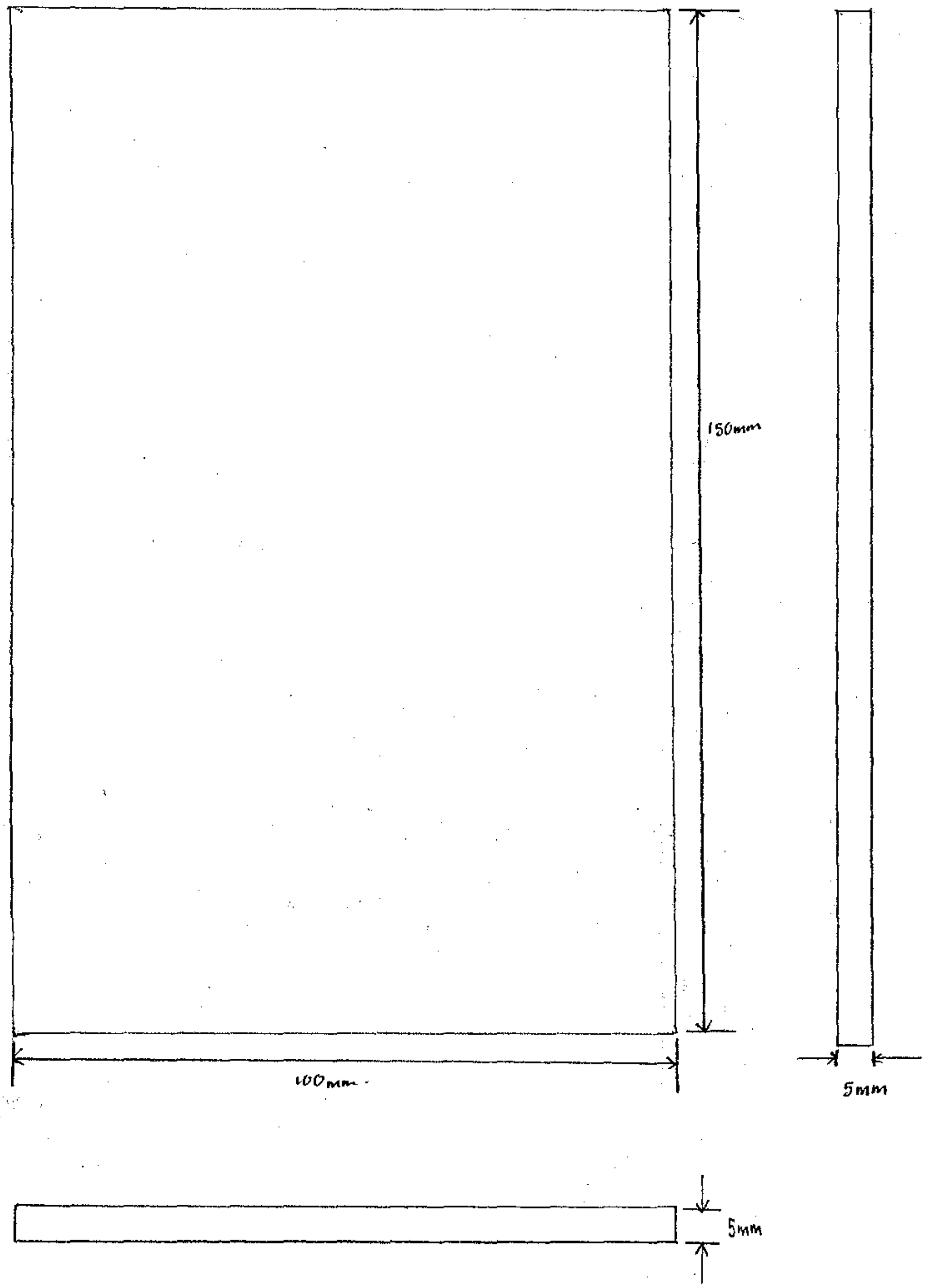
TECHNICAL DRAWING OF THE SAMPLE.

SAMPLE'S ACTUAL DIMENSION FOR CORROSION TEST



TECHNICAL DRAWING OF THE SAMPLE.

SAMPLE'S ACTUAL DIMENSION FOR IMMERSION TEST



GANTT CHART

MOHAMAD HUSAINI BIN ABDUL WAHAB

STUDY ON EPOXY MASTIC COATING OF SUBMERGE STRUCTURE

NO	*DETAIL*	*WEEK*															
		1	*2*	*3*	*4*	*5*	*6*	*7*		*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
1	Project work continues (Mechanical Test)								*MID-SEMESTER BREAK*								
2	Submission of progress report																
3	Project work continues (Mechanical Test)																
4	Pre-EDX																
5	Submission of draft report																
6	Submission of dissertation (soft bound)																
7	Submission of technical paper																
8	Oral presentation																
9	Submission of project dissertation (hard bound)																