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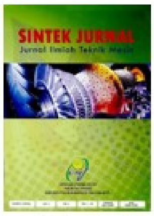

THE EFFECT OF SANDBLASTING AND AIRLESS SPRAY COATING MISMATCHES ON THE LIFE OF A STEEL BUILDING

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ABSTRACT

The quality of construction is paramount in ensuring the longevity of steel buildings. A primary cause of reduced lifespan in steel structures is the development of corrosion. To mitigate high corrosion rates, careful consideration must be given to the steel fabrication process, particularly coating. This study employs Fishbone, 4M+1E, and 5W+1H cause-and-effect analysis methods to examine the impact of the coating process on the lifespan of steel building structures. By identifying the root causes of various problem factors, the study offers recommendations and proper implementations to address these issues. Discrepancies in the coating process were identified, and several recommendations were proposed based on the root cause analysis. The findings aim to ensure the estimated lifespan of the steel piperack building structure by preventing premature corrosion. The results indicate that coating defects predominantly stem from human factors, and several repair recommendations are provided based on these findings.

Keywords: Steel Structure; Coating; Lifespan; Corrosion; Process Defects.

ABSTRAK

Kualitas konstruksi sangat penting dalam memastikan umur panjang bangunan baja. Penyebab utama berkurangnya umur pakai pada struktur baja adalah perkembangan korosi. Untuk mengurangi laju korosi yang tinggi, pertimbangan yang cermat harus diberikan pada proses fabrikasi baja, khususnya pelapisan. Studi ini menggunakan metode analisis sebab-akibat Fishbone, 4M+1E, dan 5W+1H untuk mengkaji dampak proses pelapisan terhadap umur struktur bangunan baja. Dengan mengidentifikasi akar penyebab dari berbagai faktor masalah, studi ini menawarkan rekomendasi dan implementasi yang tepat untuk mengatasi masalah ini. Ketidaksesuaian dalam proses pelapisan diidentifikasi, dan beberapa rekomendasi diusulkan berdasarkan analisis akar masalah. Temuan ini bertujuan untuk memastikan perkiraan umur struktur bangunan piperack baja dengan mencegah korosi dini. Hasil penelitian menunjukkan bahwa cacat pelapisan sebagian besar disebabkan oleh faktor manusia, dan beberapa rekomendasi perbaikan diberikan berdasarkan temuan ini.

Kata Kunci: *Struktur Baja; Pelapisan; Umur; Korosi; Cacat Proses.*

1. Introduction

The quality of a steel building is crucial in ensuring its long-term sustainability [1-3]. Steel structures are favored in construction due to their excellent mechanical properties, abundant availability, ease of fabrication, and economic viability [4-6]. Hence, steel remains an optimal choice to ensure structural strength, load-bearing capacity, and extended service life of buildings [7,8]. However, it is not uncommon for steel structures to experience premature deterioration before reaching their anticipated lifespan, often due to significant damages that directly impact their longevity [9-11].

One of the primary causes of structural damage in steel buildings is corrosion [12-14]. Corrosion can compromise the structural integrity of steel as a load-bearing element [15-17]. While corrosion processes cannot be completely halted [18,19], they can be anticipated to slow down the rate of degradation during the structural lifespan [20,21].

To mitigate high corrosion rates, the coating process during steel fabrication plays a critical role. As part of a collaborative project with PT Pertamina on the Steel Structure Piperack R11 within the RDMP "Refinery Development Master Plan" RU-V in Balikpapan, PT XYZ Plant 3 is currently implementing steel fabrication processes involving coating. Therefore, based on this background and the ongoing project case study, this internship report explores how the coating process in steel fabrication can influence the lifespan of steel building structures, particularly the piperack structure, in the event of mismatches during the coating process. This research aims to investigate the impact of coating discrepancies on the lifespan of Piperack R11 structure within RDMP RU-V.

2. Methods

This study utilizes a combination of qualitative and quantitative methods to assess the impact of the coating process on the lifespan of steel building structures. The research begins with a comprehensive Fishbone (Ishikawa) diagram to visually map out the potential causes of coating defects. The 4M+1E framework (Man, Machine, Material, Method, and Environment) and the 5W+1H technique (Who, What, Where, When, Why, and How) are employed to conduct a thorough cause-and-effect analysis. This dual-method approach allows for a systematic identification of root causes associated with coating failures.

The experimental component of the study involves preparing steel samples and subjecting them to standardized coating procedures. The samples are divided into groups, each representing different stages and conditions of the coating process, including variations in surface preparation, coating application, and environmental factors. Accelerated corrosion testing, such as salt spray and humidity tests, are conducted to evaluate the performance of the coatings under controlled conditions. Data collected from these tests include corrosion rate measurements, visual inspections, and adhesion tests.

The research conducted at PT XYZ utilized a pull-off test during the surface preparation process prior to painting. After completing the pull-off test, the next step was surface cleaning, followed by another pull-off test and the painting process. Quality control was conducted at the final stage. The following flow chart outlines the steps in this research (Figure 1):

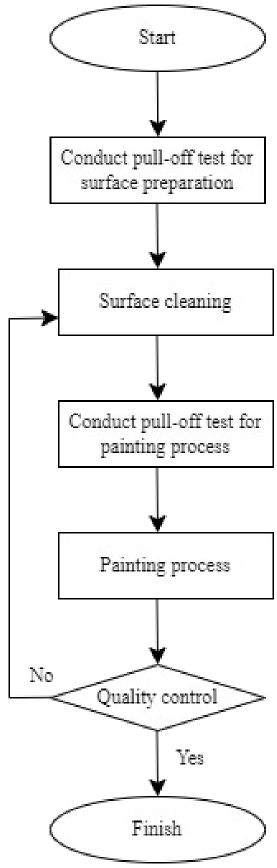

Figure 1. Coating Process Flow Chart

To analyze the data, statistical methods are applied to determine the significance of each identified root cause. Recommendations for improving the coating process are developed based on the analysis, aiming to mitigate human errors and other identified factors. These recommendations are then validated through a series of implementation trials, ensuring their effectiveness in real-world applications. The ultimate goal is to enhance the durability of steel structures by refining coating processes and minimizing the risk of premature corrosion.

3. Results and Discussion

3.1. Coating Process

Surface Preparation

Surface preparation is conducted to assess the readiness of materials, components, and areas before proceeding with the subsequent coating process. The steps for surface preparation are as follows:

a. The steel to be coated must be checked for its rust grade, which indicates the level of rust on its outer layer. The rust grade inspection revealed that the steel is at level B, indicating that the surface has started to rust, and some of the outer layers have begun to peel off. Below is an image showing the results of the rust grade inspection (Figure 2).

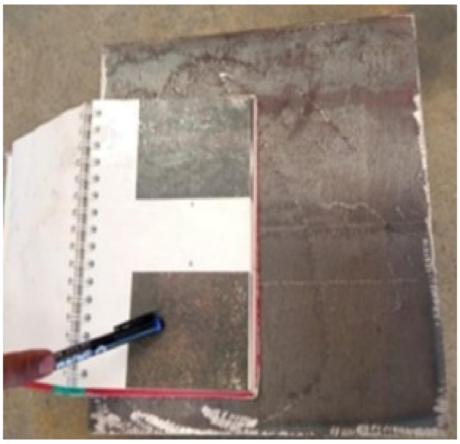

Figure 2. Rust Grade

b. An inspection of the area designated for the coating process must be performed. The goal of this stage is to ensure that the environment is free from contaminants and that conditions comply with the applicable standards. This includes checking room temperature, humidity levels, and readiness for air pollution prevention, among other factors (Table 1).

Table 1. The Result of an Inspection of the Area

Air Temp [°C]/Rel.humidity [%]/Substrate temp. [°C]	Dew Point [°C]	Weather Condition	Wind Strength	Wind Speed Value
32.0/68.00/34.0	25.0	Sunny	Calm	< 0.3 m/s
31.0/73.00/32.0	25.0	Sunny	Calm	< 0.3 m/s
31.0/67.00/32.0	24.0	Sunny	Calm	< 0.3 m/s

c. A blotter test, standardized by ASTM D 4285, is conducted to determine if the air compressor contains oil or water. This test confirmed that no oil or water was found in the air compressor (Figure 2).

Figure 3. Blotter test

d. An abrasive test on the steel grit to be used for the sandblasting process must be conducted. The procedure involves mixing the steel grit with water to determine if it is contaminated with oil or other substances. Subsequently, a pH test is performed, yielding a pH of 6. Then, 5% silver nitrate is added, and the mixture is stirred to check for any dirty white precipitates. The following images illustrate the tests conducted.

Surface Cleaning

The surface cleaning stage is carried out once the results from the surface preparation of materials, substances, and areas meet the required standards and customer specifications. The steps in sandblasting include:

a. Preparing steel grit and loading it into the sandblasting tank.
b. Using complete personal protective equipment.
c. Setting the nozzle pressure to 4 to 7 bar for 1 steel rod. Air is supplied from the air tank at a pressure of 6.9 bar or 100 PSI. Steel grit is then projected onto the steel rod with an estimated duration of 1 hour per steel rod.
d. Steel that has undergone sandblasting must be immediately coated with the subsequent layer within no more than 5 hours to minimize the reattachment of contaminating substances to the steel. Below is an image of the steel that has undergone the sandblasting process.

Painting Preparation

This stage is conducted to assess the readiness of the material after the sandblasting process and before starting the subsequent coating process. The steps involved are:

a. Checking the cleanliness level of the steel surface that has undergone sandblasting, specifically regarding rust. This is done by visually comparing the steel with a standardized rust level reference. The result achieved is that the steel reaches a Sa3 cleanliness level.
b. Conducting a dust assessment test by applying a clear adhesive to detect any dust adhering to the steel. The result obtained is at level 2, indicating an acceptable level of dust that allows for proceeding with the next coating layer.

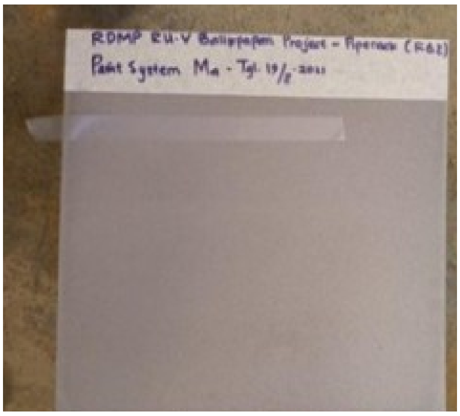

Figure 4. Dust Assement Test

c. Checking the thickness of the blasting layer using a thickness gauge applied to the steel. The result obtained is a thickness of 95 microns.

Figure 5. Thickness Of the Blasting Layer

d. Measuring the oxidation levels of water and salt solutions using an ORP meter. The result for water oxidation is 5,7$\frac{\mu S}{cm}$ and the salt content calculated is (17-5,7) $\frac{\mu S}{cm}$ x 1,2 = 11,3 $\frac{mg}{m^2}$.

Figure 6. Salt Content Check Result

e. Inspecting the area to be used for painting application, similar to the inspection process for surface preparation.
f. Measuring the temperature of the steel to be coated with paint, ensuring it is in accordance with standards and customer requirements.

Figure 7. Check The Steel Temperature

Painting

The painting system implemented by PT XYZ for the RDMP RU-V project involves three layers of paint: primer, intermediate, and topcoat.

Table 2. Painting Compositions

Layer	Generic Type	Paint Manufacture	Mixing Ratio	Color/Ral	Thinner
Primer	Galvosil	Hempel	8.5 liters : 1.5 liters	Metal Grey	0870M
Intermediate	Hempadur/ Hempaprime	Hempel	20 liters : 3 liters	Light Grey	8450
Finish	Hempathane	Hempel	20 liters : 6 liters	Sky Blue	8080

Table 3. Paint Drying Times

Surface Temperatures	10°C (50°F)		20°C(68°F)		30°C(86°F)	
	Min	Max	Min	Max	Min	Max
Galsovil (Primer)	7 Hours	48 Days	3 Hours	21 Days	2 Hours	14 Days
Hempadur/Hempaprine (2nd/Intermediate)	7 Hours	48 Days	3 Hours	21 Days	2 Hours	14 Days
Hempathene (Finish)	7 Hours	48 Days	3 Hours	21 Days	2 Hours	14 Days

The painting process steps are as follows:

a. Applying the primer coat.
b. After 10 minutes of drying, performing a Dry Film Thickness (DFT) check.
c. Checking the steel temperature before starting the application of the second layer.
d. After 4 hours of drying, performing another DFT check and then checking the steel temperature before starting the application of the topcoat. Once the final layer has been applied, while it is still in a wet state, a Wet Film Thickness (WFT) check is performed to measure the thickness of the wet film

before solvent evaporation. The result of this check is 150 μm (Figure 8).

Figure 8. WFT Check

Pull of Test

The pull-off test is conducted to determine the adhesion strength of the paint layer after application, using a pull-off adhesion tester. The result obtained from this test is 11 MPa, and the paint failure mode is 100% cohesive failure of the topcoat layer (Figure 9).

Figure 9. Pull of Test

3.2. Identification, Analysis, and Discussion

Based on direct observations with the project engineer through interview methods, the service life of buildings with steel structures can range from 10 to 15 years if the steel fabrication process is conducted according to standards. Issues in the coating process are usually discovered during inspection or QC after the coating process is completed and before the steel enters the packing process. These problems can arise from multiple causes, such as from the applicator, the surrounding environment, or the material itself.

Problems encountered in the coating process are summarized in the Table 4.

Table 4. Coating Problems

No	Issues Encountered
1	Paint adhesion failure
2	Coating defects such as orange peel, paint sagging, and uneven paint thickness at various points on the same steel rod
3	Painting overspray

Fishbone Diagram

The fishbone diagram is used to identify potential factors contributing to the problems. This diagram has five main components, each with factors causing issues, including material, method, manpower, machine, and production environment [22-24]. The specific factors depend on the type of production conducted. The analysis in coating is divided into two: adhesion problems and painting defects (Figure 10).

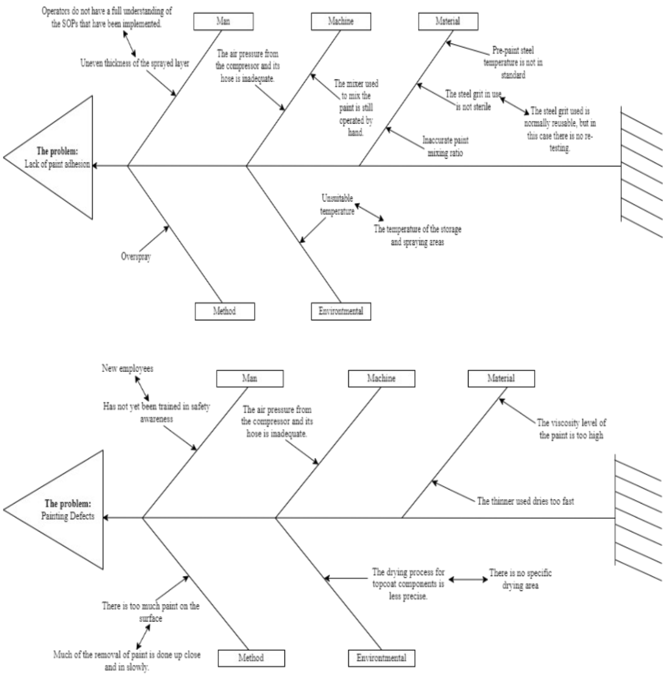

Figure 10. Fishbone Diagram

4M+1E and 5W+1H Analysis

Further analysis regarding the influence of the factors in the fishbone diagram on coating issues and the identification of root causes is conducted using 4M+1E and 5W+1H methods.

Table 5. 4M+1E and 5W+1H Analysis

Problem Causes	Types of Contributing Factors		Cause Analysis
Lack of Paint Adhesion	Man	What	The paint spraying point done by the operator is not evenly distributed thickness
		Why	Operators do not fully understand the SOPs applied
		Where	Uneven thickness may occur in the primary, middle layers, as well as the end
		When	-
		Who	Operators are new employees and have not yet joined training
		How	Organize and ensure mandatory training for new employees
	Machine	What	The air pressure released by the compressor and its hose is not to standard paint stirrers commonky used during the process paint mixing is still manually
		Why	There was a leak in the compressor hose and some time there was an obstruction that fell on the compressor hose there was no paint mixer visible
		Where	Compressor and hose storage areas are not secure from range of destructive things
		When	-
		Who	Hose leaks caused by rats gnawing on the hose
		How	Move the compressor and its hose to a more enclosed or higher place and ensure that it is safe from all things that are destructive Organize a paint mixer machine
	Material	What	Inaccurate paint mixing ratio steel grit used is less sterile Non-standardized steel temperature before painting
		Why	Measurement of the mixture dose is done manually and according to the estimates of the operator who is considered to memorize the dose Steel grit is used usually and reusable but in this case there is no retesting The temperature of the steel in the storage area and when it will be processed is different
		Where	-
		When	-
		Who	-
		How	Provides a dosing device to accurately measure the mixing ratio If you want to minimize budget expenditures by using steel grit more than once, you should test it every time before use. Provide a special steel storage area with constant temperature

	Method	What	Uneven stirring of the paint mixture Accumulated wet paint
		Why	Stirring is done manually and may result in decreased stirring intensity Paint has not dried completely
		Where	Stirring is done in a bucket Primary or second coat of paint
		When	Stirring is done before starting the painting process When starting the next coat of paint
		Who	Manually stirring by operator
		How	Organize a paint mixer machine Provide a dedicated drying area that is exposed to proper sunlight and air
	Environt ment	What	Temperature is not suitable
		Why	Frequently changing weather conditions and no regular temperature checks
		Where	The temperature of the storage and spraying areas
		When	At the time before starting painting process (primer layers, middle, or topcoat)
		Who	-
		How	Always check the temperature before starting painting process
Orange Peel Defects		What	The thinner used dries too fast Much of the removal of paint is done up close and in slowly. The viscosity level of the paint is too high
		Why	-
		Where	-
		When	-
		Who	-
		How	Use thinner product that can be suitable for the ambient temperature Keep the distance of spray 15-20 cm from the object Adjusting the viscosity level and air pressure with standardization
Melted Paint Defect		What	There is too much paint on the surface
		Why	Spraying method
		Where	Much of the removal of paint is done up close and in slowly.
		When	This defetct usually found on the topcoat of paint
		Who	When the topcoat of paint start to dry
		How	Spraying is done more than once by paying more attention to equalization
Overspray Painting	Man	What	Lack of concern to the environtment
		Why	Has not yet been trained in safety awareness
		Where	-
		When	-

	Who	New manpower
	How	Ensure the mandatory training for new employees
Method	What	-
	Why	Failure to carry out a risk assessment prior to work
	Where	The painting process is being applied near the completed parts
	When	-
	Who	-
	How	Implementation of paint SOPs
Environt ment	What	Drying process of finished components is incorrect
	Why	There is no specific drying area in place to ensure the quality
	Where	Drying is carried out next to the white paint spray process
	When	The final drying
	Who	-
	How	Provide a dedicated drying area that is exposed to sunlight and the proper air.

Cause-Effect Analysis

Table 6. Cause-Effect Analysis

No	Types of Contributing Factors	Problem Causes	Cause Analysis
1	Method	Manual inspection	No double-checking with tools
		No sampling	Reliance on supporting tools
2	Man	Lack of knowledge	Lack of discipline
		Lack of accuracy	Workers feeling fatigued
3	Material	Wet product used	Paint product adhesion to steel is weak
4	Machine	Test machine unable to detect	Test machine design limitations
		No improvement to the machines used	Machines cannot be halted for modification
5	Environm ent	Improper drying process	No dedicated drying area

According to data calculations by the project engineer, an improper coating process can increase the corrosion rate. A continuously increasing corrosion rate can shorten the expected lifespan of the steel. The cause of the increased corrosion rate is the issues arising in the coating process, resulting in steel that does not meet standards (Table 6).

4. Conclusion

This study concludes that meticulous surface preparation is critical for enhancing paint adhesion and overall coating effectiveness on steel structures. Common defects such as inadequate paint adhesion, orange peel, paint sagging, and overspray were identified as significant contributors to accelerated corrosion. The root cause analysis using Fishbone, 4M+1E, and 5W+1H methods revealed that these issues primarily stem from human factors, particularly untrained new employees, as well as improper methods, suboptimal environmental conditions, and equipment and material deficiencies. Consequently, a high corrosion rate, resulting from a non-standard coating process, significantly affects the structural integrity and lifespan of steel buildings.

To address these issues, it is recommended to implement comprehensive training programs for all employees, emphasizing adherence to Standard Operating Procedures (SOPs) and best practices. Process improvements should include the development of a simple paint mixture stirring machine and the establishment of a designated drying area with an adjustable roof to control environmental conditions during coating. Routine Quality Control (QC) inspections should be conducted at each stage to promptly identify and rectify defects, using visual markers for traceability. Additionally, a dedicated storage area for fully fabricated steel should be created to protect it from environmental factors that could compromise coating quality. Further research should explore the long-term effects of different coating materials and methods under various environmental conditions and investigate advanced technologies to enhance coating durability and performance on steel structures. These steps will contribute to more robust, durable steel buildings, improving safety and cost-efficiency in the long term.

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