



Experimental Study on The Effect of Epoxy Zinc and Thinner Ratio on Platform Structure Coating Quality

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Abstract

Paint serves as a coating material that provides aesthetic value, adhesive strength, and protection to surfaces from environmental corrosion. The one of critical aspect is the paint and thinner ratio, which can influence adhesive strength and the performance of protection. This experimental study investigates the effect of varying ratios of epoxy zinc paint (Avantguard 750) and thinner (08450) on adhesion strength and drying rate. Paint was mixed with thinner at 10%, 20%, 30%, 40%, and 50% of the paint's volume. Steel plates were used as test specimens, coated via spray method. Adhesion quality was assessed using the "X-Cut Test" and "Cross Cut Tape Test" based on ASTM D3359 Methods A and B and the adhesion tests showed excellent results with a rating 5, indicating no peeling. Drying quality was evaluated using the "Solvent Rub" method according to ASTM D4752-20. Dry tests also have positive results with a rating of 5 within 6 to 24 hours. The findings suggest that variations in thinner concentration do not significantly affect adhesion strength or drying time.

Keywords: Mixing ratio, adhesion strength, drying rate

1. INTRODUCTION

Painting is a coating material that serves three main functions: decorating, reinforcing adhesion, and protecting the surface of an object from corrosive environments. The basic components of paint consist of four elements: binder, pigment, solvent/thinner, and additives. Each of these components plays a specific role in protecting the painted material from external environmental factors.

According to Gunadi [1], thinner is a liquid that functions to dilute the mixture of pigment and binder to achieve the proper viscosity for application. Incorrect mixing ratios can lead to coating defects like sagging, rough surfaces, or orange peel texture. A previous study by Nico Johansyah Habibie [2] titled "The Effect of Paint-to-Thinner Mixing Ratio on the Quality of Painting Results" showed that different ratios produced different gloss levels. For example, a 1:1.4 ratio for Nippe 2000 resulted in a gloss level of 9.1 GU, while a 1:1.5 ratio for Danagloss yielded 90.2 GU. This indicates that there is no universal 1:1 mixing ratio and that finding the ideal ratio is essential. Therefore, this experimental study aims to identify the optimal paint-to-thinner ratio for coating steel plates used in offshore platform fabrication, providing both qualitative and quantitative insights.

In the painting process, several factors must be fulfilled to achieve a good-quality finish. These include surface cleanliness of the metal, room temperature, paint quality, the ratio of paint to thinner, mixing process, spray distance, and the condition of the spraying equipment. Based on the author's experience and observations, the ratio of paint to thinner is a crucial factor. In many fabrication companies, especially in the oil and gas sector, painters typically mix paint and thinner according to each company's standard operating procedures. This is supported by paint manufacturers, who often prescribe specific mixing ratios for their products to achieve optimal results. Incorrect ratios can result in paint being too thick or too thin, leading to defects such as improper drying, sagging, lack of gloss, orange peel texture, and poor adhesion. So, the ratio of paint and thinner in the painting process is one of the important factors for the quality of the paint in the painting results.



2. METHODS

2.1. Materials and Equipment

This research utilized ASTM A36 carbon steel plates as test specimens, each measuring 150 mm × 150 mm × 5 mm. The coating materials included Epoxy Zinc Avantguard 750 paint and 08450 thinner, provided by Hempel Coatings. The application was performed using a conventional air spray system with a standard nozzle and compressor setup.

Inspection equipment included:

- Roughness tester
- Wet Film Thickness (WFT) comb
- Dry Film Thickness (DFT) gauge (Elcometer)
- Whirling hygrometer ambient condition monitoring
- Cross-cut cutter and X-cut knife
- Adhesion test tape according to ASTM D3359
- Methyl Ethyl Ketone (MEK) solvent for drying resistance testing.

2.2. Surface Preparation

Before coating, surface preparation was conducted by abrasive blasting to achieve a surface cleanliness grade of Sa 2½, following ISO 8501-1 standards. Surface roughness was measured using a roughness tester, targeting value between 50 µm and 100 µm, to ensure optimal adhesion conditions. Three measurement points were taken on each specimen to determine surface profile uniformity.

2.3. Paint and Thinner Mixing

The Epoxy Zinc paint was mixed with thinner 10-50% due to base on field observations, some painting workers added thinner inconsistently. The mixing ratios applied were:

- Adding 10% thinner from the paint volume
- Adding 20% thinner from the paint volume
- Adding 30% thinner from the paint volume
- Adding 40% thinner from the paint volume
- Adding 50% thinner from the paint volume

Mixing was performed using a mechanical mixer for 3–5 minutes to ensure homogeneity. The mixing process was carried out under controlled room conditions to minimize contamination or premature solvent evaporation.

2.4. Coating Application

The coating was applied using a conventional air spray gun. Application parameters included:

- Nozzle size: 1.5 mm
- Spray distance: 20–30 cm
- Spray angle: perpendicular (90°) to the surface
- Ambient temperature: approximately 30°C
- Relative humidity: below 85%

Each specimen was coated in a single coat to achieve the target Wet Film Thickness (WFT) corresponding to a Dry Film Thickness (DFT) of approximately 70–90 µm.

2.5. Drying Performance Test

Drying performance was evaluated using the Solvent Rub Test in accordance with ASTM D4752 standards.

The test procedure involved:

- Rubbing the coated surface using a cloth saturated with MEK.
- Applying a double rub (back and forth counts as one cycle) in a consistent motion.
- Performing the test at two intervals: 6 hours and 24 hours after coating application.

The coatings were rated based on ASTM D4752 standards from rating 5 to rating 0. Three specimens per mixing ratio were tested to ensure result consistency.



2.6. Adhesion Strength Test

Adhesion was evaluated using two methods:

- Cross-Cut Tape Test (ASTM D3359 Method B): A crosshatch pattern was cut through the coating, and tape was applied and removed to assess coating retention within the squares.
- X-Cut Tape Test (ASTM D3359 Method A): An "X" was cut through the coating, and tape was applied across the cuts to assess adhesion around the incision points.

Observations were made visually and supplemented with photographic documentation with result rating 5 to rating 0 as per reference ASTM D3359.

2.7. Data Analysis

Data collected were analysed using statistical methods.

- Normality of the data was tested using the Shapiro–Wilk test.
- Homogeneity of variances was checked using Levene’s test.
- Differences between groups were analysed using an Independent Samples T-Test and One-Way ANOVA.

A significance level of 5% ($p < 0.05$) was used for all statistical tests to determine if thinner ratio variations significantly influenced DFT, drying performance, or adhesion strength

3. RESULTS AND DISCUSSION

3.1. Surface Preparation Results

The surface preparation through abrasive blasting achieved a cleanliness grade of Sa 2½ based on ISO 8501-1 standards. Surface roughness measurements, as shown in Table 1, ranged from 84 to 97 µm, with an average of 90 µm. This fulfils the target range of 50–100 µm necessary for optimal coating adhesion.

Table 1. Surface Roughness Results

Specimen	Surface Roughness
A1	97 microns
A2	93 microns
A3	88 microns
B1	92 microns
B2	85 microns
B3	90 microns
C1	86 microns
C2	94 microns
C3	87 microns
D1	84 microns
D2	94 microns
D3	92 microns
E1	88 microns
E2	95 microns
E3	93 microns



3.2. Coating Application and Film Thickness

The coating process was performed using a conventional air spray technique with different paint-to- thinner ratios (10%, 20%, 30%, 40%, and 50%). After application, Dry Film Thickness (DFT) measurements, summarized in Table 2, showed values ranging from 70 μm to 90 μm , with an overall average of 84 μm . Specimens with higher thinner content (40%–50%) initially showed slightly lower solvent resistance but achieved acceptable drying levels after 24 hours. This suggests that thinner content can slightly delay early drying but does not affect final curing.



Figure 1. Paint Materials (a) with Thinner 10% (b) with thinner 50%

Table 2. Dry Film Thickness Measurements

Specimen	DFT 1 (μm)	DFT 2 (μm)	DFT 3 (μm)	Average DFT
A1	82	86	84	84
A2	74	84	86	81
A3	90	94	84	89
B1	80	70	68	73
B2	74	76	62	71
B3	82	72	96	83
C1	88	78	88	85
C2	86	82	78	82
C3	96	92	88	92
D1	82	86	84	84
D2	84	74	86	81
D3	94	90	84	89
E1	88	90	94	91
E2	86	82	80	83
E3	87	90	92	90

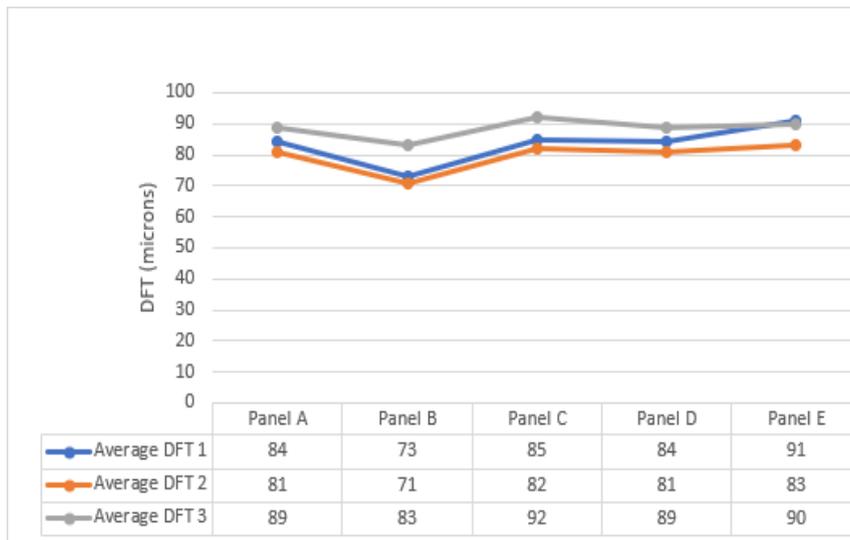


Figure 2. Dry Film Thickness Graphics

3.3. Drying Test Results

Drying performance was evaluated using the Solvent Rub Test method in accordance with ASTM D4752 standards. In this method, the degree of curing and solvent resistance of the coating is assessed by applying a defined number of double rubs using a cloth saturated with methyl ethyl ketone (MEK). The solvent rub ratings provide an indication of the coating's ability to resist chemical attack and physical abrasion at different curing stages. Classification according to ASTM D4752, Rating 4 means the rubbed area looks shiny, there is a little zinc attached to the fabric after testing with 50 rubbing. While rating 5 has the interpretation no effect on the rubbed area, no zinc attached to the fabric after testing with 50 rubbing. The drying levels of the coatings, assessed at 6 hours and 24 hours after application, are presented in Table 3.

Table 3. Drying Results

Specimen	Thinner Ratio	Rating after 6 hours	Rating after 24 hours
A	10%	4	5
B	20%	4	5
C	30%	3	4
D	40%	3	4
E	50%	3	4



Figure 3. Results obtained after testing the dryness levels of all specimens



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3.4. Adhesion Test Results

The adhesion strength of the coatings was evaluated using two standardized methods: the Cross-Cut Tape Test (ASTM D3359 Method B) and the X-Cut Tape Test (ASTM D3359 Method A). These tests assess the mechanical integrity of the coating film when subjected to mechanical stress. In the Cross-Cut Tape Test, a lattice pattern was made by making multiple cuts through the coating layer down to the substrate, followed by application and rapid removal of adhesive tape to check for coating detachment. In the X-Cut Tape Test, two cuts were made in the form of an "X" across the coated surface, and similar tape removal was performed to evaluate adhesion strength around the incision.

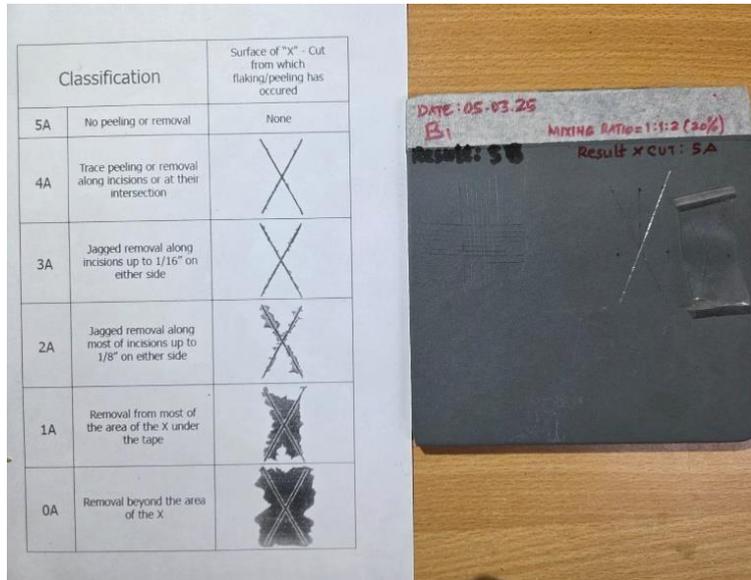


Figure 3. Results of the X-cut tape test: rating 5A

Visual examples of the testing results are shown in Figures 3 and 4. Figure 3 shows the outcome of the X-Cut Tape Test, where a rating of 5A was achieved, indicating excellent adhesion with no visible peeling or detachment along the cut edges. Figure 4 displays the Cross-Cut Tape Test result, which attained a rating of 5B, characterized by smooth cut lines and complete coating retention within the lattice squares.

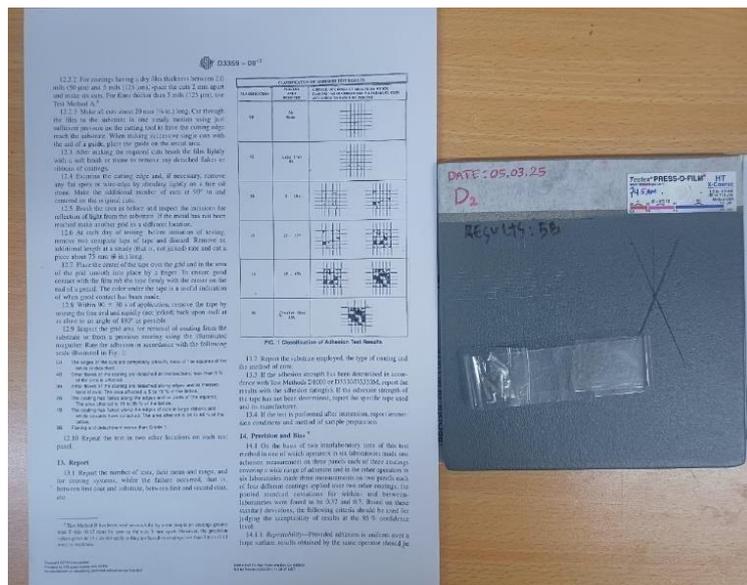


Figure 4. Results of the Cross-cut tape test: rating 5B

The results are also summarized in Table 4. All specimens tested, across different thinner ratios (10%– 50%), consistently achieved the highest ratings in both the Crosscut and X-Cut Tape Tests, indicating excellent adhesion performance. These findings confirm that variations in thinner content within the tested range did not



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negatively impact the coating's ability to adhere to the steel substrate. The consistent high adhesion ratings suggest that the integrity of the coating was maintained, regardless of changes in viscosity caused by different thinner concentrations.

Table 4. Adhesion Test Results

Specimen	Thinner Ratio	Cross-Cut Test Rating	X-Cut Test Rating
A	10% (1:1:1)	5B	5A
B	20% (1:1:2)	5B	5A
C	30% (1:1:3)	5B	5A
D	40% (1:1:4)	5B	5A
E	50% (1:1:5)	5B	5A

The superior adhesion performance can be attributed to two main factors: first, the robust formulation and high-quality resin system of the Epoxy Zinc Avantguard 750 coating, which provides excellent mechanical anchorage and chemical bonding; and second, the thorough surface preparation process, which achieved a Sa 2½ cleanliness grade and optimal surface roughness between 84 µm and 97 µm, facilitating strong mechanical interlocking between the substrate and the coating layer. Together, these factors contributed to a stable and durable coating system capable of resisting delamination and mechanical stress under varied application conditions.

These outcomes also emphasize the importance of achieving correct surface preparation standards in ensuring coating performance, especially when working in critical environments such as offshore structures. Furthermore, the results validate the reliability of the coating formulation in maintaining its mechanical properties even when minor deviations in application parameters, such as solvent addition, occur.

3.5. Statistical Analysis

To further substantiate the experimental observations, statistical analyses were conducted on the collected data. The purpose of these analyses was to determine whether differences observed among specimens with varying thinner ratios were statistically significant.

First, a normality test was conducted using the Shapiro–Wilk method. The results, shown in Table 5, indicated that the Dry Film Thickness (DFT) data were normally distributed ($p > 0.05$), whereas the panel rating data (related to drying performance) slightly deviated from normality assumptions ($p < 0.05$).

Table 5. Normality Test Result

Variable	p-value	Conclusion
Dry Film Thickness (DFT)	0.762	Normally Distributed
Panel Rating (Drying Test)	0.043	Not Normally Distributed

Next, homogeneity of variance was assessed using Levene's Test. As summarized in Table 6, the test confirmed that the variances for both DFT and drying panel ratings were homogeneous across different thinner ratio groups ($p > 0.05$). This condition satisfies one of the critical assumptions for conducting parametric tests such as ANOVA. Subsequently, an Independent Samples T-Test was performed to evaluate potential differences between extreme thinner ratios (i.e., 10% versus 50%). The results, detailed in Table 7, showed no statistically significant difference ($p > 0.05$) between these groups for both DFT and drying performance, suggesting that thinner variation within the tested range did not critically influence these properties.

Finally, a one-way ANOVA test was conducted to analyze the overall effect of thinner ratio variation across all groups. As presented in Table 8, the p-values obtained for both DFT and drying panel ratings exceeded 0.05, confirming the absence of statistically significant differences among the five thinner ratio groups.

Table 6. Homogeneity Test Result

Variable	p-value	Conclusion
Dry Film Thickness (DFT)	0.598	Homogeneous
Panel Rating (Drying Test)	0.071	Homogeneous



Table 7. Independent Sample T-Test Result

Comparison	p- value	Conclusion
DFT (10% vs 50% thinner ratio)	0.214	No Significant Difference
Drying Rating (10% vs 50%)	0.176	No Significant Difference

Table 8. Anova Test Result

Variable	F-value	p-value
Dry Film Thickness (DFT)	1.287	0.305
Drying Rating	2.015	0.117

These statistical findings collectively reinforce the conclusion that thinner content variations between 10% and 50% do not significantly affect the dry film thickness, drying performance, or adhesion strength of the epoxy zinc coatings. This validates the experimental observations and supports the assertion that the coating system maintains its performance characteristics across a range of mixing ratios, offering greater flexibility in practical industrial applications.

4. CONCLUSION

Based on the experimental study conducted on the influence of paint-to-thinner mixing ratios on coating quality, the following conclusions are drawn:

1. Variations in the thinner content from 10% to 50% did not significantly affect the adhesion strength of the epoxy zinc coating applied to steel plates. All specimens consistently achieved an excellent adhesion rating of 5 according to ASTM D3359 standards
2. Drying performance showed slight initial differences at 6 hours, with higher thinner content leading to marginally lower solvent resistance. However, by 24 hours, all specimens reached acceptable drying levels, indicating that thinner content does not affect the final curing state

From the test results in this study, the addition of thinner of 10%, 20%, 30%, 40% and 50% of the paint volume still meets the requirements for painting Epoxy Zinc paint.

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