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Effect of Retaining Preconsruction Primer (PCP) on the Quality of High Performance Protective Coatings Systems

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In construction of new ships and large steel bridges in Korea, pre-construction primers (PCP), also known as shop primer, are routinely used and retained as an integral part of the protective coating system. Retention of PCP's can significantly reduce building schedule and cost. Retaining PCP through the so-called "sweep blasting" procedure eliminates or minimizes the necessity of a second blast operation, thus shortening overall schedule as well as reducing labor cost and hazardous waste disposal cost.

This study evaluates the feasibility of retaining PCP as the part of primer for high performance protective coating systems applied to ships' hull, bottom and ballast tanks. Upon proving that the retention of the PCP is a viable option, the process of coating application can be improved significantly in terms of cost and working schedule of new ships and large steel bridges.

Results indicate that use of the PCP via sweeping blasting in conjunction with standard high performance protective coating systems does not degrade the overall performance of the coating systems. At the same time, it is also highly recommended that the secondary surface preparation should consist of grit blasting of weld burnt and other damaged areas to SSPC SP-10 grade (Sa 2.5 Gr.), Near White Blast Cleaning with proper application and attention to detail.

Keywords : *pre-construction primer, shop primer, blasting, protective coating, Sa 2.5 Gr.*

1. Introduction

In many shipyards, pre-construction primer (PCP), sometimes referred to as prefabrication or shop primer, is routinely applied to stock steel plates and shapes using automatic blast cleaning and primer application equipment. This procedure is cost effective and compliments the shipyard manufacturing technology. High-performance epoxy coating systems are generally known to protect seawater ballast tanks for at least 10 years with 2% coating area failure in five years and 5~10% failure in 10 years before the coatings are completely replaced.[1] While some epoxy primers offered good recoatability for epoxy tank linings, there have been some cases where catastrophic tank lining failures have resulted from applying epoxy tank linings over primers based on alkyd or epoxy ester formulations. Now famous the 1985 survey by the National Shipbuilding Research Program (NSRP) of United States found that it was inconclusive in terms of the compatibility of inorganic zinc primers top-coated with epoxy coatings in immersion service.[2] During last two decades, however, applying epoxy for immersion grade coatings over these standard inorganic zinc primers achieved mixed results. Some had good performance whereas others failed prematurely.

While the U. S. yards were switching from prefabrication primering to block priming, Korean yards used and continued to prefect PCP application techniques. As the result, here in Korea, standard zinc load inorganic zinc PCP is successfully used to reduce the amount of primers failure during the fabrication stages of a new shipbuilding.[3] The PCP primers are proprietary organic coating, and many of the tank coating systems can be applied over the PCP after using the so-called "sweep blasting" rather than more through "full blasting". The sweeping blasting method is to blast the burned and mechanically damaged areas to the near white metal finish grade (SSPC SP-10 Gr., or Sa 2.5 Gr.), whereas a simple pass-through blasting is used for other areas where PCP is intact. In other words, once the PCP was applied, it was not removed except in those cases where the owner was willing to pay a premium in cost and schedule.

These days, it has become a common practice to employ automatic PCP application in the commercial shipbuilding market. These primers (zinc silicate type) are welded through without detrimental effect, which increase the attractiveness of this approach. There still has been, however, argument the legitimacy of this practice between the fabricator and ship owner, and in many cases full blasting on the PCP treated block assemblies was requested by the ship owner. It is critical to evaluate the quality of the coating system applied on the sweep blasted blocks, comparing with the one applied on the full blasted blocks to utilize this approach. In this study, therefore, we compared both coating system's quality to provide the basic technical data to be used in deciding blasting method of the second surface treatment of PCP coated blocks.

2. Previous study on PCP applied surface

The main function of surface blasting for the steel surface is to provide proper surface roughness, or anchor pattern, which is critical in achieving physical adhesion between steel substrate and organic coating materials. Empirically acceptable surface roughness for organic coating is 40~75 μm, whereas surface roughness higher than 100 μm is known to be the cause of excessive use of coating materials to fill all the bottom section of the deep pitches formed by blasting, since the organic coating film thickness is measured from the top part of the substrate. Experimental results also suggested that surface roughness of 40~75 μm is fairly enough to provide proper coating quality.[4]

Secondary surface treatment of steel surface for coating application is defined as all types of surface treatments after PCP coating has been initially applied. Grit blasting, grinding using either wire brush or power tools (sanding disc, rotary disk) are typical second surface treatment procedures. In Europe, heavily damaged PCP coated steel surfaces, such as burnt area, mechanically damaged area and weld burn area, are grit blasted to the SSPC SP10 (or Sa 2.5 Gr.) before applying top coats. On the other hand, partially contaminated areas, such as zinc salt, marking area, were sweep blasted, which is known to cover 50~70% of the total PCP coated surface. Other study reported that except for the areas to be under cathodic protection, it is beneficial to retain the intact PCP coating to utilize the extra protection provided by the PCP coating. In this case, it is recommended to use power tool grinding or fresh water washing of the PCP coated surface rather than applying sweep or full blasting as the secondary surface treatment.[5]

Recommendation from coating makers regarding secondary surface treatment of PCP coated blocks to be top-coated with epoxy coatings for immersion service is summarized in Table 1. It is noticeable that the intact (or non-contaminated) PCP coated area is not subjected to additional surface cleaning before applying top-coat. Less contaminated area, such as zinc salt developed area, is also needed sweep blasting only. Compatibility of PCP with several top-coat systems is covered in ISO 12944-4 specification, "Corrosion protection of steel structure by protective paint system - Part 4,[6] as summarized in Table 2.

Table 1. Recommended 2nd surface treatment of PCP applied blocks

Area / Maker	Welded, Burnt Damaged, Rusted Area	Zinc Salt, Other Contamination	Minor Area (Rectification)	Intact PCP
K	Sa 2.5 Gr.	Sweep Blasting	St 3 Gr.	No Treatment
J	Sa 2.5 Gr.	Sweep Blasting	St 3 Gr.	No Treatment
C	Sa 2.5 Gr.	Sweep Blasting	St 3 Gr.	No Treatment
I	Sa 2.5 Gr.	Sweep Blasting	Power Tooling	No Treatment

Table 2. Compatibility of PCP with several top-coat systems [6]

PCP Type		Top Coat System							
Binder Type	Anti-Corrosion Pigment	Alkyd	Chlorinated Rubber	Vinyl/ Vinyl Chloride	Acryl	Epoxy *	Polyurethane	Zinc Silicate	Bitu.
Alkyd	Miscellaneous	+	(+)	(+)	(+)	−	−	−	+
Polyvinyl Butyral	Miscellaneous	+	+	+	+	(+)	−	−	+
Epoxy	Miscellaneous	(+)	+	+	+	+	(+)	−	+
Epoxy	Zinc Dust	−	+	+	+	+	(+)	−	+
Silicate	Zinc Dust	−	+	+	+	+	+	+	+

+ = Compatible, (+) = Check compatibility with the paint manufacture, − = Not compatible
* Including epoxy combination (e.g., coal tar epoxy)

As shown in the Table 2, the inorganic zinc silicate type PCP, currently most widely used, retains excellent compatibility of top coat except the alkyd type paint. All these results clearly indicated that secondary surface treatment of the intact PCP applied steel surface is not necessary in application of top coat. By eliminating the full blasting of these areas, significant amount of total cost can be saved in new shipbuilding, while overall working schedule will be also reduced.

Another advantage for retention of the intact PCP coated area is to avoid unnecessary reblasting of blocks in the summer season. For new shipbuilding, it is required to inspect the cleaned steel surface before application of top coat. In the humid summer season, a flash rusting of the blasted steel surface is common problem upon delay of inspection due to scheduling conflict of the fabricator and the on-site inspector. In this case, reblasting of the rusted surface is inevitable, which causes sharp increase of labor as well as delay of fabrication schedule at the same time. Retention of intact PCP coatings during the inspection period, occurrence of flash rust can be reduced dramatically.

3. Experimentals

To evaluate the dependence of top-coating systems quality on the retention of PCP coating, two mock-up blocks were fabricated following the same procedures for new shipbuilding. Once PCP coated mock-up blocks were prepared, these blocks were left under outdoor condition for one month without additional works to simulate the actual fabrication practice. After one month of outdoor exposure, one block was sweep blasted and the other was full blasted to the Sa 2.5 grade, followed by top coat application on both blocks. In Table 3, surface condition and other information of the two, testing blocks, which is labeled as "sweep blasted" block and as "full blasted" block, were summarized, of which actual shape is shown in Fig. 1.

Table 3. Preparation of mock-up blocks

2ndary Surface Cleaning	Coating Spec.	Remarks
Set #1: Full blasting (Sa 2.5 Gr.) Set #2 : Sweep blasting	Modified Epoxy (D.F.T. = 150μm x 2)	Mixture of double & single structure

Table 4. Testing schedule for mock-up blocks

Stage	I	II	III	IV	V
Work	PCP Coating	Block Fabrication	Outdoor Exposure	Blasting & Top Coating	Evaluation
Action	D.F.T. : 12~20 μm (Dry Film Thickness)	Cutting Welding Grinding Fairing	D.F.T. Salt conc. Roughness PCP condition	D.F.T. Salt conc. Roughness PCP condition	Physical Properties

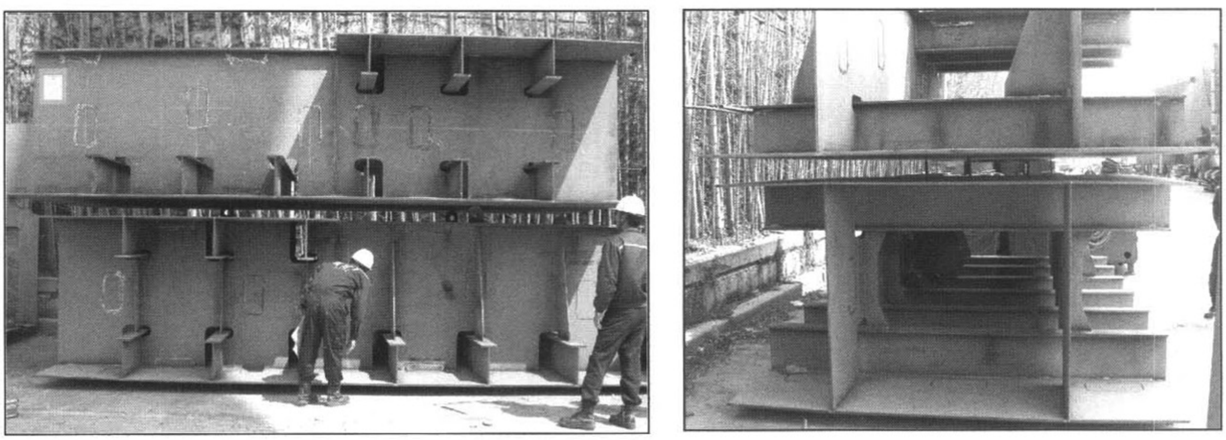


Fig. 1. Mock-up blocks

In Table 4, working schedule for these blocks is divided into five successive stages, in which each stage is selected based on normal yard practice for new shipbuilding. During this period, surface condition and degree of contamination and/or degradation of the PCP coating on the blocks were monitored. Both flat section and edge section, such as corners, cut edges, hole edge were examined and recorded. During each monitoring, surface roughness of each block surface (PCP coated or removed) was measured following ISO 8503-4 specification ("surface profile of abrasive blast-cleaned surface") with a digital gauge (DIAVITE™ DH-5 model). Evaluation of the quality of top coats applied on the either sweep blasted or full blasted block surface was carried out with pull-off adhesion test following ASTM D4541 specification using a commercial tester (ELCOMETER™ 110-PATTI model).

4. Results and discussions

4.1 Block surface condition after stage II

After mock up blocks were made of PCP coated steel plate, surface condition was examined. Typical surface contaminations generated from fabrication procedure are weld fumes, weld discoloring in front and back side due to weld heat, weld bead and spatter, grinding mark, oil spot. Fig. 2 shows these contaminations on the PCP coated block surface.

It is common practice to remove these contaminations thoroughly during secondary surface cleaning (Stage IV, in the Table 4) using grit blasting before application of top coat. During the Stage II, some of the areas where PCP was completely removed due to specific fabrication works, such as welds, were touch-up coated with water soluble PCP for temporary corrosion protection until the block reached to the Stage IV. Surface roughness profile of the blocks after the Stage II was measured, and the

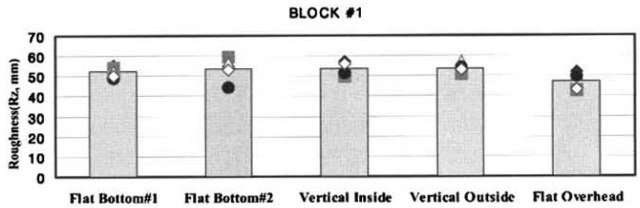


Fig. 3. Surface roughness distribution of the PCP coated blocks right after fabrication

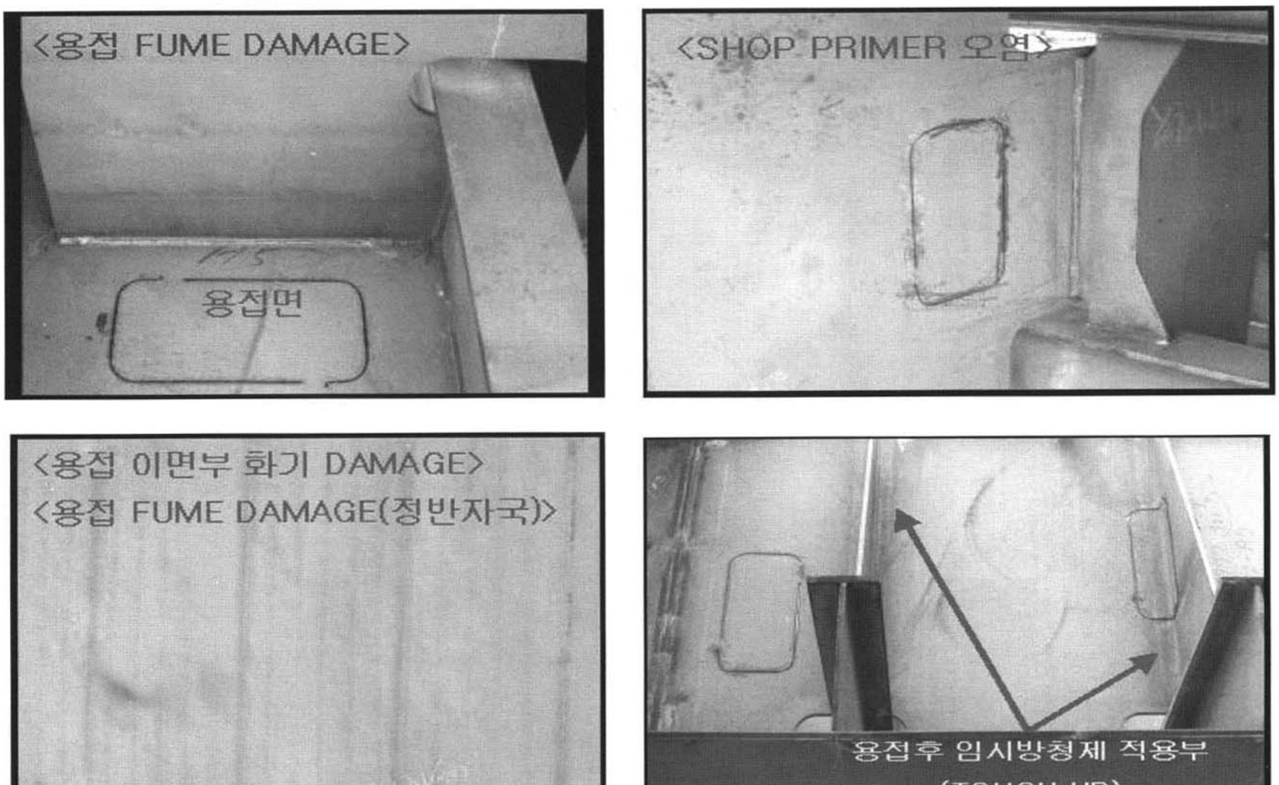


Fig. 2. Typical surface contaminations on the PCP coated blocks right after fabrication

values for #1 block were 42.5 ㎛ ~ 59.7 ㎛ (avg. of 52.1 ㎛), and were 35.8 ㎛ ~ 62.4 ㎛ (avg. of 50.6 ㎛) for #2 block. In Fig. 3, surface roughness measurement results on the #1 block are summarized.

4.2 Block surface condition after stage III

Fabricated blocks were stored outdoor without any additional protection for a month. After one month, surface conditions of the blocks were as follow :

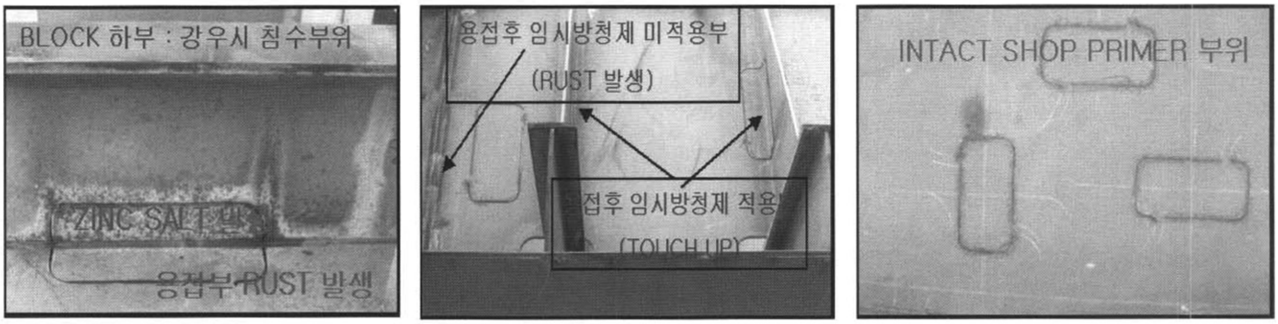
- zinc salts were developed in the precipitation immersion section (bottom area) (Fig. 4a)
- rusts were found in welds and grinding work areas without touch-up coatings (Fig. 4b)
- no rust was found in the burnt damage area (due to back plate welding or torch flame fairing)
- no rust was found in the intact PCP area (Fig. 4c)

4.3 Block surface condition after stage IV

4.3.1 Block #1 (full blasting condition)

This block was grit blasted in a full blasting condition, and the surface conditions of the blocks right after blasting were as follow (Fig. 5) :

- more than 90% of PCP coating was removed
- zinc salt, rust spots, and other contaminations were completely removed
- weld were maintained in the Sa 2.5 Gr. condition (near



(a) (b) (c)

Fig. 4. Typical surface contaminations on the PCP coated blocks after outdoor exposure

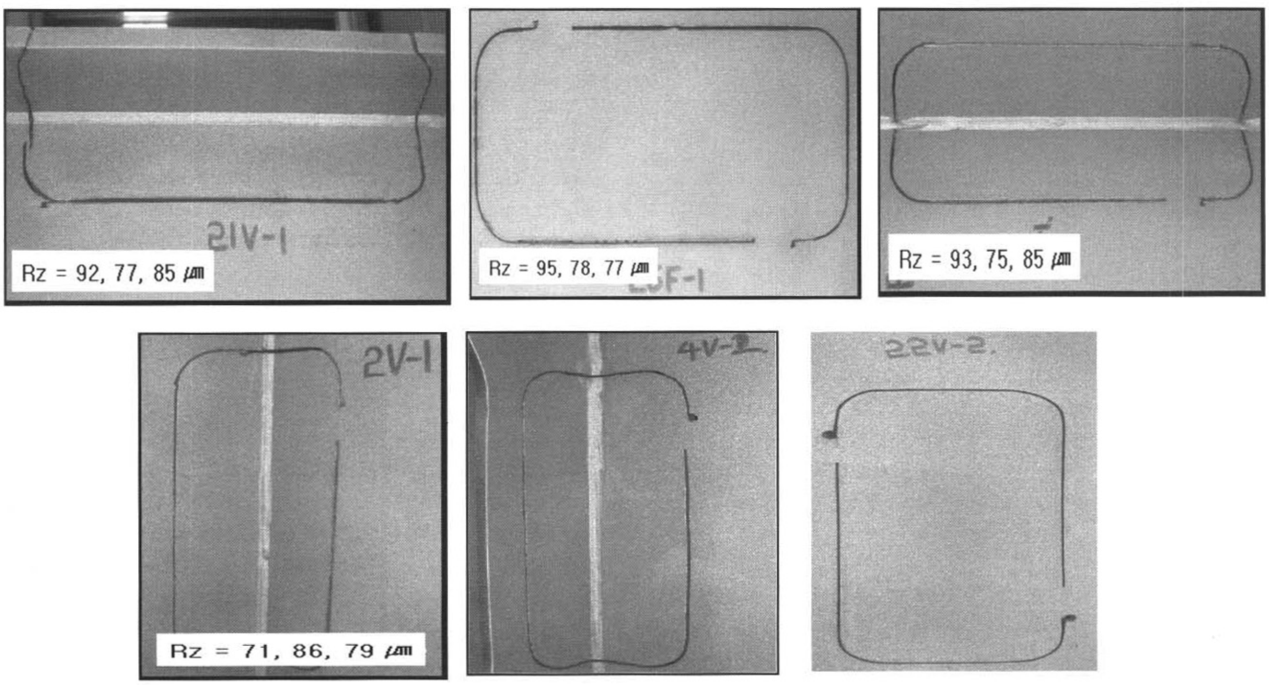


Fig. 5. Typical surface condition of the PCP coated blocks right after full blasting

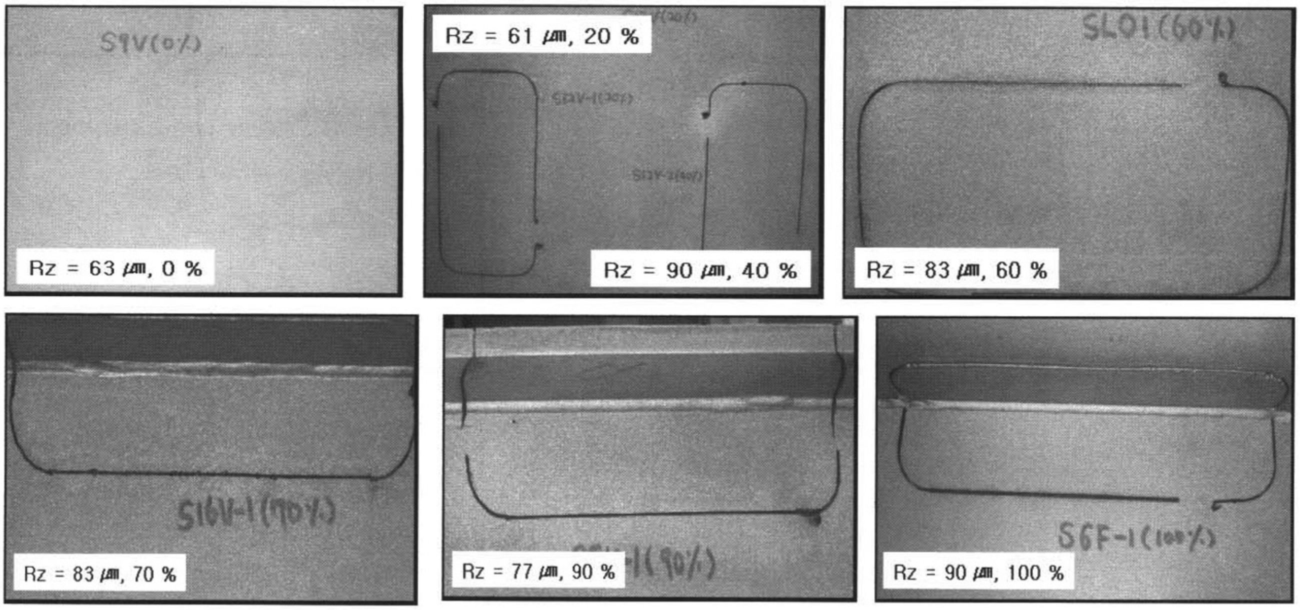


Fig. 6. Typical surface condition of the PCP coated blocks right after sweep blasting

white metal finish)
- PCP on the weld's back side was completely removed

Surface roughness profile of the block after full blasting was measured, and the values for the block were 60 μm ~ 120 μm (avg. of 83.1 μm).

4.3.2 Block #2 (sweep blasting condition)

This block was grit blasted in a sweep blasting condition, and the surface conditions of the blocks right after blasting were as follow (Fig. 6) ;
- Intact PCP coatings were retained
- zinc salt, rust spots, and other contaminations were completely removed
- weld were maintained in the Sa 2.5 Gr. Condition (near white metal finish)
- PCP on the weld's back side was completely removed

Surface roughness profile of the block after sweep blasting was measured, which were 40 μm ~ 120 μm (avg. of 75.2 μm). The amount of PCP removed from the sweeping blasting procedure was evaluated in the range of 0% ~100%, which is shown in Fig. 7. It shows that 10~20% of PCP removal was achieved around 40% of the total surface area of the sweep blasted block, whereas intact PCP was retained around 10% of the whole surface during the sweeping blasting.

4.4 Surface roughness variation along each stage

In the surface roughness measurements of the PCP coated blocks at each Stage, it is noticeable that there is minor variation on the surface roughness of the blocks along each stage. Right after PCP coating, the roughness

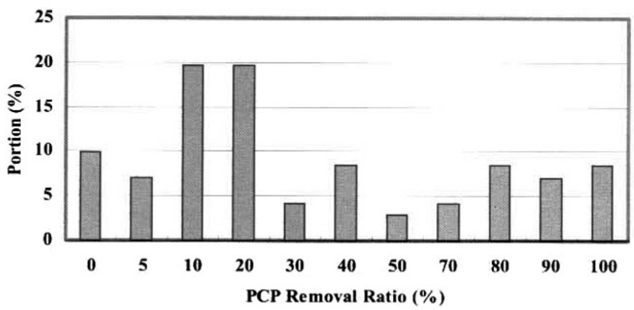


Fig. 7. The amount of PCP removed from the sweep blasting

was about 51 μm, which changed to either 84 μm for full blasting or 75 μm for sweep blasting. According to Marine painting manual, requirement of average surface roughness for protective coating should be in 50 ~ 75 μm range, with maximum allowable value of ~ 100 μm,[4] which indicated that the current condition of full blasting and sweep blasting is quite satisfactory.

4.5 Top coating thickness after stage IV

After secondary cleaning, the two blocks were coated with high solid epoxy coating using an airless spraying method. Two successive coatings were applied, and each coating's target Dry Film Thickness (D.F.T.) was 150 μm. In Fig. 8 shows the block condition after completion of spraying application. D.F.T. measurements made on the two blocks showed 398 μm (block #1, full blasted) and 414 μm (#2 block, sweep blasted) of full coating thickness, which satisfy ISO 12944-5 specification.[7] According to the specification, D.F.T. of the coating should be in the

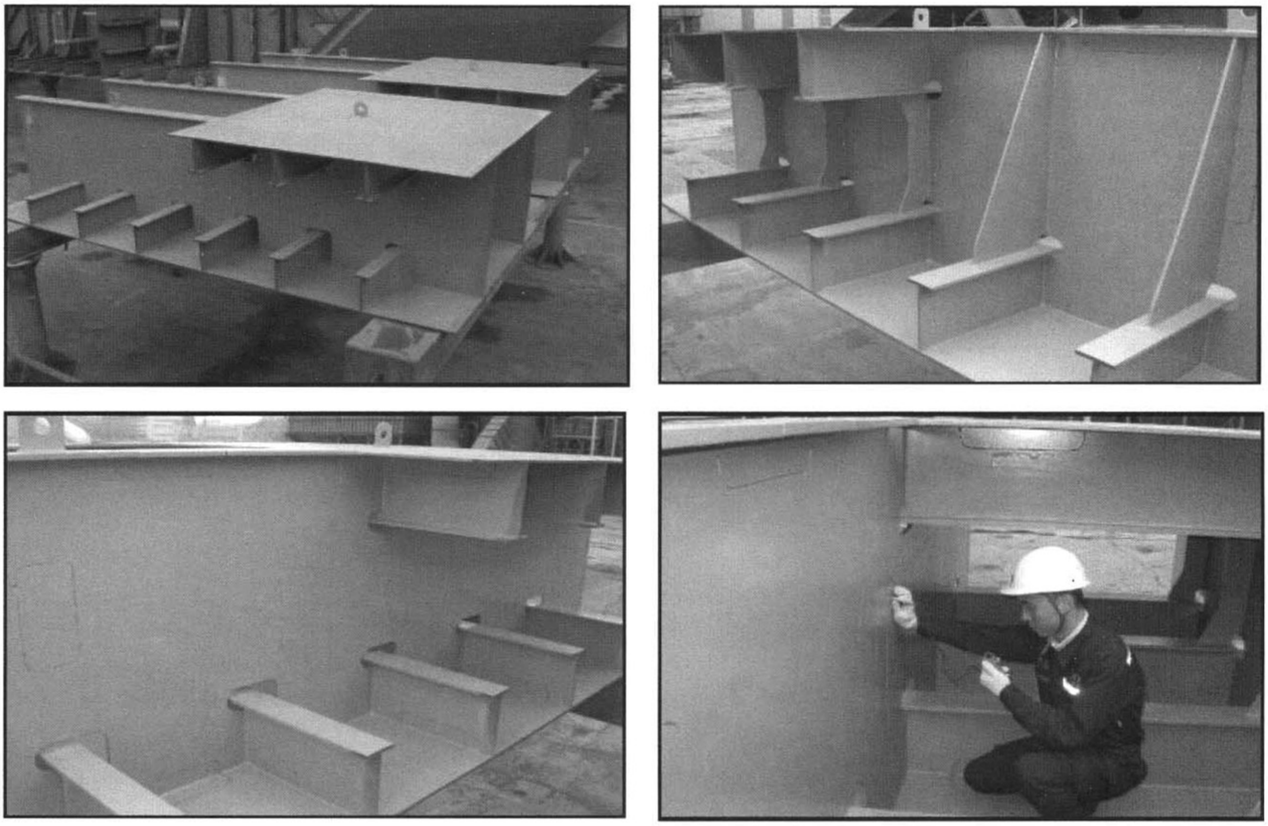


Fig. 8. Blocks after final coating

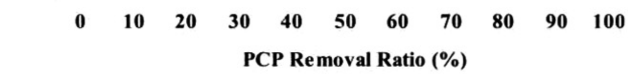


Fig. 9. Coating's adhesion strength with variation of PCP removal ratio

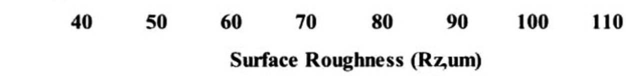


Fig. 10. Coating's adhesion strength with variation of surface roughness

range of 80% ~ 300% of the target value.

4.6 Evaluation of coating's adhesion strength

Effectiveness of coating applied on the two blocks was evaluated by measuring the pull-off adhesion strength of the coat to the steel substrate following NORSOK standard, in which minimum strength of 5MPa is required according to ISO 4624 specification.[8] For this purpose, several locations were selected based on the previous evaluation on PCP removal ratio and subsequent surface roughness. Measurement results on the selected areas showed that the adhesion strengths of the final coatings were over 11MPa, satisfying the NORSOK requirement regardless of PCP removal ratio and subsequent surface roughness. The coating's adhesion strengths are summarized in Fig. 9 and Fig. 10 for PCP removal ratio and surface roughness, respectively. These results suggest that retention of intact PCP via sweep blasting does not degrade the final coating's quality.

5. Conclusions

Evaluation of the feasibility of retaining PCP as the part of primer for high performance protective coatings systems revealed that use of the PCP via sweeping blasting in conjunction with standard high performance protective coating systems did not degrade the overall performance of the coating systems. Measurement results of the final coatings' adhesion strength on the selected areas showed that the adhesion strengths of the final coatings satisfied relevant requirement regardless of PCP removal ratio and subsequent surface roughness. Based on these results, retention of the PCP is a viable option to improve the process of coating application significantly both in terms of cost and working schedule of new ships and large steel bridges.

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