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A Weldable Precoated Stainless Steel "WELCOLOR"

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The body can be viewed from the next page.

A Weldable Precoated Stainless Steel "WELCOLOR"*

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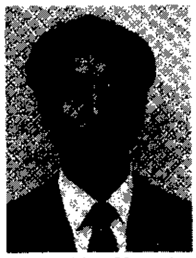

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A weldable pre-coated stainless steel sheet, ***WELCOLOR,*** *has been developed to make it possible to use water proof techniques in electric resistance welding. The paint to obtain electric conductivity between the electrode of the welding machine and the steel sheet and the method of top coating have been studied on the technological basis of RIVERLITE COLOR®, a high grade prepainted stainless steel sheet, which have been in production for roof and exterior usage.*

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This report outlines the performance characteristics of WELCOLOR.

1 Introduction

WELCOLOR (registered tradename), the precoated stainless steel strip weldable by resistance welding developed by Kawasaki Steel, is outlined. Precoated stainless steel sheets, coated with organic paints on corrosion resistant surfaces of stainless strip, were approved April 1981 as G 3320 in Japan Industrial Standard (JIS) and have mainly been applied to roofs and exteria of structures. The advantages of applying precoated stainless steel strip to roof materials are the prevention of roof from "trickled rust" due to iron dust contamination, the improvement of corrosion resistance to marine breeze and low concentrate corrosive gases, and the higher design possibilities for roofs by choosing preferable color and its tone.

The basic functions of roof are to be proof against water and wind. Therefore, coupled with its durability, the roof material should have better construction performance to make it possible for roof to be proof against water and wind.

As for jointing methods in roof construction with metallic materials, mechanical joints like folding bend joint and bolting have been mainly used.[1] Since stainless steels show more spring-back due to its larger work-hardening than precoated galvanized steel, final shape of joints and their folding tightness are more apt to get loose than the galvanized steel. Loose joints cause penetration of water into the crevices, and freezing of the water in winter increases the looseness, thus causing water leakage.

A higher durability of the precoated surfaces of stainless steel makes it less necessary to recoat even after application for several years. It is, however, necessary to prevent the joints from water-leakage in order to use the roof for a long period.

Welding will provide joints as good and reliable as in

* Originally published in *Kawasaki Steel Giho*, 17(1985)3, pp. 258–264

the mechanical joints. It is thought that seam weld is superior to other welds in the welding operation on the roof and in the reliability of joints of thinner gage material. In order to apply resistance welding to precoated stainless steel, it is required to coat the paints having electrically conductive particles on the surface of the strip so as to make it possible to conduct electric current through the particles, or to prepare the precoated strip having the portion left uncoated and scheduled to be weld. In the later case, uncoated part is coated with fast-dry paint after welding[2].

In this report, weldability and durability of WELCOLOR, classified into the former category, are outlined.

2 Structure of the Film Coated on WELCOLOR

Several ways for using the conductive particles in coating film so as to permit resistance welding over the coating are as follows:

(1) Powder of single kind of metal or alloy,[3~5]

(2) Powder of single kind of metal or alloy and carbon powder,[6]

(3) Powders of metals or alloys in two kinds either soft or hard.[7]

(4) Carbides of metals or alloys together with powder of two or more kinds of metals.[8]

In these cases, optimum relation between the size and the amount of the particles and thickness of coated film is essential for making the precoated material weldable.

WELCOLOR has two types: **WELCOLOR-P** and **WELCOLOR-Z**. Their schematic illustrations are shown in **Fig. 1**.

WELCOLOR-P is a precoated stainless steel strip coated with epoxy resin paint containing electrically conductive particles (Fe_3P) as primary paint, and the way for using the conductive particles belongs to (1) described above. Though WELCOLOR-P is top-coated over the whole surface of the strip after welding, it is free from the restriction to welding no matter where the welding portion may be and has variable choices of color and its tone of top coat.

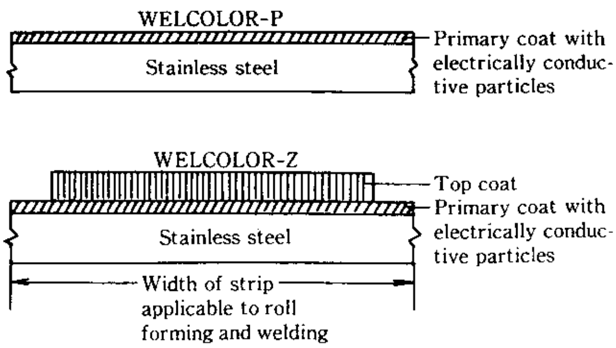


Fig. 1 Schematic illustration of WELCOLOR strip in the transverse section

Table 1 Effect of top coat on the spot weldability of two-coat-two-bake precoated stainless steel*) with film containing iron phosphide particles

Top coat variables			Welding variables		Spot weldability**)
Dry film thickness (μm)	Size of particle (μm)	Amount of particle (%)	Electrode force (kgf)	Welding current (kA) × (cycle)	
15	3	25	160	8 × 19	×
			350	8 × 24	△~○
15	5	25	160	8 × 19	×
			350	8 × 24	△~○
15	3	12.5	250	8 × 19	×
	5	12.5	350	8 × 24	×~○

* Primary coat: 5 μm thick dry film contains 20% iron phosphide particles of 3 μm mean dia.

** Spot weldability: Good ○ > △ > × poor

WELCOLOR-Z is produced by top-coating of a primary coated WELCOLOR-P, leaving only the area about 25 mm width from the edge of strip, thereby minimizing the area to be top-coated after welding and improving the finish color tone. In seam-welding of WELCOLOR-Z across its width, welding started from top-coated area needs a larger electrode force and brings about sparking; on the contrary, welding started from primarily coated area gives the same weld performance as WELCOLOR-P.

Table 1 shows the results of experiment on spot weldability of stainless steel strip with the two-coat-two-bake-precoated films containing electrically conductive particles. Smaller ratio of diameter of the particles to the thickness of the film coated tends to result in unstable welding because of sparking and hole-making, though with some occasional making of good nuggets. In the method of dispersing the conductive particles with smaller diameter to both primary and top coat films, it is necessary, from the point of weldability, for thickness of coat films to be thinner. However, this is not preferable from the point of the resistance to weathering of films coated. In order to improve the resistance to weathering of top coat, a thicker coat and larger conductive particles are required in proportion to film thickness. To produce the film satisfying this requirement, it is essential to use a special coating method successful in bringing the larger particles into film to be coated on the strip as top coat[4].

This explains why in WELCOLOR, conductive particles are dispersed not on the top coat but only on the

Table 2 Mechanical properties of WELCOLOR (thickness, 0.5 mm)

0.2% *PS* (kgf/mm²)	*TS* (kgf/mm²)	*El* (%)	HV (5kgf)
24～28	59～67	55～60	154～165

primary coat where stable weldability is intended (WELCOLOR-P), with edges about 25 mm wide having high welding chances left free from primary and top coats in the two-coat-two-bake type (WELCOLOR-Z). As a result of this type of coating, WELCOLOR-Z has no trace of particles mounting up to top coat and makes it easy to improve color tone in addition to reduce the effect on the surfaces of rolls forming the WELCOLOR-Z into roof parts. The coating of WELCOLOR, including primary coat and top coats, is carried out with the method of reverse roll coating.

Stainless steel strip having highly ductile and corrosion resistant weld zone, such as SUS 304 and RIVER LITE 430LT (extra low C, N, Ti stabilized 17%Cr steel) is mainly used as the base material of WELCOLOR. Top film on WELCOLOR-Z is precoated by silicone polyester resin paint and with applicator roll having grooves. The paints made of fluorine resins are also applicable to top coat. The base materials of WELCOLOR are softened through special annealing. Mechanical properties of SUS 304 strip applied to the base material are shown in **Table 2**.

3.1 Performance Characteristics of Dry Film on WELCOLOR

Since WELCOLOR-P is exposed outdoor with primarily coated surface until being top-coated after welding, the primary film precoated on WELCOLOR-P is required to be resistant to corrosion and weathering as well as to be easily formable and weldable.

Table 3 Performance characteristics of dry film on WELCOLOR-P

Test item	Test results
Dry film thickness (μm)	5
60 gloss (%)	1
Pencil hardness	3 H
Xylene rabbing (turn)	16
Cross scoring test (JIS G 3320, 8.1.1)	100/100
Cross scored Erichsen test (6 mm height)	100/100
Impact test (JIS G 3320, 8.1.2)	No damage
Flexibility (min. bend radius)	2 *t*
Hot water resistance (90°C up × 4 h)	No damage
Salt spray resistance (5% NaCl, 35°C × 3 500 h)	No rust, no blister

Table 4 Performance characteristics of dry film on WELCOLOR-P tested for 300 h with Weather-Meter

Test item \ Condition		Prior to weathering	After 300 h weathering
Cross scored Erichsen test (6 mm height)		100/100	100/100
Impact test (JIS G 3320, 8.1.2)		No damage	No damage
Flexibility	0 *t*	4	3.5
	1 *t*	5	4
	2 *t*	5	5
External appearance		—	No change

Table 3 shows the results of tests on the performance of the dry film, with 5 μm thickness, primarily coated and baked on WELCOLOR-P. Its base material was 0.3 mm thick, dull finished SUS 304 strip and its paint was composed of modified epoxy resin, small amount of TiO_2, some kinds of pigments and 30% by weight of iron phosphide with 3 μm mean-diameter.

The dry film on the WELCOLOR-P showed excellent adhesiveness to the base metal and corrosion resistance to salt fog for a long term. Results of weathering test with Weather Meter are summarized in **Table 4**. Film of epoxy resin paint is easy, in general, to suffer from chalking due to its poor resistance to weathering, on the contrary, film of the epoxy resin paint on WELCOLOR-P showed retarded degradation. This slow degradation might be based on the restricted penetration of ultra-violet beam into the film by dispersed conductive particles in the film.

3.2 Performance Characteristics of Post Coated Film on WELCOLOR-P

WELCOLOR-P was post-coated with three types of paints made of modified polyurethane (non-yellow changeable) resin, medium-oil type futallic resin, and long-oil type futallic resin. After aging for 20 days, tests on their dry films with 30 μm thickness of these paints were carried out, and it was proved that the film of modified polyurethane resin paint had best performance. **Table 5** compares the performance characteristics of polyurethane resin paint film as top coat (color: brown) by post-coating between on the WELCOLOR-P and on non-precoated stainless steel strip. It is known from Table 5 that the film of polyurethane resin paint

Table 5 Performance characteristics of post coat film* on WELCOLOR-P

Test item \ Base material		SUS 304 without primary coat	WELCOLOR-P
Dry film thickness (μm)	primer	—	5
	top	30	30
60 gloss (%)		54	50
Cross scoring test (JIS G 3320, 8.1.1)		70/100	100/100
Cross scored Erichsen test (6 mm height)		0/100	100/100
Impact test (JIS G 3320, 8.1.2)		Peeled	No damage
Flexibility (min. bend radius)		$6t\sim10t$	$2t$
Salt spray resistance (5% NaCl, 35°C x 3 500 h)		Large blister (Initiated at 1 500 h)	No blister

* Polyurethane resin paint

post-coated as top coat on WELCOLOR-P has more excellent properties that on non-precoated stainless steel strip with dull finish. In case of post-weld coating over non-precoated stainless steel strip, it is necessary to top coat over dry-type primary coat.

As for the WELCOLOR-P having the film damaged partially during roll-forming, welding, or other constructive operations, it is also recommended to recoat the primary coat over the surface having been suffered from damage. In this case, specially modified epoxy resin paint should be so sprayed or brushed as to be about 40 μm thick in dry condition.

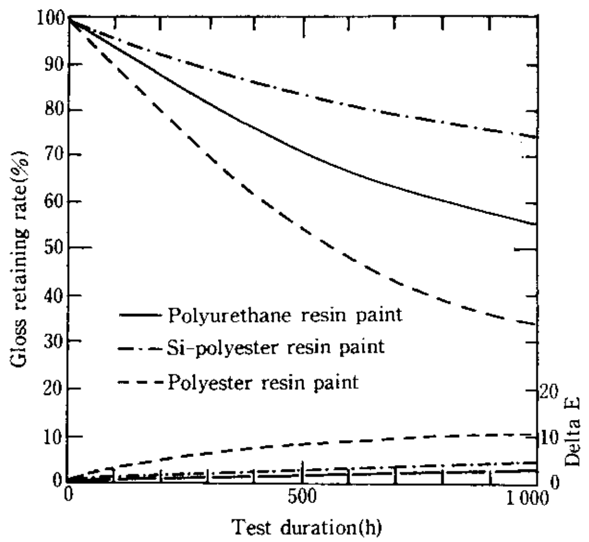


Fig. 2 Results of Sunshine Weather Meter test on post coated film on WELCOLOR-P (Color; brown)

The changes in color tone and gloss retaining rate examined with Sunshine Weather Meter on modified polyurethane resin paint (color: brown) are shown in **Fig. 2**. The gloss retaining rate of post coated film of polyurethane resin paint is inferior to that of precoated film of silicone polyester resin paint; however, the former is superior to that of precoated film of polyester resin paint and its change in color tone based mainly on chalking is less than that of precoated film of silicone polyester resin paint.

From the results described above, the interval of repainting to the post-coated part may be estimated nearly ten years, though not definite depending on the circumstances of the roof and judgment on degradation.

4 Performance of Resistance Welded Joints and Post Coat over the Joints

4.1 Strength of the Joints

Effects of electrode force on peel strength of spot welded joints of WELCOLOR have been examined by pulling the outer two specimens that had been set and welded as shown in **Fig. 3**. The specimens were taken from the same WELCOLOR as described in Sec. 3.1. Welding conditions were as follows:

(1) Initial pressing period, current flowing period and holding period are 19 cycles,
(2) Welding current is 8 kA, and
(3) Diameter of welding electrode is 5.0 mm at its top.

The results of the examination are shown in **Fig. 4**. Peel strength of spot welded joints of two and three fold specimens has the tendency to increase with increasing electrode force; however, that of four fold specimens has no or less effect of electrode force. Peel strength was higher than 75 kgf/cm^2 to two-fold specimens and fracture took place, showing a satisfactory jointing, at base

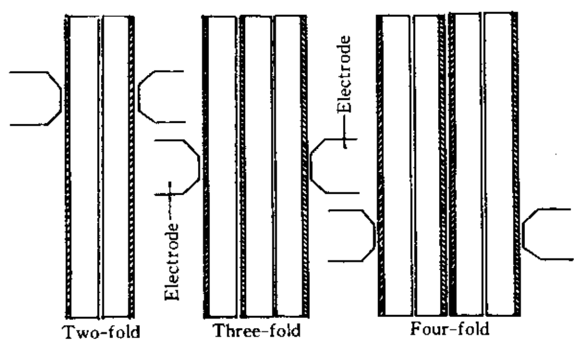


Fig. 3 Setting of specimens for resistance spot welding test of WELCOLOR-P (thickness; 0.4 mm)

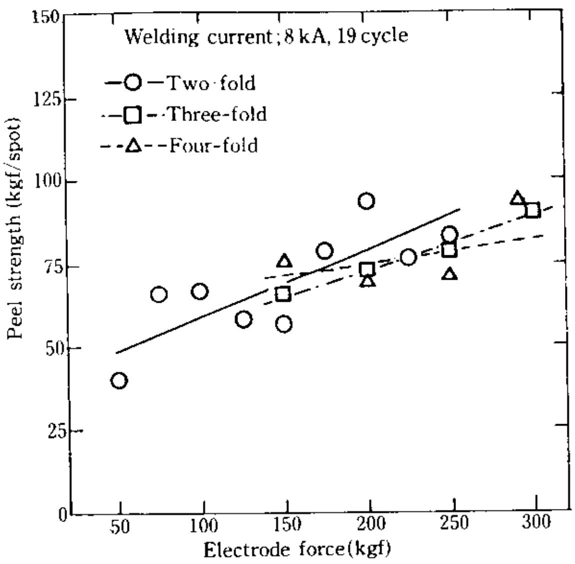


Fig. 4 Effect of electrode force on peel strength of spot welded joints of WELCOLOR-P (Electrode; CF, 5.0 mm dia)

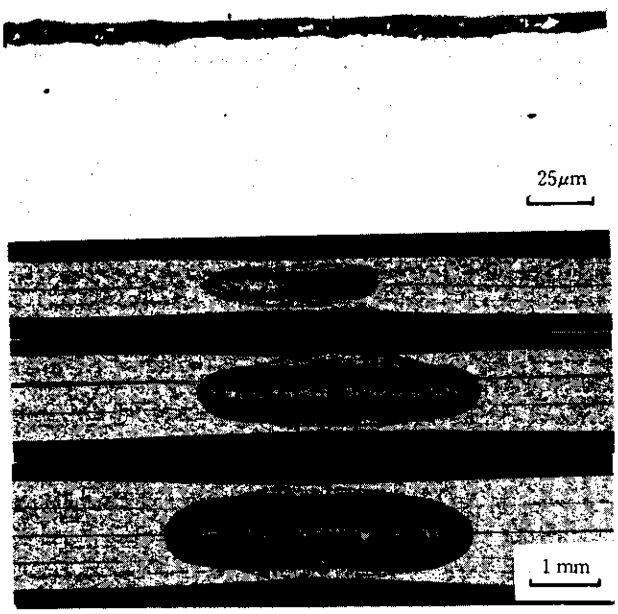
metal of three- and four-fold specimens welded under the electrode force of 150 kgf/cm², the lowest electrode force experimented.

Photo 1 shows the microstructures in cross section of the film coated on the WELCOLOR-P used in the experiment and the microstructure of the cross section along the diameter of the nugget obtained under electrode force of 250 kgf/cm². All of these welded pieces prove also from structural aspect that these joints are satisfactory.

To clarify the contamination of the top of electrode by coated film and occurrence of unsatisfactory welded joint due to the contamination, spot welding of 30 points in succession without cleaning of electrode chip has been carried out. Slight contamination and no poor joint were observed.

Effect of mixing ratio of electrically conductive particles on tensile shear strength of spot welded joint has been examined using the specimens so welded as the bottom (non-precoated) surfaces of two sheets are in contact with each other. Sheets used in this experiment had 6 μm thick film coated with the epoxy resin paint having the particles with 3 μm mean diameter. External appearance of nuggets and tensile shear strength of spot welded specimens obtained by 250 kgf/cm² electrode force and 8 kA welding current are shown in **Photo 2**. It has been observed that the range of 15 to 35% mixing ratio has no effect on the strength.

There was only slight difference of peel strength between the joints welded as top (coated) surfaces of two



Welding current; 8 kA
Electrode force; 250 kgf

Photo 1 Dispersion of electrically conductive particles in primary coat film of WELCOLOR-P and structures of spot welded joints

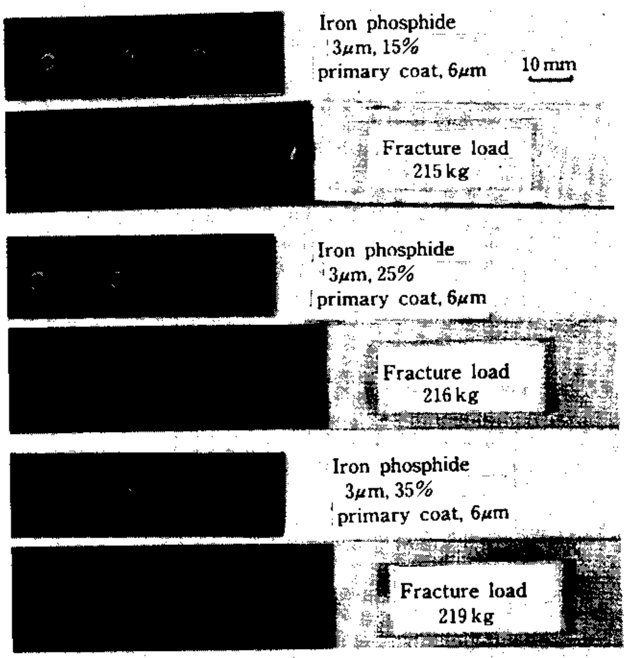


Photo 2 External appearance of nuggets and tensile shear strength of spot welded specimens with different amounts of electrically conductive particle

sheets are in contact with each other and those as the bottom (uncoated) surfaces of two sheets are in contact with each other. Peel strength of the joints of the coated sheet with the film having the conductive particles with 3 μm mean diameter and 15% mixing ratio was 59 kgf to the former type joint and 65 kgf to the latter.

Microstructure of the longitudinal section of seam welded part of 0.4 mm thick WELCOLOR, welded by 140 kgf electrode force and 5 kA welding current with self-travelling seam welder for stainless roof (Osaka Denki Corp., SE-V_{SR} Type), is shown in **Photo 3**. Peel strength of the seam welded part is shown in **Table 6**. The peel strength and the microstructure, with no peeling at seamed part, mean sufficient jointing at the welded part.

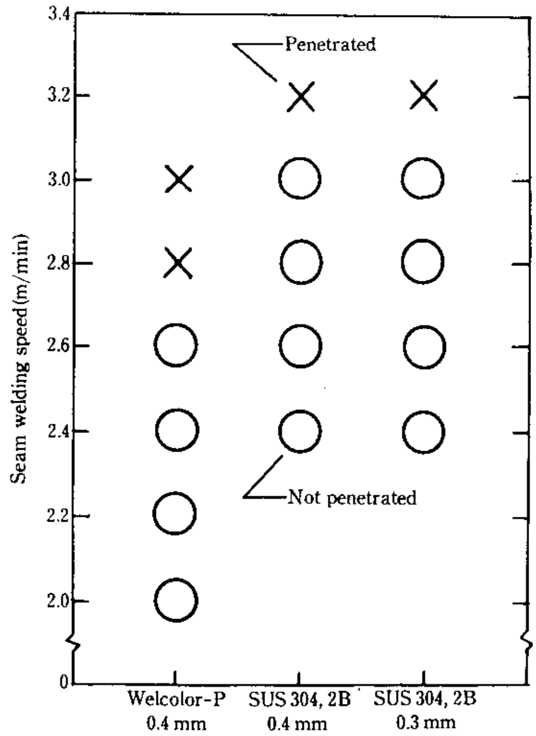
WELCOLOR is resistance welded beyond organic coat film; therefore, it is true that WELCOLOR is less advantageous to the welding than uncoated materials. WELCOLOR-P using 0.4 mm thick SUS 304' and SUS 304 2B strip with 0.4 mm thickness have been welded with the conditions of 180 kgf electrode force, 1.5 : 1.0 cycle ratio on current flow and stop, 2.5 to 2.7 kA welding current and folding each coated surface for WELCOLOR, and 2.7 to 3.0 kA welding current for 2B finished SUS 304. Seam welding speed to obtain water-proof welded joints, detected by color checker, is shown in **Fig. 5**. According to this result, about 90% of the optimum welding speed for uncoated strip is suitable for the seam-welding of WELCOLOR in order to maintain water-proof properties of the welded joints.

Welding current; 5 kA
Electrode force; 140 kgf

Photo 3 Microstructure in the longitudinal section of seam welded joint of WELCOLOR-Z

Table 6 Peel strength of seam welded joint of WELCOLOR

Specimen 0.4 mm	Peel strength (kgf/cm^2)	Type of fracture
Two-fold	175~200	Base metal, ductile
Three-fold	165~200	Base metal, ductile



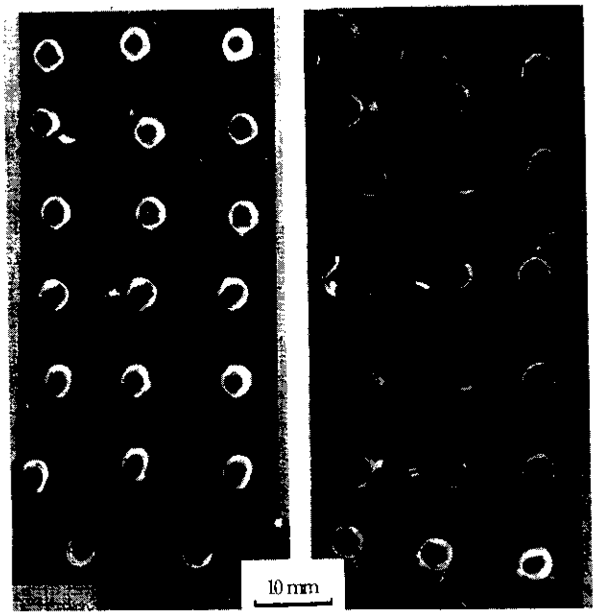
Welding current; 2.5 kA for WELCOLOR
2.7 kA for 2B finish
Electrode force; 180 kgf

Fig. 5 Effect of seam welding speed on tightness of welded joint

4.2 Rust Resistance of Welded Joints

In roof construction, it may not be so that weld zone is post-coated immediately after welding, and in not a few cases, bad weather, unreadiness of workers, or inspection of welded parts, will necessitate post-coating even after a few weeks after welding. Therefore, it is important to protect the welded part from rust in obtaining fair top coating which will lead to the durability of the welded joints.

The specimens with spot welded joints were exposed to spray of acidified water and salt fog containing 5%NaCl. Appearance of the specimens after exposure is shown in **Photo 4**.



a b

(a) Acidified water spray: pH = 4.0 (sulfuric acid), 25°C × 24 h
(b) Salt spray: 5% NaCl, 35°C × 24 h

Photo 4 Appearance of spot welded joints after spray tests

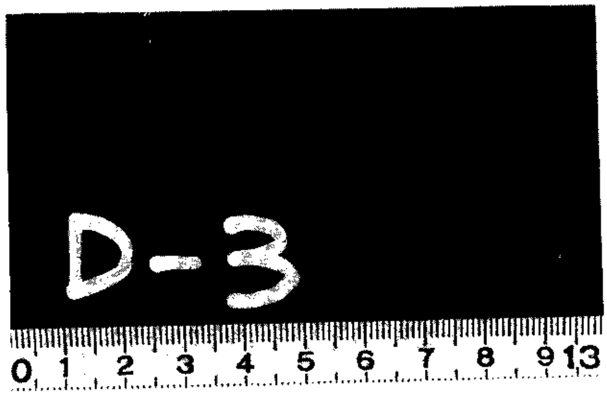


Photo 5 Appearance of seam welded joint of WELCOLOR after atmospheric corrosion test for 30 days on the roof

The specimen exposed to salt fog showed slight rusting along outer zone of nuggets and the specimen exposed to the fog acidified by sulfuric acid (pH 4) as acid rain showed no rusting. Appearance of seam-welded specimen exposed to the atmosphere at the 3 m high roof near Hanshin Works of Kawasaki Steel (Nishinomiya district) is shown in **Photo 5**. The specimen had rain seven times during the exposure in autumn and showed no rusting with only slight contamination.

From the results of these experiments, it is suggested that seam weld zone on WELCOLOR will not rust, even if it was left unpostcoated, as long as it is not exposed to concentrate marine breeze.

4.3 Touch-up Treatment on Welded Joints

Postcoating of welded portion, including primarily coated portion, is essential for keeping corrosion resistance and durability of welded joint for long period. In this case, the primarily coated film of welded portion has been damaged by the heat of welding; so durability is not enough even if the portion is repaired with only top coat paint. **Table 7** shows the experimental results on durability of the seam welded joint post-coated. It is recommended to use the method of recoating primarily coated surface with an isocyanate hardening type, modified polyurethane resin paint as postcoat.

4.4 Welding Technique

WELCOLOR has been applied to roofs using RSW technique, a system also developed by Kawasaki steel to buildup water-proof roofs. RSW technique will be introduced separately in another edition, and an example of roof construction by this technique is shown in **Photo 6**.

Table 7 Resistance to peeling of post coat film on seam welded joint

Oxidation of welded joint	Post coating		Salt spray		Dew cycle 520 h
	Primary coat (Epoxy)	Top coat (Polyurethane)	500 h	1 000 h	
Heavily oxidized	20 μm	20 μm	Resistant	Resistant	No peel*
	—	20 μm	Small blister (partial)	Blister (50%)	No peel*
Slightly oxidized	20 μm	20 μm	Resistant	Resistant	No peel*
	—	20 μm	Small blister (partial)	Blister (30%)	No peel*

* Cross scoring test: Salt spray of 5% NaCl at 35°C

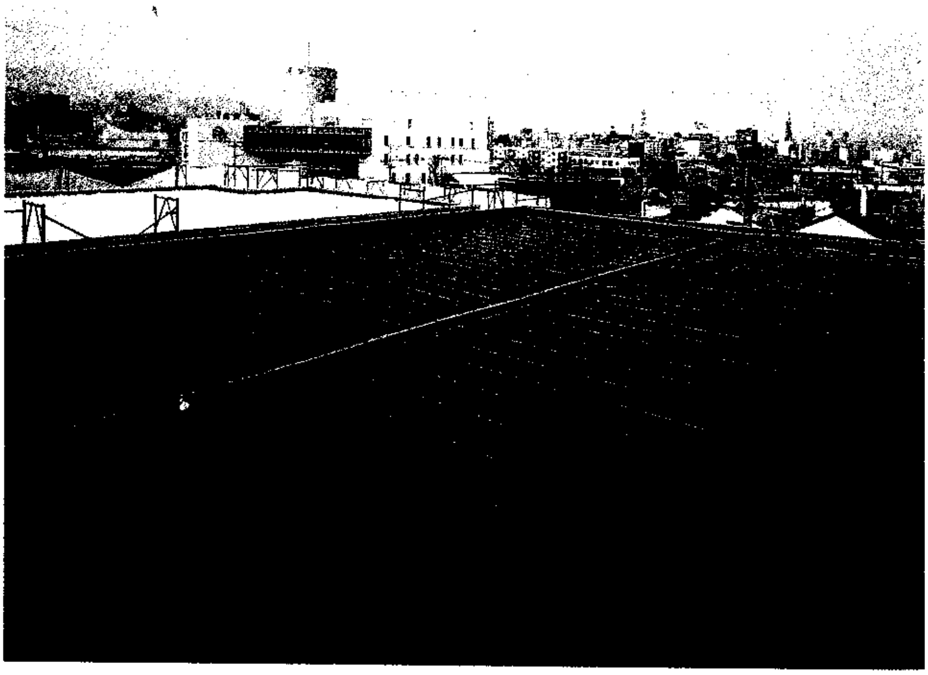


Photo 6 An example of the roof made of WELCOLOR-Z using RSW technique

5 Summary

Performance characteristics of coat film and weldability of WELCOLOR, an electric resistant weldable stainless steel strip precoated with the epoxy resin paint containing electrically conductive particles, are outlined. With WELCOLOR it is easy to select preferable color and tone in response to user's choice of top coat paint. Needs of perfect water-proof construction are increasing along with a growing interest in the maintenance-free system, and the water-proof construction covering not only roofs and exteria of structures but also the fields of civil works for underground markets, subways and tunnels. WELCOLOR is suitable for applications to such fields. Continuing efforts are being made toward developing the precoated stainless steel strip having better formability, durability and weldability, and applicable to more serious circumstances.

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