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Kawasaki Steel has developed dull-finished stainless steel sheets SILVER SOFT for building use. Their main features are: (1) soft tone appearance, (2) good flatness, (3) excellent surface uniformity, and (4) availability of three different surfaces finishes (i.e., rough tone, fine tone, and the emboss-dull finish which is characterized by emboss patterns on the reverse side). Color variation in combination with the FANCY COAT COLOR system is also available. The dull-finished stainless steel sheets with rough tone have been successfully used for the exterior walls of the annex of Kawasaki Steel's Research Laboratories.

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Introduction

In modern architecture, steel has, together with glass d concrete, become an indispensable material.
A noticeable trend of architecture in recent years is a ove toward full of individualistic and high-grade nosphere far less constrained by conventional styles. the case of building materials, too, increasing use is ing made of materials not previously seen, like rusty el sheets and checkered plates in unique design, and ernal and extrernal use of materials having high athering properties, including stone, polycrystalline glass, aluminum and stainless steel panels, and large-sized tiles.

At the center of such trends, stainless steel has, together with stone and glass, become indispensable as a building material with which to express originality. Further, the application of stainless steel is increasing in revival mood buildings as an effective use of stainless steel is found useful in breeding a noble finishing touch by a harmony of old style and modernity.

However, the hairline and mirror surface finishes which played main scheme of convenional design emphasized the sharp metallic appearance of stainless steel. In terms of designability, therefore, linear image was stressed, thereby limiting end uses.[1] The dull-finish stainless steel will therefore open a horizon of stainless steel as a panel material because of its softer impression.

Introduced here are the features of dull-finished stainless steel SILVER SOFT which Kawasaki Steel has recently commercialized, and an example of its use for the exterior panels of the annex to Kawasaki Steel's Research Laboratories.

2 Dull-Finished Stainless Steel for Building Use

The term "dull finishing" is a generic term for a special finishing for delustering with fine unevenness given to the surface of the stainless steel sheet. In the past, dull-finish stainless steel sheet was manufactured as

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stainless steel base sheet to improve the adhesion of paint and as press plate for plastic decorative boards. In comparatively recent years, it was manufactured for use in side panels of rolling stock. More recently, the product came to attract attention for use as building purposes, especially for external panels, as indicated in the previous chapter. Main reasons for this are considered to be the softer material image and low levels of luster unlike the conventional finish of stainless steel, which make the strainless conspicuous. In the case of external panels for buildings, however, quality specifications are far more rigid than the conventional applications in terms not only of designability, but also of surface uniformity.[2)]

Kawasaki Steel has developed new dull-finished stainless steel sheet SILVER SOFT for use as a construction material, drawing on the techniques accumulated from manufacturing stainless steel base sheet for painting and as side panels for rolling stock.

2.1 Manufacturing Methods

The manufacturing techniques used for dull-finished stainless steel are classified into the blast method and roll method. Details of these manufacturing methods, and their respective merits and demerits are shown in **Table 1**. After considering the respective merits and demerits and available technical know-how, Kawasaki Steel has adopted the roll method.

During manufacture, measures are taken to ensure uniformity of the surface color tone required for a building material by controlling the surface color tone of the pre-rolled strip coil, controlling the dull roll surface, and using a flatness correction method that will not hurt the surface features.

2.2 Type and Range of Products

To respond to the demand for various textures of building materials, the following three kinds of finish are made available: (1) rough tone SILVER SOFT R; (2) fine tone SILVER SOFT F; and (3) embossed-dull finish SILVER SOFT DE, in which patterns embossed on the bottom surface are brought into relief on the dull-finished top surface. These features are summarized in **Table 2**.

As further variations of these three types combination with colored clear resin coating (using four standard colors of clear, gray, bronze, and gold) is also available.

As the base material, SUS 304, other JIS-type stainless steels, and high corrosion-resistance steels unique to the company such as R445LY and S30-2 are available, thereby allowing the most appropriate steel type to be selected according to the environmental conditions of the use. The ferritic type of steel gives a slightly higher-luster finish than austenitic type.

The products are available in coils with a thickness of 0.3 mm to 2.0 mm and a width of 600 mm to 1 219 mm, and in sheets with a maximum length of 8 m.

Table 1 Comparison of manufacturing methods of dull finished stainless steel

	Manufacturing process	Merits	Demerits
Roll method	Rolling with rolls engraved by spark etching, chemical etching, blasting, lasar etching and other techniques	1. Excellent flatness 2. High productivity 3. Good surface uniformity	1. Unsuitable for small lot production
Blast method	Directly blasting alumina shots, silica beads, iron grids and other shots	1. Suitable for small lot production	1. Poor flatness 2. Low productivity 3. Poor surface uniformity

Table 2 Variety of Kawasaki Steel's dull finished stainless steel and their features

Description	Features
Dull finish (rough tone) SILVER SOFT R	· Dull finish with relatively rough surface profile · Rondom emboss-like appearance at close look
Dull finish (fine tone) SILVER SOFT F	· Dull finish with relatively fine surface profile · Uniform, white appearance suited especially for roofing
Emboss-dull finish SILVER SOFT DE	· Dull finish with emboss pattern on the bottom side · Fabric-tone appearance

2.3 Properties of the Products

Examples of surface roughness measurements on the dull-finished stainless steel sheets are shown in **Fig.1** . It can be seen that these sheets have a surface roughness larger than 2D material (as-AP-processed finish after cold rolling, which gives a comparatively low luster) by an order of one digit or more.

Figure 2 shows the relationship between brightness, which expresses the degree of specular reflection, and whiteness, which expresses the degree of scattered reflection. Compared with 2D material, the dull-finished stainless steel shows a significant decrease in specular reflection and an increase in scattered reflection. This provides the following features for the dull-finished stainless steel sheet:

(1) Distortion is not conspicuous, because the surroundings are not mirrored on the surface.
(2) The texture is soft.

The corrosion resistance of dull-finished stainless steel is not much different from that of 2B material in the SST and CASS tests, but its relatively larger surface

Table 3 Durability of clear coatings (post coat) on dull finished (rough tone) stainless steel (SILVER SOFT R)

Test item	Conditions	Results	
		Fluolo-resin paint	Silicon-aclylic resin paint
Hardness	Pencil Test (JIS)	3 H	4 H
Boiling water	500 h in boiling water	Normal	Normal
Complex-cycle test	[SST 4 h → Dry(60°C) 2 h → Wet(50°C-95%RH) 2h] 10 cycle	Normal	Normal
Wet-heat-cycle test	[Wet(50°C-95%RH) 4 h → Cold(−30°C) 1 h → Hot(80°C) 1 h] 200 cycle	Normal	Normal
SS-WOM	5 000 h (Black panel temp.: 63°C)	Normal	Normal

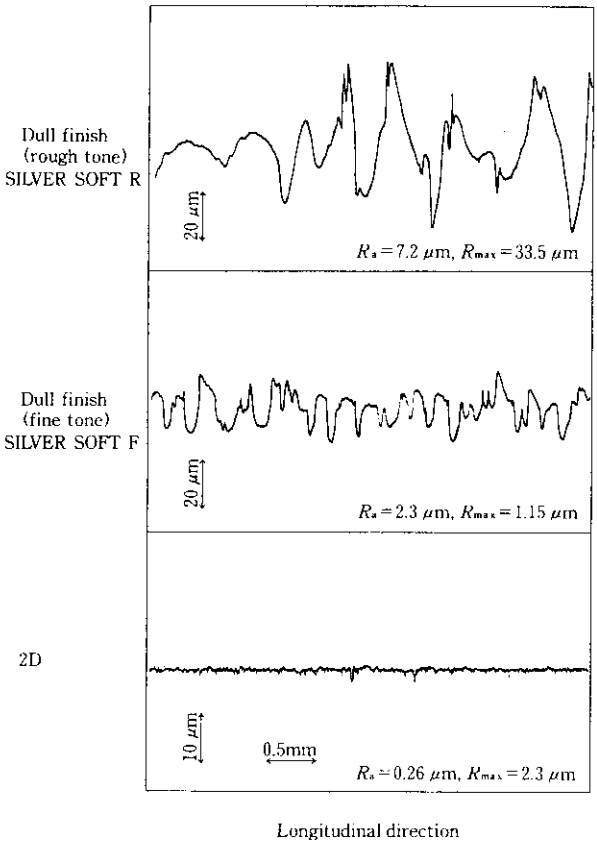

Fig. 1 Surface profile of dull-finished stainless steel sheet (longitudinal direction)

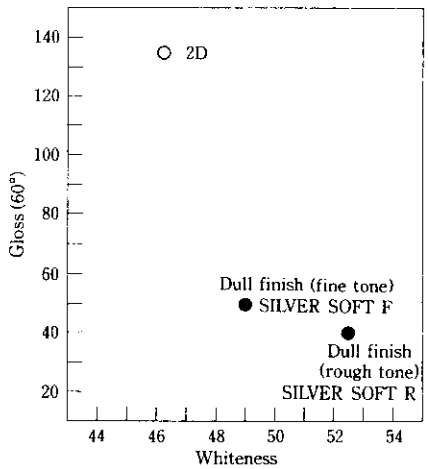

Fig. 2 Optical properties of dull finished stainless steel sheet

roughness tends to cause more dust deposition difficult to be washed away with rain water, making it liable to getting soiled.

2.4 Post-Coat Clear

To prevent fouling and contracted rust generation, the application of a colored clear resin coating is effective, but where no other choice but post-forming painting is allowed, post-coat clear is required. For the post-coat clear which provides long-term durability, a curable fluororesin paint and silicon-acrylic resin paint are used. At present, no long-term record is available, but both types of paint have indicated outstanding results in accelerated weathering tests as shown in **Table 3**.

3 Application of Dull-Finished Stainless Steel to the Annex of Kawasaki Steel's Research Laboratories

3.1 Background

The annex of Kawasaki Steel's Research Laboratories was built as a common-use facility to meet expansion and replenishment of research field accompanying business expansion from the year 2000 onward and to eliminate problems of aging office buildings and insufficient space in Chiba Works.

3.1.1 Design of the panels

For the base material of the panel, SUS 304 in a sheet thickness of 1.5 mm was used. Its top surface was coated with the silicon-acrylic resin paint called "Daime-

taloncoat Clear T," and its bottom surface was coated with vermiculite resin emulsion (5-mm thick).

3.1.2 Location and scale of the project

Exterior of the Research Laboratory building:	4 900 m^2
Exterior of the restaurant building:	960 m^2
Total:	5 860 m^2
Total weight:	80 t (approx.)

3.1.3 Manufacturing sequence

Sheet manufacture at Hanshin Works of Kawasaki Steel → Tajima Junzo, Ltd. (Shearing → forming → clear resin coating) → at site (delivery and installation).

3.2 Design of the Exterior Panels

3.2.1 Panel dimensions

One of the most important elements in the outside appearance of a building is the elevation (basic module) of exterior panels.

The basic module for the panels was determined by the column span of the building, floor height and available dimensions for the panel manufactured. As for the lengths of the panel, 1 800 mm and 3 600 mm were chosen as divisible figures for the column spacing of 7 200 mm. For the width, 1 125 mm and 1 429 mm were selected from the standard steel sheet widths of 1 219 mm (4 ft) and 1 523 mm (5 ft), taking a bending allowance into consideration.

Combinations of these dimensions were examined by considering the following factors :

(1) The elevation of the entire building must be neat and elegant.
(2) Good balance must exist between the curtain wall, windows, emergency exits, and smoke exhaust.
(3) There should be no handling problems during site installation.

After considering these three factors, the basic module was determined with a length of 3 600 mm and a width of 1 125 mm.

3.2.2 Panel shape and details

The dull-finished stainless steel sheets were formed into finished panels by bending four sides, and were assembled into exterior panels by fixing them to reinforcing steel frames.

The best shape and details of the panel were examined by considering the following factors, using "double sealing" as a basis:

(1) Flatness
Since a stainless steel sheet is made of hard material, accurate bending becomes more difficult as the sheet thickness is increased.
(2) Water Resistance
Cut sheet is less effective in maintaining rain water resistance than side-bent sheet.
(3) Cost
As the sheet thickness is reduced, the material cost is decreased, but more reinforcing steel framework will be reqiured. The maximum available sheet thickness was 2.0 mm, and both 1.5 mm and 2.0 mm thickness was examined.

Type A panels (bent on four sides) and type B panels (bent at bottom and top and as-cut on both sides) with a sheet thickness of 1.5 mm and 2.0 mm, respectively (four sets in total), were made up and subjected to a water leakage test, visual flatness test and cost comparison.

The results of the tests and cost examination were as follows:

(1) Flatness
Slight distortion was visually observed in type A panels with a sheet thickness of 2.0 mm.
(2) Water Resistance
No problem occurred with either type, but considering the fact that the panel was to be used for an exterior wall for many years and that the life of the sealing material was about seven years, type A was considered superior.
(3) Cost
The panel from 1.5-mm-thick sheet was lower in cost than that of 2.0 mm.

From this evaluation, a panel with a sheet thickness of 1.5 mm bent on four sides was adopted as shown in **Fig. 3**.

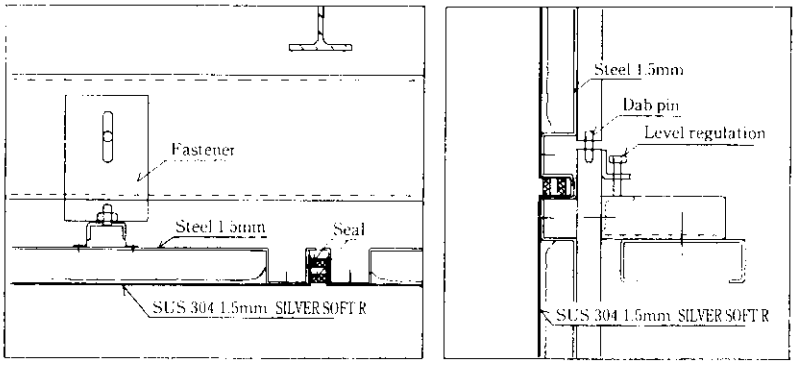

Fig. 3 Standard panel section of exterior wall

Photo 1 Perspective view of the annex of KSC's Research Laboratories with newly developed dull-finished stainless steel SILVER SOFT exterior panels (metallic silver color)

3.3 Manufacture and Installation of the Panels

3.3.1 Manufacture (factory forming)

The dull-finished panels comprise the finished material supported by a reinforcing steel frames. Dull-finished stainless steel sheets delivered from Kawasaki Steel Hanshin Works were cut according to the determined width, drilled, and then bent. The formed material was coated to a film thickness of 13 μm to 18 μm with silicon-acrylic-resin paint by an electrostatic coater, and then baked to a base-material temperature of 180°C for 30 min. These surface panels were then assembled to the reinforcing steel frames which had been simultaneously fabricated, given a vermiculite resin emulsion coating to the bottom surface, and delivered after final product inspection. They satisfied the dimensional tolerances shown in **Table 4**.

3.3.2 Installation (site work)

Panel installation was carried out from the ground floor upwards, and **Table 5** shows the various positioning tolerance values from the base line.

By using the foregoing study and manufacturing method, it was possible to achieve the desired external appearance suited to the purpose of the building: modern, and yet dignified as shown in **Photo 1** (the exterior is composed of dull-finished stainless steel panels and heat reflecting glass window panels).

Table 4 Tolerance for panel size

Item	Tolerance	JIS A 4706
Inside width of frame	±1.5	±3.0
Inside height of frame	±1.5	±3.0
Expectant size of frame (<100)	±1.0	±2.0
Expectant size of frame (>100)	±1.5	±2.0
Diagonal dimension of frame	±3.0	±3.0

Table 5 Tolerance for panel setting

Item	Tolerance
Level of panel	±1.5
Plumb of panel	±1.5
Joint width	±1.5

4 Concluding Remarks

The dull-finished stainless steel sheets SILVER SOFT produced by Kawasaki Steel have the following features:

(1) Soft visual texture, high flatness and surface uniformity, and inconspicuous distortion.
(2) A wide range by the combination of three different kinds of textural finish and coating colors.

The company has adopted the dull-rolling method to manufacture this material, which has achieved the desired flatness and mass production capability. The use of a high corrosion-resistant type of steel provides outstanding durability, and the material is suitable for use under rigorous conditions.

In the future, the company intends to further enhance quality by preventing distortion due to bending work and by preventing smearing without applying the clear coating.

The annex of Kawasaki Steel's Research Laboratories was awarded the Excellent Building prize by Chiba City.

This annex building was constructed by the kind cooperation of Tajima Junzo Ltd. a joint venture between Obayashi Corporation, Maeda Corporation and Konoike Construction Co., Ltd., and others. Our deep appreciation is hereby extended to these organizations.

References

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2) Y. Shinya: *Sutenresu (The Stainless),* **34**(1990)1, 11-14