

Trends and Future Prospects on the Development of Surface Treated Steel Sheets and Building Materials for Housing and Architectural Use

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Abstract:

Trends on the development of surface treated steel sheets and building materials for housing and architectural use were described and future prospects were discussed. The properties of the surface treated steel sheets developed by environment-friendly chromate-free technique at JFE Galvanizing and Coating Co., Ltd. were shown. The developed products individually demonstrated excellent corrosion resistance, superior durability, sophisticated designs as well as antibacterial and antifungal properties, compared with conventional steel sheets. High performance building materials for protection against disasters, environment, aging infrastructures and declining birthrate were described as to building materials. Developed steel sheets and building materials satisfied the social needs. JFE Galvanizing and Coating Co., Ltd. supplies the products for housing and architectural use introduced here to realize the concept “a house consisted of only steel.”

1. Introduction

JFE Galvanizing and Coating Co., Ltd. produces and sells surface treated steel sheets (galvanized steel sheets and pre-painted steel sheets) for use in housing and architectural materials as well as building materials manufactured by forming and processing those materials. These products are mainly used in building materials for housing and architectural use, namely, interior finishing materials, external facing materials, lightweight steel members and light temporary materials.

If the current environment surrounding building materials for housing and architectural use is considered, social needs such as environmental protection

and energy saving, depopulation and super-aged society, disaster prevention and disaster mitigation measures, strengthening of the physical distribution network, aging infrastructures and the pursuit of amenity may be mentioned. Development of products that respond to these issues is strongly desired.

First, this paper describes recent technical trends in the development of surface treated steel sheets and building materials for housing and architectural use responding to the above-mentioned social background. Next, the performance of developed products is presented, and their suitability for social needs is discussed. Finally, the results of a comprehensive consideration of the future prospects of building materials as a whole are described.

2. Technical Trends and Development of Surface Treated Steel Sheets for Building Material Use

2.1 Trends in Development of Chromate-Free Techniques

In steel sheet materials for building material use, chromate-free techniques, which were also introduced in the Japanese Industrial Standards (JIS)¹⁾ in recent years, have become the main stream in surface treatment technology from the viewpoint of environment-friendly techniques, including adaptability for recycling. First, an outline of the chromate-free techniques of JFE Galvanizing and Coating Co., Ltd. are presented.

[†] Originally published in *JFE GIHO* No. 41 (Feb. 2018), p. 14–19



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2.1.1 Development of chromate-free technique in JFE Galvanizing and Coating

The cross-sectional coating structure and main properties required in the developed chromate-free steel sheets are shown in **Fig. 1**. The coating film comprises a chromate-free chemical conversion film applied to the surface of a hot-dip 55% Al-Zn coated steel sheet²⁾, which displays high corrosion resistance, a primer coating and top coating.

As a substitute for chromate-type rust prevention techniques, rust prevention design was performed from the viewpoints of (1) corrosion protection by a self-healing effect, (2) suppression of the corrosion reaction by formation of a stable passive film, (3) strengthening of the barrier effect against corrosive agents and (4) strengthening of adhesion with the substrate Al-Zn coating. In addition, a technique for further strengthening the corrosion resistance of formed parts by introduction of an original resin technique was also established.

Figure 2 shows the relationship between elongation during bending and the initiation period of white rust. Corrosion resistance was investigated by a cyclic corrosion test (CCT) using the test cycle provided in JIS H 8502. Compared at an elongation strain of approxi-

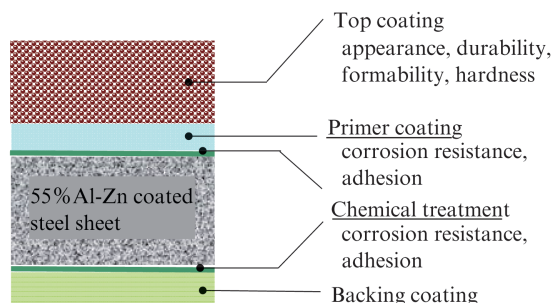


Fig. 1 Cross-sectional coating structure of developed chromate-free coated steel sheet

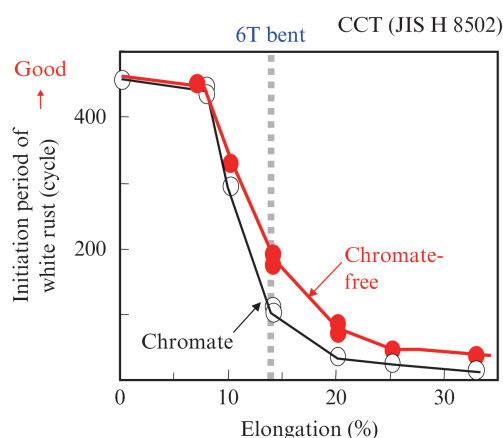


Fig. 2 Corrosion resistance of developed chromate-free coated steel sheet

mately 14% (equivalent to 6T), which shows the average degree of bending of building materials, the initiation period of white rust of the developed chromate-free coated steel sheet was approximately 1.2 to 1.5 times longer than that of the conventional chromate-type pre-painted steel sheet.

The developed chromate-free coated steel sheet also shows outstanding performance in abrasion and scratch resistance, weathering resistance, and acid rain resistance, among other properties.

2.2 Trends in Development in High Performance Products Applying Chromate-free Technique

This section presents a detailed description of products which are based on the chromate-free technique described above and are given the performance demanded in surface treated steel sheets for building material use corresponding to current social needs.

First, from the viewpoints of environment-friendliness and maintenance-free performance, a waterproof fluorocarbon resin top-coated steel sheet with an excellent anti-fouling property and durability is described. Next, a high design chromate-free coated steel sheet in which a cubic effect is given to the product after forming in pursuit of amenity is introduced. A high performance chromate-free coated steel sheet with antibacterial and antifungal properties from the viewpoints of amenity and maintenance-free performance is also described. In this section, the performance of these products is presented and their suitability for social needs is considered.

2.2.1 Waterproof fluorocarbon resin top-coated steel sheet

A waterproof fluorocarbon resin top-coated pre-painted steel sheet with a combination of high durability and an excellent anti-fouling property was developed.

Figure 3 shows the relationship between the number of test cycles and the area ratio of blister and white rust when the corrosion resistance of a part with the equivalent of a 33% elongation strain (2T equivalent) corresponding to a severe degree of bending was investigated by a CCT (JIS H 8502).

The developed steel sheet showed higher corrosion resistance than the conventional material when compared at the same number of cycles. Because 55% Al-Zn coating layer softened by heat treatment was adopted in the developed material, the improved crack resistance of bended parts contributes to improvement of corrosion resistance.

Photo 1 shows photographs of the appearance of the developed steel sheet and the conventional material

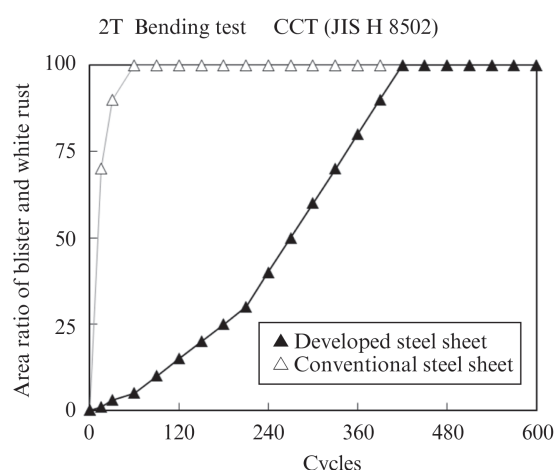


Fig. 3 Corrosion resistance of developed waterproof fluorocarbon resin top-coated steel sheet

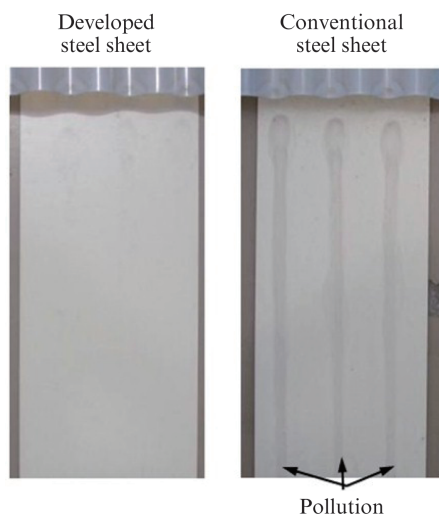


Photo 1 Anti-fouling property of developed waterproof fluorocarbon resin top-coated steel sheet (Exposure test for 30 days in Chiba)

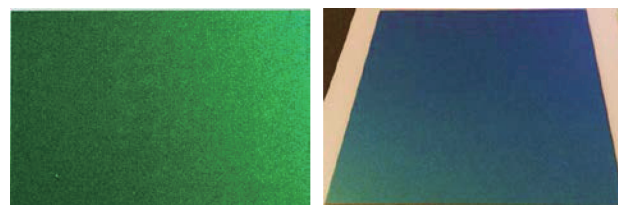
after a 30-day exposure test in Chiba, Japan. A corrugated sheet was arranged at a top of the samples so as to investigate the anti-fouling property by simulating the flow of rainwater at the same position. In the conventional material, clear fouling by rain streaks can be seen, but in contrast, fouling of the developed material was very slight.

With the conventional technique, it was difficult to satisfy both weathering resistance, corrosion resistance and chemical resistance of the fluorocarbon resin top-coated steel sheet and the anti-fouling property. In this development, it was possible to improve fouling resistance by imparting hydrophilicity to the surface of the fluorocarbon coating film.

This development also made it possible to realize a long-term guarantee, including forming portions, at distances 500 m or more from the coastline.

Table 1 Color difference measured by multi-angle color-difference meter

Angle (degree)	Developed steel		Conventional steel	
	0°	70°	0°	70°
<i>L</i> value	26.0	26.0	11.0	13.7
<i>a</i> value	-9.5	-4.9	-5.2	-1.1
<i>b</i> value	3.5	-18.8	0.6	0.0



A : 0°

B : 70°

Photo 2 Appearances of developed steel

2.2.2 High design chromate-free coated steel sheet

Metal siding is a type of an external facing material. As one characteristic feature, it is given excellent appearance and a high design property by use of steel sheets, which are available in diverse patterns. Up to the present, materials with a wood style, plastered wall style, brick, stone and metal styles and other patterns have been developed⁴⁾. On this occasion, JFE Galvanizing and Coating developed a chromate-free coated steel sheet with a high design property, in which the color appearance changes depending on the viewing angle, in order to supply formed products with a cubic effect and high-grade sense after forming.

Table 1 shows the color difference of the developed steel at acceptance angles of 0° and 70° measured by a multi-angle color-difference meter. The *a* value and *b* value of the conventional pre-painted steel sheet showed virtually no change depending on the acceptance angle, but in contrast, the *a* value and *b* value of the developed steel changed depending on the acceptance angle. The appearances of the developed steel when a light source was placed directly above the material and the material was photographed from directly above (acceptance angle: 0°) and from an angle (acceptance angle: 70°) are shown in **Photo 2**. The color appearances of the developed material changed greatly depending on the viewing angle.

This product has been registered as non-combustible material NM-8697. Wide use in walls and roofs as a sophisticated high design architectural material is expected in the future.

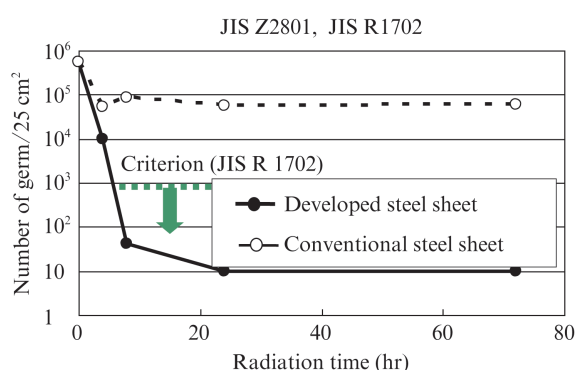


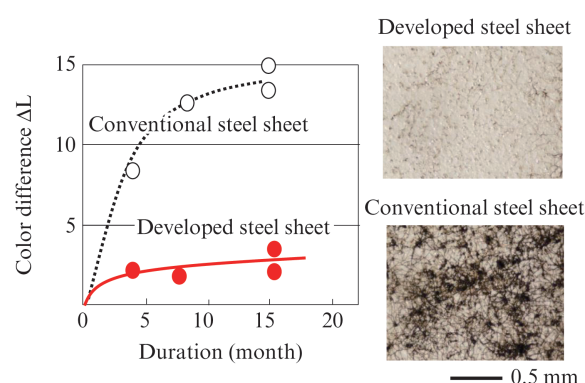
Fig. 4 Effect of "Optclean" on sterilization

2.2.3 Antibacterial/antifungal chromate-free coated steel sheet

The chromate-free coated steel sheet "Optclean," in which antibacterial and antifungal properties are realized by utilizing a photocatalyst, was developed by using techniques of Toto Ltd. and JFE Galvanizing and Coating Co., Ltd.

The colon bacilli extinction effect of the developed steel sheet was investigated in accordance with the methods provided in JIS Z 2801 and JIS R 1702. **Figure 4** shows the relationship between the number of viable germs and the irradiation time with an ultraviolet fluorescence lamp. With the conventional pre-painted steel sheet, the number of viable germs did not decrease even to 1/10 after irradiation for 8 h, and the number of viable germs did not decrease with increased irradiation time thereafter. In contrast, with the developed steel sheet, the number of viable germs decreased to 1/1 000 or less after irradiation for 8 h, and became less than the criterion specified in JIS R 1702 shown in dotted line in the figure. Furthermore, virtually no viable germs could be observed after irradiation for 24 h.

The outdoor antifungal property of the developed steel sheet was investigated at an alcohol storage facility. **Figure 5** shows the results of an investigation of the change over time in the color difference as an index of the occurrence of *Cladosporium*. With the conventional pre-painted steel sheet, the color difference increased with test time. After 15 months, the occurrence of *Cladosporium* became remarkable, as can be seen in the optical microscope photograph, and the color difference ΔL reached approximately 15. On the other hand, in the case of the developed steel sheet, the occurrence of *Cladosporium* was slight after 15 months, and the color difference ΔL was approximately 3, or about 1/5 that of the existing pre-painted steel sheet. Thus, a remarkable *Cladosporium* suppression effect was confirmed. A reduction in the frequency of facility cleaning work and other benefits can be expected as a result of the antifungal property of the

Fig. 5 Effect of "Optclean" on restricting the occurrence of *Cladosporium*

developed steel sheet.

In addition, the developed steel sheet shows an outstanding anti-fouling property owing to its super hydrophilicity. It also displays an excellent lubricating ability and anti-galling property during forming.

3. Technical Trends and Development of Building Materials for Housing and Architectural use

3.1 Trends in Development for Disaster Prevention and Mitigation

In the 1995 Southern Hyogo Prefecture Earthquake and the 2011 Tohoku-Chiho Taiheiyo-Oki Earthquake, many buildings collapsed and burned, including those lost in fires after the earthquakes. Because large earthquakes with a seismic intensity of 7 on the Japanese seismic intensity scale are also assumed in the future, high seismic performance and fire preventive performance are demanded. Moreover, with the increasing scale of typhoons and higher frequency of unexpected strong rain and tornados in recent years, higher wind resistant performance and waterproof performance than in the past are now required.

It has been widely recognized that the application of metal external facing materials, which are lightweight and noncombustible materials, contributes to improvement of the seismic performance and fire preventive performance of buildings. Since new wind-resistant and waterproof building materials have also been developed, examples of those materials will be introduced in the following.

3.1.1 Interlocking-type high strength folded plate roof "Tightlock 500"

With active construction of large-scale logistics facilities in response to growing demand for individual parcel delivery, etc., demand for metal folded plate

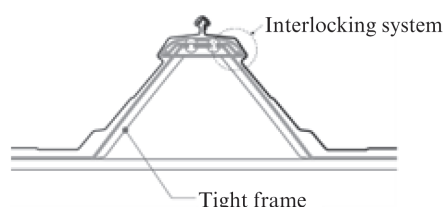


Fig. 6 Details of folded plate roof "TIGHTLOCK 500"

roofs as roofs for this type of building is also expanding. Therefore, JFE Galvanizing and Coating developed the interlocking-type high strength folded plate roof "Tightlock 500" with high wind resistant performance and good workability. **Figure 6** shows the structural details of Tightlock 500. High wind resistant performance is realized by fitting (interlocking) a strong tight frame and a folded plate roof. In a dynamic wind-resistance test, the joining strength of a conventional folded plate roof locked by a straight seam ($t=0.8$ mm) was 3 900 Pa, but with Tightlock 500 of the same thickness, destruction did not occur even at 9 000 Pa, which was the upper limit of test machine capacity.

3.1.2 Ultra-durability TPO film laminated steel sheet "Eco-lami"

The ratio of sheet-applied membrane waterproofing in waterproof construction methods is estimated to be on the order of 25%, and approximately 15 million m^2 /y of sheet waterproofing membranes are used. In the past, there were instances in which leakage occurred due to pinholes, peeling or other sheet damage by strong wind, etc. Therefore, JFE Galvanizing and Coating developed "Eco-lami," in which a TPO film is laminated on "JFE Ecogal" as a steel sheet for use in waterproof construction methods.

Figure 7 shows a schematic diagram of the waterproof membrane of Eco-lami. A surface layer consisting of a TPO (thermoplastic polyolefin elastomer) film and a TPO sheet of the same material are unified by heat welding by a high temperature hot blast. The TPO film has excellent weathering resistance, chemical resistant performance and workability and also has outstanding durability owing to a film thickness of 200 μm or more. Wind pressure resistant strength is also high because the TPO film is unified with the steel sheet. Approval as a noncombustible material (approval No.: NE-0022) has also been obtained from Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT). **Photo 3** shows an example of construction using "Eco-lami."

3.2 Trends in Development in Repair Market

Many of the factories, warehouses and other indus-

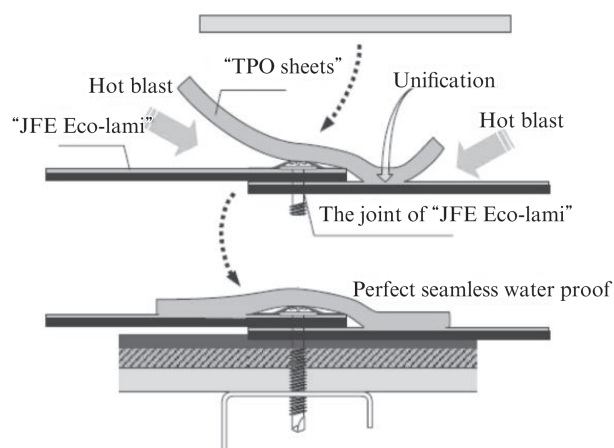


Fig. 7 Details of seamless water proof with "Eco-lami"

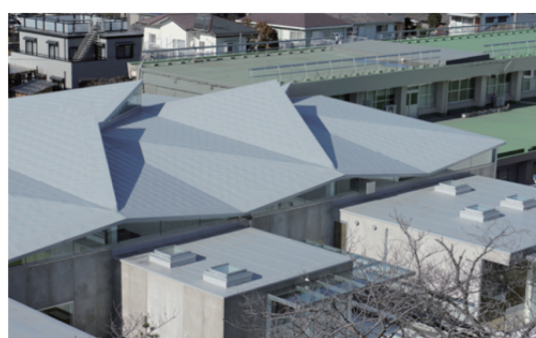


Photo 3 Construction example of "Eco-lami"

trial facilities constructed since Japan's era of high economic growth have been in use for more than 50 years and are now suffering deterioration with age, heightening the need for repair. Because it is desirable to repair these industrial facilities while they are in operation, the general practice in roof repairs is the method of construction to cover the existing roof with a new roof.

In low-rise residential structures, the method of construction to cover decorative slate roofs with metal roofing has been widely used for many years, and JFE Galvanizing and Coating also developed a specified length horizontal roofing material with a high design property called "Masame FLeX." The following introduces examples of metal repair roof for non-residential buildings.

3.2.1 Corrugated slate repair roofing "Slatecover780" and "Slatecover650"

Because corrugated slate had been used widely in factories and warehouses since the early Showa era (late 1920s), and the total roofing area greatly exceeds 1 billion m^2 ⁵⁾, a repair market of 800 000 m^2 /y or more is projected. Moreover, the problem of treatment of asbestos-containing slate as an industrial waste has also heightened demand for repair by the cover

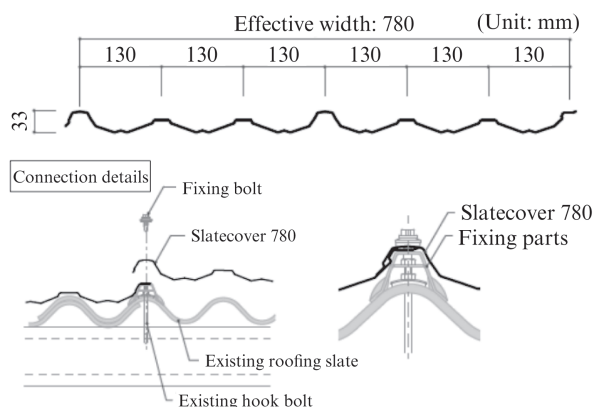


Fig. 8 Details of "SLATECOVER780"

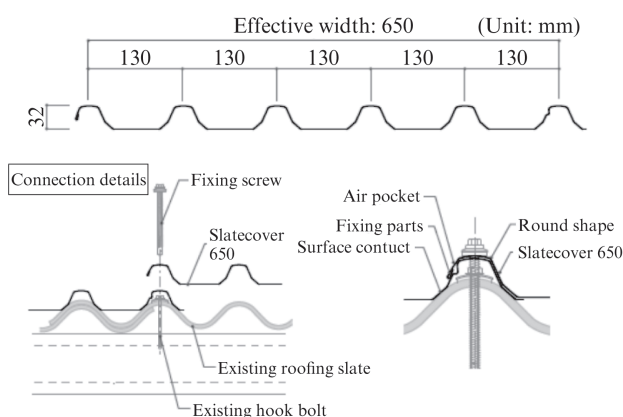


Fig. 9 Details of "SLATECOVER650"

method⁶⁾. On the other hand, from the environmental viewpoint, construction methods which do not generate slate dust during construction are also demanded.

Against this background, JFE Galvanizing and Coating developed "Slatecover780" for economy when fixing a new roof to an existing roof and "Slatecover650" for improved workability when fixing a new roof to the frame members.

As shown in **Fig. 8**, Slatecover780 is a metal roof which is fixed by attaching dedicated fixing parts to the existing hook bolts used to secure the existing slate. Although the material coil width is unchanged at 914 mm, the height of the roofing is reduced except at the fixing parts, and on the other hand, the working width is expanded to 780 mm by reinforcement by forming ribs in the low ridge parts to secure out-of-plane stiffness and strength. As a result of this expansion of the working width and the adoption of dedicated fixing parts, work efficiency was increased by 20% or more in comparison with the conventional method of fixing a new roof to an existing roof. Moreover, because the new roof is fixed to the existing roof, this is also an environment-friendly product that does not generate dust during construction.

Slatecover650, as shown in **Fig. 9**, is an innovative



Photo 4 Construction example of "SLATECOVER650"

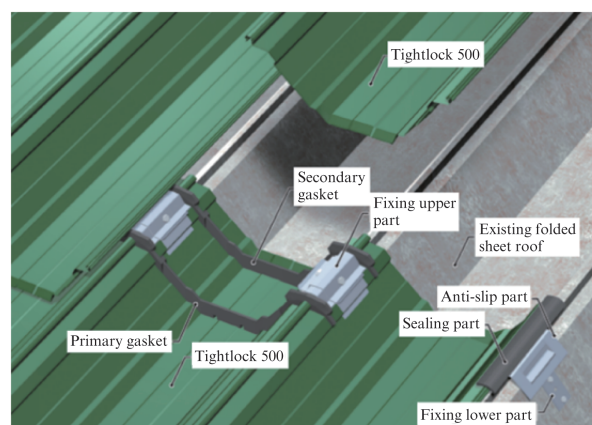


Fig. 10 Details of "DANDAN"

product which is provided with an oblique shape that follows the shape of the slate, and enables easy adjustment of variations in the existing slate roof and conformity to the shape of the existing slate by elastic deformation of the steel sheet roofing by only the force of stepping on the metal roofing. In addition, air pockets provided at the parts where the steel sheets overlap prevent penetration of rainwater by the capillary phenomenon, and the round shape (R structure) at the crown of the ridge makes it difficult for rainwater to accumulate by eliminating depressions at fastening screw points, thereby improving water cut-off performance. **Photo 4** shows an example of repair construction of a slate roof.

3.2.2 Joint method for folded plate roof repair "Dandan"

When repairing folded plate roofs, it is difficult to bring long folded plate roofing materials and large-scale roof forming machinery into the construction site due to the urbanization of site areas. Therefore, a construction method for longitudinal joining of easily-transported short folded plate roofing materials on the roof was demanded.

As shown in **Fig. 10**, JFE Galvanizing and Coating

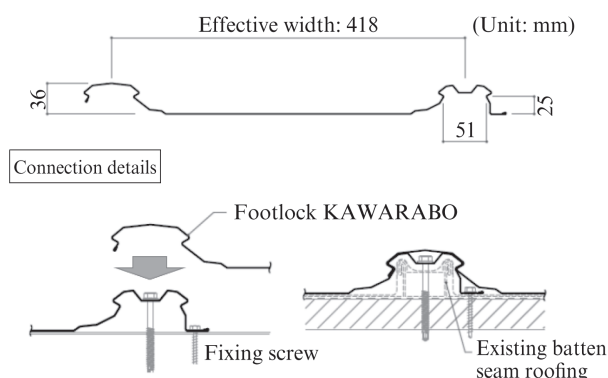


Fig. 11 Details of "FOOTLOCK KAWARABO"

developed the joint method for folded plate roof repair "Dandan," which consists of lower fixing parts that are attached to the existing folded plate roof, upper fixing parts for longitudinal joining, and gaskets for water cut-off. The folded plate roofing materials for construction on the existing roof are the above-mentioned Tightlock 500. Therefore, even at the longitudinal joint parts, the wind pressure resistant performance equal to or higher than that of Tightlock 500 is ensured. The roof also demonstrates high watertightness due to the adoption of an open-joint structure with a high durability primary gasket for suppression and discharge of infiltrating water and a secondary gasket for airtightness.

3.3 Trends in Development as Countermeasures for Low Birthrate and Aging Population

With the decline in the number of skilled technical personnel due to the ongoing trends toward lower birthrates and an aging population, the development of products and construction methods that are simple in construction and few working steps are desired.

The following introduces examples of products particularly for simplification of site construction work.

3.3.1 Fitting-type 1-piece roof "Footlock KAWARABO"

To achieve simplification of site construction work, JFE Galvanizing and Coating is promoting commercialization of a complete fitting-type metal roof product that can be installed simply by stepping on the roofing material. In 2010, a complete fitting-type folded plate roof "Footlock600" with a working width of 600 mm was commercialized. Recently, the company also developed a full-fitting type metal roof "Footlock KAWARABO" which is also suitable for repair of existing batten seam roofing and standing seam roofing. As shown in Fig. 11, in Footlock KAWARABO, a 1-piece structure is adopted in a batten seam roof,

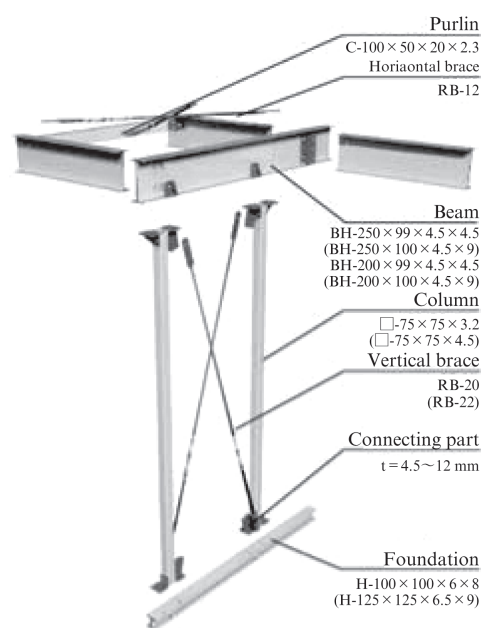


Fig. 12 Framing structure of "FRAME KIT"

which had consisted of 3 pieces (body, clip, cap) in the conventional type. As an additional advantage, advanced skills are not necessary at the construction site, as the roof is fitted simply by stepping on the Footlock connection.

3.3.2 Normalized steel frame "Frame Kit"

As shown in Fig. 12, the normalized steel frame "Frame Kit," which was developed for use in low-rise buildings up to 3 stories, can be assembled simply by tightening bolts without site welding of the structural steel members, which are manufactured at the steel fabrication shop.

Frame Kit has been highly evaluated for a number of advantages, including the fact that welders and other skilled personnel are not necessary, construction can be performed in the limited space available in urban areas without bringing in large-scale heavy machinery because the individual members are comparatively lightweight, and a fire resistive covering is not necessary in order to obtain approval thanks to the original fireproof structure of Frame Kit itself. As a result, adoption of this product as the framework for low-rise rental housing in the Tokyo Metropolitan area has increased in recent years. In addition to rental housing, adoption in new facility applications, such as homes for the elderly, stores, nursery schools, etc. has also expanded.

4. Summary and Future Prospects

Surface treated steel sheets and building materials

for housing and architectural use developed by JFE Galvanizing and Coating Co., Ltd. in recent years were described, centering on trends in development and product performance. Based on the performance and features presented in this report, all of the developed products can be considered to satisfy the social needs demanded in today's building materials.

As future prospects, ever-greater expansion of the range of applications of global environment-friendly chromate-free coated steel sheets is expected accompanying introduction of these products in JIS standards. In products in which even high functions are required for amenity, it also appears that the chromate-free technique will become central to the techniques that form the foundation for rust prevention in the future.

In the field of building materials, since further decreases in the work force employed in the construction industry are foreseen, even higher demand for simpler construction methods than those at present is expected.

Moreover, in building material technology as a

whole, techniques which consider the composite advantages of steel sheets and building materials, namely, application of building materials with excellent workability using long life and high performance surface treated steel sheets, will become increasingly important in the years to come.

JFE Galvanizing and Coating Co., Ltd. will supply the various types of products for housing and architectural use introduced in this report to society in order to realize the concept of "a house consisted of only steel."

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