TECHNICAL MANUAL FOR THE DESIGN AND CONSTRUCTION OF ROOFS OF STAINLESS STEEL SHEET

N⁰ 12006

Japan
Stainless Steel
Association

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Nº 12006

Prepared by the Japan Stainless Steel Association and Nickel Institute, 1985

For Publication of the English Edition

This is the English edition of the "Technical Manual for the Design and Construction of Roofs of Stainless Steel Sheet" published by Japan Stainless Steel Association in 1985 to promote the use of stainless steel sheet roofing in Japan, with a commentary on "Welding Processes" in use in Japan.

The topics covered in this Manual range from elementary facts about stainless steel to a practical commentary on structural methods and construction using stainless steel sheet roofing. In Japan, construction clients, architects, roof sheet metal workers and roofing contractors are using this Manual as a technical document when installing stainless sheet roofing.

Attention should be paid to the fact that this Manual was edited for use in Japan, taking into account Japanese climate and construction technology.

This Manual has been prepared as a joint project of the Nickel Development Institute and Japan Stainless Steel Association and was sponsored by the Institute.

April, 1989

Japan Stainless Steel Association

STATEMENT

(from Japanese edition)

Stainless steel is a metal having good corrosion resistance and durability, and a pleasing appearance. It is also commonly considered to be a necessary building material in modern architecture. Recently, various new stainless steel applications have been developed utilizing its outstanding features in constructing high-quality, multi-storied buildings.

Demand for roofing stainless steel (mainly resin-coated stainless steel sheet), which was developed as a roofing material for housing, gyms, factories, and warehouses, has increased remarkably. The average annual increase in demand for roofing stainless steel has been more than 25 per cent for several years. Resin-coated stainless steel sheet, bake-finished with high-quality organic paint on the surface of the rust-resistant stainless steel, has good corrosion resistance and durability, and can be used semi-permanently with almost no maintenance. Since roofing materials are exposed to rigorous natural and corrosive conditions for long periods, it can be said that pre-coated stainless steel sheet is the ideal roofing material.

Pre-coated stainless steel sheet is still virtually unknown to the general public, however, and even architects and roofing workers do not sufficiently understand its characteristics, processing methods or structural roofing techniques.

This Committee has prepared and distributed this “Technical Manual for the Design and Construction of Roofs of Stainless Steel Sheet” to disseminate information and to increase demand for roofing stainless steel. Preparation was begun in June, 1980, in cooperation with and under the direction of the authorities in the Ministry of Construction, the Architectural Institute of Japan, the building industry and the roofing sheet metal industry. After more than four years of careful discussions and examinations, we can now publish the book. We will be happy if it is useful for guidance in roofing design and construction, and for the promotion of the use of stainless steel.

We greatly appreciate the cooperation of Michikatsu Hirano, Professor of the Science University of Tokyo, who, as Chairman of “Preparation Comittee” and the “Working Group for the Preparation of the Draft”, made great efforts to prepare this book, and the cooperation and time of other Committee members.

April, 1985

Special Committee for Roofing Materials,
Developing Committee
Japan Stainless Steel Association

PREFACE

(from Japanese edition)

Recently, the use of stainless steel sheet has become widely accepted as a roofing material. In response to this, the Japan Stainless Steel Association began to prepare this technical manual by establishing the Committee for the Preparation of the Technical Manual for the Design and Construction of Roofs of Stainless Steel Sheet in April, 1980, to assist and encourage sound development of roofs using stainless steel sheets.

The Committee commissioned the examination of this draft by organizing a working group-which has met more than 20 times to examine the draft–to liaise with the people concerned with manufacturing and constructing, and to put together the Technical Manual for the Design and Construction of Roofs of Stainless Steel Sheet (Draft) to be submitted to the Committee. Writing of the Manual began in April, 1984, under the auspices of the Committee.

In preparing the draft, we discussed many ways of incorporating relevant information concerning the stainless steel roof. Actual conditions–which the Structural Standards for Roofs of Steel Sheet (published by the Japan Galvanized Sheet Association) and Commentary for Construction on Structural Standards for Roofs of Steel Sheet (published by the Committee for the Diffusion of the Structural Roofing Method Made of Steel Sheet) have already described–were taken into account. Our basic policy is, therefore, to make our explanation short and clear and to supplement both the earlier books by avoiding duplication and by identifying items unique to the stainless steel sheet roof.

We advise readers to use both of the above-mentioned books along with this Manual. It is better to consult the “Structural Standards for Roofs of Steel Sheet” to learn of the proper sheet thickness and interval of the channel clip according to wind pressure, and then to consult this Manual to learn whether or not the channel clip must be of stainless steel.

Since stainless steel sheet roofs have a short history, it is probable that new products and methods will appear on the market in the future. Accordingly, it is difficult to standardize. The Manual was published thanks to the Committee members, especially to the working group members who prepared and examined the Draft even though busily engaged in their own tasks. I would like to express my appreciation of their efforts. I also am appreciative of Mr. Tadao Motoyoshi and Mr. Mitsuo Umezawa of the secretariat who engaged in the general affairs of the Committee and in the exchange of information with all the departments of the Japan Stainless Steel Association.

April, 1985 Preparation Committee of the Technical Manual for the Design and Construction of Roofs of Stainless Steel Sheets Chairman, Michikatsu Hirano

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Part I BASIC FACTS

1. Types and Characteristics of Stainless Steel

1.1 What is stainless steel?

Iron rusts easily by oxidizing in the air, but rusts little when it contains chromium 10%. By adding nickel, corrosion resistance is further improved.
Stainless steel is an alloyed steel which contains more than 11 % chromium in iron. There are other types of stainless steels – which contain nickel, manganese and molybdenum. It is clear, therefore, that there are many types and variations of stainless steel which depend on alloying with these elements.

1.2 Classification of stainless steel

Actually, there are scores of classes of stainless steel defined by the Japanese Industrial Standard. Including stainless steel that is produced by private stainless steel manufacturers, this number of stainless steel alloys amounts to more than 100 steel classes.

These steel alloy classes are roughly divided on the basis of the fundamental element: 1 chromium type stainless steel containing chromium as a fundamental element; 2) chromium-nickel type stainless steel containing chromium and nickel.

When these are classified on the basis of the metallic structure, they can be roughly classed into three types: martensitic, ferritic and austenitic.

Chromium grade stainless steels are classified by their martensitic structure or a ferritic structure as martensitic and ferritic stainless steels, respectively. The metallic structure of chromium-nickel grade stainless steel is representative of austenite, and it is referred to as austenitic stainless steel (Table-1.1).

The chemical elements of some representative steel types are shown in Table-1.2.

(1) Chromium type stainless steel

Chromium type stainless steel has the following two ferromagnetic types.

a. 13 chromium type stainless steel

The metallic structure of 13 chromium type stainless steel is basically martensitic structure after quenching. SUS 410 is a representative type.

b. 18 chromium type stainless steel

The metallic structure of 18 chromium type stainless steel is ferritic. SUS 430 is a representative type.

(2) Chromium-nickel type stainless steel

Since the chromium-nickel type stainless steel contains approximately 18% chromium and approximately 8% nickel, this type is generally called 18-8 stainless steel, and the metallic structure is an austenitic structure. Representative steel types are SUS 304 and SUS 316.

Table-1.1 indicates the classification of stainless steel types, and Table-1.2 gives the chemical composition of representative stainless steel types.

Table 1.1 Classification of stainless steel types

Classification of basic components				Classification by metallic structure
Classification of basic components	Popular name	Representative letter symbol of steel	Abbreviated name	
Chromium type	13 chromium type	SUS 410	13Cr	Martensitic type (Note 1)
	18 chromium type	SUS 430	18Cr	Ferritic type
Chromium－nickel type	18 chromium－8 nickel type (18－8 type)	SUS 304	18Cr－8Ni	Austenitic type
		SUS 316	18Cr－18Ni －2.5Mo	

Remark 1 : SUS indicates the abbreviated name of the Steel special Use Stainless designated by the Japanese Industrial Standard.

Remark 2 : Cr, Ni and Mo are element symbols for chromium, nickel and molybdenum, respectively.

(Note 1) : Metallic structure after quenching.

Table 1.2 Chemical composition of representative stainless steels

Type of material / Composition, %	SUS 304	SUS 316	SUS 430	SUS 410
C (Carbon)	0.08 and below	0.08 and below	0.12 and below	0.15 and below
Si (Silicon)	1.00 and below	1.00 and below	0.75 and below	1.00 and below
Mn (Manganese)	2.00 and below	2.00 and below	1.00 and below	1.00 and below
P (Phosphorus)	0.045 and below	0.045 and below	0.040 and below	0.040 and below
S (Sulfur)	0.030 and below	0.030 and below	0.030 and below	0.030 and below
Ni (Nickel)	8.00～10.50	10.00～14.00	(Note 1)	(Note 2)
Cr (Chromium)	18.00～20.00	16.00～18.00	16.00～18.00	11.50～13.50
Mo (Molybdenum)	－	2.00～3.00	－	－

(Note 1) (Note 2) : May contain 0.6% nickel. (SUS 304,316,410,430 have the same number in AISI.)

1.3 Characteristics of stainless steel

1.3.1 Physical properties

The physical properties of representative stainless steels are as described in Table-1.3. In Table-1.4 they are compared with aluminium, copper and mild steel for roofing. The physical properties of stainless steel are summarized as follows:

Table 1.3 Physical properties of stainless steel (representative class)

Type of material Class (JIS)		SUS 304	SUS 316	SUS 430	SUS 410
Density g/cm³		7.93	7.98	7.70	7.75
Specific electric resistance μΩ−cm (room temperature)		72	74	60	57
Magnetism		No	No	Yes	Yes
Specific heat cal/g/°C(0～100°C)		0.12	0.12	0.11	0.11
Average thermal expansion coefficient (×10⁻⁶/°C)	0～100°C	17.3	16.0	10.4	9.9
Thermal conductivity cal/cm²/sec/°C/cm	100°C	0.0389	0.0389	0.0624	0.0595
Modulus of longitudinal elasticity kgf/mm²		19,700	19,700	20,400	20,400
Melting point (°C)		1400～1450	1370～1400	1430～1510	1480～1530

Table 1.4 Comparison table of physical properties of various materials

Type of material	SUS 304	Aluminium alloy (A5052P)	Copper (C1220P)	Mild steel (SPCC)
Density g/cm³	7.93	2.68	8.9	7.85
Specific electric resistance μΩ−cm (Room temperature)	72	4.9(0°C)	By quality(O)2.5 By quality(H)1.9	14.2～19.0
Magnetism	No	No	No	Yes
Specific heat cal/g/°C (0～100°C)	0.12	0.23	0.0921 ～0.0939	0.115
Average thermal expansion coefficient (×10⁻⁶/°C)(0～100°C)	17.3	23.8	14.1～16.8	12.2
Thermal conductivity cal/cm²/sec/°C/cm(100°C)	0.0389	0.33(25°C)	0.70～0.87 (20°C)	0.142～ 0.138
Modulus of longitudinal elasticity kgf/mm²	19,700	7170 (38°C and below)	12,000 ～13,500	21,000 23,000
Melting point (°C)	1400 ～1450	593～649	1083	1530

(A) Electrical properties

The electrical conductivity of stainless steel is less than that of other steels. Specific electric resistance generally tends to be greater for steel types which have greater chromium or nickel content. Specific electric resistance of chromium-nickel type stainless steel (SUS 304) is a little greater than that of chromium type stainless steel (SUS 430 and SUS 410), but it is much greater–by approximately 3-4 times, approximately 40 times, and approximately 15 times–than that of mild steel, copper and aluminium, respectively. For this reason, the electric current required for spot welding stainless steel is much less than that required for spot welding other materials.

(B) Thermal properties

The specific heat of stainless steel is almost the same as that of mild steel. Heat conductivity, however, is in general less than that of mild steel. The heat conductivity of chromium type stainless steel is about half that of mild steel; that of chrome-nickel type stainless steel is about one-third that of mild steel and about one 24th that of copper. Accordingly, when stainless steel sheet is welded, attention must be paid to phenomena including uneveness and distortion which occur since heat is concentrated at a point and the cooling rate is slow. The thermal expansion coefficient of chromium type stainless steel (SUS 430) is the same as that of mild steel; but that of chromium-nickel type (SUS 304 and SUS 316) is approximately 1.5 times that of mild steel. Where chromium-nickel type stainless steel is used for roofs, therefore, sufficient recessing should be considered for joining of roofing and backing materials.

(C) Magnetism

Chromium type stainless steel has strong magnetism and is drawn to any magnet, while the chromium-nickel type stainless steel normally has no magnetism and is not drawn to magnets. Among the chromium-nickel type stainless steels, there are some steel classes–such as SUS 304--that have magnetism because the metallic structure of the processed part can be transformed during cold processing by such techniques as bending and drawing.

1.3.2 Mechanical properties

The mechanical properties of representative stainless steels are shown in Table-1.5. Table-1.6 compares the mechanical properties of stainless steels with those of various materials. As shown in the tables, there is a lot of difference between the mechanical properties of stainless steel and those of other materials, such as mild steel, copper and aluminium. There is also a difference between chromium type stainless steel and chromium-nickel type stainless steel. Furthermore, there is no clear yield point in stainless steel as opposed to mild steel. Therefore, the stress which is required to produce a permanent set of 0.2% is normally used as the proof stress instead of the yield point.

The mechanical properties of SUS 430 (chromium type) generally resemble those of low carbon steel: the proof stress is high while the tensile strength and elongation are low compared with chromium-nickel type stainless steels such as SUS 304.

On the other hand, though SUS 304 (chromium-nickel type) has low proof stress, the tensile strength is high. It is superior in workability to SUS 430 due to its high elongation and ductility. Accordingly, 180° tight bending does not produce cracking. When SUS 304 is formed and processed as a construction material, attention must be paid to the fact that SUS 304 has remarkable hardenability due to cold working.

Table 1.5 Mechanical properties of stainless steel

Type of material		SUS 304	SUS 316	SUS430	SUS 410
State		Appointed solution treatment	Appointed solution treatment	Annealing	Annealing
Proof stress (0.2%) kgf/mm²		21 and over(29)	21 and over(28)	21 and over(32)	21 and over(32)
Tensile strength kgf/mm²		53 and over(66)	53 and over(65)	46 and over(51)	45 and over(50)
Elongation %		40 and over(57)	40 and over(55)	22 and over(31)	20 and over(31)
Hardness	H R B	90 and below(82)	90 and below(83)	88 and below(81)	93 and below(78)
	H V	200 and below(168)	200 and below(170)	200 and below(163)	210 and below(154)

Remark : These are standard values that were prescribed by JIS. However, numerical value in () is an example of an average measured value of lmm thick sheet.

Table 1.6 Comparison table of mechanical properties of various materials

Type of material		SUS 304	Aluminium alloy (A5052P)	Copper (C1220P)		Galvanized steel sheet
State		Appointed solution treatment	H34	By quality(O)	By quality(H)	Annealing
Proof stress (0.2%) kgf/mm²		21 and over (29)	18 and over (22.0)	–	–	28.5 and over
Tensile strength kgf/mm²		53 and over (66)	24~29(26.5)	20 and over	28 and over	34.5 and over
Elongation %		40 and over(57)	6 and over(10) (t1.6)	35 and over	–	26.7 and over
Hardness	HRB	90 and below(82)	–	–	–	68 and over
	HV	200 and below(168)	–	–	80 and over	123 and over
	HB	–	68	–	(HV0.5 and over)	

Remark 1 : The aluminium alloy H34 is made by stabilization processing after cold rolling. This alloy is classified in the 1/2 hardness class.
Numerical values within parentheses present values of the standard mechanical properties of an aluminium alloy.

Remark 2 : (O) of copper represents a mild material that is finished with an annealing and (H) represents materials hardened by cold rolling. Futhurmore, for roof material, there are also 1/2 and 1/4 hard materials.

1.3.3 Corrosion Resistance

(1) Passive state coating

The superiority of stainless steel corrosion resistance and rust resistance results from the fact that a strong passive state coating (the same as an oxide coating) is formed on the metal surface by uniting the chromium contained in the stainless steel with the oxygen in the air. The passive state coating - a thin film of 3/1,000,000 mm, and invisible to the naked eye – is tight and tough and resists rupture and corrosion. Corrosion of this coating occurs when the following matter adheres to the surface causing red rust to occur:

a. Salt
b. Harmful gas such as sulfur dioxide–in exhaust gas from automobiles or air-conditioning equipment of buildings
c. Harmful gas involved in flue gas from chemical plants
d. Chemicals, such as hydrochloric acid, sulfuric acid, phosphoric acid and chlorine water
e. Washing chemicals for stain removal and descaling
f. Corrosive gas from hot springs

Whenever the causes are removed and the damaged parts contact air, the coating is regenerated by uniting the chromium in the stainless steel with oxygen in the air.

Thus, the corrosion resistance of stainless steel can be semi-permanently maintained so long as the passive state coating on the surface is regenerated. For example, flatware and sinks made of stainless steel become stained with salt, soy sauce, fats and oils and the passive state coating of the surface is damaged. It is washed after use so that the passive state coating is regenerated and the fine appearance is maintained in the long term.

The action of passive state coating and corrosion resistance are further improved when nickel is added in addition to chromium. Stainless steel which has a high chromium and nickel content therefore shows better corrosion resistance. The relative corrosion resistance of the representative steel classes is SUS 410, SUS 430, SUS 304 and SUS 316 in that order.

(2) Transferred rust

When different types of metals come in contact through water, an electrolytic cell or couple is formed and one metal corrodes preferentially to the other. This phenomenon is called galvanic corrosion.

Stainless steel is not subject to galvanic corrosion even when it is in contact with virtually any type of metal, so long as the passive state coating is intact on the surface. Rather, it will accelerate corrosion of the metal with which it is in contact. Red rust occurs promptly on a nail which comes in contact with a stainless steel surface. This is red rust on the nail, and is not rust from the stainless steel.

As mentioned in the above example, rust occurring due to galvanic corrosion is called “transferred rust”. It results from iron powder floating in the air along railroads, and steel, aluminium, copper and other metal debris left after work.

Since transferred rust damages the passive state coating and induces rust of the stainless steel itself when it is left as is for a long time, adequate inspections are necessary to remove it.

1.3.4 Formability

When the stainless steel is processed, attention should be paid to its proper processing.

(1) Spring back

A metal characteristically springs back when an added load is removed, if it has been transformed by adding the force. This is called spring back.

The spring back of stainless steel is greater than that of mild steel or aluminium. Therefore, when bending, the angle should be set at 2° to 3° less than the desired angle so as to achieve the desired angle. For example, it is better to set the bending angle at about 88° in order to maintain angle of 90°.

(2) Minimum bending radius

When a metal is bent, tensile stress is added to the fibres on the outside of the bend and compressive stress to the fibres on the inside of the bend. A crack occurs on the outside of a plate when the outside elongation exceeds a certain limitation. The processing limit in which a crack will not occur in the plate is called the minimum bending radius, and the value depends on the stainless steel type. A crack does not occur in SUS 304 when a 180° tight bend is made, while for SUS 430 a crack may occur when the inner radius of the bending is too small. The minimum bending radii of the representative types of stainless steel are compared with those of other metallic materials in Table-1.7.

Table 1.7 Minimum bending radius (inside) of various annealed metallic materials

Type of material	SUS 410	SUS 430	SUS 304	Mild steel (SPCC)	Copper (C1220P)	Aluminium (A5052P)
Minimum bending radius	(0.5～1.0)t	(0.5～1.0)t	(0～0.5)t	(0～1.0)t	(0～1.0)t	(0～1.5)t

Remark 1 : All materials are finished by annealing.
Remark 2 : “t” indicates the thickness (mm) of a material.

(3) Cold work hardening

Metals have the general characteristic of increased deformation resistance and hardening when bending or drawing is done at room temperature; this is called work hardening. Aluminium, mild steel and stainless steel have greater work hardening, in that order, among general building materials. In particular, since the work hardening of SUS 304 and SUS 316 is greater than that of SUS 430, it is difficult to correct a bent part if it has been bent improperly. Accordingly, it is necessary to perform the bending process correctly the first time.

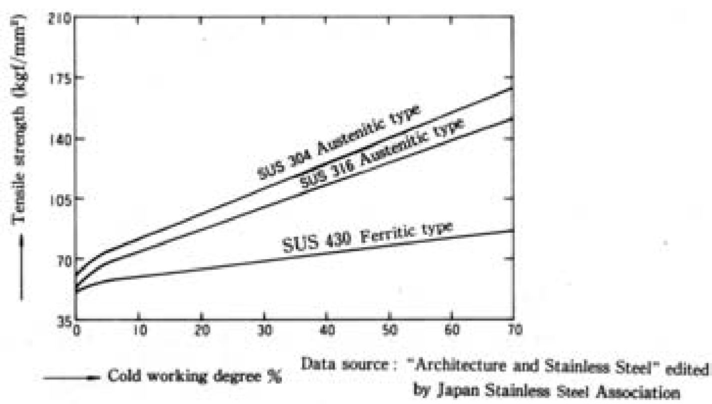


Figure 1 .1 Work hardening by types of stainless steels

(4) Shearing resistance

Methods such as the intercept, punching, notching, and trimming are called shearing working methods. Since shearing working is performed as preprocessing in normal forming working, when there is a failure, the materials will be wasted and there will be an influence on the finished state of the product.

Stainless steel is hard and tough. Greater shearing force is required for stainless steel than for mild steel. In particular, austenitic stainless steel – SUS 304 and SUS 316 – has a shearing resistance of approximately 1.5 times greater than that of mild steel.

Attention should be paid to selection of the shearing machine, the wear of the cutting blade and/or the clearance between the cutting blades.

1.3.5 List of characteristics of stainless steel type

The basic characteristics of stainless steel, and other characteristics related to stainless steel as a building material, are briefly listed in Table-1.8.

Table 1.8 Characteristics by types of stainless steel

Type of material / Characteristics	Austenitic type (18−8 types) SUS 304, SUS 316	Ferritic type (18 chromium types) SUS 430	Martensitic type (13 chromium types) SUS 410
Magnetism	No	Yes	Yes
Hardenability by quenching	No	No	Yes, but materials with high carbon content crack easily after cooling.
Work hardening	High work hardenability. Types containing high nickel content have lower hardenability.	A little hardening by cold work	Work hardening of the same trend as mild steel is shown.
Corrosion resistance and anti weatherbility	Superior characteristics.	Inferior to austenitic type.	Inferior to ferritic type.
Impact and elongation	Excellent. Good formability	Inferior to austenitic type.	Same as ferritic.
Weldability	Excellent. Requires quick cooling from 800 to 500℃ after welding.	Inferior to austenitic type. Heat affected zone grain growth and embrittles	No good. Welding requires pre and post heating to avoid weld cracks.
Low temperature resistance	Sufficient toughness is retained even to -200℃.	Inferior to austenitic type.	Same as ferritic.
Anisotropy	It is almost nonexistent.	Yes. Bends at right angles to the rolling direction.	Yes
Thermal expansion	About 1.5 times that of mild steel.	Almost the same as mild steel.	Same as ferritic
Thermal conductivity	About 1/3 that of mild steel.	1/2 that of mild steel.	Same as ferritic

Remark : The presence of magnetism is checked after annealing.

2. Types and Features of Stainless Steel Roofing

2.1 Types of stainless steel roofing

The following four types of stainless steels are used as roofing materials.

(1) Noncoated stainless steel

(2) Precoated stainless steel

(3) Chemiluminescent coloured stainless steel

(4) Plated stainless steel

These stainless steels exhibit different features as roofing materials. Their optimum use requires understanding the features of each material.

2.2 Noncoated stainless steel

(1) Material and steel class

Noncoated stainless steel is made of cold rolled stainless steel sheet (JIS G 4305) or cold rolled stainless steel strip (JIS G 4307). SUS 304, SUS 316 and SUS 430 are the main steel classes used. Other proprietary steel classes are used as well as Japanese Industrial Standard products.

Generally, the above materials are annealed for ease of machine cutting and bending. It is, however, not easy to cut them with snips or bend by hand as required in roofing work.

(2) Surface

Since noncoated stainless steel is silver white and highly reflective if uncoated, a surface finish such as 2D, 2B or HL (hair line) is applied to the roofing materials to be used, in accordance with the Japanese Industrial Standard. 2D is an eggshell finish in dull grey, 2B is a smoother and glossier finish than 2D, and HL is a finish having a long and continuous polished or scratched surface (see Annex Table 1).

Even if such a surface finish is used, stainless steel sheet has high reflectivity and can render a roof quite bright. Stainless steel should be used only after studying the surrounding environment of where the roof is to be constructed.

A noncoated stainless steel is also produced in which a film is attached to the surface. This film is a coating to protect against transferred rust due to contact with work tools, (such as a roll molding machine), or transferred rust due to steel powder (from nails, bolts, nuts, and steel material powder), which contacts the roof during assembly work. If left alone, it will deteriorate and break away. In the process of deterioration it will leave the roof looking shabby and mottled. The film therefore should be promptly removed after completion of the work.

(3) Corrosion resistance and weatherability

Since noncoated stainless steel leaves the surface exposed to the air, attention should be paid to the following two points:

a. It may happen that transferred rust from materials such as steel powder becomes attached to the roof. This transferred rust does not damage the stainless steel itself, but in many cases the fine appearance of the roof will be spoiled in those sites where airborne steel powder is present.

b. It may happen that red rust occurs on the surface due to salinity. This red rust is the corrosion of the stainless steel itself. According to the results of atmospheric exposure tests carried out in many areas of Japan, however, the loss in weight of stainless steel is extremely small.

It is desirable that steel classes superior in corrosion resistance, such as SUS 316, are used in coastal areas so that their fine appearance is not spoiled.

Table 1.9 Regional corrosion weight loss (g/m^2) for five years' atmospheric exposure

Area / Material quality	Pacific coast area		Sea of Japan coast area	Inland area		Industrial area	
	Omaezaki	Makurazaki	Wajima	Takayama	Obihiro	Kawasaki	Tokyo
Ordinary steel	822	636	549	381	337	3112	1404
Weathering high-tensile-steel (50k)	598	409 *	383	280	287 *	1434	876
SUS 304	6 $\times 10^{-2}$	12 $\times 10^{-2}$	7 $\times 10^{-2}$	11 $\times 10^{-2}$	12 $\times 10^{-2}$	67 $\times 10^{-2}$	74 $\times 10^{-2}$
Aluminium alloy	108 $\times 10^{-3}$	81 $\times 10^{-3}$	80 $\times 10^{-3}$	48 $\times 10^{-3}$	85 $\times 10^{-3}$	1663 $\times 10^{-3}$	580 $\times 10^{-3}$

Note : * Corrosion weight loss for four years.
Data source : An extract from the "Study of Various Metallic Materials and Rust Preventive Coatings", edited by the Committee of Rust Prevention for Steel Structures.

(4) Advantages and disadvantages of stainless steel sheet as a roofing material

Advantages:

a. Creates the impression of space.

b. Ease of welding. Pretreatment and post treatment are easier than for precoated stainless steel

c. Lower cost than other roofing stainless materials

Disadvantages:

a. Colourless

b. High light reflectance. Distortion is emphasized.

c. The occurrence of transferred rust due to steel powder or red rust caused by salt air is inevitable in certain environments. In such locations, cleaning should be carried out frequently to maintain the original appearance.

2.3 Precoated stainless steel

(1) Material and steel class

The original precoated stainless steel sheet is made of cold rolled stainless steel sheet (JIS G 4305) or cold rolled stainless steel strip (JIS G 4307). SUS 304 and SUS 430 are the main steel classes. Proprietary steel classes are also used. Since annealing is generally used for these original sheets, it is superior in workability.

(2) Surface

A high-quality organic coating material is baked onto the as-rolled surface. There are two types of coating materials, Clear and Colour, for which the specifications and performance are provided in the JIS G 3320 (see Reference at the end of this book).

(3) Corrosion resistance and weatherability

Corrosion resistance of precoated stainless steel is excellent, as indicated in Table 1.10. Therefore, it is only rarely possible that transferred rust due to steel powder or red rust caused by salt air (salinity) occur. The coating will naturally fade, gloss will be lost and the base will eventually be exposed.

Table 1.10 Corrosion resistance of coating

Item	Test name	Testing method	Evaluation method
Corrosion resistance	Salt spray test	JIS G 3320	1000 hours after, test piece shall be free from defects such as rust or blisters.
Chemical resistance	5 % sulfuric acid	Normal temperature, 24 hours	Test piece shall be free from rust and blisters.
	5 % sodium hydroxide	〃	〃
	3% sodium chloried	〃	〃
	5 % acetic acid	〃	〃
Accelerated weathering	Sunshine weather meter test	JIS A 1415	Test piece shall be free from abnormality after 2000 hours.

(4) Coating strength

The strength of the coating is assured as indicated in Table 1.11, in accordance with JIS G 3320. Attention should be paid to damage caused when the coating is scratched with a metallic brush or when extreme bending or drawing is performed.

Table 1.11 Strength of coating (JIS G 3320)

Test item	Outline of test method	Condition after testing
Lattice pattern cutting test	Cut the lines of the lattice pattern to reach the base materral through the coating at intervals of using a single-edged safety razor, etc	No defect on the tested portion.
Impact test	A weight is dropped on a specimen from top of Dupont's impact testing machine.	No peeling from the base metal and no cracking on coating.
Bend test	180 degrees bend with coated surface on the outside of bend.	No peeling of coating on the outside of the bent portion at any place not less than 7mm from each side edge of the test piece.
Pencil hardness test	Line writing is done with a pencil of H hardness.	No scratch mark on the coating.

(5) Fire prevention performance

Superior fire prevention performance is assured by passing the qualification test for fire prevention performance of noncombustible materials (Noncombustible material, No. 1006).

(6) Advantages and disadvantages of stainless steel sheet as a roofing material:

Advantage:

a. The occurrence of transferred rust caused by the attachment of steel powder can be avoided.

b. Precoated stainless steel does not rust when it is exposed to corrosive gas or salt air.

c. Various colours can be selected.

d. A glare shield effect can be achieved.

e. Distortion is not great.

f. Cutting and bending is superior because annealing is used.

Disadvantage:

a. The coating may be damaged when working or fitting if sufficient care is not taken.

2.4 Chemiluminescent coloured stainless steel as a roofing material (Inco Colour)

Stainless steel is widely used in utensils and appliances as well as in construction materials. It is used to take advantage of the attractive appearance of the stainless steel itself, but its colourlessness is undeniable. For this reason, chemiluminescent coloured stainless steel was developed to maintain the characteristics of stainless steel and to have colour. Originally, it was developed for relatively small appliances. It now can be used for regular size plates and steel strip. Chemiluminescent coloured stainless steel has five standard colours- red, gold, green, blue and black.

(1) Material and steel class

SUS 430 is provided mainly in cold rolled stainless steel sheet (JIS G 4305) and cold rolled stainless steel strip (JIS G 4307). As a matter of course, any steel class similar to SUS 430 can be used,with the colour tone being a little different for each steel class.

(2) Surface

When stainless steel is immersed in a mixed aqueous solution of chromic acid and sulfuric acid, a transparent passive state coating forms on the surface. The passive state coating formed in the air does not exceed a constant thickness, but the passive state coating formed in this mixed aqueous solution becomes thicker with time. When the coating is thicker, colour sense is produced due to light interference, and the tone of colour changes according to the coating thickness. INCO Colour stainless steel is produced by forming a 0.1 or 0.2 micron thick coating (approximately 50 times the thickness of the normal stainless steel passive coating), and by performing a special hardening treatment on the surface coating to protect it from changes in colour tone during use.

(3) Corrosion resistance and weatherability

Since INCO Colour stainless steel has a thick passive state coating, its corrosion resistance is superior to that of normal uncoated stainless steel. On the other hand, the maintenance of the initial colour tone depends on the weatherability of the hardening treatment. According to various accelerating test results and experience in actual buildings, however, good performance can be expected.

(4) Advantages and disadvantage as a roofing material

The surface coating of INCO Colour stainless steel is hard and difficult to damage. But, damaged, it is difficult to restore.

2.5 Plated stainless steel

Copper plated stainless steel is a roofing material where stainless steel provides the strength and copper plate the design appearance characteristics of copper.

(1) Material and steel class

The material is a cold rolled stainless steel strip (JIS G 4307) which is annealed to improve formability and workability. This is because the similarity of the natural currents of copper and stainless steel makes it necessary to control galvanic corrosion caused by the contact of different types of metals at the cut end face, and because SUS 304 is the most appropriate steel class.

(2) Surface state

Copper electroplated stainless steel has a glossy appearance resembling copper plate. Normally, the quantity plated on the weather side is greater than that on the back side. A polished mark is placed on the back side to distinguish it.

(3) Corrosion resistance and weatherability

The copper plated layer produces the surface changes characteristic of copper in air and also produces verdigris in good conditions. Abrasion loss is as described in Table 1.12, and the copper plated layer is maintained for more than 10 years under normal conditions. The stainless steel base metal will be exposed eventually, but the roofing function can be maintained for a long period, as is the case with precoated stainless steel sheet. When it is desirable to maintain the appearance after exposure of the stainless steel, it is possible to restore the appearance with a coating material.

Table 1. 12 Example of abrasion loss of copper

Area	Kiryuu	Awa Shirhama	Sado	Kure	Amagasaki
Environment	Country	Beach	Beach	Seashore industrial area	City heavy industrial area
Abrasion loss (μ/year)	0.2	1.0	0.75	0.8	0.9

Data source : Nisshin Steel Co. Ltd.

(4) Advantages and disadvantages of copper plated stainless steel as a roofing material

Advantages:

a. The initial transferred rust can be avoided.

b. A calm colour tone characteristic of copper develops after about three to six months.

c. Since it has greater strength than copper alone, lengthy components can be fabricated and handled.

Disadvantages:

a. It can develop a mottled appearance just after plating.

b. The copper plating can become locally worn away if the upper roofing material is roofing tile or sited in locations where rainwater drips.

c. The durability of copper plating is not permanent, and the bare surface of stainless steel is

3. Maintenance of Stainless Steel Roofing

3.1 Necessity of maintenance

Stainless steel is superior in corrosion resistance and is a metal that resists rust well when compared with mild steel or aluminium. But stainless steel can stain or rust, depending on the conditions of use and the environment. If daily maintenance is neglected, staining and rust can become noticeable; so cleaning measures should be taken promptly.

Corrosion and rust resistance of stainless steel is due to the fact that the chromium element contained in the steel forms a strong passive state coating on the surface by combining with oxygen in the air, and this passive state coating prevents further oxidation on the bare surface, protecting the surface from further corrosion. If this coating is left damaged, or the combination of oxygen with chromium is cut off, rust appears on stainless steel.

The passive state coating is regenerated, however, and the function of corrosion resistance is restored after removing the corrosion causes and allowing the chromium to combine with oxygen.

There are various causes of fouling or rust on stainless steel. In many cases, it is caused by the attachment or deposit of steel powder floating in the air, by elements in harmful gas, or by the attachment of salinity from salt air. Rust of stainless steel refers to the condition where that which attaches itself rusts in site, or the condition where the passive state coating is damaged. The rust can be easily removed in the initial stages, and the surface passive state will be restored.

Even if this rust is left as is for a long period, its appearance can be almost completely restored by appropriate cleaning.

Rusting of stainless steel is fundamentally different from that of mild steel and aluminium– stainless steel rust presents only the appearance of rust and is not corrosion of the material itself. Therefore, maintenance of stainless steel roofs is performed for sustaining the fine appearance and not for maintaining the waterproofing ability (as is the case with mild steel or aluminium roofs).

The design or execution of stainless steel roofs should be performed after having the owner of the building sufficiently understand the fouling and rust of stainless steel roofs. Maintenance of its fine appearance may be necessary and require periodical cleanings depending on the environment. The owner should be made aware of these requirements.

3.2 Causes of rust and staining

(1) When sediment or dust splashed from road construction work, building or vehicles becomes deposited.

(2) When steel powder floating in the surrounding air along railroads, from iron works or from garages or other sources becomes attached.
(3) When the stainless steel is exposed to sulfur dioxide or other harmful components of exhaust gas from automobiles.
(4) When it is exposed to the smoke dust emitted from factories, incinerators, air-conditioning equipment, or harmful components of exhaust gas.
(5) When it is exposed to corrosive gas found in hot spring regions.
(6) When the salinity of the salt air in the coastal area becomes attached.
(7) When cleaning chemicals become attached.
(8) When fingerprints or dirt from handling become attached.

3.3 Care and cleaning of coated and noncoated stainless steel roofs

3.3.1 Care and cleaning of noncoated stainless steel roofing

(1) Transferred rust

a. Light transferred rust

Transferred rust due to steel powder can be easily and cheaply removed when it is wiped up when still red with a sponge or cloth soaked in neutral detergent or a soap-and-water solution followed by rinsing and wiping dry.

b. Heavy transferred rust

When the transferred rust is left for a long time it will be transformed into a heavy rust mixture such as iron hydroxide, iron oxide and iron sulfur dioxide. Such rust can be removed by using commercial cleaning chemicals or 15% nitric acid. In cases where the rust still cannot be removed, the stainless steel surface should be polished by scouring off the rust with emery paper or a stainless brush to the extent that the stainless steel surface is slightly damaged. After the rust is removed, sufficient wiping with water is necessary to wash off the cleaning chemicals.

(2) Rust due to the attachment of harmful components of exhaust gas or corrosive gas

The stainless steel surface becomes dirty easily in industrial zones or urban districts, and it appears as fine spotted rust. In many cases, this is caused by the harmful components of exhaust gases from automobiles or air-conditioning equipment and industrial flue gas. In the case of relatively light staining, it can be easily cleaned by using neutral detergent or a soap-and-water solution followed by rinsing.

(3) Rust due to the attachment of salinity

When stainless steel is exposed to the salt air of coastal zones, red rust occurs relatively quickly on SUS 304, and more so with SUS 430, and more rapidly than in other environments. It can be removed by the same method as described in (1).

In coastal districts, it is desirable to clean the stainless steel surface periodically, i.e., two to three times annually.

When stainless steel roofs are constructed in coastal zones, SUS 316, which is superior in corrosion resistance to SUS 304 or precoated stainless steel, should be adopted.

(4) Rust due to the attachment of cleaning chemicals

This kind of rust should be removed with a neutral detergent or soap-and-water solution. If that is impossible, cleaning chemicals should be used, followed by water rinsing.

(5) Staining due to dirt from fingerprints and handling

These stains should be removed with neutral detergent or a soap-and-water solution. If the surface is not easily cleaned, it should be wiped with a sponge or cloth soaked in an organic solvent, such as alcohol, benzene and acetone. If this is insufficient, cleaning chemicals for stainless steel should be used. In each case, careful rinsing and wiping should be done after cleaning.

3.3.2 Care and cleaning of precoated stainless steel roofing and chemiluminescent coloured stainless steel

Since the surface of precoated stainless steel is protected by the coating film, rust does not occur as long as the film is not broken down. It is inevitable that surface staining will occur due to the attachment of steel powder and sediments. When the surface shows staining, careful cleaning should be carried out, paying attention to the following items.

(1) Dirt and steel powder attached on the surface should be lightly wiped off with a soft cloth.

(2) Fingerprints and oil should be lightly wiped off with a soft cloth soaked in a water-soluble neutral detergent, then wiped off with water and finally, the moisture should be wiped off with a dry cloth.

(3) Use of a metallic brush or coarse detergent using grit or scouring powder should be avoided because the coating film will be damaged.

(4) Since organic solvents, such as alcohol, benzene and acetone, dissolve the coating film and disturb the colour tone, they should not be used even if they can remove fats and oils, except in case of chemiluminescent coating.

(5) Acidic or alkaline detergents, such as hydrochloric acid, nitric acid, cleaning agent for tiles and caustic soda should not be used because discolouration occurs when they are used.

(6) Commercial cleaning chemicals except for neutral detergent should not, in principle, be used. Particularly, cleaning chemicals used for descaling should absolutely not be used. If staining or rust remains after using a neutral detergent, a part of the stain should be cleaned by using a commercial cleaning chemical as a trial, and should be used after confirming that no abnormality occured on the surface coating.

3.3.3 Precautions for care and cleaning

(1) Noncoated stainless steel roofs

a) The cause and state of staining and rust depend on the individual case. It is best to devise the most appropriate care and cleaning method according to the actual conditions.

b) When cleaning chemicals are used to remove stains and rust, the cleaning effect should have been previously tested by carrying out a trial wiping on a part of the surface. If a successful. result is obtained, cleaning should be commenced. Not only the stained and rusted parts, but the surrounding parts should also be cleaned as well as possible. Unless all parts of the surface are cleaned, its appearance will look shabby because of the irregularity of the surface gloss.

c) The surface should be sufficiently rinsed with water after using cleaning chemicals so as to remove residual chemicals. If left as is, it will be the cause of new rust. Furthermore, some cleaning chemicals cause skin problems; so the work should be carried out using rubber gloves.

d) Cleaning tools, such as cloths, natural sponges, nylon sponges, and scrubbing brushs should be used in the direction of the polishing finish. If a circular motion is employed, it is difficult to remove stains and a shabby appearance results.

Furthermore, the use of a coarse cleanser or emery paper is absolutely prohibited except for cases where heavy fouling must be removed, because fouling damages the stainless surface and causes rust by allowing steel powder to become attached.

(2) Precoated stainless steel roofs and chemiluminescent coloured stainless steel roofs

a) Acidic or alkaline detergents, such as hydrochloric acid, nitric acid, cleaning agents for tiles and caustic soda should not be used because discolouration will occur.

b) Commercial cleaning chemicals, except for neutral detergents, should not, in principle, be used. In particular, cleaning chemicals for descaling should absolutely not be used. If the stains or rust are left after using a neutral detergent, a part of the stain should be cleaned using a commercial cleaning chemical as a trial; if no abnormality occurrs in the surface colour tone, then it can be used.

Part 2 STAINLESS STEEL STRUCTURAL ROOFING

This Part explains the materials used for stainless steel roofs, and the roofing structural method. Since the mechanical properties of stainless steel sheet are not different from those of normal galvanized sheet, there are almost no differences between the structural methods for stainless steel sheet and those for galvanized sheet.

Therefore, the structural roofing method is mainly explained from the view point of determining the extent to which stainless steels should be used for various parts which are utilized to fix to the roof backing. The size of each portion necessary to secure against high wind is not, in principle, mentioned here. For details, it would be better to consult the “Structural Standards for Roofs of Steel Sheet” (published by the Japan Galvanized Sheet Association, in 1977) .

The parts to be used in Chapter 1 of Part 1 show the type of material of the parts which are used in various structural roofing methods and the structural method for gutters mentioned in Chapter 2 and thereafter. However, Part I will be referred to for selecting which one is desirable among the various potential material types.

The figures printed in “red” in this Part refer to stainless steel materials. Furthermore, hinoki (Japanese cypress) is sometimes recommended as a material type. This is because hinoki deteriorates little, assuming that stainless steel used with other woods is not durable. As a matter of course, even if hinoki is recommended, other woods may be used if they have more deterioration resistance and strength than hinoki.

Chemicals such as creosote are generally used in preservative treated woods. These chemicals can corrode stainless steel; so they should not be used.

1. Parts

The four types of roofing stainless steel sheet mentioned in Part I are used as a roofing materials for V-beam roofs and flat lock-seam roofs. In this chapter, the stainless steel sheet roofing parts necessary for roof construction are explained.

1.1 V-beam roofing parts

Table 2.1 Parts for V-beam roofing

Part name	Example of material used	Surface treatment	Mechanical properties	Remarks
Fixing bolt Joint bolt	SUS 430 SUS 304 SUS 305 SUS 305J1 SUS 316 SUS XM7		Equivalent to 4T	
Fixing nut Joint nut	Same as the above		Same as the above	
Waterproof washer Waterproof joint washer Joint flat washer	Same as the above			
Fixing packing Joint packing	Chloroprene type rubber			
Tight frame	SPHC SPCC	HDZ 40 and over	Tensile strength 28kgf/mm² and over	Used under normal environmental conditions
	SUS 430 SUS 304 SUS 316			Used under corrosive environmental conditions
Fixing metal fittings	Same as the above			Same material as roofing material
Eaves closer End closer Ridge covering Apron Eaves frame	Same as the above			Same as the above
Deformation preventive piece	Same as the above			Same as the above
Barge suspension piece	Same as the above			JIS G 4317 "Hot Rolled Stainless Steel Equal Leg Angles"
Small screw Nut for a small screw	Same as fixing bolt			
Washer for a small screw Waterproofing washer for a small screw	Same as fixing washer			

Non-shaped sealing compound	Silicon type			Contorms to the JIS A 5755
Shaped sealing compound	Chloroprene rubber			
Rivet	SUS 305			Blind rivet

1.2 Parts for flat lock-seam roofing

The parts to be used for flat lock-seam roofing should be selected in accordance with Table 2.2.

Table 2.2 Parts for flat lock-seam roofing

Part name	Example of material used	Mechanical properties	Remarks
Small screw	SUS 430 SUS 304 SUS 305 SUS 305J1 SUS 316 SUS XM7		
Nut	Same as the above		
Flat washer	SUS 430 SUS 304 SUS 316		
Packing	Chloroprene type rubber		
Hook bolt	SUS 430 SUS 304 SUS 305 SUS 305J1 SUS 316 SUS XM7	Equivalent to Table 2.5	The nut is same as that for the small screw
Tortoise washer	SUS 430 SUS 304 SUS 316		
Nail	SUS 304		
Rivet	SUS 305		Blind rivet
Tapping screw	SUS 410 SUS 430		Including screws having corrosion control head
Sleeper	SUS 304 Plastic		
Backing material	Asphalt-saturated felt 17 kg/roll and over		
Soft solder	Sn content 60~65 %		JIS 3282 H60S~H65S
Non-shaped sealing compound	Silicone type		JIS A 5755
Shaped sealing compound	Chloroprene type rubber		
Corrugated eaves closer	Chloroprene type rubber		Including foaming agent
Joiner			No standard has been determined

1.3 Combination of stainless steels of different steel classes

Since the difference in electric potential between various classes of stainless steels is much smaller than that between different metals (such as between stainless steel and mild steel, between stainless steel and copper, and between stainless steel and aluminium), problems concerning the strength due to the electric potential are rare.

Electric potential causing red rust can occur, however, depending on the method of combining steel classes. Roofing materials and other parts should be selected after taking into account the following points,

(1) The best method is to use the same steel class throughout.

(2) When different stainless steel classes are selected, it is best to combine stainless steels having the same metallic structure.

The metallic structures of the various steel classes indicated in Tables 2.1 and 2.2 are as follows:

Table 2.3 Structure of metal of each class for parts

Structure of metal	Class
Martensitic structure	SUS 410
Ferritic structire	SUS 430
Austenitic structure	SUS 304, SUS 316, SUS 305, SUS 305J1, SUS XM7

(3) When steel classes having different metallic structures are combined, parts having a small area should be of a higher grade than those of large area. The rough order of the stainless steel grades is as follows:

Austenitic type ——————- Ferritic type —————- Martensitic type high
grade <———————————————————— > low grade SU5316 ————
———————- SUS430 ———————- SUS410 SUS305
SUS305JI
SUS304
SUSXM7

(4) If steel classes having different types of metallic structures are combined, it is preferable to carry out corrosive protection treatment, such as touching up and caulking on the small parts if they are of lower grade than the large parts.

Since fastener materials such as screws and bolts used for the stainless steel sheet roofing provide the strength and integrity, the steel classes actually manufactured are, in many cases, limited. Care should be taken in selecting the above materials.

Recommended combination of roof materials with the above fastener materials is as follows, taking into account corrosion resistance:

Table 2.4 Combination of roof material and bolt and screw fastener materials

Class of roof material	Screw and bolt material	
	Desirable class	Class used after corrosion control processing
SUS 304, SUS 316	SUS 304, SUS 316, SUS 305, SUS 305J1, SUS XM7	SUS 430, SUS 410
SUS 430	SUS 304, SUS 316, SUS 305, SUS 305J1, SUS XM7, SUS 430	SUS 410

The mechanical properties of the stainless steel materials are indicated in Annex Table 2. The mechanical properties of the stainless steel bolts differ according to the manufacturer because of the lack of a unified standard. Therefore, in the case where stainless steel bolts are used, it is necessary to ensure that mechanical properties conform to specification requirements and establish the need for caulking during installation.

The hook bolt should be more than the tensile strength indicated in Table 2.5. Furthermore, yield strength should be at least 1/3 the tensile strength.

The shapes of the V-beam roofing parts are shown in Figs. 2.1 and 2.2, and Fig. 2.3 shows how to use them.

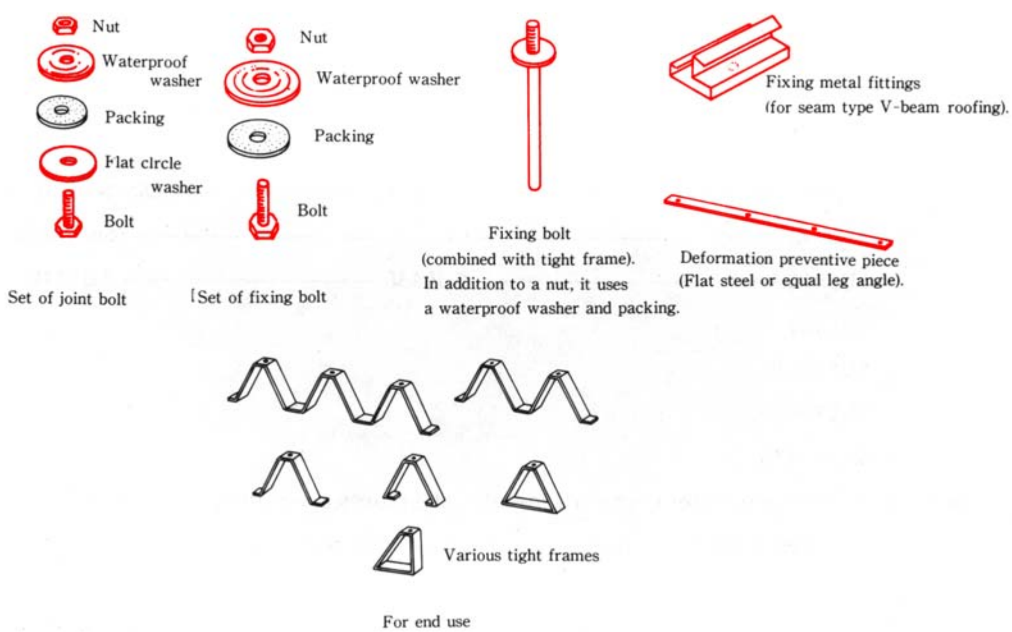


Figure 2.1 Connecting parts for V-beam

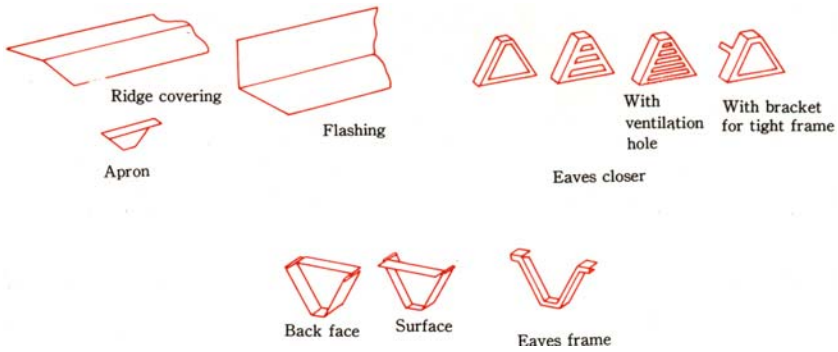


Figure 2.2 Parts for V-beam roofing

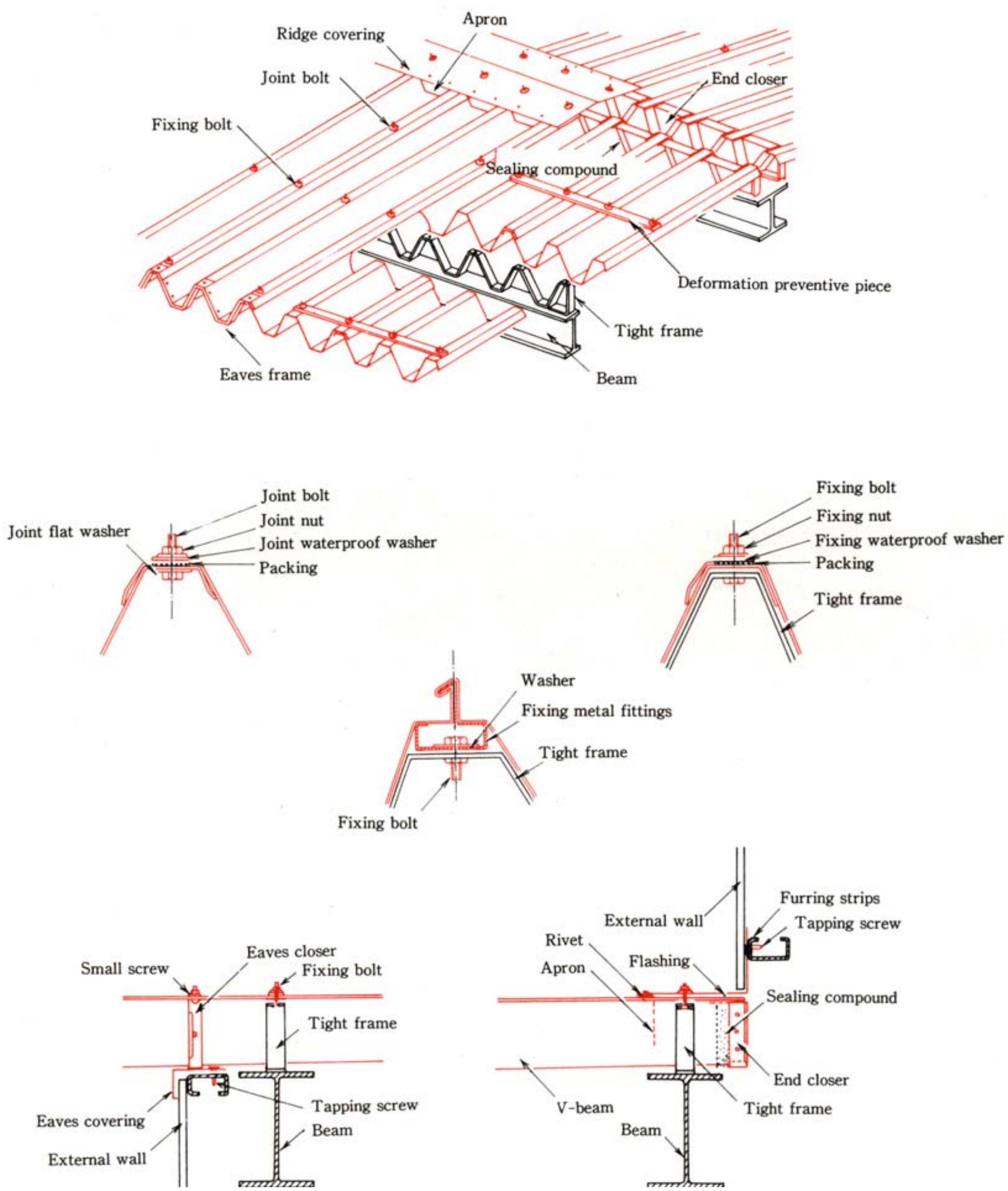


Figure 2.3 Example of usage of parts

The hook bolt should be of greater tensile strength than indicated in Table 2.5.

Table 2.5 Allowable temporary stress loading for various hook bolts,

kgf/bolt

Kind of hook bolt / Bolt diameter	L type hook bolt	Pipe bolt (50)	Pipe bolt (34)	Channel bolt	L type hook bolt
M6	40	7	12	27	85
M5(reference)	30	—	—	—	—

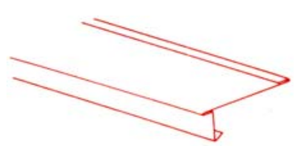
Figs. 2.4 and 2.5 show how to use the accessory flat lock-seam roofing and corrugated sheet roofing parts.

The accessory parts used in flat seam-lock roofing and corrugated sheet roofing are roughly as indicated in Table 2.6.

Table 2.6 Roof structural method and these parts

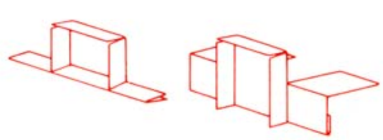
Roof structural method / Name of parts	Shaft type batten seam roofing	Nonbatten seam roofing (partial channel clip)	Nonbatten seam roofing (continuous channel clip)	Standing seam roofing	Dovetail joint roofing	Corrugated sheet roofing
Channel clip	○	○	○	○	○	×
Barge flashing	○	○	○	○	○	×
End cap	○	○	○	×	×	×
Closer	×	×	×	×	×	○
Barge covering	△	△	△	△	△	△
Ridge covering	△	△	△	△	△	△
Flashing	△	△	△	△	△	△

○: Necessary items.
△: Used depending on the case.
×: Not used.



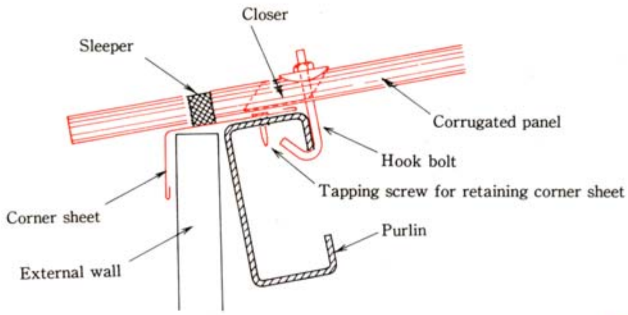
Barge flashing used for roofing sloped by 10/100 and over.

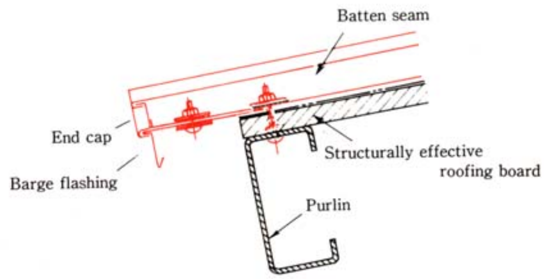
Barge flashing used for roofing sloped by 10/100 and less.

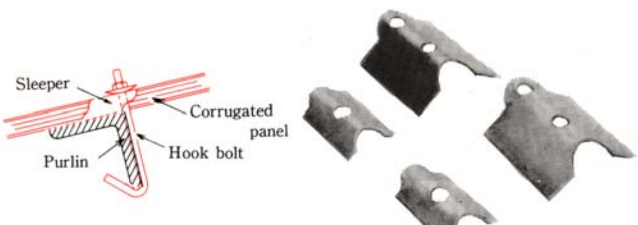


End cap for nonshaft type batten seam roofing.

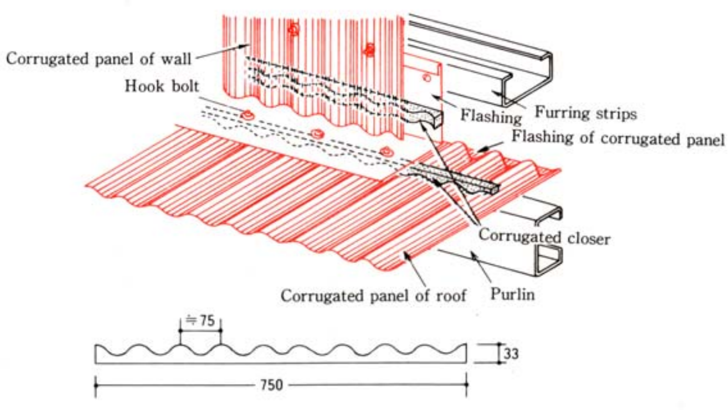
Figure 2.4 Parts for lock-seam roofing





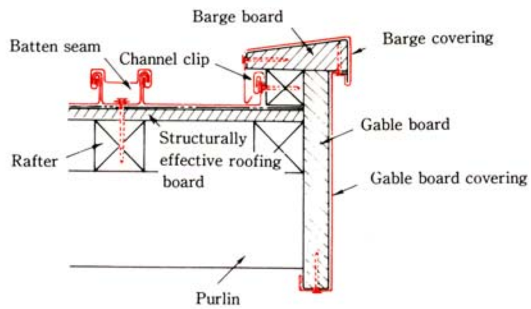


Sleeper and an example of the way to attach

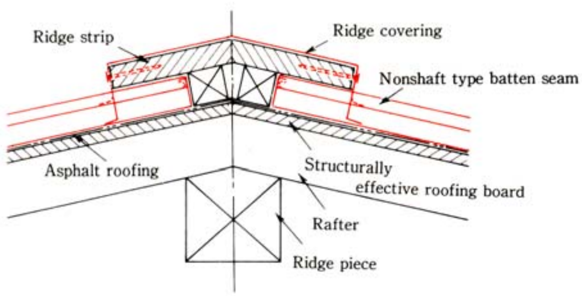


Example of a corrugated closer

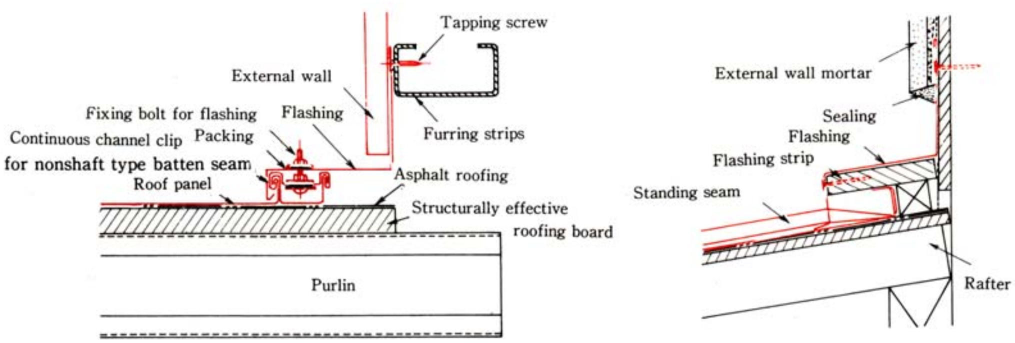
Figure 2.5 Example of use of parts for flat lockseam and corrugated roofing (No. 1)



Example of use of barge covering



Example of use of ridge covering



Example of use of flashing between roofing and side wall

Figure 2.5 Example of use of parts for flat lock seam and corrugated roofing (No. 2)

2. V-Beam Roofing

The V-beam roofs should be designed and constructed in accordance with steel sheet roofing standards.

How the materials and parts are used, in terms of the fitting of each part, is indicated below by steel class.

2.1 Eaves

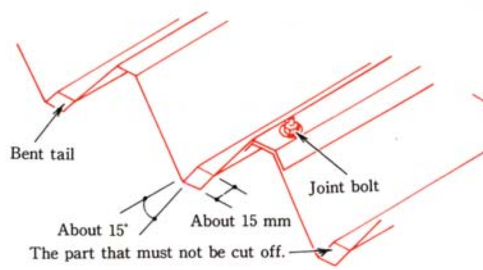


Figure 2.6 Eaves fabrication

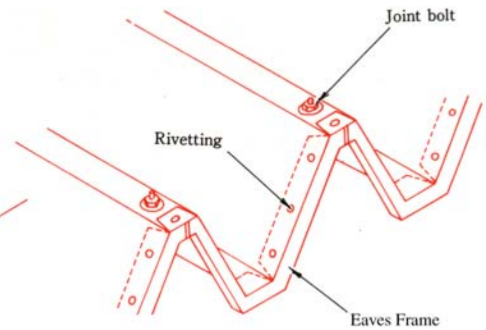


Figure 2.7 Eaves frame

2.2 Outlet

The circular type outlet should be used. Rectangular and square types should not be used. If one outlet is insufficient, two outlets should be installed.

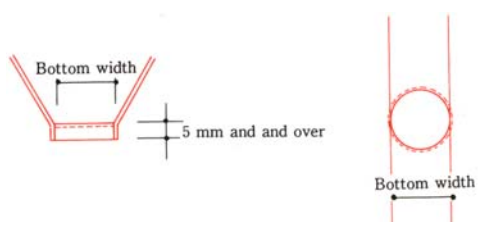


Figure 2.8 Gutter outlet

2.3 Eaves closer

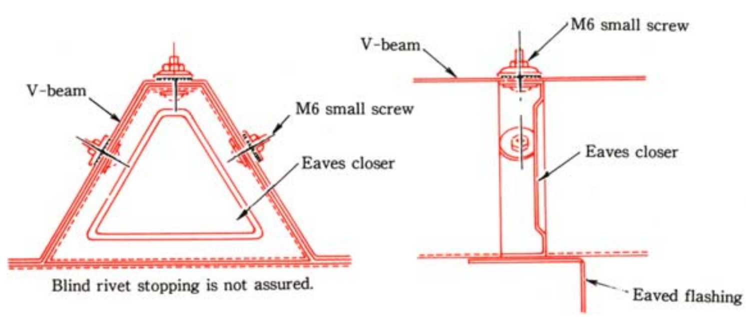


Figure 2.9 Example of installation of eaves closer

2.4 Barge

There are two methods of fitting the barge: one reinforces the V-beam of the barge ends by using deformation preventive pieces, and the other method uses a barge covering.

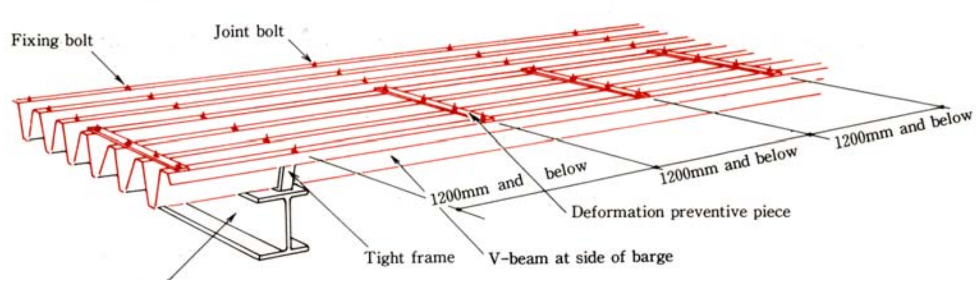


Figure 2.10 Barge fabrication with a deformation preventive piece

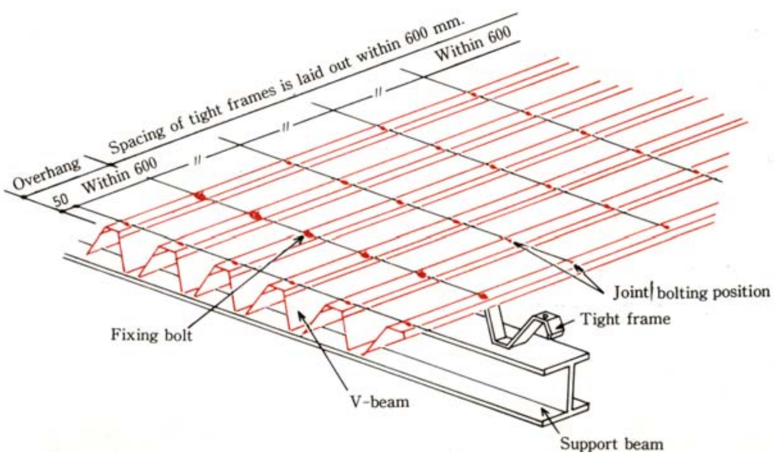


Figure 2.11 Example of layout of joint bolts

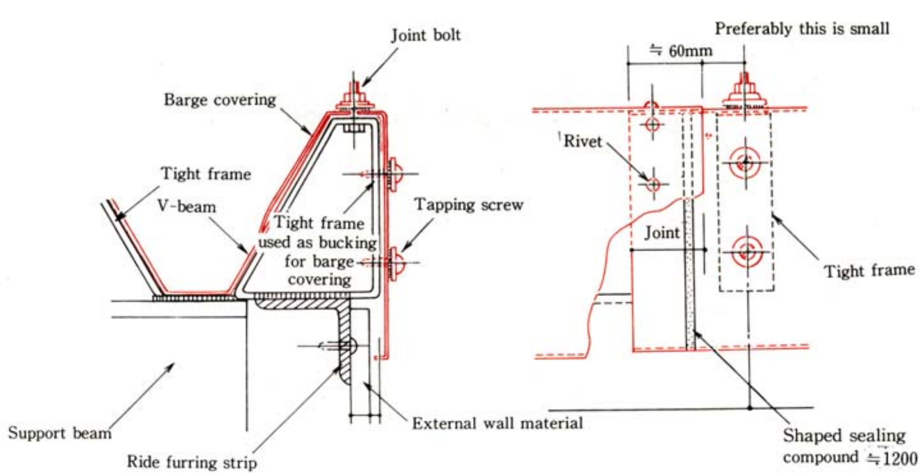


Figure 2.12 Barge fabrication with barge covering

2.5 End closure

An insert type end closer is normally used but a riveting method is also applied.

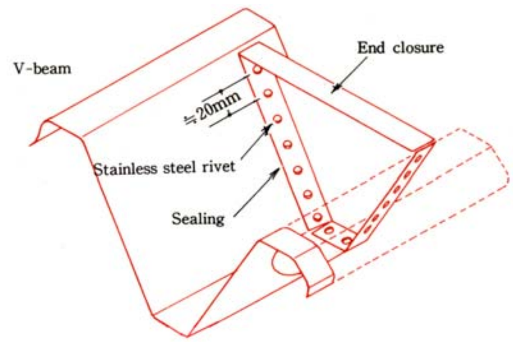
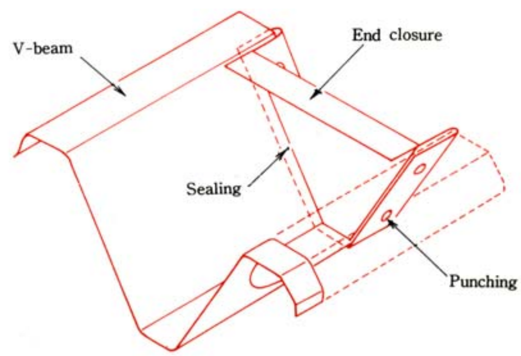


Figure 2.13 Riveted end closure



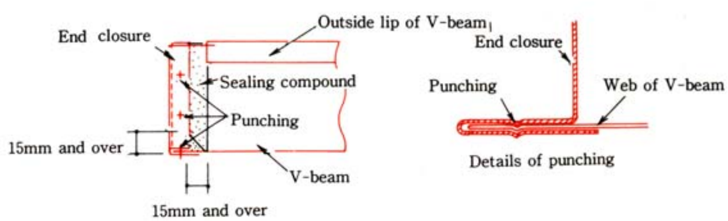


Figure 2.14 Inserted and closure

2.6 Ridge

The ridge finish should be covered with the ridge covering after installing the end closure. The ridge covering method in which an apron is inserted according to the V-beam (Fig. 2.16) is used more often than the method in which the apron is cut and fitted into the V-beam (Fig. 2.15).

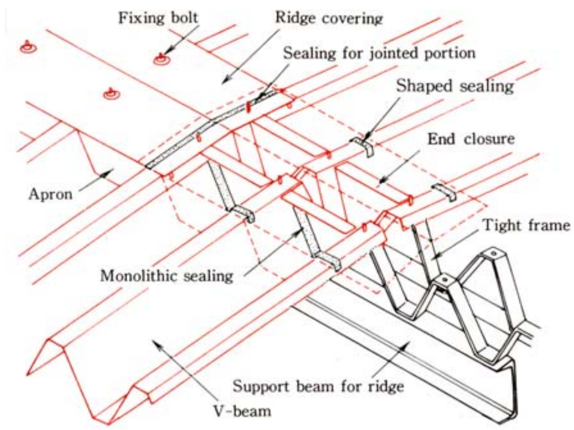


Figure 2.15 Ridge fabrication

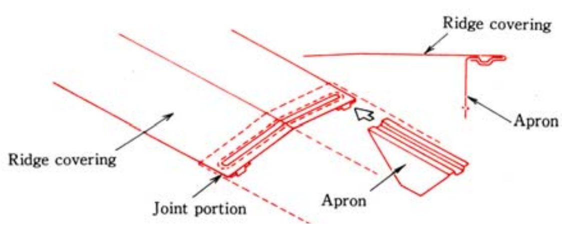


Figure 2.16 Insertion method of apron into ridge covering

For shed roof ridges, the method in which the ridge is covered with the ridge covering (Fig. 2.17) is used.

In the case where the roof pitch is extremely small, the same method as for eaves can be applied. In this case, rainwater should not come into contact with the back face of the roofing material.

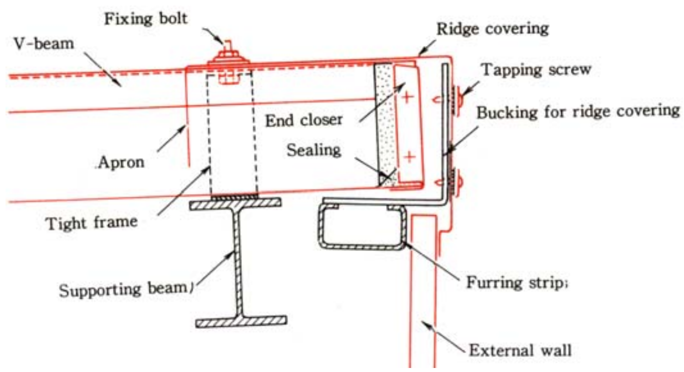


Figure 2.17 Shed-roof fabrication

2.7 Flashing of high point

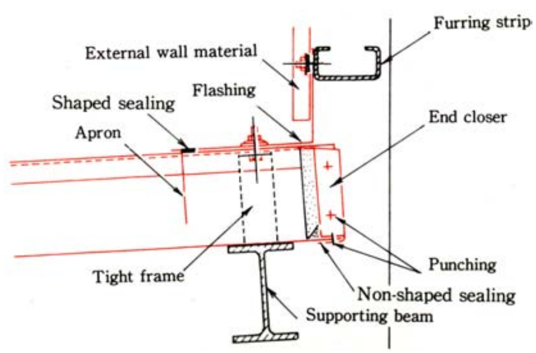


Figure 2.18 Flashing at high point

2.8 Flashing of slope

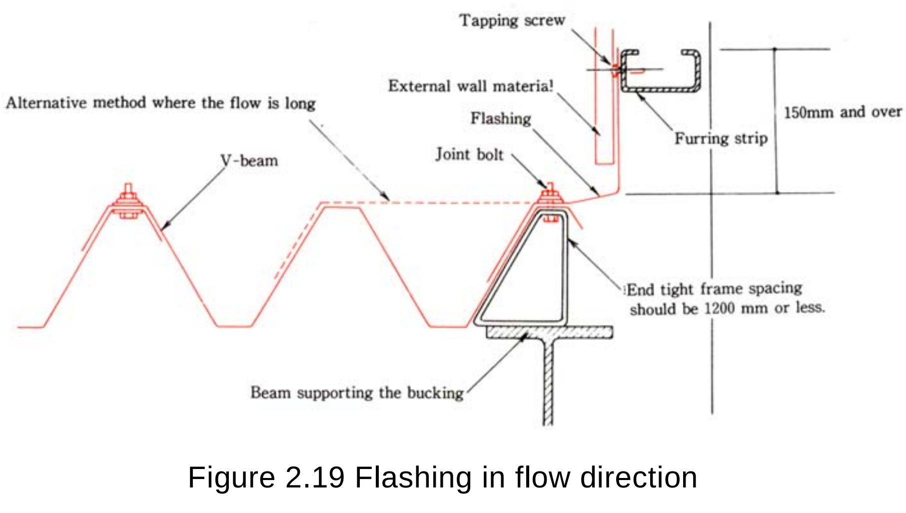


Figure 2.19 Flashing in flow direction

3. Nonshaft Type Batten Seam Roofing (Partial Channel Clip)

3.1 Standard structural method and members

The standard structural method and members are shown in Fig. 2.20

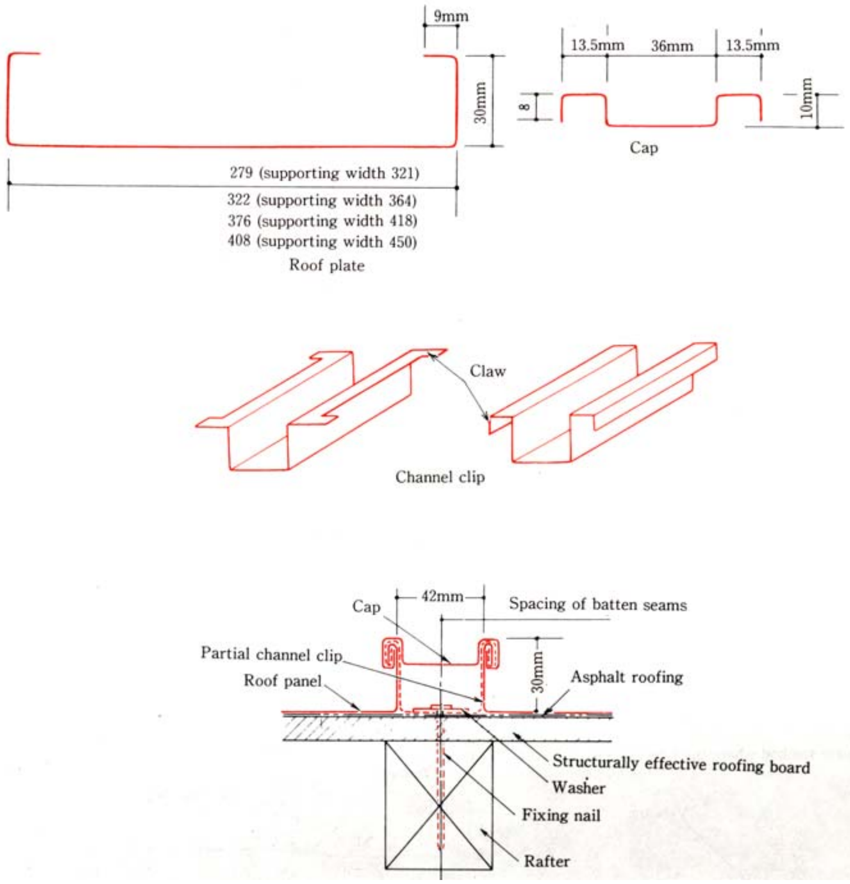


Figure 2.20 Nonshaft type batten seam roofing (partial channel clip) structural method

3.2 Eaves

Fig. 2.21 shows how to fit the batten seam and backing of eaves.

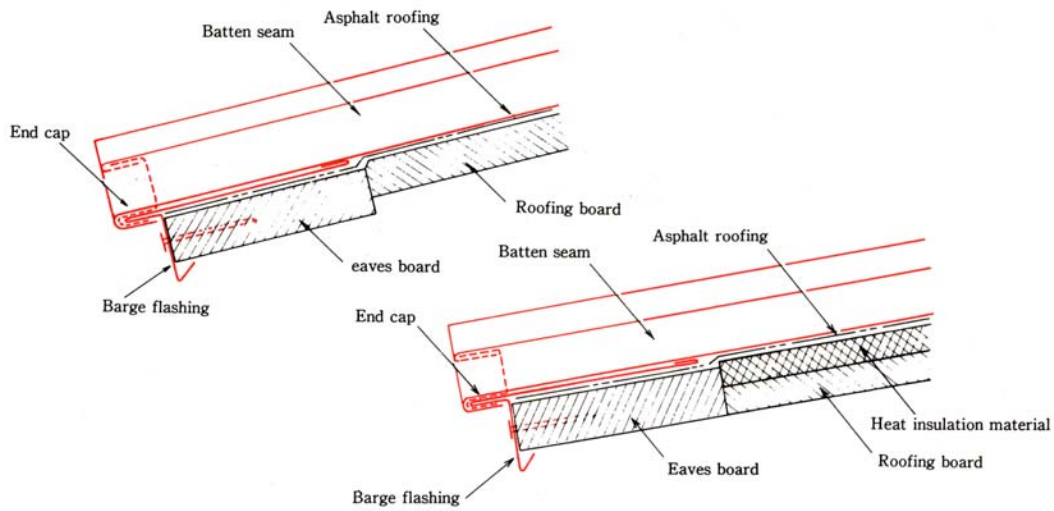


Figure 2.21 Fabrication of asphalt roofing and eaves

3.3 Barge

The length of the barge ends, and the spacing between the channel clip and batten seam, should be in accordance with the specifications of the "Structural Standards for Roofs of Steel

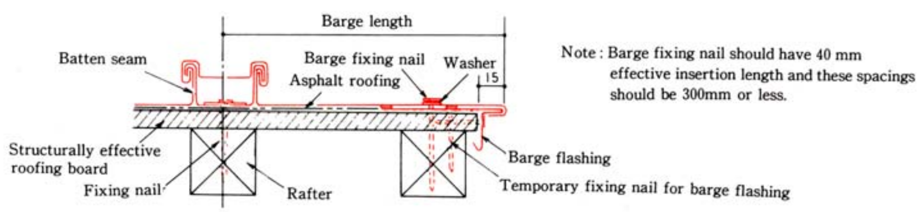


Figure 2.22 Barge fabrication

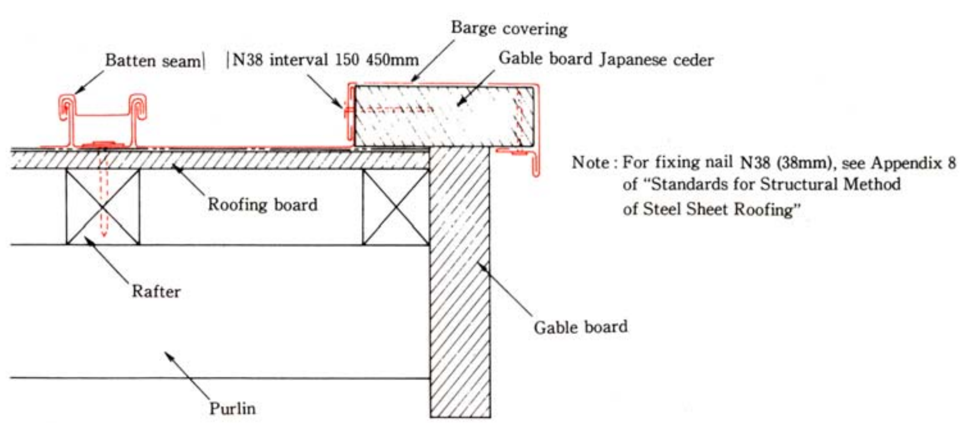


Figure 2.23 Barge coveving fabrication

3.4 Ridge

Structural methods used for ridge and shed roofs are shown in Figs. 2.24 and 2.25, respectively. For structural methods without ridge strips, see "Nonshaft Type Batten Seam Roofing (Continuous Channel Clip)".

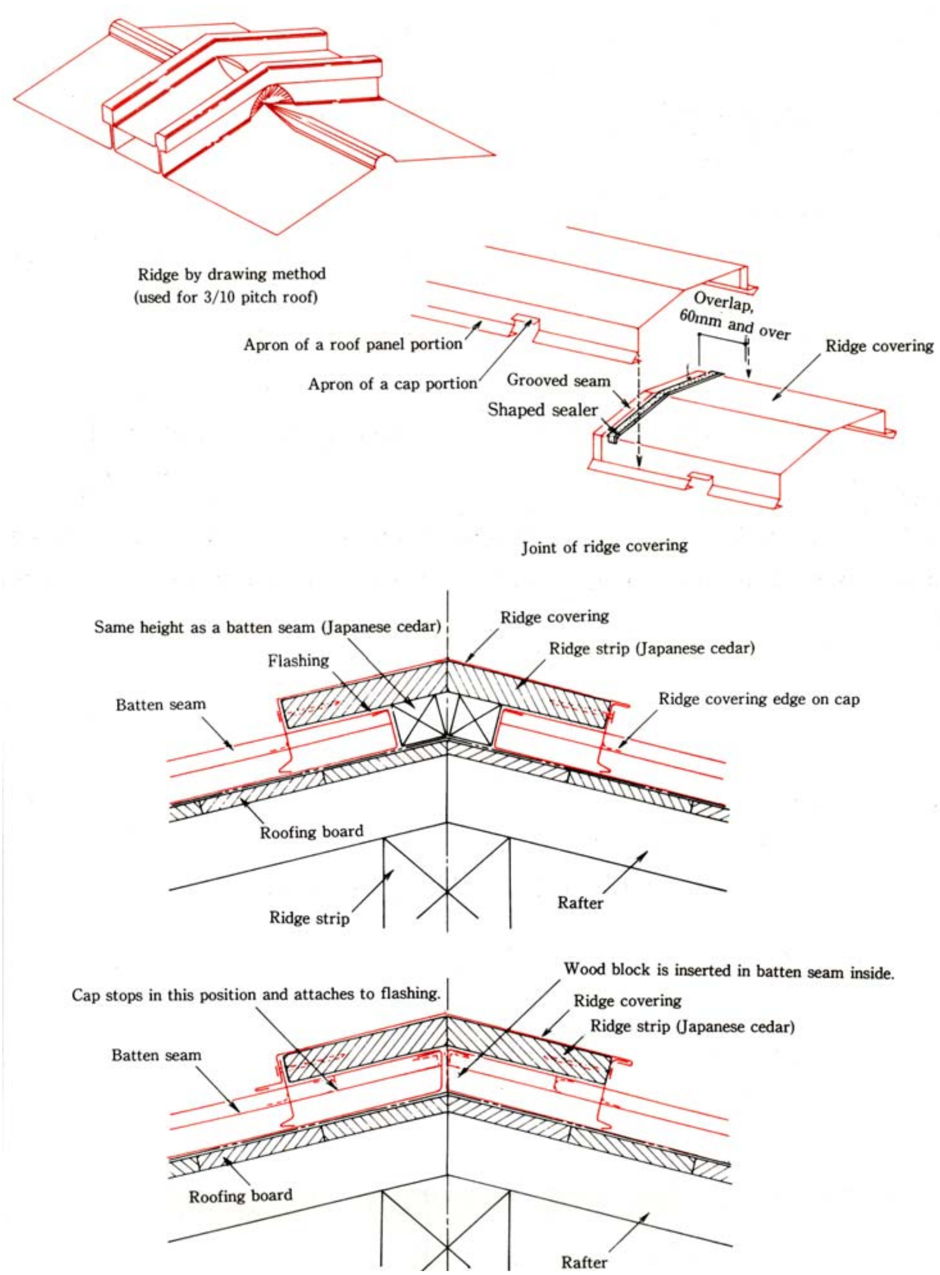


Figure 2.24 Ridge fabrication

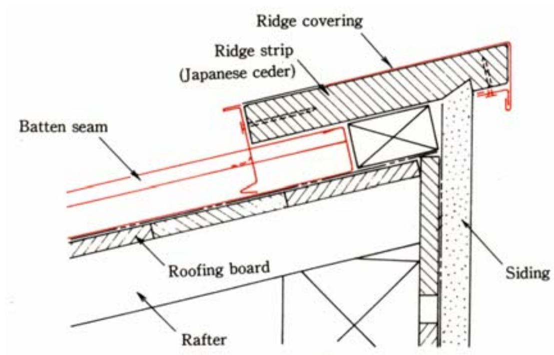


Figure 2.25 Shed-roof fabrication

3.5 Flashing of high point

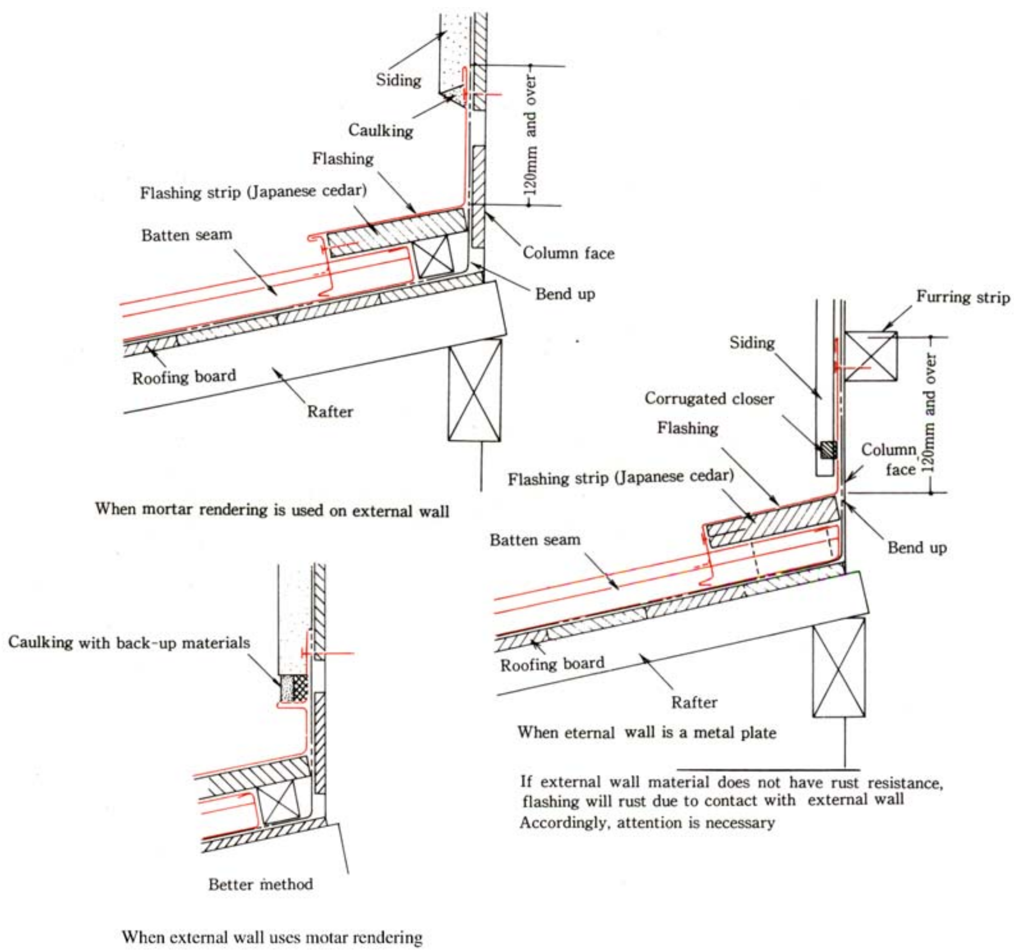


Figure 2.26 Flashing at high point

3.6 Flashing of slope

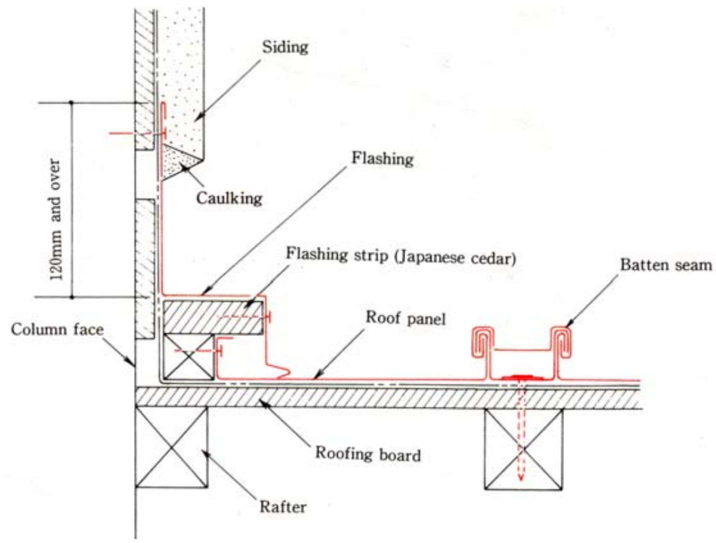


Figure 2.27 Fabrication by flashing

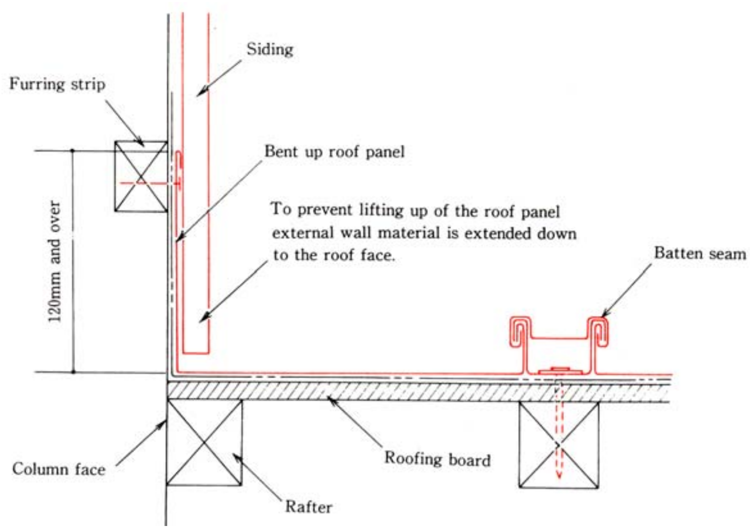


Figure 2.28 Fabrication by bending up of roof panel

4. Nonshaft Type Batten Seam Roofing (Continuous Channel Clip)

4.1 Standard structural method and members

The standard structural method of the nonshaft type batten seam roofing (continuous channel clip) and the shapes of its members are shown in Fig. 2.20, where the roof panel and cap are the same as in Fig. 2.20.

The spacing of the batten seams, length of overhang, spacing of purlins and size of barge ends should be in accordance with "Structural Standards for Roofs of Steel Sheet".

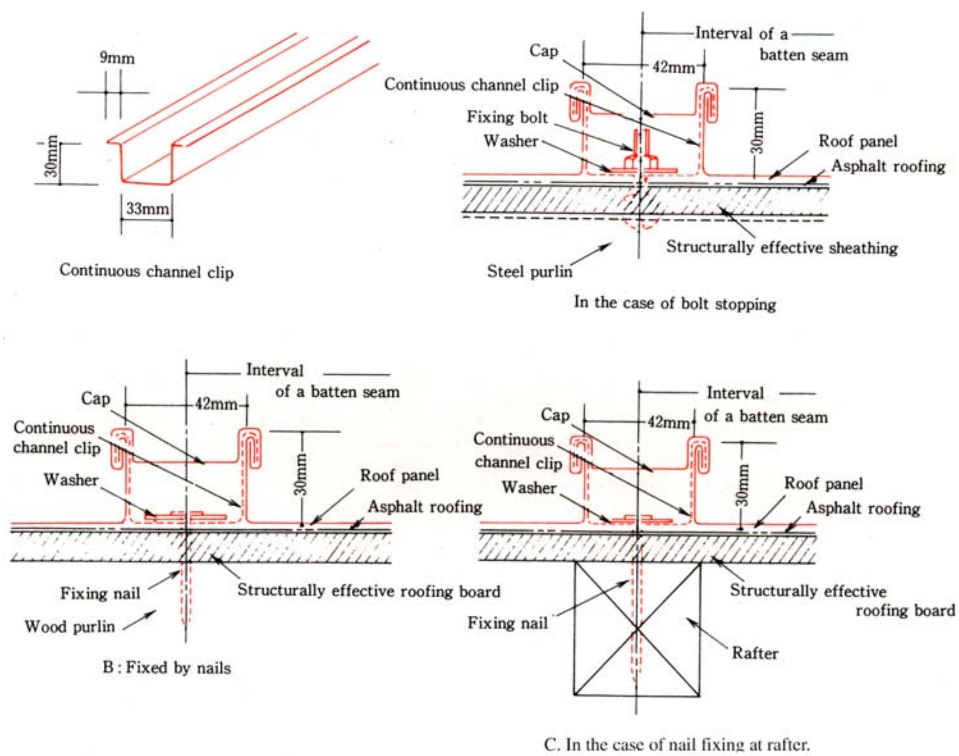


Figure 2.29 Standard structual method of nonshaft type batten seam roofing (continuous channel clip)

The spacing of the barren seams (supporting width) are 321, 364, 418 and 450 mm, respectively.

4.2 Eaves

Fig. 2.30 shows how to fit the eaves.

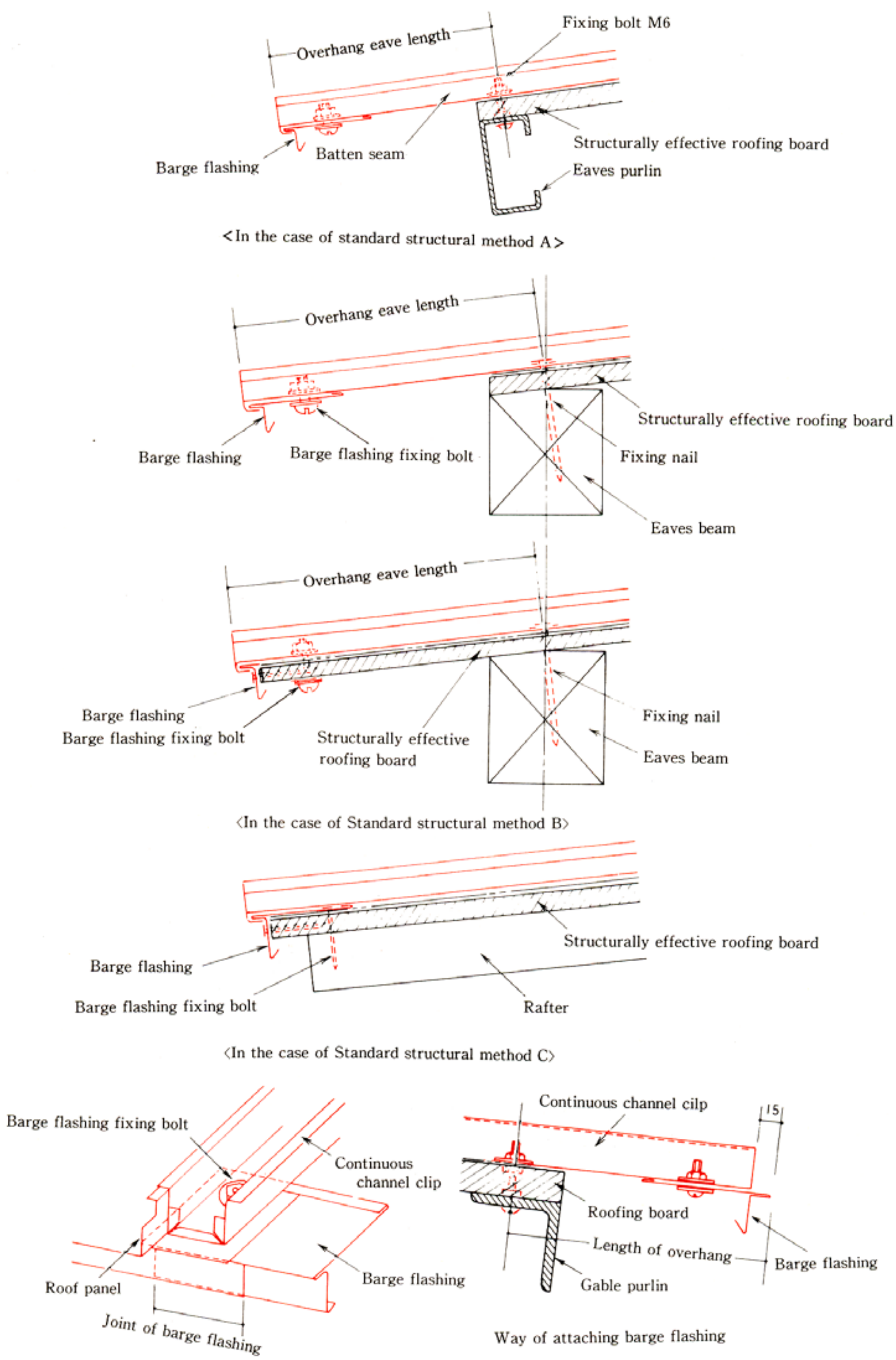


Figure 2.30 Eaves fabrication

4.3 Barge

Fig. 2.31 shows how to fit the barge as a standard structural method.

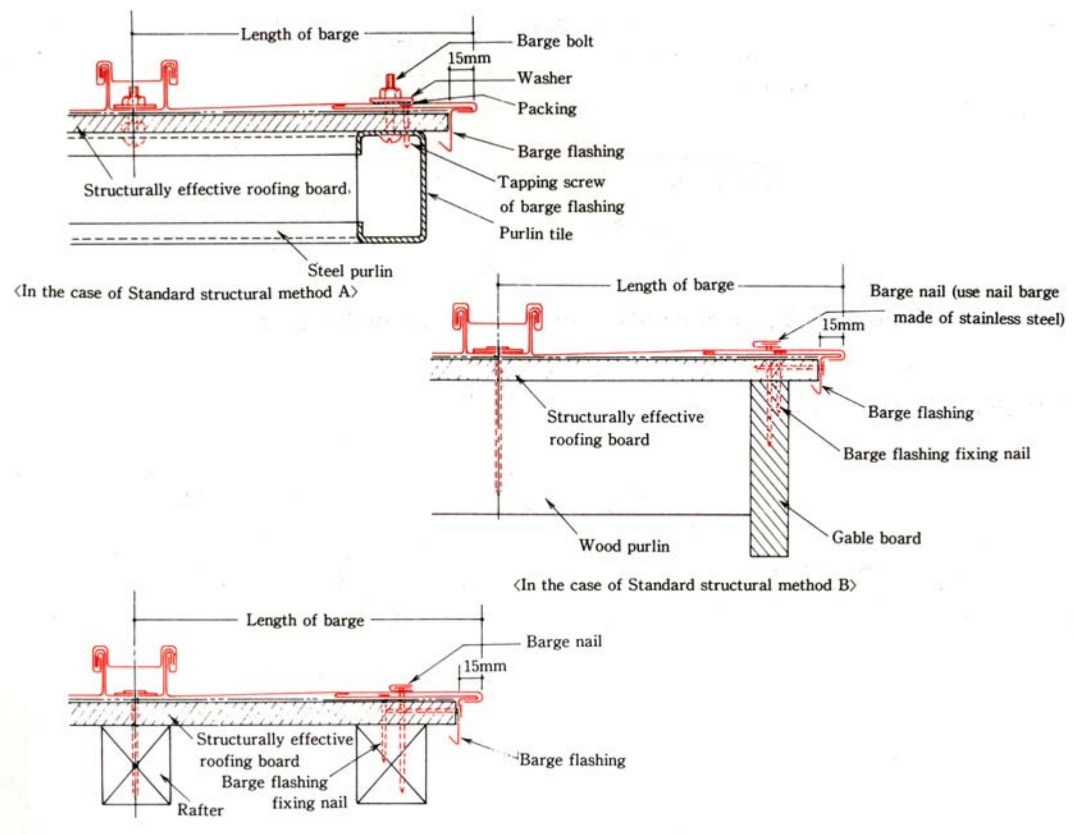


Figure 2.31 Barge fabrication

4.4 Ridge

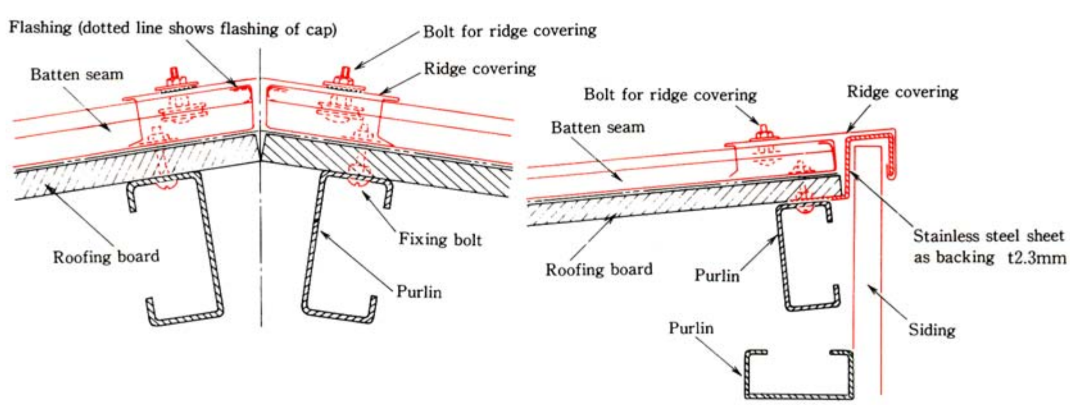


Figure 2.32 Ridge fabrication

4.5 Flashing at high point

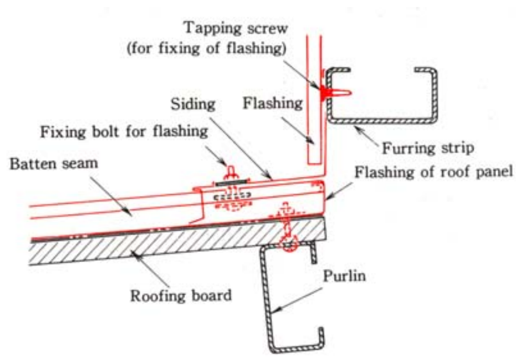


Figure 2.33 Fabrication of flashing at high point

4.6 Flashing in flow direction

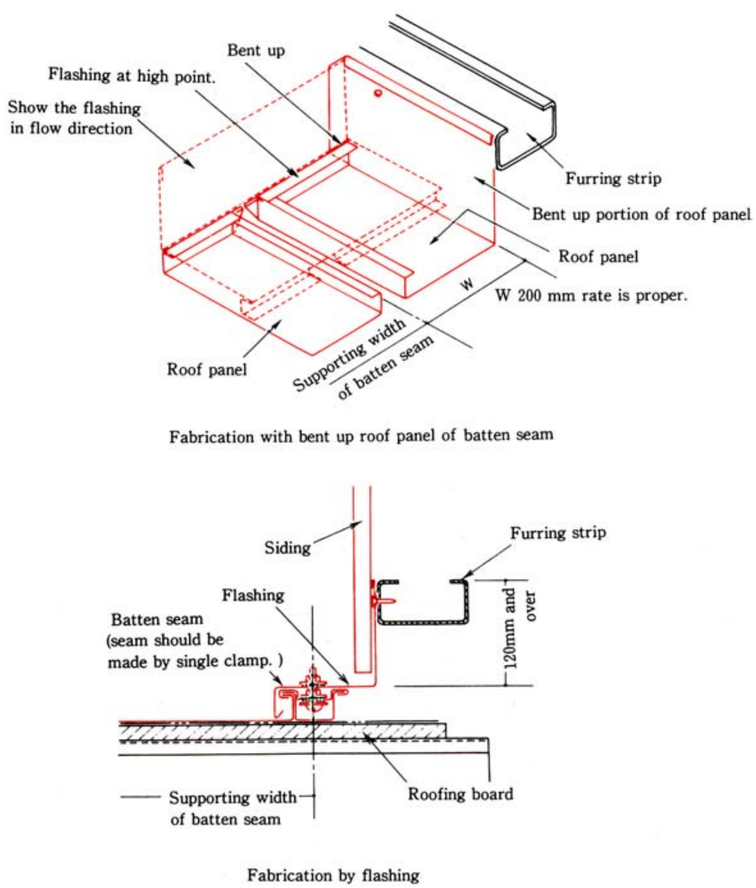


Figure 2.34 Fabrication of flashing in flow direction

5. Standing Seam Roofing and Dovetail Joint Roofing

5.1 Standard structural method and members

The standard structural methods and members of standing seam roofing and dovetail joint roofing are shown in Fig. 2.35.

The roof panel thickness, spacing of channel clip and length of barge end should conform to the "Structural Standards for Roofs of Steel Sheet".

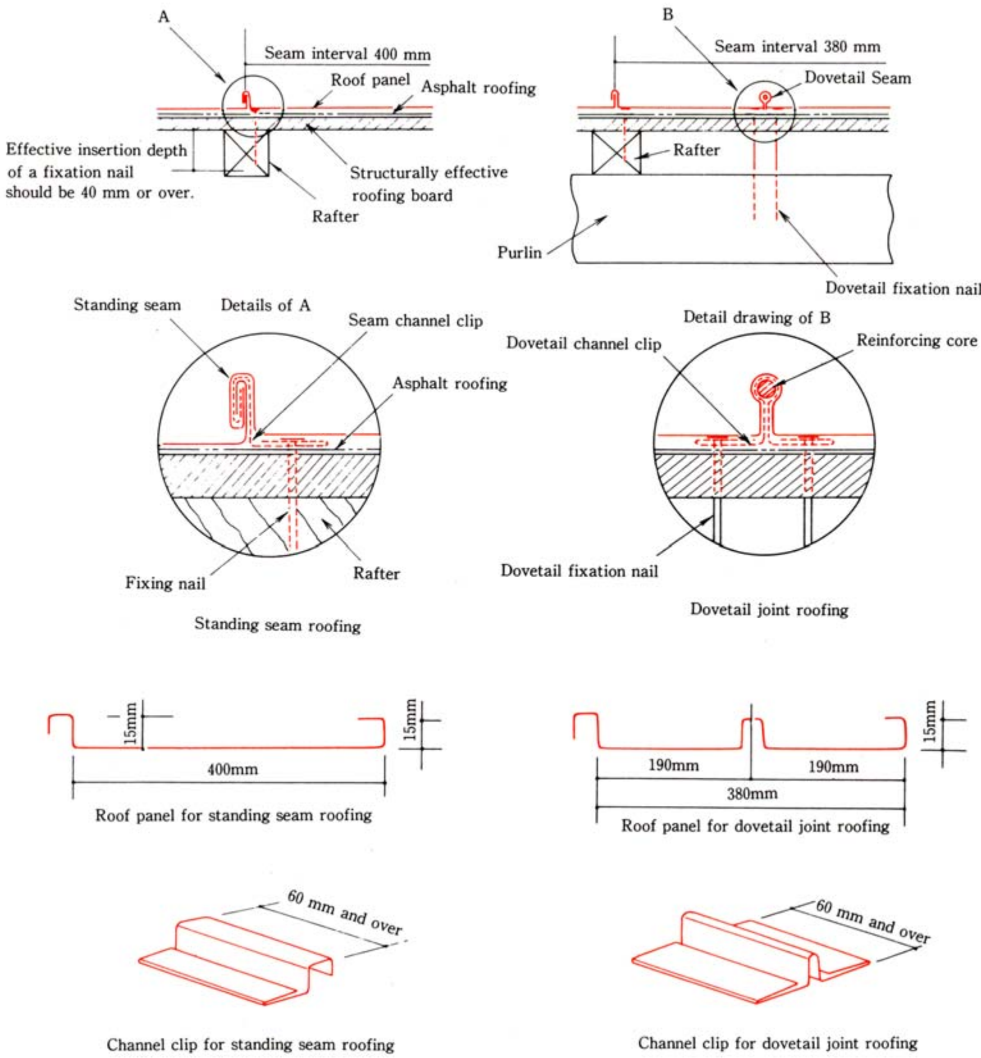


Figure 2.35 Standard structural method and parts for standing seam and dovetail joint roofing

5.2 Eaves

Figs. 2.36 and 2.37 show how to fit the eaves of standing seam roofing and dovetail joint roofing, respectively.

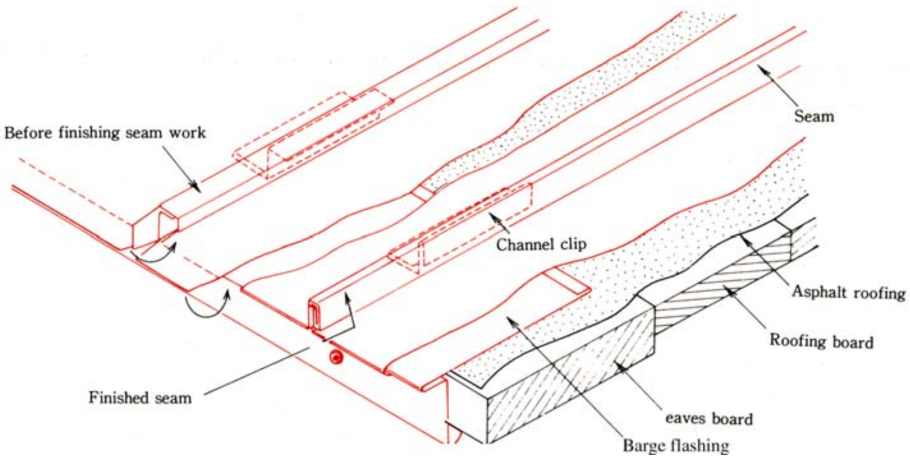


Figure 2.36 Eaves fabrication of standing seam roofing

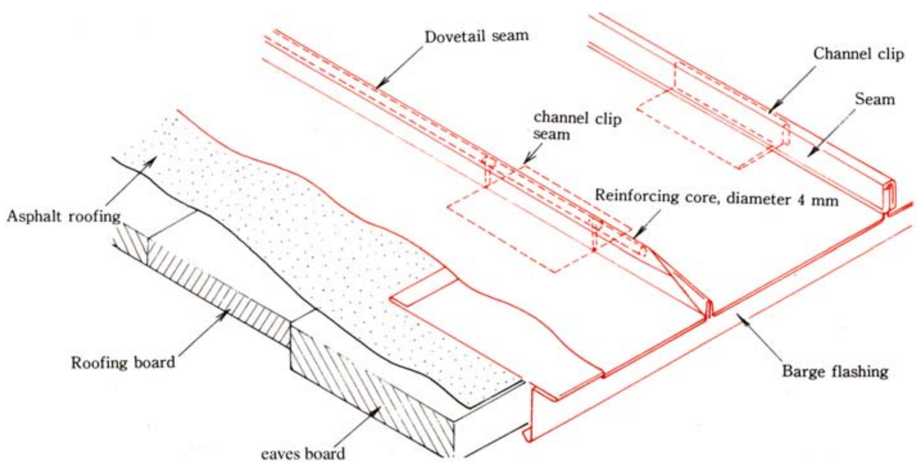


Figure 2.37 Eaves fabrication of dovetail joint roofing

5.3 Barge

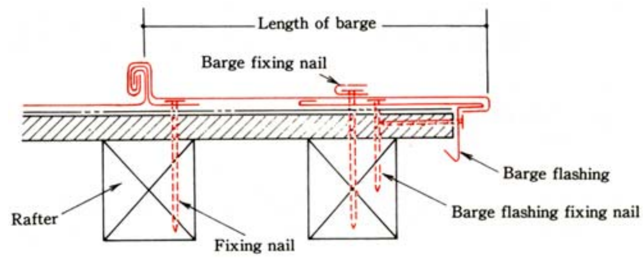
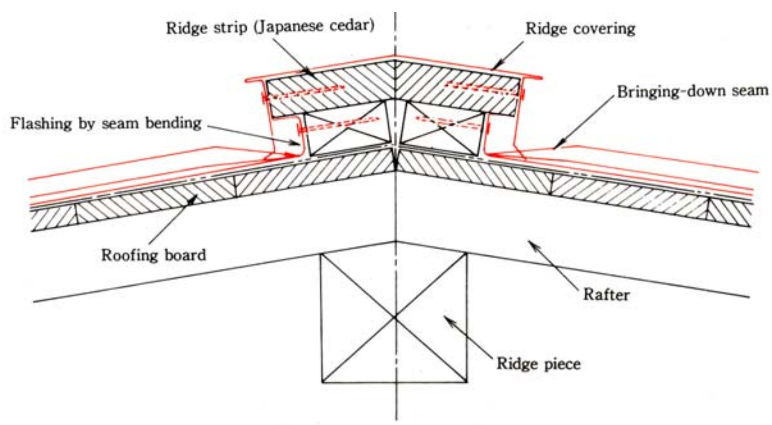


Figure 2.38 Barge fabrication

5.4 Ridge

Figs. 2.39 and 2.40 show how to fit the ridge.



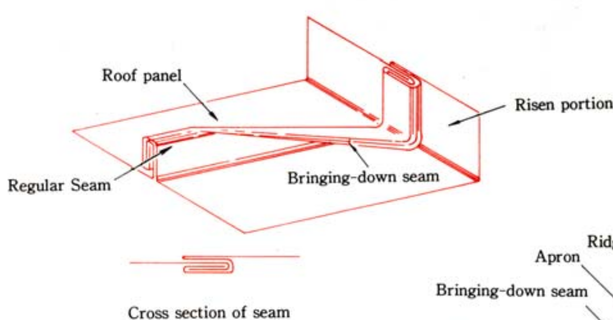


Figure 2.39 Ridge fabrication and bringing-down seam

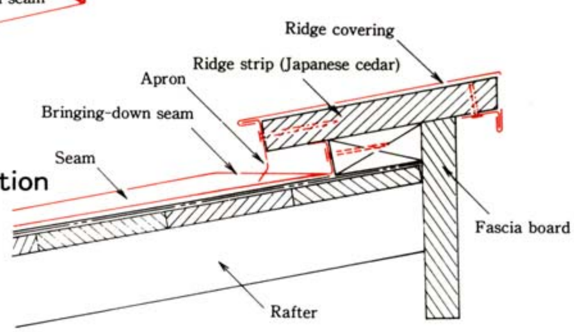


Figure 2.40 Ridge fabrication of shed roof

5.5 Flashing of high point

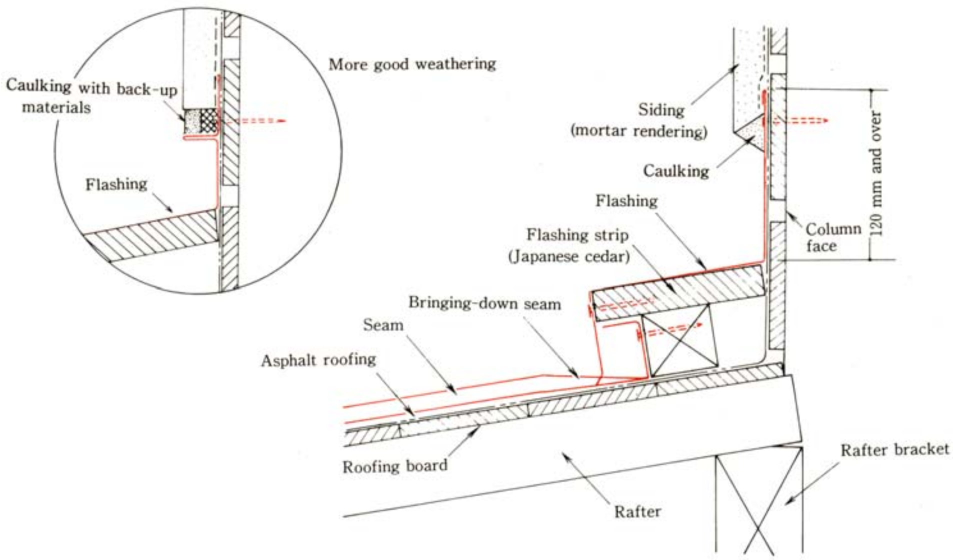


Figure 2.41 Flashing fabrication at high point

5.6 Flashing of slope

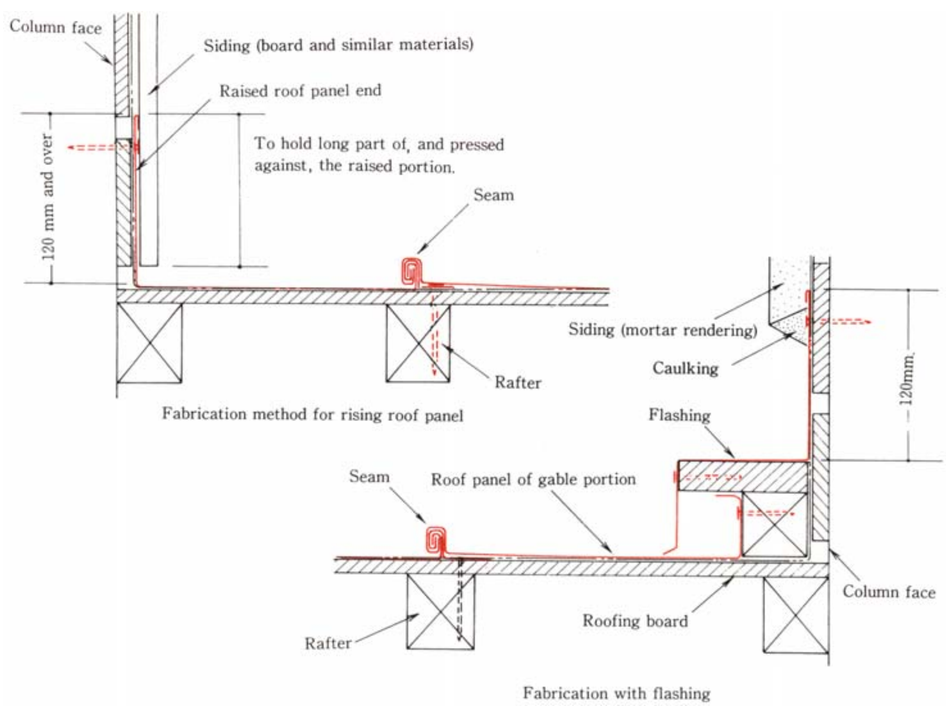


Figure 2.42 Flashing of flow direction

6. Corrugated Sheet Roofing

6.1 Standard structural method and members

The length of overhang, corrugated panel thickness, spacing of purlins, number of fixed bolts should conform to the “Structural Standards for Roofs of Steel Sheet”.

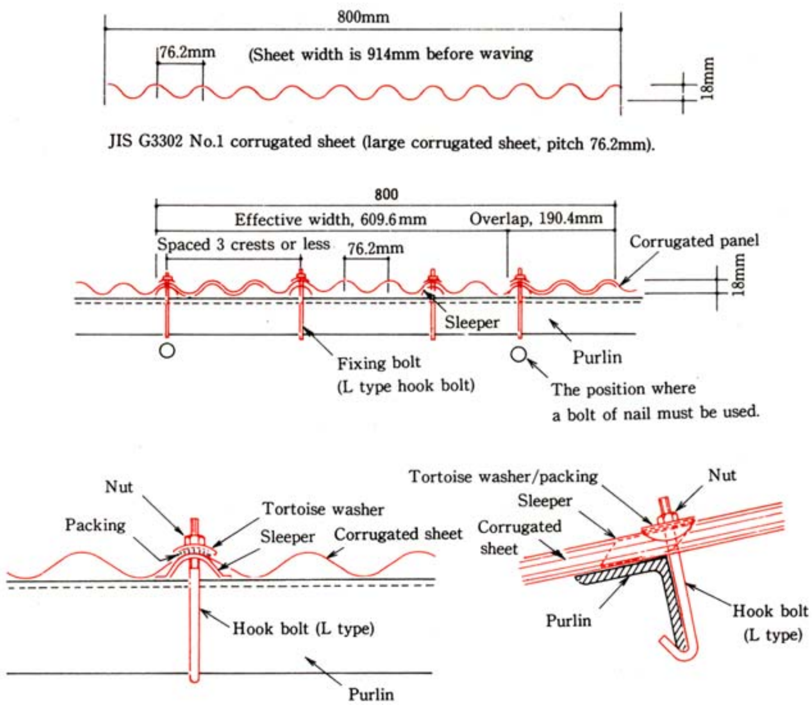


Figure 2.43 Standard structural method and parts for large corrugated sheet roofing

6.2 Eaves

Fig. 2.44 shows how to fit the eaves.

A thick channel (normally 2.3 mm or more) may be used for the purlin mentioned under “Eaves Fabrication” to prevent deformation.

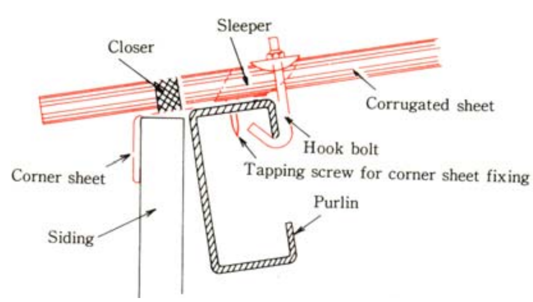


Figure 2.44 Eaves fabrication

6.3 Barge

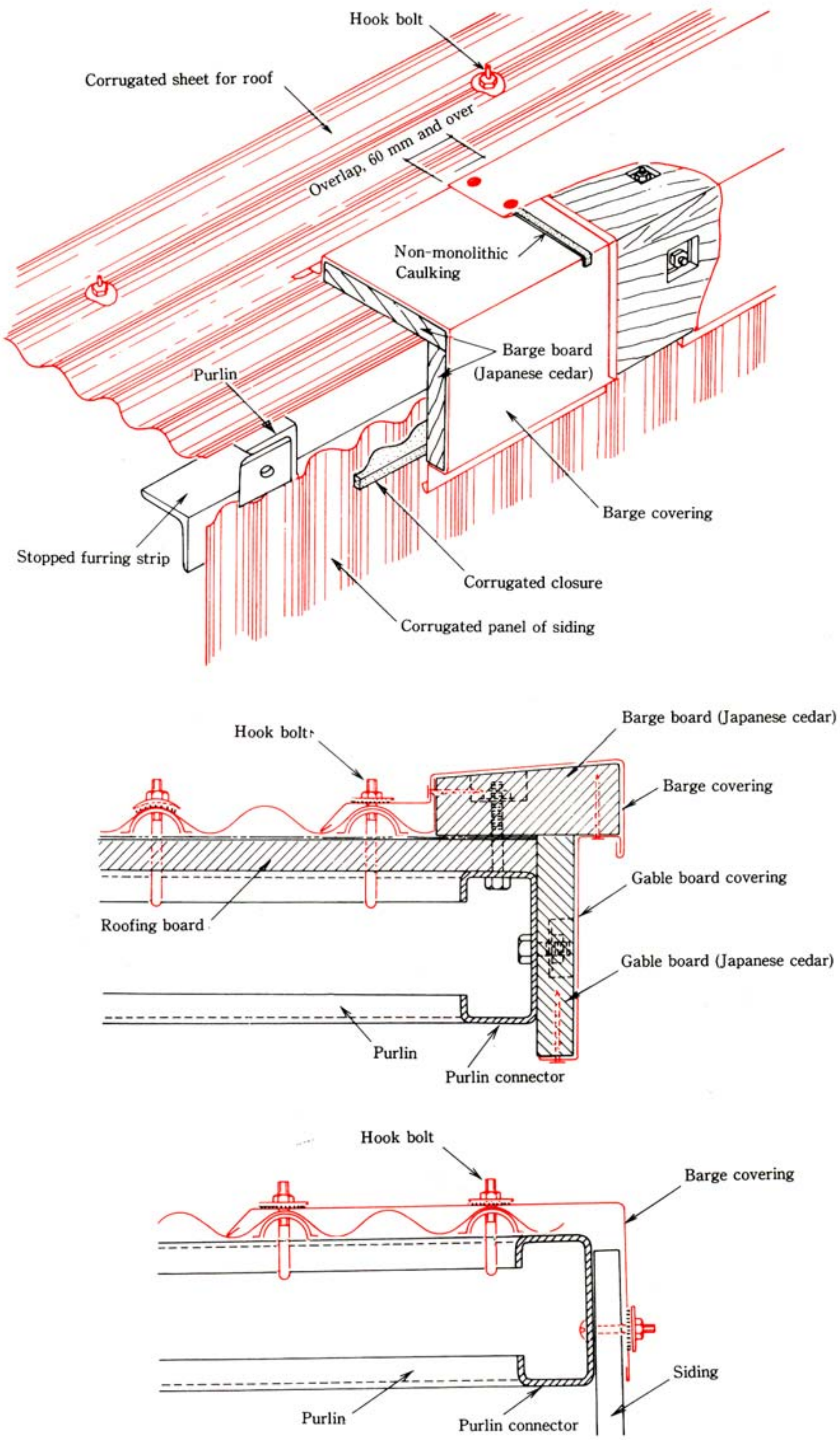


Figure 2.45 Barge fabrication

6.4 Ridge

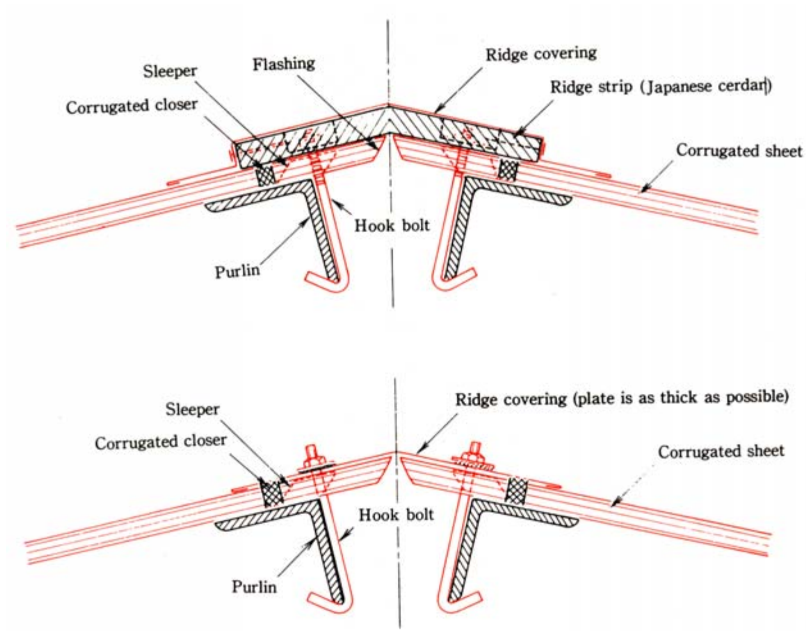
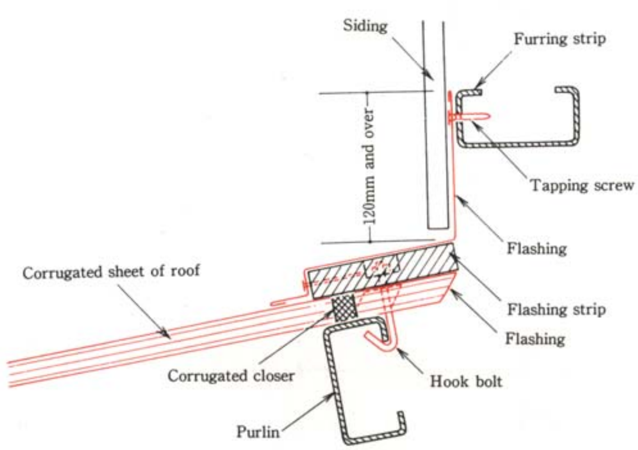


Figure 2.46 Ridge fabrication

6.5 Flashing of high point



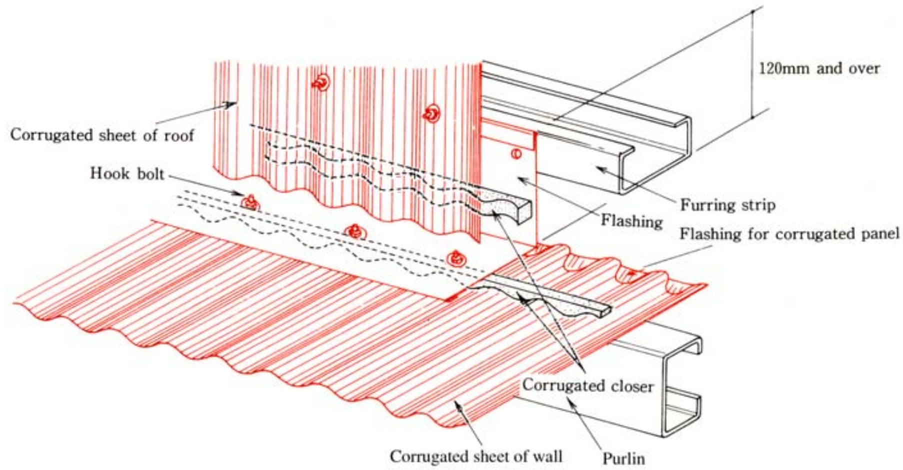


Figure 2.47 Flashing at high point

6.6 Flashing of slope

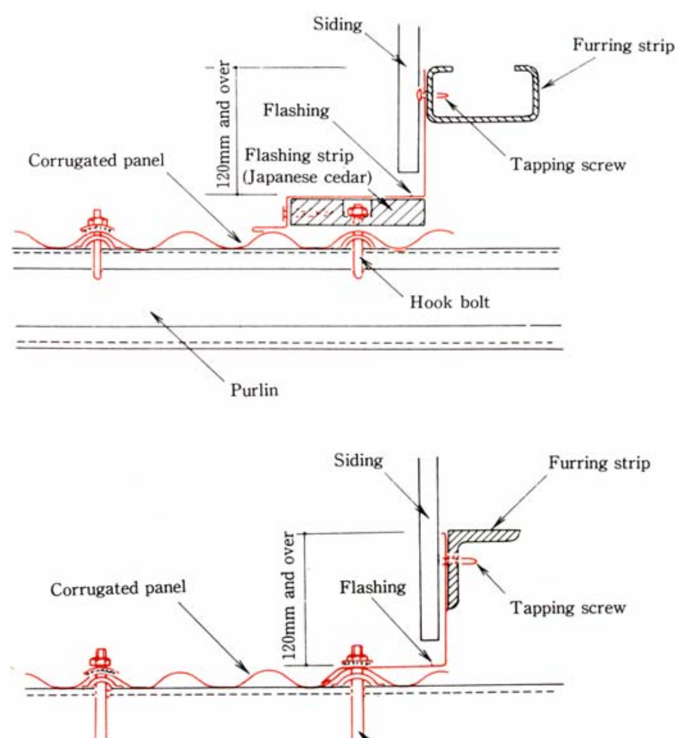


Figure 2.48 Flashing in flow direction

7. Dutch-Lap Roofing (Transverse Roofing)

7.1 Banking

Among stainless steel sheets, the expansion coefficient of SUS 304 is almost equivalent to that of copper. Therefore, Dutch-lap roofing panel should have almost the same dimensions as those of the copper sheet. If it is larger, the panel can be lifted due to thermal change.

The work can be easily carried out and successful results can be obtained when 0.3 or 0.35 mm-thick panels are used.

7.2 Roofing panel

There are two Dutch-lap roofing methods: clamp roofing and stub roofing. The shape of the roofing panel in each case is shown as follows:

The seam sizes of roofing panels shown in these figures are the standard sizes. Different sizes can be adopted according to the panel dimensions and local custom.

(1) Clamp roofing

The roofing panel for clamp roofing is shown in Fig. 2.49.

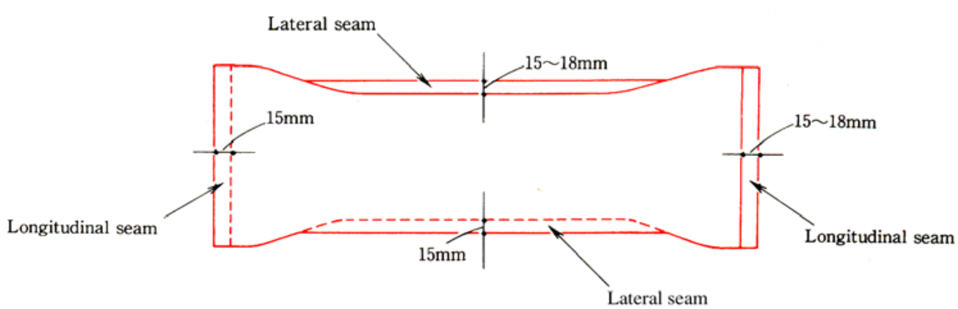


Figure 2.49 Roofing panel for clamp roofing

(2) Stub roofing

The roofing panel for stub roofing is shown in Fig. 2.50.

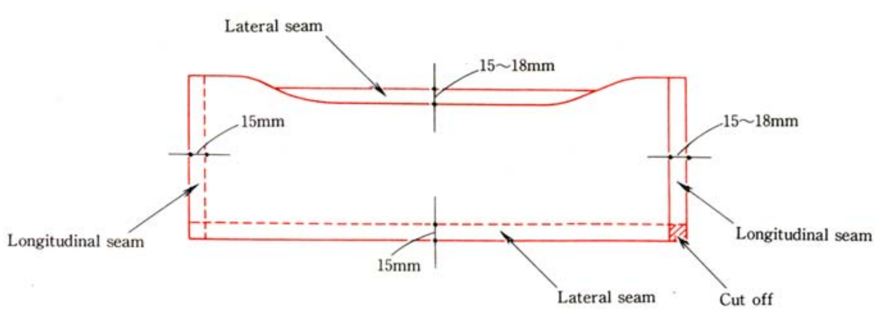


Figure 2.50 Roofing panel for stub roofing

7.3 Roofing method

As an example of the Dutch-lap roofing method, the stub roofing method is shown in Fig. 2.51.

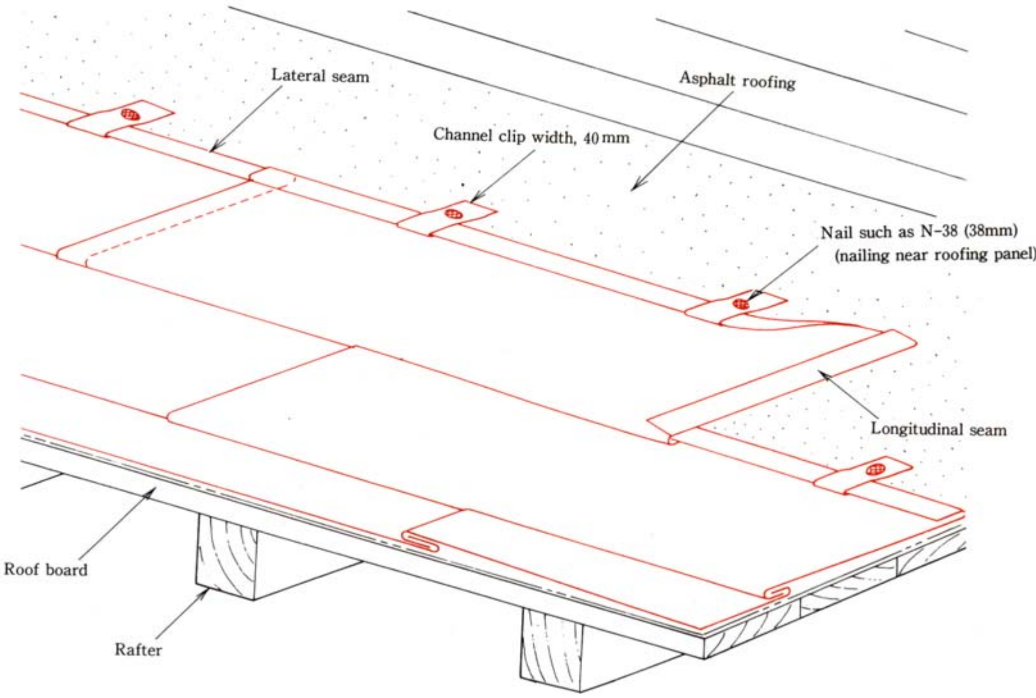
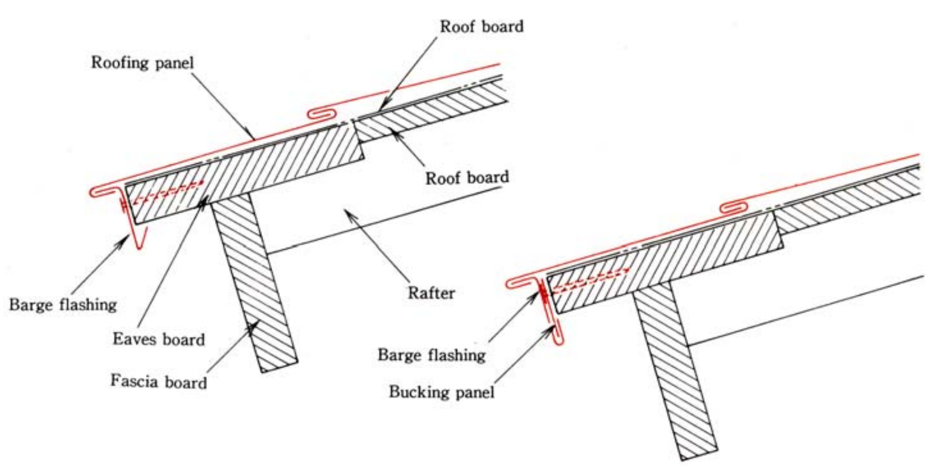


Figure 2.51 Dutch-lap roofing (in the case of stub roofing)

7.4 Eaves

Fig. 2.52 shows each type of eave fabrication.



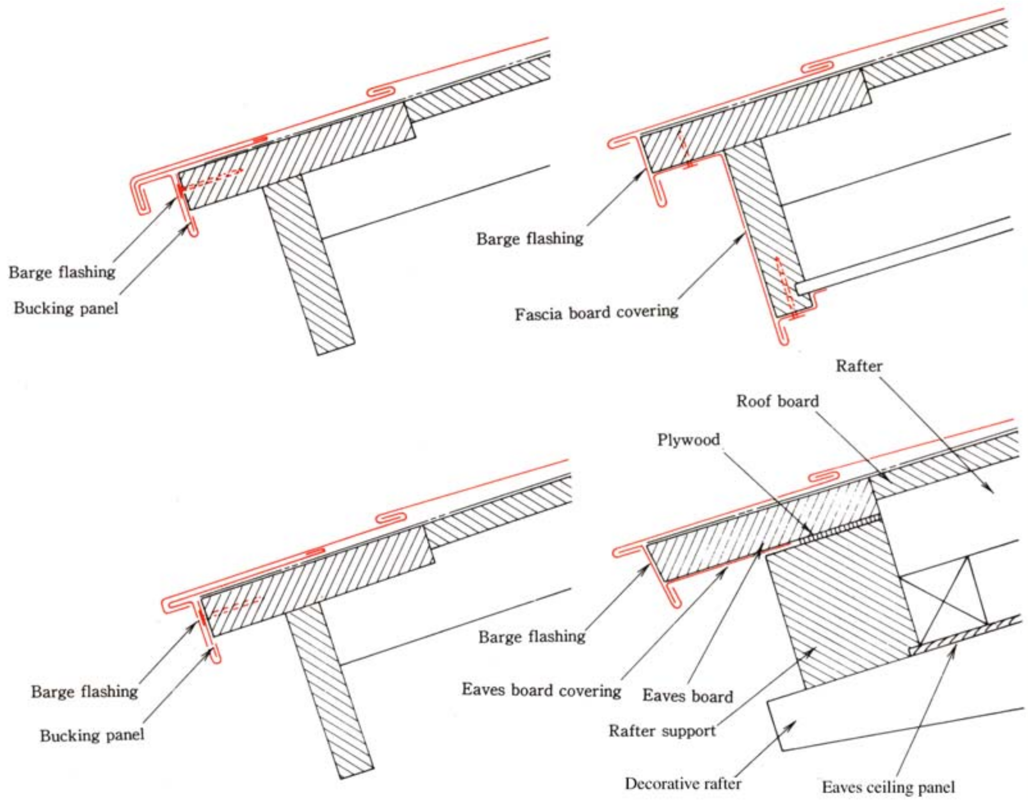


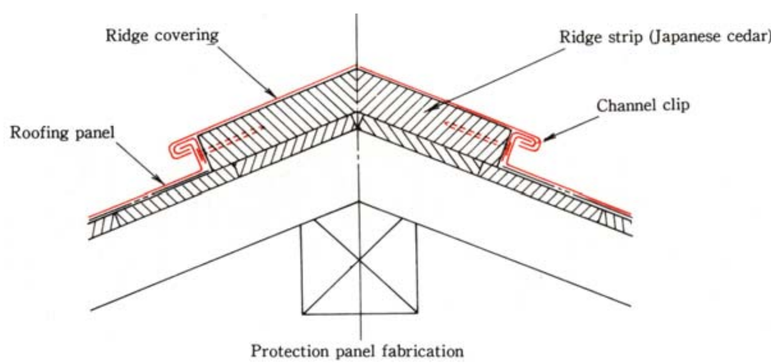
Figure 2.52 Various eaves fabrication

7.5 Barge

The barge fabrication should conform to that of the eaves.

7.6 Ridge

Fig. 2.53 shows each type of ridge fabrication.



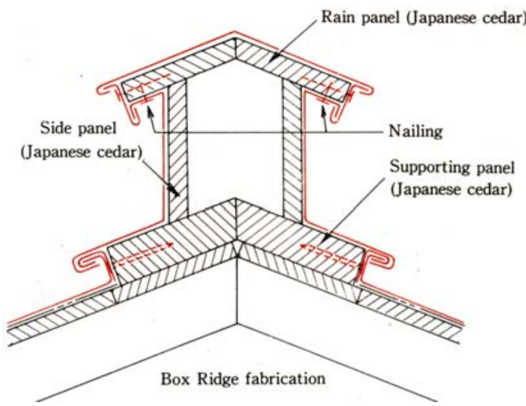


Figure 2.53 Ridge fabrication

7.7 Flashing

Fig. 2.54 shows flashing fabrication. The lashing for the high point is the same as that of the slope.

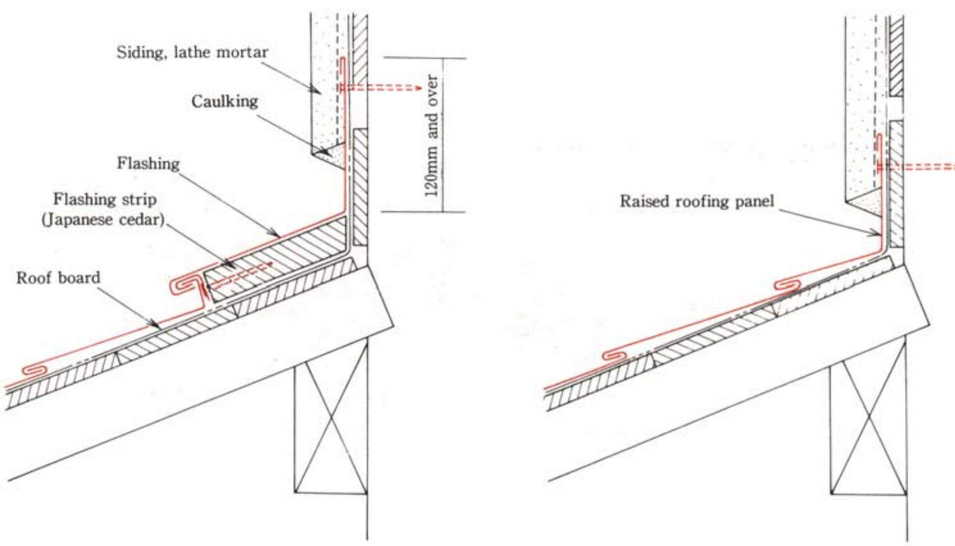


Figure 2.54 Flashing fabrication

8. Shaft Type Batten Seam Roofing

8.1 Standard structural method

The shaft type batten seam roofing standard is the structure given in Fig. 2.55.

The dimensions such as the spacing of batten seams, length of barge ends, spacing of fixing nails and spacing of shaft type fixed nails should conform to "Structural Standards for Roofs of Steel Sheet".

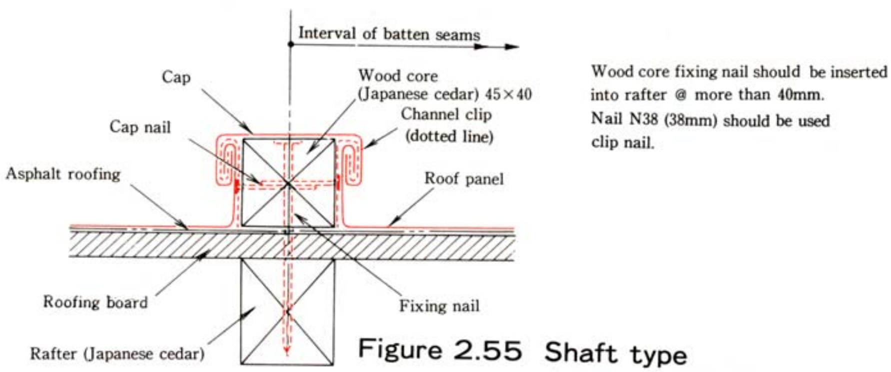


Figure 2.55 Shaft type batten seam roofing

8.2 Eaves

Two examples of how to fit eaves are shown in Figs. 2.56 and 2.57.

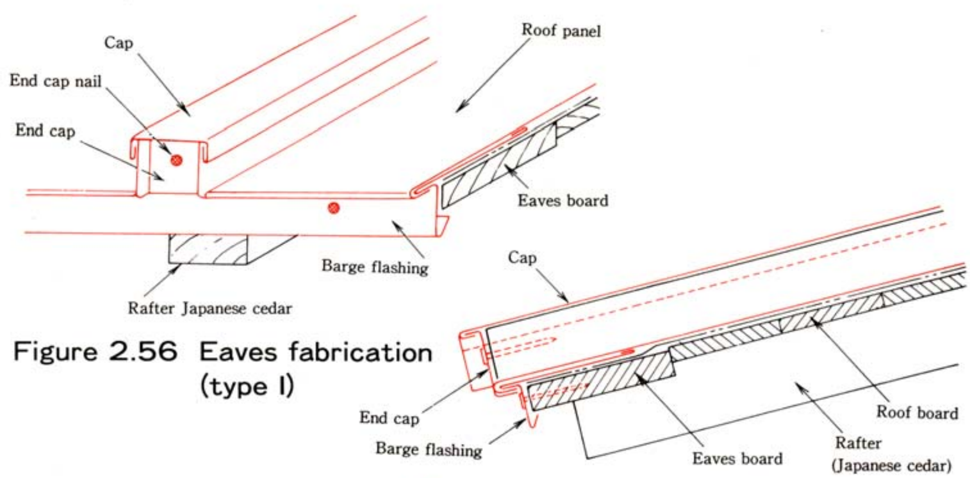


Figure 2.56 Eaves fabrication (type I)

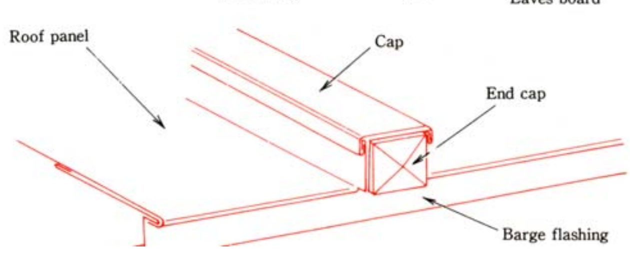


Figure 2.57 Eaves fabrication (type II)

8.3 Barge

Figs. 2.58 and 2.59 show how to fit the barge.

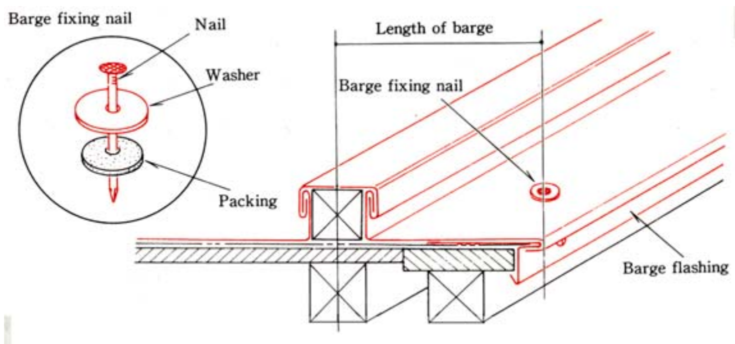


Figure 2.58 Barge Fabrication

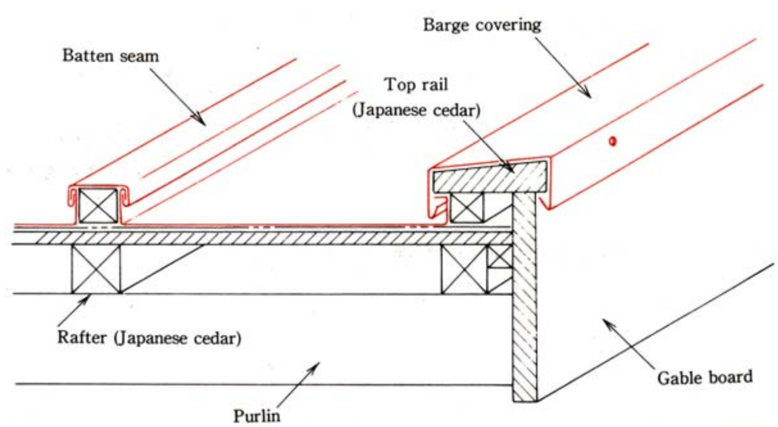


Figure 2.59 Fabrication by barge covering

8.4 Ridge

Fig. 2.60 shows how to fit the ridge.

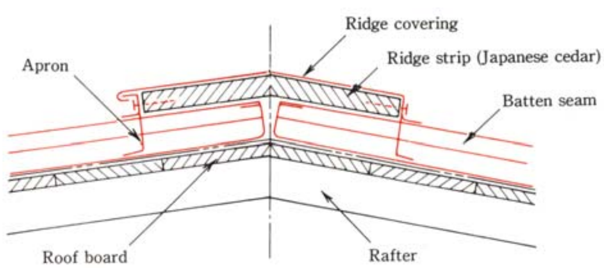


Figure 2.60 Ridge fabrication

8.5 Flashing of high point

The flashing of the high point is shown in Fig. 2.61. The flashing bending method for the roof panel high point is shown in Fig. 2.62.

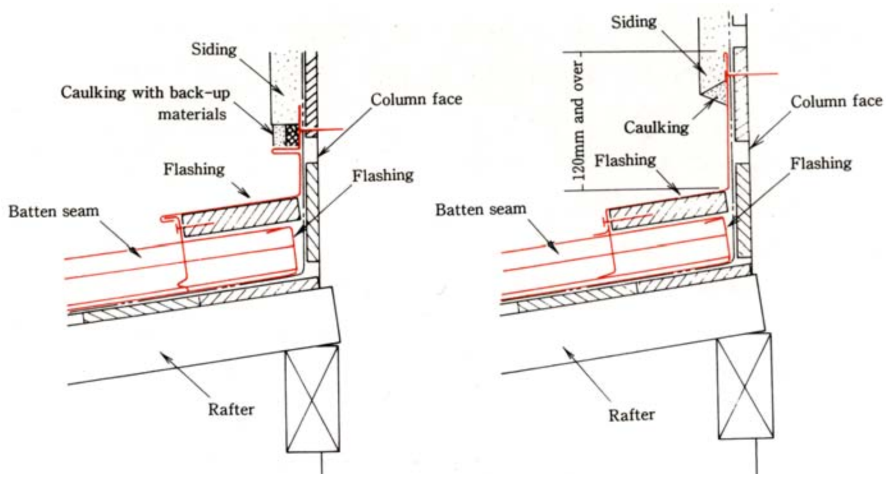


Figure 2.61 Flashing at high point

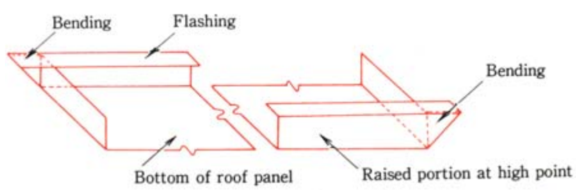


Figure 2.62 Flashing method at high point

8.6 Flasing of slope

Fig. 2.63 shows how to fit the slope flashing.

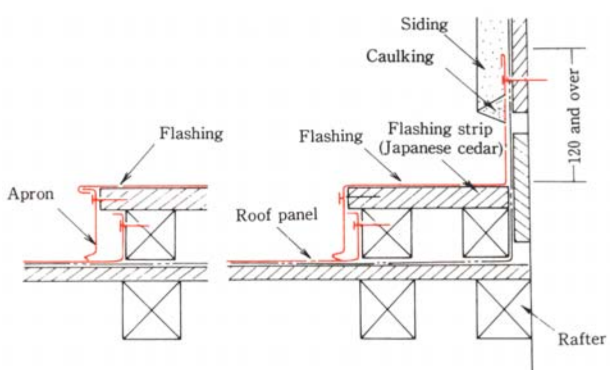


Figure 2.63 Flashing attached to roofing panel at high point

9. Welded Seam Roofing

9.1 Outline of the construction method

This construction method is a patented method of processing the joint of a stainless steel roof panel (roofing panel) to a sheet by continuous welding. Since the joint is continuously welded, complete water-tightness and air-tightness can be maintained. Therefore, it can be applied to any sloped roof.

On the other hand, this method is strongly affected by temperature change. Accordingly, special precautions should be taken, for example, when installing expansion joints. The construction method for the roof backing is the same as that for general flat lock-seam roofing. Even if there are some differences, depending on the backing condition and the existence of insulating materials, the roof panel is laid down to the backing of steel purlin through a channel clip. Tack welding is carried out by using a spot welder to install the roof panel and channel clip.

The roof panel is shaped so that the welded portion is left standing, and welded with a small-sized mobile seam welder. During seam welding, the work should be subject to confirmation of seam specification conformance. The fabrication of ridge, eaves barge flashing and barge are nearly the same as those of the batten seam roofing method. When there is a projection in the structure, it is necessary to use a special parts welder.

9.2 Types of welders

For welded seam roofing, the following welders are necessary in addition general tools for metal work.

a) Spot welder

It is used for tack welding of roof panel and channel clip.

b) Mobile seam welder (power: AC, partially DC; single-phase or three-phase; 200V; 10 to 45kVA)
It is used for welding the roof panel joint, can be freely operated on roofs, and has dedicated cables and water-cooled hoses.

c) Welder for special parts

This machine is used for special parts such as projections. When nonconforming portions are found by inspection after the completion of the welding work, this welder can be used manually for the repair or welding work of fine portions.

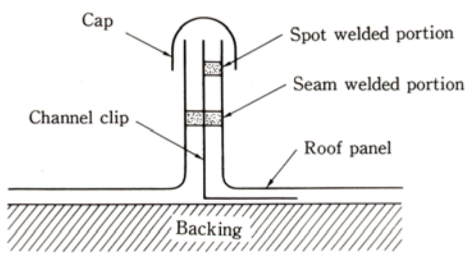
9.3 Welding processes by manufacturer

(1) P & P welding process

The P & P welding process was originated in Japan by the Nippon Stainless Steel Co., Ltd. P & P is short for permanent and perfect.

(a) Outline of welding sequence

Tack welding should be carried out on the channel clip and one end of the raised portion of the roof panel. Then, seam welding should be carried out, after snipping the channel clip at a point below that position, and lapping one roof panel onto a second. Finally, a cap should be put on the welded raised portion.



P & P welding process

(b) Conditions of the materials used at the welded points

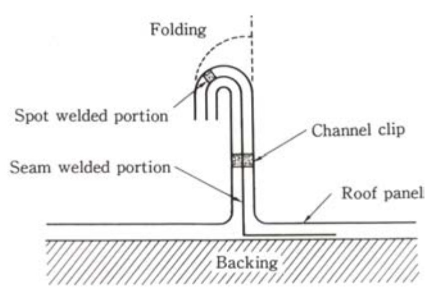
It is possible to weld totally precoated roofing materials (precoated stainless steel) used in the P & P welding process. This is because electrically-conductive stainless steel powder is mixed in the resin-coating materials. Either seam or spot welding can be carried out.

(2) R-T welding process

The R-T welding process was developed by the Rostfria-Tak Corporation (R-T Corp.) of Sweden, and was introduced to Japan by the Sanko Metal Industrial Co. Ltd. in 1980.

(a) Outline of welding sequence

Tack welding should be carried out on the channel clip and one end of the raised portion of the roof panel. Then, seam welding should be carried out by snipping the channel clip at a point below that position, and by lapping one roof panel onto a second. Finally, the spot welded raised portion and its surrouding should be folded by a seam bender.



R-T welding process

(b) Conditions of the materials used at the welded points

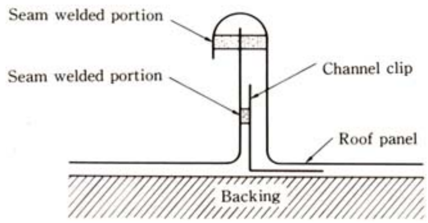
There are two types of materials used: one is coated after welding noncoated materials; the other is bake-coated with an electrically conductive coating before welding.

(3) SG welding process

The SG welding process was developed in 1983 by the Nippon Metal Industry Co., Ltd., with the support of the Hokkaido Metal Waterproof Cooperative. SG is short for seam guard.

(a) Outline of welding sequence

The channel clip and one end of the raised portions of the roof panel should be seam welded. Then, seam welding should be carried out after lapping the first panel with another folded roof panel already bent at its lower end.



SG welding process

(b) Conditions of the materials used at the welded points.

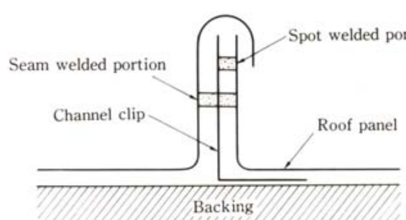
Since the welded portion is noncoated stainless steel, coating should be carried out after welding.

(4) NZ welding process

The NZ welding process was developed jointly by the Nippon Yakin Kogyo Co., Ltd. and Whole Japan Metal Plate Industry Union (Zenkoku Bankin Kogyo Rengokai). NZ is an abbreviation of the first initials of both groups.

(a) Outline of welding sequence

Tack welding should be carried out by spot welding the channel clip and one end of the raised portion of roof panel. Then, by snipping the channel clip at a point below that position, and by lapping it with another roof panel which has already been bent, seam welding should be performed below the spot welded portion.



NZ welding process

(b) Conditions of the materials used at the welded points

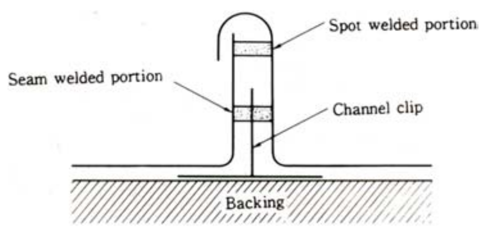
Since the welded portion is noncoated, coating should be carried out after welding.

(5) RSW welding process

The RSW welding process was developed in 1982 by the Kawasaki Steel Corporation. RSW is short for river seam weld.

(a) Outline of the welding sequence

Tack welding should be carried out by spot welding the channel clip to one roof panel. Another roof panel, previously bent, should be placed over the first vertically raised roof panel. Then, seam welding should be carried out by snipping the channel clip at a point below that position, and by lapping one roof panel onto a second.



RSW welding process

(b) Conditions of the materials used at the welded points

There are two types materials used: one is noncoated at the welded portion; the other can be welded in the precoated state.

10. Gutter

10.1 Half-round gutter

The cross-section and joint of the half-round gutter are shown in Fig. 2.64. Methods used to stop water at the end of the gutters are shown in Fig. 2.65.

Normally, soldering is performed in the joint. However, in the case of stainless steel, many joints peel. And so an overlap joint is made employing sealing tape within the joint and secured by riveting.

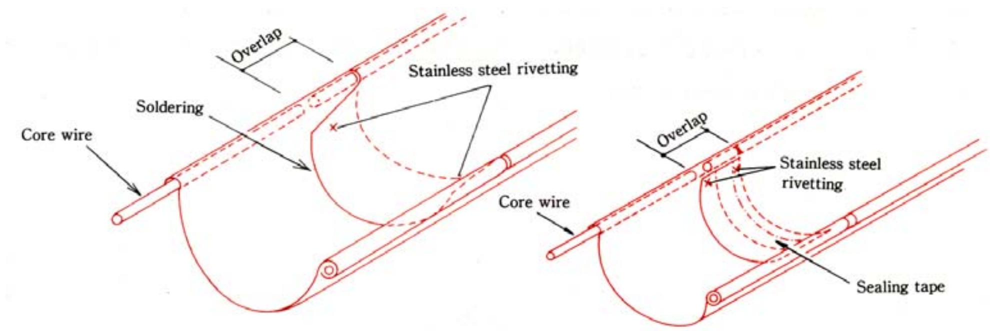


Figure 2.64 Half-round gutter

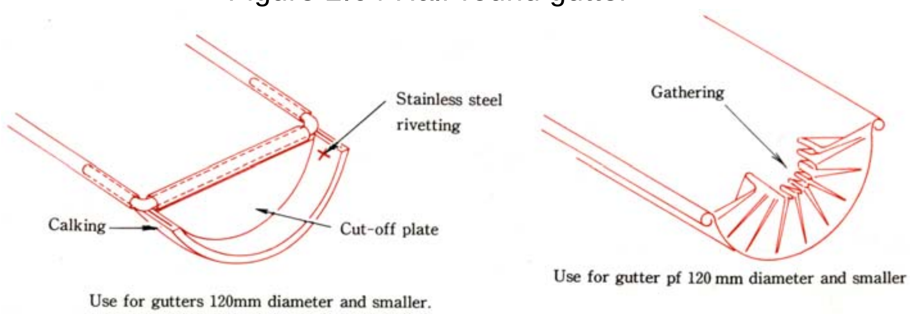


Figure 2.65 Cut-off method

Eaves gutter is fitted after being received into the bracket metal. Fig. 2.66 gives examples of bracket metals. Each metal is stainless steel. However, the metals which are made by passive state treatment, such as annealing or acid pickling, are used in the case where fabrication is done by smith forging or welding.

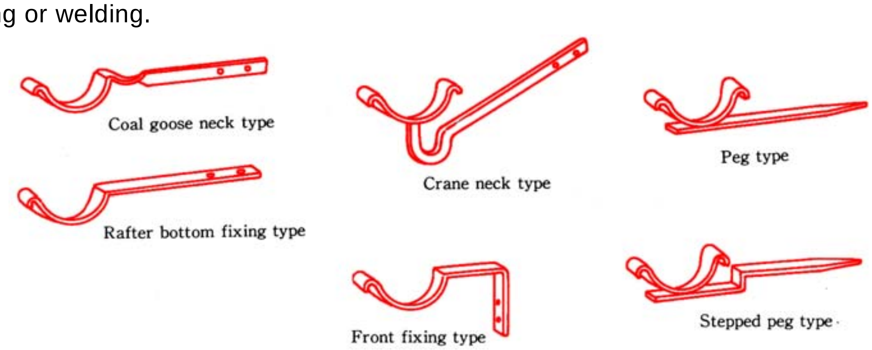


Figure 2.66 Strap hanger for half-round gutter

Eaves gutter fitting methods differ a little according to the snow quantity. Fig. 2.67 shows how to fit this type of eaves gutter.

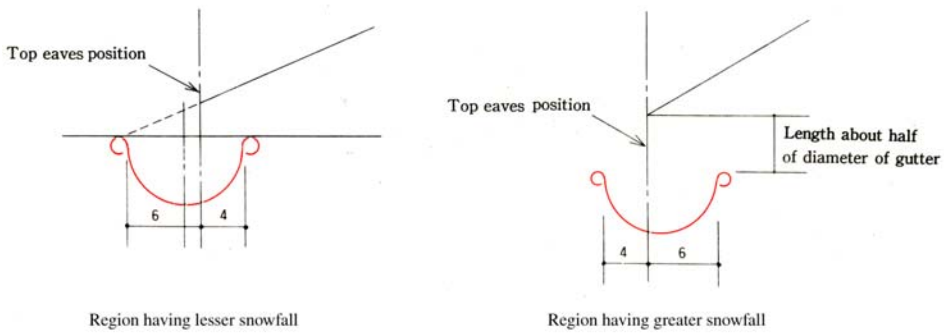


Figure 2.67 Half-round gutter installation method

10.2 Box gutter

An example of a single box gutter is shown in Fig. 2.68. There is also a double box gutter made by putting a half-round gutter into it.

A single box gutter is sloped, but the slope of a double box gutter is not apparent from the outside.

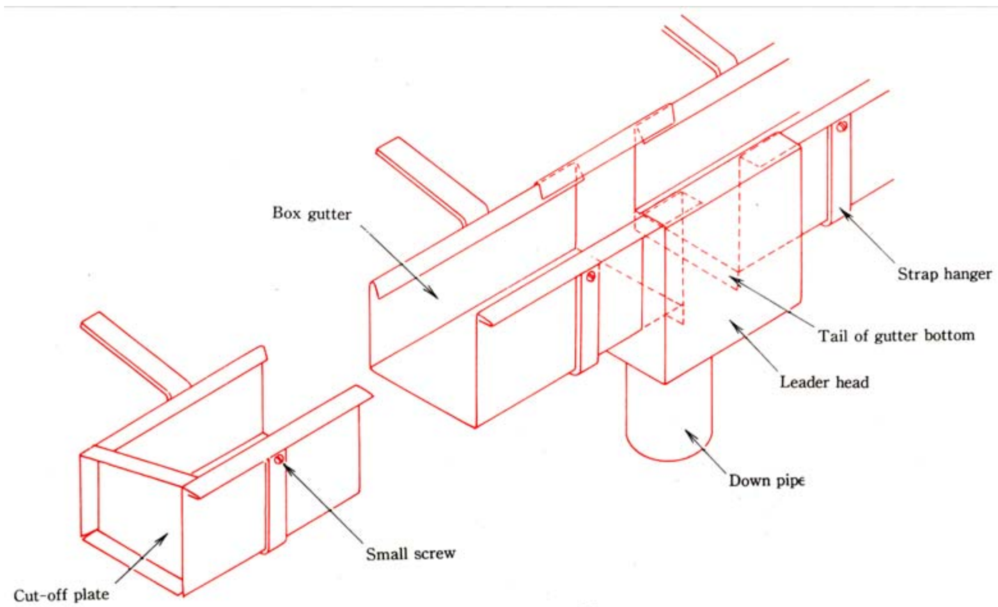


Figure 2.68 Example of box gutter

10.3 Down pipe

There are round down pipes and box down pipes. Fig. 2.69 shows a cross

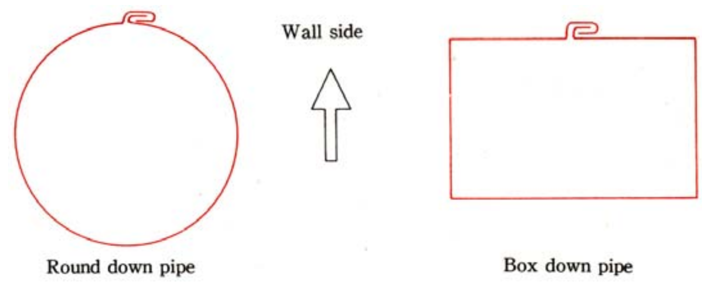


Figure 2.69 Down pipe

Fig. 2.70 shows examples of down pipe clamp metal.

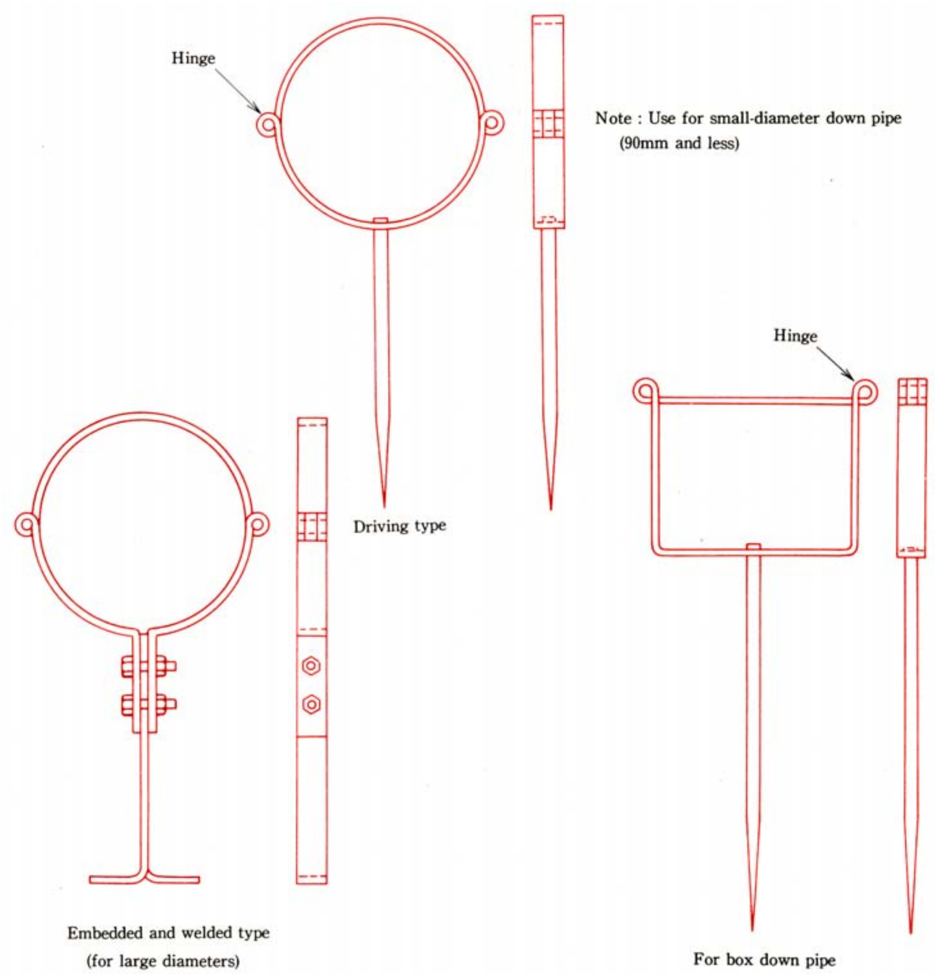


Figure 2.70 Strap for down pipe

10.4 Leader head, gutter outlet and gooseneck

The leader head is fabricated by devising a design. In particular, the front portions have various decorations.

The purpose of the gutter outlet is to collect the water of the half-round gutter. It is simpler than the leader head.

The purpose of the gooseneck is to connect between the gutter outlet and the down pipe, and the same gooseneck as that of the circular gutter is normally used.

The leader head functions as both the gutter outlet and gooseneck.

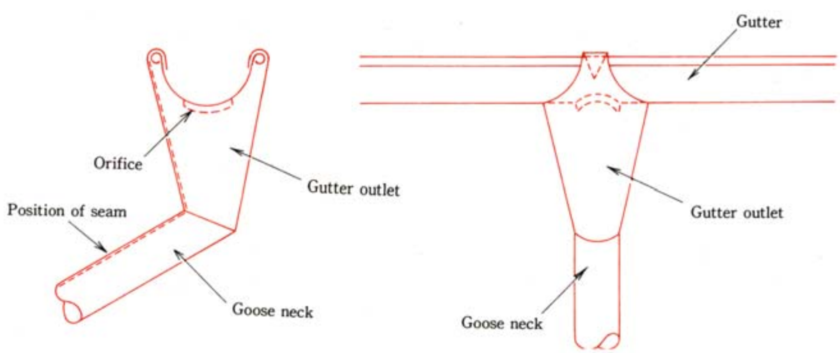


Figure 2.71 Example of gutter outlet and gooseneck

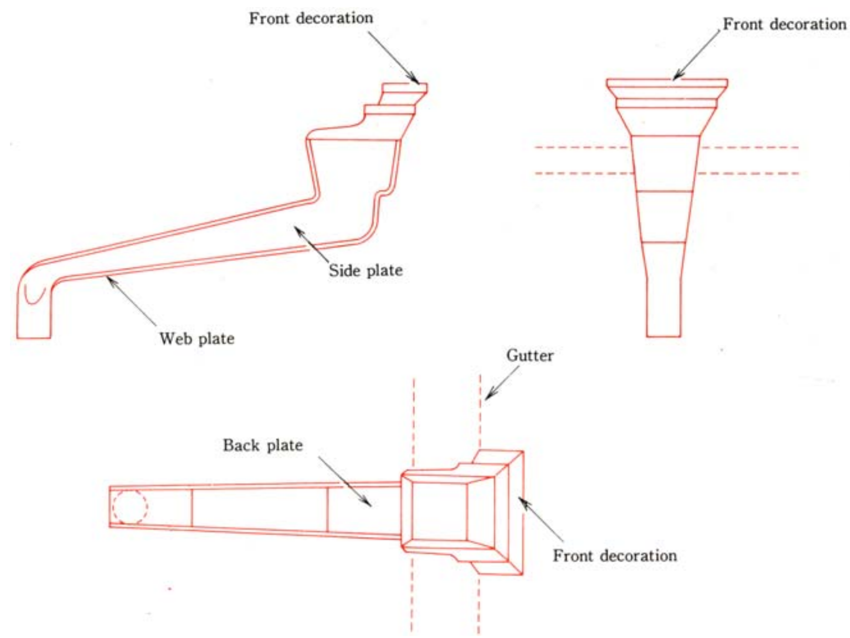


Figure 2.72 Example of leader head

10.5 Valley gutter

(1) Joint method

Commercial sheet thickness is not necessarily satisfactory for the valley gutter. Therefore, the lack of sheet thickness should be compensated for by joint adding. The joint method is such a case, and is shown in Fig. 2.73. It is not advisable to make the joint in the longitudinal direction, as defects such as roof leaks occur. Recently, the welded joint has been used as a joint method.

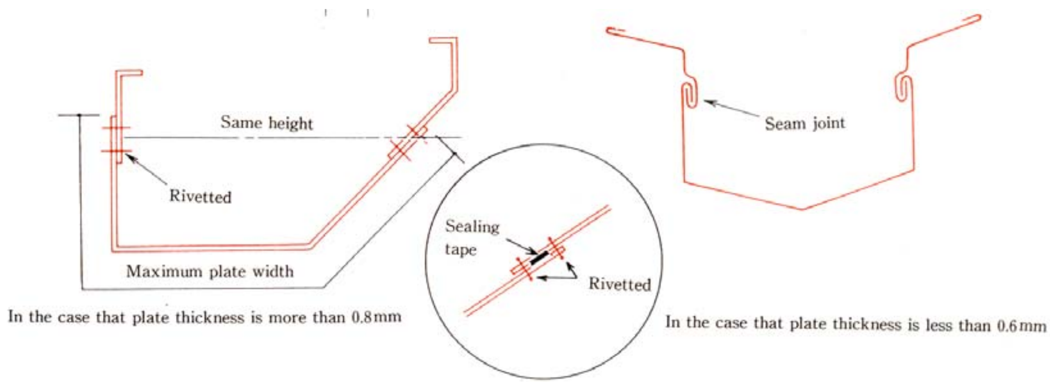


Figure 2.73 Example of connection of valley gutter

(2) Expansion

When the valley gutter is made without a joint, deterioration or deformation occurs due to the temperature change. Attention should be paid, especially to stainless steel sheeting which has a greater temperature change than galvanized steel sheeting. A suitable single length of one valley gutter may be considered to be approximately 10 m.

When a design is made for a valley gutter which exceeds 10 m in length, the structure and size of the expansion joint should be designed, taking into account the thermal expansion coefficient and local temperature conditions.

Fig. 2.74 shows details of a typical expansion joint.

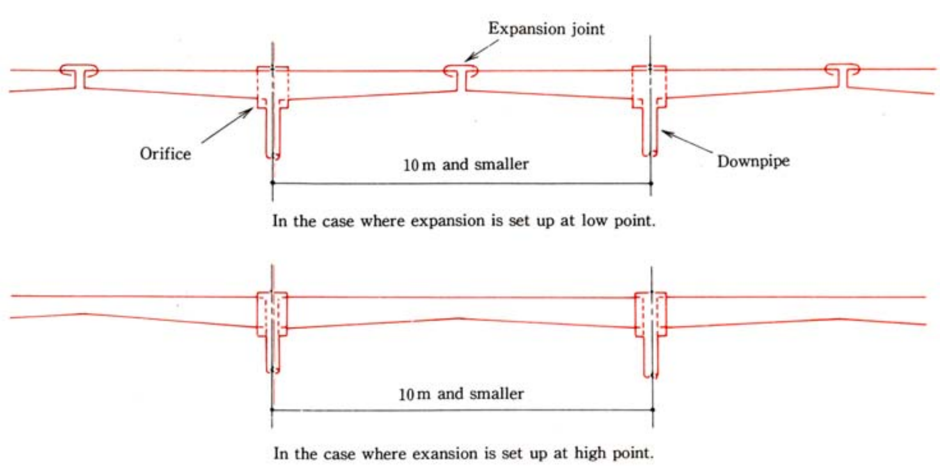


Figure 2.74 Setting method for expansion joint

An example of expansion joint is shown in Fig. 2.75.

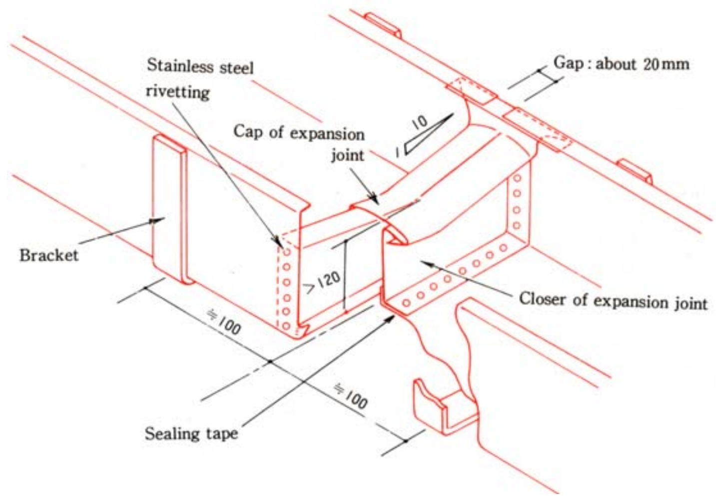


Figure 2.75 Example of expansion joint

(3) Outlet

An example of the outlet is shown in Fig. 2.76. It illustrates where the expansion joint is installed at the high point.

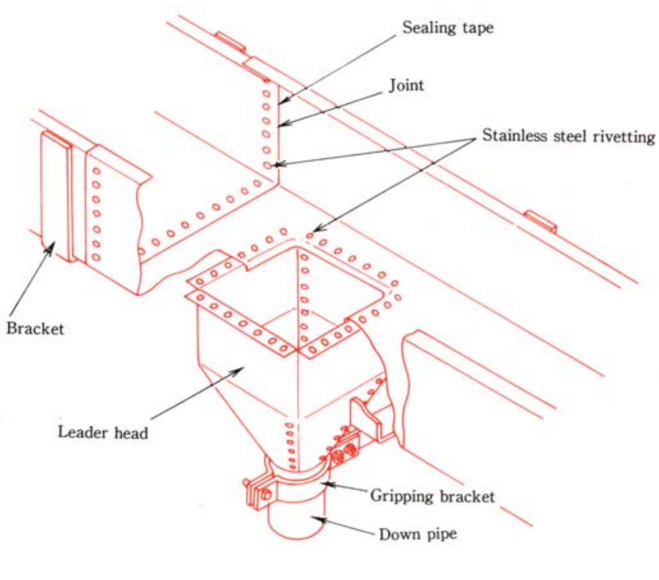


Figure 2.76 Example of outlet

(4) Drain hole

The drain hole is also called an overflow hole. Figs. 2.77 and 2.78 show examples.

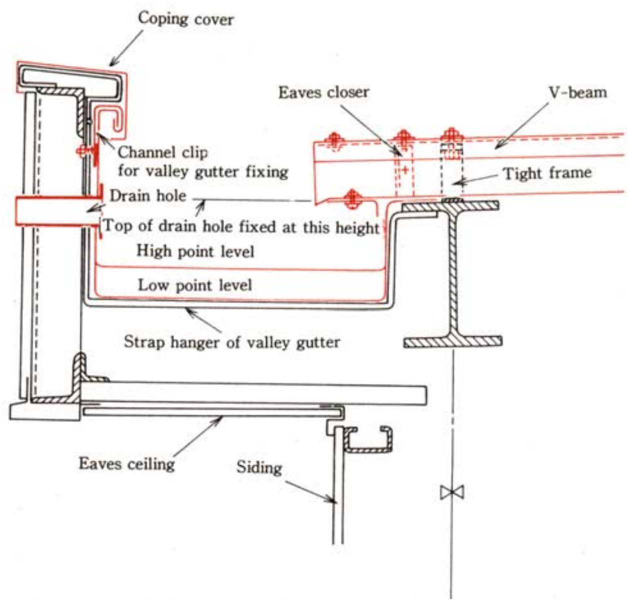


Figure 2.77 Example of drain hole of valley gutter

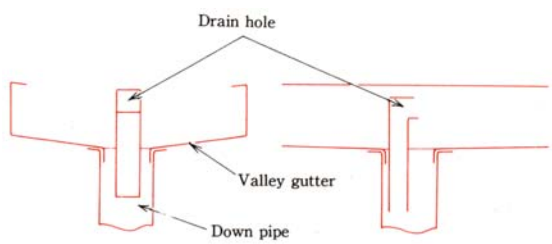


Figure 2.78 Example of drain hole installed at orifice

10.6 Corner valley

A corner valley is shown in Fig. 2.79. In the case of the structural method of Fig. 2.80, Sketch 1, surface A has greater rainwater flow than the surface B. Therefore, the point of the surface B is flooded by the running water and water leakage can occur. To prevent this, it is better to arrange the rainwater flow by setting a barrier in the centre portion of the valley gutter as shown in Fig. 2.80, Sketch 2.

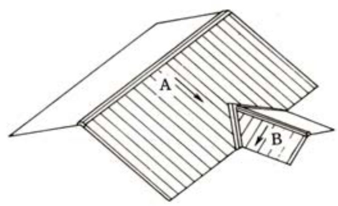


Figure 2.79 Corner valley

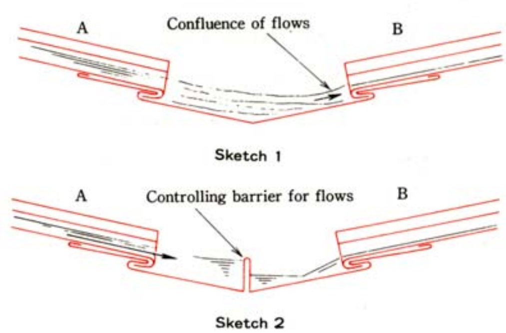


Figure 2.80 Example of corner valley and flow control method

Fig. 2.81 shows an example in which a stage is lowered from a roofing board. If possible, it is advisable to use this method.

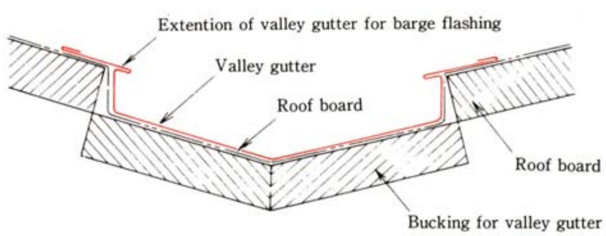


Figure 2.81 Example of lowered corner valley level from roof board level

10.7 Screen

An example of the screen is given in Fig. 2.82.

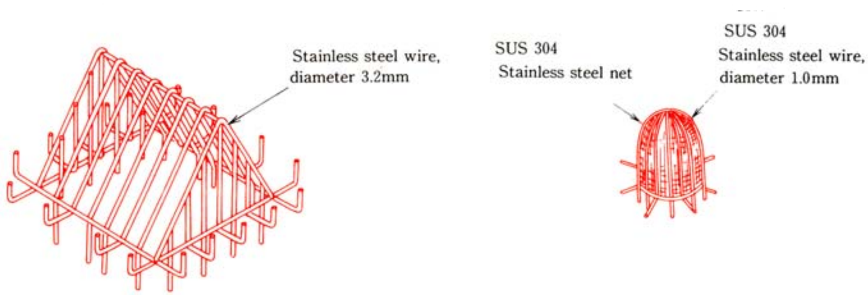


Figure 2.82 Screen

11. Coping

Recently, coping covers using stainless steel have become popular, employing relatively thick sheet, 1.0 mm to 2.0 mm.

These copings, are processed as bottom joint types and screwed to the structure through backing metals. Further, supporting materials are inserted into the joint and the coping is finished by filling with nondetermined sealing materials.

This coping is installed in all types of buildings.

Recently, these copings have been standardized, mass produced, and marketed. They can be more easily used for absorbing the temperature change at the joint portion, by omitting the sealing and by using special corner parts, such as L, T and Z types as a set. Fig. 2.85 gives an example.

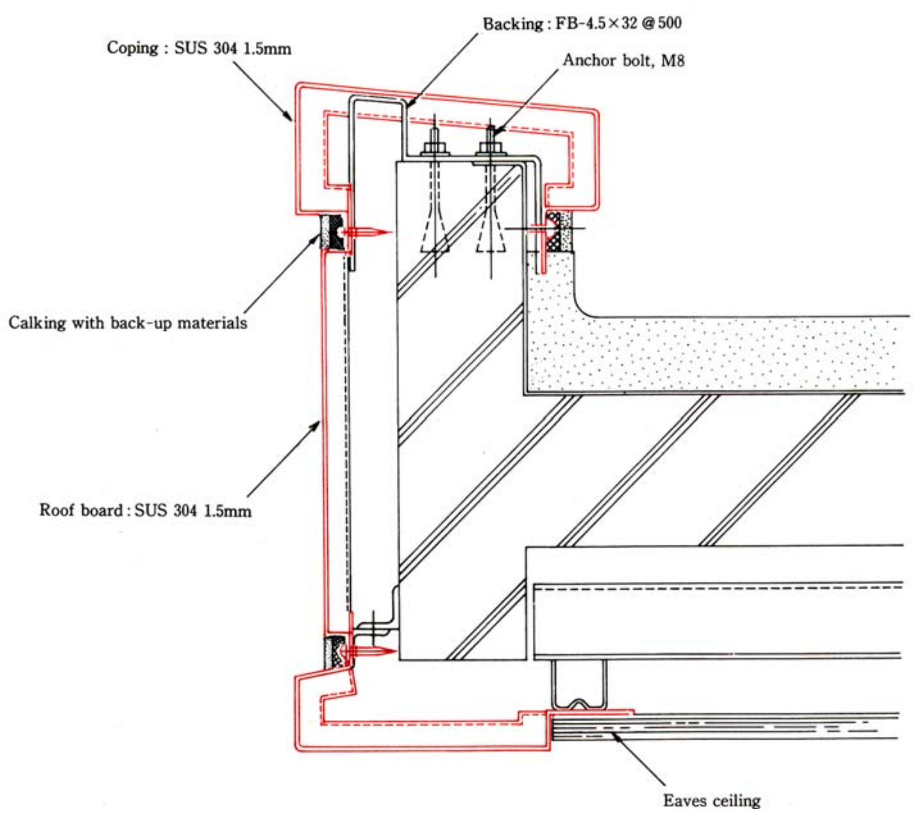


Figure 2.83 Example of coping

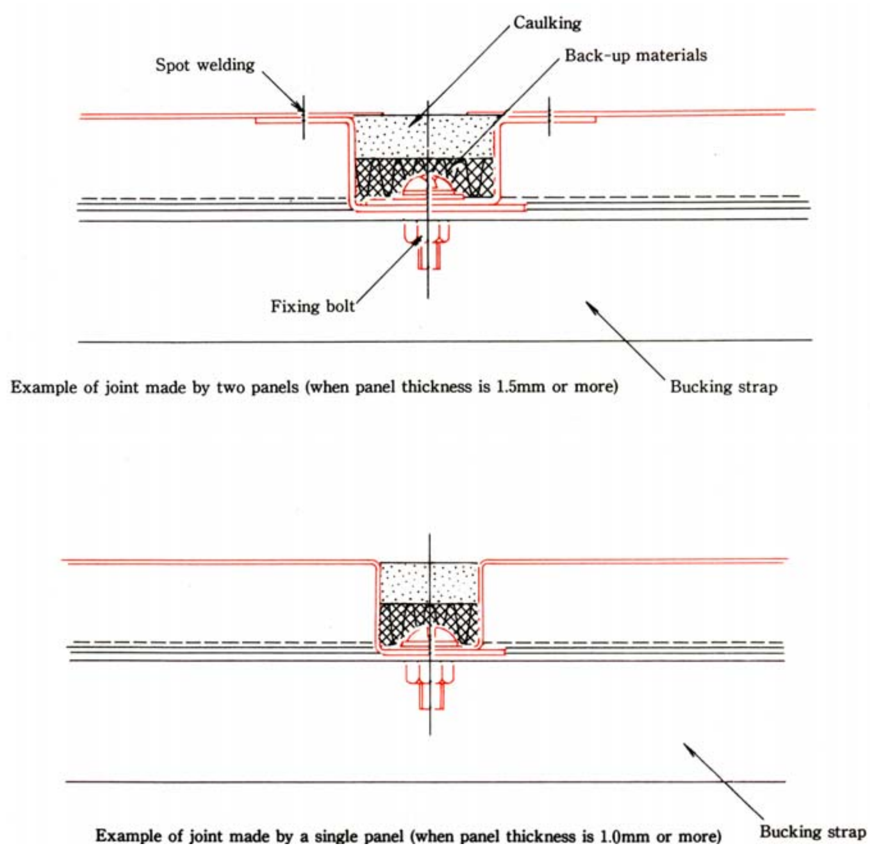


Figure 2.84 Example of joint

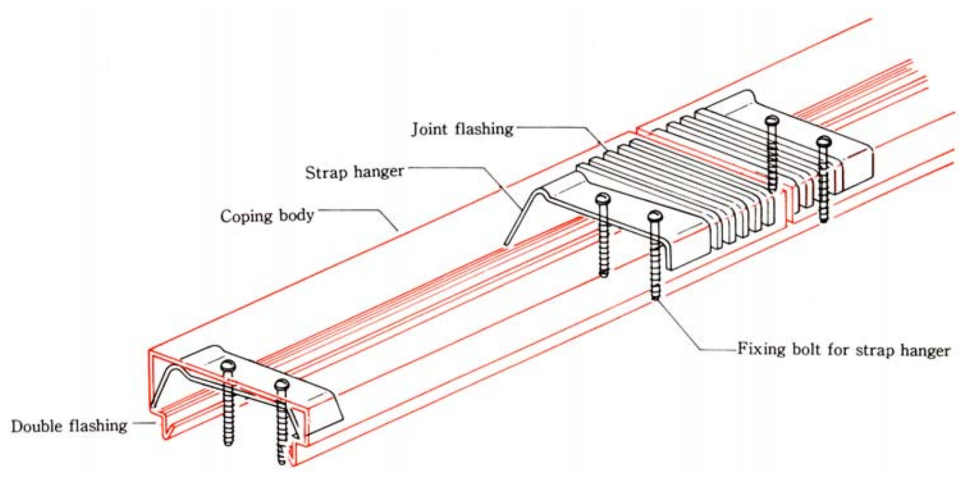


Figure 2.85 Example of prefabricated coping

Part 3 CONSTRUCTION OF STAINLESS STEEL ROOFS

Stainless steel roofs can be constructed the same way as normal steel sheet roofs. Attention should be paid to the following two points:

(1) Fabrication should be carried out by taking into account the working properties of stainless steel.

(2) Fine appearance and superior durability depend upon protecting the passive state coating or coating film of the stainless steel surface.

In this Part, the stainless steel roof construction method is compared with that for normal steel sheet roofs.

1. Transportation and Storage

1.1 Transportation

(1) Surface protection

When moving sheets and coils, they should be handled so as to avoid surface abrasions, scratches or bruises. Therefore:

a) Cushioning materials should be installed at points of contact.

b) Covering should be provided to avoid deposits of dust and iron.

c) Wide hoisting accessories, such as nonmetallic sling belts, should be used instead of metallic wire rope.

(2) Prevention of distortion

Distortion can easily occur in sheets and coils when they are being moved. Therefore:

a) Sheets should be carried on flat nonmetallic (wooden) pallets.

b) Sheets should be stacked and laminated, and the whole bundled with protective covering.

c) Stainless steel sheets should be moved within a shop on a pallet.

d) Coils should be stopped on skids to prevent rolling.

e) The external surface should be wrapped in protective covering and well bundled. Sufficient bundling prevents movement of the centre portion of the coils called “bamboo”.

(3) Prevention of attachment of foreign matter

Attachment of mud, fats and oils must be avoided to prevent rust or surface fouling. Rainwater should also be avoided.

1.2 Storage

(1) Prevention of impact and contact

Damage may occur when stainless steel impacts or makes contact with other objects during storage. Protective covering may be necessary.

(2) Prevention of distortion

a) Sheets should be piled on a flat pallet.

b) Coils should be put on the skid as lying cylinders.

c) When coil diameter decreases, the coil should be rolled to prevent crushing or should be left standing.

(3) Prevention of rust and fouling

a) Attention should be paid so that mud and debris do not become attached. Avoid mud and debris on sheets or coils especially if intended for further processes; when stainless steel is processed with mud or debris present, it causes surface flaws during working.

b) Attachment of mud, oil or water should be avoided.

c) Contact with different types of metal and steel powder should be avoided. If possible store in special frames and racks.

2. General Working

2.1 General

When stainless steel is processed, attention should be paid to damage to the passive state coating and coating film on the stainless steel surface, as well as to prevention of rust induction caused by the use of inadequate tools.

On the other hand, stainless steel has great work hardness when the plastic working is done in ordinary temperature conditions. Therefore, stainless steel requires, in many cases, different treatment from the working of galvanized sheet.

It is advisable to utilize only tools dedicated to stainless steel working.

2.2 Workshop and work table

The workshop should be always kept clean so as not to leave fats and oils, water, sediment, bits and filings of different type of metals.

The work table should be smooth and covered with thick paper or laminated wood, so as not to come in direct contact with the stainless steel.

2.3 Marking-off

It is advisable to use sharpened red- or blue-colored pencils, not marking-off pen.

It is better not to use felt pens and oil pens because the marking-off line will not vanish. It may be convenient for the marking-off line to be put onto the back face of the sheet, i.e., onto the face where the line will not be visible when finished. This will save the trouble of later erasure.

2.4 Damage and protection of coating

A coating film extends and shrinks in a complicated manner when bending or drawing. The sheet hardness, sheet thickness, coating hardness, coating material, temperature and speed and method of working all influence the coating when bending or drawing. The degree of influence of each factor has not yet been defined. The following has been determined empirically:

(1) When the sheet is hard, the force required for working increases, and the coating film is more easily damaged. Therefore, when working it is preferable to use soft annealed sheet.

(2) When forming thick sheets, many flaws in the form of cracks occur in the coating film. In Fig. 3.1, for example, where the ratio of sheet thickness is 1:2 and the inner bending radius is r for both sheets, there is no expansion or shrinkage on the centre line of sheet B, while surface A extends and surface C shrinks. Assuming r = t and 2t sheet thickness, surface A expands 1.5 times the expansion of 1t sheet thickness. Therefore, when the expansion coefficient is the same, the 2t thick sheet is more easily cracked. Thus, when the sheet is thick, the coating film is easily cracked even though the inner bending radius is the same as that of the thin sheet.

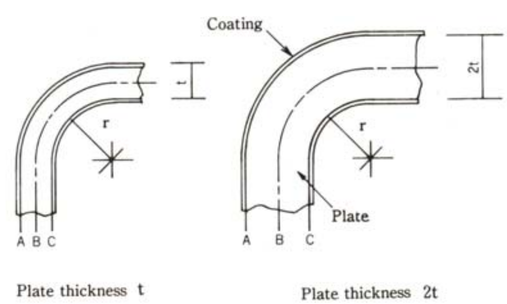


Figure 3.1 Expansion of coating

(3) Flaws accompanying working occur easily when the temperature is low. This is because the expansion coefficient of the coating film decreases as the temperature decreases. If the working temperature is normally 20°C ± 15°C, there is no concern when twice the sheet thickness is used as a bending radius in the case of less than 0.4 mm-thick sheet, and triple the sheet thickness with 0.4 to 0.8 mm-thick sheet. Bending of less than three times the sheet thickness should be avoided in less

than 5°C conditions because cracking and peeling of the coating film occur.

(4) When the rate of bending increases, the coating film will easily damage. Further, when a maximum bend is processed at one time, it will be easily damaged. Roll forming has a particularly strong tendency to do this.

(5) The degree of occurrence of flaws depends upon the working method, and flaws generally occur in working in the following order:

i) Simple bending.

ii) Bending by press (including a little reduction of area).

iii) Bending by roll forming.

iv) Bending by hammering.

The flaws in the case of i) and ii) can be reduced as the conformity increases between the metal and the stainless steel sheet.

In roll forming iii), the sheet is stretched when bending, as shown in Fig. 3.2. Accordingly, the coating surface is more easily damaged than that of i) and ii). In order to reduce the flaw, the number of roll stages should be increased, and the bending angle should be decreased at each stage (see Fig. 3.3).

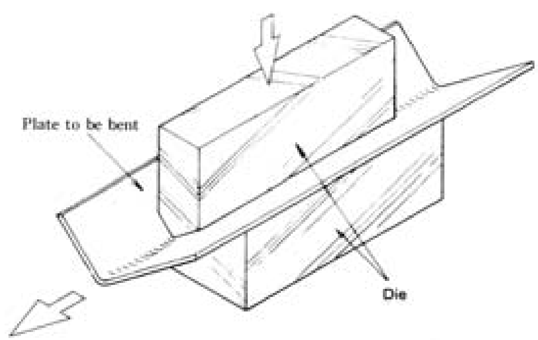


Figure 3.2 Explanatory drawing for rolling forming process

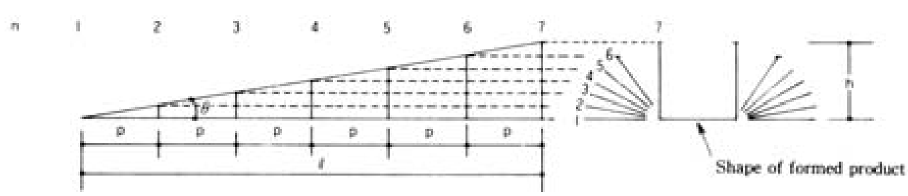


Figure 3.3 Rolling steps and their intervals

In Fig. 3.3, n indicates the number of roll stages, p the roll interval, the ℓ the distance between first roll and final roll. Maximum height size of the cross-section of the formed product is h, and θ indicates bending angle. The value of θ is normally approximately 1°25'. When the angle is greater, overstrain may affect the coating film.

A representative method of bending by hammering in iv) is bending by hand using wooden clappers and a bending table. In this method, a flaw may occur in the bending portions because the bending radius is very small. This method may be avoided since a high degree of skill is required to avoid flaws.

A coated surface is protected by the use of an adhesive removable film, called a guard film, and made of polyethylene or soft chloroethylene sheet of approximately 0.5 mm thick. An adhesive agent is coated on the back face of this film.

Guard film is effective in protecting the coating against abrasion and bruising during working. It is not effective in preventing cracks of the coating film which occur in bending. Further, it is advisable that the guard film be left attached until completion of the roofing work; long periods between sticking and peeling can make removal difficult due to ultraviolet degradation in direct sunlight.

2.5 Transferred rust

For noncoated stainless steel working, attention should be always paid to the prevention of transferred rust. For precoated stainless steel, transferred rust does not occur because the surface is protected by the coating film except where the coating is damaged or peeled, and at cut edges.

In many cases, the transferred rust accompanying working occurs when the working machines and tools contact the stainless steel surface–invisible steel particles are attached to the stainless steel sheet. There are two types of particulates:

1) The particulates accompanied by the wear of machines and the tools themselves.
2) The particulates of steel sheet left over from previous working.

It is almost impossible to prevent the occurrence of the transferred rust due to former particulates. This phenomenon can be prevented, however, if maintenance of machines is adequately performed. Most of the transferred rust in working is caused by the latter particulates. In order to prevent it, it is better to use machines and tools dedicated to the stainless steel, and to avoid using them for other types of sheet working. When the use of machines and tools for other kinds of working is unavoidable, steel powder and debris attached to the machines should be completely removed.

2.6 Repair of flaws when working

Where the coating film is damaged when working, a cold dry coating–recommended by the manufacturer– is evenly coated on the surrounding portions, using spray or brush, after removing and washing the fouling off the coating surface.

The repair of joint portions by welding and soldering is executed in the same way as above.

3. Working Method and Precautions

3.1 Cutting

Since stainless steel is extremely tough, the force required for cutting is greater than that for mild steel (soft sheet, approximately 1.45 times; hard sheet, approximately 1.65).

Therefore, sheets less than 0.5 mm thick can be cut with a snip, but sheets more than 0.5 mm thick cannot be cleanly finished and so they are machine cut.

Attention should be paid to cutting as follows:

3.1.1 Cutting with a snip

(1) The snip blade should be kept sharp. Its use for stainless steel as well as other materials should be avoided.

(2) Cutting should be carried out more slowly than for galvanized sheet.

(3) Since the cut edge of stainless steel characteristically hardens, it is difficult to recut to correct dimensions. It is necessary to cut precisely and initially along the marking-off line.

(4) The snips should not be used all the way down to the blade end. When snips are used to blade end, cracks of distortion may occur perpendicular to the cut direction from the blade end.

(5) Attention should be paid so that burrs occurring in cutting do not appear on the finished product surface:

a) Where the marking-off line is on the back side of a stainless steel sheet, the sheet should be cut with the finished product portion of the sheet placed on the right-hand side of the cutter, as viewed by the operator.

b) Where the marking-off line is on the top side of a stainless steel sheet, the sheet should be cut with the finished product portion of the sheet placed on the left-hand side of the cutter, as viewed by the operator.

(6) When a stainless steel sheet is cut with snips, strain is produced on the cut edge of the sheet. To remove the strain, the sheet should be placed on a surface plate and topped with a mallet, or a correcting roll used.

(7) If a burr occurs in cutting, it should be shaved off with a file.

3.1.2 Cutting by a machine

As mentioned above, the force required for the cutting of stainless steel is approximately 1.45 times that for soft sheet and 1.6 times that for hard sheet, assuming that the galvanized sheet is 1. As a reference, where the flat sheet is cut (in the case where shear angle is not changed in cutting), the shear loading (Fs) can be obtained by the following formula:

$Fs = ktW \cot\theta$ (kgf)

where

k: Correction factor for the material bending, and actually k = 1

t: Sheet thickness (mm)

W: Shear workload required per unit area (kgf-mm/mm^2)

Further, material, W having shear resistance, τ (galvanized sheet; approximately 36 kgf/mm^2, soft stainless steel sheet; 52 kgf/mm^2, hard sheet; 56 kgf/mm^2) can be roughly computed as $W = 0.5t\tau$

θ: Shear angle (degree)

Shear angle means the angle shown in Fig. 3.4, with 12° the upper limit.

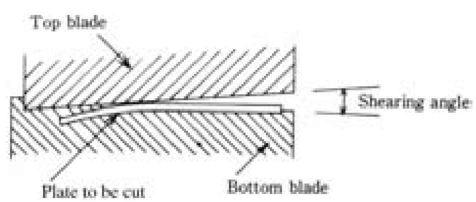


Figure 3.4 Cutting

Cutting by a machine is effective when it is carried out on more than 0.6 mm-thick plate. The cutting machine is roughly divided into the straight blade cutter and rotary cutter.

There are foot cutters (foot-operated shearing machine), power cutters (square shearing machine), and gap shearing machines which can feed and cut long-size sheet as a straight blade cutter. Among them, the gap shearing machine is mainly used for heavyweight sheet.

The rotary shearing machine is mainly used as a rotary cutter. This cutter is able to cut plate freely to a straight line or curve.

Since a machine can more quickly and more cleanly cut the sheet than snips, it is better used for mass production.

When the gap between the double blades is of a size suitable for the sheet thickness, burrs and tears at the cut edge will be avoided.

Galvanized sheet is cut with a gap approximately 10% of the sheet thickness, but it is better to have a smaller gap for stainless steel sheet – SUS 430, 6 to 7%, and SUS 304, 5 to 6%.

Attention should be paid to work as follows, except for the above-mentioned:

(1) The table face of the cutter should be covered by a paper or soft cloth to avoid damage to the sheet surface.
(2) The surface of pressure fitters in contact with the stainless steel sheet should be sufficiently cleaned to avoid deposits of debris and steel powder.
(3) The blade for cutting stainless steel should be always sharper than that for galvanized sheet.
(4) The normal gap between double blades should be maintained.
(5) Prior to this work, a trial cutting should be conducted to confirm the following items in addition to checking the above-mentioned:

a) Suitability of the supporting method of the sheet
b) Sheet hardness
c) Suitability of cutting speed
d) Existence of lube oil

N.B. Although the word "cutter" is used, "shearing machine" is the proper machine term.

3.2 Bending

3.2.1 Bending by hand

Bending by hand is performed by using wooden clappers and a sword edge as shown in Fig. 3.5. In this work, the sheet is put on the bending table and bent by hammering with wooden clappers.

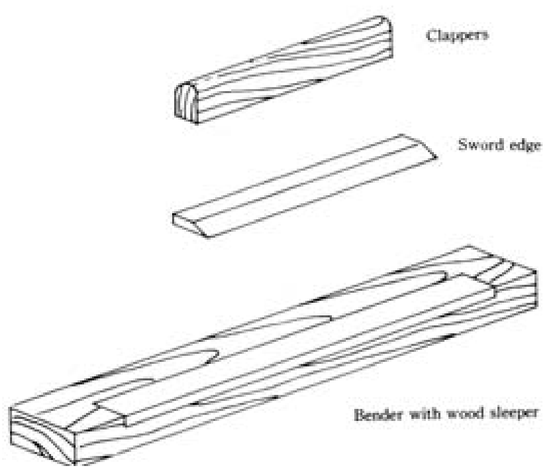


Figure 3.5 Manual bending tools

With this bending method, the sheet is very sharply bent, and the internal bending radius approaches zero. In this bend method the coating film of precoated stainless steel sheet is easily damaged. Precision bending depends upon the worker’s skill.

3.2.2 Mechanical bending

Bending can be roughly divided into three formats, as shown in Fig. 3.6:

a) Impact bending: Bending using punches and dies. V-bending is a typical example, as shown in sketch A.

b) Folding: By fixing one side of the material, another side is bent by the tool which rolls along the shape.

c) Rolling: The material is bent by continuously moving three rolls, for example.

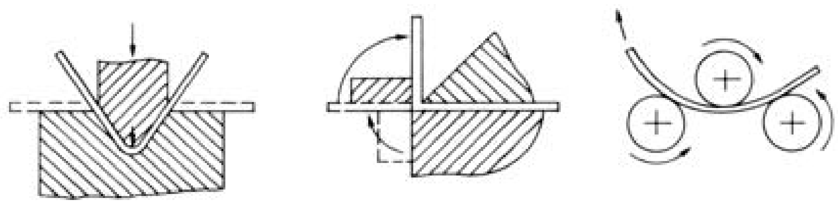


Figure 3.6 Bending processing model

The minimum bending radius represents the limit of sheet bending without producing cracks. Cracking does not occur in SUS 304 or SUS 316, even if a 180° bend is made. With SUS 430 it is advisable to avoid mechanical bending.

In the case of precoated stainless steel sheets–either SUS 304 or SUS 430–bending radius should be more than sheet thickness; a crack may occur in the coating film when the bending radius is less than sheet thickness.

At any rate, it is advisable to confirm the minimum bending radius by the actual bending. Attention should also be paid to the case where the minimum bending radius is different in the rolling direction and at right angles to the rolling direction, depending on the sheet.

After bending, spring back occurs. Since a stainless steel sheet has a greater spring back than galvanized steel sheet, sufficient over bending should be performed so as not to lessen the desired or specified bending angle. For example, in the case where 90° bending is necessary, 88° bending may be used as an inside angle.

SUS 304 is milder and more readily workable than SUS 430. However, work hardening occurs when SUS 304 is subjected to plastic deformation. It should be noted that it is difficult to get the proper angle after improper bending since the bent portion is hardened when bending is first performed.

Fig. 3.7 shows the work hardenability of the typical steel classes, comparing the bending characteristics of SUS 304 and SUS 430 in Table 3.1.

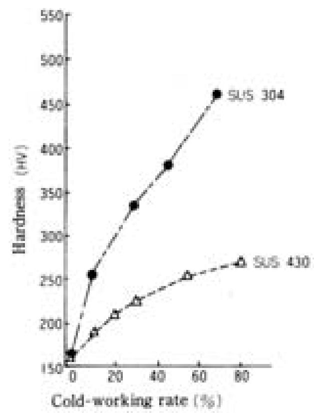


Figure 3.7 Comparison of hardenability of SUS 304 with SUS 430

Table 3.1 Comparison of bendability of SUS 430 with SUS 304

Bending method	Plate thickness mm	Bending radius	Class	
			SUS 430	SUS 304
Manual bending	1.0 or less	180 degrees bending	A	A
		90 degrees bending	A	A
Mechanical bending	1.0 or more	180 degrees bending	B	A
		90 degrees bending	A	A

A : good B : a little inferior

3.2.3 Force required for the bending

The force required for the bending increases in proportion to the tensile strength of the sheet. When sheets with the same thickness are bent under the same working conditions, the force required to bend SUS 430 is approximately 1.65 times, and SUS 304, 1.9, assuming that the force required to bend galvanized sheet is 1.

As a reference, the approximate formula for punching force (P) necessary for the bending working with V dies is indicated in the case of simple bending (free bending).

$P = 2cbt^2 a\sigma_B/3L$ (Free bending)

where

c: Normally considered to be 1 to 2 as a correction factor

b: Sheet width (mm)

t: Sheet thickness (mm)

σ_B: Tensile strength of the sheet (kgf/mm^2)

L: Shoulder spacing of dies (mm)

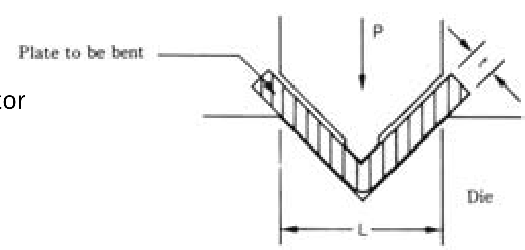


Figure 3.8 Free bending

There are manual bending, brake press bending, and hydraulic pressure bending machines:

The manual bending machine is used for the bending sheets of 0.5 mm or less, while the hydraulic pressure brake press bending machines are used for bending thicker and longer sheets. The brake press and the hydraulic pressure machines are superior in precision bending to the manual machine. Furthermore, the hydraulic pressure type machine is able to bend the sheet by changing the angle with the same die.

3.2.4 Roll forming

Roll forming of stainless steel may be conducted with the same method as for galvanized sheet except for the following items:

(1) Noncoated stainless steel sheet, particularly SUS 304, is subject to surface flaws and distortion due to the working and frictional heat which occur during the working process. Forming speed should therefore be slower than that for galvanized sheet, with a maximum speed of 25 m/min.

(2) In order to avoid flaws due to the difference in peripheral speed of the contact portion of roll and sheet, an idle roll(s) should be incorporated.

(3) Overbending should be provided at the final 2 or 3 stage rolls, taking spring back into account.

(4) The internal bending radius requires a minimum of 1.5 times the sheet thickness and generally twice or more is preferred. Further, it is preferable that the sheet thickness be 2 mm or less for roll forming.

(5) It is necessary that the roll surface should always be polished and cleaned before forming to prevent surface flaws due to the attachment of foreign material.

(6) The following methods prevent the occurrence of the flaws during the forming process:

a) For noncoated stainless steel sheet:
   Work should be conducted by applying a protective guard film.

b) For precoated stainless steel sheet:
   Work should be conducted by adjusting the roll or by applying a guard film.

3.3 Punching

3.3.1 By press

Press punching is carried out under the same conditions as for cutting.

When punching by blanking, where thin sheet is used and precision is required, a clearance between the dies and punch of 2 to 4% of the sheet thickness is adequate. When the clearance is too great, a burr may be produced.

3.3.2 Drilling

For this sheet, drilling is carried out under almost the same conditions as for galvanized sheet. Attention should be paid to the following, along with the possibility of work hardening:

(1) The drill should not be idled on the sheet surface before drilling. Particularly, for SUS 304, drilling would be complicated by work hardening of the surface portion contacted by the drill.
(2) Drilling speed should be slower than that for galvanized sheet or for carbon steel. Normally recommended feed speeds are listed in Table 3.2.

Table 3.2 Drill feed speed

Drill diameter mm	Feed speed mm/rotation
3.2 and below	0.03
6.4 and below	0.05
13 and below	0.08
13~15	0.1

(3) In deep drilling, a crank shaft type drill having a thin wave standard point angle (180°) should be used. When the hole depth is three times the hole diameter, the drilling speed should decrease by 20%, and when four times, by about 30%.
(4) In drilling thin sheet, a hardwood backing strip should be used so that the drill can completely penetrate the sheet.

3.4 Joint

As to stainless steel sheet joint methods, these include mechanical joint methods, such as seam, bolt and rivet, as well as other joint methods, including welding, soldering and brazing.

3.4.1 Seam joint

As to sheet seam joints, there are the small, spiral and duct seam joints. The bending method for seam joints is the same as that for galvanized sheet. Note that stainless steel sheet must be bent with an angle slightly greater than that applicable for galvanized sheet because the former has a large spring back.

3.4.2 Bolt joint

In principle, bolts, nuts and washers used for the bolt joint should be made of the same stainless steel material as the joint sheet. Since the nut can friction weld to the bolt during clamping –when both are SUS304 and when the bolt clamping is done at high speed – SUS XM7 should be used as either the bolt or nut. (The steel classes specified in ASTM standards have been adapted to the Japanese Industrial Standards (JIS).)

3.4.3 Rivet joint

Blind rivets are often used for roofing work. Generally three types of alloys are used for this type of rivet. It is recommended that material made of SUS 305 be used.

The rivet hole should be made with a hand drill after locating the gauge mark with a triangular punch. Since stainless steel has a high level of work hardening characteristics, rivets made of stainless steel must be struck straight out with a large hammer when riveting stainless steel sheets.

3.4.4 Solder joint

Since stainless steel slowly transfers heat and has great thermal expansion (SUS 430, same as that of mild steel; SUS 304 and 316, 1.5 times that of mild steel), its solder joint is technically more difficult to make than that for galvanized sheet.

Procedures for making a solder joint are:

(A) Pretreatment

(1) The coating film of the joining surfaces, and the passive state coating of the stainless steel sheet for precoated stainless steel sheet surface, should be completely removed. The passive state coating should also be completely removed in the case of noncoated stainless steel sheet, by using sandpaper.

(2) The joining surface should be cleaned free of debris, fats and oils. Where the coating is taken off by using a remover, it in turn should be washed off thoroughly with water.

(3) An appropriate stainless steel flux should be applied to the joining surfaces. The flux should be evenly applied – using a bamboo spatula with a sharp point – on the whole joining surface.

(4) Allow time for the flux to activate the joint.

(B) Solder the joint

(1) So called "6-4 solder", which has the range from H60Sn to H65Sn provided in the Japanese Standard Code, Z 3282, is applicable for the stainless steel solder. Other appropriate stainless steel fluxes may be used.

(2) The point of a soldering iron should be washed regularly with mixed hydrochloride and water to keep it clean.

(3) The soldering temperature should be from 200 to 250°C. Better workability can be obtained when stainless steel special flux is used.

(4) The best way to handle long-length joints is to previously spot solder at intervals of about 5 cm. The soldering speed should be half that of mild steel, and solder should be slowly poured into the joint.

(C) Aftertreatment

(1) To improve appearance after the completion of soldering, surplus solder should be shaved off with a wooden or stainless steel spatula.

(2) The excess flux of the soldered joint should be washed off with water after sufficiently neutralizing it with a weak ammonia-water or soap-and-water solution. Red rust will occur on the soldered portion unless this is carefully carried out. Neither caustic soda nor caustic potash should be used to remove the flux.

(3) For precoated stainless steel sheet, the repair coating should be made after joint clean-up.

3.4.5 Welding

There are many welding methods for joining stainless steel sheet. Among them, the methods normally used for roofing are TIG welding, resistance spot welding and seam welding, as indicated in Table 3.3

Stainless steel welding is not difficult. Since stainless steel has different characteristics from mild steel, however, allowances should be made in preparation and during welding. Particularly, thermal expansion and conductivity should be taken into account as being greater than for mild steel.

It is best to refer to "Recommended Practice for Welding of Stainless Steels", edited by the Japan Stainless Steel Association, for detailed welding methods of stainless steel sheet.

Table 3.3 Various welding methods for stainless steel

Data source : "Stainless Steel Welding Standard", edited by Japan Stainless Steel Association

Item / Welding method	Application plate thickness mm	Class					Usage
		SUS 410 13Cr	SUS 430 18Cr	SUS 304 18Cr - 8Ni	SUS 309S 22Cr - 12Ni	SUS 310S 24Cr-20Ni	
Shielded arc welding	t>0.8	2	2	1	1	1	Mainly for butt and fillet welding of thick plate, and padding for large-size pipe and castings.
TIG welding	0.5>t<3	3	3	1	1	1	Mainly for butt and fillet welding of sheet metal, and small-size pipe.
Resistance spot welding	0.15<t<3	3	3	2	2	2	For lap welding where it does not need air tightness-airplanes, cars and kitchen utensils.
Resistance seam welding	0.5<t<3	3	3	2	2	2	For lap welding where it dose not need air tightness-in automobile parts, sinks, gas burner and cold storage equipment.
Brazing	0.3<t<2	4	4	3	3	3	For sheet metal welding and precision parts – no strength reguirement

Remark : Numerical values in above table mean;

1. Good, recommended 2. Normally recommended; however, restrictions sometimes required. 3. For special purposes. 4. Remainder.

4. Roofing Work

4.1 Precautions

Stainless steel roofs are, in principle, erected under the same conditions as those for galvanized steel sheet and precoated galvanized steel sheet. Attention should be paid to the following:

(1) Avoid contact of stainless steel with other metals, especially carbon steel.

(2) Avoid damage and abuse to the roof surface.

For example:

a) Workers should remove sediment–particularly metallic debris–attached to shoe soles.

b) Workers should wear footwear with soft soles.

c) Sufficient care should be taken by laying footboards where workers frequently walk.

(3) Workers should wear clean gloves and avoid touching the stainless steel sheet with bare hands.

(4) Where marking-off lines are needed, a sharp-pointed red or blue pencil should be used instead of a marking-off pin or nail. When using an oil felt pen, marking should be accurate since the colour cannot be removed.

(5) To avoid spatters of concrete, mortar and welding, the roof surface should be covered with sheets of plywood. Special care should be taken to avoid weld spatter.

Mortar dropped on a stainless steel sheet surface should be immediately removed before it hardens.

(6) Drilling debris or cutting chips created during fabrication should be completely removed at the end of the work period. If left as is, red rust can develop from night fog. Special attention should be paid to noncoated stainless steel.

(7) Where a batten seam clamper or roll forming machine is employed, care must be taken to avoid direct contact with the stainless steel sheet surface. Chrome plating, for example, should be executed so as not to contact steel material with the stainless steel sheet. When forming sheet on site using a roll former that has plating damage, transferred rust may occur by the attachment of the invisible particulates of steel powder on the surface.

(8) In batten seam and standing seam roofing, clamping can be difficult when the sheet thickness attains 0.5 mm.

When seam clamping is done with thicker sheets, clamping work can be easily executed by lengthening the shank of the manual seam clamper.

(9) Attention should always be paid to the finished state of the seam joints during seam clamping. If the coating film appears to be damaged, it is necessary to check immediately whether there are abnormalities in the tools and/or working method.

Where the coating film is damaged, fouling should be removed and the coated surface repaired using a coating repair agent recommended by the manufacturer.

4.2 Cleaning

Cleaning after the roofing work is finished should be conducted as follows:

4.2.1 Noncoated stainless steel roofs

Where fouling occurs on the stainless steel sheet surface, cleaning should be carried out using neutral detergent:

(1) Trial wiping should check if the fouling and rust come off. When successful, that method should be used.

(2) With cleaning tools such as cloth, sponge, natural sponge, scrub brush and fine-eyed nylon pad, scrubbing should be done parallel to the polishing direction of the stainless steel sheet, and with as much load as possible. Circular scrubbing is not recommended and should be avoided to protect the original finish.

(3) For heavy fouling, the use of coarse cleanser, sandpaper and steel wool should be avoided– not only will the stainless steel sheet surface be damaged and the gloss lines damaged, but steel powder easily attaches and causes red rust.

(4) When a commercial cleaning chemical is used to remove heavy fouling, not only the fouled portions but surrounding portions should be cleaned.

(5) After completing the cleaning, the following items should be checked so that:

a) Tools, nails, bolts, nuts, and cut debris of steel materials are not left on the work.

b) Fats and oils, cement and mortar are not attached.

c) Cleaning chemicals are not left on the work.

d) Adhered matter from the adhesive films for surface protection is not attached.

e) Dirty footprints are do not remain.

4.2.2 Precoated stainless steel roofs

Prior to the completion of the construction work, an inspection should be made to ensure that the job site is free from debris, spatter and tools. If fouling has occurred, from debris, hands, fats and oils, it should be removed in the following manner:

(1) Dirt and steel powder should be lightly wiped off with a soft cloth.

(2) Oil should be lightly wiped off using a soft cloth and a water-soluble neutral detergent, then rinsed with water. Finally, moisture should be wiped off with a dry cloth.

(3) Metallic brushes and coarse detergents involving scouring powders should be avoided because the coating film will be damaged.

(4) Since organic solvents, such as alcohol, benzene and acetone dissolve the coating film and disturb colour tone, they should not be used even if they can remove fats and oils.

(5) To avoid discolouration, acidic or alkaline detergents–such as hydrochloric acid, nitric acid, cleaning agents for tiles, and caustic soda – should not be used.

(6) Commercial cleaning chemicals–except for neutral detergents–should not, in principle, be used. Particularly, cleaning chemicals for descaling should absolutely not be used. If fouling or rust remains after using a neutral detergent, a commerical cleaner should be used on a trial area to develop an acceptable means for removing fouling or rust .

Attached Table 1　Principal surface finishes of stainless steel

Name	Surface finishing condition	Surface finishing method	Main use and standard
No.1	Silver white, no gloss	Heat treatment and pickling are performed after hot rolling.	For uses not requiring surface gloss. (AISI standard)
No.2D	Dull grey finish	Heat treatment and pickling are performed after cold rolling using dull roll.	For multipurpose use and building material (JIS standard)
No.2B	More gloss and smoother than 2D	Light cold rolling provides proper gloss to the finished material of No. 2D.	For multipurpose use and building material (principal products on the market). (JIS standard)
BA	Gloss approximating mirror	Bright heat treatment is carred out after cold rolling. Further rolling treatment to provide gloss.	Automobile parts, household electric appliances, kitchen utensils, decoration uses (JIS standard)
No.3	Rough finish with gloss	No.2D or No.2B finished materials belt ground with belt of grain size from 100 to 120.	Construction material, kitchen utensils. (JIS standard)
No.4	Fine finish with gloss	No.2D or No.2B finished materials belt ground with belt of grain size from 150 to 180.	Construction material, kitchen utensils, automobiles, medical treatment appliances and food plants. (JIS standard)
No.240	Fine grinding finish	No.2D or No.2B finished materials belt ground with belt of grain size 240.	Kitchen appliances. (JIS standard)
No.320	Grinding finish finer than No. 240	No.2D or No.2B finished materials. belt ground with belt of grain size 320.	Kitchen appliances. (JIS standard)
No.400	Gloss close to BA	No.2B material finished with No.400 buff.	Construction material and kitchen appliances. (JIS standard)
HL	Hairline finish	Hairline made with a belt of grain size from 150 to 240.	Most common finish in construction materials. (JIS standard)
No.6	Dull satin finish having less reflection factor than No.4	No.4 finished material ground with Tanpico brush.	Construction material, decoration uses. (AISI standard)
No.7	Semi-mirror finish having high reflection factor	Material polished with 600 grain rotary buff	Construction material and decoration uses. (AISI standard)
No.8	Highest mirror finish with reflection factor without hair lines	Polished with buff after successive grinding abrasives	Construction material, decorative and reflective uses, mirrors. (AISI standard)

Embossing	Uneven finish	Rolled by etched or carved roll.	Construction material, decoration uses. (Non standard)
Etching	Carved finish by chemical treatment	Covering designed part with acid resistance material and etching other portions with ferric chloride solution.	Objects of art, construction material, kitchen utensils. (Non standard)
Electro-poli shing	Unique gloss finish	Grinding object is electrolyzed as anode in perchloric or phosphoric acid solutions. During the process, high points are removed and an extremely even or flat surface is produced free of high and low profile points. It also has the advantage that a passive state film is formed on the surface	Decorative pipe, decorative uses. (Non standard)
Chemical grinding	Middle gloss finish	Grinding object is dipped in perchloric or phosphoric acid solutions. During this processing method, without electrolysis, material is easily and speedily ground.	Necessary daily goods, vessels and the like. (Non standard)
Molten salt method	Black color finish with good abrasion resistance	Dipped into molten salt of sodium dichromate.	Optical parts, Objects of art. (Non standard)
Acid black colour oxidation method	Some tones are obtained, but not with good abrasion resistance	Dipped into sulfuric acid solution (90 ~ 100°C) containing oxidizing agent.	Optical parts, objects of art. (Non standard)
INCO colour method	Some tones are obtained with good abrasion resistance	Dipped into sulfuric acid solution (80 ~ 90°C) containing chromic acid. After colourization the coating receives a hardening process.	Construction material, kitchen utensils. (Non standard)
Painting method	Some tones are obtain and processing cost is low	Painted with synthetic resin type paint and baked.	Construction material, kitchen utensils. (JIS standard)

Remarks:
1. JIS standard is an abbreviation of Japanese Industrial Standard.
2. AISI standard stands for the American Iron and Steel Institute.

Attached Table 2 Mechanical properties of various steels related with roofing construction

JIS	Symbol of class	Tension test: Yield strength kgf/mm²	Tension test: Tensile strength kgf/mm²	Tension test: Elongation %	Hardness test: Hardness Brinell	Hardness test: Hardness Rockwell B	Hardness test: Hardness Vickers	Bending test: Bending angle	Bending test: Inside radius -multiple of the thickness		
G4304 Hot rolled stainless plates and sheets G4305 Cold rolled stainless plates and sheets G 4306 Hot rolled stainless steel sheet in coil G 4307 cold rolled stainless steel sheet in coil	SUS 304	21 and over	53 and over	40 and over	187 and below	90 and below	200 and below			After solution treatment	
	SUS 316	21 and over	53 and over	40 and over	187 and below	90 and below	200 and below				
	SUS 430	21 and over	46 and over	22 and over	183 and below	88 and below	200 and below	180 °	1.0	After annealing	
G4309 Stainless steel wire	SUS 304－W1		50～80	30 and over						After solution treatment	Diameter 5.0－14.0mm W½H 5.0－6.0 mm
	SUS 304－W2		75～105								
	SUS 304－W ½ H		105～135								
	SUS 305－W1		50～80	30 and over							
	SUS 305J1－W1		50～80	30 and over							
	SUS 316－W1		50～80	30 and over							
	SUS 316－W2		75～105								
	SUS 316－W ½ H		105～135								
	SUS 430－W2		50～75							After annealing	
	SUS 410－W2		50～75								
G4315 Stainless steel wires for cold heading	SUS 304－WSA		55～65	40 and over						Diameter WSA 1.50 to 5.50mm WSB 1.50 to 14.0mm	
	SUS 304－WSB		57～70	25 and over							
	SUS 305－WSA		50～65	40 and over							
	SUS 305－WSB		52～70	25 and over							
	SUS 305J1－WSA		50～65	40 and over							
	SUS 305J1－WSB		52～70	25 and over							
	SUS 384－WSA		45～60	40 and over							
	SUS 384－WSB		47～65	25 and over							
	SUS XM7－WSA		45～60	40 and over							
	SUS XM7－WSB		47～65	25 and over							
	SUS 430－WSB		47～65	10 and over							
	SUS 410－WSB		47～65	10 and over							
G 4317 Hot rolled stainless steel equal leg angles	SUS 304	21 and over	53 and over	40 and over	187 and below	90 and below	200 and below			After solution treatment	
	SUS 316	21 and over	53 and over	40 and over	187 and below	90 and below	200 and below				
	SUS 430	21 and over	46 and over	22 and over	183 and below	88 and below	200 and below			After annealing	

Attached Table 3 Standard size of cold rolled stainless steel plates (JIS G 4305)

(Unit : mm)

Thickness							Width × Length
							914×1,829
0.3	0.4	0.5	0.6	0.7	0.8	0.9	1,000×2,000
1.0	1.2	1.5	2.0	2.5	3.0	4.0	1,219×2,438
5.0	6.0	7.0	8.0	9.0	10.0	12.0	1,219×3,048
15.0	20.0						1,500×3,000
							1,524×3,048

Attached Table 4 Standard thickness of cold rolled stainless steel strip (JIS G 4307)

Unit : mm

Standard thickness								
0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2
1.5	2.0	2.5	3.0	4.0				

Remarks : Width conforms to plate width.

JAPANESE INDUSTRIAL STANDARD

Precoated Stainless Steel Sheets

1. Scope

This Japanese Industrial Standard specifies the precoated stainless steel sheets in cut length and in coils, hereinafter referred to as "sheets and coils", respectively, intended mainly for the use of roofs, outdoor and interior parts of buildings. Sheets and coils are coated with organic paint and baked on the cold reduced stainless steel sheet in coil specified in JIS G 4307.

Remark: In this standard, units and numerical values in { } are in accordance with the International System of Units (SI) and given for reference only.

2. Grade and Designation

Sheets and Coils shall be classified into 4 grades, and the designation, the classification of coating and the base metal shall be as shown in Table 1.

Table 1 Designation, Classification of Coating and Base Metal

Designation of grade	Division of coating	Base metal
SUS C 304 SUS CD 304	One side (1) Both sides	SUS 304
SUS C 430 SUS CD 430	One side (1) Both sides	SUS 430

(1): The term "one side" in "division of coating" is so defined as one side being certified by painting and the reverse side as merely having a protective layer.

3. Physical Properties of Coating

After being tested in accordance with 8.1.1 to 8.1.4 inclusive, sheets and coils shall conform to the requirements specified in Table 2.

Table 2 Physical Properties of Coating

Test item	Condition after testing (by visual examination)
Lattice pattern cutting test	No defect on the tested portion.
Impact test	No flaking from the base metal and no cracking of coating.
Coating bend test	No flaking of coating on the outside of the bent portion at any place not less than 7 mm from each side edge of the test piece.
Pencil hardness test	No scratch mark on the coating.

4. Corrosion Resistance of Coating

Sheets and coils shall be salt spray tested in according to 8.2.1. As a result of this test continued for the period of time specified in Table 3, the test piece shall be free from defects. However, slight blisters on the test piece may be acceptable.

Table 3 Salt Spray Test

Classification	Salt spray test
Coated side	1000h

5. Appearance

Sheets and coils shall be free from holes, breaks, non-uniformities in colour, any remarkable discrepancy of hue and other imperfections that are detrimental to practical use. However, coils may include a few welds and irregular portions which are not readily removed.

6. Dimensions and Shapes

6.1 Dimensions

6.1.1 The thickness of sheets and coils shall be expressed as the thickness of the base metal prior to coating, which shall be regarded as the nominal thickness. The preferred nominal thickness should be as given in Table 4.

Table 4 Nominal Thickness Unit: mm

0.30	0.35	0.40	0.50	0.60	0.70	0.80

Remark : The thickness other than those given in the above table shall be agreed upon between the purchaser and the manufacturer.

6.1.2 The width of sheets and coils and the length of sheets shall be as given in Table 5.

Table 5 Width and Length Unit: mm

Preferred width	Preferred length			
610	------			
762	1829	2438	3048	3658
914	1829	2438	3048	3658
1000	2000	3000		
1060	------			
1219	2438	3048	3658	

Remarks: 1. 610 and 1060 in width should not be applied to sheet.
2. When the width of sheets and coils and length of sheets other than those given in the above table are required, they will be agreed upon between the purchaser and the manufacturer.

6.2 Dimensional and Shape Tolerances

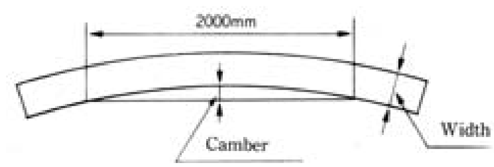
6.2.1 Tolerances on width and length for sheets and coils shall be as given in Table 6.

Table 6 Tolerances on Width and Length Unit: mm

Division	Tolerance on Width		Tolerance on Width
	Mill edge	Slitted edge	
Sheets	+10 0	+5 0	+10 0
Coils	+10 0	+5 0	+ Not specified 0

6.2.2 The camber for sheets and coils shall be measured at any position according to the way given in Fig. 1, and the value shall not exceed 2mm per 2000mm in length. Where the sheets are under 2000mm, the tolerance shall be not more than 2mm per full length.

Fig. 1 Measuring Method of Camber



7. Weight

7.1 The weight of sheets and coils shall be expressed in kilograms (kg) in theoretical weight.
Remark: The term "weight" used in this standard means the "mass".

7.2 The method of calculation of the weight of sheets and coils shall comply with Table 7 according to the nominal dimensions. The unit weight, the weight of single sheet and the unit weight of coil obtained by Table 7 are given in Attached Tables 1 to 3, inclusive.

Table 7 Method of Weight Calculation

Order of calculation		Method of calculation	Number of digits in calculated result
Basic weight $kg/mm \cdot m^2$	SUS C304 SUS CD304	7.93 (1mm in thickness · $1m^2$ in area)	—
	SUS C430 SUS CD430	7.70 (1mm in thickness · $1m^2$ in area)	—
Unit weight, kg/m^2		Basic weight ($kg/mm \cdot m^2$) × thickness (mm)	Rounded off to 4 significant figures

Sheet	Area of sheet, m^2	Width (mm) × length (mm) × 10^{-6}	Rounded off to 4 significant figures
	Weight of single sheet, kg	Unit weight (kg/m^2) × area (m^2)	Rounded off to 3 significant figures
	Weight of a single bundle, kg	Weight of a single sheet (kg) × number of sheets in a single bundle of the same dimensions	Rounded off to integral number of kg
	Total weight, kg	Total weight of each bundle (kg)	Integral number of kg
Coil	Unit weight of coil, kg/m	Unit weight (kg/m^2) × width (mm) × 10^{-3}	Rounded off to 3 significant figures
	Weight of a single coil, kg	Unit weight of coil (kg/m) × length (m)	Rounded off to integral number of kg
	Total weight, kg	Total weight (kg) of each coil	Integral number of kg

Remarks:
1 . When sheets are ordered by number of sheets, the calculation of total weight shall follow such method that "weight of a single sheet (kg) x total number of sheets", and the results shall be rounded off to integral number of kg.
2. The number of sheets, when the bundle weight is specified, shall be obtained by dividing the specified weight by the weight of a single sheet, and then rounded off to integral number.
3. The length of coil, when the coil weight is specified, shall be obtained by dividing the specified weight by the unit weight of coil, and then rounded off to integral number.
4. Rounding off the numerical value shall be in accordance with the rule provided in JIS Z 8401.

8. Test

8.1 Product Test

8.1.1 Lattice pattern cutting test

Lattice pattern cutting test shall conform to each clause of the following:

(1) Straight lines shall be cut to reach the surface of base metal through the coated layer so as to form squares using a safety razor blade with single edge or other cutting apparatus.

(2) Eleven straight lines shall be cut crosswise at right angles, at intervals of 1 mm.

8.1.2 Impact Test

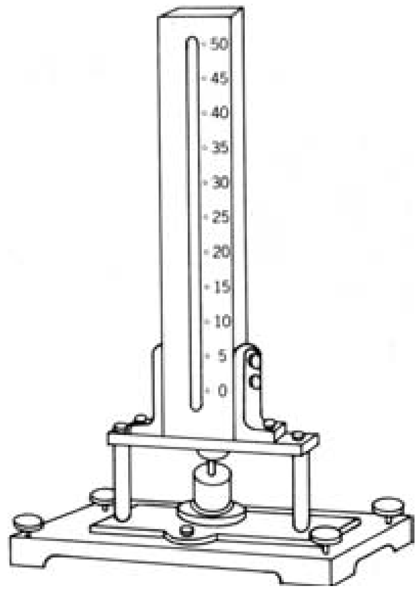
The impact test shall conform to each of the following:

(1) A weight shall be dropped onto a test piece from the top of a Du Pont type impact tester specified in Fig. 2.

(2) The testing weight shall be 500 ± 1g, and the radius of indenter shall be 6.35 ± 0.03mm.

(3) The weight shall be dropped from a height of 500mm above the test piece.

Fig. 2 Du Pont Type Impact Tester



8.1.3 Bend test

The bend test shall conform to each clause of the following:

(1) The test piece shall have a width of 75mm to 125mm and a length almost twice as long as the width. Unless otherwise specified, the longitudinal axis of test piece shall be parallel to the rolling direction of the base metal.

(2) The test piece shall be bent with a hand vise or other suitable means at 180° so as the coated surface becomes the outside surface of the bent portion.

(3) The internal spacing of the bend shall be as given in Table 8.

Table 8 Internal Spacing of Bend

Nominal thickness mm	Internal spacing of bend
0.40 and under	2 sheets of nominal thickness
Over 0.40 to 0.80 inch	3 sheets of nominal thickness.

8.1.4 Pencil hardness test

The pencil hardness test shall conform to each of the following conditions:

(1) The lead of H in hardness of a pencil equal or superior to Ordinary Grade specified in JIS 5 6006 shall be cut so as to obtain a flat surface at a right angle to the direction of the lead, as shown in Fig. 3.

(2) Holding the prepared pencil at 45 degrees to the surface of the test piece, straight lines shall

be drawn with the pencil in the direction as shown in Fig. 4. The lines shall be not less than 20mm in length and not less than three in number.

Fig 3 Pencil Cutting Method

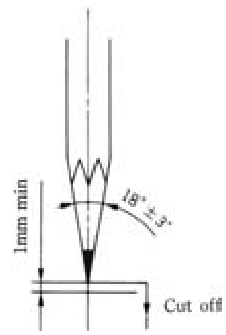
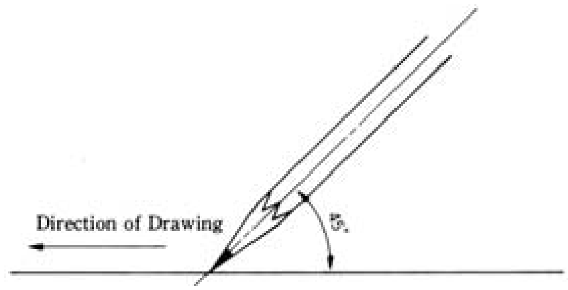


Fig. 4 Pencil Hardness Testing Method



Reference: The load to be applied while drawing a straight line shall be approximately 1 kgf (9.8 N)

8.2 Performance Test

8.2.1 Salt spray test The salt spray test shall conform to each clause of the following:

(1) The size of the test piece shall be 75 x 150mm.

(2) The section including the surface within 10mm from each edge of the test piece shall be sealed by suitable means.

(3) The test method shall comply with JIS Z 2371.

8.3 Cautions for Testing The cautions for testing shall conform to each clause of the following: (1) The tests shall be conducted for flat sheets with normal surface.

(2) The product tests shall be carried out at ambient temperature [(2)].

Note [(2)]: Ambient temperature shall be equivalent to standard temperature Class 4 (20 ± 15°C) specified in J IS Z 8703.

9. Inspection

9.1 Sampling method of specimen One specimen for lattice pattern cutting test, impact test, bend test and pencil hardness test shall be taken from each lot consisting of 30 tonnes or less of the same class, dimension, colour and classification of coating. One additional specimen shall be taken when the weight of the same lot exceeds 30 tonnes. One test piece shall be cut from one specimen.

9.2 The test results of physical properties of coating, appearance, dimensions and shape shall conform to the requirements specified in 3., 5. and 6.

9.3 When a part of the test results for physical properties of coating fails to conform to the requirements, a retest–using double the number of test pieces taken from the same lot–may be carried out. In this case, the lot shall be rejected unless all of test pieces satisfy the requirements.

9.4 Corrosion resistance property of coating is a performance test, and the test result shall conform to the requirements of 4.

10. Marking

10.1 The sheets and coils that passed the inspection shall be packed, as a rule, and the following items shall be marked on each package by suitable means at the manufacturer's premises:

(1) Designation of grade
(2) Name of colour
(3) Dimensions
(4) Number (for sheets) or length (for coils)
(5) Weight of sheets or coils
(6) Manufacturer's name or its identifying brand

Example of indication:

(a) For sheet

SUS C 304	□	0.35	x	914	x	1829
Disgnation of grade	Name of colour	Thickness (mm)		Width (mm)		Length (mm)
SUS CD 304	□□	0.40	x	1000	x	2000
Disgnation of grade	Name of colour	Thickness (mm)		Width (mm)		Length (mm)

(b) For coil

SUS C 430	□	0.30	x	1060	x	1635
Disgnation of grade	Name of colour	Thickness (mm)		Width (mm)		Length (mm)

10.2 The sheets and coils that passed the inspection shall, as a rule, be marked the following items on each sheet (or on each coil) by suitable means.

(1) Nominal thickness
(2) Designation of grade
(3) Manufacturer's name or its identifying brand

11. Report

The purchaser may request the manufacturer to present reports on the test results, as well as the grade, dimensions and quantities, if necessary.

1) Attached Table 1 Unit weight

Unit: kg/m^2

Nominal thickness, mm \ Designation of grade	SUS C 304, SUS CD 304	SUS C 430, SUS CD 430
0.3	2.379	2.310
0.35	2.776	2.695
0.4	3.172	3.080
0.5	3.965	3.850
0.6	4.758	4.620
0.7	5.551	5.390
0.8	6.344	6.160

Attached Table 2 Weight of a single sheet

Designation of grade	Width(mm)	762				914				1000		1219		
	Thickness (mm) \ Length (mm)	1829	2438	3048	3658	1829	2438	3048	3658	2000	3000	2438	3048	3658
SUS C304, SUS CD304	0.3	3.32	4.42	5.52	6.63	3.98	5.30	6.63	7.95	4.76	7.14	7.07	8.84	10.6
	0.35	3.87	5.16	6.45	7.74	4.64	6.19	7.73	9.28	5.55	8.33	8.25	10.3	12.4
	0.4	4.42	5.89	7.37	8.84	5.30	7.07	8.84	10.6	6.34	9.52	9.43	11.8	14.1
	0.5	5.53	7.37	9.21	11.1	6.63	8.84	11.0	13.3	7.93	11.9	11.8	14.7	17.7
	0.6	6.63	8.84	11.1	13.3	7.95	10.6	13.3	15.9	9.52	14.3	14.1	17.7	21.2
	0.7	7.74	10.3	12.9	15.5	9.28	12.4	15.5	18.6	11.1	16.7	16.5	20.6	24.8
	0.8	8.84	11.8	14.7	17.7	10.6	14.1	17.7	21.2	12.7	19.0	18.9	23.6	28.3
SUS C430, SUS CD430	0.3	3.22	4.29	5.36	6.44	3.86	5.15	6.44	7.72	4.62	6.93	6.87	8.58	10.3
	0.35	3.76	5.01	6.26	7.51	4.51	6.01	7.51	9.01	5.39	8.08	8.01	10.0	12.0
	0.4	4.29	5.72	7.15	8.59	5.15	6.86	8.58	10.3	6.16	9.24	9.15	11.4	13.7
	0.5	5.37	7.15	8.94	10.7	6.44	8.58	10.7	12.9	7.70	11.6	11.4	14.3	17.2
	0.6	6.44	8.58	10.7	12.9	7.72	10.3	12.9	15.4	9.24	13.9	13.7	17.2	20.6
	0.7	7.51	10.0	12.5	15.0	9.01	12.0	15.0	18.0	10.8	16.2	16.0	20.0	24.0
	0.8	8.59	11.4	14.3	17.2	10.3	13.7	17.2	20.6	12.3	18.5	18.3	22.9	27.5

Attached Table 3 Unit weight of coil

Unit: kg/m^2

Designation of grade	SUS C 304, SUS CD 304						SUS C 430, SUS CD 430					
Thick-ness(mm) \ width (mm)	610	762	914	1000	1060	1219	610	762	914	1000	1060	1219
0.3	1.45	1.81	2.17	2.38	2.52	2.90	1.41	1.76	2.11	2.31	2.45	2.82
0.35	1.69	2.12	2.54	2.78	2.94	3.38	1.64	2.05	2.46	2.70	2.86	3.29
0.4	1.93	2.42	2.90	3.17	3.36	3.87	1.88	2.35	2.82	3.08	3.26	3.75
0.5	2.42	3.02	3.62	3.96	4.20	4.83	2.35	2.93	3.52	3.85	4.08	4.69
0.6	2.90	3.63	4.35	4.76	5.04	5.80	2.82	3.52	4.22	4.62	4.90	5.63
0.7	3.39	4.23	5.07	5.55	5.88	6.77	3.29	4.11	4.93	5.39	5.71	6.57
0.8	3.87	4.83	5.80	6.34	6.72	7.73	3.76	4.69	5.63	6.16	6.53	7.51