Technical Note No. 22

CLADDING METALS 1 - Ferrous Metals

Introduction

The metals most commonly used in cladding systems are aluminium alloy and steel. However, stainless steel, copper, lead and bronze can be and have been used to create a more distinctive appearance and/or to improve the durability of the facade.

Table 1 compares the typical physical properties of metals suitable for cladding. This Technical Note describes the properties and uses of ferrous metals including plain carbon steel, zinc coated steel and stainless steel. Non-ferrous metals are described in Technical Note 23.

Plain carbon steel

Properties

Plain carbon steels are iron-carbon alloys that may contain small amounts of other alloying elements such as manganese, phosphorous, sulphur, copper and silicon. Mild steel refers to steel with a carbon content up to 0.25% to which no other alloying elements have been deliberately added. It is strong, ductile and readily weldable.

Steel will quickly corrode when exposed to normal moist atmospheres; consequently, when used externally, it is common for mild steel to be galvanised, and then painted for architectural reasons. Failure to galvanise steel prior to application of paint coatings is a common cause of corrosion – certain architectural paint coatings (e.g. polyester powder coatings) do not fully protect against corrosion. The corrosion resistance of mild steel can be increased by adding up to 0.1% copper.

Plain untreated mild steel generally has a yield strength of approximately 250 N/mm^2 and an ultimate tensile strength of about 420 N/mm^2.

Metal	Density (kg/m^3)	Thermal conductivity (W/m°C)	Coefficient of thermal expansion (×10^{-6}/°C)	Modulus of elasticity (kN/mm^2)	Tensile strength (N/mm^2)	Melting point (^{o}C)
Aluminium	2800	200	24	70	70 to 140	680
Mild-steel	7850	55	12	207	420 to 510	1900
Stainless steel	7800	15	17	207	500	1440
Copper	8930	400	17	100 to 130	210 to 360	1083
Lead	11340	35	30	1.4	15	327
Brass (40% zinc)	8400	129	21	103	370 to 540	905
Aluminium Bronze	8800	70	18	120	420 to 690	1050

Table 1 Typical values of some physical properties of metals suitable for cladding

Both these values may be increased up to approximately 460 and 600 N/mm^2 respectively by cold working and heat treatment. The strength of the steel does not have a significant effect on the elastic modulus.

Strength may also be increased by altering the alloy composition, particularly increasing the carbon content, although the increased strength is at the expense of reduced ductility.

The strength is progressively reduced at temperatures greater than 300^{o}C requiring fire protection for structural elements.

Classification of Steels

British Standards for steel are being replaced by European Standards, which use different classification systems. BS EN 10027 sets out designation systems for steels. Part 1 covers a naming system and Part 2 gives a numbering system. Two alternative naming systems are given, one based on the intended use of the material and mechanical or physical properties and the other based on composition.

The most relevant parts of the system based on use and mechanical /physical properties are as follows:

- a letter (S for structural, B for reinforcing, E for engineering), followed by the yield strength in N/mm^{2,} or
- Y (for prestressing) followed by the tensile strength in N/mm^2, or
- H denoting cold rolled flat products of high strength steel for cold forming followed by the yield stress or T and the tensile strength, or
- D for other flat products followed by C for cold rolled, D for hot rolled or X where rolling condition not specified.

There are three systems based on composition, which relate to non-alloy steel, non-alloy steel with high manganese content and alloy steel.

For non-alloy steels the letter C is used followed by the carbon content multiplied by 100. For alloy steels, the letter X is followed by the carbon content multiplied by 100 followed by the chemical symbols of the alloying elements in order of decreasing concentration followed by the percentage compositions of the alloying elements to the nearest integer separated by hyphens.

The numbering system consists of five digits. The first digit is 1 for steel. The next two digits indicate the material group number as defined in the standard, for example 01 and 91 are for general structural steel with a tensile strength less than 500N/mm^2. The final two digits are sequential numbers allocated by the European Registration Office.

Applications

Steel is used in building facades in many forms including:

- Hot rolled structural sections for the main building frame,
- Cold forming of sheet or plate may be used to produce lighter structural sections for curtain wall frames, cladding rails and purlins and for making brackets.
- Steel strip is used for profiled metal sheeting, cladding panels, vapour barriers, flashings, copings, etc.
- Black bolts and nuts are produced by machining forged steel. High strength friction grip bolts are made by forging and are heat treated after manufacture.
- Hot rolled steel bars are used for reinforcement of concrete.
- Brackets, screw fixings, etc.

Standards covering products relevant to cladding are as follows:

BS 1449 *Steel plate sheet and strip* has been replaced by a large number of European standards. The following are relevant to materials used for cladding:

BS EN 10051 *Specification for continuously hot rolled uncoated plate sheet and strip of non-alloy steels. Tolerances on dimensions and shape*.

BS EN 10131 *Cold rolled uncoated low carbon and high yield strength steel flat products for cold forming. Tolerances on dimensions and shape*.

BS EN 10149 *Specification for hot rolled flat products made of high yield strength steels for cold forming.*

BS 4360 *Specification for weldable structural steels* has also been replaced by a number of European Standards. The most relevant is BS EN 10025:1993, *Hot rolled products of non-alloy structural steels and their technical delivery conditions*.

In the BS 4360 classification, grades were based on the tensile strength whereas European grades are based on the yield strength. Thus grades 40A, 43A and 50A in BS 4360 are equivalent to S235, S275 and S355 in the current European Standard. Additional confusion arises from the fact that a previous version of BS EN 10025 issued in 1990 was based on the tensile strength and used the prefix Fe.

The letters following the strength in these grade designations indicate impact performance and a C in the current European system indicates suitability for cold forming.

Guidance on the structural use of steel is given in BS 5950 and guidance on the use of profiled steel cladding is given in CP 143: Part 10 and BS 5427.

Zinc coated steel

Zinc coating is the most common way of protecting steel against corrosion, although it is often pre-treated and then over-painted to enhance corrosion resistance and appearance. Zinc protects the underlying steel in two ways:

- The zinc acts as a physical barrier between a potentially corrosive environment and the steel substrate. Under most conditions zinc corrodes more slowly than steel; under normal atmospheric exposure zinc corrodes at a rate of between about 1/10 and 1/50 of that of steel.

- The zinc gives galvanic or sacrificial protection at unprotected cut edges and at scratches.
  For minor defects in the zinc coating it will continue to protect the underlying steel by galvanic action, giving very good performance in clean, neutral conditions, performing well in mildly alkaline conditions, but subject to chemical attack in acidic (industrial) environments. Larger areas of damage (maximum $40mm^2$) should be repaired using either zinc-rich paint or low melting point zinc alloy repair rods or powders, which should be at least equal to the thickness of the original zinc coating. The degree of protection also depends on the area of zinc exposed adjacent to the defect. Where the zinc is painted the area of zinc exposed adjacent to a defect will be reduced and consequently the degree of protection will also be reduced.

There are many methods of zinc coating steel:

- Continuous hot-dip galvanising
- Hot-dip galvanised coating of articles
- Thick hot-dip galvanised coating
- Centrifugal galvanising (BS 729)
- Zinc spray (BS EN 22063)
- Zinc plating
- Sherardizing
- Coatings incorporating zinc dust

The most widely used methods are continuous hot-dip galvanising of coil, hot-dip galvanised coating of articles, zinc plating and sherardizing, which are described below.

The specifier must select the zinc coating appropriate for the type of component and the finish that offers the required economy, strength, formability and level of corrosion resistance depending on the exposure conditions. Wear resistance and surface appearance may also be important properties of the zinc coating.

Continuous hot-dip zinc galvanising of coil

Hot-dip galvanising is one of the most common methods of zinc coating and provides the thickest protective zinc layer. A mixture of zinc and aluminium can also be used and gives better performance for the same thickness. When thin steel sheeting is manufactured, it is wound into large rolls known as ‘coil’. In the galvanising of coil, the steel, in one continuous process, is:

- De-coiled;
- Chemically cleaned by immersion in dilute hydrochloric acid (‘pickling’) to remove all corrosion products (i.e. traces of rust and mill scale);
- Dipped into a bath of molten zinc maintained at a temperature of about 450°C;
- Cooled, inspected and re-coiled.

Continuous hot dip coating of steel strip and sheet is covered by the following standards (BS EN 10214, BS EN 10215, BS EN 10142, BS EN 10143 and BS EN 10147). When specifying coated steel sheets, it is necessary to specify both the steel sheet and the coating. The thickness of coating is the fundamental criterion of the quality of a hot dip coating.

The standard notation for describing coated products is as follows:

- Number of standard,
- Steel name,
- Letter identifying coating; Z for zinc, ZF for zinc/iron, AZ for aluminium/zinc and ZA for zinc/aluminium,
- The coating weight in kg/m^2,
- Surface finish, N for normal spangle, M for minimised spangle and R for regular iron zinc alloy due to diffusion of iron through the zinc coating.(only applicable to zinc coatings),
- Surface quality, A for as coated, B for improved and C for best quality,
- Surface treatment, C for chemical passivation, O for oiling, CO for passivation and oiling, and U for untreated.

Hot-dip galvanising of steel articles

In this process steel components (e.g. window frames) are dipped into a bath of molten zinc. The zinc reacts with the surface of the steel to form a layer of zinc/iron alloy and a coating of zinc is deposited on the surface as the article is withdrawn from the bath. The appearance of the coating should be continuous, smooth and free from flux stains.

The specification for hot dipped galvanised coatings is defined by a single standard, namely BS EN ISO 1461. At an early stage it is necessary to define the type of post-treatment required, (e.g. chromating, phosphating or a heavier coating for additional protection) and the coating weight and thickness.

Attention should be paid to the conditions of storage to avoid wet storage staining, which can occur on freshly galvanised components when stored under damp and badly ventilated conditions. The use of additional surface treatments, such as chromate treatments, reduces the formation of storage stains.

Some fabricated assemblies may suffer from warping and distortion at the temperatures used for hot dipping; at particular risk are assemblies that are dipped more than once to cover the entire surface area (e.g. asymmetrically shaped sections). The risk of distortion is affected by a number of factors including differential expansion/contraction effects caused by the use of sections of unequal thickness, and the relief of internal stresses from prior welding or cold forming operations. It is advisable to discuss design of the fabrication with the fabricator and the galvanizer.

Electroplated zinc

Here, coatings are produced by plating zinc onto a steel electrode in an electrolysis bath. The procedure for zinc plating is covered in BS 1706. This method of zinc protection is suitable for metals used in occasionally corrosive conditions.

When specifying zinc plating it is necessary to specify the surface treatment as well as the coating thickness. A typical specification might be Fe/Zn 8c 1A, where:

- ‘Fe’ refers to the base metal (iron or steel);
- ‘Zn’ refers to the type of coating on the base metal (zinc);
- ‘8’ refers to the minimum local thickness of 8μm of the zinc coating;
- ‘c’ refers to the chromate conversion coating, if omitted this means a chromate conversion coating is not required (details of the type of conversion coating should be given separately);
- ‘1’ refers to the class of finish required;
- ‘A’ designates the type of chromate coating.

The electroplated articles should be free from clearly visible plating defects such as blisters, pits, roughness, cracks or unplated areas. The coating should be bright, although heat treatment may cause slight dullness. If heat treatment is required for the purpose of stress relief, the correct grade of steel needs to be specified according to its maximum tensile strength.

The types of conversion coating used on electroplated zinc are specified in BS 6338. The colourless coatings, which may have a bluish tinge, have limited protective value and are used mainly for temporary protection during storage and handling. The yellow coatings have good bare corrosion resistance and are good bases for paint and powder coatings, whereas the olive green coatings are used exclusively for corrosion protection.

All chromate conversion coatings harden with age and therefore should be handled carefully for the first 24 hours after treatment, with any tests deferred until the expiry of that period.

Sherardizing of steel

This method of zinc coating is by a process of diffusion in which articles are heated in close contact with zinc dust and an inert operating medium. The process is normally carried out in a slowly rotating, closed container at a temperature of approximately 385°C and forms a uniform coating on all articles, including those of irregular shape. This process is only suitable for relatively small pressings, forgings, nuts and bolts, and gives a rough surface finish affording good adhesion of most paints.

When specifying a sherardized coating it is necessary to specify the class of coating depending on the environment and the minimum thickness. A typical specification might state that the zinc dust shall contain not less than 94 per cent by mass of metallic zinc, not more than 0.2 per cent by mass of lead and not more than 0.0005 per cent by mass of copper, with all particles passing through a 75μm sieve.

Some articles may be too fragile to withstand the rotary movement required during sherardizing and it is advisable to consult the sherardizer at the design stage. The life of sherardized coatings in any given environment is proportional to the thickness of the coating. Where doubt exists concerning the appropriate class of coating, advice should be sought from the sherardizer.

The surface finish of sherardized metals is defined in BS 4921. The type of finish should have a matt grey appearance and may show superficial scratches. The coatings are relatively hard and scratches are not detrimental to the corrosion resistant qualities.

Cut edges/damage

At a cut edge, or scratch which penetrates through to the steel substrate, the zinc offers significant protection, but as it corrodes, the exposed steel will in turn corrode quickly. It is therefore advisable to paint areas where the underlying steel has been exposed.

Stainless steel

The predominant alloying element in stainless steel is chromium and a concentration of at least 12 per cent by weight is required to give steel its stainless quality. Corrosion resistance can be enhanced by additions of nickel and molybdenum to give three classes of stainless steels:

- Austenitic stainless steels offer the highest corrosion resistance because of the high chromium content (at least 17 per cent) and additions of nickel (minimum of 8 per cent), and are produced in the largest quantities; austenitic stainless steels also offer very good formability and weldability. Austenitic stainless steels are non-magnetic.
- Martensitic stainless steels are hard and strong but have poor toughness; typical applications are cutlery and razor blades. Martensitic stainless steels are magnetic.
- Ferritic stainless steels generally have lower strength, ductility and corrosion resistance than austenitic stainless steels. Ferritic stainless steels are magnetic.

Martensitic and ferritic stainless steels are not generally used in buildings, as they are very hard to work.

The corrosion resistance of stainless steel is due to the presence of an extremely thin but tough transparent surface film of chromium oxide; any damage is normally repaired very quickly by the chromium reacting with atmospheric oxygen. Resistance to corrosion is high in a variety of environments, especially the ambient atmosphere, but rust will eventually occur when in contact with water and air is excluded. Corrosion of stainless steel may also occur more rapidly in heavily polluted, marine or chlorinated environments. Further advice is given in publications of the Nickel Development Institute.

Stainless steels only require a periodic wash with soap and water to maintain the original bright, reflective surface finish - a wide variety of which are available. However, severe staining of stainless steels will occur if placed in contact with normal carbon steel fasteners in exposed situations because of rusting; satisfactory service may be obtained by using carbon steel fasteners with a stainless steel cap. If aluminium fasteners are used care should be taken to ensure that the junction between the metals will remain dry and/or they are electrically insulated from each other to prevent galvanic corrosion.

Stainless steels do not exhibit a clearly defined yield point and strength is normally characterised by the 0.2% proof stress. For fully annealed austenitic material this is about 200N/mm^2. Stainless steel exhibits a high degree of ductility. The ultimate tensile strength is about 500N/mm^2 and occurs at an elongation of about 40%. Both proof stress and ultimate strength can be increased substantially by cold work.

British Standards for stainless steel are being replaced by European Standards resulting in changes to the notation used to describe different grades. Stainless steel is classified using the system given in BS EN 10027 described above and requirements are given in BS EN 10088. Part 1 of BS EN 10088 lists the grades of stainless steel that are available.

The most commonly used grades of stainless steel in cladding are types 304 and 316. Using the European classification system type 304 stainless steel is given the name X5CrNi18-10 or the number 1.4301 and type 316 becomes X3CrNiMo17-12-2 or 1.4404.

The physical properties of these grades are similar, the main difference being the resistance to corrosion, which is greater for type 316 due to the inclusion of molybdenum. Type 316 is also significantly more expensive.

CWCT Guide to good practice for facades requires the use of type 316 for sheet in external locations. For brackets and fixing components type 304 is suitable for normal exposure but type 316 is recommended for severe exposure conditions such as areas exposed to heavy industrial pollution and coastal areas.

The performance of stainless steel also depends on the design details, level of care taken during fabrication and the quality and frequency of maintenance adopted for the building facade.

Summary

This Technical Note has reviewed the range of ferrous metals, their grades and finishes, suitable for use in the manufacture of windows and cladding.

British Standards are being replaced by European Standards. Reference is made to the European Standards and significant differences from the British Standards.

The choice of metal will depend on many factors such as aesthetics, durability requirements, initial cost, cost of maintenance and programme constraints.

References

BRE, 1986, *Zinc-coated steel, Digest 305,* Building Research Establishment.

BS 729, 1971, *Specification for hot dip galvanized coatings on iron and steel articles,* British Standards Institution, (replaced by BS EN ISO 1461).

BS 1449 *Steel plate, sheet and strip* Part 2, 1983, *Specification for stainless and heat-resisting steel plate, sheet and strip,* British Standards Institution, (mainly replaced by BS EN 10088).

BS 1706, 1990, *Method of specifying Electroplated coatings of zinc and cadmium on iron and steel*, British Standards Institution.

BS 4921, 1988, *Specification for sherardized coatings on iron or steel,* British Standards Institution.

BS 5427, *Code of practice for the use of profiled sheet for roof and wall cladding on buildings,* Part 1, 1996, *Design,* British Standards Institution.

BS 5950, *Structural use of steelwork in building,* British Standards Institution.

BS 6338, 1982, *Specification for chromate conversion coatings on electroplated zinc and cadmium coatings,* British Standards Institution.

CP 143, *Code of practice for sheet roof and wall coverings*, Part 10, 1973, *Galvanised corrugated steel,* British Standards Institution.

BS EN 10027 *Designation systems for steels*
Part 1, 1992, *Steel names, principal symbols,*
Part 2, 1992, *Numerical system,*
British Standards Institution.

BS EN 10088 *Stainless steels,*
Part 1, 1995, *List of stainless steels,*
Part 2, 1995, *Technical delivery conditions for sheet/plate and strip for general purposes,*
Part 3, 1995, *Technical delivery conditions for semi finished products, bars, rods and sections for general purposes,* British Standards Institution.

BS EN 10142, 1991, *Specification for continuously hot-dip zinc coated low carbon steel and strip for cold forming: Technical delivery conditions,* British Standards Institution.

BS EN 10143, 1993, *Continuously hot-dip metal coated steel sheet and strip. Tolerances on dimensions and shape*, British Standards Institution.

BS EN 10147, 1992, *Specification for continuously hot-dip zinc coated structural steel sheet and strip. - Technical delivery conditions,* British Standards Institution.

BS EN 10214:1995. *Continuously hot-dip zinc-aluminium (ZA) coated steel strip and sheet - Technical delivery conditions*, British Standards Institution.

BS EN 10215:1995. *Continuously hot-dip aluminium-zinc (AZ) coated steel strip and sheet - Technical delivery conditions*, British Standards Institution.

BS EN 22063, 1994, *Metallic and other inorganic coatings. Thermal spraying. Zinc, aluminium and their alloys,* British Standards Institution.

BS EN ISO 1461, 1999, *Hot dip galvanised coatings on fabricated iron and steel articles - Specification and test methods*, British Standards Institution.

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