Introduction

The metals most commonly used in cladding systems are aluminium alloy and mild 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. This Technical Note gives guidance on the properties of non-ferrous metals and their specification and use in cladding applications. Ferrous metals are described in Technical Note 22.

Table 1 compares the typical physical properties of metals suitable for cladding and an appraisal of each is given below, covering composition(s), durability, use and compatibility.

Aluminium

Properties

High purity aluminium (99 per cent and above) has excellent durability and low density, high thermal and electrical conductivity but low strength. For more general use, alloying elements are introduced to produce metals that retain these general characteristics but with higher strength.

The excellent durability and corrosion resistance of aluminium and aluminium alloys are due to the formation of an extremely hard oxide layer on the metal surface when exposed to air. If the surface is pitted by any of the air-borne pollutants usually found in industrial or marine atmospheres, the resulting chemical reaction produces a larger volume of powdered corrosion product than the volume of the original pit, thereby sealing off the surface and inhibiting further corrosive action. In general, corrosion of aluminium only occurs to any great degree under strong acid or alkaline conditions.

Aluminium alloys do not exhibit a clearly defined yield point and the strength is normally characterised by the 0.2% proof stress which is the stress giving a permanent strain of 0.2%.

Aluminium alloys can be produced with strength properties similar to those of mild steel. However, the most commonly used grade for window and curtain walling frames (6063T6)

<table>
<thead>
<tr>
<th>Metal</th>
<th>Density (kg/m³)</th>
<th>Thermal conductivity (W/m°C)</th>
<th>Coefficient of thermal expansion (x10⁻⁶/°C)</th>
<th>Modulus of elasticity (kN/mm²)</th>
<th>Tensile strength (N/mm²)</th>
<th>Melting point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>2800</td>
<td>200</td>
<td>24</td>
<td>70</td>
<td>70 to 140</td>
<td>680</td>
</tr>
<tr>
<td>Mild-steel</td>
<td>7850</td>
<td>55</td>
<td>12</td>
<td>207</td>
<td>420 to 510</td>
<td>1900</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>7800</td>
<td>15</td>
<td>17</td>
<td>207</td>
<td>500</td>
<td>1440</td>
</tr>
<tr>
<td>Copper</td>
<td>8930</td>
<td>400</td>
<td>17</td>
<td>100 to 130</td>
<td>210 to 360</td>
<td>1083</td>
</tr>
<tr>
<td>Lead</td>
<td>11340</td>
<td>35</td>
<td>30</td>
<td>1.4</td>
<td>15</td>
<td>327</td>
</tr>
<tr>
<td>Brass (40% zinc)</td>
<td>8400</td>
<td>129</td>
<td>21</td>
<td>103</td>
<td>370 to 540</td>
<td>905</td>
</tr>
<tr>
<td>Titanium</td>
<td>4500</td>
<td>21</td>
<td>9</td>
<td>110</td>
<td>240</td>
<td>1940</td>
</tr>
<tr>
<td>Aluminium Bronze</td>
<td>8800</td>
<td>70</td>
<td>18</td>
<td>120</td>
<td>420 to 690</td>
<td>1050</td>
</tr>
</tbody>
</table>

Table 1  Typical values of some physical properties of metals suitable for cladding
has lower strength with a proof stress of 160 N/mm\(^2\) and an ultimate tensile strength of 180 N/mm\(^2\). As the structural design is normally governed by limits on deflection, and the modulus is not affected by the strength of the alloy, using a higher strength alloy will give little benefit. The modulus of aluminium is approximately a third that of steel so that structural members of the same shape and size will give deflections three times as great when made of aluminium. The coefficient of thermal expansion is about twice that of steel hence thermal movements will also be greater.

The 3000 series alloys usually used for roll forming profiled cladding panels have a proof stress of about 200N/mm\(^2\).

**Material classification**

British Standards covering aluminium have largely been replaced by European Standards. A wide range of alloy compositions is available as described in BS EN 573 *Aluminium and aluminium alloys - chemical composition and form of wrought products*. This standard gives two alternative classification systems for the different alloys, one using chemical symbols and the other using four digits. Where chemical symbols are used they should be enclosed by square brackets and followed by a number, which indicates the amount of the element present. In the four-digit system, the first digit indicates the principal alloying elements as follows:

- **1XXX** pure aluminium (99% or more)
- **2XXX** copper
- **3XXX** manganese
- **4XXX** silicon
- **5XXX** magnesium
- **6XXX** magnesium and silicon
- **7XXX** zinc
- **8XXX** other element
- **9XXX** unused

In both systems the full classification starts with EN AW-, A indicating aluminium and W that it is wrought rather than cast.

Physical properties are also dependent on the temper, which is defined in accordance with BS EN 515 *Aluminium and aluminium alloys - wrought products - temper*. Temper is denoted by a letter as follows:

- **W** solution heat treated
- **F** as fabricated
- **O** annealed
- **H** strain hardened
- **T** thermally treated to produce tempers other than F, O or H

Within the tempers there are further subdivisions denoted by additional digits or letters.

Solution heat treating refers to a process in which the metal is heated and maintained at a sufficiently high temperature to allow the constituents to enter a solid solution and subsequently cooled rapidly to hold the constituents in solution. The metal will subsequently undergo ageing in which precipitation from the supersaturated solid solution occurs resulting in a change in properties of the alloy. Natural ageing occurs at ambient temperature but the process can be speeded up by artificial ageing at elevated temperature.

**Applications**

The 3000 series alloys containing manganese are used for profiled sheeting.

In the extrusion industry the most widely used alloys are the 6000 series. Grade 6063 is suitable for intricate extruded sections of mid-strength, forms well in temper condition T6 (solution heat treated, artificially aged and not cold worked after solution heat treatment) and has high corrosion resistance and a good surface finish. It is therefore widely used for curtain wall and window framing members. Grade 6082 may be used for heavier duty profiles.
Site formed flashings and fully supported roofing are formed in high purity aluminium with less than 1% alloying elements.

Grade 5005 is a sheet aluminium suitable for anodising.

The required properties of wrought aluminium for various purposes are given in a number of standards. Those most relevant to cladding are as follows:

- BS EN 485 *Aluminium and aluminium alloys - sheet, strip and plate.*
- BS EN 755 *Aluminium and aluminium alloys - extruded rod, bar, tube and profiles.*

A number of British standards give guidance on the use of aluminium as follows:

- BS 8118 *Structural use of aluminium,*
- CP 143 *Code of practice for sheet roof and wall coverings,*
  Part 1: *Aluminium corrugated and troughed,*
  Part: 15 *Aluminium,*
- BS 5427 *Code of practice for the use of profiled sheet for roof and wall cladding on buildings.*

**Finish**

The natural finish as a result of the normal manufacturing process is known as mill finish. In this condition aluminium darkens and dulls over time. The extent to which this occurs depends on the environment: slight dulling will arise in a rural location, whereas severe dulling and pitting can occur in industrial and marine environments. This type of finish would only be considered for a suitably clean environment and where a decorative finish is not important.

Anodising is the controlled surface oxidation of aluminium by immersion in an electrolyte, usually dilute sulphuric acid. A low voltage, high amperage direct current is passed through the metal component, using it as the anode and increasing the thickness of the natural, integral oxide layer. Colour agents can then be added to the (porous) surface film if required, and the film sealed to give a hard, weather-resistant surface.

Aluminium can also be finished with various organic coatings. These may be wet applied but powder coatings are commonly used. Finishes are described in greater detail in Technical Note 25 *Selection of applied finishes for metal.*

Regular maintenance and washing down of aluminium should prevent permanent discoloration from industrial pollutants and reduce the risk of corrosion. Aluminium can be recycled after the component has served its purpose.

**Copper**

**Properties**

Copper may be used on its own or as a component of the alloys brass and bronze, which are described separately. Copper has excellent durability without any protective treatment, offers easy maintenance, varying shades, changing visual characteristics, easy workability and compatibility with other materials. The thermal conductivity of copper is very high (Table 1) which is a disadvantage in terms of limiting heat loss from the building.

Copper seals itself against corrosion by a film consisting mainly of oxides. In general, traditional copper roofing and cladding can be expected to last for 60 years or more. Failure tends to result from long term thermal movement causing fatigue at bends near welted joints rather than perforation due to corrosion. Thus life expectancy is somewhat dependent on the detailing and tightness of welted joints. Installations that accommodate thermal movement to a greater extent tend to have a longer life expectancy. Specialist advice should be sought for copper used on sites with heavy industrial pollution.

Oxidation will change the original reddish-gold shades of copper to pale brown and dark brown in a few years and eventually to the distinctive light green patina seen on older buildings, which
protects the copper from further corrosion and remains virtually unchanged.

Sea air, pollution, orientation and rainwater all affect the rate of oxidation. Development of the green patina takes 5 to 7 years in saline climates, 5 to 8 years near heavy industry, 10 to 14 years in urban surroundings and up to 30 years in clean environments. A certain amount of rainwater is necessary and the process takes much longer for vertical surfaces due to rapid runoff, except in coastal areas. The natural progression of patina can be prevented with lacquer or other coatings.

To achieve the desired appearance and tint, copper can be treated mechanically (by surface grinding, polishing or sandblasting) or chemically to produce various shades of brown or even black. Some methods have been developed for tinting copper green, although such artificial tinting may hamper the formation of the natural protective oxide coat and patina (and may not produce a uniform appearance). Removal of any oxidation can be achieved by pickling the plates, for example, with a solution containing 10 per cent sulphuric acid.

Copper can cause corrosion of steel, aluminium or zinc if there is direct contact between the metals and an electrolyte (e.g. water) is present. Lead, stainless steel and brass are unaffected by direct contact. Copper can dissolve slightly in water flowing over the surface and this can also cause corrosion if the water subsequently flows over other metals. Run-off can also cause staining of stone and concrete.

Copper is toxic to plants and animals and care should be taken where runoff discharges into ponds.

Rainwater run-off containing certain residues leached from concrete or cement mortar can cause copper to take on a blue-green colour. There are also some bituminous compounds which can corrode copper.

Copper is fully recyclable and a substantial proportion of the world’s demand is currently provided from recycled copper scrap.

Material Classification

British Standards are being replaced by European Standards. BS EN 1412:1996 Copper and copper alloys - European numbering system, gives a system of designating copper alloys based on a six-character reference. The first character is C for copper. The second character relates to the method of production and the most relevant will normally be W indicating wrought. There then follow three digits allocated by CEN TC 133 which define the composition and the final character is a letter designating the material group as follows:

- A or B Copper
- C or D Alloys with up to 5% alloying elements
- E or F Alloys with more than 5% alloying elements
- G Copper/aluminium alloys
- L or M Binary copper/zinc alloys
- R or S Complex copper/zinc alloys
- K Copper/tin alloys

All copper should comply with BS EN 1172: Copper and copper alloys - sheet and strip for building purposes. The designation of alloys in accordance with this standard includes a letter followed by three digits giving information on the strength or hardness of the material. Strength is indicated by R followed by the 0.2% proof stress and hardness is indicated by H. The full designation of copper complying with this standard includes the type of product (sheet or strip) followed by the number of the standard, the six character alloy reference, R or H with a three digit number and the size of the piece of metal. For example

Sheet EN 1172 CW024A R240 0.6x1000x2000

would be a sheet 0.6mm thick measuring 1m by 2m of wrought copper with a proof stress of 240N/mm².
Applications

Copper is expensive hence its use will generally be restricted to structures where the high cost can be justified by the high durability or aesthetic considerations. Principal uses are for gutters, downpipes, flashings and as a fully supported cladding material for roofs and walls. Part 12 of CP 143 Code of practice for sheet roof and wall covering, gives guidance on the use of copper. Guidance is also given in Copper Development Association Handbook, TN32.

Bronze

Bronze covers a range of alloys of copper with tin or aluminium. Due to the high cost of tin, aluminium bronze is more likely to be used in cladding. Aluminium bronze has high corrosion resistance, which can be superior to stainless steel. Tensile strength is similar to that of mild steel. The initial golden appearance will tone to a rich brown colour after a few months under normal atmospheric conditions. Pre-patinated bronze may be used to enhance the immediate architectural effect.

Due to its high cost, use is generally limited to prestige structures. A notable use of bronze is the cladding to Portcullis House, the new parliamentary building in Westminster.

Brass

Brass covers a range of alloys of copper and zinc, which have good durability. Some brasses contain small quantities of additional elements.

Gilding brass, which contains 10 to 20% zinc, can be heavily worked and is suitable for decorative work. Cartridge brass contains about 30% zinc and is very ductile and suitable for deep pressing and drawing. It may be used for building furniture including hinges and locks. Common brass contains 36 to 38% zinc and is used for most ordinary cold pressings.

Lead

Properties

Pure lead is a highly ductile, weak and dense material that can creep under its own weight, but is highly resistant to corrosion. Thermal expansion of lead is relatively high (Table 1) so it is customary to limit the size of sheet and incorporate only loose jointing to minimise distortion during thermal movement.

On exposure to the atmosphere and rainwater, lead reacts with carbon dioxide and sulfur dioxide to form a protective film or patina. In the initial stages exposure can give rise to a streaky appearance and soluble salts can be washed off by rain causing staining of other materials. Patination oil can be used to minimise this effect.

Experience has shown that lead sheet can be used in contact with other metals such as copper, zinc, iron, aluminium and stainless steel without risk of significant bimetallic corrosion. The exception is lead and aluminium used together in a marine environment where the chemical reaction between the lead oxide surface layer and the sodium chloride in salt water creates a caustic run-off which can attack aluminium. Severe corrosion can also occur in crevices. The use of lead sheet in contact with aluminium in marine conditions is not, therefore, recommended.

Lead should be protected from uncured concrete, for example by applying a coat of bitumen, to minimise attack by alkalis present in the cement. Lead can also be attacked by acids derived from moss and lichen and by condensation.

Material classification

BS 1178 which gives requirements for lead for building purposes requires a lead content of at least 98.8%. A small quantity of copper (between 0.03 and 0.06%) is required and has the effect of increasing the resistance to thermal fatigue. BS 1178 gives a range of thicknesses designated by code numbers as follows

<table>
<thead>
<tr>
<th>Code No</th>
<th>Thickness</th>
<th>Weight</th>
<th>Colour</th>
</tr>
</thead>
</table>


Cladding metals 2 – non-ferrous metals

<table>
<thead>
<tr>
<th>(mm)</th>
<th>(kg/m²)</th>
<th>code</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1.32</td>
<td>14.97</td>
</tr>
<tr>
<td>4</td>
<td>1.80</td>
<td>20.41</td>
</tr>
<tr>
<td>5</td>
<td>2.24</td>
<td>25.4</td>
</tr>
<tr>
<td>6</td>
<td>2.65</td>
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<td>7</td>
<td>3.15</td>
<td>35.72</td>
</tr>
<tr>
<td>8</td>
<td>3.55</td>
<td>40.26</td>
</tr>
</tbody>
</table>

Applications

The most common use of lead in facades is for flashings but it can also be used in sheet form to cover large areas. Due to its weight and low strength lead must be fully supported. Lead sheet for roof and wall coverings is covered in BS 6915.

In certain circumstances lead can be toxic and its use is covered by specific safety legislation.

Titanium

Titanium is generally used in industrial and aerospace applications where the high cost can be justified by the good durability and high strength to weight ratio, however it has recently been used in the cladding industry.

The natural finish is dark grey but it is readily anodised to give a range of colours. The strength of the pure metal is less than that of mild steel but commercially produced titanium contains small quantities of oxygen, nitrogen, carbon and iron and has a tensile strength of up to 750 N/mm². Deliberate addition of alloying elements gives greater strength however the modulus is not greatly affected and where the design is limited by deflection it may not be possible to take advantage of the increased strength.

The high durability is due to a tightly adhering oxide film, which readily reforms if damaged.

Titanium has been used to provide anodes in impressed current cathodic protection systems for reinforced concrete and has also been used as a sheet cladding material.

As with other materials, the use of titanium requires a clear understanding of its properties and limitations. Due to its hardness, like stainless steel, it can be difficult to shape or curve without distortion occurring (often referred to as oil canning). Care may also need to be taken with handling to avoid indelible marking.

Summary

This Technical Note has reviewed the range of metals, their grades and finishes, suitable for use in windows and cladding. Reference is made to the appropriate British or European Standard for specification purposes. The choice of metal will depend on many factors such as aesthetics, durability requirements, initial cost, cost of maintenance and programme constraints.

References


BS 6915, 1988, Specification for design and construction of fully supported lead sheet roof and wall coverings, British Standards Institution.


BS EN 1172: 1997: *Copper and Copper alloys: Sheet and Strip for Building purposes*, British Standards Institution.