BRONZE IN HISTORIC BUILDINGS

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WHAT IS 'BRONZE'? This simple question produces many answers from 'a type of metal' and 'a metallic brown colour' to a dictionary definition of 'a brown alloy, chiefly of copper and tin'. However, only the first answer is completely correct. Although 'bronze' was originally defined as a metal alloy of copper and tin, a modern scientific dictionary reveals that the term also encompasses alloys of copper with many other metals including aluminium, manganese and beryllium as well as zinc, lead, and a wide variety of other trace elements, depending on the end use of the bronze. In all of these alloys there is a high percentage of copper, and it is this copper which imparts its durability.

In architecture, the term is generally used to include all metal alloys of a particular colour, varying from a dark copper to almost black, rather than according to their chemical composition. However, here again there is some confusion since the colour range of bronze when newly manufactured can vary from a deep rich pink colour through to a dark gold depending on its constituents. It is in fact the oxidation of the surface which gradually changes this colour to the brown bronze which we generally associate with the metal. Oxidation occurs rapidly depending upon the environmental conditions, including its exposure to rain and humidity, and indeed atmospheric pollution. The acids from our skin in handling such items as push plates, door handles and handrails also has an effect on the oxidation process.

This colour change can be appreciated by looking at the copper coins in our pockets, from the 'copper' colour of a recently minted coin gradually proceeding to darker shades of brown on the earliest ones. Pennies minted in the 17th and 18th centuries for instance (not that I am suggesting that one would find one in your pocket), would be very deep brown to black in colour.

HISTORIC USE

Bronze (copper and tin) has been known to man since the dawn of the 'Bronze Age' over 5,000 years ago. Its use was then confined to relatively small items on which a high value was placed, such as jewellery, coins and military items in the form of spearheads and protective helmets. Generally these were produced by casting and subsequent hand working.

The Romans used bronze as a decorative cladding for doors, as at the Pantheon, although it was not until the middle ages that bronzes were used for architectural purposes to any great extent, and then mostly for door facings of an elaborate design, the cost and value of the bronze symbolising the grandeur of the building. There is evidence of doors dating from the 15th century again demonstrating the durability of the metal. The majority of the buildings on which bronze has been used in this country date from the 18th and 19th century, the latter using bronze alloys for both doors, window framing, feature columns and internally, for decorative and functional screens, gates, and of course sculptures and other works of art. The value historically attributed to bronze can be seen by the bronze medals still awarded at the Olympics and other sport events – third only to gold and silver.

THE ALLOYS

Architectural forms of 'bronze' are in fact often forms of brass in that they are an alloy of copper and zinc, patinated or toned to a 'bronze' colour. Copper is always in a very high percentage from 60 to 90 per cent in most of these alloys. Gilding metal, for example, which is frequently referred to as bronze, is in fact 90 per cent copper and 10 per cent zinc. Being so rich in copper, it readily gives the rich 'bronze' brown on oxidisation which we associate with 'bronze' the metal. The oxide layer also imparts its corrosion resistance which can be further enhanced by protection with wax for both internal and external uses.

The choice of alloy will usually depend on the form of bronze being used: sheet, extruded section or casting.

Sheet material is often 90/10 gilding metal as above, but occasionally it may be found to be phosphor bronze, which is an alloy of mainly copper with typically five to seven per cent tin and 0.2 per cent phosphorous. Phosphor bronze is a harder metal than gilding metal, but is not so readily available in sheet thickness and size. Brass sheet can also be patinated to bronze colour. This would typically have a mixture of 60 per cent copper and 40 per cent zinc with minor traces of other elements.

Extrusions are readily available in brass for patination, but for little extra cost special sections can also be extruded in bronze, usually manganese bronze which is slightly stronger, typically consisting of 57.5 per cent copper, 1.5 per cent lead, one per cent manganese and 40 per cent zinc. This alloy has a rich dark gold colour when extruded but soon forms a light brown bronze patina.

Castings are usually made from different bronze alloys depending on whether they are structural or decorative. Both alloys give a rich golden brown when new, and are copper-rich in

Double glazed, weather stripped bronze window frames provided for a Grade II listed building were manufactured using bronze extrusions and factory patinated prior to delivery.

the order of 84 to 85 per cent, with other metals being tin, zinc, lead, nickel and phosphorous. The structural alloy has a higher content of tin (around six to seven per cent) and less zinc (approximately two per cent). Brass castings could also be used, patinated to colour of choice, but casting brass is naturally lower in copper (approximately 65 per cent) and higher in zinc (at 34 per cent), and it is not as strong.

This discussion on the various alloys would be incomplete without mentioning the other so-called 'bronzes' such as aluminium bronze which possesses good tarnish resistance and is particularly suitable if the metal has to be rolled or bent to shape. Gun metal is also a 'bronze' but not often used in architectural works, and its colour can be achieved by patination on many of the other alloys. Nickel silver and silver bronze are alloys of copper, zinc and nickel, and are particularly tarnish- and oxidation-resistant. They contain no silver. (The name refers to light silvery straw colour which is due to its high nickel content – typically 10–18 per cent.)

PRODUCTION METHODS

Sheet bronze and brass are produced by rolling an ingot until the appropriate thickness is reached, with other processes being added to achieve the hardness or softness appropriate to the end use. Common thicknesses for sheet metal fabrication are 1mm, 1.2mm, 1.5mm, 2mm and 3mm, with the latter generally being the maximum thickness for gilding metal. Brass sheet is however readily available up to 50mm thick although this is seldom used. While brass sheet is available up to 2.5 x 1.25m, gilding metal is available in sheets from 3.05m (10ft) x 1m.

Extrusions of metal are produced by forcing hot billets of the alloy through dies under extreme pressure to form profiles in long lengths. These lengths are then subjected to a straightening and annealing processes to render them stable and suitable for fabrication. Profiles such as angles, tee sections, round, rectangular and square bars are readily available in brass but very few are available in any alloy of bronze. Some simple sections are available only in phosphor bronze. The lengths of extrusion available are typically 3–3.6m.

Special profiles can be produced by this process, but a die would have to be made to match the profile required and this is a relatively costly process. However, if the quantity of profile required is sufficiently large, extrusions can prove very cost effective. It should be noted that a lead time of around eight to ten weeks is usually required for special profiles.

Bronze castings are made using two principal methods: sand casting and investment or lost wax casting. The former will have a textured finish taken from the sand particles which may replicate the original, or which may need further hand work to produce the surface finish required. Sand casting can be used on most sizes of casting, but is particularly suitable for large items such as columns, large framing members and more bulky items. Investment or lost wax castings produce a much smoother finish and will probably require little or no handwork to render immediately usable. They are, however, only suitable for small decorative items similar to those in the photograph.

When replicating an existing item, the casting process must take into account the contraction of the alloy as it cools – typically 1 in 77 (1¼ per cent) for 'yellow' metals. Should dimensional accuracy be important, then a wooden pattern will have to be manufactured slightly larger than the item it replicates to allow for the contraction. A timber pattern can be cost effective if there is large number of similar castings to be produced. If absolute dimensional accuracy is not critical, then one of the original items (if removable) can be used as a pattern, thus saving the considerable cost.

Planing is a viable method of producing relatively small quantities of profile to be replicated, as no die or master pattern has to be produced. The only special item is a cutting blade profiled to the section required. The process takes place in a specially built planing machine, many of which date back to the early 20th century. A bar of the alloy of appropriate cross section is clamped to the bed of the machine (usually a large heavy flat cast iron table), which is then driven under the cutter blade, each stroke literally planing off the surface of the metal until the required profile is met. Complex profiles may require more than one blade shape to complete the section. The lead time on production will depend on the individual machine shop's workload, but is unlikely to be as long as for extrusions.

Drawing is particularly suitable for large profiles which cannot be planed and for smaller quantities where extrusions would be too expensive. It is carried out by pulling or drawing strips of brass or gunmetal of approximately 1mm thick through a succession of formers until the required shape is achieved. The cost of manufacturing the special formers and the final die has to be offset against the quantity of profile required. However, the dies are generally not as expensive to produce as those for extrusions, and some of the companies possessing this equipment have a large library of stock dies to choose from, saving the cost of a new die if one of these is acceptably close to the profile of the original.

The first part of the drawing process produces a metal shell to the profile required. The problem of fixing this metal shell can be overcome by filling the shell with a matching hardwood profile, so that the final drawing process clenches the metal onto the timber. This creates a stable profile which can be easily fixed through the timber and is very light in weight compared to a solid metal profile. The length available using this process can be up to seven metres, which may also be advantageous.

Drawn bronze mouldings are typically used for the framing of shopfronts and are commonly used in such conservation areas as Regent Street in London. The production method is often identical to that used originally, perhaps 50 to 70 years ago.

Machining processes such as milling and turning will be dealt with when discussing the manufacturing processes used in the case study which follows.

RESTORATION AND REPLICATION OF BRONZE ARCHITECTURAL STRUCTURES – A CASE STUDY

To illustrate the various aspects of restoration, repair and the construction of new bronze structures to replicate existing, we will study the techniques being used on a contract currently in progress in central London on a Grade II* listed building which has was built in the early 1900s. The building, which is faced with Portland stone, rises six floors and has bronze windows, doors and door screens, and ornamental internal screens, some up to six metres high. The screens incorporate doors

and decorative grilles involving castings. The project includes the restoration of bronze work to its former glory and at the same time upgrade the building to modern standards demanded by commercial occupancy.

Most of these bronze windows have vertical central pivot lights which had become inoperable and virtually sealed by the build-up of paint over the years. Some had lost ironmongery and much of the glass had been broken. A start was made by removing all glass and the paint was stripped back using chemicals, washed down and dried. The bronze frames were then restored back to their bare metal by hand using various abrasive pads, finishing with a Scotch Brite pad. The surface was then toned using toning powder, a fine reddish brown powder containing chemicals which, when rubbed onto the surface of brass and gilding metal, accelerates oxidation. This was mixed to a paste and rubbed on the surface until the desired bronze colour had been achieved, any surplus removed, and a hard natural wax applied for protection.

Windows were reglazed using double glazing units, and because the original rebate (for single glazing) was of insufficient depth, to protect the edge of the double glazing unit from UV degrade, 15mm wide strips of bronze were fitted to the double glazing units on the outside, effectively deepening the rebate.

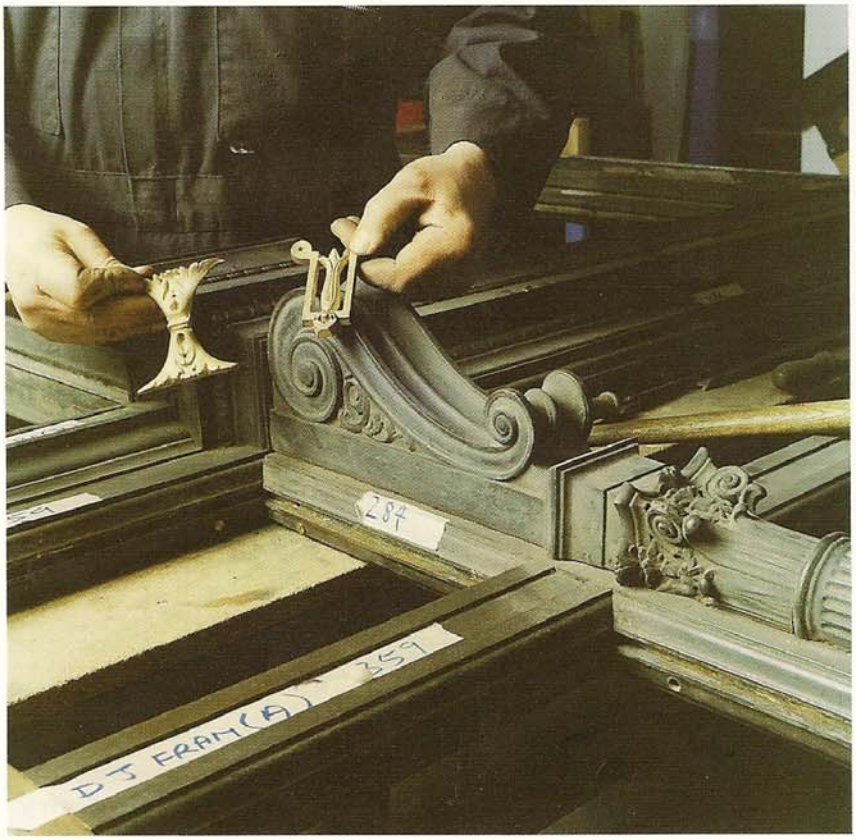
Some windows had to be renewed. The replacements were made to match the existing by using the planing process to produce the basic matching sections and then fabricated in the factory. Toning and waxing took place on site after installation.

Ironmongery was removed and brought back to the works for cleaning, replacing parts and manufacturing new as necessary, before being returned to site, cleaned and oiled, and left in working order.

When the project started, the large interior decorative screens were found to have been dismantled previously. Although they had been protected, marked and left on the floor of the interior of the building, no key had been retained as to the location of the various components, and the craftsmen faced the daunting task of creating complete screens from the jigsaw of parts without a picture of the completed jigsaw on the box. Some components were returned to works for repair and renewal as necessary. Missing components of the decorative panels were recreated by using lost wax castings, CNC machine turning and sheet fabrication, and planed sections, all combined to precisely match the original. The various surface finishes produced by the different manufacturing techniques were all harmonised by toning and waxing to match the existing.

RESTORATION OF BRONZE FINISHES

Most of the bronze in the case study had been neglected for some years, and therefore corrosion of the surface had caused discolouration from the brown bronze to a green patina as can be seen from the photograph above. These screens were cleaned by first removing the dust and dirt with a non-ferrous bristled brush, and washed with neutral PH soap in warm water using a lint free cloth and bristle brushes. This was followed by thorough rinsing and drying. In some cases a little white spirit was required to assist in the removal of heavy build-up of greasy dirt. (Where items had been heavily encrusted with hard wax and corrosion, special processes such as the Doff system may be employed by registered specialists to minimise the risk of damaging the fine surfaces.) Once clean, the bronzes were retoned and coloured to match the existing by experienced craftsmen, and rewaxed for complete protection. In bronze toning work of this nature, it is important to bear in mind that the chemicals used raise issues of health and safety, and should therefore only be used by fully trained experienced operatives.



These replica castings before toning, contrast against dirty cast screens showing the early stages of green patination, before cleaning and refinishing.

Off-site patination at the workshop can be used to finish various alloys to a bronze colour, but this is more suitable for new works and relatively small components which do not require significant handling for subsequent fixing on site. It is also more difficult to match to existing colours than toning and waxing.

MAINTENANCE OF THE SURFACE

It is strongly recommended that those responsible for maintenance of the building and its finishes take out a contract with a specialist bronze maintenance company. The frequency of maintenance will vary from internal to external, from coastal regions to inner cities and rural areas. The unsocial habits of vagrants in the major cities such as London's Regent Street, where there is a high proportion of bronze, means it is necessary to care for the bronze on a two to three week cycle if excessive corrosion caused by urination and vomiting does not occur. The regular cleaning of the surfaces and protection with further wax is absolutely essential to maintain the bronze in good condition. In less aggressive environments, maintenance on a monthly or even three-monthly basis may be appropriate. Internal maintenance depends very much upon the quality of internal finish that the client wishes to maintain, but it is unlikely that attention more that once every three months would be required. In all cases it would be necessary to wash down with warm mild soapy water to remove dirt, to rinse clean and to rewax. If there is damage or slight corrosion to the surface, this would have to be gently removed by mild abrasives, retoned to match existing and the whole rewaxed. On shopfronts and windows in particular, collaboration should be saught with the window cleaners who frequently use detergents for cleaning the windows, as these can themselves cause the wax to be removed and corrosion to occur if left on the surface. Such problems can be avoided if the window cleaners rinse off the detergent and wipe the bronze surface.

Further Reading and References

Copper – The Vital Metal, The Copper Publication 121, The Copper Development Association

Practical Building Conservation –Technical Handbook Volume 4 Metals. English Heritage

Hughes, Richard and Rowe, Michael *The Colouring, Bronzing and Patination of Metals*

Architectural Metalwork in Copper and its Alloys – The Copper Development Association.

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