



The Guide to Copper in Architecture



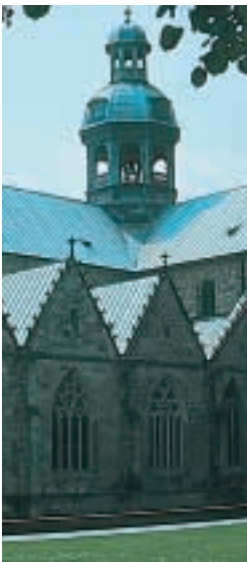
INTRODUCTION

This Guide is intended to give an introductory background to copper as the roofing and cladding material for the future in the UK. For further information on specific topics visit the website www.cda.org/arch.

COPPER...

a pure, natural material used for centuries as an effective roof covering, with the added attraction of unique, changing visual characteristics. Offering an effectively indefinite design life, it is extremely durable and resistant to corrosion in any atmosphere, requiring no decoration, maintenance or cleaning. Copper is environmentally friendly, fully recyclable, safe to use and can be worked at all temperatures.

THE PAST...



Hildersheim Cathedral, 1280.

Copper was one of the first metals used by man. Historically, the use of copper can be traced back over 10,000 years, through archaeological finds of copper weapons, jewellery and household goods. Evidence of early metal working and refining sites have been discovered in many places, including the Middle East, Africa and China.

The Ancient Egyptians mined for copper over 4,000 years ago and the Romans used copper from mines in Britain.

Many of the great churches of medieval Europe were roofed in the material. Indeed, a 13th century copper church roof in Germany survives intact to this day. Copper's distinctive green patina plays a major part in the skylines of most European cities. Tried and tested fixing details and techniques make copper the

most trouble-free material for roofing, cladding, flashings, gutters, downpipes and other details.

...PRESENT...

Not that copper technology has stood still. Cladding copper today is more pure than in the past, ensuring consistent performance as a thoroughly modern building material. Advances in prefabrication, together with in-situ machine forming, mechanised seaming and fixing technology have greatly improved productivity. The substantially lower costs resulting from these modern techniques now allow copper to be used on a much wider variety of building types than in the past.



Hounslow East Station, London. Architect: Acanthus Lawrence & Wrightson. Copper Contractor: Brodericks.

Architects today are taking advantage of the flexibility of copper as a distinctive external covering for any building element including all roof slopes, cladding, soffits, fascias, flashings, gutters and down-pipes.

...AND FUTURE

With the growing awareness of sustainability and increasing concern for the health and safety of those constructing and maintaining our buildings, copper is more than ever the cost-effective, adaptable roofing and cladding material of the future.

A museum at the University of Pennsylvania displays a copper frying pan that has been dated to be more than 50 centuries old.



Copper alloy mesh cladding at Plymouth Theatre Royal Production Centre. Architect: Ian Ritchie Architects. Copper Contractors: Lockerwire Weavers/Rubb TM.

SOURCES

Most copper is produced from open-cast mines and reserves are plentiful with deposits worked in all five continents. The copper is extracted from vast volumes of ore, mainly copper sulphides, by smelting - and then refined by electrolysis in huge tank houses.

At the start of the 18th century, about 90% of the world output of copper was smelted in South Wales, although today most copper refining is carried out close to the main sources of ore in different parts of the world.



2 Newhams Row, London. Architect: Glas Architects and Designers. Copper Contractor: Metalex.

A substantial proportion of the world's demand for copper is currently provided from recycled copper scrap, a practice which has been established for many years. Even the ancient copper roof covering of the Royal Palace in Stockholm (removed because of a failed substrate) was recycled in the form of commemorative coins.

Consumption, Reserves and Recycling of copper are dealt with in more detail on page 6 and on the website www.cda.org/arch.



Peckham Library. Architect: Alsop and Stormer Architects. Copper Contractor: Cleveco.



Brewery Square, London. Architect: Hamilton Associates Architects. Copper Contractor: Brodericks/CGL Systems.

We're in no danger of running out of copper: known world-wide resources are estimated at nearly 5.8 trillion pounds of which only 12% have been mined throughout history and most of that is still in use today.



JLE Vent Shafts, London. Architect: Ian Ritchie Architects. Copper Contractor: Entech.

PROPERTIES

COPPER

- Periodic symbol: Cu.
- Density: 8930kg/m³.
- Melting point: 1083°C.
- Thermal expansion: 0.0168mm/m/°C (20-100°).
- Tensile strength: 210 - 240 N/mm² (soft - half hard).

COPPER FOR ROOFING AND CLADDING

Phosphorus deoxidised non-arsenical copper is used with the designation C106. The copper is rolled to thicknesses ranging between 0.5 and 1.0mm (1.5 - 3.0mm for curtain walling) but a 0.6 - 0.7mm thickness is usually used for roofing. Allowing for seaming, 1m² of copper roof weighs approximately 6.5kg.

Copper can be worked at any temperature and does not become brittle in cold weather. It is available in sheets or strips and is generally regarded as a lightweight covering requiring a supporting substrate (such as 25mm boarding), although thicker, self-supporting copper panels are used for cladding. Copper is also available in prefabricated rolled profiles, flashings, shingles, gutters and downpipes.

Suitable pitches range from 5° (or less in special circumstances) to 90° and even negative pitches (such as bell section soffits) are easily handled. "Temper", or the malleability of copper sheet, ranges from "soft" to "half hard" depending upon application.

Archaeologists found 5,000 year old copper tubing in serviceable condition at the Pyramid of Cheops in Egypt.



Mews houses, Dublin.
Architect: de Blacam and Meagher. Copper Contractor: Miskin Services.

INDEFINITE LIFE

Copper roofs have been known to perform well for over 700 years and it is invariably substrates - not the copper itself - which eventually fail.



Renovation of top dome, Bank of Scotland HQ, Edinburgh. Roofing Contractor: D. Blake & Co.

CHARACTERISTICS

LIGHTWEIGHT

Copper when used as a fully supported roof covering is half the weight (including substrate) of lead and only a quarter of tiled roofs, with consequent savings in supporting structure and materials generally.

LOW THERMAL MOVEMENT

With a thermal expansion value 40% less than both zinc and lead, properly designed copper roofs minimise movements due to thermal changes, avoiding deterioration and failure. In addition, the high melting point of copper ensures that it will not "creep" or stretch as some other metals do.

NO MAINTENANCE

Copper does not require any decoration, cleaning or maintenance. It is therefore particularly suited for areas which are difficult or dangerous to access after completion.

DURABLE

Copper exposed to the outside protects itself by developing a patina over time, which can reform if damaged, ensuring extreme durability and resistance to corrosion in virtually any atmosphere. Unlike some other metals, copper does not suffer from underside corrosion.



Housing association terraced housing, Sutton.
Architect: ECD Partnership.

COST-EFFECTIVE

With its indefinite life and unique visual characteristics, copper roofing is often found on prestigious buildings and might be perceived as a "premium" material. However, recent independent research has shown that, because of light weight and other benefits, copper roofs are comparable with zinc, stainless steel, aluminium and even some clay and concrete tiles when considering overall roofing costs (including structure). Copper roofing is considerably less expensive than lead, Welsh slate or hand made clay tiles.



DHSS Laboratories at Coleraine, Northern Ireland.
Architect: Todd Architects and Planners.
Roofing Contractor: Edgeline Contracts.

Using life cycle costings, the research also reveals copper as a more cost-effective material than virtually any other for roofs with a 30 year or greater life, due to its durability, maintenance free nature and ultimate salvage value. With the growing interest in copper roofing by building designers, contractors are becoming increasingly familiar with prefabrication, mechanised seaming and other cost saving techniques. The cost competitiveness of copper is resulting in its use on a much wider variety of building types than in the past - not just on prestigious projects.



Multi-storey car park, Caernarfon.
Designers: Adams Consulting Engineers.
Roofing Contractor: Varla (UK).

LEADEN HALL SCHOOL, CLOSE TO SALISBURY CATHEDRAL

"To have used any material other than copper would have made it impossible to achieve this building economically with the lightness of touch and elegance of detailing required. The choice of copper was acknowledged by English Heritage, CABE and the Cathedrals Fabric Commission, and helped greatly with obtaining planning and listed building consent on this sensitive site, with wide public support. The cost-effectiveness of copper was also essential to the affordability of the project." Keith Harnden, Architect.

Architect: Keith Harnden.



A document entitled 'Comparing Costs', summarising the research by Davis Langdon & Everest, is available from Copper in Architecture.



The Crown Street Regeneration Project, Gorbals, Glasgow.
Architect: Hypostyle.
Roofing Contractor: A & J Roofing Specialists.

SUSTAINABILITY

'Sustainability' is a widely used description today which still remains difficult to define or apply useful quantitative measures to. However, by any standards copper has impeccable environmental credentials and is well-used by architects with long experience of sustainable construction, as shown later. The following pages address the major issues but research in this field continues and the most up-to-date information on copper, architecture and the environment can be found on the website www.cda.org/arch.



The River Station Cafe, Bristol. Architect: Inscape Architects. Roofing Contractor: J E Gibbings & Sons.

COPPER AND NATURE

Copper is a natural element within the earth's crust which has been incorporated into living organisms throughout the evolutionary process. It is an essential nutrient required by all higher life forms. Copper is required as part of a balanced diet. It is especially important for pregnant women, the developing foetus and newborn babies. A typical recommended daily requirement is 1-2 mg for adults and 0.5-1 mg for children. Nature is well adapted to making best use of copper, protecting itself from any negative effects. This applies at the most basic levels right up to the most complex metabolic functions of the human body. It also holds true with the long-term effects of man's use of copper on buildings.



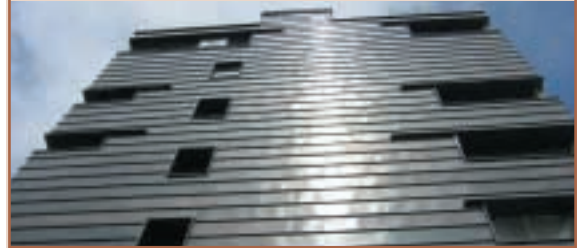
The Stuart House, Futureworld, Milton Keynes. Architect: Jonathan Ellis-Miller Architects. Roofing Contractor: Cotswold Metal Roofing.

A deficiency in copper is one factor in the increased risk of developing heart disease.

FRANCES GARDNER HOUSE, UNIVERSITY COLLEGE, LONDON

"We chose copper for its exemplary environmental credentials: a natural material, with low embodied energy in production, with a high percentage from recycled sources, and the potential for future recycling. Its longevity and ability to age gracefully, with a changing patina through time, make it a truly sustainable and beautiful material." Keith Bradley, Partner, Feilden Clegg Bradley Architects.

Architect: Feilden Clegg Bradley Architects.



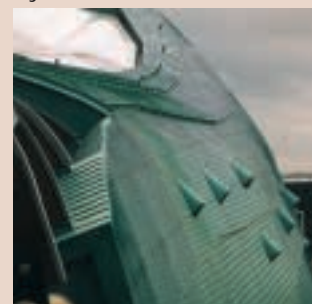
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2. Landner L and Lindström L, 'Copper in Society and in the Environment', 1999, Swedish Environmental Research Group (MFG).
3. 'Copper in Human Health – a Review', 1985, Copper Development Association publication TN42.
4. 'Copper in Human Health', 1992, Copper Development Association publication No. 96.
5. Callcut V and Bendall K, 'Copper the Vital Metal', 1998, Copper Development Association publication No. 121.

INTERNATIONAL CENTRE FOR LIFE, NEWCASTLE UPON TYNE

"By its very nature, this project called for a "living" material for its organic roof form. Long life and sustainability were important criteria, as well as copper's ability to handle complex shapes with ease." Mike Barry, Site Representative, Terry Farrell and Partners.

Architect: Terry Farrell and Partners.



CONSUMPTION, RESERVES AND RECYCLING

Western World consumption of copper is shown in the graph below. China is now the largest copper consumer after the USA. Copper consumption can be attributed to five market sectors of which construction consumed 38% of copper take-off (including 13% for electrical installations within buildings), the remaining four sectors being electrical and electronics, transport, industrial equipment and consumer durables. It is estimated that only 12% of known copper reserves have been mined throughout history. Most copper is extracted from open cast mines which can be found in all five continents. Local environmental impact of mining is strictly controlled and refining is carried out close to the main sources of ore.

RARE LIMITED HEADQUARTERS, WARWICKSHIRE

"Although copper was chosen principally for its visual characteristics, it was important to us and our client that materials on these buildings should be environmentally sound and sustainable. Long life, low maintenance and full recyclability justify the extensive use of copper for rain screen cladding and a variety of different roof forms throughout the complex."
 Bill Gething, Feilden Clegg Bradley Architects.

Architect: Feilden Clegg Bradley Architects.



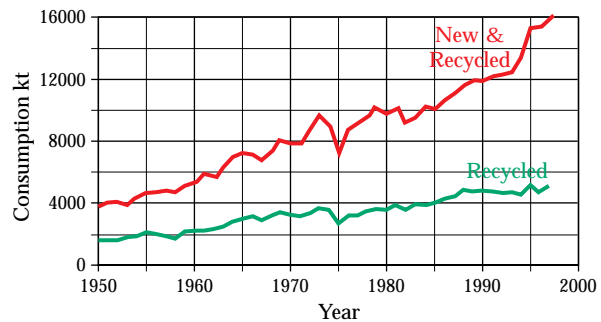
THE ABRAHAM BUILDING, LINACRE COLLEGE, OXFORD

"Following an energy audit, recycled copper was chosen for all pipework, gutters, downpipes, flashings and soakers, based on embodied energy considerations. Copper was also used for difficult to maintain flat roofed areas where long life is important."
 David Turrent, Director, ECD Architects.

Architect: ECD Architects.



The recycling of copper is a well established practice and its extent follows overall consumption patterns: by 1985, more copper was recycled than the total consumption in 1950. This is due to the relative ease - compared with other metals - of re-using both processing waste and salvaged scrap from eventual demolition, as well as the incentive of copper's value. Today, copper scrap is re-used ad infinitum and about 55% of copper used in architecture comes from recycled sources.



Western World Consumption of Copper
 (Source: Metal Statistics, Metallgesellschaft)



The Masonic School, Rickmansworth. Architect: Walton Smart Associates.

DURABILITY AND LIFESPAN

Copper roofing and cladding exposed to the elements develop a protective patina over time which can reform if damaged. This ensures extreme durability and resistance to corrosion in virtually any atmospheric conditions and, unlike some other roofing metals, copper does not suffer from underside corrosion. Consequently, it is invariably the supporting substrates or structure which eventually fails rather than the copper cladding itself and copper roofs have been known to perform well for over 700 years. Similar empirical evidence cannot



Private house swimming pool annexe, Berkshire.
Architect: Trinéire Designs.
Roofing Contractor: Cotswold Metal Roofing.

HOUSING ASSOCIATION FLATS, SUTTON

"Being heavily involved with sustainable building since the 1973 oil crisis we wanted to do a copper roof for some time. It patinates naturally, emphasising the organic forms of the buildings and there is a high percentage of recycling in the copper industry. Sustainable materials were important to us and our client on this project."
David Turrent, Director, ECD Architects.

Architect: ECD Architects.



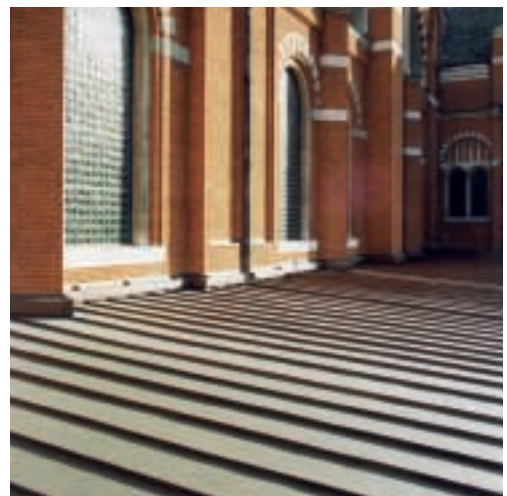
be provided for more recently developed cladding materials such as stainless steel, even though long life spans (e.g. 100 years) are claimed for them.

Copper's patination process is complex, involving initial formation of copper oxide conversion films, gradually interspersed over a number of years with cupreous and cupric sulphide conversion films, and culminating with conversion of the sulphide films to the green copper sulphate patina. The rate of corrosion from the copper surface decreases with patination and is considered to average between 0.0001 and 0.0003mm per year. For a 0.6mm thick sheet, this equates to no more than 5% corrosion over 100 years. The lifespan of copper roofing and cladding can therefore be regarded conservatively as 200 years, subject to substrate and structure, and this is endorsed by experience. Naturally, this has a significant effect upon comparative whole of life assessments in terms of energy consumption, CO₂ generation and cost.

ECOLOGICAL ROOF GARDEN, LONDON

"All materials for this small roof top conservatory were either recycled, recyclable or renewable. The copper cladding has a low embodied energy and negligible maintenance, and is a durable material with no further finish. Its natural, living surface changes to reflect the passage of time." Sumita Sinha, Director, Eco=logic.

Architect: Eco=logic; Cladding Contractor: Biz.



Chapel Roof at Westminster RC Cathedral, London.
Architect: John Phillips.
Roofing Contractor: L S Smerald.

EMBODIED ENERGY AND CO₂

An important, but often misused environmental indicator is the 'embodied energy' of a material, which is the total energy consumed during every phase of each life cycle from cradle to grave. Estimates for the various roofing and cladding metals vary wildly, partly because of a lack of current information but also because of basic errors such as:

- comparing energy per tonne rather than per m² of material, thus misrepresenting thinner, lighter materials such as copper
- using inappropriate life span estimates (such as 70 years for copper compared with 100 years for stainless steel) resulting in additional theoretical "energy use" for unnecessary re-roofing
- ignoring current, more efficient recycling practices used in the copper industry.

The following tables provide useful, up-to-date comparisons of embodied energy and carbon dioxide emissions for typical roofing and cladding metals, considered over 'whole of life' (or 'End of Life').

Material thicknesses shown are typical for fully supported roofing techniques. Values are taken from a study performed by the Fraunhofer Institute with the participation of PE Europe GMBH Life Cycle Engineering. (Source: German Ministry for Environmental Affairs, 2004).

	Copper	Stainless Steel	Aluminium
Thickness (mm)	0.6	0.4	0.7
Life span (years)	200	100	100
Embodied Energy (MJ/m ²)	103.3	157.2	115.4

With continuing concerns about global warming, embodied CO₂ emissions also provide an important indicator: for example, the BRE Environmental Profiling System provides a weighting for CO₂ eight times greater than that for SO₂. The following estimates, from the same source as for those above, offer guidance.

	Copper	Stainless Steel	Aluminium
Thickness (mm)	0.6	0.4	0.7
CO ₂ equivalent emissions (kg/m ²)	6.6	10.9	7.5

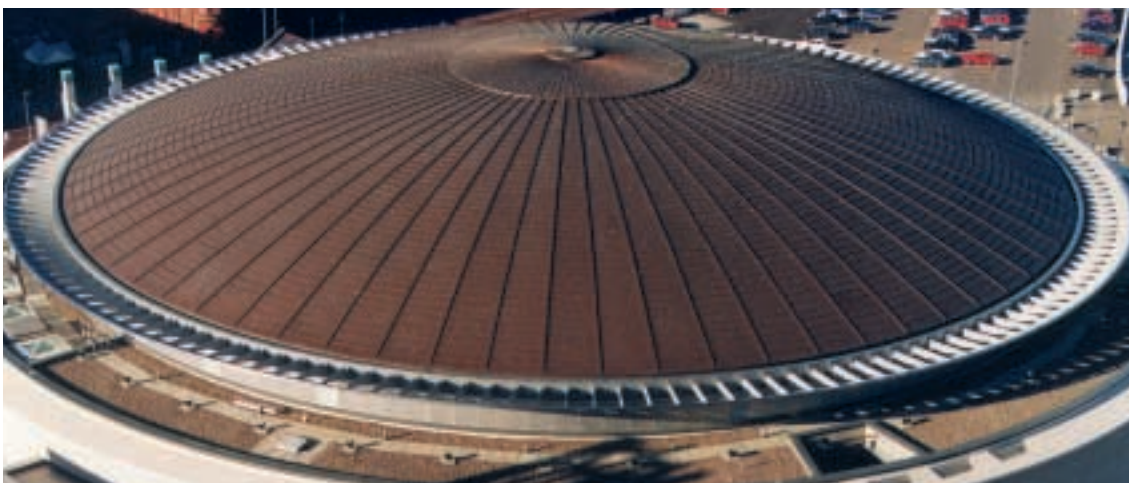
Another problem in making assessments of this sort is that available information is invariably dated. Production processes are improving all the time in terms of efficiency and waste limitation. In addition, the latest construction techniques such as the long strip method offer long life, complete roofing solutions with lower costs and embodied energy values which have yet to be properly assessed.

The most accurate, detailed copper life cycle data is now available via a dedicated website www.copper-life-cycle.org.

WAYSIDE COTTAGE, NEWNHAM ON SEVERN

"Camphill Village Trust takes a particularly responsible approach to environmental issues. They are keen to use materials which are safe, natural and recyclable, so copper roofing is regularly used in their communities. Here, curved copper roofs sit comfortably alongside 'green' turfed lower roofs." Paul Knowles, Director, Quattro Design.

Architect: Quattro Design with initial design input from David Austen.

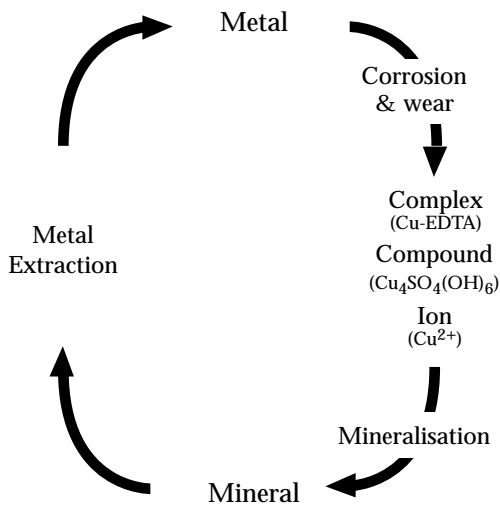


Waterfront Hall, Belfast. Architect: Robinson and McIlwaine. Roofing Contractor: Edgeline Contracts.

RAINWATER RUN-OFF FROM COPPER

From time to time, concern is expressed about the possible effects of copper in rainwater run-off, particularly in countries where copper roofs, cladding, gutters and flashings are widely used. These misplaced concerns are often fuelled by laboratory experiments involving high doses not encountered in the natural world. Much scientific research has been carried out to understand the complex processes occurring in the environment with rainwater runoff from copper roofs. This has demonstrated that extensive use of copper to clad buildings is environmentally safe and this can be supported by detailed information available via the Copper in Architecture Campaign. We have already seen that copper is essential to life but, of course, all chemicals and elements become toxic - at some levels. Very small amounts of copper material are carried in rainwater run-off.

Through natural processes of binding to organic matter, adsorption to particles and precipitation, the copper run-off finally comes to rest in a mineral state as part of the earth's natural background of copper material, continuing the natural extraction/mineralisation cycle.



Copper gutters, downpipes, flashings and weatherings at Linacre College, Oxford (BREEAM Gold Medal). Architect: ECD Partnership. Roofing Contractor: Cotswold Metal Roofing.

If released to the soil, the remaining available copper is taken up by organic matter in soil or at sewage treatment plants, or by other chemicals. This forms compounds with minimal, if any, amounts ultimately joining the natural background presence of copper in aquatic environments. As an example, dissolved copper levels in Swiss lakes - the subject of an alarmist report by the World Wide Fund for Nature a few years ago - are reported to be 50-85% lower than official environmental criteria levels. This is close to natural background levels, despite the extensive use of copper on buildings in the surrounding area. In any event, copper does not bio-accumulate and it is well known that no harmful effects have occurred with the extensive use of copper plumbing in homes throughout the world.



Globe House offices, London. Architect: GMW. Roofing Contractor: Richardson Roofing.



Copper roof installation at Linacre College, Oxford.

CDM REGULATIONS, HEALTH AND SAFETY

Copper is non-toxic and presents no risks with long term contact. Consequently, the legislative controls and continuing programme of health monitoring needed for site workers and those handling other metals such as lead do not apply to copper workers. The weight of copper needed to cover a given area is substantially less than that of lead, reducing lifting



Unilever Research Laboratory, Colworth House, Sharnbrook.
Architect: Sheppard Robson.
Roofing Contractor: Kelsey Roofing.

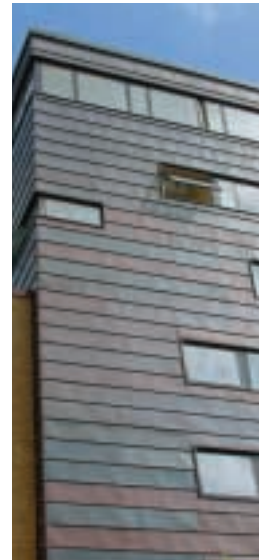


Copper alloy cladding at Portcullis House, London.
Architect: Michael Hopkins and Partners. Roofing/Façade
Contractors: Watson Steel/Seele Alvis Fenestration.

problems - particularly at high levels.

Copper is therefore a safer alternative to lead for flashings and other weatherings - even on non-copper roofs.

Copper maintains a consistent malleability and "feel" which makes manual working entirely predictable. Indeed, metal roofing installers show a clear preference towards copper over other metals. It can be worked at all temperatures and, unlike metals such as zinc, does not become brittle and break to form sharp edges in cold weather. Copper is ideally suited to mechanisation techniques, including preforming of trays and joints in safe locations and the use of automatic seaming machines on roofs, minimising high level work (as recommended by the Health and Safety Executive).



University College London.
Architect: Feilden Clegg
Bradley Architects. Copper
Contractor: NDM.



Duke of York's Headquarters, London. Architect: London Bloc
Architects. Copper Contractor: T+P Lead Roofing.

ARCHITECTURAL QUALITIES

ROOF FORMS

Copper is a fully supported sheet roofing material which is easily formed mechanically or by hand, on site or in the factory, to suit virtually any three



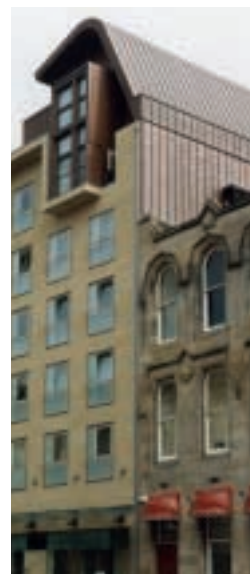
*BBC 'Home Front in the Garden' Shelter.
Designer: Diarmuid Gavin. Copper Contractor: Richardson Roofing.*

dimensional shapes - including complex curves and details. Pitches from 5° to 90° can be accommodated, as well as negative pitches, such as soffits. The thin nature of copper sheet and the ability to

A typical recommended daily requirement of copper is 1-2 mg for adults and 0.5-1 mg for children.



*House and Music Room, Surrey.
Architect: John Newton.
Roofing Contractor: Titan Building Products.*



*Brunswick Hotel, Glasgow.
Architect: Elder & Cannon.
Roofing Contractor: A & J Roofing Specialists.*

produce slim joints between sheets - particularly when using the "long strip" method to avoid horizontal joints - allow large, geometric shaped roofs and cladding to be finished with a visually continuous covering of quality. With copper, the designer has real freedom and almost no limitations on roof form.



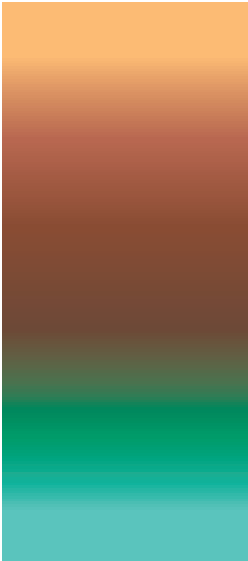
Nymans Garden, West Sussex. Architect: Winchester Design (Architects). Roofing Contractor: Wessex Roofing.

COLOUR

The natural development of a patina, with colours changing from gold to chocolate brown, and eventually to the distinctive light green seen on older roofs in our towns and cities, is a unique characteristic of copper. A full understanding of this process is important for building designers.

PATINA

When exposed to the atmosphere, copper oxide conversion films form, changing the surface colour of copper from salmon pink to russet brown within a few days. As weathering progresses over a number of years, cupreous and cupric sulphide conversion films intersperse with the initial oxide film increasingly darkening the surface to a chocolate brown. Continued weathering results in conversion of the sulphide films to the basic copper sulphate patina which, when complete, gives the distinctive light green colour of older copper roofs. In marine climates, the surface patina will also contain some copper chloride.



Development of Patina.

The eventual development of the light green patina can take 7 to 9 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.

Copper is biostatic and bacteria will not grow on its surface. It is used in gardening sprays and powders to get rid of destructive mildew.



Mews houses, Dublin. Architect: de Blacam and Meagher. Copper Contractor: Miskin Services.

A certain amount of rainwater is necessary to form the green patina and the process takes much longer for vertical surfaces, due to rapid run-off, except in coastal areas. Apart from internal applications, the natural progression of patina cannot be successfully prevented with varnishes and other coatings: this characteristic of copper is one of its unique features - not just visually, but also in terms of exceptional longevity - and should be anticipated in a building's overall design.



Ion Bar, Ladbroke Grove, London.



Putney Bridge, London. Architect: Paskin Kyriakides Sands. Roofing Contractor: Cotswold Metal Roofing.

PRE-PATINATED COPPER

One of the most interesting recent developments with copper is the immediate provision of the distinctive green patina which would normally take



*Baggy House, Devon.
Architect: Anthony Hudson Architects.
Roofing Contractor: Richardson Roofing.*

several years to occur in situ. Different systems are now available which create a similar process to "natural" patination, not just a coating which could be eroded with time.

Pre-patinated copper is, of course, particularly useful for repairing old copper roofs to give a close match to the existing colour. But its potential is most exciting when considered as a completely modern building material, combining continuity of the distinctive green colour with the freedom of form available with copper - even in situations such as vertical cladding, soffits and gutters where rainwater driven patination might never occur.

Other treatments are also available including pre-oxidised copper which gives a mellow, dark brown colour straightaway. This treatment disguises any surface markings which might occur on bright mill finish copper and can advance the natural patination process.

The Statue of Liberty in New York contains
179,000 pounds of copper.

BRIAR HILL NURSERY, NORTHAMPTON

"Copper shingles clad the various blocks of this playful building with different treatments to reflect the various stages of oxidation and patination. We needed to find a material that was delightful, robust, tactile, maintenance-free and able to retain our design concept - the answer was copper." Mark Pennington, Project Architect, Peter Haddon and Partners.

Architect: Peter Haddon and Partners.



CONTINUITY

In addition to being a distinctive, long life roofing material, copper has traditionally been used to form associated elements such as flashings, weatherings, vents, gutters and downpipes - as well as to cover details such as cornices, mouldings, finials and even sculptures. Modern design takes this further with the growing use of copper for vertical cladding, rain screens and curtain walling, often linked in with the



*CRS Retail Store, Cardiff. Architect: GHM Rock Townsend.
Roofing Contractor: Kelsey Roofing.*

covering of other elements such as transoms and mullions. The freedom of form with copper and the weather-tightness which current techniques ensure allow vertical and roofing surfaces to run into each other so that complete continuity of material and performance is maintained.



*Department of Chemistry, University of Cambridge.
Architect: Nicholas Ray Associates. Copper Contractors:
Richardson Roofing & T R Freeman.*



View from Edinburgh Castle over the City showing numerous copper roofs of different ages.

THE WIDER VIEW

The skylines of many cities in Europe and Scandinavia demonstrate the extensive use of copper on a wide range of building types over many years. In the past, its use in some parts of the UK has been more patchy than in others, determined by factors such as cost and availability of material, with copper often restricted to the more prestigious and monumental buildings.

These factors no longer apply today. Copper is now a thoroughly modern material which, in cost and technical terms, is appropriate to a much wider range of buildings and its extensive use has already been demonstrated by some of our best designers.



Temasek Polytechnic, Singapore. Architect: Stirling Wilford.

It would be artificial for those involved in the planning process to cite the limited historical use of copper in our cities as an established architectural tradition which must be maintained in the future. For copper to play a growing part in our city skylines, responding to the demands of architects and their clients, is entirely natural.



Dartington Glass Works, Plymouth. Architect: Form Design Group. Roofing Contractor: J E Gibbings & Sons.



Urbis, Manchester. Architect: Ian Simpson Architects. Copper Contractor: Varla (UK).

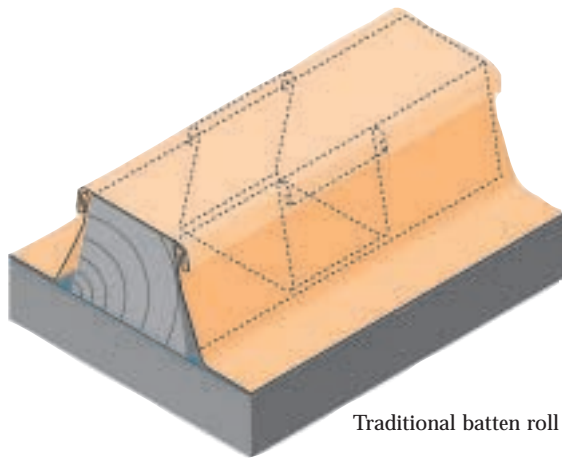
STANDARDS

Copper for roofing and cladding should comply with BS EN 1172 : 1997 - 'Copper and Copper Alloys: Sheet and Strip for Building Purposes'. There is also a British Standard Code of Practice CP143: Part12: 1970 which deals with Sheet Roof and Wall Coverings in Copper.

LAYING METHODS

TRADITIONAL SYSTEM

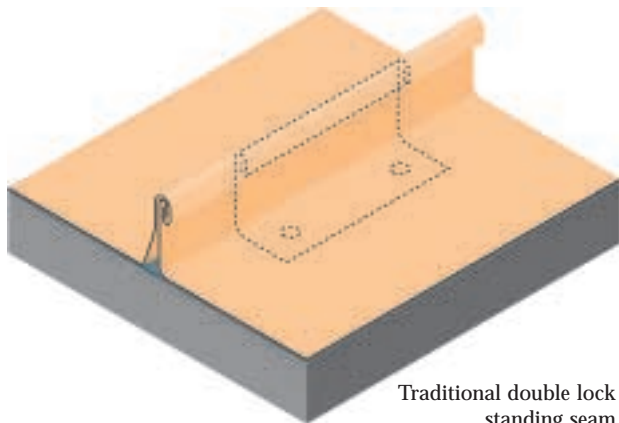
Traditional laying methods rely entirely upon the skills of hand application and the forming of soft copper sheet with appropriate tools. Normally, sheet lengths will not exceed 2m and fixing is direct, usually using fixed clips only.



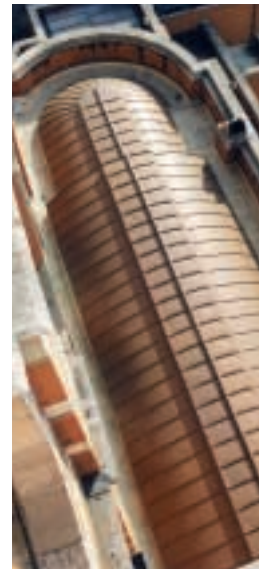
Traditional batten roll



Traditional batten roll method.



Traditional double lock standing seam



Westminster R C Cathedral, London.

Architect: John Phillips.
Roofing Contractor: L S Smerald.

The system utilises batten rolls and/or standing seams and gives the appearance of being more 'hand finished' compared with the Long Strip method, due to the softer temper of copper used. The same techniques apply equally to wall cladding and roofing.

The Traditional batten roll method, commonly seen on older buildings, enables a roof to appear structured with defined sections and is particularly appropriate to lower pitched roofs subject to foot traffic.

OTHER SYSTEMS

Copper can be used in a variety of other forms including shingles, tiles, cassette panels, bonded panels - and even profiled sheets capable of self support between purlins.



Profiled sheet roofing on commercial offices, Belfast.

Architect: Knox & Markwell.
Roofing Contractor: Edgeline Contracts.



Copper tiles.

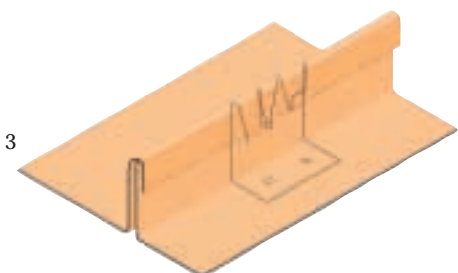
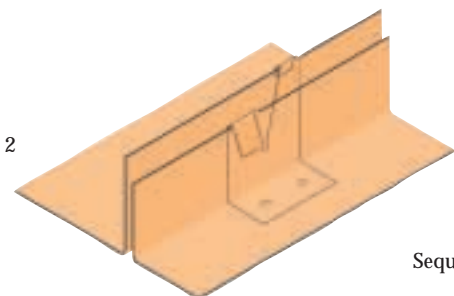
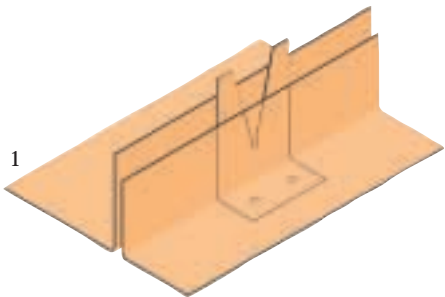
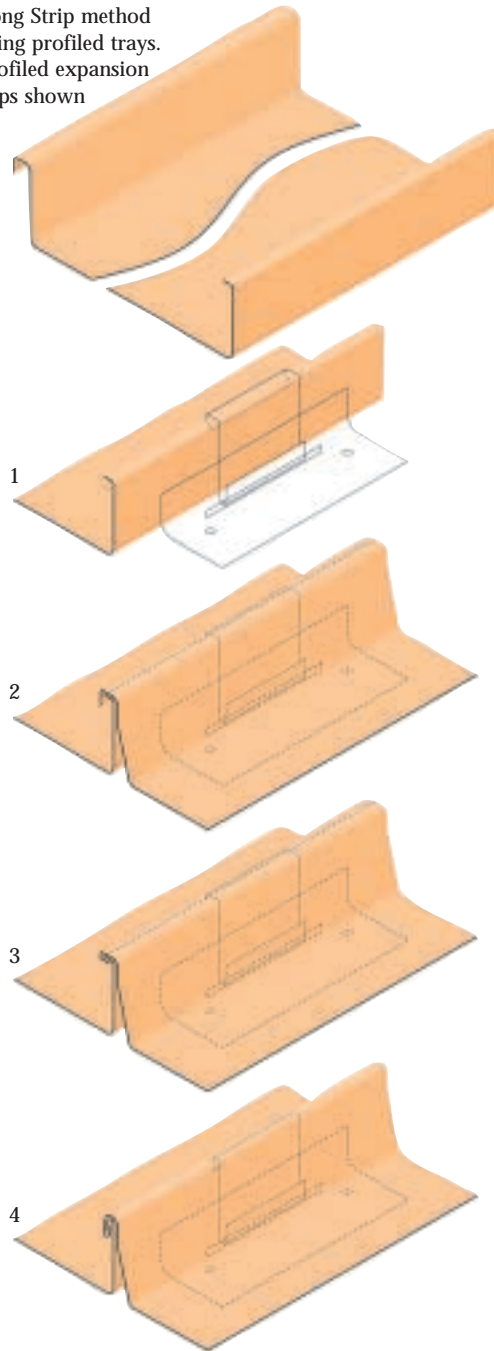
Copper is an essential part of the human diet. It helps iron-rich foods make red haemoglobin in the blood. Copper is also involved in the formation of collagen (the fibrous protein in bone, cartilage, tendons and other connective tissue) and protective coverings for nerves.

LONG STRIP SYSTEM

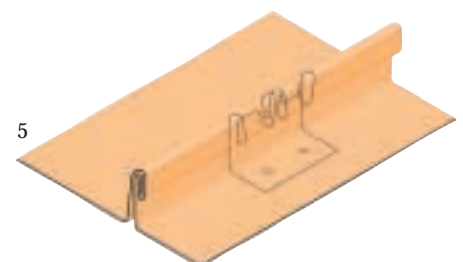
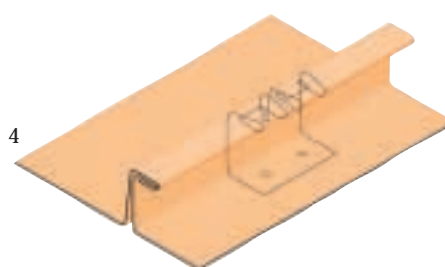
The Long Strip copper roofing system has been used in the UK since 1957, although prior to that it had been widely used on the Continent, particularly in Switzerland and Scandinavia, for many years. The main advantages of Long Strip are the elimination of the many cross welts required with the Traditional methods and considerable scope for prefabrication with on-site machines and mechanised seaming - particularly where anticipated by the roof design. This modern method offers substantial reductions in labour charges and the overall cost of copper roofs, greatly expanding potential applications and building types.

An essential feature of this method is the use of a harder temper copper, generally formed into profiled "trays" and seamed by machine in long lengths up to a nominal maximum of 10m. This harder copper allows thermal expansion of the bay to be transferred, without buckling, to one or both ends of the bay (depending upon pitch), which is catered for using special details with expansion clips as well as fixed clips, both of which are generally available in either "fishtail" or "profiled" designs. In terms of seam type, the double lock standing seam is the most common but for wall claddings and steep roof pitches (above 35°), the angle seam can be used. Long Strip installations look smoother than Traditional, with less prominent seams, reducing the "quilting" which can occur with the cross-welting Traditional system.

Long Strip method using profiled trays. Profiled expansion clips shown



Sequence with fixed fishtail clips shown



When Columbus sailed to the Americas, his ships, Nina, Pinta and Santa Maria, had copper skins below the water line. The copper sheathing extended hull life and protected against barnacles and other kinds of biofouling. Today most seagoing vessels use a copper-base paint for hull protection.

DESIGN AND INSTALLATION

SUBSTRATES

Fully supported roofs require a decking underneath, the most common material being wood. However, other materials can be used for a substrate provided that clips can be fixed securely. Wall cladding can use either self-supporting copper panels or thinner copper bonded to a substrate.



Installation of pre-formed curved trays.

An underlay is recommended separating substrate and copper, which can allow movement in the copper, provide a temporary weathering for the building during construction, deal with irregularities on the substrate surface and offer some sound absorption.

VENTILATION

Copper is not affected by the underside corrosion which can cause premature failure of most other metal roofing materials and does not require complex ventilation measures. It is therefore entirely suitable for use on either non-ventilated or ventilated roof constructions.

For non-ventilated roofs, adequate vapour control layers should be properly installed with sufficient insulation. For ventilated roofs, ventilation in accordance with the Building Regulations is provided by gaps at upper and lower edges of the roof or, if these are not feasible, by formed copper hoods.

Special consideration or advice may be needed for areas with high humidity or where air conditioning is to be used: contact the European Copper in Architecture Technical Advisor via Copper in Architecture (opposite).

CORROSION & COMPATIBILITY

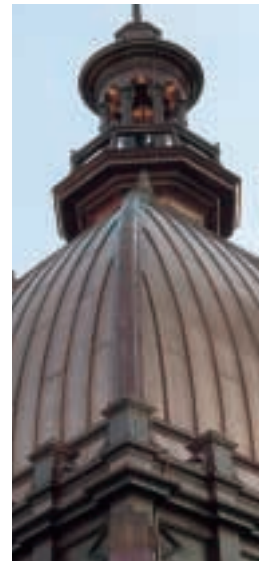
The natural electrical potential of copper is comparatively high and it is not affected by other metals on the outside of buildings. However, copper can cause corrosion to some other metals like steel, aluminium or zinc if there is direct contact between the metals and an electrolyte (such as water) is present.

Furthermore, if rainwater from copper roofing or cladding runs onto other metals with a lower electrical potential, there may be interaction unless they are protected and maintained by established methods. Metals unaffected by the above are lead, stainless steel and brass. These metals can be joined to copper without any corrosion problems.

Rainwater running off bitumen exposed to the sun can cause corrosion problems for various materials including copper. Certain residues washed out of concrete or mortar can cause copper to take on a blue-green colour. Also, the wash-off from red cedar shingles can cause metals to corrode.

LIGHTNING PROTECTION

Due to its good electrical conductivity and resistance to corrosion, copper maintains an important role in lightning protection applications. The high conductivity of copper facilitates the rapid transmission of lightning energy, offering the path of least resistance and avoiding damage to a building's fabric. Copper roofs may be used as part of a lightning protection scheme where the copper skin, gutters and rainwater pipes can be linked and bonded to an earth termination facility.



The specified thickness of copper is usually adequate for lightning protection and further guidance is available in BS 6651. Needless to say, the old wife's tale that copper roofs and lightning conductors actually attract lightning is not based on fact.

TOOLS

The basic tool kit carried by the plumber working on metal roof coverings will be adequate for small Traditional system jobs in copper. These would include shears, pliers, mallets and turning and



Machine forming of curved trays.

forming blocks. Other basic items include swivel bending machines and folding benches for folding 1 or 2m long copper sheets for profiles. Portable hand-formers, as well as motorised deforming machines with various ancillary tools, are available for drawing and upsetting standing seams of curved areas such as domes. These machines can punch, notch, upset, draw and flange.

MECHANISATION

Based upon the Long Strip system, machines continue to be developed for factory or site prefabrication and mechanised seaming, reducing installation time - and cost. Specialist machines now include edging and folding machines for the production of double lock standing seams. Machines can also form single and double-sided upstands on copper strip in one operation, with variable upstands. On some models, the copper strip is delivered from the roller pre-profiled on both sides, with allowance made for lateral transverse expansion within the double lock standing seams. With the increasing popularity of copper, specialist roofing contractors are ensuring a bigger share of this growing market by investing in mechanisation systems.



Mechanised seaming, Long Strip system.



Mechanised Long Strip tray formation from rolled copper sheet.

FURTHER INFORMATION

COPPER IN ARCHITECTURE is part of the European Copper in Architecture Campaign, sponsored by the European Copper Institute.

For details of all aspects of COPPER IN ARCHITECTURE

visit www.cda.org.uk/arch

For design inspiration visit

www.copperconcept.org

The COPPER IN ARCHITECTURE initiative offers:

- guide documents on various aspects of copper in architecture
- information on copper contractors and contact with suppliers
- free technical advice and CPD seminars for professional practices
- a comprehensive 120-page design manual 'Copper Roofing in Detail'
- architectural design, innovation and craftsmanship awards

COPPER IN ARCHITECTURE

1 Brunel Court, Corner Hall, Hemel Hempstead HP3 9XX

Tel: 01442 275700 • Fax: 01442 275716 • E-mail: helpline@copperdev.co.uk

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architecture
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www.cda.org.uk/arch
www.copperconcept.org

Tel: 01442 275700
Fax: 01422 275716
E-mail: helpline@copperdev.co.uk