



HOW COPPER & COPPER ALLOY SURFACE APPEARANCES EVOLVE

INTRODUCTION

Copper has a long tradition as a building construction and design material. It has commonly been used for centuries for roofs and decades in various external structures e.g. facades, cladding, gutters, and down pipes. In recent years, interest in using copper and its alloys has grown amongst architects and planners due to their favourable environmental performance.

With the growing use of metals in outdoor design, some interest about how metals interact with the environment is of increasing interest. With regard to this, the European copper industry invested in research to understand how the appearance of copper based materials changes in response to different conditions. Several other research programs have also been undertaken in relation to sustainability and environment. All results show that copper is a sustainable, long lasting material which causes no harm to the environment. This brochure summarizes the latest research on surface appearance as well as evolution of copper and copper alloy surfaces on buildings in different locations throughout Europe.

HISTORICAL EVIDENCE

The red metal is part of mankind's history and has been a reliable companion since the Bronze Age. Scientists believe that the roof of Parthenon, Acropolis of Athens, Greece (447 B.C. – 432 B.C.) was built using small bronze sheets and that the doors of the western cellar were strengthened with bronze bars and that the eastern doors were probably hollow bronze. In parts of Europe copper was considered one of the best roofing materials as early as 16th century. John III of Sweden (1568-1592) wanted a copper roof on his palace "Three Crowns" in Stockholm.

COPPER IN MODERN ARCHITECTURE

Photo 1: Naturally patinated surface of the **Auditorium of the University of Technology**, Espoo, Finland (built: 1949–66), architect: **Alvar Aalto**. The copper covered amphitheatre-like structure contains the main auditoriums, while its exterior can be used for plays and other activities.

Photo 2: Weathered façade of **Dipoli conference centre**, Espoo, Finland. Designed by architects **Reima and Raili Pietilä** and completed in 1966. The key example building of organic architecture uses extensively materials from Finnish nature, such as pine wood, copper, and natural rocks.

Photo 3: **Metso main library**, city of Tampere by architects Reima and Raili Pietilä was opened in 1986.

Photo 4, 5: **de Young Museum**, San Francisco, designed by **Herzog & de Meuron**, opened on October 15, 2005. The embossing and perforation is intended to remind us of light filtering through treetops. In this way, the outer cladding of the building corresponds intensively with the surrounding park landscape and the luscious stock of Golden Gate Park's trees, like an abstract work of art. Photo 4 taken Feb. 2006, photo 5 in Feb. 2015.

To see copper references in modern architecture from architects including **Foster+Partners** and **Renzo Piano** visit copperconcept.org.



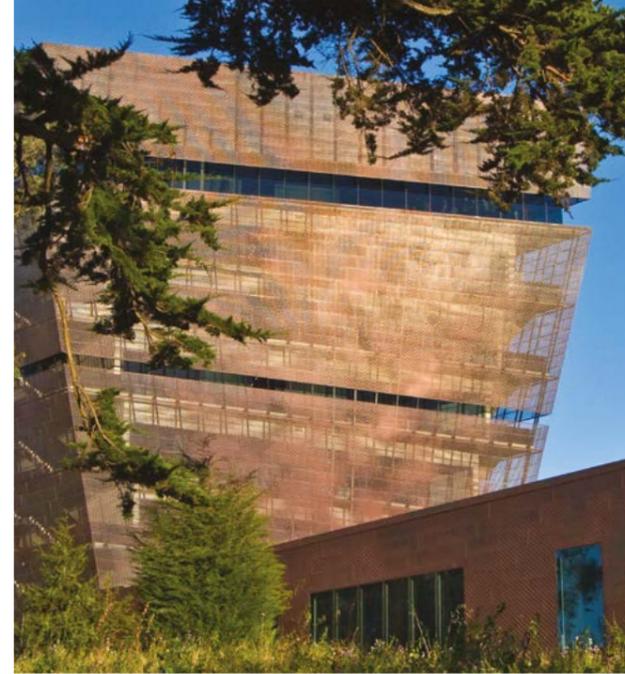
1



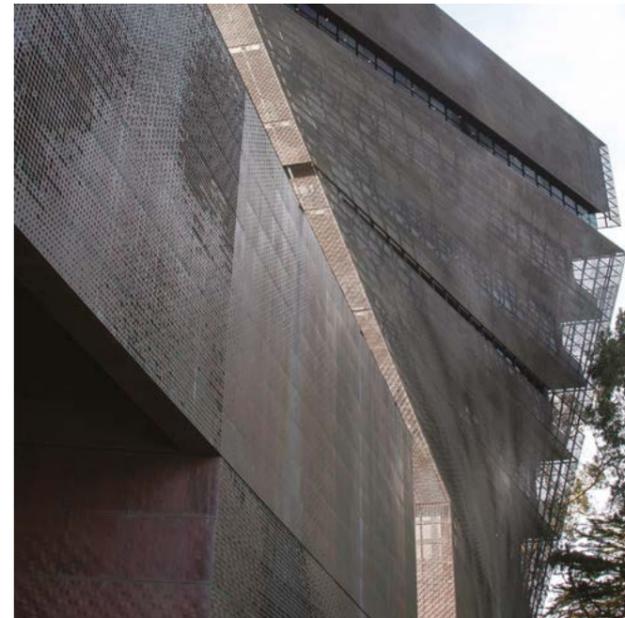
2



3



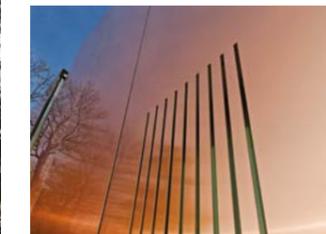
4



5

COPPER AND IT'S WINNING CHARACTERISTICS

- **Long life-time**
Often lasting 200 years or more, there are some copper roofs which are around 350 years old.
- **Formability**
Copper can easily be formed mechanically or by hand, on site or in the workshop, to suit virtually any three dimensional shape - including complex curves and details.
- **Maintenance free**
A copper roof or façade needs no special maintenance.
- **Temperature and weather resistant**
This means a very long service life. Copper is ideal for cold climate conditions and places where temperature variations are high as it does not break when worked/formed.
- **Natural beauty and variable surfaces**
Available in many shades of colour from natural orange-red to brown and green as well as many lively surfaces.
- **Durable and fire safe**
Copper doesn't change its properties over time, resists sunshine, UV rays, water, humidity and is non-combustible.
- **100% recyclable again and again without loss of performance**
Saves natural resources and maintains its value.
- **Essential for all life**
Copper is a naturally occurring element; it is present in the earth's crust. All life needs copper to function properly.
- **Copper has low embedded CO₂ ...**
The copper industry is at the forefront of industries committed to reducing the environmental impact of its operations. For more information on copper life cycle data please visit www.copper-life-cycle.org.



Cover:
Hof, Germany
Radiotherapy Centre
Architect: hiendl_schneis architekten
Copper Product: Copper
Completion year: 2012
Photos: © Foto Eckhart Matthäus/www.em-foto.de
Photos taken 10.2011 and 04.2017 (weathered)

COLOUR AND PATINA

The natural development of patina is one of copper's unique characteristics: exposed to the outside atmosphere it protects itself by developing a patina layer over time which makes it weather resistant with a lifespan over many generations.

Changes are very gradual and not entirely predictable – just like the weather, which, in turn, is solely responsible for copper's continual changes. The prevailing concentrations of air pollution and the environmental conditions essentially determine the composition and protective properties of the patina. The interaction of the patina with the local atmospheric conditions will determine the surface appearance and how it changes over time.



To see more examples how copper & copper alloy clad buildings change their visual appearance over time go to weathering.copperconcept.org

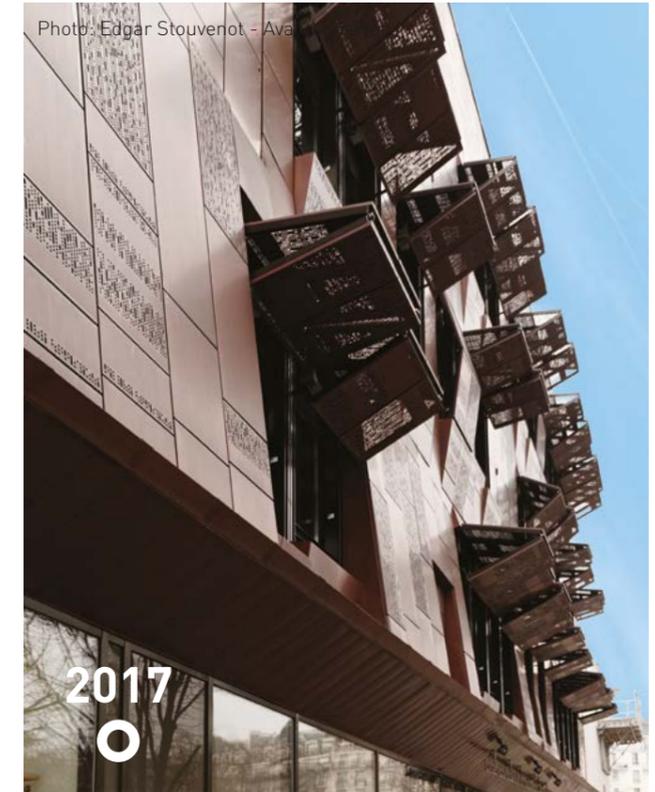
Photo 6, 7:
Dabas, Hungary
Market Hall
Architect: Kiss Járomi Építésziroda
Copper Product: Copper
Completion year: 2011
Photos: ECI
Photos taken 05.2011 and 11.2016 (weathered)



6, 7

TYPICAL SURFACE APPEARANCE EVOLUTION OF COPPER AND COPPER ALLOYS USED IN ARCHITECTURE

- **Copper**
Within a few days of exposure to the atmosphere surface begins to oxidise, changing its colour to chestnut brown which gradually darkens over several years and later may become a typical green patina.
- **Brass**
An alloy of copper and zinc. The original shiny surface changes through from initial matting gradually to a greenish-brown that further develops to greyish brown then dark brown/anthracite colours. Sloped areas ultimately may develop a patina surface akin to that of pure copper, yet quite clearly different.
- **Bronze**
An alloy of copper and tin. The original warm reddish-brown surface develops in a distinctive manner through weathering. A brown-red surface oxidation with a brown-grey undertone is typical for this alloy; the material then gradually changes to dark brown anthracite throughout - the subsequent patina coating forms much more slowly than with pure copper.
- **Golden Alloy**
This golden material is an alloy of copper with aluminium and zinc, which is very stable and keeps its golden shade over time. It behaves differently to pure copper in the environment as it has a thin protective oxide layer containing all three alloy elements when produced. As a result, the surface retains its golden colour indefinitely and simply loses some of its sheen as the oxide layer thickens with exposure to the elements, giving a matt gold coloured appearance.



COPPER



Photos: Esko Tuomisto



2015
○

COPPER



HELSINKI
FINLAND
MERIPAVILJONKI
Architects: Arkkitehtitoimisto Freese Oy
Completion year: 2014



○
2014



2005
○



○
2003

Photo: Pyhä Henrik

Photo: ECI



2010
○

COPPER



TURKU
FINLAND
ST HENRY CHAPEL
Architects: Sanaksenaho Arkkitehdit Oy
Completion year: 2003



BRASS



AHRENSHOOP
GERMANY
MUSEUM OF ART
Architects: Staab Architekten
Completion year: 2013

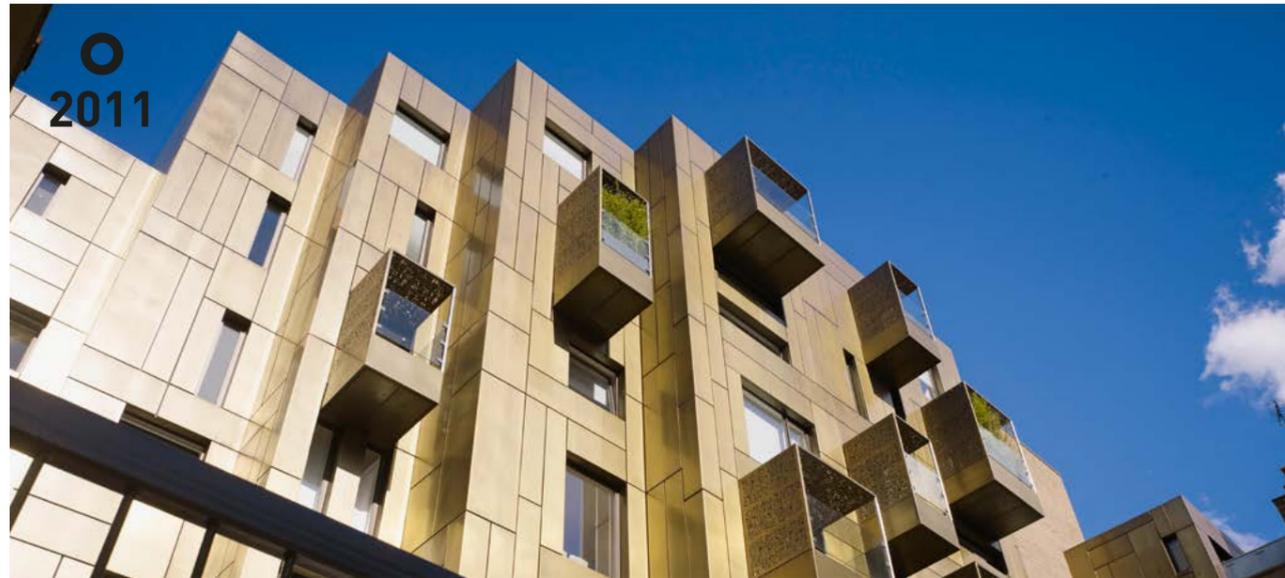
BRASS



HARD
AUSTRIA
HOTEL AM SEE
Architects: FRÜHARCHITEKTURBÜRO ZT GMBH
Completion year: 2011



BRASS



BRONZE



QR CODE

LONDON
UK
10 WEYMOUTH STREET
Architects: Make
Completion year: 2009

QR CODE

LONDON
UK
GRANARY
Architects: Schmidt Hammer Lassen /
Pollard Thomas Edwards Architects
Completion year: 2011

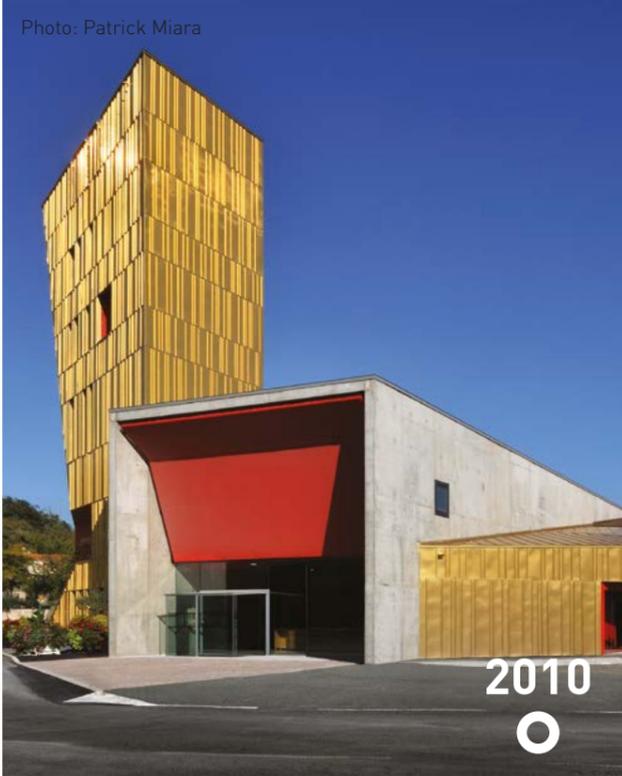


Photo: Patrick Miara

2010
○

GOLDEN

VENDÉE
FRANCE
TOUR DE ARTS DES HERBIÈRES
Architects: Forma 6, Nantes
Completion year: 2010



Photo: Edgar Stouvenot - AvantagesWeb

2017
○



Photo: Rosangela Borghese

2017
○



Photo: Chris Hodson

2012
○



Photo: Rosangela Borghese

2017
○

GOLDEN PERFORATED

LONDON
UK
TIDEMILL ACADEMY
Architects: Pollard Thomas Edwards Architects
Completion year: 2012



SCIENTIFIC STUDY

The European copper industry has invested in understanding the surface appearance of copper based materials in different conditions and supports the research work carried out by the KTH Royal Institute of Technology Surface and Corrosion Science in Stockholm. The on-going study is a long-term project that aims at assessing and generating a comprehensive understanding of atmospheric corrosion processes of copper and copper-based alloys used in building applications. Copper and three copper alloys (brass, bronze and golden alloy) have been exposed at unsheltered conditions at four test sites in Brest, France, representing four distances from the coastal line.

The way the protective patina forms, its thickness and composition largely influence the visual appearance of the material. Scientific results confirm that the level and how rapid the surface appearance change depend primarily on:

- **air quality & weather conditions:** the concentration of air pollutants, deposition of particles and prevailing weather conditions largely influence the patina composition,
- **distance from the sea:** (materials close to marine splash areas will develop a green hue quite quickly, whereas materials placed in urban environments may tend towards a dark brown hue),
- **alloy composition,**
- **surface inclination and orientation.**

Selected pictograms from the KTH study show changes in surface appearance after 6 months, three and five years in different locations exposed at inclinations relevant for roofing (45 degrees) and facades (90 degrees) for four different copper based materials: Natural Copper, Brass, Bronze and Golden alloy.

Locations:

- **Marine:** Exposure site St Anne, 25m distance from sea shore, high corrosivity level environment
- **Inland:** Exposure site Langonnet, 40km distance from sea shore, moderate corrosivity level environment

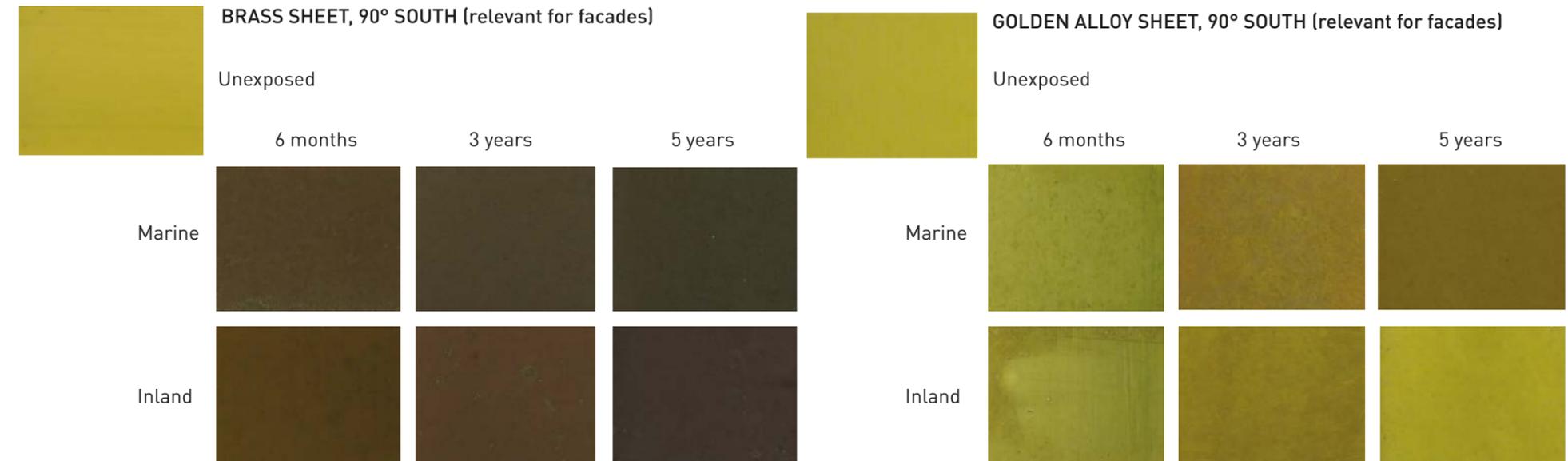
The pictures shown are for illustrative purposes only and should not be considered as exact representation of colour or visual changes in all situations or all time frames.

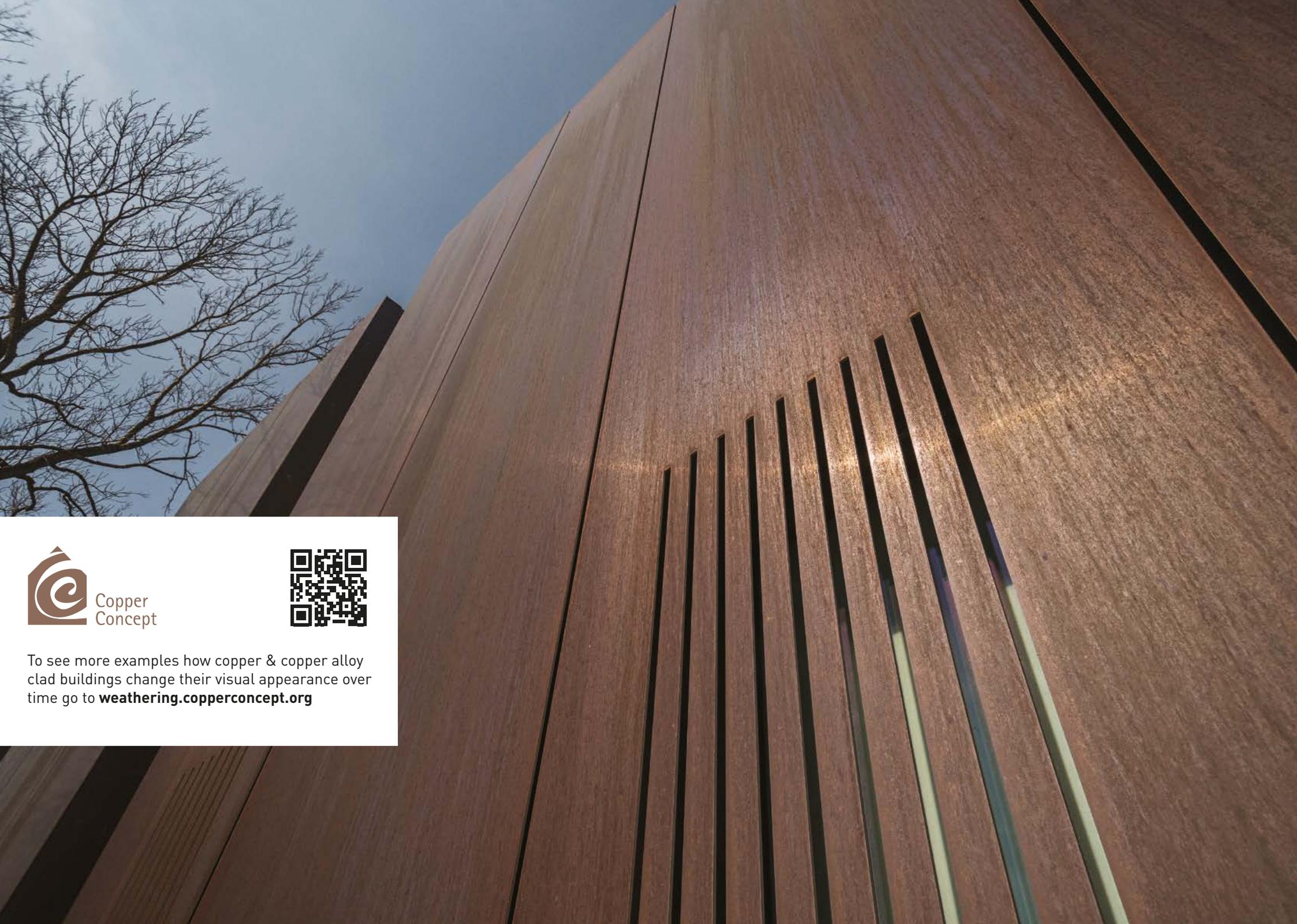


For full information on the KTH study download "Surface appearance of copper-based materials at unsheltered marine conditions" from copperconcept.org/en/publications



All photos on pages 14-15 are copyright KTH Royal Institute of Technology, Surface and Corrosion Science. e-mail: ingero@kth.se website: <https://www.kth.se/profile/ingero/>





To see more examples how copper & copper alloy clad buildings change their visual appearance over time go to weathering.copperconcept.org