A GUIDE TO

BUILDING MATERIALS AND THE ENVIRONMENT

VERSION 3.1

CHRIS HALLIGAN

AND JOANNE DENISON

In collaboration with

SGP
Architects + Masterplanners

norse
CONSULTING

This edition is dedicated to two inspirational leaders:

David Taylor

14th January 1943 - 11th December 2014

Stuart Richardson

10th June 1948 - 10th December 2015

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ACKNOWLEDGEMENTS

The Authors gratefully acknowledge the contributions of the many people (too numerous to list) who have helped bring this work to fruition. Those organisations and companies who have generously supplied illustrations are accredited accordingly.

AUTHOR'S NOTE

The popular internet resource of 'Wikipedia.org' appears as a link throughout this guide. While recognising that this website has academic limitations in terms of fully referenced content, it is nevertheless useful as a ready source of information for readers on the fundamental nature of materials and their source. It has not been used to assess any environmental impacts nor to arrive at any of the conclusions included in this guide.

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THE AUTHORS

CHRIS HALLIGAN

Is a Senior Chartered Architectural Technologist with Norse Consulting. He has over three decades of experience in architectural practice and the promotion of sustainable design. As well as holding a MSc with distinction in Sustainable Architecture, he has lectured widely on the subject across several countries and is the author of numerous published technical articles. He currently sits on the Climate Change Panel of the Chartered Institute of Architectural Technologists (CIAT).

JOANNE DENISON

Has worked for architectural practices both in the UK and New Zealand, where she co-authored *"Dry First Time"*, an investigation into waterproofing and tanking technology. Since co-authoring the original edition of this publication, she has changed careers to become one of Yorkshire's leading food and lifestyle photographers.

INTRODUCTION

This guide is intended to be a practical aid to help designers consider the environmental implications of commonly (and occasionally not-so-common) specified building materials. It comprises three main sections:

Part 1 is a short overview of sustainable construction;

Part 2 is an extensive summary of materials used in construction products providing an insight into the environmental impact of their production, use and eventual disposal;

Part 3 contains a range of data sheets for materials and elements with guidance on their advantages and disadvantages, practical considerations and sustainable alternatives.

The guide is fully interactive with many useful links to external sources of further information.

The foreword to the third edition has kindly been provided by Sandy Patience, architect and editor of the Greenspec website (*https://www.greenspec.co.uk/*).

PREFACE TO THE THIRD EDITION

It is now over ten years since the original version of this guide was first published and subsequently won The RIBA Presidents Award for Outstanding Practice-Based Research. Much has happened in the intervening period.

With social, political and economic upheavals of the past decade, sustainability seemed to take a backseat for a number of years in the face of more "immediate" problems. However, nature has a way of providing nasty reminders on how vital it is to our existence on this planet.

After my highly fulfilling time at Stephen George + Partners, I moved to work in the sphere of social housing for a number of years. During that time, I kept abreast of events pertaining to sustainability and the environment. Then just a few years ago, I started receiving enquiries once again on the subject of sustainable design. Faced with a host of world-wide extreme weather events and a fuel crisis, attention has been focused on sustainable design to provide solutions. This upturn in interest, encouraged by a recent collaboration with Race Cottam Associates, prompted me to contact my former work colleagues at Stephen George + Partners and, between us, we agreed to produce this new, fully revised edition as a collaborative project.

Unfortunately, (from my point of view, at least) my former colleague and co-author Jo Denison has left the world of architecture to become one of Yorkshire's leading food and lifestyle photographers. So, although much of the original work was undertaken by Jo, this latest re-write has been my sole responsibility.

When I began to revisit the last edition, I was shocked at how much had changed in a relatively short space of time. The increasing frequency of extreme floods, droughts, storms, heatwaves and forest fires seems to have begun to finally focus establishment attention on what we might have done to our planet and the consequences of this do not lie in some far flung future but are becoming very real here and now. Added to this a fuel crisis and ongoing materials shortages are creating a greater demand for low impact and sustainable solutions.

Developments in concrete technology (for example) have moved from the niche to the mainstream and the composition of insulation materials has come under intense scrutiny due to the tragic events of Grenfell. When we wrote in the first edition about the Great Pacific Plastic Sargasso, its existence was not widely known. Today it is relatively common knowledge — to the point where single use plastics are beginning to be banned in many countries. Some technologies though have fallen by the wayside. Touted as the "next big thing," they failed to attract funding for further development. This, unfortunately speaks volumes on our present economic system and the value attributed to sustainability.

In Britain we have the government initiative of "Net Zero," and in Scotland, the Passivhaus standard has just been adopted as the norm for new housing. However, despite all this, there is still no UK legislation covering the embodied carbon or general sustainability of materials. Most of the focus continues to be on operational energy. This does not mean it is a subject not being addressed – far from it. In fact, the often spurious sustainable credentials of materials seems to be a prime vehicle for unscrupulous marketeers to employ in a quest for sales. This practice has become known as "Greenwash," and is one of the main aspects for specifiers to be aware of. The only way to avoid this is knowledge. Hence the need for this work. Without truly understanding the impact of our actions, through an intelligent selection of materials which will not damage the environment, can we ever hope to leave our descendants a planet which will support their continuing survival?

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FORWARD

SANDY PATIENCE - ARCHITECT

Following establishing his own award-winning London-based architectural practice, Sandy founded and developed the GreenSpec website. This online mresource has grown to become one of the foremost sources of information on the sustainability of building materials.

https://www.greenspec.co.uk/

It's 13 years since Chris Halligan and Joanne Denison published the last edition of Building Materials and the Environment. 2010 saw the high water mark of the UK Government's intervention to reduce the environmental impact of new housing. Initiatives included the Code for Sustainable Homes and the Zero Carbon house, two potentially heavy-hitting transformational pieces of legislation outside of Building Regulations. Their appearance in the construction industry was progressive and timely. Still, shortly afterwards, both came to be seen by industry as brakes on profits and were marginalised by the then-ruling administration as 'green crap'.

Prominent was the 'Code's' concern for the environmental impact of building materials. The Code was based on a database of effects listed by the BRE's Environmental Profiling - an early form of Environmental Product Definition (EPD). Each profile set out a comprehensive set of impacts associated with the extraction through to the disposal of a building product. The result was a simple numeric 'Ecopoint'. The idea of a life cycle for each product specified in a building was radical. However, the reductive nature of an 'Ecopoint' still left the specifier with little understanding of the material's essential and sometimes visceral nature - its origins, characteristics, manufacturing, uses, and uses eventually disposed of at demolition.

The well-timed publication of Building Materials and the Environment fulfilled the need for a broader understanding of buildings' impacts on the wider ecosystems. The guide became widely popular among architects, designers, constructors and students who were becoming aware of environmental damage wrought by design decisions.

The guide's great success was that it could help underwrite an approach to building design that expressed a preference for using a materials palette that was arguably more sustainable than the ones more commonly used in mainstream construction.

This awakening interest was mapped closely by a burgeoning development of alternative materials. Products, be they environmentally improved or direct substitutions for existing products; low-impact traditional materials that had been superseded; or new materials often developed and already in use overseas, were starting to be shipped by mostly new suppliers with an eye to the future. The symbiotic relationship between design demand and supply efficiency has taken time to evolve. Many of the earliest outlier suppliers went to the wall because of inexperience, but luckily, enough have survived to stabilise this still infant market.

Though the usual market factors such as investment and expertise have played an essential role in developing the sector, the most crucial element has been the education of designers and specifiers in sustainable construction techniques to form demand.

The construction industry is notoriously nervous when it comes to the use of new building techniques. So it often takes a leap of faith to design in new ways using alternative materials. To minimise the risk, there still needs to be manufacturers providing backup to specifiers, but it also needs easily digestible, more general guidance for students and building designers. Setting out fundamentals and tracking technological developments, this timely update of Building Materials and the Environment fits the bill.

Sandy Patience March 2023

greenspec®

SUSTAINABLE CONSTRUCTION

SECTION 1

Photo: Kjeuring (Wikimedia Commons)

SOME CONSIDERATIONS

WHY ARE SO FEW BUILDINGS GENUINELY SUSTAINABLE?

"The basic principles are very straightforward; minimise artificial lighting, heating and mechanical ventilation, avoid air-conditioning, conserve water, use the site and materials wisely and recycle where possible. And yet, poor design too often results in buildings having an unnecessarily high environmental impact.

A fundamental requirement for success is establishing a clear client brief that rates sustainability targets as importantly as style, image and aesthetics. Putting sustainability at the core of the design brief helps to ensure that the building will be more economical, comfortable, productive, humane and better looking than a conventional building.

Delivering sustainable buildings requires a new design vocabulary. Climate responsible buildings, which are based on the principles of bio-climatic design, require the architect and engineers to work as an inter-disciplinary team. This will deliver intelligent buildings that work with natural systems to provide (for free) much of the requirements for lighting, heating, cooling and ventilation...

Integrated design places the engineer (and ideally the contractor and facilities manager) alongside the architect as equal partners in the design process."

Professor David Strong, formerly of the Building Research Establishment Founder of the InSite consultancy.
(BRE 'Constructing The Future' - Issue 32, Summer 2007

INTRODUCTION

It is one thing to learn and write about sustainable architecture; it is quite another to have the opportunity to practise it. This approach to building design is still in its infancy and for a client to commission a project with sustainability as a key design constraint is still relatively rare. Such an intention often requires a philosophy of altruism towards the planet and its future inhabitants and in an economic system where such an approach is often perceived as having no financial incentive, the designer may find it surprising to be asked to consider such issues. Fortunately, recent legislation, combined with an increasing awareness of the environmental impact of development is ensuring that issues of sustainability are taking an ever more prominent place in architecture.

In 2008, I was with Stephen George + Partners. We were asked to design a sustainable construction training and research centre for North West Kent College and Prologis. As well as providing a space for education, the building itself was to be designed as a teaching resource, providing examples of low energy design and utilising a wide range of sustainable materials to demonstrate their potential. My team's task would be to oversee the technical resolution of the design in accordance with sustainable design principles. We therefore set about investigating the sustainable credentials of every major element we wished to incorporate in the eventual design. Our research began to provide some interesting and often surprising results. Against expectations, we sometimes found that a material we considered as being one of the most environmentally friendly was not quite what it appeared. On the other hand, many widespread and commonly used materials turned out to have quite good environmental credentials by default.

Having generated a large amount of data, some of which we felt wasn't commonly known within the architectural profession, we felt it a shame not to collate this in a form which would be of some practical use Hence the work in front of you began.

When using this guide, an overview of the material in question will be found in Part 2 together with links to external sources of information. Part 3 comprises data sheets summarising advantages, disadvantages, considerations and sustainable alternatives for each material.

Recent geo-political and environmental events have generated a resurgence in the market for sustainable materials. However, this has not made selection of these easier – far from it. With the expansion of the "green" market and manufacturers' attempts to capture a greater proportion of it, has arrived the concept of "Greenwash." Claims and counter-claims often made employing only a selective focus are widespread. Our aim today as it was originally is to provide access to enough objective information to enable selection of materials with the least harmful impact. Again, we can't provide answers – merely a starting point for enquiry.

To begin to understand the issues integral to sustainable architecture, we need to understand what the 'words of the moment' mean and how they relate to some of the main issues.

EMBODIED ENERGY MEASUREMENT (EE)

The embodied energy of a product is the sum of all energy used in extraction of the raw material, manufacture of the product, transportation to site and the incorporation of the product into the building (sometimes including the energy of all services including mileage driven by staff coming to work and manufacture of the equipment used in the production of the product). The less extraction, processing and refining involved, the lower the embodied energy.

Be aware, embodied energy figures can be misleading; they are open to varied interpretations and definitions of what are to be included.

Embodied energy figures are supplied in 3 terms:

- Cradle to Gate – factory gate.
- Cradle to Site – taking into account the energy involved in delivering the finished product to site.
- Cradle to Grave – which accounts for the energy involved in reuse, down cycling or disposal at the end of the product's design life.

'Cradle to Cradle, as a concept exists, however, the term is actually copyrighted as it is the title of a 2002 book by architect William McDonough and chemist Michael Braungart. This gave birth to a program and institute dedicated to certifying products which might qualify for this description. It does however seem to be run on a commercial basis. Despite this, the concept of cradle-to-cradle is the basis of a circular economy, which in turn is almost the definition of "Sustainability." Information on the circular economy is available from both the Ellen MacArthur Foundation and the EU based Sustainability Guide website.

THE CIRCULAR ECONOMY

The concept of the circular economy has been the subject of considerable research and some very useful guidance on its implementation and impact is available in the shape of two freely available reports. (See links below). Possible carbon savings are quantified against various approaches and actions during the lifetime of a building. However, despite its title, financial or commercial (i.e. "Economic") considerations are rarely mentioned. This of course highlights one of the major stumbling blocks to achieving sustainability in any sphere – the fact that there is often perceived to be no financial benefit in it and environmental concerns are not attributed any monetary value. The truth is that while we are attempting to shift practices towards sustainable practice and technologies, the economic system we operate in makes it difficult. The key lesson of the circular economy could well be that it simply illustrates that our existing economy is not fit for purpose in providing a habitable global environment.

But that is probably something for another book....

Embodied energy indicates the amount of energy used in production, measured in MJ/kg; it does not recognise the type of fuel used in the process and therefore is not an indication of CO_2 emitted, which would be embodied carbon.

LINKS

Circular Economy | Sustainability Guide

How to Build a Circular Economy | Ellen MacArthur Foundation

Embodied carbon is a more complex figure, measuring the energy consumed during a defined lifecycle and then taking into account the source of the energy and its impact on the environment. While the same product made in two different factories (one using coal energy, and the other hydro power) might have the same embodied energy value, they would have vastly different embodied carbon values. Embodied carbon is difficult to measure accurately; it takes into consideration detrimental effects to the environment resulting from the source of power.

EE figures do not take into account the energy available within a material (the inherent energy). As the term suggests, this is chemical energy that can be released through combustion or chemical engineering. Recycling recovers inherent energy.

It is important to consider the durability and recyclability of a product. There are advantages in investing in high embodied energy products that will last the duration of the building, compared to lower EE products that will need replacing more frequently or require considerable maintenance. There are additional advantages to investing in high EE products that can be recycled or reused at the end of their life.

IMPORTANT

Consider cradle to factory gate figures as a good source for comparison of materials but don't lose sight of distance of transportation to site. Because of discrepancies in figures used for testing, **always use figures from a single source as a tool for comparison**.

LINKS

One of the main sources of information regarding embodied energy is the Inventory of Carbon & Energy (ICE) by Sustainable Energy Research Team (SERT) at Bath University. This document is available at: https://greenbuildingencyclopaedia.uk/wp-content/uploads/2014/07/Full-BSRIA-ICE-guide.pdf

Additional important research is available from the Centre for Building Performance Research at the University of Victoria in Wellington, New Zealand.

http://www.victoria.ac.nz/cbpr/projects/embodied-energy.aspx

BREEAM AND THE BRE GREEN GUIDE TO SPECIFICATION

The BRE Green Guide to Specification is an environmental profiling system based on the environmental impact of various constructions. The methodology was developed by the BRE and it is used within the BREEAM scheme to give credits. It is available online by registering at:

http://www.thegreenguide.org.uk/index.jsp

However, the system itself has been subject to some criticism. As mentioned, it assesses composite construction rather than individual materials, which may lead to problems if your desired approach isn't currently included in the ratings. Furthermore, every entry has an aggregate rating made up from an assessment of the following considerations:

- Climate Change
- Water Extraction
- Mineral Resource Extraction
- Stratospheric Ozone Depletion
- Human Toxicity
- Ecotoxicity to Freshwater
- Nuclear Waste (higher level)
- Ecotoxicity to Land
- Waste Disposal
- Fossil Fuel Depletion
- Eutrophication
- Photochemical Ozone Creation
- Acidification

The method by which these ratings are arrived at is not transparent and leads many observers to question their true worth. An oft-cited example is that of uPVC windows, some of which, despite being derived from petrochemicals, containing chlorides and (in common with most plastics) using phthalates, (plasticisers suspected to be responsible for a whole range of damage to the bio-sphere,) receive an A+ rating – the same or even better than many timber windows.

Some of the most inexplicable comparisons come when examining insulation. Originally the Green Guide gave embodied energy ratings as Megajoules per kg of material. This quantification

no longer appears in the current Green Guide having being replaced by a measure of embodied carbon. This change however has not resolved the apparent contradiction where EPS insulation derived from petrochemicals scores higher than straw bale and is equal to sheep's wool in overall sustainability.

- Straw bale A rated – kg of CO2 eq. (60 years) -53.0
- Wool A+ rated – kg of CO2 eq. (60 years) 3.9
- EPS density 30 kg/m - A+ rated – Kg of CO2 eq. (60 years) 12.0

A high BREEAM rating depends on the materials in a building being predominantly at least 'A' rated. As BREEAM seems to be moving towards becoming a common standard in building procurement, there is a danger that materials will be selected merely to achieve the BREEAM rating demanded by a brief, rather than from any true environmental consideration or intellectual design process.

LINKS

The BRE's Green Guide to Specification is available at:
http://www.thegreenguide.org.uk/index.jsp

Individual Environmental Profiles for some materials used to assess ratings are available via the BRE's 'Green Book Live' website:
http://www.greenbooklive.com/page.jsp?id=9

ENVIRONMENTAL PRODUCT DECLARATIONS

The International EPD System is the world's first and longest operational EPD programme, originally founded in 1998 as the Swedish EPD System by the Swedish Environmental Protection Agency (SEPA) and industry.

It seeks to provide transparent and usable data based against a common standard for manufactured products and services taking into account the potential impact of those items on various environmental categories. In concept it seems very similar to the BRE's Green Guide but has the added advantage of being international in nature. However, like the BRE, the EPD system is run on a commercial basis with organisations paying to have their products and services assessed and certified in the EPD system. Although well publicised, a requirement for EPD certificates does not seem to have become a commonplace requirement amongst UK specifiers.

LINKS

International EPD System | EPD International (environdec.com)

The EPD | EPD International (environdec.com)

CARBON LOCK UP OR CARBON SINK

Trees and plants require CO_2 to grow. The quantity of CO_2 a tree or a field of hemp or straw has absorbed before it is chopped down and turned into a building product can be calculated. The building using the product can then be said to have 'locked up' this amount of CO_2 in Kg/m^2. Of course this will be re-released at some point in the future when the product comes to the end of its life.

Lime-based products are often marketed as being 'Carbon Negative'. Although requiring energy (and therefore responsible for a degree of carbon dioxide emission), the curing or re-absorbtion process which lime undergoes throughout its life 'fixes' CO_2 as part of its chemical make up. However, it should be noted that CO_2 is also emitted or driven off from the raw material as part of the production process.

LINKS

Embodied Carbon Dioxide in Hemp/Lime technology:
http://www.limetechnology.co.uk/upload/documents/Hemcrete/HEMCRETE%20-%20EMBODIED%20CO2%20-%20DATASHEET_H0509.v1.pdf

CARBON OFFSETTING / CARBON NEUTRAL

Many companies claim to be carbon neutral through the following process. The quantity of CO_2 generated through the creation of a product is analysed; this figure can then be 'offset' through payments made to carry out processes such as planting trees and installing energy saving light bulbs in remote villages in impoverished countries.

While the intentions behind carbon offsetting are commendable, should they be used to claim green credentials for products that are toxic to the environment and end user? Mastic asphalt production consumes a large amount of energy and usually receives a very low rating under the BRE Green Guide. However, by virtue of a levy imposed by the Mastic Asphalt Council (MAC) on its members which is then passed on to a carbon offsetting scheme, it is possible for MAC to declare that the entire Mastic Asphalt industry is now Carbon Neutral.

It might be argued that offsetting is merely avoiding the issue and buying our way out of trouble and that the cost of doing so is wholly dependent on the methodology used to assess the likely cost of offsetting the impact of the project or process in question. As an example we can look at the following:

Assume a small office building of 900m^2 floor area emits 18.5kg/m^2 of carbon per year. (2002 UK Building Regulations). This equates to a total of 16650kg of carbon per year. Over a 60 year lifespan, this will result in 999 tonnes of carbon being emitted. We can convert this to carbon dioxide by multiplying the amount by 44/12 (the ratio of the atomic weights of CO_2 and carbon). This gives a total of 3663 tonnes of carbon dioxide arising from the building during its 60 year life.

Now, it is estimated that 1 hectare of mature oak woodland can offset 275 tonnes of carbon dioxide over a 100 year period. So to completely offset the carbon emissions of this building by tree planting would require enough money to plant and maintain 13.32 hectares of oak woodland for 100 years. If the oak has to be planted in the first place, add on another 25 years for it to mature enough to actually begin absorbing enough CO_2 to qualify as 'offsetting.' The true scale of what these figures imply should be taken into account when considering offsetting as an option, as it seems very unlikely that the money paid to do this will be anywhere near a realistic level of investment.

NET ZERO

At the time of writing, the UK government is promoting a "Net Zero," initiative. However, this again only takes into account operational carbon, completely ignoring embodied forms. A proposal did appear in early 2022 for a new Approved Document ("Part Z") to be introduced to the Building Regulations. However, this quickly disappeared due to receiving inadequate political support.

Should the UK succeed in widespread adoption of a Net Zero design strategy, this of course will ensure that the carbon footprint of new buildings lies almost wholly within their fabric – meaning the issue of sustainable materials will achieve an even greater proportional importance.

MATERIALS

The selection of sustainable materials is dealt with in-depth during the succeeding chapters. However, certain basic considerations should be taken into account regarding these materials. What is their impact on the environment arising from their production and use? What are their end-of-life options?

Consider that, 300 years ago, every material available would be a product of nature. There were no industrial processes available to produce synthetic materials such as plastics. Consequently, everything would be expected to eventually decay or be reused in either a new building or in another capacity.

In today's society, life without artificially produced materials is almost unthinkable. However, the plastics we produce and use today will be in the environment forever. A vast area of the Pacific Ocean is now known as 'The Plastic Sargasso,' as it has become choked with the discarded remnants of plastic consumer goods. Even the much heralded introduction of biodegradable plastics should be viewed with some suspicion as the decay process for these is far from proven outside the laboratory. The best to be hoped for is for any plastic items to be recycled. However, the very term 'recycling' is a misnomer. Most materials are not actually used again in the same manner, but are actually 'down-cycled' via yet another industrial process; e.g. plastic bottles become clothing. However, how much energy does this take?

As designers, in addition to considering the impact in energy arising from selection and use of materials, we should think about exactly what is going to happen to them beyond the life of the building. Are they easy to dismantle? Are they easy to reuse? Obviously, this has implications for composite materials which are not easily separated.

PLASTICS

Plastic has assumed the status of a major problem in terms of the global environment. Much of the publicity surrounding this material refers to disposable items such as drinks bottles and much of the effort to improve sustainability revolves around recycling and recycled content. However, construction is second only to the packaging industry as a producer of plastic waste and far from reducing the amount consumed, between 2019 and late 2021 actually increased its plastic waste output by almost 46%. This continued the trend for the four years up to 2018 when UK construction increased its output by over 69%. Even when care is being taken to source items of a more sustainable nature and ensure recycling of discarded material, the small nature of items such as insulation retaining clips, cable ties and sheeting means that a great deal make there way into the environment.

ENV23 - UK statistics on waste - GOV.UK (www.gov.uk)

Some materials are inherently harmful to the environment but so ingrained within the modern world that we accept their harmful effects by the justification of their more useful attributes. Plastic in particular is a problem. Recycling plastic is often seen as a solution to its use. But only small percentage of the virgin plastic produced globally gets recycled. Most of the rest is discarded and eventually finds its way into the environment. This is most noticeable in the mid-Pacific "Gyre," where the world's maritime currents end up, usually carrying pieces of plastic which, although not truly decaying, are constantly reducing in size to almost microscopic levels.

The term "Microplastics," has been coined to describe pieces of plastic less than 5mm in size. These particles are now so prolific, they have appeared in the environment far beyond the well publicised Pacific "Plastics Sargasso." The geographical extent of plastic detritus is now absolute, being found in the snows of the highest mountains to the depths of the Mariana Trench. This Microplastics have been seen in shellfish for a number of years. However, their appearance in the wider food chain has now resulted in their being found in healthy humans – from blood donors to new born infants. Plastic is an intrinsic part of modern life and occurs in almost every aspect of industrial materials. It would be impossible to note every item where plastic is a constituent part so we would merely encourage vigilance on the part of the specifier if you would prefer to completely avoid this material. With plastic production predicted to continue to increase in coming years, the prevalence of microplastics will only increase along, presumably with their detrimental effect on humans, and to animals.

LINKS

Microplastics Found in Humans: What Does It Mean for Our Health? | SELF

Microplastics have moved into virtually every crevice on Earth (nationalgeographic.com)

Microplastics are everywhere — but are they harmful? (nature.com)

PACKAGING

Many building materials now arrive on site in palletised or shrink wrapped units. There may even be specially produced elements of packaging designed to protect the materials during shipment. These may be plastic, polystyrene, timber or metal spacers, guards or protectors. All of these items need to be collected and either disposed of or recycled. In the case of pallets, these can be re-used many times in a similar role. However, smaller items are difficult to collect and re-use and will often end up in landfill.

It is estimated by the UK government's Department for Environment, Food and Rural Affairs (DEFRA), that the recovery rate for packaging waste in the commercial and industrial stream increased from 33% in 1998 to 60% in 2005. This measure however, has only increased to 63.2% by 2021. DEFRA has also previously identified that packaging can often account for up 20% of site waste by volume and occasionally be up to 50% of waste arisings.

As the construction industry strives to reduce its waste impact (largely due to the financial implications of landfill tax together with initiatives such as WRAP), the percentage of unrecyclable site waste generated by packaging will assume an ever-greater proportion of the total. In addition much packaging is of petrochemical origin and will not degrade in an environmentally friendly fashion. Unfortunately, the sight of metres of polythene wrapped around bushes and trees at the roadside is now a common sight. Such sheeting almost always is the product of being lost from goods being transported by road. It is estimated that up to 80% of packaging of building materials could be recovered.

University of Toronto. "Ecologists sound alarm on plastic pollution." ScienceDaily. ScienceDaily, 17 September 2020. www.sciencedaily.com/releases/2020/09/200917181303.htm

"The group first estimated that 24-34 million tonnes of plastic emissions currently enter aquatic ecosystems every year. They then modelled future scenarios using existing mitigation strategies: reducing production of plastic waste (which includes bans), improving management of plastic waste that is produced, and continuous recovery (i.e., cleanup) from the environment.

The researchers found that even with parallel efforts in all three solutions, the level of effort required within each is enormous:

1. a 25 -- 40% reduction in the production of plastic across all economies;
2. increasing the level of waste collection and management to at least 60% across all economies -- with a change from 6 -- 60% in low-income economies;
3. recovery of 40% of annual plastic emissions through cleanup efforts.

"To put that last number into people power, the cleanup alone would require at least 1 billion people participating in Ocean Conservancy's annual International Coastal Cleanup".

So why are building materials now dispatched with such a degree of packaging? The answer given by suppliers is usually one of protection. Heavy or fragile materials can often be damaged during transit or off-loading. Packaging is seen as a method of protecting materials during these operations.

However, case studies have indicated that the degree of packaging required to adequately protect materials during transport may not be the most cost-effective method of doing so. If, for example, an unpackaged shipment of materials suffers some damage during transit, the financial impact of losing this "sacrificial" quantity can be compared favourably against providing excessive packaging. Say, a pallet of concrete blocks with no protection will suffer loss of a small number of units through damage, the total cost of replacing these blocks may be less than wrapping and protecting the pallet with plastic and polystyrene – petrochemicals which will eventually go to landfill. Furthermore, a regime for recycling the damaged blocks may already exist and be implemented on site whereas packaging is usually considered superfluous and difficult to re-use.

Some companies are already adopting this alternative approach to transporting goods. Some steel and aluminium cladding suppliers, for example, dispatch products sandwiched between already damaged sheeting as protection during transit. However, the sheeting is not retrieved and responsibility for disposing of or reusing the sheeting is left with the contractor.

A new approach to industrial packaging has been introduced by companies such as Swiftpak who purport to deal with this issue from a sustainable viewpoint including such initiatives as deposit return schemes.

RECYCLING

The re-use of building materials, either as a constituent ingredient or as a wholly reclaimed element has vastly increased over recent years. The advent of landfill tax and environmental legislation has ensured that it makes financial sense for materials suppliers to actively try to re-use at least a proportion of recycled content in their products.

Some elements of course can be re-used wholesale. This is usually termed 'reclamation' but is in reality the purest form of recycling. Bricks, roofing tiles, masonry, timber and some steelwork can all be salvaged during demolition operations. This historically has been most prevalent in the conservation industry where old materials are actively sought out to visually match those in an existing building. While often reducing energy expenditure (and therefore carbon emissions) against using newly produced materials, this may not universally be the case. Structural steel frames, for example, if dismantled via bolted connections should theoretically be capable of being reused in new buildings. However, as noted in section 2.24, this may not be economical. Similarly, brickwork may be very difficult to reclaim if it has previously been laid in cement mortar rather than lime. Removal of the cement mortar from the bricks may prove very difficult, time consuming and labour intensive.

Recipro is an organisation which was formed to facilitate salvaging and re-use of materials. It is, however, an operation local to the Wirral area and does not seem to have been repeated in too many other areas.

When this guide was first being written, the UK government's **WRAP** initiative was largely aimed at industry and construction in particular. Exploring the WRAP website today, one would be hard pressed to even find a mention of the building industry. It appears to have been completely removed from WRAP's remit. Unfortunately this includes the useful interactive database on the recycled content of products. Instead the area being concentrated on is food packaging. It is intriguing to consider why this might be: Is it due to the overwhelming success of the previous campaign meaning construction waste is no longer a problem? In the face of such a unlikely scenario, it is hard not to be cynical in one's assumptions.

"Recycling" seems to be a catch-all term used to denote any materials (or part thereof) which can be reused. However, much so-called "recycling" perhaps should be termed "downcycling," as the product being recycled may not be used as the same element. Much demolition rubble from concrete and brick walls, floors etc ends up as fill for new buildings. This is often termed "recycling" but true recycling would involve reusing such wall and floor elements as just that rather than as fill. Some materials are capable of being recycled as new for reuse as similar elements. Obvious examples include aluminium and steel which can be processed into new elements with a fraction of the energy consumption involved in the original production. More commonly however, is the process of "downcycling," where the material undergoes a process to become a quite different product. Such a process is becoming far more common with salvaged plastics. Discarded plastic products are now being formed into numerous elements such as wall-ties, garden furniture, landscaping elements, drainage media and even insulation. While a valid approach to the problem of what to do with discarded plastic items, this only accounts for a tiny percentage of the world's plastic production and would have to expand vastly to make a dent in the amount of plastic which finds its way into the biosphere each year.

LINKS

Reciprico
https://www.recipro-uk.com/

ENV23 - UK statistics on waste - GOV.UK (www.gov.uk)

RE-USE: DESIGNING FOR DECONSTRUCTION

In a world of limited resources, it would seem the obvious course of action to re-use as much of a building as possible when replacing it. However, rationality unfortunately does not seem to be one of humanity's strong points! The developed world in particular has traditionally viewed disposal as "someone else's problem." Indeed, our largely consumption based economy almost depends on it. Although re-use of construction materials and elements is far from a new concept, it most certainly has not been mainstream for the last couple of hundred years.

However, recent initiatives towards facilitating this have made the prospect easier to implement. The concept of being able to dismantle and re-use elements of a building is considered under BREEAM and LEED and the BRE has carried out studies into designing buildings so they can be dismantled with relative ease. Reconditioned structural steel is now accepted by funders if acquired and prepared under certain methodologies. Some steel stockholders now actually list second hand steel elements available for sale.

LINKS

Design for Deconstruction – helping construction unlock the benefits of the Circular Economy | BRE Group

Assuming a building is to be eventually dismantled requires consideration during detailed technical design and the buy-in of the original contractor.

For example:

- Steelwork should have bolted or mechanical connections rather than welded;
- Composite materials should be avoided unless produced with the specific ability to come apart;
- Adhesives again should not be employed;
- Masonry should be laid in lime-based mortar as this is easily removed unlike cement, which almost ensures brickwork cannot be used for anything other than fill.

The concept of dismantling may of course inherently suit modular construction methods – but the ease of re-using elements still needs to be taken into account at construction.

RE-USE: MINING THE ANTHROPOCENE

Having habitually discarded the products of the Industrial Revolution for the last couple of centuries, it is now beginning to be realised that materials lying in landfill may actually be a resource there to be won in the same way minerals are quarried or mined. This has most notably started in respect of Pulverised Fuel Ash (PFA), a waste product from coal fired power stations which can act as a cement substitute. As electricity production has moved away from solid fuel, the amount of PFA produced has correspondingly reduced. Somewhat ironically, also as embodied carbon has become of concern, the demand for PFA for use in low carbon cement has increased to the point where there is now a shortage. PFA previously dumped in landfill is now being excavated for industrial use by the cement industry.

This reflects a wider concept of seeking to revive discarded materials for use. Whereas metals have always been reclaimed as scrap, other elements from demolished buildings have not been (apart from the obvious architectural salvage trade.) The detritus of landfill is increasingly being viewed as a resource. But to fully realise this concept, new industrial processes have to be perfected to render these elements as viable construction materials.

Architect Duncan Baker-Brown explores the concept of Mining the Anthropocene in his recent book **"The Re-use Atlas,"**

LINKS

BakerBrown – An Insight into the Re-Use Atlas No.1

Duncan Baker-Brown on mining the Anthropocene | AJ Climate Champions with Hattie Hartman (podbean.com)

TRANSPORT

The transportation of building materials makes a definite contribution to their overall carbon footprint. What that proportion is can vary greatly, depending on distance, mode of transport and the amount of embodied energy or carbon arising from the production process. For instance, cement has such a huge carbon footprint, the energy required for its bulk transport is likely to be only a very small proportion of the total, whereas the transportation energy required for timber will assume a larger proportion of the total due to its inherently lower overall carbon footprint.

It is extremely difficult to arrive at a 'level playing field' for various materials. Different weights and volumes of different materials are required to perform the same job. Hence, a greater volume of timber may be required to replace concrete or steel as a structural element on a project; it will most likely be transported further but it weighs considerably less.

A simple concrete paving slab may incur an energy debt through transport due to delivery of the limestone used in the cement, the delivery of the actual cement, the delivery of the aggregate, the delivery of the packing materials and eventually the delivery of the finished material to a merchants and finally to site. Clive Richardson's PhD for the University of Huddersfield examined in-depth the embodied energy of such a concrete paving slab. He found that out of the top ten contributors to the carbon footprint of this product, six were related to transport. Despite this result, the contribution to the overall embodied energy was far less than that of production.

There does not seem to be any conclusive agreement on the contribution of transport to the embodied energy or carbon of a material. An article published by Davis Langdon for Building Magazine in 2007 states that "research results suggest that…15% [of emissions are associated] with transport of materials."

As regards the contribution to the carbon footprint arising from transportation from abroad, again very little definitive information is available. The UK Environment Agency has produced a freely downloadable Carbon Calculator for assessing the embodied energy of both materials and the construction process. This allows one to assess the emissions arising from transportation by road, rail or water. Generally speaking, waterborne options result in about a 90% reduction of the emissions arising from road transport with rail being between the two. Although shipping of materials in bulk would seem to imply an economy of scale which results in low emissions per unit, the scale of the shipping industry in our global economy has come under increasing scrutiny in recent years. Cargo vessels use the dirtiest and most polluting oil available for fuel in addition to which accidental spills of bulk goods and fuels contribute to increasingly polluted oceans. Greenpeace have raised this issue as a cause for concern and estimate that the emissions associated with global shipping may be larger than those arising from the aviation industry. However, there is at present no real effort being made to assess, quantify and control carbon emissions from the shipping industry, which remains largely immune to most international climate change agreements. In the Tyndall Centre's 2010 report entitled "Shipping and climate change: Scope for unilateral action", it is pointed out that the method of calculating the carbon emissions from the UK's shipping traffic may be flawed and these may be up to six times the level currently stated.

Transport of materials has minimal impact on environmental accreditation systems such as BREEAM or LEED. In some versions of LEED, points are available for materials sourced within 500 miles! Of course in the context of North America, this may be considered relatively 'local'.

As with any other aspect of sustainability, an accurate assessment of the impact of transport is difficult to arrive at. For example, transportation of timber elements from Canada will incur a carbon debt but the benefits of using timber over an alternative material must be taken into account against this. Also, the emissions of domestic road transport would seem to dwarf any other form of transport.

So perhaps the rule of thumb would be to source materials manufactured as close to site as possible unless the material in question provides overriding benefits which would outweigh any emissions arising from its transportation over a longer distance.

LINKS

Environment Agency Carbon Calculator
https://www.gov.uk/guidance/carbon-calculator

Tyndall Centre Report
https://documents.manchester.ac.uk/display.aspx?DocID=42721

Mackay Carbon Calculator
UK Gov

RENEWABLE ENERGY GENERATION AND BUILDING ORIENTATION

This document does not look into the complexities of renewable technologies; it is a vast topic on its own, but if renewable technologies are to be considered then these should not be bolt-on accessories to tick the green credentials box. It is generally considered that large scale, community energy generation is the only environmentally feasible option for electric power production. Micro renewable technologies generally provide poor return on both financial and energy investment. One exception is water heating for which solar thermal technology is now an established and efficient method of provision with a relatively short payback period.

With all technologies we would encourage caution; pay back periods and performance data require careful and considerable investigation. However, with the recent substantial increases in energy costs being experienced in the UK, particularly in regard to gas, the commercial imperatives associated with their replacement have shifted favourably towards renewables.

Nevertheless, the primary design consideration should be the minimising of energy which materials used during the construction and life of the building. Only then should renewable energy generation be considered. Passive design to make the most of the freebies (sun and wind) through orientation should be maximised.

If alternative power sources are installed, ensure enough money is available for the full system, and that they are installed in the correct location to work efficiently, with suitable training and support for management of the system to ensure continuing efficiency. Many new technologies function badly through lack of user/occupier training and poor management (all the gear, no idea!) and cost saving in installation and management systems (great idea, no gear!). It is essential that knowledge of operation of a facility is passed on to the building users.

LINKS

Renewable Energy Information
https://www.renewableenergyhub.co.uk/main/renewable-energy-information/

'GREENWASH'

FLEXIBILITY

Eco buildings are often carefully designed for defined occupancy numbers. If there are more people and equipment than expected then the building will be too warm; fewer people, less equipment and the building will be too cool. Building managers need education in how to run the building, and occupiers with an understanding of the low energy systems in place will be more accepting of cool mornings and slightly warmer afternoons, a different concept to the fully regulated, energy hungry, air conditioned work environments we have become used to.

As the evidence of climate change has become apparent, the increase in spurious claims by business in respect of sustainability has vastly increased over the last decade. Any aspect of the environment and natural world is necessarily complex and there seems to be no end of companies willing to exploit this fact to deflect attention from damaging aspect of a product. These claims are particularly apparent with plastics and petro-chemical derivatives.

To demonstrate some of the issues, we can look at expanded polystyrene (EPS), the producers of which claim: *"Climate goals cannot be achieved without EPS"* **(BASF closes EPS recycling loop and launches Neopor® McycledTM containing recycled material)** and that *"EPS has a low carbon impact because clean manufacturing technologies equate to minimal energy and water inputs with no production waste"* **(Expanded Polystyrene (EPS) (bpf.co.uk)**. Furthermore, this site touts EPS as being "98% air," meaning lower transport costs and therefore less fuel emissions.

The reference to recycling perhaps alludes to the truth of the situation, i.e: *"EPS can be successfully recovered and recycled wherever facilities for recycling of EPS exist,…"* Such facilities are not widespread and the technology for doing so is in its infancy (Recycling the unrecyclable | Resource Magazine).

The European Union is attempting to create a "Polystyrene loop," to encourage recycling as it is estimated that at present only 7.5% of EPS waste is recycled with 52.5% being incinerated.

In reality, polystyrene is effectively a single use plastic. Its light nature means that it easily blows away from refuse stores and usually breaks down into the small spherical units of which it consists. This characteristic makes the material very difficult to clean up and remove from the environment especially where sheets of it are being cut and shaped in the open air – such as on building sites.

EPS is undeniably intrinsically low carbon – however, it is very easy to take only one characteristic of a material and laud that without recognition of the holistic nature of the entire material. Low carbon does not automatically equal sustainable.

LINKS

The Polystyrene Loop: LIFE 3.0 - LIFE Project Public Page (europa.eu)

Polystyrene pollution and practical solutions - Fidra

EPS IN THE LANDSCAPE
PHOTO : WIKIMEDIA COMMONS: TREVOR RICKARD

NO EASY ANSWER?

It is inherently difficult to satisfy every aspect of environmentally friendly construction. Design decisions and material selection will be constantly challenged and revised as costs, construction times, knowledge of materials and legislation all change as the project continues.

Most importantly, keep in mind WHY the building is 'green' and try not change this ethos as problems arise.

Green design is not inherently more expensive to build and may well be cheaper in capital costs as well as running costs. But use of innovative or unusual construction may come at a price and the installation of renewable energy generation will always cost more.

Before design work even begins, certain guidelines should be put in place to ensure that the sustainable design remains achievable.

- Clarify what is wanted from the building by the client?
  - by the contractor?
  - by the designers?
  - by the end user?
- Produce a clear brief
- At an early stage clarify the environmental approach with all parties
- Work as a team and ensure buy-in from all members of the design team and the client
- Establish the level of environmental impact what is the building trying to achieve?
- Set performance targets, if this is a BREEAM rating, appoint an assessor at an early stage
- This is likely to be pioneering design – mistakes will be made, allow for this
- Use non-toxic materials
- Design from the outset with products in mind. Involve manufacturers at the earliest stage and have alternative options

It is impossible to please everyone; there may be conflicting demands between costs, performance, time and sustainability

- Keep in mind items that can or cannot be compromised
- Ensure the client is aware of how organic materials will look
- Use passive not mechanical solutions
- Renewable energy generation should be a last resort, not the first

HOW TO DO IT!

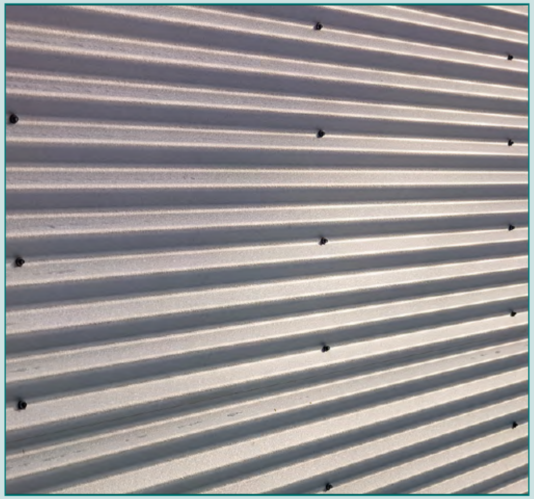
THE ABSOLUTE BASICS

- Integrated design team from inception
  - Allow enough time (and money) to test a new idea until you are sure it will work
  - Buy-in from whole team is essential (including client)
  - Client's support is critical
  - Do not assume 'business as usual' will do
  - Ensure contractor understands the obligations
- Have a clear target
  - Be aware that box-ticking does not automatically create a sustainable building
  - Do not expect a passive building to meet the same temperature parameters as an air-conditioned environment
- Have a realistic energy strategy based on
  - Reducing the overall energy demand of building as much as possible through passive design
  - Minimising the remaining energy demand of the building through efficient use.
  - Only then considering renewable technology to meet any residual demand
  - Agree a realistic occupancy rate with the client and ensure they understand the impact of this on the internal environment
  - Design the building to passively use natural day lighting and ventilation.
- Design in adequate controlled ventilation to prevent internal overheating
  - Limited width for cross ventilation and natural day lighting
  - Sufficient height for daylight penetration
  - Exposed thermal mass with night cooling (approx 1 sq.m per square metre of floor area) for commercial projects
  - 35 – 40% of wall area glazed is optimal for commercial projects
  - Provide solar shading appropriate to orientation (internal blinds don't really count).
  - Passive solar gain for housing
  - High efficiency envelope design
  - High insulation values
  - High level of airtightness
  - Triple-glazed or D/G argon-filled windows
  - Use materials with low embodied energy and toxicity
  - Remember - the ONLY renewable resources on earth are things which grow.
- Consider end of life options
  - Is recycling or reuse possible?
- Make sure the occupants know how to use the building properly
- Monitor the performance of the building in use, so you know whether it is working and can act if it is not.

MATERIALS SUMMARY

SECTION 2

Photo : Wikimedia Commons: JOGOS
Public Assets, CC BY-SA 4.0



ALUMINUM CLADDING
PHOTO: PHOTOS.COM WEBSITE

ALUMINIUM AWAITING RECYCLING
PHOTO: NORSK RESIRK A/S

CLICK HERE TO VIEW

- **Aluminium Data Sheet**

2.1 ALUMINIUM

Aluminium is the most abundant metal in nature and the third most common element in the Earth's crust after oxygen and silicon. The raw material in the production of aluminium is the clay soil bauxite – named after the French region of Les Baux where it was first discovered. The largest bauxite deposits today are in Australia, West Africa, Brazil and Jamaica.

Bauxite is formed when certain rocks rich in aluminium crumble. While 8% of the Earth's crust is aluminium on average, bauxite consists of 50 to 60% aluminium. Bauxite is extracted from open mine sites located in tropical and subtropical areas of the globe. About four tonnes of bauxite are needed to produce one tonne of aluminium.

The process of making metallic aluminium is carried out in two successive stages and is very energy intensive.

The stages are:

1. The chemical process to extract anhydrous aluminium oxide or alumina (A12O3) from the ore, and;
2. The electrolytic process to reduce the alumina to aluminium.

RECYCLING

While aluminium is very costly to the environment in extraction and processing, it is relatively simple to recycle. The recycling of aluminium uses 95% less energy than the production of primary metal from raw materials.

Anything made of aluminium can be recycled indefinitely: cans, aluminium foil, plates, window frames and garden furniture can all be melted down and used to make the same products again.

The aluminium can is 100% recyclable; there are no labels or covers to be removed. Recycling one kilogram of aluminium can save about eight kilograms of bauxite, four kilograms of chemical products and fourteen kilowatt-hours of electricity.

ANODISED ALUMINIUM

Anodising is an electro-chemical process whereby the natural oxide film on aluminium is thickened by passing an electric current through dilute sulphuric acid in which the aluminium sits. The anodising process seals the surface, provides an option to colour the metal, increases aluminium's hardness and corrosion resistance and provides better adhesion for paints and primers. As aluminium oxide film is created from the aluminium itself, it is integral to the aluminium and cannot crack or peel. The exterior of the aluminium will continue to oxidise through its lifetime, affecting its appearance.

PRACTICAL APPLICATIONS

Window Frames, Curtain Walling, Rain Water Goods, Architectural Trims, Ironmongery, Cladding

2.2 ASPHALT

THE GREAT PITCH LAKE IN TRINIDAD
PHOTO: JW2C (WIKIMEDIA COMMONS)

MASTIC ASPHALT BEING LAID
PHOTO: MASTIC ASPHALT COUNCIL

CLICK HERE TO VIEW

- **Asphalt Data Sheet**

LINKS

Aluminium production
https://www.aluminiumleader.com/production/how_aluminium_is_produced/

Aluminium recycling
https://www.snelsonsltd.co.uk/

Although the majority used commercially today is a synthetic product derived from petroleum, asphalt can be found, mined and collected in its natural state. Natural asphalt is formed over thousands of years as heat and pressure act on the organic remains of ancient animals and vegetation, forming oil. Over time some crude oil rises to the surface, the more volatile components evaporate and the remaining residue is known as asphalt. Its properties depend on the percentage of entrained clay and other impurities. The consistency varies from semi-liquid to almost solid. It is collected from natural deposits in various places around the world, the largest being the Pitch Lake on the island of Trinidad discovered by Sir Walter Raleigh in 1595. Other locations include the La Brea tar pits in Los Angeles; Bermudez Lake, Venezuela; and Uintah Basin, Utah, USA. Asphalt is transported in its raw form and refined in plants within each country by drying out the more volatile compounds. (Mastic) Asphalt's waterproofing properties have been used for centuries as a glue, preservative, mortar and waterproofing material. Noah was reputed to have caulked his ark in asphalt. "Mastic" describes the consistency of the material as being a viscous fluid.

The Mastic Asphalt Council has declared itself to be carbon neutral. It has achieved this by imposing a levy on its members which has then been used to offset the carbon emissions arising from mastic asphalt's use. This is calculated at 165kg per tonne of mastic asphalt laid.

In recent years, asphalt has been subject to research by the large suppliers in an attempt to render it more sustainable. Aggregate Industries have produced 'Life' asphalt, which is a cold applied foamed mix of bitumen and water produced at lower temperatures than traditional asphalt and uses 90% recycled aggregate. A carbon emission saving of up to 45% is claimed over hot mix asphalt.

Porous asphalt (also known as previous macadam), is available which can be used as part of a Sustainable Urban Drainage System. Described as "open graded, angular aggregate with a thin binder coating of polymer modified bitumen," this allows surface water to infiltrate through it. It either percolates into the ground or to an attenuation or retention tank for harvesting and re-use. There are reports of minimised durability partly due to increased winter salting maintenance and surface freezing. This is disputed by suppliers but has been subject to further research in Holland where the system has been widely installed.

Many cities have expanses of skyward facing, black asphalt used as roofing or hard surfacing which, by virtue of its coloration, has been associated with the urban heat island effect.

PRACTICAL APPLICATIONS

Waterproofing, Roofing, Tanking, Road Surfaces, Car Park Decks, Paving

2.3 BAMBOO

BAMBOO GROWING
PHOTO : WIKIMEDIA COMMONS: ANNIE076

A BAMBOO BUILDING IN NORTHERN CHINA
PHOTO WIKIMEDIA COMMONS

CLICK HERE TO VIEW

- **Bamboo Data Sheet**

Bamboo is a very versatile plant. There are almost a thousand species of bamboo, which can be processed with varying amounts of energy into such diverse items as cladding, blinds, flooring, roofing, kitchen utensils, matting, clothing, cleaning products or even foodstuffs. Bamboo, which is actually a form of grass, is the fastest growing plant in the world with some species managing up to 120cm per day at their peak. This vigorous growth means that fertilizers and pesticides are very rarely necessary in its cultivation.

One of the main uses in architecture at present is for cladding. Bamboo can be processed into large cladding panels which are similar in appearance to oak but with a high degree of dimensional stability due to the bamboo's density.

Traditionally, in the Far East, bamboo is used structurally. However, the performance of the material is difficult to prove by standard calculation. Accordingly, some oriental authorities make allowance in legislation for the employment of experienced individuals as design advisors employing "rule of thumb" techniques.

The main drawback with specifying bamboo in the UK is that the main constituent of its carbon footprint will be transportation. It is inevitable that any bamboo used in Britain will have been imported from the Far East. However, the fast growing nature of bamboo means that it provides a continuous carbon sink. The emissions associated with transportation should be offset against this. A 2003 report for Delft University of Technology concluded that bamboo used in a processed form would be slightly less environmentally advantageous than a timber alternative. It would however usually be far more economic.

Also worth noting is that any laminated bamboo panels will often use formaldehyde based adhesives in their make-up.

PRACTICAL APPLICATIONS

Cladding, Panels, Flooring, Furniture, Structure, Roofing

LINKS

General Information
https://www.ukbamboo.com/bamboo-construction/

https://www.bath.ac.uk/case-studies/researchers-transform-bamboo-into-dependable-building-material/

https://www.designingbuildings.co.uk/wiki/Bamboo

http://www.bamboogrove.com/bamboo-building-materials.html

2.4 BASALT

LA GOMERA BASALT QUARRY IN SPAIN
PHOTO : WOUTER HAGENS, CC BY-SA 3.0 VIA WIKIMEDIA COMMONS

BASALT FABRIC NINGBO KAXITE SEALING MATERIALS CO., CC 4.0>, VIA WIKIMEDIA COMMONS

CLICK HERE TO VIEW

- **Steel Data Sheet**

Continuous Basalt Fibre (CBF) is a recently developed material which is produced from basaltic rock to provide a range of products for use in various industries in place of more carbon intense traditional materials.

Only a small number of countries actually produce CBF (the most prominent being the USA and China) with much of the relevant technology developed in Austria. CBF is produced via a single step extraction process from molten basaltic rock and then processed into fabric or fibres for use as a component of manufactured products. One of the primary areas on interest of the construction industry is its use in wall-ties and reinforced concrete. As well as having characteristics of durability superior to steel, it is also inert and embodies very low conductivity. CBF is therefore used to produce thermally efficient wall ties which can avoid thermal bridging without the need for the plastic based breaks used in steel wall ties. In addition, CBF is cheaper than stainless steel, which is often used in areas where water penetration may be a risk.

As UK Building Regulations become more onerous and take into account the thermal bridging effect of wall ties, basaltic products are proving functionally more attractive than steel.

Basalt can also be used to produce rebar for integration in structural concrete, replacing steel – which basalt is twice as strong as and five times lighter than. Despite these properties and claims that it can reduce project costs over traditional steel reinforcement and have up to 60% less carbon emissions than traditional steel reinforced concrete, basalt rebar is currently only typically used in specific situations (such as marine environments).

Other construction products include mesh (again replacing steel) and fibres for reinforcement of concrete. It is also used as a replacement for glass fibre products.

Although the initial extraction process of melting rock is very energy intensive, one company at least has developed use of an AC powered oven which operates by means of an electromagnetic field rather than combustion.

CBF shares a primary raw material with mineral wool insulation in the form of basaltic rock. The construction and demolition sector in EU countries only generates more than 2.5 million tonnes per annum of mineral wool waste. In addition, mineral wool waste in Europe accounts for 20 to 60% of the production volume. CBF production therefore offers a potential route for constructive re-use of this waste material – most of which currently goes to landfill.

PRACTICAL APPLICATIONS

Structural and masonry reinforcement, wall ties

LINKS

General Information
Sustainability - IB Engineering

Basalt Technology

Mineral Wool Recycling
https://www.ibe.at/wp-content/uploads/2021/03/Recycling-of-mineral-wool-waste-4.htm

2.5 BITUMEN

PEEL N STICK TANKING BITUMEN
PHOTO: JO DENISON, STEPHEN GEORGE + PARTNERS

COLD REFINED BITUMEN
PHOTO: BURGER (WIKIMEDIA COMMONS)

CLICK HERE TO VIEW

- **Bitumen Data Sheet**

Bitumen is the end product of oil refining after the distillation of volatile products such as petrol and diesel; it is the black sticky stuff left over in the bottom of the oil barrel, a by-product of the fuel industry. It is chemically the same material as asphalt, but man-made and mass-produced in a much shorter time frame; the properties depend on the nature of the crude oil and the oil refining process.

Although bitumen is generally used to describe any sticky black goo, the differences are as follows:

Asphalt – naturally refined crude oil, found in lakes on the earth's surface and used as a waterproofing material in liquid form heated in large kettles.

Bitumen – is the end product of oil refining (a man-made process) after the distillation of volatile products such as petrol and diesel, commonly available as sheeting material for laying on roofs, traditionally available as liquid "pour and roll."

Pitch/Tar – is produced from the destructive distillation of (mainly) coal, wood and peat. Pitch is considered to be more solid and tar more liquid.

Asphalt and pitch are generally not compatible materials. Asphalt cannot be laid over bitumen, not due to chemical incompatibility but because molten mastic asphalt is too hot and will melt the bitumen. Bitumen sheeting can be laid over asphalt.

Bitumen is used extensively in the production of waterproofing membranes when combined with plastics or rubbers. These materials are relatively durable layers of bitumen bound by polyester or fibreglass matting, but at the end of their life, due to the difficulties in recycling, they most often become a fuel source. Although road surfacing is now often recycled for re-use, the same is not true of bituminous roofing membranes. Most of these efforts seem to be located in the Low Countries, with companies such as Derbigum being based in Belgium along with Eurobitume, the European Trade organisation for bitumen producers and users.

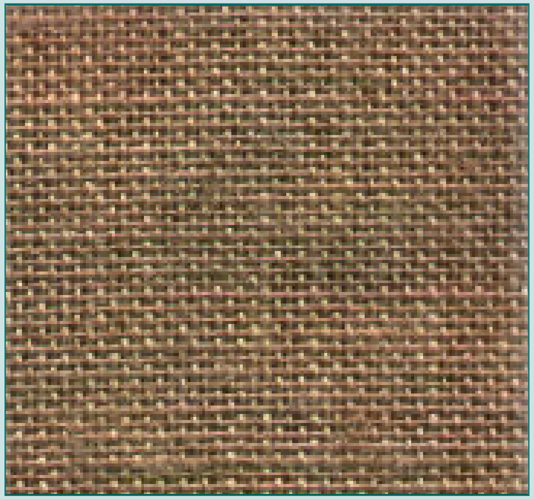
PRACTICAL APPLICATIONS

Waterproofing, Roofing, Tanking, Road Surfacing

LINKS

General Information
http://en.wikipedia.org/wiki - Asphalt, Bitumen, Pitch, Tar.

https://www.eurobitume.eu/bitumen/sustainability/



JUTE BACKING
PHOTO: LUIGI CHIESA (WIKIMEDIA COMMONS)

LOOPED PILE CARPET
PHOTO: PHOTOS.COM WEBSITE

CLICK HERE TO VIEW

- Carpet Data Sheet - Natural
- Carpet Data Sheet - Synthetic

2.6 CARPET

Carpet is a textile floor covering consisting of an upper layer of dyed material (pile) attached to a backing. Pile is woven or twisted from fibres, natural or synthetic.

FIBRES AND YARNS

Wool – wool and blended wool. Wool is durable, easily dyed and abundant; when blended with synthetic fibres such as nylon (often in 80% wool and 20% nylon mix) the durability level increases.

Nylon – Nylon is easily dyed and printed, it has excellent wear characteristics, but stains easily. Petrochemical derived, the price of Nylon depends on the price of crude oil, approximately 5kg of oil is required to make 1kg of Nylon.

Polypropylene (also called olefin) – is cheap, difficult to dye and does not wear as well as wool or nylon. Large looped polypropylene is only suitable for light domestic use as it mats down quickly. Smaller loops are more resilient. Commercial grade carpets have very small loops and are well constructed, they wear well, clean easily and can be glued direct to the floor. Polypropylene is of course a petrochemical derived plastic. Although products containing PP often exhibit the "Recyclable," symbol, it is estimated than only about 1% of that discarded every year is disposed of in an eco-friendly manner.

Polyester – Is stain resistant, but it tends to easily crush down or mat; used for mid-low price carpeting.

PTT – variant of polyester with more crush, stain resistance and resilience.

Binding - Cotton, Jute or Wool with latex (natural plant extract) backing. The use of organic wool, natural bindings, natural padding, and formaldehyde-free glues is becoming more common with increased environmental awareness.

SUSTAINABLE MATERIALS

Carpet produced from natural materials helps create a safer and healthier building. Natural carpet fibres include sisal (fibre from an agave plant, principally grown in Brazil and Tanzania), wool, coir (coconut husk) and jute (fibre from a vegetable plant also known as hessian or burlap, principally grown in India and Bangladesh).

Wool Carpet – the sustainable, biodegradable choice, superior in performance to synthetic carpets in many ways. These include its durability, stain-resistance (Lanolin found in sheep's wool acts as a stain inhibitor), richness of texture and plushness and its many natural advantages such as fire resistance and anti-static, which means that it does not have to be treated with as many chemicals. It has some vulnerabilities, namely to mildew and moths and there has been some criticism of the treatments applied for these but it is possible to buy untreated carpets. Wool carpets which have jute backing, only use natural dyes and are installed without adhesive are the ultimate eco-friendly option.

Plant Fibre Carpets – these completely 'natural' biodegradable carpets involve the use of plant fibres. These are all easy to clean and maintain, provide good sound insulation, do not harbour allergens, are naturally anti-static and extremely durable, as well as providing a uniquely natural look. However, they cannot replicate that "plush" carpet feeling .and, while soft underfoot, they can be uncomfortable to sit on for long periods. They are also vulnerable to moisture so may be unsuitable for certain rooms.

SYNTHETIC YARN CLOSE-UP
PHOTO: PHOTOS.COM WEBSITE

Carpets made from natural materials are biodegradable without cost to the environment. Foam underlay, while not biodegradable, is available using 85% recycled content and alternative fibre boards are available with sound absorption qualities but limited underfoot cushioning. Underlay tacked down in place of adhesive allows reuse.

It is possible to find carpet made completely from recycled food and drink containers (polyethylene terephthalate); the dying methods are said to be less polluting and require less energy than other flooring.

DYEING PROCESS & ADHESIVE

For thousands of years materials were dyed with natural plant and animal extracts. A desire to create varied and fade resistant colours led to the production of many synthetic dyes.

Conventional synthetic carpet may be bad for the user and the environment. Carpets are often heavily treated with fungicide, fire retardant, dye, stain proofing and anti-static measures meaning they may be continually giving off fumes of volatile organic compounds (VOCs) and other potentially harmful chemicals. Where carpet tiles are glued down, be aware of VOC content in the adhesive; factory applied pressure sensitive glues avoid waste but do not eliminate off-gassing.

TAKE BACK SCHEMES

While some carpet companies offer take back schemes, these are often limited to good quality clean carpets, or on new sites shrink wrapped unused palettes. Some nylon carpet manufacturers downcycle redundant carpet tiles with literature stating 'where possible, (this criteria is rarely quantified and usually very limited to unused clean product or factory off cuts) into extrusion moulded plastic composites. Dirty, soiled and otherwise landfill material is sent for 'material and energy recovery' – incineration.

Check before specifying.

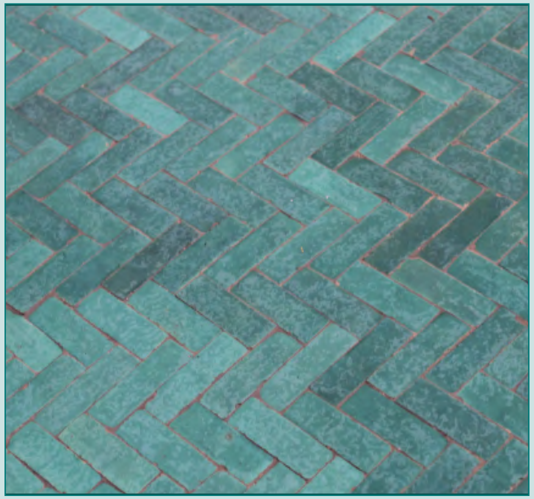
BRE GREEN GUIDE TO SPECIFICATION

Carpets under the Green Guide almost typify the difficulties involved in attempting to ascertain what is sustainable or not. Under the Domestic category, carpets (regardless of whether they contain plastics), receive ratings ranging from A (very good) down to E (quite bad). However under the Commercial category, carpets of similar composition for the most part are all rated A with single examples at B and A+. This latter example is a synthetic polypropylene / polyamide carpet. Reclaimed and re-used carpet tiles are the same A rating as the new examples. As is usual with the BRE Green Guide, end-of-life solutions are not taken into account.

CLICK HERE TO VIEW

- Carpet Data Sheet - Natural
- Carpet Data Sheet - Synthetic

2.7 CERAMIC TILE



TRADITIONAL CERAMIC TILES IN MARRAKECH
PHOTO : WIKIMEDIA COMMONS - LISHUILYNN

CERAMIC WALL TILES
PHOTO : WIKIMEDIA COMMONS: ALEXANDRE MANCINI

CLICK HERE TO VIEW

- **Ceramic Tile Data Sheet**

Ceramic tiles are usually comprised of natural clay baked in kilns at a high temperature which then receive a glaze coat which is then fired once again to transform this into a glossy colourful finish. This glaze may be derived from a sand base and coloured with natural pigments. However, traditionally, this includes chemical compounds which can be toxic heavy metals or even mildly radioactive. Due to the firing process, ceramic tiles may have a fairly high embodied energy content when compared to say, cork sheeting. The actual content can vary according to the product but the Bath University ICE quotes 9MJ/Kg as an average. This can be compared to the averages for carpet and vinyl flooring which are 74.4MJ/Kg and 65.64MJ/Kg respectively.

The major environmental impact of ceramic tiling arises from its manufacturing process which in the past has been energy intensive and can result in pollutant emissions. However in this respect, it is little different to most other industrially produced building materials. Manufacturers in recent years have made strenuous efforts to become more sustainable and it is not unusual to find new tiles being produced with between 25 and 36% recycled material.

There is a range of alternative materials to traditional ceramic tile which use predominantly recycled material. This may consist largely or wholly of recycled glass or a concrete based compound.

The strength of ceramic tile lies in its robustness and durability. Ceramics generally last a very long time and are not replaced with the same frequency as, for instance, carpet. When the whole life cost of tiles is therefore compared to the alternative, the environmental impact can be greatly reduced. In addition, the density of the tiles often allow them to provide a degree of thermal mass to a building. Finally, the generally inert nature of ceramic tile lends itself for use in specialist areas such as laboratories or food preparation areas.

For these reasons, ceramic tiles are generally considered a sustainable material. However, it should be borne in mind that some of the ancillary installation products (such as VOC containing adhesives or plastic trims), may have a more adverse environmental impact than the tiles themselves.

PRACTICAL APPLICATIONS

Internal wall & floor finishes, external facades, swimming pools, paving

LINKS

Recycled Glass Tiles
http://www.sustainablefloors.co.uk/recycled-glass-tiles.html

General Information
https://continuingeducation.bnpmedia.com/article_print.

LATTICE CLAY 'THERMOPLAN BLOCKS
PHOTO: NATURAL BUILDING TECHNOLOGIES

POLYCHROMATIC BRICKWORK IN CHESTER
ALEX LIIVET FROM CHESTER, UNITED KINGDOM, CC0, VIA WIKIMEDIA COMMONS

2.8 CLAY

Clay is a type of fine soil or rock – any fine-grained material consisting mainly of hydrated aluminium silicates that occur naturally in soil and sedimentary rock.

Clay shows plasticity through water content; it hardens when dried and when fired in a kiln permanent chemical and physical reactions occur. Clay is widely used in making bricks, ceramics, cement and below ground drainage.

CLAY BLOCKS

Clay blocks, both fired and unfired, are possible alternatives to concrete.

At the time of writing the original version of this guide (2010), at least two unfired clay blocks were available in the UK in the form of the "Naterra," and Ibstock's "Ecoterre." However, these do not seem to have been commercially successful and no longer are on the market. Be aware, if a source is located and specified unfired material will absorb water and potentially wash away or slump when wet. It is essential to ensure the correct location is chosen for these products.

Any fired clay product will have a relatively high embodied energy content due to the power required for the kiln in which it was produced. However, this embodied energy (and subsequently carbon dioxide emissions) can be reduced by selecting a brick type from the most local brickworks, hereby reducing transportation.

Fired clay 'lattice' blocks are popular in Europe. Poroton or Ziegel are German trade names which are now available and manufactured in the UK in conjunction with Ibstock and Natural Building Technology. These are marketed under UK trade names such as 'Thermoplan'.

This product offers a lightweight, thin bedded block with a vapour permeable structure and insulating properties due to its cellular nature. The omission of the cavity system with its twin leaves may also offer environmental benefits due to the resultant increase in speed of construction on site.

CLAY DRAINAGE PRODUCTS

Vitrified clay pipe work is in widespread use for below ground drainage. Although requiring more labour to lay than plastic alternatives, clay has none of the impacts associated with petrochemicals and incorporates far fewer of the toxins.

CLAY PLASTERS

Clay plasters are available as alternatives to gypsum. They harden by drying not by a chemical reaction, so are easy to work and repair through the addition of water; but as a result have a relatively soft finish perhaps liable to dents and knocks. Clay plasters are breathable and so are suitable finishes for vapour-permeable structures. Clay also has the advantage of providing inherent thermal mass, absorbing and diffusing water vapour, conditioning the interior space. Clay plaster is not suitable over plasterboard as the boards absorb water, making the plaster dry and brittle. If unsuitable in other locations and thermal mass is needed, consider a clay ceiling.

CLAY BOARD

Clay boards are available as an alternative to plasterboards. They offer good sound absorption, thermal mass and vapour permeability. The boards

CLAY DRAINS BEING LAID
PHOTO: NAYLOR DRAINAGE LTD

CLAY BOARD
MAX MILLER JUN., CC BY-SA 4.0 VIA WIKIMEDIA COMMONS

CLICK HERE TO VIEW

- Fired Hollow Clay Blocks Data Sheet
- Unfired Clay Blocks Data Sheet
- Clay Drainage Data Sheets
- Clay Boards Data Sheets

cannot survive prolonged contact with water or damp conditions and are fairly thick and heavy, requiring additional fixing details. Clay board is an expensive option compared to plasterboard but exceeds plasterboard in thermal comfort performance and provides an alternative to those wanting to move away from gypsum. It also has far superior acoustic qualities and so this combined with its robustness lends itself to use in schools.

BRICKS

Bricks are an ancient building material. Clay is quarried or dug, ground to the correct particle size, mixed with water and formed into shape. These are then dried, usually in waste heat from the kiln, before being fired in kilns at temperatures between 1000 and 1200°C. It is the quality of the clay and the impurities within which determine the nature of the brick; the heat of the kiln and the percentage of different additives such as lime or iron ore determine the colour of the brick, with pink bricks typically containing iron and yellow/white bricks containing lime. High strength bricks are blue/grey in colour; these bricks are fired at higher temperatures and the constituents within melt to form silicates which cool to form glass, creating a hard impermeable brick. This engineering brick was used by the Victorians as a damp proof course and for large chimneys and bridge structures. The use of brick declined significantly after the 1960s with the increased popularity of concrete blocks, which are bigger and therefore quicker and cheaper to build with.

Bricks can be reused whole if they have been used previously with traditional lime mortar. This cleans off quite easily in contrast to cement mortar more common amongst the modern building industry. This adheres too well, dries hard and so is too labour intensive to remove to be commercially viable on anything but a very small scale. The Brick Development Association provides guidance on the end-of-life options for bricks and produces a guide which makes an honest distinction between "re-use," and "downcycling," for which they are to be commended. Some years ago, unfired clay blocks were marketed under the tradename "Naterra." However, these failed to make an impact on the UK building industry and are now no longer available.

Bricks require minimal maintenance, lasting for hundreds of years; are recyclable when used in conjunction with a lime mortar; offer thermal mass; and availability of the raw material is plentiful. Carbon release from firing the kiln and from transportation is the major source of environmental concern.

PRACTICAL APPLICATIONS

Traditional Brickwork, Cellular Bricks, Unfired / Fired Blocks, Clay Plasters, Clay and Reed Internal Lining Boards

2.9 COMPOSITE MATERIALS

COMPOSITE STEEL-CONCRETE FLOORING BEING LAID.
PHOTO: JOHN COOPER, STEPHEN GEORGE + PARTNERS

Composite materials combine two or more dissimilar materials, either by chemical or mechanical means.

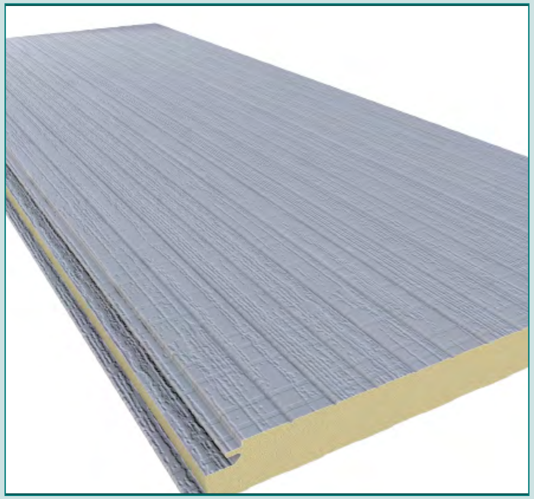
Examples include any form of laminate (worktops, cubicles, board materials), composite cladding panels, steel shuttered concrete floor slabs or concrete. It could be argued that timber panels such as OSB or plywood are composite materials but the elements used are generally of the same type (wood) and therefore can usually be recycled fairly easily.

Although exhibiting many beneficial properties in terms of cost-effectiveness and performance in use, the end-of-life options for composite materials may be limited. To be recycled, constituent materials need to be separated out. This is not always possible or financially viable. Composite cladding panels can have the steel recycled but first the insulation has to be stripped out. A single recycling plant has now opened in the UK to deal with discarded composite panels. This however seems to be mainly directed at panels with foam insulation cores (as opposed to mineral fibre) which may have originally used hazardous blowing agents in their formation. The insulation core is stripped out, shredded and effectively burned for fuel. This of course must have a substantial carbon footprint which will add to the overall embodied carbon of the material. The process avoids landfill and allows recycling of the steel skin. However, it can only probably be considered as a disposal solution rather than a recycling one.

The BRE in conjunction with NetComposites have produced *The Green Guide to Composites* which offers guidance in the form of a published document and an online tool. This examines the composition and production of composite insulated steel cladding panels and will provide a rating under the BRE's Green Guide to Specification for a range of inputs. However, end-of-life options do not feature heavily within this assessment method.

In steel-shuttered concrete decking, up to 79% of the steel of the profiled sheet from demolished structures is commonly recycled for re-use. However, the concrete can only be 'downcycled' for use as fill etc. The profiled steel will of course prevent the advantages of thermal mass offered by the concrete from being fully exploited due to removing the face of the concrete from direct exposure to the internal heat gains. The BRE Green Guide to Specification gives **"Powerfloated in situ reinforced concrete slab on shallow profiled metal decking"** an A+ rating.

We cannot conclude this section on composite materials without mentioning Grenfell Tower. It is well known that this residential tower block quite recently was subject to a disastrous fire resulting in substantial loss of life. The reasons for this were numerous but one of the main failings was the external cladding which was aluminium sheet bonded to a plastic-based insulant. This proved extremely combustible and demonstrated serious shortcomings in the testing and approval process for such materials. As well as driving a widespread change in legislation and practice it can be expected that use of similar composite panels may well reduce in the immediate future. Their use on high-rise residences has already been prohibited meaning many are being replaced and in turn creating a demand for disposal facilities.



A COMPOSITE CLADDING PANEL
AWIPANELS, CC BY-SA 4.0 VIA WIKIMEDIA COMMONS

CLICK HERE TO VIEW

- **Composite Cladding Panels Data Sheet**
- **Composite Flooring Data Sheet**
- **Designing for Deconstruction**

LINKS

Design for deconstruction
https://bregroup.com/buzz/design-for-deconstruction-helping-construction-unlock-the-benefits-of-the-circular-economy/?cn-reloaded=1

Recycling of composite steel panels
https://esynergyrecycling.com/construction-demolition-waste-composite-insulated-panels/

The Green Guide to Composites:
https://www.brebookshop.com/details.jsp?id=148926

Engineered Panels In Construction (EPIC)
http://www.epic.uk.com/end_of_life.jsp

https://www.epic.uk.com/circularity-in-the-construction-sector/

2.10 ICF

A product rapidly becoming more common in domestic design is the ICF block. ICF stands for **"Insulated Concrete Formwork".** This is a composite system comprising interlocking blocks (which work a little like Lego), with a hollow interior section.

The blocks themselves are usually made from polystyrene insulant with plastic ties. A version exists which uses cement-bound recycled woodchip. Steel reinforcement is threaded down the resulting cavity and then the void is filled with concrete.

The woodchip based version requires additional applied insulation but the polystyrene can have an intrinsic U value of down to 0.16W/m2°C with no additional work. Some woodchip based versions use mineral fibre insulation rather than polystyrene and also use a large proportion of recycled waste timber for the main part of the block.

It is the potential for high insulation values together with a naturally efficient airtightness which attracts designers of sustainable housing. However, it is essentially a composite product and therefore difficult to recycle at demolition. It must be borne in mind however, that houses tend to have a longer existence than commercial buildings, often far beyond their initial design life.

LINKS

General Information
https://icfa.org.uk/

A CLOSE-UP TOP VIEW OF ICF BLOCKS UNDER CONSTRUCTION
PHOTO: MIKEOG39 - HTTP://WWW.WISEHOMEDESIGN.COM

ICF HOUSE UNDER CONSTRUCTION
PHOTO: THE CONCRETE SOCIETY

CLICK HERE TO VIEW

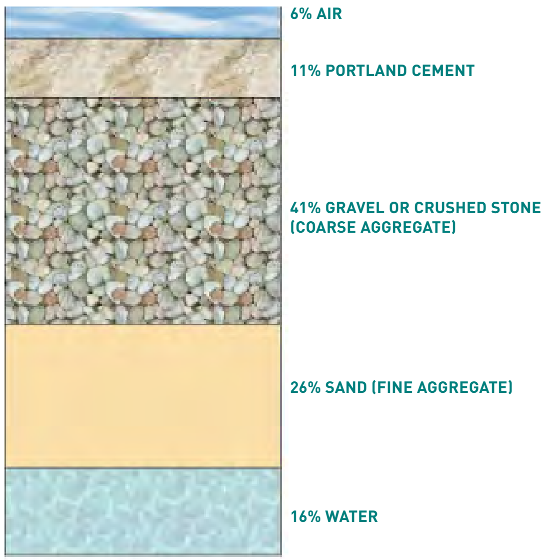
- **ICF Blocks Data Sheet**

2.11 CONCRETE AND CEMENT PRODUCTS

DEMOLISHED INSITU CONCRETE – RECYCLED AGGREGATE
PHOTO: LA FARGE

AGGREGATE QUARRY
PHOTO: LA FARGE

Concrete, or rather the cement used in its production, is widely known as a building material with one of the highest associated carbon emissions in the construction industry. It is estimated that cement production accounts for up to 10% of the world's carbon dioxide emissions. However, despite this, the use of concrete can often be invaluable in the design of low energy buildings. Concrete has an ability to absorb heat for many hours before re-emitting it. This allows exposed concrete to be used as a climate modifier in passive design, being used for night cooling in commercial buildings and for heat storage in domestic housing. The thermal mass offered by concrete is difficult to economically replicate by other means. However, innovative lightweight products which present an alternative method of providing a similar climate modifying solution are now becoming available to the construction industry.



THE COMPOSITION OF CONCRETE

These are termed **'Phase Change Materials'** and are discussed below.

There is scope to far reduce concrete's intrinsic environmental impact through the use of alternative constituent materials.

POURED CONCRETE (IN SITU OR PRE-CAST)

A properly designed concrete mixture will possess the desired workability for the fresh concrete and the required durability and strength for the hardened concrete. Typically, a mix is about 10 to 15 percent cement, 60 to 75 percent aggregate and 15 to 20 percent water. Entrained air in many concrete mixes may take up 5 to 8 percent.

AGGREGATES

Although often the subject of heated environmental debate due to the proximity of suitable geological deposits to rural areas, aggregates have a very low environmental impact. They do not usually require a great deal of processing and can easily be recycled. The primary source of any carbon emissions arises from transportation. So, as with brick selection, a relatively local source is important for sustainable design.

RECYCLED AGGREGATES

Use of recycled aggregate is questionable as a sustainable option. While it minimises mining of natural material, the angular nature of RCA compared to the round pebbles of natural aggregate often requires a higher cement content to fill in those gaps. As cement is by far the most environmentally adverse constituent

LIMESTONE AGGREGATE
PHOTO: LA FARGE

LIMESTONE AGGREGATE.
PHOTO: EMADRAZO (WIKIMEDIA COMMONS)

of concrete, this can be undesirable. In addition, the processing of RCA requires more energy than do virgin gravels. The additional energy required to crush, wash and grade the RCA before it can be used in concrete and the additional cement content that it requires, raises questions regarding its use as a sustainable material.

Due to its appearance in exposed concrete, we would recommend that RCA be only used in concealed areas and then only if a reasonable source of RCA can be found. RCA is only environmentally sound as long as it doesn't travel more than 20 miles from its source and is of the correct size and shape to be suitable in the desired mix.

The concrete supplier would need to work with the design team / contractor to advise whether locally sourced RCA aggregate is available and if it can be suitably reused without compromising strength and increasing cement content. RCA may be usefully used to replace 30% of virgin aggregate. BS8500 covers the recommended quantities of RCA in concrete mixes. It seems that RCA is most suitable for road base/railway ballast; 75-80% of RCA ends up as sub base fill for road building and airfield pavements.

SECONDARY AGGREGATES

Secondary aggregates consist of a wide range of materials derived from waste products arising from other industrial processes. Often, these will be available on a geographical basis, depending on what is available locally. Examples include slate quarrying spoil from Wales, china clay stent (chalk spoil) from South-west England, slag from the steel industry in the North and glass cullet from recycled glass collection points.

CEMENT

Cement is any liquid or viscous material with adhesive properties; common forms include gypsum plaster, common lime, hydraulic lime, natural pozzolana and ordinary portland cement. As previously stated, cement is responsible for a huge amount of worldwide energy consumption (and therefore carbon dioxide emissions):

**600,000 tonnes of cement =
846,000 tonnes limestone, plus
192,960 tonnes clay, plus
32,000 tonnes sand.**

The concrete we use today generally uses ordinary portland cement or OPC. OPC contains calcium compounds, silica, alumina, and iron oxide. These materials are put in a rotating kiln and heated to drive off water and calcines to form clinker, which is then ground into a fine powder – cement. The detrimental effects of cement production for concrete can be somewhat offset by use of alternative products. Most of these are by-products of other industries and so are not being produced especially for inclusion in concrete products.

Cement alternatives include:

GGBS (iron slag)
Fly Ash (coal ash)

A CEMENT FACTORY LOOMS OVER MONTERREY, MEXICO
PHOTO : HECTOR MARTÍNEZ (FOTOGRAFÍA DE)

HOPE CEMENT WORKS, DERBYSHIRE
PHOTO: DAVE PAPE (WIKIMEDIA COMMONS)

Silica Fume (by-product of silica production)
Metakaolin (from oil sand)
Rice husk ash (from rice paddy fields)
Currently, the most readily available alternatives within the UK are GGBS (Ground Granulated Blast furnace Slag) and PFA (Pulverised Fuel Ash).

Cement types are described under BS EN 197-1. The main three examples described here are as follows:

CEM 1 – Portland Cement (see above)
CEM 2 – Fly Ash (PFA) Cement
CEM 3 – GGBS Cement
Be aware that cement alternatives can affect traditional set times and the colour of concrete. Therefore the likely impact of specifying these should be discussed with the manufacturer. Manufacturers are very keen to promote concrete as a sustainable material. Contact a manufacturer with a plant close to the site as soon as possible. Explain your requirements, the manufacturer will advise suitable mix proportions (percentage of cement substitute and RCA as permitted under BS 8500) to achieve the desired strength and appearance without compromising quality. Depending on location and acceptable appearance, mixes of differing levels of sustainability can be achieved. Manufacturers will be aware of locally available material and given time may be able to source specifically to meet individual sustainable requirements.

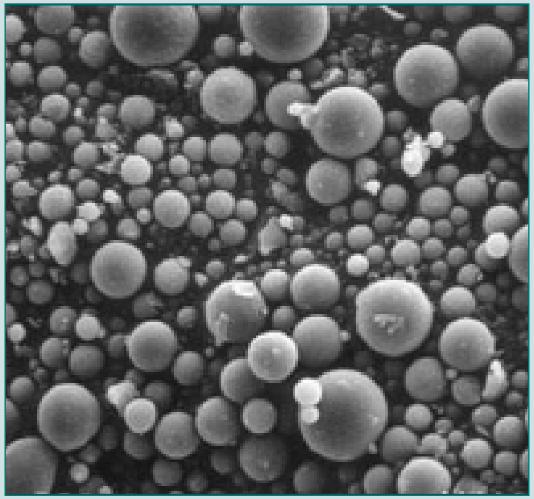
In the last decade, the availability of low carbon cement has become far more widespread in the UK. The carbon footprint of the cement making process has come under well-publicised scrutiny leading to efforts on the part of the concrete industry to address the considerable global warming potential of the material. The Institute of Civil Engineers have led a consortium of stakeholders to propose a framework for reducing the carbon footprint of the process through a **"Low carbon concrete routemap,"** This sets out a vision for decarbonisation by 2050.

PFA (PULVERISED FUEL ASH)

Ash is produced as a result of burning coal for the production of electricity. In a coal fired power station there are two types of ash produced, Pulverised Fuel Ash (PFA), also known as fly ash in many countries, and Furnace Bottom Ash (FBA). All the UK coal fired power stations have what are known as 'wet bottom' furnaces, where the ash is flushed from the furnace using water. This means the FBA is washed in copious quantities of water making it suitable for use as an aggregate. Virtually all the UK production of FBA for many years has been used in the manufacture of lightweight concrete blocks. Due to its method of production all leachable materials are removed and as a result there are no known risks to the environment or the user from FBA (otherwise known as Lytag). Lytag can also be created from PFA, in order to produce the rounded pellets the raw powder material is palletised then sintered (heating without melting) at 1250°C.

When UK electricity production relied on coal, fly ash was available in abundance. However, between 2010 and 2021, the proportion of coal fired power stations in Britain has fallen from 37% to 2.1% of the total. While the demand for PFA hasn't reduced, the domestic supply has. This has been partly replaced by Biomass Ash as this fuel has replaced coal in some instances.

The UK plans to phase out all coal fired power stations by 2025. This will of course virtually end the production of PFA in this country. Approximately e 1.5 million tonnes a year of PFA is used in the manufacture of aerated concrete blocks and grouts for mine filling and ground stabilisation raising the question of where this will be



FLY ASH MAGNIFIED 2000X PHOTO: UNITED STATES DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION

PFA PHOTO: LA FARGE

sourced from in future. It is estimated that there are over 50million tonnes of PFA in landfill sites across the UK. Proposals have been made to extract this for use in industry.

PFA represents the largest proportion of the ash produced from a power station, with about six times the volume of FBA being produced. This is a fine powder (like talcum), grey to dark grey in colour. Large proportions of ash are used in cementitious applications, e.g. cement manufacture, concrete additives, block making, precast concrete and grouting. When fly ash is used to extend CEM I cement (OPC) the saving in carbon dioxide emissions per tonne of concrete are in the region of 20-30% for mixes designed with equal 28 day strength. The use of fly ash rather than OPC creates concrete which is a darker grey in colour.

As noted above, not all PFA can usually be used as a cement substitute. To be suitable, it must contain less than 7% carbon. This can depend on the quality of the coal used to fire the power station from where it is sourced and the nature in which it has been burned. Ash produced earlier during the power stations' firing cycle will have a higher carbon content than that produced when the station has been working for some time. In addition, PFA which has been stockpiled for some time (and is therefore wet) may not be suitable for use as a cement replacement. China burns a vast amount of coal in its power stations. As well as generating a large proportion of the world's carbon emissions, this results in a huge quantity of fly ash – much of which appears not to be dealt with in an environmentally sustainable fashion. So, although a waste product and therefore possessing a low carbon footprint, PFA is the product of a process contributing substantially to climate change emissions and outside of the UK is associated with environmental pollution.

GGBS

Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. These operate at a temperature of about 1,500 degrees centigrade and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials form a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimises the cementitious properties and produces granules similar to coarse sand. This 'granulated' slag is then dried and ground to a fine powder.

The major use of GGBS is in ready-mixed concrete, and it is utilised in a third of all UK 'ready-mix' deliveries. Specifiers are well aware of the technical benefits, which GGBS imparts to concrete, including: better workability, making placing and compaction easier, lower early-age temperature rise reducing the risk of thermal cracking in large pours, elimination of the risk of damaging internal reactions, high resistance to chloride ingress, reducing the risk of reinforcement corrosion and high resistance to attack by sulphate and other chemicals.

In the production of ready-mixed concrete, GGBS replaces a substantial portion of the normal Portland

FLY ASH SPILLAGE FROM SETTLING POND PHOTO: BRIAN STANSBERRY, WIKIMEDIA COMMONS

FLY AS DUMPING IN CHINA
PHOTO: ZHAO GANG / GREENPEACE

cement content, generally about 50% but sometimes up to 70%, (which is the maximum amount practiable). The higher the proportion, the better the durability. The disadvantage of the higher replacement level is that early-age strength development is somewhat slower.

GGBS is also used in other forms of concrete, including site-batched and precast. Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.

Incorporating GGBS as a cement substitute will lead to a lighter, almost white finish to the finished concrete. As GGBS is a finer material than OPC, it will give a smoother, higher quality finish often suitable for exposure in the finished building, a feature which compliments concrete's role in providing thermal mass inside the building.

GGBS as a cement substitute has moved from a "difficult-to-source," to a mainstream ingredient in recent years. So much that there can even be shortages due to it being a by-product of an industry which doesn't really exist in the UK any longer. Concrete utilising GGBS is available as a proprietary mix under a variety of trade names from several major producers.

CHEMICALLY ENGINEERED CEMENT SUBSTITUTES

In recent years, work has been undertaken by several companies seeking a viable alternative to OPC and even recognised replacements discussed above. These alternatives are usually a product of a low temperature chemical process which avoids the energy input required by normal cement. In addition, they seek to also avoid using materials which, although waste products, arise from processes which are themselves environmentally destructive (such as PFA).

One such product has been developed by Cenin. Cenin Cement Replacement is available in wet or semi-dry forms for in-situ or pre-cast applications. It is produced by the chemical mixing of various waste materials to create a substance which acts in a similar manner to traditional cement. Typically, it uses mainly ash from CHP plants but is capable of being produced from a variety of industrial by-products, depending on local availability. It is produced by a chemical process using minimal heat, this is in contrast to traditional OPC production which uses a vast amount of heat energy. Therefore, whereas the carbon dioxide emissions associated with conventional OPC production can be up to 853kg per tonne of cement, Cenin products are estimated to be around 43kg CO_2 per tonne. Furthermore, Cenin have plans to power their plant via an anaerobic digestion system fuelled by food waste. This will see the overall emissions fall as low as 18kg / tonne. Cenin are currently working with several major cement and concrete suppliers to incorporate their product into mainstream production.

A potentially revolutionary development in low carbon cement production has seemingly been abandoned. This was 'Novacem'. Developed in the UK this used magnesium silicate as a raw material, processed at relatively low temperatures (700oC), to produce magnesium carbonate. In addition to low production temperatures rendering low energy content fuels viable (such as bio-mass), the chemical process of carbonation actually sequesters carbon dioxide. It was claimed

CONCRETE BLOCKWORK UNDER CONSTRUCTION
PHOTOS.COM WEBSITE

that the production process for 1 tonne of Novacem absorbed up to 100Kg more than it emitted. Production was scheduled to commence in around 2015. However, the developers failed to find commercial backing for production and the intellectual rights were eventually sold and seem to have sunk without trace.

CARBON ENTRAINED CONCRETE

One approach to rendering concrete production more sustainable is to utilise it as a carbon sink. An introduction of carbon dioxide into a mix allows cement content to be reduced by around 4% by volume. The carbon dioxide is used to aid cure the mix causing mineralisation in the concrete to fix the CO_2 permanently. The CO_2 feedstock originates from carbon capture technologies. This procedure has been pioneered in the USA by companies such as CarbonCure, whose commercial operation depends on selling carbon credits to companies wishing to achieve a carbon reduction target. As such the trading of carbon credits is similar in concept to Carbon offsetting in that it allows industry to continue emissions while paying to achieve their legal obligations in this respect.

As the process depends on carbon capture technology, the industry in currently limited by the commercial availability of this. As of late 2021, there were 27 operational carbon capture plants worldwide, with the majority (12) being in the USA. CarbonCure is therefore purely a North American concern at present.

The situation in the UK can be summed up by the following excerpt from the ICE Low Carbon Concrete Routemap:

“While there has been considerable discussion about carbon capture and storage (CCS) in the media and industry, there has been little development other than test exemplars of carbon capture at individual cement plants. There is not currently a commercial business case, although the UK Government is exploring ways to incentivise commercial carbon storage.”

FIBRE REINFORCED CONCRETE

Fibre reinforced concrete (as its name suggests), uses steel or polypropylene fibres instead of steel mesh as reinforcement. The plastic fibres offer a substantial saving in embodied energy (and therefore carbon emissions) over traditional steel mesh. Further emissions savings over traditional mixes are available due to the increased speed of construction. Fibre reinforced mixes are often used in composite decking systems which can use less cranage and plant and can reduce site operations by up to three weeks over alternative systems. Fibre reinforced concrete can use low carbon cement substitutes such as GGBS, (see below). However, as noted elsewhere in this guide, recycling composite materials presents problems.

ALKALI ACTIVATED CEMENT

AACM’s are produced at room temperature by reacting an aluminosilicate precursor with an alkaline solution as an activator. These were invented over 100 years ago but have not been employed as a viable OPC substitute to date due to cost. The search for a low carbon cement replacement has spurred an increase in interest and extensive research is currently being undertaken by an industry body known as A3CM.

CONCRETE MASONRY BLOCKS

It is estimated that AACMs can offer cradle-to-gate greenhouse emission savings of between 40 and 80% over a performance equivalent material. As AACM products do not easily relate to current concrete and cement standards, PAS 8820 has been developed in conjunction with the HS2 railway project.

MICROSILICA CONCRETE

Microsilica is also known as silica fume. It is a waste product arising from the production of silicon alloys in electric arc furnaces using quartz and coke as raw materials. Until the 1970's, most microsilica was discharged to the atmosphere as smoke. Environmental legislation necessitated collecting and (initially) land filling the silica fume but also resulted in it becoming economically viable to seek industrial uses for this. Microsilica can be used as a partial cement substitute and can be combined with other replacements such as GGBS. Microsilica concrete offers high resistance to aggressive environments (such as marine locations) and to corrosion caused by anti-icing salts. However, the main benefit is often considered to be the high strengths attainable when cured correctly. Microsilica concrete is widely used therefore in the construction of high-rise structures. In the Burj-Dubai (currently the world's tallest structure at 818m), microsilica helped achieve concrete strengths of 60-100N/mm2. Such high strength offers the possibility of designing with slimmer elements, thereby reducing embodied energy content of the finished building.

CONCRETE BLOCKS

Most blocks are currently made with Portland cement, however, on request this can often be replaced with a percentage of GGBS or PFA. In addition, manufacturers have sought to replace the aggregate content with suitable alternatives. In reality, standard concrete blocks have been made using Furnace Bottom Ash for years and as such are quietly 'sustainable'.

Various blocks are available which are made from a mixture of alternative aggregates:

- Autoclaved Aerated Concrete is a light weight block; with the addition of aluminium powder the concrete expands to 5 times its original volume.
- Blocks made with waste aggregate from the china clay industry.
- Blocks made with expanded clay as aggregate - a patented process requiring more investigation to fully assess its environmental credentials.

Ask the percentage by volume of the 'sustainable' material from the manufacturer; bear in mind the proximity of the site to the manufacturing plant. A more sustainable block from further away becomes less sustainable compared to a local product.

THE HOOVER DAM : A LOT OF CONCRETE IN ONE PLACE....
APK, CC BY-SA 4.0 VIA WIKIMEDIA COMMONS

Concrete blocks have the advantage of being sound and fire resistant, but usually require a finish unless fair-faced blocks are left exposed. For walls requiring high impact resistance and durability, blockwork may be the most viable option.

The Concrete Block Association gives the average recycled content of aggregate concrete blocks as being 24% with the average cement content being 89Kg/tonne2. Of this an average 19% is replaced by cement substitutes.

MORTAR AND RENDER

Cement products are robust and hard wearing; cement is almost too hard for certain building materials such as natural stone. The mortar is too rigid and does not allow the building to move, causing cracking and accelerating spalling. In addition cement mortar being so rigid does not facilitate easy reuse of building materials.

The lack of flexibility in cement based mortar and render mixes has led to the incorporation of movement joints within buildings along with their associated fillers and sealants which are often petrochemical or toxin based. Prior to the development of cement based products, the traditional materials would be lime based. Lime mixes incorporate a degree of flexibility and therefore usually do not need the number of movement joints associated with modern masonry clad buildings. However, their water resistance can be less and therefore greater care is required in both detail design and execution on site. Lime based mortars and renders are dealt with below.

VAPOUR PERMEABILITY

Cement products do not breathe, which is why this product offers exceptional performance in areas of moisture, i.e. ground floor slabs. Cement products should never be used with vapour permeable structures as they will trap moisture within the structure and accelerate deterioration. See chapters on Lime and Clay for vapour permeable alternatives.

STEEL V. CONCRETE

The major environmental debate over the use of concrete in buildings comes from whether it is preferable to use instead of steel, particularly for structural frames. This issue is addressed in a later section.

PRACTICAL APPLICATIONS

Blocks, Precast / Insitu Elements, Roof Tiles, Paving, Mortar, Render, Structural Elements, Floor Slabs, External Works, Civil Engineering

LINKS

Cement Production
http://www.cement.org/basics/concretebasics_concretebasics.asp

Sustainable Concrete
https://sustainableconcrete.org.uk/Sustainable-Concrete/What-is-Concrete/Aggregates.aspx

The Concrete Centre
https://www.concretecentre.com/

https://www.concretecentre.com/Performance-Sustainability-(1)/Material-Effieciency/End-of-life-recycling.aspx

LCC Products
https://www.technologyreview.com/2015/03/19/73210/what-happened-to-green-concrete/

Concrete Block Sustainability
https://www.cba-blocks.org.uk/wp-content/

Carbon Capture Technology
https://academic.oup.com/ce/article/4/1/2/5686277

Alkali Activated Cement
https://a3cm.co.uk/what-is-an-aacm/

https://www.concrete.org.uk/fingertips-nuggets.asp?cmd=display&id=902

Low Carbon Concrete Routemap
https://www.constructionleadershipcouncil.co.uk/wp-content/uploads/2022/04/Low-Carbon-Concrete-Routemap_27-April-2022.pdf

GGBS
https://ukcsma.co.uk/what-is-ggbs/

PFA
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/296519/LIT_8272_420835.pdf

http://www.ukqaa.org.uk/information/faqs/

Microsilica Concrete
http://www.silicafume.org/

CLICK HERE TO VIEW

- **Concrete Blocks Data Sheet**
- **Concrete Data Sheet**
- **Cement Mortars & Renders Data Sheet**

2.12 CROPS

THE CORK OAK AFTER HARVESTING
PHOTO: FRITZ GELLER-GRIMM AND FELIX GRIMM (WIKIMEDIA COMMONS)

FLAX FLOWERS
PHOTO: STEN PORSE (WIKIMEDIA COMMONS)

Biomass products such as hemp and flax are experiencing a growth in popularity in commercial mainstream construction, as manufacturers of building products search for products capable of delivering carbon neutrality or acting as a carbon sink. Traditional thatching products remain firmly in the one off residential market. However, moving into mainstream popularity in both commercial and residential markets are green roofs, in particular extensive sedum roofs. Cork has long been a high quality harvest with many uses in the construction industry.

CORK

Cork is harvested from the cork oak tree, widely cultivated in Spain, Portugal, Algeria, Morocco, France, Italy and Tunisia. Cork Oak forests cover approximately 25,000 square kilometres in those countries with Portugal providing 50% of the world's cork. Cork Oaks form a thick, rugged and corky bark and live about 150 to 250 years. Virgin cork (or 'male' cork) is the first cork cut from generally 25 year old trees. The harvesting of cork does not harm the tree and a new layer of cork regrows, making it a renewable resource. Another 9 to 12 years is required for the second and subsequent harvests, and a tree can be harvested twelve times in its lifetime. The first two harvests generally produce poorer quality cork. Used as insulation, cork has extremely low embodied. energy and embodied carbon but is unfortunately quite expensive.

PRACTICAL APPLICATIONS

Insulation, Floor Flooring

FLAX

The flax plant is grown for seed and fibre; it produces linseeds (linseed oil) and linen. Hemp cloth is harsher and more robust than linen; it was also cheaper, which led to the choice of using hemp over flax for uniforms in the 1800s. Linseed oil dries rapidly making it suitable for paints and varnish. Like hemp, the crop is planted in April and can be harvested in August. The shive (the centre of the stem) can also be used as filler in clay mortars. Canada is the leading linseed producer.

Flax insulation uses the fibre of the plant's stem mixed together in a 'non woven' matting. It has temperature and moisture regulating qualities, being able to absorb moisture in high humidity and release it again when humidity is low. Potato starch can be used to bind the material, making it 100% natural; however, it is often mixed with a textile binder such as cotton, and sometimes plastic binding agents. Typically, the insulation is treated with borates that act as a fungicide, insecticide and fire retardant (borate is a natural mineral). Flax insulation has thermal conductivity of 0.037W/m2°C. The material can be handled manually with no harmful affects to users or occupants of a building.

Flax is a non hazardous biodegradable fibre from a renewable source. Insulation trade names include:

- Isonat
- Flax 100
- Isolina

Flax is also the basic ingredient of linoleum. 'Lino,' although not incorporating any of the toxins intrinsic to vinyl, has a relatively high embodied energy content due to the industrial process needed to manufacture it. However, at 25MJ/kg, this is a fraction of that required for PVC sheet (65MJ/kg).

INDUSTRIALLY GROWN HEMP
PHOTO: MARKUS HAGENLOCHER (WIKIMEDIA COMMONS)

HEMP SHIVE
PHOTO: COPYRIGHT © 2000-2009 LIME TECHNOLOGY LIMITED)

PRACTICAL APPLICATIONS

Insulation, Lino Flooring

HEMP

Hemp is an amazingly versatile plant. It is a non-hazardous biodegradable fibre from a renewable source. It has been used as a source of fibre, fuel and nutrition for thousands of years, and has been described as the most widely grown crop in the world. It also has a bad reputation because of its association with the recreational drug cannabis. Varieties of industrial hemp grown today have been specially bred since the 1930s to have no drug content and European hemp was always of very low narcotic content compared to its Eastern relative.

Cannabis refers to the biological name of the plant and refers to 22 different species. Cannabis sativa is a multi-purpose plant that has been domesticated for bast (the skin of the stem), a multi-purpose fixed oil in the “seeds” (achenes), and an intoxicating resin secreted by epidermal glands. The common names hemp and marijuana have been applied loosely to all three forms, although historically hemp has been used primarily for the fibre and its fibre preparations, and marijuana for the drug and its drug preparations. The current hemp industry is making great efforts to point out that “hemp is not marijuana.”

Hemp as a crop is easy to grow, with high yields and low impact; it requires no herbicide or pesticide and all of the plant can be used. It is an annual crop planted in late spring when ground temperatures have warmed up, and harvested mid August/September. It has long been popular with farmers as a way of removing hardy weeds. The crop is cut, left to dry and baled after 2-3 weeks.

Hemp building products are numerous. The woody outer stem is used to make insulation, sometimes in combination with flax and/or wood chips.

Hemp has good thermal and acoustic properties, it is claimed to have good thermal mass, it is ‘vapour open’ and is hygroscopic allowing the structure to breathe, conditioning interior spaces. Hemp is naturally resistant to insect attack but uses Ammonium Phosphate as fire retardant, it is safe to handle without protective clothing and has a thermal conductivity of 0.040W/m°C. Some hemp insulations contain a thermoplastic binder of about 8-10%. Shive can be used as filler in hemp plaster.

The shive has a multitude of uses, one of the most common being chopped and combined with lime for a variety of construction elements. In this form it is generally known as ‘Limecrete’ or ‘Hempcrete’ and can be used for self – insulating floor slabs or to cast walls, usually on non-commercial projects such as self-build housing.

In the UK a proprietary system known as ‘Tradical Hemcrete’ is marketed by Lhoist – a French based lime manufacturer. Originally this was a product supplied by Lime Technology but there appear to have been some movement in the ownership of production.

HEMCRETE BEING SPRAY APPLIED
PHOTO: COPYRIGHT © 2000-2009 LIME TECHNOLOGY LIMITED)

MODCELL PANELS UNDER CONSTRUCTION
PHOTO: MODCELL (WWW.MODCELL.CO.UK)

Hemcrete is the product of a controlled production process utilising lime and some cement content. It can be cast in situ between formwork, sprayed onto a frame, pre-cast as panels or made into blocks. In the last few years, the development and use of Hemp-lime seems to have retreated from the commercial sphere in the UK. Although supremely sustainable, Hempcrete suffers from a long cure time and being affected by atmospheric humidity, cannot be used year round in the British climate. There were hopes that this limitation could be overcome by the use of factory produced pre-cast wall panels. Known as "Hemclad," these were employed by Marks & Spencer on their retail outlet at Cheshire Oaks. However since completion in 2014, this particular product seems to have disappeared from the UK market. An equivalent is sold in the USA by American Lime Technology but there does not appear to have been any further take-up in Britain.

Hemp-lime construction offers carbon lock-up both through the plant's photosynthesis during growth and through the effects of lime curing (which absorbs carbon dioxide during the process.) However, this latter element is somewhat negated by the carbon emissions associated with the slaking (burning) process necessary to produce lime in the first place. Hemp-lime technology also offers inherent insulating properties and as a block it can be load bearing. However, the eventual thickness of the construction can be quite large.

There is an issue regarding the measurement of the thermal properties of Hemp-lime materials. As noted in the following section on Insulation, the industry standard expression of W/m2°C ('U' value) may not be an adequate method of describing the insulating properties of Hempcrete. A standard heat loss calculation is based upon the material in question maintaining a steady state. However, Lime Technology point out that the moisture content of Tradical Hemcrete imparts a degree of phase change capacity in the material leading to what they describe as "dynamic thermal performance." This allows Hemcrete to have a thermal dampening effect which is difficult to quantify by the commonly used U-value calculation. In fact, Lime Technology illustrate this in their publication "The Thermal Performance of Tradical Hemcrete" by a measured example which demonstrates that, despite having a calculated theoretical U-value of 0.29 W/m2°C, the actual heat loss of the examined building equated to 0.11W/m2°C. Lime Technology's own offices are constructed from Tradical Hemcrete and are being monitored to study the actual thermal performance of the material further.

THE FINISHED BUILDING
PHOTO: MODCELL (WWW.MODCELL.CO.UK)

PRACTICAL APPLICATIONS

Insulation, In-situ Wall Construction (mixed with lime), Pre-cast Wall Construction (mixed with lime), Blocks (mixed with lime)

STRAW

Straw is an agricultural by-product, being the stalk of Wheat, Barley, Oats, Rice and Rye after the seed has been removed.

Straw bale construction has enjoyed recent and growing popularity within the residential market, with plenty of straw bale workshops for the budding home builder to attend. Traditionally there are two methods of building with straw bales. The first originates in the northern prairie of the USA and is known as the 'Nebraska method'. This involves using straw bales as large structural elements which become load-bearing. Obviously, the load-bearing capacity of the bales is limited and may be catastrophically compromised by wet weather during construction if not adequately protected. The Nebraska method is really only suitable for the simplest of buildings and is most common amongst small scale domestic applications.

The second (and more widespread) method of construction is to create a prefabricated softwood frame and fill this with 450mm wide compressed straw bales. This method has been largely pioneered by Mod-cell in the UK who have a 'flying factory' concept of production. This involves identifying a local source of straw and fabricating standardised structural panels as close to site as possible. Thereby not only does the system have inherently very low embodied energy and carbon, it vastly reduces any impact due to transportation. The finished panels are generally finished in lime render.

Straw offers excellent thermal characteristics and sound absorption, with a 50db reduction; walls can be load-bearing and have fire certification beyond 135 minutes. Straw bale is insect and rodent proof. Straw has little nutritional value and is so densely packed it cannot support a pest population; only if damaged walls are left exposed will there be a risk of infestation. The panels are designed to breathe, limiting humidity build up and mould growth; in addition, lime render exterior is a natural antiseptic further preventing fungal activity.

THATCH

Thatch is an ancient roofing material, dating back thousands of years. It is found in almost every country, from savannah grasses in Africa to coconut palm fronds in the Caribbean to banana leaves in the Amazon. It was the predominant roofing material in Britain up until the 19th Century.

All sorts of plants have been used for thatching in Britain: oats, reeds, broom, heather, bracken and various grasses. But today only three main thatching materials are used: water reed, wheat reed and long straw.

A TRADITIONAL THATCHED COTTAGE IN IRELAND
PHOTOS.COM WEBSITE

CLICK HERE TO VIEW

- **Insulation Data Sheet**
- **Straw Bale Data Sheet**
- **Hemp-Lime Data Sheet**
- **Linoleum Data Sheet**

Water reed is the most popular thatching material. Both water reed and wheat reed (actually a straw but cut with a binder and combed to give the appearance of reed) give a compact and even texture when applied to a roof. This is in contrast with long straw (wheat straw that has been threshed so that the ears and butts are mixed up together), which gives a shaggy, rounded appearance. The lifespan of thatch is around 30 to 50 years, although this varies widely depending on the skill of the thatcher, the pitch of the roof, the local climate conditions and the quality of the materials.

Thatched roofs can withstand high winds and heavy rains, provide good thermal insulation and are easy to repair. Thatch is a light material only needing a simple support structure and is flexible so can be used for any roof shape. On the downside, thatching is labour intensive and a certain level of skill is required. The materials can be expensive as reeds are increasingly imported from Europe to keep up with demand. Like all biomass materials, thatch is flammable which means that building restrictions may apply and home insurance can be high.

LINKS

Cork
http://en.wikipedia.org/wiki/Cork_Oak

Flax
http://en.wikipedia.org/wiki/Flax

https://www.jeffersoninstitute.org/flax.php

LINKS

Hemp
http://en.wikipedia.org/wiki/Hemp

https://hort.purdue.edu/newcrop/ncnu02/v5-284.html

https://www.tradical.com/hemp-lime.html

https://www.bcb-tradical.com/en/hempcrete/what-is-hempcrete/

https://www.ukhempcrete.com/

https://www.greenspec.co.uk/building-design/hemcrete-at-ms-cheshire-oaks/

Straw
https://www.modcell.com/

The Strawbale Regional Assistance Project (US self build organisation):
http://ww2.whidbey.net/jameslux/sb.htm

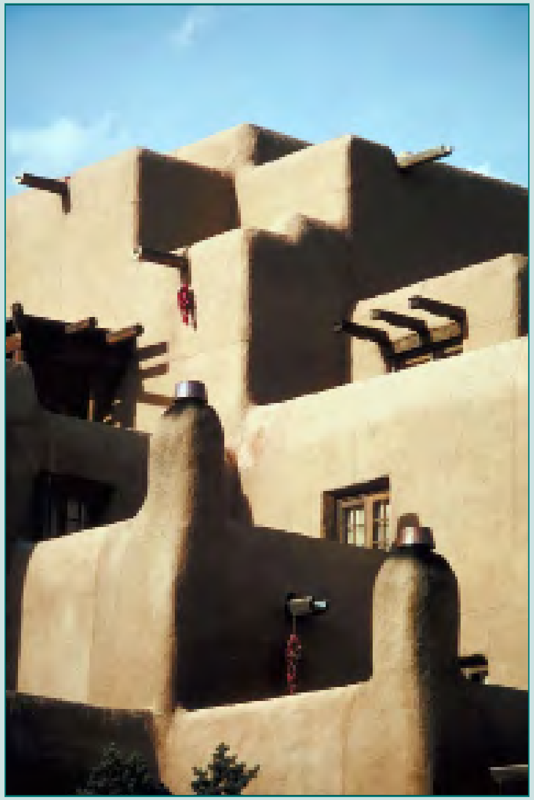
https://strawbalebuildinguk.com/

https://strawworks.co.uk/

https://strawbalebuildinguk.com/wp-content/uploads/2022/03/Straw-Construction-in-the-UK_Technical-Guide_February-2022.pdf

Thatch
https://thatchinginfo.com/

2.13 EARTH



TRADITIONAL ADOBE BUILDINGS IN NEW MEXICO USA
PHOTO: PHOTOS.COM WEBSITE

Soil or earth is the naturally formed loose covering of the earth's surface consisting of particles of broken rock altered by chemical, biological and environmental processes-weathering and erosion; it is a mixture of mineral and organic constituents.

Sand and silt are the products of physical weathering, while clay is the product of chemical weathering. Chemical weathering is the process by which rocks are decomposed, dissolved or loosened by carbonation, oxidation, hydration etc.

Earth dwellings have enjoyed a recent revival due to the perceived nature of the material; it is abundant, free and already on site, with its look, feel and smell all contributing to the sustainable image. Of course, the sustainable credentials of earth building come from the opportunity of using a material which is already on site. This assumes that the earth present on site is actually suitable for building with. Should this not be the case and earth ends up being imported from further afield, the sustainable benefits of the system are greatly eroded.

It should be noted that earth dwellings originated from dry arid climates where alternative materials such as timber were in short supply, and the thick walls provided thermal mass, keeping the interior cool during the day.

ADOBE/MUD BRICK

Adobe is made from sand, clay and water, with some kind of fibrous or organic material (sticks, straw, dung), which is shaped into bricks using frames and dried in the sun. It is similar to cob (see below). Adobe structures are extremely durable and account for some of the oldest buildings on the planet. In hot climates, compared to wooden buildings, adobe buildings offer significant advantages due to their greater thermal mass, but are known to be particularly susceptible to seismic damage.

COB

Cob structures are made from sand, clay, water and straw. English cob was made by mixing clay-based soils with water and straw, using oxen to trample it together. The mixture was lifted on to foundation stones and trodden on to the wall in a process called cobbing.

COMPRESSED EARTH BLOCK

Compressed earth does not contain straw or other additives; it is purely a combination of sand, silt and clay providing optimum strength when compressed, then left to dry. CEB is popular amongst self-builders in the south-western USA and in France. Machines for creating CEB are often small and portable, being operated by one person.

RAMMED EARTH

Rammed earth walls were an ancient construction method in areas where timber was in short supply. Many ancient rammed earth structures exist today including the Alhambra in Granada and the Great Wall of China. Traditional rammed earth structures had stabilising materials of lime or animal blood added. Rammed earth is a combination of sand/gravels (45-85%), silt (10-30%) and clay (5-15%) compressed into a solid mass; studies have proven the material's strength is related to the water content. There are two types of rammed earth construction: stabilised (added cement) and unstabilised (earth largely straight out of the ground).

A COB BUILDING
PHOTO: ARIFM (WIKIMEDIA COMMONS)

Both types however, require certain parameters to be followed in order to perform successfully. The traditional Devon adage is that an earth wall requires *"... a good pair of boots and a hat."* This is why earth buildings in the UK are commonly seen to have a solid stone (or masonry) plinth and an extensive eaves overhang.

ADVANTAGES AND DISADVANTAGES

All earth construction provides thermal mass, vapour permeability, sound proofing (due to the density of the material) and fire proofing. The unstabilised material in all forms does not tolerate contact with water or damp environments. Should moisture content rise above 13%, the wall will slump. Bear this in mind if specifying clay blocks in proposed wet areas, areas of structural support or in the vicinity of plumbing services.

Tile cannot be laid against earth materials. Neither grout nor tiles are sufficiently waterproof to protect the material. Use a waterproof panel as a barrier to the wall for splash backs and wet areas.

While earth construction offers thermal mass, external walls in the UK will require additional insulation. This may be in the form of cavity construction but it will be difficult to construct and unnecessarily complicated. A more common option would be to insulate the wall externally with render over, thereby exploiting the thermal mass of the rammed earth wall internally.

RE has had a recent revival in sustainable commercial construction and not without problems.

Investigation into RE practitioners in the UK brings up a limited number of names and contacts and a wealth of confusing information. Part of the problem is the availability of knowledge and practitioners. Here in brief is what we have discovered:

There are just two UK practitioners: Ram Cast (unstabilised) and Earth Structures UK (cement stabilised). There is a degree of disagreement between the stabilised and unstabilised camps. While it is undeniable that the stabilised variety performs better in a wider variety of weather conditions, the green credentials of this form are somewhat compromised by the importation and inclusion of cement.

Some clarification of the industry has come from Paul Joaquin who wrote his PhD on the strength of rammed earth structures and now works for Ramboll. In this work, Paul impartially explained the difference between the two constructions and the organisations which advocate them. These can be summarised as follows:

- **Earth Structures** is an offshoot of an Australian venture (where rammed earth structures are becoming more common). When engaged on a UK project, building teams are flown over from Australia for the duration for the project and back afterwards.
- **Rammed Earth Consulting** are a not-for-profit organisation promoting and providing information and advice on Earth building.
- **Simmonds Mills Architects / Builders** started building with rammed earth in 1991. The last time they worked on a site was at the Centre for Alternative Technology centre at Machynlleth, Wales. They also acted as consultants to JDDK for the Rivergreen Centre, Aykley Heads, Durham and engaged Ram Cast to help train the contractors. (On the Durham project, the local earth was found to be unsuitable for the rammed earth project and so was imported from Cornwall!).

Simmonds Mills have since moved away from rammed earth as a sustainable material, feeling it an expensive

RAMMED EARTH VISITOR CENTRE AT THE EDEN PROJECT, UK
PHOTO: ANDREW DUNN (WIKIMEDIA COMMONS)

and time consuming element, involving complicated shuttering and not so 'sustainable'(although beautiful to look at). Simmonds Mills considers RE an exciting material but do not recommend its use as a sustainable material in itself.

AN EXCERPT FROM THE WEBSITE OF EARTH STRUCTURES UK NOT PERFECT BUT....

SRE builders worldwide use cement as a stabiliser in their rammed earth walls because it makes them strong, durable and maintenance free. By selecting particle sizes that will lock together and using pneumatic tampers to compact them, it is necessary to use only a small percentage of cement to bind the earth into a solid, strong and water-resistant material.

But cement production requires lots of energy and produces CO_2. These are environmental liabilities which, when considered on their own and in the short-term cause the use of cement to be regarded unfavourably. Other stabilisers have been tried; bitumen, lime, acrylic, etc., but cement makes the best walls that last the longest. They require no extended eaves, no regular coats of lime wash and they don't fall down when they get wet. Consequently, when considered in the longer term, i.e. the life of the building, cement stabilised earth walls are far better, safer and require less energy than unstabilised earth walls or walls built using other stabilisers.

http://www.earthstructures.co.uk/whystab.htm

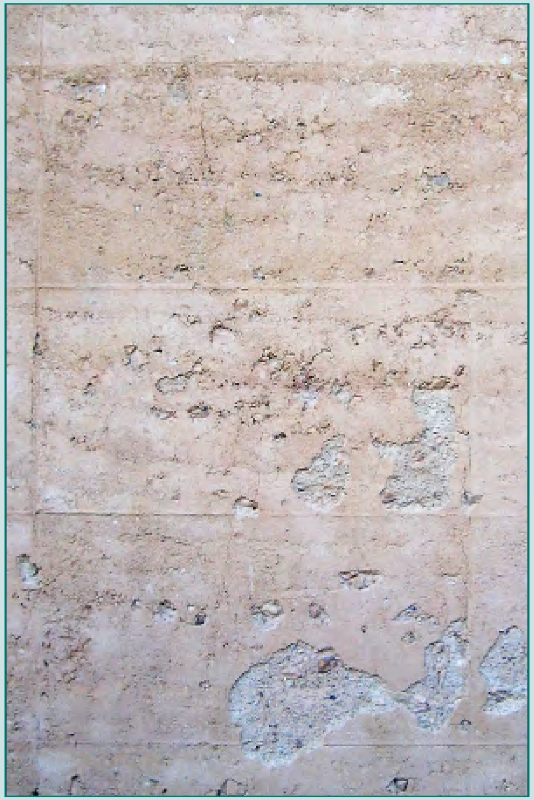
In Napa, California, Rammed Earth Works produce pre-cast rammed earth panels for construction. However, these are decorative only and non-structural.

The most notable rammed earth project in the UK recent years has been the Jewish cemetery in Bushey designed by Waugh Thistleton Architects.

THE MATERIAL

Earth of the correct consistency is important to the compressive strength of the wall and if this is not available on site it must be mixed requiring additional material (sand/clay) to be imported to site. Modern stabilisers include lime, GGBS (ground granulated blast furnace slag – a by-product of the steel industry and a cement alternative) and more usually cement. If stabilisers are used a broader range of site materials can be used.

Be aware that mud comes in many different colours and the dark grey/black or greenish mud available on site might not turn out the same as that lovely reddish warm terracotta wall in the glossy architecture magazine (that was probably Australian mud). Not to say that greys or greens are not attractive in their own right; it's all relative to those expectations.



CLOSE UP OF A RAMMED EARTH WALL
PHOTO: ANDREW DUNN (WIKIMEDIA COMMONS)

Rammed earth is not as sustainable as it is perceived. Firstly, it is rare that raw site material will have the correct consistency, with the result that material such as additional clay or sand will need importing to site. Secondly, there is a risk of collapse associated with forming a structural wall of unstabilised earth – therefore, often cement is added to stabilise it. The percentage by volume varies on the inherent characteristics of the earth but it can be greater than for a concrete wall. Adding cement to the mix compromises the 'sustainable' nature of the material but is the only fail-safe way to ensure the wall is not affected by water. Rammed earth walls are thick; at CAT, the circular walls are 500mm. The volume of cement can be considerable, even though thickness of the wall can be somewhat reduced with the addition of cement.

When building in the UK, we would recommend considerable thought is given before constructing a rammed earth structure. It will take longer and be more expensive than anticipated.

- Build the roof or a temporary shelter first and construct the wall underneath out of the way of the weather.
- Be careful with formwork; build duration is considerable and complicated formwork hired for long periods of time is very expensive. Sections of wall require considerable drying time (especially when unstabilised) requiring the formwork to be in place for longer. It is common for some sections to fall down when formwork is removed (as has done during the construction process at CAT). Stabilised earth reduces the formwork time and prevents crumbling but not to the time frames associated with concrete structures. A substantial rammed earth wall may take up to six months to construct and cure.
- Construct a test panel on site to test the colour of the wall. Imported material will change this and no wall is ever uniform in colour unless all material is pre mixed. The universities of Bath and Nottingham test soil samples and advise the correct mix for the desired consistency and strength in compression and recommend additive percentages for stabilised structures. This process takes time: approximately 5 weeks, costing several hundred pounds. This analysis of the site material should be undertaken at an early stage so that the material costs and environmental impact can be assessed.

Rammed earth works best in compression with tension or shear carried by other elements of the structure. U-values of stabilised walls are typically 1.9 W/m2°C for a 300mm thick wall and 1.6 W/m2°C for 400mm. U-values of unstabilised walls are typically 3.3 W/m2°C and 2.5 W/m2°C respectively. As rammed earth dries, there is some shrinkage and therefore movement. Design movement joints into the structure through construction of the wall in natural sections; generally joint spacing should be twice the height of the wall. Joints will be obvious in the finished wall and their layout should complement the building design. The contractor/designer should provide a detailed joint layout for approval by the structural engineer.

To take advantage of their thermal mass, rammed earth walls are ideally located in the centre of the building and not exposed to the external elements.

Rammed earth may appear to represent all that is holy and good as a construction material. It looks, feels and smells beautiful, but is it sustainable or is it just 'Eco-bling'?

A TRADITIONAL RAMMED EARTH BUILDING IN CHINA
PHOTO: BOLOBOLO (WIKIMEDIA COMMONS)

STABILISED V UNSTABILSED : A SUMMARY

STABILISED

Advantages

Compressive strength of 3-10Mpa depending on the cement content.

Stronger and less friable, can be used with more confidence as a structural material.

Can be used as an external element without additional protection.

Higher cement content means more site won material can be used as the consistency is not as critical.

Better U value.

Disadvantages

High proportion of cement (6-15%), wall can not be marketed as sustainable.

Relative humidity balancing properties are lost through the addition of cement.

UNSTABILISED

Advantages

Compressive strength of 1Mpa.

One of the most sustainable construction materials available.

Thermal and humidity properties provide pleasant ‘air conditioned’ interior spaces.

Disadvantages

High Risk.

Danger of collapse.

Danger of water damage.

RAMMED EARTH WALLS AND FLOORS UNDER CONSTRUCTION IN PERU: JYB DEVOT, CC BY-SA 4.0, VIA WIKIMEDIA COMMONS

CLICK HERE TO VIEW

- Earth Cob Data Sheet
- Stabilised Rammed Earth Data Sheet
- Unstabilised Rammed Earth Data Sheet

RECENT COMMERCIAL PROJECTS IN THE UK

1998-2001 – The Eden Project, Cornwall

2003 – Bird in the Bush Centre, Southwark, London. (Ram Cast as contractor) Construction to the Nursery extension in unstabilised rammed earth began (2003, it collapsed, was demolished and rebuilt in blockwork)

2006-2005 – Pines Calyx Conference and Event Centre, circular rammed chalk building with rammed chalk domed roof. – Ram Cast (contractor)

2005 – Rivergreen Centre, Aykley Heads, Durham - a 7.2m high unstabilised internal load-bearing wall, 500mm thick. (JDDK Architects, Simmonds Mills / Ram Cast as RE consultants)

2005 – Genesis Project, Somerset College of Art and Technology, Earth Pavilion used as a shop. (Ram Cast as consultant)

2006 – CAT AtEIC, internal load bearing walls and columns. (Simmonds Mills / Ram Cast as RE consultants)

2008 – CATWise, curved lecture theatre. (Simmonds Mills / Ram Cast as RE consultants)

2008 – Wild Bird Discovery Centre, Salthome, Teeside. (JDDK Architects)

2021 – Jewish cemetery, Bushey (Waugh Thistleton Architects)

LINKS

Rammed Earth Consulting
http://rammedearthconsulting.com/

Earth Structures contractors
http://www.earthstructures.co.uk/

The International Rammed Earth Organisation (IREO)
http://rammedearth.org/

EBUKI : Earth Building UK & Ireland
http://www.rammed-earth.info/

A Review of Rammed Earth Construction (Bath University 2003)
http://people.bath.ac.uk/abspw/rammedearth/review.pdf

RECYCLED GLASS BOTTLES
PHOTO: LA FARGE

CULLET
PHOTO: LA FARGE

2.14 GLASS & GLAZING

Glass is made by melting together several minerals at very high temperatures. Silica in the form of sand is the main ingredient. It is combined with soda ash and limestone and melted in a furnace at temperatures of 1700°C.

Sand by itself can be fused to produce glass but the temperature at which this can be achieved is about 1700°C. The addition of sodium carbonate (Na2CO3), known as soda ash, to produce a mixture of 75% silica (SiO2) and 25% sodium oxide (Na2O), will reduce the temperature of fusion to about 800°C. However, a glass of this composition is water-soluble and is known as water glass. In order to give the glass stability, other chemicals like calcium oxide (CaO) and magnesium oxide (MgO) are needed. These are obtained by adding limestone, which results in a pure inert glass.

Commercial Glass is also known as Soda Lime Glass. Most commercial glasses have roughly similar chemical compositions of: - 70% - 74% SiO2 (silica) 12% - 16% Na2O (sodium oxide) 5% - 11% CaO (calcium oxide) 1% - 3% MgO (magnesium oxide) 1% - 3% Al2O3 (aluminium oxide).

Within these limits, the composition is varied to suit a particular product and production method. The raw materials are carefully weighed and thoroughly mixed, as consistency of composition is of utmost importance in making glass. Nowadays recycled glass from bottle banks or kerb side collections, known as cullet, is used to make new glass. Using cullet has many environmental benefits; it preserves the countryside by reducing quarrying, and because cullet melts more easily, it saves energy and reduces emissions. Almost any proportion of cullet can be added to the mix (known as batch), provided it is in the right condition, and green glass made from batch containing 85% to 90% of cullet is now common.

Although the recycled glass may come from manufacturers around the world, it can be used by any glassmaker, as container glass compositions are very similar. It is, however, important that glass colours are not mixed and that the cullet is free from impurities, especially metals and ceramics. Pulverised glass cullet is finding increasing use as replacement sand aggregate in non-structural cement and lime screeds and lime mortar.

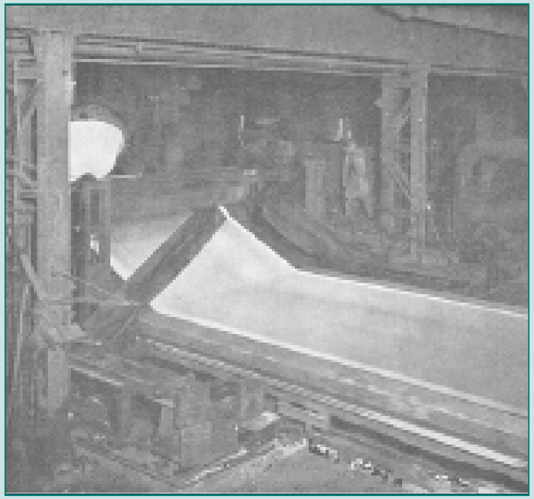
Expanded round glass granules made from recycled glass are also promoted as lightweight aggregate suitable for dry mix mortar applications, such as plasters, mortars, adhesives and screeds.

FOAMED GLASS

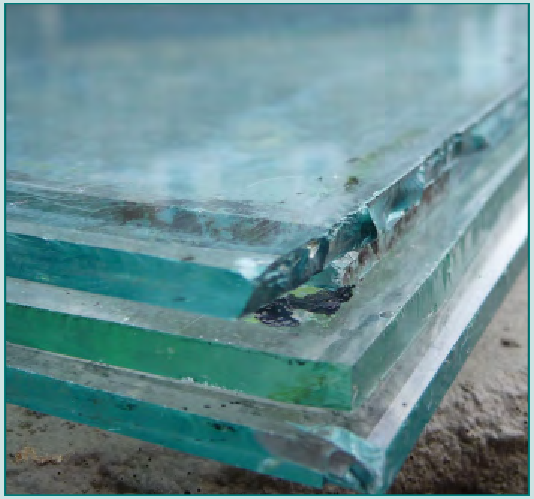
See section 2.13 on insulation.

WINDOWS

Windows are the thermal weak link in any envelope. It is at this point that a large amount of the eventual heat loss will occur and if not addressed, solar gain will be excessive. The maximum permissible U-value under the 2022 (England and Wales) Building Regulations is 1.6W/m2°C. When one considers that the optimum amount of glazing in a wall for a commercial building is around 40% of the wall area (the opaque bits of which will be insulated to at least U=0.26 W/m2°C,) this means that almost half the wall is allowed to leak heat at over six times the rate of the rest! It might be argued that the maximum benefit in energy reduction would arise from



SHEET GLASS PRODUCTION IMAGE FROM BOOK 'THE MAKING OF SHEET GLASS 1993' SCANNED BY IAN MACKY PHOTO: WIKIMEDIA COMMONS



SHEET GLASS
PHOTO: JO DENISON, STEPHEN GEORGE + PARTNERS

CLICK HERE TO VIEW

- **Windows 01 - General & Glazing Data Sheet**

greater investment in the window performance rather than improved wall U-values.

The best performing windows are triple-glazed with argon or krypton filled cavities. U-values of 0.7 – 0.9 W/m2°C are possible by using these. However, substantial reductions are also available by merely selecting double glazed versions but with low emissivity coatings and argon fill. Needless to say, most of these low energy windows originate from Germany but UK produced triple-glazed windows are starting to become available.

Argon and Krypton gases are two of the earth's six naturally occurring noble gases, also referred to as inert gases. The noble gases are colourless, odourless, tasteless, and non-flammable under standard conditions. Both gases are used to improve the thermal performance of cavities in double and triple glazing units.

The heat loss through the frame is just as important as through the glazed area. The best aluminium frames have been thermally broken for some years, but high performance windows also require that the glazing spacer material avoid thermal bridging. Polymer, glass fibre or structural foam is used instead of aluminium. Timber, should be used in an engineered form for low energy window frames. This means the use of laminated timber rather than solid section due to greater stability. The material the frame is constructed from is of far less importance than the performance of the glazing. Any embodied energy arising from production almost pales into insignificance next to the heat lost through the glass. The specification of energy efficient glazing can be a minefield. As a composite element incorporating several materials all with different thermal characteristics, any calculation method of assessment is necessarily complex. Often, it is easier therefore to defer to an already prepared rating system, such as the Window Energy Rating (WER), or that in the BRE's Green Guide to Specification. Such acceptance of third party quantifications should, however, be approached with a degree of detachment-if not outright scepticism. Under the BRE scheme for example, many apparently very similar constructions appear to get quite different ratings. Then there is the fact that uPVC windows achieve a blanket 'A' rating which is higher than alternatives with frames from steel, aluminium or even timber.

PRACTICAL APPLICATIONS

Windows, Walls, Roofs, Insulation, Fixtures & Fittings, Worktops (from recycled glass)

LINKS

General Information
https://www.britglass.org.uk/about-glass

Recycled glass products
https://www.phoenixcompactors.co.uk/blog/multiple-uses-recycled-glass

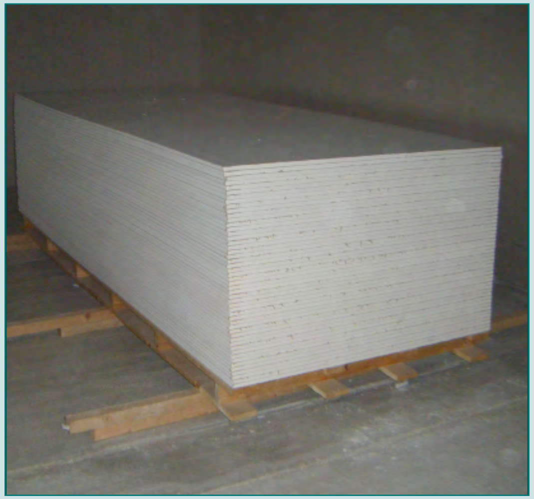
https://iopscience.iop.org/article/10.1088/1757-899X/640/1/012073/pdf

https://www.diamikglass.co.uk/

https://enva.com/resource-recovery/glass

2.15 GYPSUM

ANHYDRITE GYPSUM CRYSTAL
PHOTO: ALCINOE (WIKIMEDIA COMMONS)



PLASTERBOARD
PHOTO: JO DENISION, STEPHEN GEORGE + PARTNERS

Gypsum comes in two forms: natural and synthetic. "Natural" gypsum is a benign rock formed as calcium sulphate through precipitation in vast inland seas throughout the world during the age of the dinosaurs.

Natural and synthetic gypsum have identical chemical compositions. One hundred pounds of gypsum contain approximately 21 pounds (or 10 quarts) of chemically combined water. During the gypsum panel manufacturing process, the gypsum is ground into a fine powder and heated to about 175oC, driving off 75% of the chemically combined water in a process called "calcining." The calcined gypsum is used in producing gypsum plaster, gypsum panel products, and other gypsum-based building materials.

NATURAL GYPSUM

Gypsum (CaSO4 2H2O) is one of the most common natural minerals and is actually a form of rock. It is available in mines in several countries. The major producers of rock gypsum are Thailand, Spain, Mexico and the US.

Although in good supply presently, there is only a limited supply available worldwide, so steps to preserve the natural gypsum resources should be taken. Recycled gypsum powder can replace up to 25% natural gypsum rock in the production of new plasterboard.

SYNTHETIC GYPSUM

Synthetic gypsum, industrial gypsum, FGD (Flue Gas Desulphurised Gypsum) and DSG (Desulphurised Gypsum) are all names for gypsum which are created by man and not naturally found in mines. Synthetic gypsum is most typically created when using 'scrubbers' of lime (Ca) in coal fired power plants to clean the chimney smoke of sulphur (SO). The lime and sulphur combine and make synthetic gypsum (CaSO4 2H2O) which is a high quality and very pure gypsum.

Synthetic gypsum is not readily available to all plasterboard plants, and in some areas the production of synthetic gypsum is decreasing as oil and natural gas replace coal as the energy source in many power plants. FGD and DSG are just one of the products of sulphur dioxide removal from power station flue gases; the other waste products are often not as easy to dispose of and environmentally undesirable. In addition, to fully address all of Britain's fossil fuel power stations in this way would require about 1.5 million tons of limestone per annum and would generate a corresponding amount of waste product in addition to DSG/FGD. The Ferrybridge power station in West Yorkshire supplied substantial amounts of raw material for plasterboard but is an example of one particular installation which has now closed down in the move from fossil fuels.

HYDROGEN SULPHIDE GAS PROBLEMS

In the US and in Europe, plasterboard waste disposed of in landfills have allegedly created the dangerous hydrogen sulphide gas (H2S). Hydrogen sulphide gas is a dangerous gas that in high concentrations is lethal and in low concentration gives a rotten egg smell. The plasterboard waste in itself is not dangerous, but when the plasterboard waste is mixed with organic waste and exposed to rain in an anaerobic environment, tests have shown that hydrogen sulphide gases can develop. Plasterboard also upsets the PH balance of the watercourses. Since the cost of sending plasterboard waste to landfill has risen considerably, many plasterboard manufacturers are implementing

PLASTERBOARD IS ONE OF THE MOST WIDELY SPECIFIED BUILDING MATERIALS
PHOTO: SAMBACH (WIKIMEDIA COMMONS)

full recycling schemes.

British Gypsum does not generally identify the recycled content for individual products, however, across the UK, the average recycled content is quoted at 55%.

RECYCLABILITY

Gypsum Recycling International has developed a recycling system which attempts to ensure that gypsum and plasterboard waste become 100% recyclable. The reprocessed gypsum powder which makes up approximately 94% of the waste is sent back to the plasterboard manufacturer, so that they can make new plasterboard. The paper, with related contaminants making up 6% of the waste, can be reused in various ways. Very little gypsum is left on the paper residual. The paper residual is therefore 100% of used for composting, heat generation, building materials etc. The gypsum/plasterboard waste is recycled. Nothing goes to landfill.

Despite its potentially harmful effects to the environment if not disposed of carefully, gypsum is one of the very few materials which can probably be eternally and easily recycled. The European gypsum industry is committed to achieving a closed-loop system of manufacturing. Although a recycled content of 30% has been demonstrated to be possible by the "Gypsum-to-Gypsum," project, it has yet to be implemented formally. The UK plasterboard industry achieved a post-consumer recycled content of 9.45% in 2021. However, with the decline of fossil fuel fired power stations and the finite availability of natural gypsum, uptake of the proposals will probably only be a matter of time.

WRAP – WASTE AND RESOURCES ACTION PROGRAM

In the early 2000's WRAP ("Waste and Resources Action Plan), the UK government's organisation responsible for driving the recycling and landfill reduction worked with the plasterboard industry to produce the "Naterra," block. This was an unfired clay block which used up to 50% recycled plasterboard in its composition. However, as noted in other sections, this product failed to be adopted commercially and is now no longer available.

The apparent changes to the work of WRAP have also been covered in an earlier section.

PRACTICAL APPLICATIONS

Plaster, Plasterboard, Mouldings

LINKS

General Information
https://www.british-gypsum.com/sustainability

Recycling
https://www.retec-recycling.com/gypsum-recycling

https://www.eurogypsum.org/circularity/

https://gpda.com/sustainability/

CLICK HERE TO VIEW

- Gypsum Data Sheet
- Concrete Blocks Data Sheet

2.16 INSULATION

It is generally accepted that insulation saves more energy during its lifetime than is consumed during its production, so the origins of the material are somewhat overlooked.

Most conventional insulation materials are made from petrochemicals. They are cheap to buy and install and the general perception is that they perform better than natural alternatives. They also contain a chemical cocktail of fire retardants, adhesives and other additives in addition to the high amounts of energy consumed in their production. Once moisture is introduced into the equation, natural insulation is more effective; an attic roof may have 60% humidity which will have an adverse affect on materials that cannot absorb this moisture. Natural fibre insulation is hygroscopic, meaning it absorbs moisture without becoming wet to touch and without affecting performance. Many natural fibre insulations are treated against mould and insect infestation with borate, a natural mineral salt.

Unfortunately, natural insulation can be far more expensive than conventional materials which can put off specifiers, developers and builders. However, the benefits of natural insulation should not be overlooked. They lower embodied energy, renewable, from organic sources, non-toxic, are reuseable and recyclable, biodegradable and breathable. Generally speaking, insulation is unrecyclable. Therefore, its production introduces a range of materials into the environment which then stay there. For artificial materials, this may include the cocktail of toxic harmful materials already described.

U-VALUE AND DYNAMIC THERMAL PERFORMANCE

Heat loss through an element of a building's envelope is usually expressed by the rate of W/m2K or the U-value. This quantity arises from a calculation method which is usually based on values arrived at by examining a material's thermal performance by conduction in a steady state. This is commonly known as the 'hot box' method. This system has been subject to critcism from manufacturers of innovative insulation materials for a number of years. Notably, multi-foil manufacturers claim that it is unsuitable for their product. It is questionable whether it is suitable for assessing the thermal performance of many natural insulants also. This laboratory based method dries out the material, removing most of the moisture content. This is an unrealistic representation of materials such as straw bale or hempcrete which, not only are insulants but walling materials and will therefore usually incorporate some moisture. This imparts a degree of thermal inertia to the material. Simplistically speaking, this allows heat to enter the material and be re-radiated at a later time. This has led to a situation where some materials seem to have a theoretical U-value which is far higher than the heat loss occurring in actual use.

Some years ago, Hemcrete buildings were monitored and found to have a thermal performance which in real life was much improved over what may be expected from a standard heat loss calculation. Terming this "dynamic thermal performance" Lime Technology, the company then behind the investigation, questioned whether the standard method of measuring heat loss is adequate for natural materials such as hemp-lime.

WARMCEL CELLULOSE INSULATION (RECYCLED NEWSPAPER) BEING SPRAY APPLIED PHOTO: EXCEL INDUSTRIES

FLAX INSULATION ROLLS & BATTS
PHOTO: ISOLINA OY

This approach to thermal performance has been continued by Chris Brookman who runs "Back To Earth, a natural building materials supplier. Chris has demonstrated that the slower response to external temperatures of the likes of wood fibre insulation (the "decrement delay") can help in preventing buildings overheating in extreme temperatures. As climate change continues to illustrate its reality through a continuing series of dangerous heatwaves, such a characteristic may become increasingly essential when considering the thermal performance of new buildings.

LINKS

General Information
https://en.wikipedia.org/wiki/Dynamic_insulation

https://www.backtoearth.co.uk/natural-materials-and-performance-in-a-heatwave/

Insulation can be categorised into four main classifications shown here with the thermal conductivity in W/m°C (the lower the value the better the thermal performance).

Those derived from:	W/m°C
1. Organic sources	
Cellulose Cork	0.037-0.040
Flax	0.037
Hemp	0.037-0.039
Sheep's wool	0.036-0.040
Straw	0.045
Wood	0.038-0.040
Wood/Hemp	0.038
2. Naturally occurring minerals	
Foamed glass	0.042
Mineral/Rock Wool	0.036
Perlite	0.045-0.05
Vermiculite	0.063
Glass wool	0.032-0.040
3. 'Multi-foil' insulation	1.69-1.71
4. Fossilised vegetation	
Expanded Polystyrene	0.033
Extruded Polystyrene	0.032
Phenolic Foam Board	0.018-0.025
Polyurethane	0.019
Recycled Plastic Bottles	0.040

HEMP INSULATION BATT
PHOTO: CHRISTIAN GAHLE, NOVA-INSTITUT GMBH

1. ORGANIC

CELLULOSE

Cellulose is a generic name for an organic compound consisting of chains of glucose units. For industrial use, cellulose is mainly found in wood pulp and cotton. Newsprint recycled insulation, wood fibre/chip, hemp and flax products are all cellulose.

However, cellulose has come to represent a type of insulation made from 80% post consumer waste newsprint combined with cotton, the fibre is treated against fire, mould and insects with a borate compound. Cellulose offers all the above mentioned advantages of natural insulation in addition to being a recycled product. It is favoured by contractors as it can be blown into cavities.

CORK – ALSO SEE CROPS

Cork is harvested from the cork oak tree in sustainable forests primarily in Portugal.

Cork is recyclable and cork insulation can contain recycled material. Cork has many of the advantages of natural insulation, however it does not absorb water and is resistant to compression; some cork insulation has a small amount of formaldehyde off-gassing.

FLAX – ALSO SEE CROPS

Flax is a crop grown primarily in today's society for the seeds in the extraction of linseed oil and the fibre for the production of linen cloth. Flax insulation products are relatively new.

Flax insulation uses the fibres of the plant's stem mixed together in a 'non-woven' matting. Potato starch can be used to bind the material making it 100% natural, however it is often mixed with a textile binder such as cotton, and sometimes plastic binding agents. Typically the insulation is treated with borates that act as a fungicide, insecticide and fire retardant.

HEMP – ALSO SEE CROPS

Hemp is a crop grown for a wide multitude of uses; it is a very versatile crop. Used as insulation, hemp has good thermal and acoustic properties. Hemp is naturally resistant to insect attack but uses Ammonium Phosphate as fire retardant. Some hemp insulations contain a thermoplastic binder of about 8-10%.

SHEEP'S WOOL

Using wool as insulation is not a new concept, humans have used wool as clothing for thousands of years and evidence exists of wool used in buildings. Wool is readily available in the UK and with the price of shearing a sheep currently costing more than the price of the fleece; it seems a shame not to utilise this abundant source.

Wool has many outstanding properties. It is strong and durable and non irritant to handle, has good thermal performance, is reusable and recyclable, is naturally fire resistant and the addition of borate natural mineral makes wool resistant to insect and fungal attack. Wool is hygroscopic, being able to absorb and then re-emit a third of its weight in water vapour, and this breathing quality helps regulate moisture levels in buildings, keeping them warm in summer and cool in winter.

SHEEP'S WOOL INSULATION
PHOTO: SHADOKAT, WIKIMEDIA COMMONS

Sheep farming has a much discussed controversial effect on the environment, destroying the natural habitat of the countryside by overgrazing. The routine use of sheep dips to maintain the health of the animal's skin adds to this controversy; the chemicals used are liquid insecticide and fungicide and there are concerns concerning the disposal of the chemicals, polluting the waterways and damaging fish stocks and the health of the farmers. There are two broad classes of sheep dip: organophosphorus compounds, which were developed for chemical warfare, and synthetic pyrethroids. Organophosphorus compounds are very toxic to humans, as they travel easily through the skin.

Imported wool should be avoided as this substantially increases the embodied energy.

This issue of chemical run-off combined with the fact that wool production is economically now seen to be a part of meat farming leads the BRE Green Guide to Specification to rate sheep's wool insulation lower than artificial alternatives – even those derived from petrochemicals such as EPS.

LINKS

General Information
https://www.sheepwoolinsulation.com/

STRAW – SEE CROPS

Straw as insulation generally acts as an integral part of a walling system.

WOOD

Wood fibre products are essentially cellulose insulation, however the word cellulose is associated with insulation made from recycled newsprint. Wood chip insulation consists of wood chippings with 7-10% polyolefin binders and offers the natural and hygroscopic advantages as listed above in addition to being semi rigid. Hemp wood consists of 55% wood, 30% Hemp with 15% Polyurethane binders.

Although a renewable resource and with far less petrochemicals involved in its manufacture, wood fibre insulation does necessarily contain some chemicals such as polyamide binders, ammonium phosphate fire retardants and sometimes paraffin wax or latex.

LINKS

General Information
https://www.homebuilding.co.uk/advice/wood-fibre-insulation

https://www.eco-home-essentials.co.uk/wood-fibre-insulation.html

WOOD FIBRE INSULATION
PHOTO: THINGERMEJIG (WIKIMEDIA COMMONS)

GLASS WOOL ROLLS
PHOTO: JO DENISON, STEPHEN GEORGE + PARTNERS

2. NATURAL

GLASS WOOL

Glass wool is made from sand and limestone with fluxing agents such as soda ash, and increasingly from recycled glass with up to 80% recycled content. The material is melted at high temperatures and spun to produce long fibres. The process is integral from mixing the material to rolling of the final finished product, converting 100% of the glass to fibres. The resulting mat has elasticity, resilience, flexibility, and high air flow resistance, meaning excellent thermal performances.

Mat forming is carried out by specific tools designed to rearrange fibres in the mat. The structure and density of the products are adapted in each case, depending on the requirements of their final use.

The glass wool mat gets its final shape, strength and stability when going through a curing oven, heated to around 200°C, where it is laminated and polymerised.

The Isover website states glass wool is recyclable and while this may be true in theory, in reality, at best, factory off-cuts are put back into the system. Used soiled product is not acceptable but occasionally site surplus will be taken back at the discretion of the manufacturer.

LINKS

General Information
https://www.isover-technical-insulation.com/glasswool

MINERAL WOOL

Rockwool is a stone-based insulation. It is sourced from lava deposits of volcanic rocks which are mined and melted in a cupola furnace. As the re-melted lava comes out of the furnace, it is spun, given water repellency treatment and bound together into a wool-like fleece. During the manufacturing process, binder and impregnating oil provide stability and water-repellency before the wool is compressed to the required density and shape. The product is cured, then cut to size for packaging and delivery.

The following table gives the general material composition for rock wool insulation:

MATERIALS	SPECIFIC MATERIALS	TOTAL PERCENT INPUT (%)
First Set of Raw Materials	Igneous Rock Diabase Rock Gotland Stone Limestone Bauxite	71%

ROCKWOOL
PHOTO: JO DENISON, STEPHEN GEORGE + PARTNERS

CLOSE-UP OF FOAMGLAS
PHOTO: UNES (WIKIMEDIA COMMONS)

Second Set of Raw Materials	Industrial Waste Material (i.e. cement and steel production pre-stone wool waste post-stone wool waste)	21%

While Rockwool is formed from a 'renewable' source, these are active volcanic zones and are limited to certain hot spots around the world, mainly the Pacific Rim and other remote areas. These volcanic zones are often national parks of exceptional beauty, geological and biological interest, not to mention highly dangerous. The Diabase rock seams mined by Rockwool are ancient, laid down in time of high volcanic laid down in time of high volcanic activity during ancient geological epochs.

As noted above, the exact percentage of Diabase, which is combined with other mined materials, is undisclosed.

LINKS

General Information
https://www.rockwool.com/siteassets/o2-rockwool/blog---rwna/mold-resistance/rockwool-stone-wool-manufacturing-production-process-fact-sheet.pdf?f=20191105140101

https://www.rockwool.com/uk/about-us/sustainability/recycling/

FOAMED GLASS

Foamed glass is formed from a reaction between glass and carbon at high temperature resulting in CO_2 being trapped in minute bubbles in the glass, giving a cellular structure. The melted glass is blown with carbon dioxide and sulphur added which explains the rotten egg smell when the material is cut; it is unpleasant but not harmful. Foamed glass is available in slabs, has high dimensional stability and is non-permeable, making it ideal for insulating below-ground structures. Foamed glass contains no petrochemical binders or preservatives. The composition of foamed glass is: 5% glass, 95% gas.

Foamed glass, like glass, does not rot. It is a brittle product and can be reduced to 5% volume on disposal. Besides the mechanical and thermal properties of the product, foamed glass manufacture is an example of waste recycling on an industrial scale. Foamed glass can be manufactured fully out of waste glass, with only a minimum of virgin additives.

Below is an excerpt from the Foamglas website which contradicts other available information regarding the percentage of recycled material:

'FOAMGLAS® is environmentally sound, not only in its manufacture which utilises 60% post-consumer waste glass, but also in use and in its eventual disposal - it is totally free from CFC and HCFC.'

Foamed glass generally receives a high rating under the BRE Green Guide as its embodied energy is viewed as being very low. As it is composed largely of recycled glass, the primary energy input occurs during the production of the initial glass product.

MULTIFOIL INSULATION
PHOTO: JO DENISON, STEPHEN GEORGE + PARTNERS

LINKS

General Information
https://www.foamglas.com/en-gb/sustainability

3. MULTIFOIL INSULATION

Multifoil insulation consists of outer layers of metallised polypropylene film and approximately five inner layers of polyester wadding interleaved with four reflective aluminised films. These insulations can contain some recycled content, but are derived from non renewable sources, have high embodied energy and are non biodegradable.

There is a great deal of debate on the performance of Multi-foil Insulations. They do not perform very well under the standard method of testing insulation for conductivity and resistance. However, their supporters claim that this is due to the method of testing (the "hot-box" method) rather than their actual performance. Although there is still debate on their actual performance, the LABC has embraced the correct use of multifoil insulation and a number of products, including PhotonAir and PhotonFoil, have been registered within the LABC Registered Detail scheme ensuring their acceptance by building control across England and Wales.

Photonfoil give specific guidance on the use of their product including the following: ***"The product should be used in conjunction with other insulation materials to achieve the required thermal properties. It is critical that a minimum 20mm air-space is retained on either side of the product".***

LINKS

General Information
https://www.thermictechnology.co.uk/products/photonfoil

https://www.pbctoday.co.uk/news/energy-news/multifoils-explained/22073/

4. FOSSIL

POLYSTYRENE

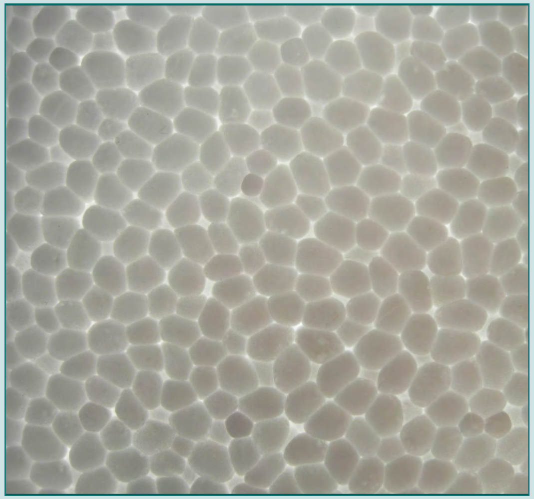
Although polystyrene can be recycled currently, the majority of polystyrene products are not because of a lack of consumer awareness regarding suitable recycling facilities and methods. Polystyrene "recycling" is not a closed loop; polystyrene cups and other packaging materials are instead usually used as fillers in other plastics, or in other items that cannot themselves be recycled and are then thrown away.

Polystyrene is not easily recycled because of its light weight (especially if foamed) and its low scrap value. Advances have been made in recycling expanded polystyrene at an industrial level.

Polystyrene is commonly produced in three forms: extruded polystyrene, expanded polystyrene foam, and extruded polystyrene foam.

EXPANDED POLYSTYRENE (EPS)

Invented in 1952 by BASF, EPS is a lightweight cellular material derived from petroleum and natural gas by-products.



CLOSE-UP OF EPS BOARD
PHOTO: PHYREXIAN (WIKIMEDIA COMMONS)

The raw material for EPS is produced in the form of small polystyrene beads containing a blowing agent (pentane) which, when exposed to steam, expand to form a light weight "prefoam" of required density.

This "prefoam" is then processed by further steam treatment until the beads fuse together, either in a mould to give that material a required shape and size or as large blocks for cutting into sheets and shapes.

Approximately 0.1% of total oil consumption is used to manufacture EPS.

EPS is used as insulation in walls, roofs and foundations, as well as a component in structural insulated panels (SIP's), insulated concrete forms (ICF's) and exterior insulated finishing systems (EFIS).

EPS contains no CFCs HCFCs or fibre, has a zero ODP rating (Ozone Depletion Potential – releasing gases that could contribute to global warning), it is not noxious, and is physically and chemically inert. It contains no known biological or physiological irritant.

EPS has been used successfully for many years in areas where moisture is a concern, specifically below ground. Fungi, bacteria and rot do not affect EPS. The performance properties will not deteriorate when exposed to moisture and/or water.

Although an insulation product, EPS is most likely to be encountered as a packaging material for goods. In Germany, at least 42% of this packaging is recycled. Of course, this also means that around 58% isn't! One of the main drawbacks of the material (in addition to its petrochemical origins) is that its globular and friable nature allows it break up easily into very small units which are then difficult to gather and dispose of meaning they can easily find their way into watercourses and even be ingested by wildlife. Consequently they are substantial contributors to the problem of micro-plastics in the marine environment.

Despite this characteristic, BASF have developed Neopor F5 Mcycled EPS insulation which contains 10% recycled material.

COLLECTION OF EPS FOR RECYCLING

Some recyclers will collect clean, un-compacted EPS free-of-charge and recycle it into insulation board for construction. If sufficient quantity (enough to fill a truck) is collected the material should be palleted and wrapped in plastic film.

Jablite Insulation recycles enough factory scrap to form 15-18% of the product but only in the premium range for domestic use. They only collect scrap from outside sources if they are approached by someone with a large supply.

LINKS

General Information
https://www.eps.co.uk/downloads/index.html

Recycling
http://en.wikipedia.org/wiki/Polystyrene#Recycling

CLOSE-UP OF XPS BOARD
PHOTO: LYNDON JOHNSON, STEPHEN GEORGE + PARTNERS

EXTRUDED POLYSTYRENE FOAM (XPS)

Extruded polystyrene foam has air inclusions which give it moderate flexibility, a low density, and a low thermal conductivity. It is used for thermal applications, the craft industry and in Structural Insulated Panel Systems (SIPS).

Trade names for XPS include "Styrofoam" and "Polyfoam". "Styrofoam" is often also used as a generic name for all polystyrene foams.

XPS traditionally uses HFCs as a blowing agent. This, combined with its ecotoxity to land results in the BRE Green Guide to Specification assigning it an 'E' rating which is very low.

XPS Styrofoam was invented by Dow Chemicals in 1941 but is now produced as "Styrofoam," by a number of companies. A curious fact is that XPS is a major constituent of napalm which led to it being a very profitable product in the 1960's due to its widespread use by the US in VietNam. This in turn led to significant boycotts of Dow by the counter-culture of the period.

PUR / PIR

PUR / PIR is a polyurethane which was discovered as a replacement for rubber in the Second World War. It is synthetic.

The first commercial applications for polyurethanes were developed in the middle of the 20th Century. Since then they have found use in an ever-increasing number of applications:

- Low-density flexible foam used in upholstery and bedding.
- Low-density rigid foam used for thermal insulation and RTM cores.
- Soft solid elastomers used for gel pads and print rollers.
- Hard solid plastics used as electronic instrument bezels and structural parts.
- Blown Plastic Insulants. This covers Phenolic, Rigid polyurethane (PUR) and polyisocyanurate (PIR) insulation products. All of these are excellent insulators with high compressible strength and moisture resistance.

The popularity of phenolic foam board has waned somewhat in recent years but is still available as insulation board or as spray expanding foam. Air is used as the foaming agent but sometimes ozone depleting gases are used.

LINKS

General Information
http://en.wikipedia.org/wiki/Polyurethane#Raw_materials

https://insulationmanufacturers.org.uk/faqs/

https://www.basf.com/global/en/media/news-releases/2022/03/p-22-168.html

RECYCLED PLASTIC BOTTLE INSULATION
PHOTO: JO DENISON, STEPHEN GEORGE + PARTNERS

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- Insulation Data Sheet

FIRE PERFORMANCE

Foamed plastic insulation boards have come under close public scrutiny in recent years and achieved notoriety as being at least partly responsible for the severity of the fire at Grenfell Tower in June 2017.

The main external insulation board used was Celotex RS5000 which was PIR while Kingspan's K15 Phenolic boards were used in smaller areas.

As has been well publicised, the fire test data for these proved to be (at the very least) "questionable." Not only did they prove to be highly combustible but also produced toxic gases when burning.

The resultant changes in UK legislation has limited their future use to low rise environments – but it should be borne in mind that the actual composition of these boards remains essentially the same as when installed on the ill-fated Grenfell Tower.

PLASTIC

Relatively new to the market is a quilt insulation made primarily from recycled plastic bottles, quoting 85% recycled materials. It is non-irritant, uses recycled material and is unaffected by moisture. The plastic comes predominantly from recycled milk bottles which are formed into batt insulation. The material is treated with a fire retardant so it doesn't burn but melts.

LINKS

General Information
https://www.thermafleece.com/product/supasoft-recycled-plastic

2.17 LIME

LIME MORTAR BEING MIXED
PHOTO: JJ SHARPE

LIME MORTAR BEING APPLIED
PHOTO: COPYRIGHT © 2000-2009 LIME TECHNOLOGY LIMITED

Lime products are made from limestone. Limestone is a sedimentary rock composed largely of the mineral calcite (calcium carbonate: CaCO3). Limestone deposits were formed through the drying of inland seas and the calcite content is mainly formed from marine animals. Limestone contains silica, clay, silt and sand.

Lime is predominantly used in construction as building stone or as lime mortar/render/putty.

The terminology for lime can be confusing.

There are two basic types of lime product; hydraulic and non-hydraulic.

To help understand these differences we must first understand the basic process of making lime products:

1. Lime is quarried from limestone or chalk (calcium carbonate).

2. The limestone/chalk is burned, driving off moisture and carbon dioxide creating quicklime or calcium oxide.

3. The lime is then 'slaked'. This is where water is added to quicklime, creating calcium hydroxide. Water is added in varying quantities, creating products of different consistency; from dry powder supplied in bags to putty supplied in sealed buckets.

4. Mortars and renders are made by adding aggregate.

There are two different basic types of lime. These differ in the way which the lime sets or hardens:

NON-HYDRAULIC

The raw material used for non-hydraulic lime contains very few impurities. This sets through carbonation, (re-absorption of the carbon dioxide from the air). This type of lime only sets through exposure to air earning itself the name 'air lime' or 'lime putty.' Modern non-hydraulic lime mortar is produced from lime derived from high calcium limestones. Non-hydraulic lime is produced in two forms: hydrated lime (bagged powder) and lime putty (supplied wet in a plastic bucket).

HYDRAULIC, NATURAL HYDRAULIC

Hydraulicity is the ability of lime to set under water. Hydraulic lime sets through a chemical reaction with water. It does not rely on carbonation and as such can set under water. Although, depending on the percentage of impurities in the raw material, some carbonation does take place. These impurities can be natural and the product is then termed natural hydraulic lime (NHL). Hydraulic limes are manufactured with added pozzolan; a product that speeds up the setting time of the lime. Pozzolans can be derived from sources such as brick dust or calcined clay.

Hydraulic lime is produced by burning limestone which contains clay and other impurities. Calcium in the limestone reacts in the kiln with the clay minerals to produce silicates that enable the lime to set without exposure to air. Hydraulic lime is used for providing a faster initial set than ordinary lime.

The scale is as follows: at one extreme, we have pure or air limes and at the opposite portland cement (OPC). Products ranging between these two extremes can have varying characteristics. These can range from a pure

LIME RENDER BEING APPLIED
PHOTO: COPYRIGHT © 2000-2009 LIME TECHNOLOGY LIMITED

LIME RENDER BEING APPLIED
PHOTO: COPYRIGHT © 2000-2009 LIME TECHNOLOGY LIMITED

soft natural permeable product with low compressive strength to a hard brittle, impermeable, fast-setting material with high compressive strength.

HYDRATED

A frequent source of confusion regarding lime mortar stems from the similarity of the terms hydraulic and hydrated.

Hydrated lime is any lime other than quicklime, so can refer to either hydraulic lime (hardens underwater) or non-hydraulic lime (doesn't harden underwater). All processed lime other than quicklime has water added in the third stage of the cycle – (I.e. slaking) and is therefore hydrated. When a minimal amount of water is used in the slaking process, then the result is a dry material. This is then ground to make hydrated lime. If excess water is used during slaking, (thereby preventing carbonation), then putty or slurry is produced.

Stored (wet) lime putty is always non-hydraulic (since hydraulic putty sets quickly after mixing with water). Lime putty made at the time of slaking is considered to have better qualities than one produced from hydrated lime.

Hydraulic and hydrated limes must not be confused. Hydrated lime is merely a form that lime can be supplied in (as opposed to quicklime) while 'hydraulic' or 'non-hydraulic' refers to a characteristic of the lime.

HEMP-LIME MATERIALS

Lime is a primary constituent of Hempcrete and Limecrete, being mixed with Hemp and cement to form either blocks, panels or the spray applied or poured mixture. Several mix specifications are available to the builder. Tradical Hemcrete is a proprietary product, the composition of which is subject to commercial confidence. The actual composition of the lime binder, therefore is difficult to ascertain but the product is known to contain a small amount of cement. The wet product cures partially by the lime content absorbing CO_2. This process contributes to Hemcrete as a carbon sink and partially offsets the emissions associated with the original lime production

Also see Crops section.

STRENGTH

Lime has a variety of strength classes.

NHL 1 or FL 1	0.5-3 mpa
NHL 2, FL 2, HL 2	2-7 mpa
NHL 3.5, FL 3.5, HL	3.5 3.5-10 mpa
NHL 5, FL 5, HL 5	5-15 mpa

Feebly Hydraulic

Used for internal works / external pointing / render on very soft masonry in sheltered areas.

Slow setting

Moderately Hydraulic

Used for mostly pointing / rendering and building works on most masonry types.

Eminently Hydraulic

Used for external works in exposed areas such as chimneys, copings or river/canal works. Faster/harder set.

LIME SETTLING TANK
PHOTO: JJ SHARPE

LIME RENDER BEING APPLIED OVER HEMCRETE BASE
PHOTO: COPYRIGHT © 2000-2009 LIME TECHNOLOGY LIMITED

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- **Lime Data Sheet**

USE OF LIME

Lime is a very varied product, the mix percentages depending on the performance characteristics required of the end product. The mixing of lime for a specific application is a specialist skill. Seek advice to ensure the correct mix is achieved, ensuring the product is fit for purpose.

UK AVAILABILITY

There are three major UK lime suppliers – Lhoist, Tarmac and (the largest) Singleton Birch. There is no UK produced version of NHL5 type lime, with this all being imported - usually from France or Portugal. The latter allows Singleton Birch to offer a lightweight external lime render which has cork granules in place of aggregate providing a degree of insulation. This is marketed as "Secil ecoCork".

LIME AND SUSTAINABILITY

- being produced at lower temperatures than cement, lime mortar requires less energy, resulting in 20% less CO_2 output.
- lime reabsorbs the CO_2 emitted by its calcination (firing), thus partially offsetting the large amount emitted during its manufacture. The more hydraulic a lime, the less CO_2 is reabsorbed during set, for example, 50% of CO_2 is reabsorbed by NHL 3.5 during the set, compared to 100% of CO_2 being reabsorbed by pure calcium hydroxide, fat lime putty.
- lime mortar can be recycled, unlike cement. Scrapped lime mortar is simply chalk and sand, normal constituents of soil and which break down, cement mortar does not break down and presents a disposal issue.
- bricks using lime mortar can be recycled unlike the cement bonded equivalent which can only be used for hardcore.
- it is strong, flexible and permeable. Traditional buildings built using lime mortar move and absorb moisture.

In comparison with cement mortar which is rigid, lime mortar 'moves' with the structure and so prevents masonry from cracking. By using lime mortar, the number of expansion joints can be reduced. Likewise, the impervious nature of cement mortar prevents it from absorbing water from the structure whereas lime mortar acts as a kind of 'wick', absorbing the moisture and allowing it to evaporate. By absorbing moisture, lime mortar is keeping the masonry drier and reducing the risk of spalling.

PRACTICAL APPLICATIONS

Cement Substitute, Render, Plaster, Mortar, Constituent of Hemcrete

LINKS

General Information - https://www.lime.org.uk/community/lime-products-introduction-benefits.html

Lime suppliers - https://www.singletonbirch.co.uk/birch-lime/natural-hydraulic-lime-calcium-hydroxide-caoh2/

Lime mortars - ttps://www.wienerberger.co.uk/content/dam/Modern_Brickwork_001.pdf

Hemcrete - http://www.limetechnology.co.uk/pages/hemcrete.php

2.18 LINOLEUM

LINOLEUM IS AVAILABLE IN A WIDE RANGE OF COLOURS
PHOTO: HOLGER.ELLGAARD (WIKIMEDIA COMMONS)

Linoleum (or "Lino" in its abbreviated form) is a composite flooring material made from a backing of canvas or burlap with layers of solidified linseed oil, pine rosin, ground cork dust, wood dust filler and calcium carbonate. It is in essence a renewable combination of materials.

Linoleum was invented in 1855, essentially from oxidised linseed oil. Naturally a very slow process, this was accelerated by heating and the resulting material turned into a varnish aimed at the waterproof clothing market, which didn't succeed. Further development led to trials in a thick floor covering which struggled to gain a footing in the market due to competition from other products. Eventually the product took off and stiff competition from other producers making the same product by different methods led to the first product name to become a generic term.

From 1860-1950 Linoleum was the floor covering of choice for high use areas, being waterproof and inexpensive. Today Linoleum has been largely replaced by polyvinyl chloride (PVC) which is still sometimes known as 'Lino'. Its popularity is due to its colour intensity and less flammable nature; the latter due to the addition of highly toxic chloride combustion products. Unlike most vinyl flooring colour goes all the way through true linoleum.

Due to true linoleum's organic nature and purported anti-allergen properties the product is still widely used within the medical / care industry.

Although a natural product with no obvious toxic effects, the energy required to produce linoleum is quite substantial.

At the time of writing the original edition of this guide, linoleum received a BRE Green Guide rating not too dissimilar to vinyl flooring. However, it now no longer appears in that system at all.

LINKS

General Information
http://www.sustainablefloors.co.uk/linoleum-vs-vinyl.html

http://en.wikipedia.org/wiki/Linoleum

CLICK HERE TO VIEW

- Linoleum Data Sheet

2.19 LIVING ROOFS

AN ESTABLISHED INTENSIVE GREEN ROOF.
PHOTO: PNWRA (WIKIMEDIA COMMONS)

AN EXTENSIVE GREEN ROOF SHOWING A RANGE OF SEDUM COLOURS
PHOTO: LAMIOT (WIKIMEDIA COMMONS)

GREEN ROOFS

An increase in population, in numbers of buildings and therefore of hard surfaced areas in our society has led to increasing surface water run off and flooding in times of heavy rain. This has led to a review of the area of hard surfaces now permitted in new developments, encouraging water permeable hard standing and water retention or attenuation to delay the release of the run-off into the water table. The green roof is one weapon in this armoury. Green roof design is also an attempt to remove the heat island affect from our cities and to mitigate the biodiversity impact of new development.

Green roofs have two levels of vegetation: intensive and extensive. Most popular due to ease of construction, speed of growth and lack of maintenance are extensive roofs, which use low growing, semi-drought resistant succulents, grasses and shrubs requiring minimum maintenance. Intensive roofs involve trees, shrubs and grasses which require 'intensive' maintenance. Intensive roofs usually involve a considerable depth of soil to facilitate planting and therefore impose an increase in load on the structure of the building, usually demanding a concrete slab as a deck. Often, intensive green roofs are designed as roof gardens because the structure is already there.

Extensive roofs by contrast are relatively lightweight. Designed to be self sustaining, the vegetation of choice is sedum, which is a succulent available in numerous varieties. Extensive farm grown sedum mats are available, being cultivated for 18 months prior to lifting. Once lifted, the matting should be installed within 24-48 hours. Extensive green roofs are installed on foam matting on a plastic drainage layer on a waterproofing membrane. Unlike intensive green roofs, the increase in loading on a building can be minimal. Steelwork may only have to be strengthened by as little as a factor of 1.4.

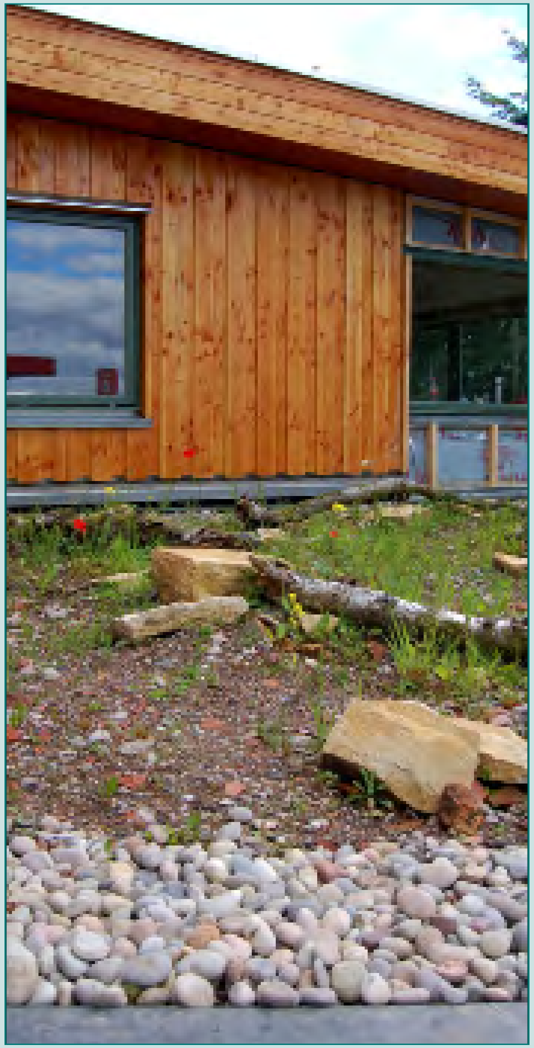
Other than the layer of vegetation matting, there isn't much to be described as 'sustainable' about the elements of a green roof. Almost all waterproofing products associated with green roof design are petrochemical based. EPDM membranes rarely use recycled content or can themselves be recycled regardless of statements on advertising literature.

The advantages of green roofs may be both sustainable and economic (despite incurring extra costs in structure and materials over a conventional roof) but have to be considered rationally.

- **Natural rainwater attenuation rather than via below ground infrastructure:**
  The cost of providing a green roof should be offset against the potential cost of providing extensive attenuation tanks and increased load on the rainwater system.

- **Increased biodiversity:**
  Although the ecological credentials of sedum (by virtue of it being monocultural) are sometimes questioned, it is undeniable that the increase in biodiversity is far greater than for a conventional roof. This factor may not only aid in securing planning approval but also may be the most economic way to meet some of the demands of BREEAM.

- **Passive cooling:**
  It is a misconception that green roofs will reduce the heat loss from a building by improving the U value. This is not the case, largely due to the amount of moisture retained in the green roof. However, in commercial buildings heating is only part of the energy load. Cooling demand is just as important. In flat-roofed city centre buildings, the uppermost storey usually has the highest cooling



A BROWN ROOF
PHOTO: THINGERMEJIG (WIKIMEDIA COMMONS)

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- **Living Roofs Data Sheets**

load. It has been proven in real-life projects that green roofs can help insulate the building from excessive indirect solar gain on the roof surface The inclusion of a green roof, therefore, may be considered against a reduction in cooling plant.

- **Maintenance:**
  A further misconception of green roofs is that they require a high degree of maintenance. In fact, other than removing the odd wind-blown seedling, maintenance should be minimal in the extreme. Biodiversity is enhanced by the lack of disturbance through maintenance.

BROWN ROOFS

Brown roofs are a variation on the green variety. They will impose a greater structural load on the building but will offer a greatly enhanced degree of biodiversity, especially in urban areas.In a brown roof design, the planting is replaced by rubble, earth, pebbles, twigs etc. This can potentially be demolition rubble from the site. The voids and detritus offer habitats for urban wildlife to a far greater degree than a planted roof. This is further enhanced once mosses and lichens begin to take hold. The advantages and cost considerations listed above are also relevant to brown roofs with probably an even lower maintenance load.

BLUE & BLUE-GREEN ROOFS

The above terms are relatively recent adoptions to describe what actually was a concept which already existed. A "Blue roof," is any roof which is designed to retain or attenuate rainwater - often for specific purposes such as irrigation or flushing etc. A "Blue-Green Roof," is one which also does this but specifically through a planted medium.

With the effects of climate change now becoming obvious in the form of extreme heatwaves and lack of rainfall, the benefits of such systems are becoming ever more apparent and cost effective. Interestingly though, such a concept is anything but new. The 19th century textile mills on either side of the Pennines would often have flat roofs with parapets which were designed to hold rainwater. This would help maintain lower temperatures on the uppermost storey in summer and also stabilise stress on the waterproof covering (usually mastic asphalt) to prolong its lifespan.

In the water-stressed environment of California, Arizona and Nevada in the Western US, (and also, in some areas of the middle-east) the concept of the blue roof for exactly the same reasons is traditionally a viable option in addition to being part of a water harvesting strategy.

However, there are drawbacks to be considered in the adoption of particularly blue roofs. The supporting roof structure needs to be capable of taking the load of retained water but probably of more concern in the face of rising global temperatures is the matter of potential infestation – particularly by species with aquatic larvae such as mosquitos.

LINKS

General Information
http://www.livingroofs.org/

http://www.thegreenroofcentre.co.uk/

https://www.designingbuildings.co.uk/wiki/Blue_roof

https://wiki.sustainabletechnologies.ca/wiki/Blue_roofs

2.20 MARINE AGGREGATES

DREDGED SAND IN HULL DOCKS
PHOTO: DAVID WRIGHT / ALBERT DOCK, HULL (WIKIMEDIA COMMONS)

HOPPER DREDGER "CHERRY SAND" ON THE HUMBER
PHOTO: DAVID WRIGHT / HUMBER GRAVELLER (WIKIMEDIA COMMONS)

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- **Marine Aggregates Data Sheet**

Generally speaking, primary aggregates have low carbon footprints. They are taken from earth in a natural state and other than washing, screening and grading, require very little processing. Although dusty and unappealing, quarries and pits are fairly temporary and can be returned to nature once worked out. The flood plains of the River Trent have been a major source of gravel in the UK for centuries and its banks are lined with historic workings which have become lakes and nature reserves.

However, the same cannot be said for sands and gravels won from marine environments. Due to the inaccessibility of many of the workings, information on the eventual environmental impact is limited. In 2019 the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection presented a paper on the issue at its 46th Session.

These mineral operations can fall into one of two geographical environments:

- Extraction of sand from intertidal areas and dunes immediately above the high water mark;
- Various aggregates (mainly gravels) dredged from offshore areas.

The former contributes greatly to beach and coastal erosion leading to potentially devastating impacts on the biosphere. Removal and excavation of dunes often leads to loss of vegetation, littoral breeding areas and coastal wetlands. Restoration of such areas is difficult and costly due to the unstable and fluid nature of the landscape. Therefore it does not happen very often

Offshore dredging of aggregates can also be destructive. As well as effectively removing the seabed which is the basis of the faunal food-chain, the disturbance caused by the process can create layers of cloudy sediment which can become anoxic, preventing biological habitation. The land reclamation projects of the Arabian Gulf have removed entire coral beds through the dredging operations employed during preparation of the initial site. In 2021-22, the north-east coast of England experienced a mass crab and lobster die-off. Although still disputed, dredging has been blamed in some quarters for this due to chemical spills associated with dredging craft. However, it is known that the increased turbidity and sediment caused by dredging degrades marine life. It is not unusual for dredging sites to suffer a 60% loss in species. (Boyd et al., 2002; Boyd and Rees, 2003; Desprez, 2000; Desprez et al., 2014; ICES, 2009, 2016; Krause et al., 2010; Newell et al., 1998, 2004).

Although the ICES Guidelines for the Management of Marine Sediment Extraction were adopted in the UK in 2003, and guidance exists in the Good Practice Guidance: Extraction by Dredging of Aggregates from England's Seabed (BMAPA/MMO, 2017) greater environmental management and assessment of operations is required in respect of these operations.

In the UK, offshore reserves are owned by the Crown Estate who estimated in 2018 that there were approximately 21 years of reserves left in British waters.

LINKS

Environmental Impact
http://www.gesamp.org/site/assets/files/2058/46_7_4.pdf

https://www.thecrownestate.co.uk/media/2753/2018-the-crown-estate-marine-aggregates-report.pdf

PEELING PAINT
PHOTO: PHOTO: DANIEL SCHWEN (WIKIMEDIS COMMONS)

2.21 PAINT

Paint is essentially a chemical coating with a variety of properties which range from the pure decorative to the protective. There are several key environmental concerns relating to the use of paint in construction:

- Many varieties of paint use solvents or Volatile Organic Compounds (VOCs) along with a range of toxic ingredients.
- Manufacture of paint is often energy intense and may lead to discharge of pollutants into the atmosphere or watercourses.
- Paint containers or surplus residue may be disposed of in an inadvisable manner by smaller builders or house-holders (burning or landfill) again leading to discharge into the atmosphere or watercourses.
- Volatile organic compounds (VOCs) are organic chemical compounds that have high enough vapour pressures under normal conditions to significantly vaporise and enter the atmosphere. VOCs are the primary environmental concern in the use of paint. Once airborne, they can cause chemical or photochemical reactions in the atmosphere contributing to either global warming or ozone depletion. Many VOCs are also suspected toxins, irritants or carcinogens.

VOCs may be natural or synthetic and there is no one definition of a VOC; various countries worldwide and even within the EU may have their own classification system. Due to this, some paint manufacturers find it possible to advertise their products as being "Zero VOC." However this may be subject to a questionable definition of what actually constitutes a Volatile Organic Compound. In the UK a system exists for the broad classification of VOC content:

Minimal	0% ⩽ VOC content ⩽ 0.29%
Low	0.3% ⩽ VOC content ⩽ 7.99%
Medium	8% ⩽ VOC content ⩽ 24.99%
High	25% ⩽ VOC content ⩽ 50%
Very High	50% < VOC content

With the move towards more airtight buildings there is concern that the off-gassing of VOCs and other chemicals from paint products may lead to their accumulation within the interior of a building or dwelling, possibly contributing to the incidence of Sick Building Syndrome, allergic sensitisation or asthma. VOC concentrations in new buildings may be 1000 times higher (or greater) than outdoors.

There is evidence to suggest that decorative paints contribute to a substantial percentage of the UK's total VOC emissions and that world-wide, the production and use of paint is a major contributor to airborne pollution.

So the key guidance relating to the specification and use of paint would seem to be "don't". However, this is not always a realistic option, if only for weather protection. What is now thought of as being 'traditional' or 'conventional' paint is often synthetic in nature. This may be water or solvent-borne for joinery or vinyl or acrylic emulsions for walls. Of all these, the least harmful choice would seem to be Zero VOC Acrylic Emulsion. However, all synthetic paints are petrochemical derived, toxic during application and entail a high degree of hazardous waste during manufacture. This includes those varieties described as 'water-borne;' which remain non-biodegradable and must be treated as chemical waste. In recent years, acrylic paint has

WHITE PRIMER
PHOTO: PHOTO: DANIEL CASE (WIKIMEDIA COMMONS)

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- **Synthetic Paint Data Sheet**
- **Natural Paint Data Sheet**

become increasingly popular due to it being water based and is often even considered an environmentally friendly option. However, it must be borne in mind that acrylic paint is still a petrochemical product and once dry is effectively a plastic coating.

The alternative would be to specify natural paint. This is a term which covers a range of products. For joinery items, water-borne, plant based paints are available with low toxicity and embodied energy. However, these are unsuitable for external use. A more robust natural paint may be solvent-based. The solvent used is usually turpentine, which is a VOC but is far less toxic than its synthetic counterparts. When considering wall paint, the following alternatives can be considered:

- Mineral paint
- Oil based emulsions
- Distemper or Casein paint
- Clay Paints
- Lime wash
- Linseed Oil paint

The above all have different benefits with some being VOC-free or having extremely low embodied energy. There are limitations with many of them in terms of use, durability and colour range. However, they all are far less polluting than the synthetic alternative and usually are non-toxic. Fuller descriptions of the benefits and drawbacks are given in the appropriate data sheets.

Disposal of paint can be especially problematic. Being a liquid, it is all too easy for unscrupulous contractors to simply pour away or put on a fire. Some manufacturers are now implementing “take-back,” systems where excess paint can be reclaimed and recycled for ingredients in the production process under the guise of **Paint 360.**

While not a widespread or mainstream topic in the UK, in some other countries such as Germany, improving interior air quality by avoiding toxic off-gassing is of concern. PPG, a large paint manufacturer now produces paint which it claims can absorb and “fix” formaldehyde emissions from decorating or building works.

Absorption of toxins is also a characteristic of the Graphenstone range of paints, which are produced from natural materials such as lime and graphene and are claimed to also absorb carbon dioxide.

LINKS

Environmental Impact
https://www.paint360.co.uk/

https://graphenstone.co.uk/

https://www.johnstonestrade.com/product/air-pure

2.22 PLASTIC

PLASTIC LITTER ON THE HAWAIIAN COAST
PHOTO: U.S. NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Plastic is a general term for a wide range of synthetic and semi-synthetic organic solid materials. The noun plastic should not be confused with the adjective plastic which describes a material which undergoes permanent change when subject to strain beyond a certain point. The word plastic is Greek in origin; Plastikos meaning fit for moulding, refers to the state of malleability during manufacture.

Due to their low cost and ease of manufacture, plastics are widely used and have replaced the more traditional materials of stone, ceramic, horn, bone, leather, wood, paper, metal and glass. The use of plastic is constrained by its organic chemistry which determines its hardness, density, heat resistance and resistance to organic solvents and oxidisation. Pure plastics are insoluble in water and relatively inert. Modern plastics contain a variety of toxic additives. For example, plasticisers such as phthalates and adipates are added to brittle plastics to improve flexibility.

Plastic takes hundreds and perhaps even thousands of years to degrade. It is estimated that since the 1950s, one billion tonnes of plastic has been discarded. Plastic does not biodegrade but does photodegrade with exposure to the sun, and then only in dry conditions; the presence of water inhibits this process. This applies even to the supposed 'biodegradable' carrier bags offered by some supermarkets.

In last few years, the effects of plastic waste on the environment have been well publicised. Degrading into tiny shards, termed "microplastics," these particles have been found throughout the environment as well as in food stock and the bodies of new-born babies. In the UK, 37% of all plastic is recycled – or to put it a more realistic way, 63% of all plastic ends up in the environment. This figure is actually quite good in international terms. Globally, we produce about 400 million tons of plastic waste per annum. Only around 9% of that is recycled. Despite the issues of plastic pollution being known about since the 1970's, the early 2000's saw a bigger increase in plastic production during a single decade than at any time within the previous 40 years.

Vast quantities of plastic waste in various stages of decomposition float around in our oceans. This waste collects in 'gyres'; areas of water where currents are at their weakest caused by the coriolis affect. Both the North Atlantic and the North Pacific have ocean gyres that have collected vast amounts of plastic debris; the Sargasso Sea in the North Atlantic and the Great Pacific Garbage Patch in the North Pacific. It is estimated the Great Pacific Garbage Patch contains more than three million tonnes of plastic; each square metre of seawater contains six pounds of plastic compared to 1 pound of plankton. This debris is ingested by marine life and finds its way back into the food chain. Islands such as Hawaii, within the gyres suffer as large quantities of waste end up on their shores. It is thought that 80% of marine debris is blown from land to sea with much being transported by river. As the situation with the oceans has become more widely known, several organisations are now engaged in attempting to clean up the discarded plastic in the pacific by use of various marine technologies. However, the production of plastic continues unabated and is forecast to reach 1,100 million tonnes by 2050. The earth's oceans already are estimated to contain up to 199 million tonnes of plastic.

That is going to take a lot of cleaning up.

BEACH – ACCRA, GHANA
MUNTAKA CHASANT, CC BY-SA 4.0 VIA WIKIMEDIA COMMONS

BEACH – CAPE VERDE
CAPTAINDARWIN, CC BY-SA 4.0 VIA WIKIMEDIA COMMONS

Although the majority of plastic waste in the UK comes from food packaging, the construction industry runs a close second – and appears to be making an effort to "top the league." In October 2021, DEFRA reported that while the UK's overall plastic waste reduced by 2.7% in the two years up to 2018. However, during the same period, the UK Construction industry's amount increased by 46%. And if that period is extended to four years, the increase is in the region of 70%! This largely comes from not only materials packaging but from offcuts and damaged components.

It is interesting to consider the reasons potentially behind the continuing increase. With the drive to create the more efficient thermal envelopes demanded by Building Regulations, many components incorporating a thermal break now use plastic elements – often small and easily discarded.

Of all the materials we have explored in this guide, plastic appears to present the biggest problem.

It is estimated that a modern apartment contains between two and three tons of plastic and that today's plastic consumption is nearly 20kg for every person on earth. Without a huge increase in the

amount of recycling, any plastic products specified in the UK are statistically almost certainly destined to end up in the biosphere.

Produced from petro-chemicals, generally impossible to dispose of completely, highly polluting – and produced in such vast amounts, it's difficult to see how the modern world can continue without it.

- All sea turtle species have plastic in their bodies
- Plastic outnumbers sea life at a rate of 6:1
- 10 million tonnes of plastic are added to the sea every year
- 100,000 marine mammals every year die as a direct result of plastics

In the UK specifically:

- For every 100 metres of UK beach, there are 718 pieces of rubbish

LINKS

Plastic waste and recycling
https://www.bpf.co.uk/Sustainability/Plastics_Recycling.aspx

http://www.sustainabilityguide.co.uk/2018/02/05/recyclable-plastic/

https://www.statista.com/topics/4918/plastic-waste-in-the-united-kingdom-uk/#topicHeader__wrapper

BEACH - SINGAPORE

PVC

Not all plastics are the same. One of the most widespread is PVC (Polyvinyl Chloride). This is also one of the most controversial types, incorporating as it does hazardous ingredients and by-products:

Chlorine - PVC consumes about 40% of total chlorine production, or approximately 16 million tons of chlorine per year worldwide. PVC is the only major building material that is an organochlorine; alternative materials, including most other plastics, do not contain chlorine. Chlorine, in addition to being highly toxic (used as a poison gas in World War One) is energy intensive to produce in a process which often allows the release of mercury into the environment.

Dioxins - Among the most important by-products of PVC are dioxins or dioxin-like compounds. Dioxins are never manufactured intentionally but are formed accidentally whenever chlorine gas is used or chlorine-based organic chemicals are burned or processed under reactive conditions. Dioxin is a potent carcinogen with no known safe dose.

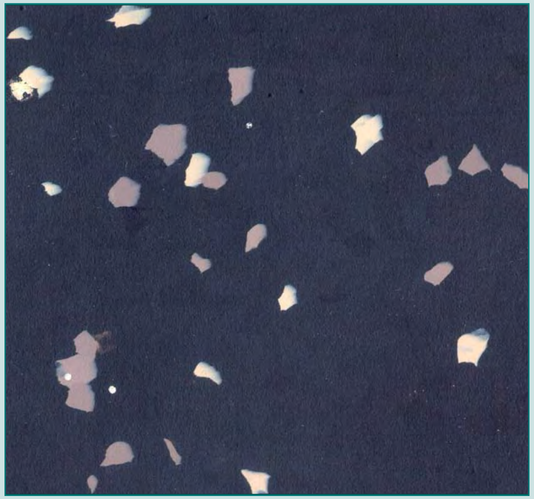
Phthalates - Phthalates are organic chemical compounds produced from oil, which can leach from everything that contains plastic into the immediate environment. Phthalates are present in higher concentrations in cities than in rural areas and have been found in deep sea jelly fish and the Arctic ice cap. PVC is a predominant material in food packaging; Phthalates leach out of the material and into the food stuffs we consume and through us back into the waterways. In addition, when plastics age and break down, the release of Phthalates accelerates. Phthalates are subject to photochemical and biological degradation in the outdoor environment but are present in every corner of our world. Plasticisers evaporating can be recognised by the 'new car smell'. 90% of all Phthalate production is used in PVC with the remaining 10% used in rubber products, paints, printing inks, adhesives, lubricants, some cosmetics, baby milk formula, cheese, margarine and crisps.

The effects of all this on our environment are controversial and the topic of much discussion. It is generally thought that exposure to phthalates affects hormone levels and has adverse effects on aquatic and invertebrate life, (turning men fish into lady fish). However the Phthalates website argues that extensive laboratory testing has not proven they cause cancer in humans and this is accepted by the International Agency for Research in Cancer. In addition, the relationship of Phthalates to fertility in humans and animals has undergone extensive tests and as yet is not confirmed. It is acknowledged that Phthalates can accumulate in simple aquatic organisms but that higher organisms such as fish can break them down without apparent harm; this is not quantified further. The site acknowledges that one form of phthalate ester (DINP) is mildly oestrogenic but has little effect on the environment. Available information is conflicting.

LINKS

PVC & Phthalates
https://healthybuilding.net/reports/7-healthy-environments-whats-new-and-whats-not-with-pvc

https://ec.europa.eu/environment/pdf/waste/pvc/en.pdf



A MIXTURE OF BEIGE AND DARK GREY COFFEE CUP WASTE
PHOTOS: SMILE PLASTICS WWW.SMILE-PLASTICS.CO.UK

MELTED SQUASHED WELLINGTON BOOTS
PHOTOS: SMILE PLASTICS WWW.SMILE-PLASTICS.CO.UK

RECYCLED PLASTICS

The permanent nature of plastic means that recycling is one of the few options available as a long term solution to its continued presence in the environment. Not every type of plastic can be recycled and unlike drink cartons, which are collected on an industrial scale, the use of recycled plastics in buildings is almost still at the cottage industry level. Rigid sheets are produced for use in a variety of applications such as cladding, partitioning or furniture. The PVC industry is making efforts to increase the amount of recycled material in its products. There are now several recycling plants in the UK which process old uPVC into granular pellets for re-use. Veka have a plant dedicated to window systems and provide such pellets for re-use in window and door frames. Recycled PVC window systems are not 100% re-used material but are usually faced with virgin material. At present, it is claimed that PVC can be recycled into new windows up to 10 times. Veka's website points out that with an average lifespan of 30-40 years for individual windows, this could mean that the material itself could possibly last up 400 years! How the number of times it has been recycled is tracked or what happens to the material after that is left unclear.

Other plastics may not be able to be recycled for similar use and may only end up being 'downcycled'. For instance, plastic bottles very rarely end up being recycled into more plastic bottles but may end up as one of a number of secondary products such as duvet fill or garden furniture. The variety of plastics present a problem in recycling as these generally have to be sorted by hand, which is time-consuming and expensive.

Plastic production in Britain is current about 4.9million tonnes per annum. Of this, approximately 3.6million tonnes becomes waste. This is an increase of over half-a-million tonnes since 2010 and maintains the UK's position as the world's second largest producer of plastic waste.

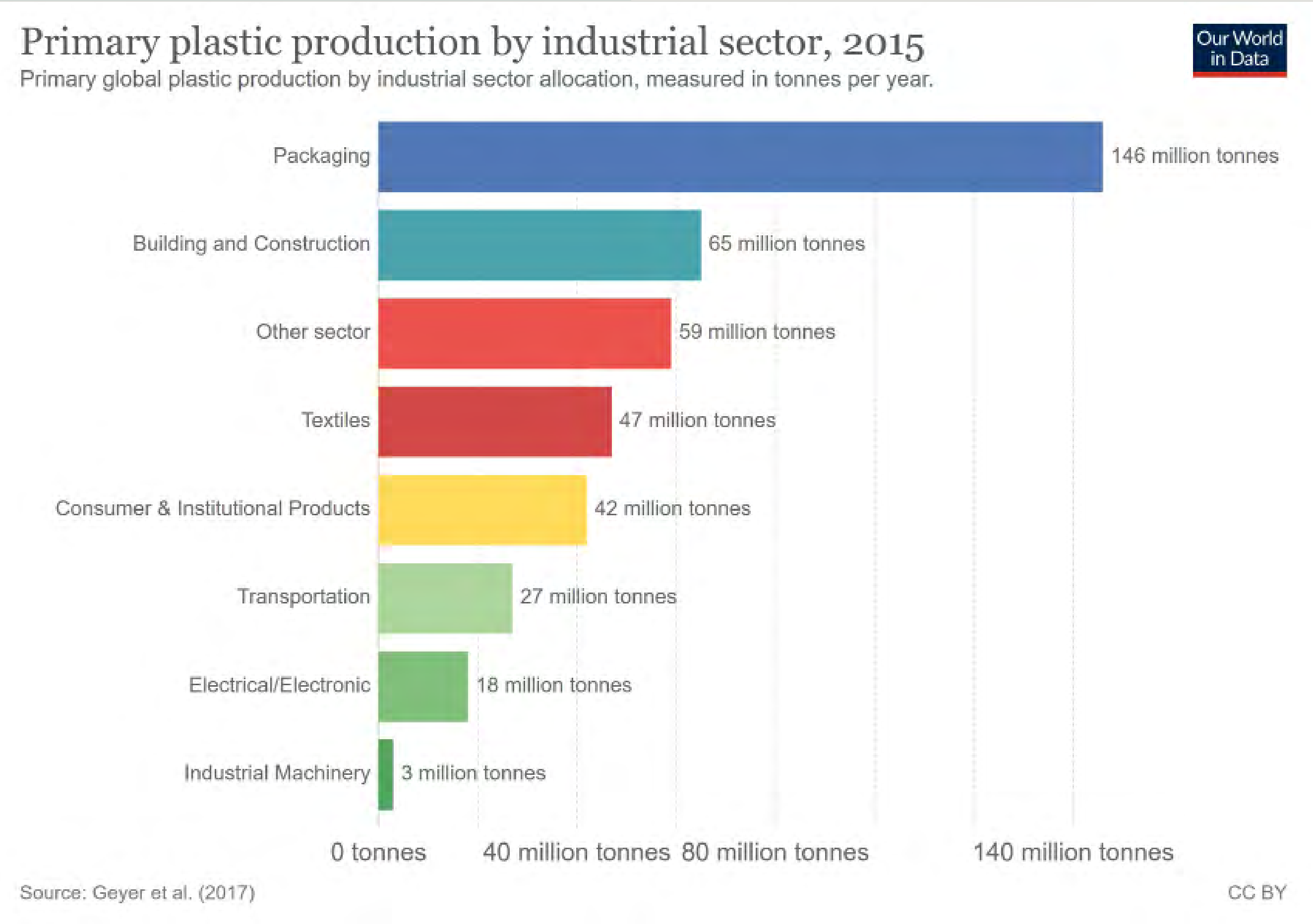
You may read that the UK recycles over 44% of its plastic packaging waste. However, this is somewhat disingenuous in that about half is incinerated for energy, 25% goes to landfill – and just 12% goes to UK recycling facilities, the rest being shipped abroad to overseas recycling facilities. (Usually with very little tracking or regulation to ensure the outcome). Without a huge increase in the amount of recycling, any plastic products specified in the UK are statistically almost certainly destined to end up in the biosphere.

LINKS

Recycled plastic supply
http://www.smile-plastics.co.uk/

http://www.recovinyl.com/

https://veka-recycling.co.uk/upvc-recycling/



JENNA R. JAMBECK, ROLAND GEYER, CHRIS WILCOX, THEODORE R. SIEGLER, MIRIAM PERRYMAN, ANTHONY ANDRADY, RAMANI NARAYAN, KARA LAVENDER LAW, CC BY 4.0 VIA WIKIMEDIA COMMONS

BIOPLASTICS

The toxic nature of many of the constituent ingredients of conventional plastic, particularly PVC when used in children's toys, has led to manufacturers exploring alternatives produced from organic sources rather than petrochemicals. These sources may consist of polymers produced from plant sugars or even genetically modified micro-organisms. Although produced by, at first glance, a more environmentally sustainable process than that normally employed through the use of petrochemicals, bioplastics still suffer from the same range of environmental problems associated with many conventional plastics. Although not uniform in nature, they may be non-degradable, non-recyclable and contain toxic plasticizers just as harmful to the environment as petrochemical plastics.

LINKS

Bioplastics
https://biomebioplastics.com/

https://ensia.com/features/bioplastics-bio-basedbiodegradable-

environment/

https://en.wikipedia.org/wiki/Bioplastic

http://www.european-bioplastics.org/

CLICK HERE TO VIEW

- **Plastics Data Sheet**
- **UPVC Windows Data Sheet**

SIPS PANELS BEING ERECTED IN A DOMESTIC SITUATION
PHOTOS COURTESY SIPS UK LTD.

2.23 PREFABRICATIONS

The prefabrication of elements off-site offers great advantages in construction time and building performance. Often referred to as "Modern Methods of Construction" or 'MMC', this may range from the manufacture of individual elements or panels to whole building systems which vastly reduce the amount of time spent on site.

SIPS

One of the most common instances of prefabricated elements is the Structurally Insulated Panel System (SIPS). These are generally timber faced panels laminated onto insulation cores (often SBS polyurethane.) The timber may be in the form of softwood planking, OSB or in North America plywood may be more common. The laminated nature of SIPS allows them to perform a load bearing function either in an external wall or a roof. In the latter case, this may enable the omission of any structural members, thereby reducing materials, complexity and facilitating a room-in-the-roof approach for housing. SIPS are often the core element of MMC building systems, particularly housing packages such as Huf Haus, Griffner Haus and Becker-Haus.

MODERN METHODS OF CONSTRUCTION

Generally speaking, MMC systems fall in to the following general categories:

- Volumetric construction: where the whole dwelling is prefabricated off site in modules which are then assembled on site. Modules may be constructed in a variety of forms from a basic structure to fully finished and serviced units.
- Panelised construction: where flat panels are produced off-site and assembled on site to produce a three-dimensional structure. The most common approach is to use open panels, consisting of a skeletal structure. Closed panels involve more prefabrication typically including lining materials and insulation. Services, windows, doors, internal finishes and external cladding may also be incorporated.
- Hybrid: a method also referred to as semi-volumetric that combines both the panelised and volumetric approaches. Typically, volumetric units are used for highly serviced areas such as kitchens and bathrooms (sometimes referred to as "pods") and the remainder of the dwelling or building constructed using panels.

These systems may be based around a variety of technologies such as SIPS or as in the case of Mod-Cell, straw bale panels assembled on site.

The advantages behind all these systems are:

1. Far less time spent on site results in a far lower carbon footprint for the construction process. As some packages can be erected from foundation to being weather-tight within 15 days, this remains true even if the panels are being imported from Germany (as they usually are).
2. High levels of insulation and far greater airtightness are achievable due to the units being produced in factory conditions with their attendant QA procedures.

SIPS PANELS BEING ERECTED IN A DOMESTIC SITUATION
PHOTOS COURTESY SIPS UK LTD.

CLICK HERE TO VIEW

- **SIPS Data Sheet**

However, for many years MMC has been promoted almost as a panacea solution to many problems of quality and sustainability. This has not always proved to be the case in that there have been very real cases proving that the erection of modular elements requires just as much care and professionalism as traditional materials.

A further warning has also been sounded by some demolition contractors that MMC elements are effectively composites which are very hard to reclaim for either recycling or re-use. So while reducing the embodied carbon footprint of a building, they can also cause a problem due to very limited end-of-life options.

LINKS

National Audit Office report on Modern Methods of Construction in Housing
https://www.nao.org.uk/report/using-modern-methods-of-construction-to-build-homes-more-quickly-and-efficiently/

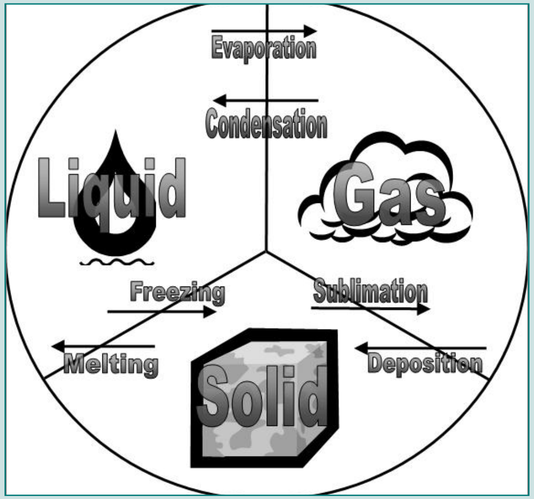
https://www.nhbcfoundation.org/wp-content/uploads/2018/11/NF82.pdf

SIPS General
https://www.sipsindustries.com/

http://www.sips.org/ (US website)

https://www.sips.uk.com/

2.24 PHASE CHANGE MATERIALS



DIAGRAMMATIC DESCRIPTION OF THE PHASE CHANGE PROCESS
PHOTO : WIKIMEDIA COMMONS : M.MANARY

WATER BECOMING ICE IS AN EXAMPLE OF PHASE CHANGE
PHOTO: WIKIMEDIA COMMONS (OPENPHOTO.NET): DARREN HESTER

CLICK HERE TO VIEW

- **PCM Data Sheet**

Often, heavyweight materials such as concrete are described as having 'Thermal Mass.' This usually describes how, during the warmest part of the day, heat can be absorbed by the material and then re-radiated a number of hours later. Exploitation of this property can help to regulate the internal temperature of a building by aiding a passive heating and cooling strategy in a temperate climate. Re-radiated heat can be dissipated by ventilation for night cooling (usually in the case of commercial buildings) or used to provide background evening heat in a domestic environment. The thermal inertia of heavyweight materials can mimicked to some extent by a group of substances known as 'Phase Change Materials; or 'PCM' for short.

PCM's work by absorbing external heat and storing it by altering their physical state. Therefore, a PCM may exist as a solid below 23°C but once the external temperature rises above this, the material may liquefy, enabling it to act as a heat sink. Once the temperature drops below this, the PCM will solidify and the stored heat will be re-radiated. Hence the thermal performance of the PCM is actually governed by temperature rather than across a time period as would be the case with true thermal mass. PCM's exist in a variety of forms and have been used outside of the construction industry for some time. The type normally used in building materials are often based on paraffin wax contained by a carrier medium.

Manufactured as proprietary products, PCM's are available as a building board for use in lieu of gypsum plasterboard or as loose bagged material which can be installed in voids or be incorporated in a structural material such as plaster or aerated concrete blocks. The board material can incorporate aluminium sheet and requires care when cutting or can be a variation on gypsum plasterboard. How these products compare to traditional plasterboard in terms of embodied energy is unknown. Similarly, it is unclear whether PCM board could be recycled.

The advantage of PCM's over heavyweight thermal mass is that they can be applied to lightweight structures such as timber frame buildings rather than depending on the actual fabric of the building to act as an environmental modifier as would be the case with using concrete. However, PCM's do introduce further chemicals in to the built environment which may ultimately be derived from petrochemicals.

LINKS

Technical Information
https://www.pcm-ral.org/pcm/en/pcm/

http://en.wikipedia.org/wiki/Phase_Change_Material

https://irp-cdn.multiscreensite.com/e3960383/files/uploaded/2014%20K%20Phase%20change%20materials.pdf

Products
http://www.pcmproducts.net/home.htm

http://www.edsl.myzen.co.uk/downloads/misc/DuPont%20ENERGAIN(r)%20PCM%20Guidebook_December%202010.pdf

https://cdn2.hubspot.net/hubfs/4153344/Microtek%20Laboratories%20December2017/PDF/MPDS3300-0044%20Rev%201.pdf?t=1516975227818

EPDM FOIL
PHOTO : WIKIMEDIA COMMONS : KVDP

A FINISHED EPDM ROOF
PHOTO: WIKIMEDIA COMMONS : KVDP

2.25 ROOFING MEMBRANES

Roofing membranes extend in type and composition from the long-serving bituminous felt seen on thousands of domestic porches through to innovative specialist products laid on large warehouses. Unfortunately, flat roofs are often seen as a 'cheap option' and accordingly, inexpensive materials are selected as the waterproof finish. This inevitably results in a correspondingly low performance and life span which has informed the public's perception of flat roofs as being unfit for purpose.

Membranous products, however can be used not only on flat roofs but on more unusually shaped structures where more rigid or traditional roofing materials would be unsuitable. They can therefore open up a wider range of architectural options.

Although an extensive area, roofing membranes can be generally described in the following categories:

- Built-up systems
- Single ply systems
- Liquid applied systems

(Previous revisions of this guide listed "Concrete Membranes," as a fourth category. However, this specialised and little used material was only available through Krete Sustain Ltd, who have now ceased trading).

BUILT-UP SYSTEMS

These generally consist of bituminous felts laid in up to three layers on a separating membrane. A wide variety of felts are available with most now being modified by the inclusion of a polymer to improve performance. The base felt may be a variety of materials ranging from glass fibre to polyester based materials. This base material will inevitably be a product of the petrochemical industry. The bituminous compound itself will also be an oil-based product. Built up felts are unrecyclable and unreusable. BRE Green Guide ratings range from C to A+.

SINGLE PLY MEMBRANES

Originally mainly used on large commercial buildings but now available on a domestic scale, membrane coverings are very popular in North America and Europe (where they often are found on warehouses which in the UK would probably be steel clad) single ply systems are generally petrochemical derived plastic-like products. They can be thermoplastic, elastomeric or PVC. They may be classed as plastics or synthetic rubbers (such as EPDM). The first two are largely unrecyclable but they potentially can be re-used if previously been fixed by mechanical means. However, many are bonded or welded by either heat or by adhesives (which may in-turn be petrochemicals). As crude oil products, single ply membranes can be associated with the pollution and high embodied energies common to such processes. Some PVC membrane suppliers provide recycling schemes but it should be borne in mind that PVC is often considered to have the greatest adverse impact of plastic products. All single ply membranes have a lifespan which is substantially longer than built up systems. BRE Green Guide ratings vary, depending on the specific build-up but A+ is possible.

There are five main types of Single Ply roofing membrane available in the UK. They are:

1. PVC (Poly Vinyl Chloride)
2. EPDM (Ethylene Propylene Diene Monomer)
3. TPO (Thermoplastic Polyolefin)
4. TPE (Thermoplastic Polyolefin Elastomer) and
5. PIB (Polyiso Butylene)

Of the above, EPDM is often considered the most environmentally friendly with a low GWP, high durability and being easily recycled. (Although in truth, this looks more like "downcycling").

TPO is partially recyclable with a lower environmental impact than PVC and TPE is an improved (supposedly) 100% recyclable version.

Issues of sustainability regarding these petro-chemical products have been tackled to some extent in recent years with attempts by the industry to provide a viable recycling programme designed to collect membranes from demolition sites. This has been driven and popularised by the European Single Ply Waterproofing Association (see link below).

LIQUID APPLIED MEMBRANES

Asphalt roofing may be included in this category but as a material is dealt with in a separate section in this book. Beyond this relatively traditional material, there is a wide range of liquid applied systems available. These are usually proprietary and are usually cold applied by brush, roller or spray. The material itself is almost universally a petrochemical. Spray application of course allows the risk of introducing the substance to the environment by windborne pollution. Usually applied in more than one layer and sometimes with a carrier or base layer sheet, liquid systems are particularly suitable for complex forms but are necessarily dependent on high standards of workmanship. BRE Green Guide ratings are unknown.

LINKS

General
https://www.buildingcentre.co.uk/news/articles/comparing-single-ply-roofing-membranes

Single Ply Roofing Association
http://www.spra.co.uk/

Recycling
https://www.eswa-synthetics.org/

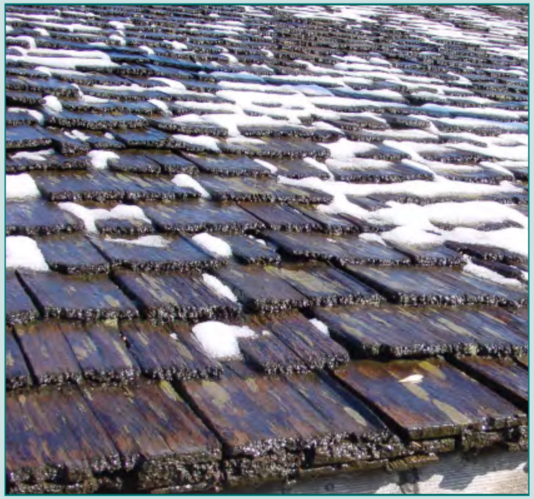
EPDM
https://www.rubber4roofs.co.uk/blog/10-reasons-why-epdm-rubber-roofing-is-the-most-eco-friendly-roofing-system

https://classicbond.co.uk/sustainability-of-epdm/

TPO / TPE
https://ravagobuildingsolutions.com/rs/wp-content/uploads/sites/41/2020/11/flag-tpo-safety-and-environment-en-2020.pdf

CLICK HERE TO VIEW

- **Roofing Membranes - Synthetic Rubber Data Sheet**
- **Bitumen Data Sheet**
- **Concrete Data Sheet**
- **Plastics Data Sheet**


TIMBER ROOFING SHINGLES
PHOTO: CAMSTER 2 (WIKIMEDIA COMMONS)


NATURAL SLATE IS COMMON ON MANY EUROPEAN HISTORIC BUILDINGS
PHOTO: PHOTOS.COM

2.26 ROOF TILES

Tiles are one of the oldest forms of vernacular roofing products. They can be completely natural products, quarried from mineral deposits and hewn into flat shapes (commonly called 'slates'), moulded and fired clay modules shaped into tiles of various shapes, or completely manufactured from materials such as concrete, fibre cement, bituminous felt etc. In addition to these, timber can be use d to produce shingles or shakes as the ultimate in sustainable roofing material. In addition to the concerns of embodied energy and source of the raw materials, weight is an important consideration. Heavier roofing materials will demand heavier structures to support them. A heavier structure will invariably involve a larger carbon footprint. However, the environmental and financial cost of a heavier structure may be considered and offset against the benefits which may accrue through exploiting its thermal mass for climate control. Roof tiles in domestic design are capable of gaining either an 'A' or 'A+' rating under the BRE Green Guide to Specification regardless of their type or composition.

TIMBER

Timber can be used to form tiling materials referred to as either shingles or shakes. Shingles are sawn and worked to a smooth finish while shakes have a rough split face. The environmental impact of timber shakes and shingles is very low if UK grown timber is used. However, the common material for shingles and shakes is Western Red Cedar imported from North America where it is a very common roofing material, especially in the western states. Specifying imported timber will add considerably to the embodied energy of the product. Care should be taken with regard to fire risk and the acidic run-off from certain species.

NATURAL SLATES

Slates are hewn or riven from naturally formed geological material. The most common variant is commonly termed 'blue slate' which in the UK is quarried in the upland areas of Wales, Cornwall and Cumbria. Until the advent of the railways, slate was a purely locally used material. However, with the advent of the industrial revolution, production expanded to roof most of Britain's 19th century cities. Although low in embodied energy, slate generates a huge amount of industrial waste which has completely altered the landscape of parts of Wales. Natural reserves of blue slate are becoming evermore limited in the UK, resulting in it becoming a prestige material with attendant high costs. As a result of this, in recent years competitor slates have been imported from Spain, India and even China. Importing these materials results in a vastly inflated carbon footprint. Also, extreme care should be exercised in their specification, as not every foreign variant is of equal quality to the indigenous variety, with some not being suitable for long term exposure to the British climate. Blue slate is a sedimentary material which can be formed into relatively thin lightweight units. Another form of slate is the stone or 'Grey' slate which is again a vernacular material traditionally used in upland areas. Usually produced from sandstone, it is rarely used outside its traditional range. Despite being a product of quarrying, the waste associated with stone slate is far less than with blue slate. However, stone slates are far thicker and heavier than the blue type demanding a far stronger roof structure. The cost of natural slate has led to a demand for artificial alternatives. These exist in a wide variety of manufactured forms, ranging from cement based products to ones which use the reconstituted waste product from quarrying. The BRE's comparative environmental assessment between slate used for flooring and that for roofing appears to be

THE DELABOLE SLATE QUARRY IN CORNWALL
PHOTO: LYNDA POULTER (WIKIMEDIA COMMONS)

NATURAL CLAY ROOFING TILES CLAY TILES
PHOTO: PHOTOS.COM WEBSITE

CLICK HERE TO VIEW

- Roof Tiles 01 - Timber Data Sheet
- Roof Tiles 02 - Slates Data Sheet
- Roof Tiles 03 - Clay Tiles Data Sheet
- Roof Tiles 04 - Artificial Data Sheet
- Stone Data Sheet

quite extreme despite their being won in practically the same manner. This is covered further in the Stone section below. Natural slates are very durable and highly robust with a potential lifespan of over 100 years. As this may often exceed the lifespan of a building, there is an established market for second hand reclaimed slates. These are a very low embodied energy solution.

CLAY TILES

Clay tiles are an extremely widespread and long established vernacular material. Although not as durable as slate, there is also a market for second-hand units. Material reserves are relatively plentiful and non-toxic. However, compared to quarried or grown products, the embodied energy of clay tiles can be quite high due to the firing process. This environmental footprint can be controlled to some degree by selecting a local source in order to reduce the transportation impact. The embodied energy of clay tiles can be mitigated further by reuse of second hand tiles. There is quite a lucrative market for reclaimed clay tiles and accordingly they may be expensive. However, re-used tiles will have an extremely low embodied energy content.

ARTIFICIAL TILES & SLATES

The cost of natural slates and tiles has led to the increasing popularity of manufactured substitutes. These are mainly produced from a cement / concrete based material but may also be produced from fibre-cement. They may be shaped into tile-like forms such as bold-roll or double roman or may be produced as slates. Most are interlocking unlike natural slates which require a double lap meaning that fewer are required to cover a given roof area.

Some artificial slates are produced ‘raw’ to look like concrete but many are shaped and used as the basis of inexpensive substitutes for natural slates. In traditional stone slate areas, plain concrete slates are often accepted by local authority development control instead of natural slates due to their bulky nature and potential to be coloured to mimic sandstone. Similarly, there are ersatz clay tile substitutes made to fulfil the same role. Although cheap and easy to lay, concrete based products have a lower life expectancy (around 50-60 years) and require a much heavier structure as support. However, they often have a relatively low embodied energy content which may be far less than natural clay tiles. Fibre cement alternatives are often specified as an alternative to blue slate but have a far reduced lifespan (20-30 years) and a degree of toxicity involved in their manufacture. Artificial substitutes for stone or blue slate also exist in the form of ‘reconstituted’ products. These generally use discarded or recycled waste material from the original product and mix it in a powdered form with a resin binder. Although incorporating a greater number of chemicals within the resinous binder, the embodied energy of such products is quite low.

All artificial slates and tiles can be reclaimed and reused but in practice very rarely are and more often than not may be reduced to rubble to be used as fill etc.

LINKS

General Information
https://whc.unesco.org/en/list/1633/pdf?t=1516975227818

https://en.wikipedia.org/wiki/Slate_industry_in_Spain

2.27 RUBBER

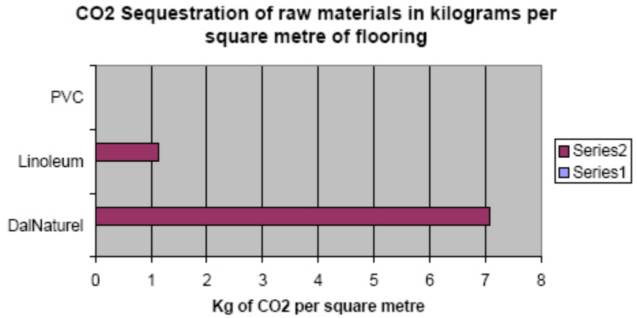
RUBBER TREES BEING TAPPED ON A PLANTATION PHOTO: JOE ZACHS (WIKIMEDIA COMMONS)

CLICK HERE TO VIEW

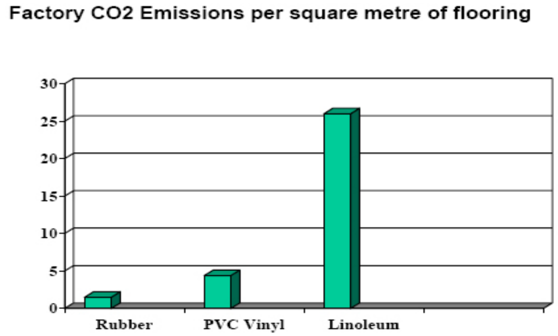
- **Synthetic Rubber Flooring Data Sheet**

Natural rubber is the coagulated juice of the rubber tree and was first used in the west in the late 18th Century. However, since World War Two, natural rubber has been largely superseded by synthetic rubber which is a petrochemical by-product. Rubber flooring tends to be Styrene-Butadiene-Rubber (SBR) while Butyl Rubber (also known as PIB), Polyisobutylene, EPDM, Ethylene Propylene Diene Monomer and Chlorosulphonated Polyethylene (CPE) are all synthetic rubbers used widely in the construction industry for seals, roofing membranes etc.

However, while synthetic rubber car tyres can be recycled, many of these artificial rubber products such as EPDM are not at present. In addition, their artificial origin causes them to suffer from the same high embodied energy and chemical off-gassing as many other petrochemical derived products. Natural rubber flooring was available up until a few years ago in the UK but now seems to have disappeared from the marketplace. It continues to be available in in some countries surrounding the Pacific basin. Given the location of agricultural production of the raw material, this probably shouldn't be surprising. Natural rubber is however still a primary ingredient of various floor coverings, albeit combined with artificial or petro-chemical derived products. In the UK an Italian version is still available which minimises additional ingredients during the production stage and so exhibits quite strong sustainable credentials.especially when one considers that these plantations are usually in rain forest areas which are under pressure from agricultural development already.



GRAPH COURTESY OF DALSOUPLE: HTTP://WWW.DALSOUPLE.COM/COMMERCIAL-DALNATUREL.PHP



GRAPH COURTESY OF DALSOUPLE: HTTP://WWW.DALSOUPLE.COM/COMMERCIAL-DALNATUREL.PHP

LINKS

General Information
http://en.wikipedia.org/wiki/Synthetic_rubber

https://www.designingbuildings.co.uk/wiki/Rubber_flooring

https://dalsouple.com.au/about-us/

https://www.artigo.com/it-all-begins-with-rubber/

2.28 SEALANTS, ADHESIVES & FILLERS

ECOSEAL COMPRESSIBLE FILM PACKAGING COMPARED TO RIGID TUBES
PHOTO : GEOCEL LIMITED

ECOSEAL SUPPLIED IN FILM 'SAUSAGES' FOR USE IN A RE-USABLE TUBE
PHOTO GEOCEL LIMITED

Sealants, adhesives and fillers make up a relatively small proportion of materials used in construction. However, overall they are a widespread and essential component of modern buildings. With the advent of energy consumption as a key driver in sustainable building design, air-tightness has assumed an important aspect of this function. An air-tight building is difficult to create without the copious use of sealants at critical junctions in the building fabric. Therefore sealant manufacturers often use this fact to advertise their products as essential to a 'green' design. Indeed, it is difficult to see how modern low-energy buildings could actually be created without the use of sealants. However, despite their essential role in reducing energy use, sealants have three main areas of environmental impact:

1. Chemical composition;
2. Packaging;
3. Disposal and recyclability.

CHEMICAL COMPOSITION

Sealants (along with fillers and adhesives) can consist of a variety of chemicals including, silicones, butyls, urethanes and a variety of polymers. Although alternatives are occasionally available, mostly these will be of petrochemical origin. As such, they will suffer from high embodied energies and will be the product of industrial processes which are not only highly polluting by their nature but are derived from non-renewable resources. In the past, sealants would have incorporated a substantial amount of VOC's in their make-up. However, recent legislation has ensured that the this has reduced. In the USA, both legislation and the LEED environmental accreditation scheme governs the amount of allowable VOC's in sealants, adhesives and fillers. This has resulted in many American sealants being promoted as 'green' by virtue of their complying with these factors. Typical values for adhesive products sold in less than 16oz containers are shown the table below:

PRODUCT CATEGORY	VOC % BY WEIGHT
Construction, Panel, & Floor Covering	15%
Caulks & Sealants	4%
General Purpose Adhesives	10%
Contact Cements (General Purpose) - includes 1 gallon	55%
Contact Cements (Special Purpose)- includes 1 gallon	80%

Generally speaking, in the USA, products which conform to the above values can be described as being "green". (Even the final category.) No similar degree of guidance seems to exist under BREEAM other than credits being available for solvent free or 'low-emission' products. Very little information is available regarding the environmental impact or assessment of sealants in the UK.

RECENT SUSTAINABLE DEVELOPMENTS

The adhesives and sealants industry has, over the last decade or so, come to realise that efforts towards sustainable products will be necessary to maintain markets increasing dictated by government legislation.

In 2011, **"Together for Sustainability," (TfS)** was formed as a chemical industry organisation to "assess, audit, and improve sustainability practices within global supply chains" and in early December 2021, The Freedonia Group published a report describing the growing impact of the environment on the industry.

There are several key areas where manufacturers are exploring and developing new products to meet the demands of low environmental impact:

- Recyclable and recycled adhesives
- Biodegradable adhesives
- Compostable adhesives
- Repulpable adhesives
- Renewable and biobased adhesives

PACKAGING

Packaging is one of the main areas where sealant manufacturers have made efforts to render their products more environmentally friendly. Many sealants are supplied in plastic application tubes and by the very nature of the product, these end up contaminated by a sticky chemical after use and are therefore difficult to recycle. Some suppliers have made advances in using a large percentage of recycled material in their packaging and replacing plastic with card based alternatives. The traditional tube has in some cases been replaced by lightweight film which has less environmental impact both in production and disposal.

DISPOSAL AND RECYCLABILITY

Sealants, adhesives and fillers by the nature of their application are are usually unrecyclable. At demolition, it is likely that they will be disposed of as part of the element to which they are adhered. As sealants are likely to contain VOC's these present a threat to the biosphere if allowed to enter the environment.

LINKS

The Sustainability of Sealants
https://www.geocel.co.uk/brands/ecoseal/

https://www.freedoniagroup.com/brochure/43xx/4301smwe.pdf

https://fastenerengineering.com/a-climate-of-change-the-demand-for-more-sustainable-adhesives-and-sealants/

https://www.adhesiveplatform.com/sustainability-of-adhesives-and-sealants/

CLICK HERE TO VIEW

- **Sealants Data Sheet**

2.29 SHEET METALS

COPPER ROOFING
PHOTOS.COM WEBSITE

CAPTION TIN CAN
PHOTO: DONAR REISKOFFER (WIKIMEDIA COMMONS)

COPPER

Copper is extracted from copper ore, the mineral chalcopyrite, from mines in Ontario, the Andes and South Australia. Copper was first discovered in its natural form in the Middle East about 9000BC. It was the discovery and experience of smelting copper which developed the knowledge required for the smelting of iron.

Copper resists corrosion through the formation of a natural protective layer, its surface reacting with water and oxygen to form brown/black copper oxide. Old copper is often seen with a green layer of copper carbonate called Verdigris, this term is applied to the green coating that covers copper, brass and bronze after exposure to air and/or seawater. This green coating is due to a process called 'patination'. Although occurring naturally over time, factory produced pre-patinated copper is now available. Other surface treatments are available including pre-oxidised copper which has a dark brown rather than shiny appearance.

Copper can have up to 80% recycled content due to its high scrap value and longevity. Copper is alloyed with zinc to make brass.

LEAD

Lead in its metallic form does occur in nature, but it is rare. Lead is usually found in ore with zinc, silver and (most abundantly) copper, and is extracted together with these metals; the main lead mineral is galena (PbS). Lead has long been an exceptional product for waterproofing; it is soft, malleable, and recyclable. Lead forms a patina of lead oxide when exposed to oxygen protecting the metal from further oxidation.

Production and consumption of lead is increasing worldwide. Total annual production is estimated at 8 million tonnes; about half is produced from recycled scrap. Top lead producing countries, as of 2008, are Australia, China, USA, Peru, Canada, Mexico, Sweden, Morocco, South Africa and North Korea.

Lead is the end product of a complex radioactive decay and together with its compounds is dangerous to human health (in short poisonous!) and should never be used in connection with food or water sources. At current rates lead supplies are estimated to run out in approximately 40 years.

TIN

Tin is smelted from cassiterite, a mineral found in hydrothermal veins in granite. Due to its low toxicity tin plated metal is used in food packaging – hence the name tin can. Tin cans are made of tin coated steel but cans are also made of aluminium and other metals. Copper is alloyed with tin to make bronze. Pewter is an alloy of tin, copper and lead.

ZINC

Rolled zinc is 100% recyclable. In Western Europe more than 90% (around 100,000 tonnes) of old rolled zinc is effectively recovered and reused in different applications each year. Zinc's typical lifespan can exceed 100 years, which is exceptional for a roofing material. This is due to its self-protecting patina developed as a consequence of exposure to oxygen, carbon dioxide and water in the air.

Zinc is also the basic constituent of galvanising. Although this is an energy intensive chemical process associated with possible toxic run-off to watercourses, it should be

CURVED ZINC ROOFING
PHOTO: KVDP (WIKIMEDIA COMMONS)

considered in the context of the alternatives. Galvanising is a more sustainable solution than steel coated with a plastic based material (see 'Plastics') and will offer a 60 year lifespan without any intermediate painting. Paint is a further chemical with its own issues of toxicity and embodied energy.

COMPARISON OF COPPER, LEAD & ZINC

Both copper and lead are very traditional building materials. However, both have relatively high amounts of embodied energy. A realistic comparison between these materials is very hard to come by. The VMZinc website states:

"Compared with other metals, very little energy is needed to manufacture zinc metal from ore - less than half the energy consumption of copper and stainless steel and less than a quarter of that used for aluminium. CO_2 and greenhouse gas emissions are, therefore, proportionally less."

This statement is supported by reference to VM Zinc's own EPD certificate and gives these comparative embodied carbon figures:

	ORE TO MATERIAL	RECYCLED MATERIAL TO METAL
Zinc	50 MJ/Kg	12 MJ/Kg
Copper	105 MJ/Kg	43 MJ/Kg

Of course the actual material used in construction components is likely to be a mix of raw and recycled. Therefore these figures probably do not represent the most likely scenario to be encountered

As if to confuse matters further, the Inventory of Carbon & Energy (2011 version) originally from the University of Bath and now published under BSRIA gives the following embodied energy figures:

	ORE TO MATERIAL	RECYCLED MATERIAL TO METAL	TYPICAL PRODUCT WITH PARTIAL RECYLED CONTENT
Zinc	72 MJ/Kg	9 MJ/Kg	53.1 MJ/Kg
Copper	57 MJ/Kg	10 MJ/Kg	16.5 MJ/Kg
Lead	49 MJ/Kg	25.21MJ/Kg	10 MJ/Kg

While the Centre for Building Performance Research at New Zealand's University of Victoria lists the following figures:

- Copper – 70.6 MJ/Kg
- Lead – 35.1 MJ/Kg
- Zinc – 51 MJ/Kg

THE STATUE OF LIBERTY – POSSIBLY THE WORLD'S BEST KNOWN COPPER CLAD BUILDING
PHOTOS.COM WEBSITE

It may be that lead and copper use a far greater weight of material over the same area to do a comparable job to zinc sheet. (Consider the difference in thicknesses between lead and zinc flashings).

In any case, all three metals would seem to be high users of energy in their manufacture. The main difference with zinc is that rainwater run-off from it is far easier to harvest for reuse. Lead's toxic qualities are well known and it is therefore not used for potable water anymore. Copper becomes toxic in sufficient quantities and it is recommended that run-off from copper surfaces is not harvested for consumption. This is somewhat disturbing when one considers the amount of water probably delivered to the UK's houses by copper pipe!

All three of these primary ores are finite resources with limited virgin stocks remaining in the world. This is particularly true of zinc and copper which are forecast to be exhausted by the middle of this century.

PRACTICAL APPLICATIONS

Roofing, Rainwater goods, Flashings, Cladding, Protective coating to other metals

LINKS

Tin
https://en.wikipedia.org/wiki/Tin

Copper
http://en.wikipedia.org/wiki/Copper

https://copperalliance.org/regional-hubs/europe/

Lead
http://en.wikipedia.org/wiki/Lead_ore

https://ila-lead.org/

Zinc - Sustainability
http://www.vmzinc.co.uk/build-zinc-systems/zinc-and-sustainable-development.html

http://www.victoria.ac.nz/cbpr/documents/pdfs/ee-coefficients.pdf

https://sustainability.zinc.org/

CLICK HERE TO VIEW

- Cooper Data Sheet
- Lead Data Sheet
- Zinc Data Sheet

2.30 STEEL

MOLTEN STEEL BEING RECYCLED FROM THE WORLD TRADE CENTRE
PHOTO: UNITED STATES NAVY

STAINLESS STEEL IS USED EXTENSIVELY IN CATERING APPLICATIONS
PHOTOS.COM WEBSITE

Steel is an alloy of mainly iron with low carbon content. Iron is made from the raw materials iron ore (hematite), coke and limestone. Ore and coke are sintered to form an iron rich clinker. Sinter, ore, coke and limestone are then smelted in a blast furnace where the mix is injected with hot air. The limestone combines with impurities and floats on top of the molten material as slag, and this is tapped off and quenched with water to create GGBS (ground granulated blast furnace slag). The first raw material smelt contains more carbon than required, typically 4-4.5% and is very brittle, this material lends itself to casting (cast-iron) but must be re-treated to further reduce the carbon content to create steel.

This process is carried out in the Basic Oxygen Steelmaking converter. The BOS uses the molten virgin material from the blast furnace (typically 80%); this mix known as hot metal is 90-95% pure and the qualities vary depending on the raw materials. It is combined with 'recycled/scrap' steel (typically 20%); the material is heated and injected with oxygen and lime to further reduce impurities. The material is then refined through injection of gasses then tapped into a ladle furnace, alloy additions may be made at this time or at the secondary steelmaking stage. Carbon content at the end of this process is typically 0.04%. The slag from this process (BOSS) is cooled and re-processed to reclaim any useable material.

Steel is also manufactured through Electric Arc Furnaces, EAF's use 100% recycled material, the electric arc current melts the steel and lime, other fluxes are added and carbon and oxygen are blown into the mix, impurities combine to make slag (EAFS). This material is tapped into a ladle furnace, alloy additions can be made now or at the secondary steelmaking stage.

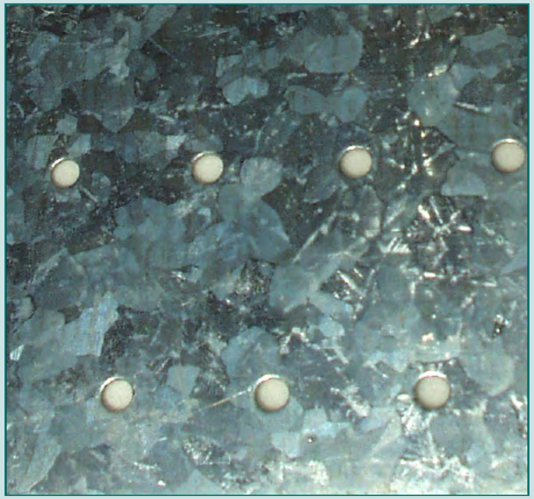
Secondary steelmaking occurs in ladle (arc) furnaces using both material from BOS and EA Furnaces where it receives extra treatments to create high grade steels.

According to the Corus publication 'Making and Rolling Steel (2008)' BOS steel in the UK is mainly used for bulk production, consumer products, and heavy engineering including construction. The EAF is generally used to make stainless, however use of EAF's for ordinary steel is increasing. The EAF process has been favoured for high grade specialist steels as it allows more control over the steel composition. Use of the EAF furnace is constrained by world supply of scrap – about 35% of global production is via this route. For constructional steelwork EAF steel is not widely used in the manufacture of thin gauge materials due to element contamination introduced from certain types of scrap, such as copper.

The steel industry has recycled material for the last 150 years largely because it is economic to do so due the infinite recyclability of the material, steel loses none of its properties during the recycling process. The energy and financial advantages of recycling steel as opposed to the smelting of iron ore to make virgin steel are considerable. Although scrap capture rates are high specifying EAF steel in an attempt to be environmentally friendly will not result in higher levels of recycling as there is not enough scrap to meet demand and as such may have a detrimental effect on the market.

In the UK, 94% of steel from demolished buildings is recycled. Recycling one tonne of steel saves 1100Kg iron ore, 630Kg coal and 55Kg limestone. It may be possible to actually reuse whole steel elements such as structural frame members and indeed, Stephen George, founder of SGP, successfully employed this process on one of his early commercial projects at the Phoenix Theatre in Leicester in 1963. However, in today's climate, legal requirements often demand stringent 'fitness for

STAINLESS STEEL COIL BEING PRODUCED
PHOTOS.COM WEBSITE



GALVANISED STEEL PLATE
PHOTO: SPLARKA (WIKIMEDIA COMMONS)

CLICK HERE TO VIEW

- **Steel Data Sheet**
- **Zinc Data Sheet**

purpose' testing for reused elements. Such testing is slowly becoming more available and financially viable in the UK. In the past steel elements in projects such as Bill Dunster's BedZed, for example, were moved over a substantial distance by road transport in order to be reconditioned and tested to the standard required by the building's insurers. However, the Steel Construction Institute now provides guidance via its P427 document on the best methods for re-use.

STAINLESS STEEL

Stainless steel is a steel alloy with minimum 11% chromium content; it stains less than carbon steel but is not stain free. It does not corrode or rust as easily as carbon steel due to chromium oxide forming a corrosion resistant surface. Stainless steel is 100% recyclable.

HOT DIP GALVANISED

Galvanising is the process of adding weather protection to steel by dipping the steel in a hot tub of molten zinc. Galvanisation refers to several electrochemical processes named after the Italian scientist Luigi Galvani.

GALVANISED STEEL

Zinc coatings prevent corrosion of the protected metal by forming a physical barrier. When exposed to the atmosphere, zinc reacts with oxygen and water molecules in the air to form zinc hydroxide which reacts with carbon dioxide in the atmosphere to form a thin, impermeable, insoluble dull grey layer of zinc carbonate. This adheres to the underlying zinc protecting it from further corrosion, similar to the protection afforded to aluminium and stainless steels by their oxide layers.

Zinc is recoverered from scrap/old steel during in the smelting process. Although a process with relatively low environmental impact, galvanising has the potential (like any other industry) to pollute unless managed properly during manufacture

LINKS

Steel
http://www.steel-sci.org/

Steel recycling
https://www.steelconstruction.info/images/3/36/BCSA_65-2022.pdf

https://www.steelconstruction.info/images/7/70/BCSA_MS-Reclaimed_Sections.pdf

https://steel-sci.com/assets/downloads/steel-reuse-event-8th-october-2019/SCI_P427.pdf

Stainless Steel Sustainability
https://bssa.org.uk/bssa_articles/environmental-aspects-of-stainless-steel/

https://www.worldstainless.org/about-stainless/environment/recycling/

Galvanised steel – General
http://en.wikipedia.org/wiki/Galvanised

https://www.galvanizing.org.uk/publications/

2.31 STONE & SLATE

STONE IS USED EXTENSIVELY IN MANY HISTORIC CITIES AND UPLAND LOCATIONS PHOTOS.COM WEBSITE

QUARRIED STONE.
PHOTO: LA FARGE

Stone or rock is a naturally occurring solid aggregate of minerals. The mining of rock for metal ore content has been one of the most important factors in human advancement.

Modern quarried stone is sometimes termed "Dimension Stone." Dimension stone is natural rock which has been selected according to colour, texture, durability and cut to specific shapes and sizes.

Stone quarries produce either dimension stone extracted through precise cutting or crushed stone extracted through explosives. Quarrying is considered an eyesore and a nuisance due to their dust and noise. Various methods are employed to reduce the negative effects of the working quarry on immediate neighbours. Strict after-use policies in the UK ensure old mine sites are made safe and turned into a usable amenity for the area. Quarry after-use is the term given to land use after mineral recovery and the details are often agreed with the mineral planning authority at the start of quarrying. The uses vary; as many quarries naturally fill with water these can include fishing reserves, reservoirs, sailing centres and nature reserves. Land based uses can include urban development, forestry, agriculture and eco-conservation. The choice of after-use depends on local constraints.

However, although large scale modern quarrying can be extremely undesirable (often due to the amount of road transport in largely rural areas associated with mineral exploitation), stone has an extremely low embodied energy. It usually requires very little processing – in the case of aggregates, almost none. However, as pointed out above, many of the adverse impacts of using stone occur from transport, whether it is lorries laden with limestone travelling through national parks or slate being imported from India or China. The selection of stone as a building material may be due to it being a local vernacular material. Therefore, specification of a locally sourced type may not only be deferential to the existing context but be supportive of traditional local trades and skills in addition to minimising transportation.

Slate mining and quarrying can lead to contamination of watercourses if not managed correctly. The visual impacts in the historical slate winning areas of the UK have been quite extreme. North Wales for example exhibits a landscape which has been almost wholly shaped by slate quarrying. However, this itself is not necessarily environmentally harmful.

FLOOR FINISHES

Slate and stone have both been used as hard-wearing, high quality floor finishes for centuries. However, the BRE's environmental assessment of these once again presents a confused picture. UK produced limestone floor tiles receive an 'A' rating while UK produced slate floor tiles are rated as 'E' This is despite a roof build-up using natural slates being rated at 'A' or above and imported Chinese granite floor tiles 'B'.

It is unclear what difference in winning or processing leads to the disparity between what is effectively the same material (slate) and it is difficult to understand how a material transported half way around the globe could be more sustainable than a locally won tradition. Caution should be exercised therefore is taking such assessments at face value without additional investigation.

PRACTICAL APPLICATIONS

Walling, flooring, roofing, external furniture, sculpture and details

LINKS

Stone Masonry - General
http://www.sustainablebuild.co.uk/ConstructionStone.html

https://www2.bgs.ac.uk/mineralsuk/buildingStones/services.html

Quarrying impacts
http://www.sustainablefloors.co.uk/the-impact-of-quarrying.html

https://www.barbourproductsearch.info/SSQ-UK-slate-sustainability-file016318.pdf

Types
https://usenaturalstone.org/geology-natural-stone/

https://www.stonefed.org.uk/uploads/companydirectory/Selecting%20the%20correct%20stone.pdf

CLICK HERE TO VIEW

- Stone Data Sheet

2.32 ARTIFICIAL / RECONSTITUTED / CAST STONE

ARTIFICIAL STONE BLOCKS PHOTO BY GEORGES GRONDIN HTTPS://PIXNIO.COM/. CREATIVE COMMONS LICENSE

CAST STONE BALUSTERS ADAM BLIGHT VIA SHEPTON CLASSIC STONE – CREATIVE COMMONS LICENSE

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- **Art, Stone Data Sheet**

Cast stone is defined by the United Kingdom Cast Stone Association (UKCSA) as:

"Any product manufactured with aggregate and cementitious binder intended to resemble and be used in a similar way to natural stone".

Various terms are used to describe this material which, although of modern popularity in traditionally stone areas due to it usually costing less than the natural product, has actually been around for a few thousand years.

The Romans used a form of cast stone as a result of their expertise in the use of concrete. The knowledge was not lost with the demise of the centralised Roman state and examples of cast stone still can be seen in the ruins of Visigothic buildings in North Africa.

Cast stone enjoyed a renaissance along with classical architecture in the 18th century due to its flexibility and suitability for ornamental featurework. One of its most widespread uses today is in this same sphere.

Many cast stone proprietary products use bespoke manufacturing processes with a wide range of ingredients. These usually comprise a binder in the form of cement or resin and a tactile pigmentation material intended to mimic the appearance of natural stone once dry. In many cases, this is actually natural stone powder.

It could be expected that this final ingredient be re-used or recycled demolition material or processing waste from natural stone products but this rarely is the case, with manufacturers stressing that they actually use the finest primary sourced material.

There is very little information on the environmental impact or embodied energy or carbon attributed to cast stone. One of the sole sources is a study undertaken by Devanshu Mudgal, Emanuele Pagone Rayan, A. Alkhunani and Konstantino Salonitis from Cranfield University in 2021 entitled **"Life-cycle-Assessment of Cast Stone Manufacturing: A Case Study"**

Their results are cited below in the comparison table. Unsurprisingly, as a material incorporating industrial processing, transport of multiple materials and cement based binders, the embodied carbon for cast stone appears to be relatively high compared to the natural alternative.

Material	Embodied Carbon $KgCO_2/Kg$
Cast Stone	0.61
Concrete (Generic)	0.1
Natural Stone (Generic)	0.073

Despite this, cast stone manufacturers and their trade organisations sing the praises of cast stone's sustainable credentials.

LINKS

General Information
https://ukcsa.co.uk/

2.33 TIMBER

FSC LOGO ' ©1996 FOREST STEWARDSHIP COUNCIL AC' FSC ID CODE: FSC-GBR-1083

TREATED WESTERN RED CEDAR
PHOTO: VINCENT TIMBER (WWW.VINCENTTIMBER.CO.UK)

Timber has been used as a building material from the most ancient of times. It is currently seeing renewed popularity as cladding material as we find ourselves looking for those obvious eco-credentials on new buildings. However, before we merrily clad and construct all new buildings in timber, a thought needs to be given as to where the timber comes from. Timber needs to be sustainably sourced; there are two main certification systems operating in the UK, FSC and PEFC. The two systems are independent and it is unlikely that small timber merchants will have both certifications, if any and only perhaps being able to demonstrate a Chain of Custody certificate (see below).

Timber is one of (if not the only) truly sustainable materials. The fact that it grows as part of an ongoing renewable ecosystem presents unique challenges to its use as an industrial material. Even if lauded as a "carbon negative," or renewable material, its production can involve processes highly destructive to humans, animals and nature generally. As timber's popularity increases due to its sustainable credentials, the rewards for unscrupulous suppliers become ever more attractive. Without constant and adequate vigilance, the harvesting of timber, particularly from countries with less robust standards of governance continues, to generate instances of deforestation, destruction of biodiverse environments, pollution of watercourses and contravention of human rights. This problem is not confined to smaller projects in obscure locations as can be demonstrated by the examples of both European and UK Parliament building projects in the early 2000's having been discovered to incorporate illegally logged timber.

ACCREDITATION AND CHAIN OF CUSTODY

Chain of Custody certification verifies that the wood in a product is from a certified forest or other controlled source, or is reclaimed. Every link in the supply chain from forest to final product needs its own Chain of Custody certificate. Each certificate has a unique number and this number must appear on product labels or invoices. There are several accreditation schemes operating worldwide. These include the following:

- Canadian Standards Association Standard (CSA)
- Sustainable Forestry and Initiative (SFI)
- The Australian Forestry Standard (AFS)
- Sistema Brazileiro de Certificação Florestal (CERFLOR)
- Certificación Forestal en Chile (Certfor)
- Malaysian Timber Certification Council (MTCC)
- Forest Stewardship Council (FSC)
- Programme for the Endorsement of Forest Certification Schemes (PEFC)

However, as previously noted, only the last two should really be considered of relevance in the UK, so we shall look at these in a little more detail.

TREATED SIBERIAN LARCH
PHOTO: VINCENT TIMBER (WWW.VINCENTTIMBER.CO.UK)

FSC

The Forest Stewardship Council (FSC) certification aims to ensure that timber products come from environmentally and socially responsibly managed forests. The FSC council is a international non-governmental organisation, supported by major environmental groups including Greenpeace, Friends of the Earth, the Woodland Trust and World Wide Fund for Nature (WWF).

The FSC system is based on actual ground level performance, not just paper systems. The forests must be managed with respect for the environment, wildlife and the people who live and work in them, FSC protects the rights of indigenous people to use the forest, protecting sacred sites from felling, the forest owner must use local workers, pay fair wages and support the local community and as such FSC is endorsed by the environmental charities listed above. As well as an acceptable and detailed management plan, an FSC-certified forest must undergo rigorous annual inspection visits and if any corrective action requests are issued they must be implemented or the certificate withdrawn.

The FSC has 3 levels of certification.

FSC 100%

All the timber or fibre in the product comes from FSC certified source.

FSC RECYCLED

All the timber in the product is post consumer reclaimed material.

FSC MIXED SOURCES

The timber fibre in the product is a mixture of some of the following:

- Timber from FSC certified forest
- Post consumer reclaimed material
- Controlled sources

The FSC certification process requires each country or region to prepare and submit a National Standard for Forest Management. Once accredited the national standard is used by certification bodies to measure forest performance in that country. In this way, each country sets its own standard, taking account of all local factors and interests. Inspections are undertaken by independent organisations accredited by FSC such as the Soil Association. The accreditation process ensures that all these different standards are equivalent so that FSC-certified timber from any country or region can be mutually recognised in the chain of custody with no risk to its credibility. FSC timber from certified forestry in Sweden would be equivalent to certified timber from anywhere in the world.

FSC continually scrutinise companies using their certification and a number have been disassociated from the organisation for contravention of FSC policies. This may include deforestation, destruction of environments of high conservation value, illegal logging and violation of rights. Care should be taken when specifying timber to ensure it is not sourced from one of these suppliers which can be checked on the FSC website (see links below)

PEFC

Founded in Geneva, Switzerland in 1999, the Programme for the Endorsement of Forest Certification (PEFC) is a non-governmental, non-profit organisation promoting

UNTREATED SWEET CHESTNUT
PHOTO: JO DENISON, STEPHEN GEORGE + PARTNERS

sustainable forests through independent third party certification. PEFC bases its criteria on regionally accepted intergovernmental conventions and guidelines. PEFC is represented at national level through local certification systems, which can become members of PEFC and if they meet the international criteria are endorsed to use the PEFC logo.

PEFC has in its membership 35 independent national forest certification systems of which the majority have been through a rigorous assessment process involving public consultation and the use of independent assessors to provide the assessments on which mutual recognition decisions are taken by the membership. These systems account for more than 200 million hectares of certified forests producing millions of tonnes of certified timber to the market place making PEFC the world's largest certification system. PEFC is largely commercial, strongly supported by the forestry industry but less so by environmental groups.

LINKS

FSC
https://uk.fsc.org/

https://connect.fsc.org/actions-and-outcomes/current-cases

PEFC
http://www.pefc.co.uk/

Illegal timber importation
https://eia-international.org/forests/illegal-logging-and-timber-trafficking/

https://chathamhouse.soutron.net/Portal/Public/en-GB/RecordView/Index/187050

DURABILITY

Timber Research and Development Organisation (TRADA) Classification

TRADA are a not-for-profit organisation which aims to *'To provide members with the highest quality information on timber and wood products to enable them to maximise the benefits that timber can provide.'*

Timber species and their origins and their appropriate uses vary hugely; this can be a minefield of confusing data. Trada classify the durability of timber species based on decay. The testing of the timber is low tech; a 50x50mm stake is hammered in to the ground, left and at periodic intervals someone comes along and whacks it with a mallet. When it breaks it is then categorised into durability levels ranging from 1-5. The classifications quoted refer to the resistance to fungal decay of the heartwood of the species only. The sapwood of most species is non-durable or slightly durable and should not be used in exposed situations without preservative treatment. Five classes of natural durability to wood-destroying fungi are recognised in BS EN 350-1 "Guide to the principles of testing and classification of the natural durability of wood:"

Timber ranges from Class 5 not durable, knotty softwood to Class 1 very durable tropical hardwood.

Class 1	Very Durable
Class 2	Durable
Class 3	Moderately Durable
Class 4	Slightly Durable
Class 5	Not Durable

FSC AND PEFC COMPARED

This information is adapted from Table 1 of the 2004 FERN report "**Footprints In The Forest.**"

This report concludes in the Executive Summary that *"...FSC remains the only credible scheme."*

Link: EU Based Forest Protection Group
https://www.fern.org/

TREE SECTION SHOWING HEARTWOOD
PHOTO: MPF (WIKIMEDIA COMMONS)

	FSC	PEFC
Is the scheme based on a set of clear minimum performance based thresholds?	Yes	No
Does the scheme require balanced participation in standard-setting process?	Yes	No
Is the standard setting dominated by forestry sector?	No	Yes
Does the certification scheme certify at Forest Management Unit or regional level?	FMU	Mostly regional
Are field visits required?	Yes	Not Always
Is consultation of stakeholders in certification process required?	Yes	Yes
Is annual monitoring of certified areas required?	Yes	Yes
Is the scheme transparent (i.e. are standards and summary reports freely available on websites)?	Yes	No
Is there a label and well defined chain of custody available?	Yes	Yes
Does the scheme prohibit the conversion of forests to plantations or other land uses?	Yes	No
Does the scheme prohibit use of Genetically Modified Organism trees?	Yes	No

UNTREATED LARCH
PHOTO: JO DENISON, STEPHEN GEORGE + PARTNERS

TYPICALLY WEATHERED WOOD
PHOTOS.COM WEBSITE

HEARTWOOD AND SAPWOOD

Heartwood is wood that has died and become more resistant to decay as a result of deposition of chemical substances (a genetically programmed process). Heartwood is usually much darker than living wood, and forms with age. Some uncertainty still exists as to whether heartwood is truly dead, as it can still chemically react to decay organisms.

Sapwood is the wood that is not heartwood, in the growing tree it is living wood. All wood in a tree is first formed as sapwood. Its principal functions are to conduct water from the roots to the leaves and to store up and give back according to the season the food prepared in the leaves. The more leaves a tree bears and the more vigorous its growth, the larger the volume of sapwood required.

TIMBER PRESERVATION - THE ALTERNATIVES

The use of externally exposed timber is increasing. Paint / varnish / timber treatment in general is costly to the environment and to the building owner, and we are seeing a move away from treated timbers to exposed natural timber. This timber needs careful selection to ensure longevity of the product.

The world is split between people who don't mind that that the timber will fade to a greyish hue in the sun and those that believe it should remain the same uniform colour for its whole life. This is what often drives the decision to provide timber with a surface treatment – not whether it needs it for longevity. If an artificial finish is selected, be aware that a maintenance demand is being created by this. Alternatively, also be aware that if left untreated it is highly likely that the timber will weather unevenly depending on the exposure to sun and rain.

UNFINISHED EXTERNAL JOINERY

SUITABLE SPECIES

- European Oak (durable)
- Sweet Chestnut (durable)
- Western Red Cedar (European grown) (moderately durable)
- European (not UK) Larch (Moderately durable)
- Douglas Fir (Moderately durable

GUIDANCE

- Use seasoned wood
- Avoid using sapwood, especially when using moderately durable wood
- European Oak and Sweet Chestnut contain a great deal of tannin. This will initially stain but then wash off. Use corrosion resistant fixings (e.g. stainless steel) and protect surfaces from staining during this period
- All unpainted wood regardless of species will gradually lose its original colour and fade to a light grey

UNTREATED WESTERN RED CEDAR
PHOTO: JO DENISON, STEPHEN GEORGE + PARTNERS

UNTREATED CEDAR SHINGLES
PHOTO: VINCENT TIMBER (WWW.VINCENTTIMBER.CO.UK)

UNFINISHED CLADDING

Detailing is key to longevity of untreated cladding, with evidence of non-durable and slightly durable timber lasting 100 years in good condition.

SUITABLE SPECIES

- European Oak (durable)
- Sweet Chestnut (durable)
- Western Red Cedar (European grown) (moderately durable)
- Larch (not UK) (Moderately durable)

GUIDANCE

- Avoid using sapwood, especially when using moderately durable wood
- ‘Green’ wood can be used and dries naturally. Allow sufficient fixings to absorb shrinkage.
- European Oak and Sweet Chestnut contain a great deal of tannin. This will initially stain but then wash off. Use corrosion resistant fixings (e.g. stainless steel) and protect surfaces from staining during this period.
- Larch requires harsh cold winters to slow the growth rate down create a durable timber. UK Larch grows too fast in our mild climate. If UK Larch is desired specify a number of growth rings per section to ensure durability.
- Non-durable timbers have been successfully used as cladding, some over 100 years old. Detailing is of paramount importance.
- There is a relationship between cladding longevity and the depth of eaves. 600mm should be the optimum.
- Design a splash zone of no less than 150mm above the ground.
- Ventilate behind the cladding.
- Ensure the sawn ends are treated and/or well vented.

PLATOWOOD SPRUCE
PHOTO: JO DENISON, STEPHEN GEORGE + PARTNERS

THERMOWOOD CLADDING
PHOTO: FINNFOREST LTD - WWW.FINNFOREST.CO.UK

THERMOWOOD

Thermowood is heat treated softwood from FSC certified forests. Thermowood is a generic term for thermally modified wood, and only members of the Finnish Thermowood Association are licensed to use the description. Lunawood and Platowood are both 'Thermowood'. The treatment takes fast grown softwood and stabilises the structure with steam treatment, creating a material with hardwood qualities. The heat treatment process requires no chemical additives and removes resin from redwood timber. As a result there is no resin leakage or "bleed" through the surface coatings. The combined effect of this, together with the improved stability, leads to a lower maintenance requirement. Thermowood is durable softwood with no chemicals or additives that performs as a hardwood.

ACCOYA

Wood acetylation as used by the brand name Accoya is the chemical modification of wood at a molecular level. This treatment improves the durability of the timber by mimicking and enhancing a natural process. Wood naturally contains "free hydroxyls", which absorb and release water depending on current climatic conditions, which is why timber swells and shrinks with the weather.

Acetylation changes the free hydroxyls within wood into acetyl groups by reaction of the timber with acetic anhydride, a form of acetic acid (vinegar in its dilute form). When free hydroxyl groups are transformed into acetyl groups, the ability of the wood to absorb water is greatly reduced, rendering the wood more dimensionally stable and, because it is no longer digestible by enzymes, extremely durable. Acetylated wood is non-toxic and does not have the environmental issues associated with traditional preservation techniques. Accoya is sustainably sourced soft wood with properties of hardwood.

LINKS

TRADA
https://trada.azurewebsites.net/

Wood preservation – general
https://www.greenspec.co.uk/building-design/wood-preservatives/

http://en.wikipedia.org/wiki/Wood_preservation#Wood_acetylation_

Thermowood
https://www.metsagroup.com/en-gb/metsawood/products-and-services/products/thermowood/

Acoya
https://www.accoya.com/uk/?gclid=Cj0KCQjwhqaVBhCxARIsAHK1tiM0hpN0lYSxY0f47-8aPWu9s-x8ykO3Ymvpa3ysupjUST-7_DQeDaUaAshxEALw_wcB

Corporate responsibility
https://www.wwf.org.uk/timberscorecard?utm_source=Grants&utm_medium=PaidSearch-Generic&pc=AUZ014007&gclsrc=aw.ds&&gclid=Cj0KCQjwhqaVBhCxARIsAHK1tiOC2EzyYR9XoQfxyevf2-SGCNL8T-d4EtEjT0Gypba8Q8oRUo-DF1caAjdvEALw_wcB

ACCOYA IN CLOSE UP
PHOTO: © TITAN WOOD LTD

ACCOYA AS CLADDING
PHOTO: © TITAN WOOD LTD

CLICK HERE TO VIEW

- **Processed/Engineered Timber Data Sheet**
- **Composite Timber Sheets Data Sheet**

COMPOSITE TIMBER, STRUCTURAL MEMBERS & BOARDS

Composite timber products are popular having many advantages over ordinary timbers:

- They can utilise smaller dimensions of timber as the raw material, but can be manufactured to create large dimension composite beams and sheets, etc.
- Less timber overall is required to make products which are lighter and stronger than timber. Reduced quantities and smaller sizes of timber means less pressure on native forest timber production.

However there are concerns:

- Most boards use toxic resins, though alternatives are beginning to appear.
- Much of the timber content originates from non-sustainable sources. FSC products are still difficult to obtain.

COMPOSITE TIMBER MATERIAL TYPES

FIBREBOARDS

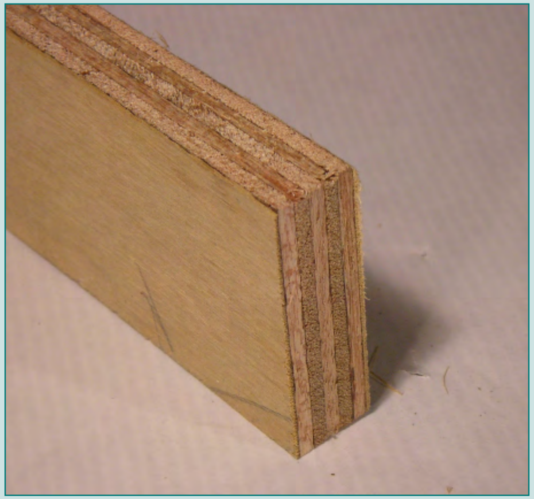
Fibreboard is a sheet material made from glued and pressed softwood dust or chips, commonly used throughout the construction industry. Fibreboard is strong and has a stable, smooth and scratch-resistant surface. As fibreboard is usually made from waste produced during wood processing, it is an efficient use of forest resources. Fibreboards usually rely on their inherent resins to bond though conventional medium density fibreboard (MDF) contains urea-formaldehyde or phenol-formaldehyde, which off-gasses into interior air. Some non-formaldehyde MDFs are available but some like diisocyanate resins can cause asthma during manufacture. Formaldehyde is a suspected carcinogen and instrumental in causing asthma. Therefore some countries restrict or even ban the use of MDF. The greatest risk will come in working the material, when masks should be used and adequate ventilation employed.

PARTICLEBOARDS

Particleboard is made from chips of timber bonded with urea formaldehyde resins to form boards (sheets) by applying mechanical pressure and heat. They have a low strength and stiffness, good fire resistance and airtightness. OSB is bonded largely using the more stable phenol formaldehyde.

PLY-BASED BOARDS

- Conventional plywood is made of thin veneers of wood that are bonded together with formaldehyde resins. Its strength is derived from gluing an odd number of sheets of veneer with the grain of adjacent sheets at right angles to each other.
- The majority of hardwood plywood is composed of a core layer faced with higher quality woods using urea-formaldehyde (UF) glue.
- Softwood plywood is used for exterior and structural applications (walls, floors, roofs), and its adhesive consists of phenol formaldehyde (PF) resin. PF is a more expensive and water-resistant glue, which off-gasses at a relatively slower rate than UF glues.
- Blockboard is constructed from softwood timber core strips up to 30mm wide, which are glued between outer veneers whose grain runs in the opposite direction.



PLYWOOD
PHOTO: ROTOR DB (WIKIMEDIA COMMONS)

OSB
PHOTO: ELKE WETZIG (WIKIMEDIA COMMONS)

- Laminboard is constructed in a similar fashion as block board but the core strips are not more than 7mm wide. It is a finer quality timber board with a better finish than block board.

OSB

Oriented Strand Board (OSB) is an engineered, mat-formed panel product made of strands, flakes or wafers sliced from small diameter, round wood logs and bonded with a binder under heat and pressure. OSB uses selectively prepared new wood strands during its manufacturing process and is recyclable into other products. Resin binders and waxes are completely cured and stabilised, so there is no measurable off-gassing from panels. The manufacturing process uses nearly 90% of the log, with the balance used to supply energy. Typically, an OSB panel is 95 to 97 percent wood, and 3 to 5 percent additives such as wax and resin.

PLYWOOD V OSB

In 2007, the World Wide Fund for Nature (WWF) estimated that the UK was the third largest importer of illegal timber in the world, spending around £712 million a year on illegal wood and that much of this was plywood from tropical sources. The use of illegally sourced timber was so widespread in the UK that it even found its way into construction work being undertaken for Parliament's new buildings in London!

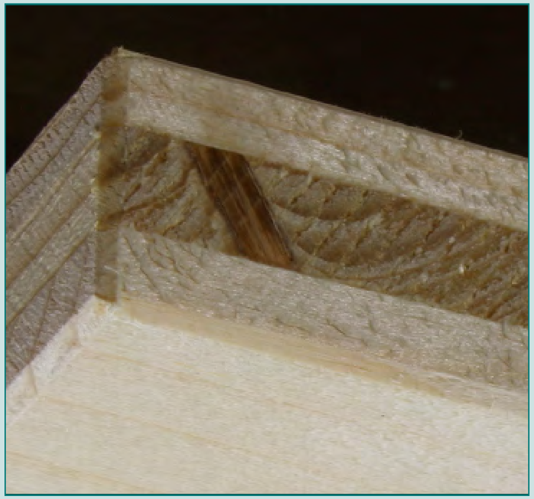
Since that time, a concerted effort appears to have been made to greatly improve enforcement of the rules governing illegal timber use and substantial progress appears to have been made

GLUED LAMINATED TIMBER

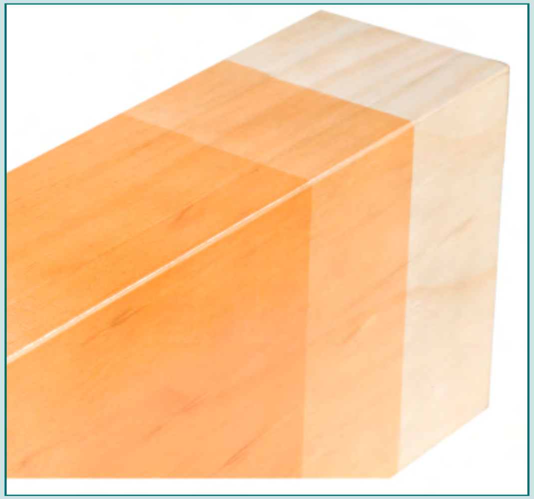
Glulam (in its widely abbreviated form) consists of small sections of timber glued together to form a designed structural member. Glulam utilises small sections of timber and as such is an efficient use of timber; in addition it is engineered to be stronger than solid timber sections of the same size. Glulam offers great design flexibility and visual appeal. Care should be taken to ensure the timber used is from certified sustainable sources. Glulam is generally marketed as being more environmentally friendly than steel or concrete, however a considerable amount of glue is used in the construction.

GLUE IN COMPOSITE BOARDS

Polyurethanes play a major role in today's materials, Polyurethane-based binders, typically used both with wood and rubber, are used in composite wood products to permanently glue organic materials into oriented strand board, medium-density fibreboard, long strand lumber, laminated veneer lumber, strawboard and particleboard. If composite boards are specified, try to source non-formaldehyde bound types. The most common adhesives in engineered timber are phenolic resins, can include any of various synthetic thermosetting resins (Bakelite, the original synthetic resin) created by reacting phenol with formaldehyde. Despite often using a form of formaldehyde, these are often more stable with less off-gassing than urea based versions



CLT IN CLOSE UP
ELKE WETZIG (ELYA), CC BY-SA 3.0VIA WIKIMEDIA COMMONS



ACCOYA USED AS GLULAM
PHOTO: © TITAN WOOD LTD

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- **Processed/Engineered Timber Data Sheet**
- **Composite Timber Sheets Data Sheet**

LVL TIMBER

LVL (Laminated Veneer Lumber) is quite similar to vertically laminated glulam beams, but is made in a similar manner to plywood. LVL is manufactured from veneers that are rotary peeled, dried and laminated together under heat and pressure with an adhesive. The grain on each ply is usually oriented in the same direction as the length of the member. LVL can be used for structural members, curtain walling and windows.

PARALLAM

Parallam or Parallel Strand Lumber (PSL) is a product of a patented process which uses almost every kind of wood, including substandard veneer sheets which would normally be considered as waste. The constituent timber is cut into strands which are aligned parallel for maximum strength. These are then bonded in phenolic resin before being compressed and cured in microwave ovens. The Parallam is then extruded and generally sawn into rectangular beams. The manufactured nature of Parallam means that it can provide longer, deeper and stronger structural members than sawn timber elements. Also, it is subject to a higher degree of uniformity.

Parallam has a striking appearance and can be machined as an homogenous material. Most Parallam is produced in the USA and Canada (where the process originated).

LINKS

Pavatex & Diffutherm
https://www.soprema.co.uk/en/gamme/insulation/pavatex

https://www.backtoearth.co.uk/product/internal-external-wood-fibre/

https://www.udidaemmsysteme.com/product/insulation-boards/udiunger-diffutherm-nf-wood-fibre-sandwich-layer-insulation-board/

CLT
https://en.wikipedia.org/wiki/Cross-laminated_timber

https://www.archdaily.com/893442/cross-laminated-timber-clt-what-it-is-and-how-to-use-it

DIFFUTHERM BOARD
PHOTO: NATURAL BUILDING TECHNOLOGIES

PAVACLAD SYSTEM UNDER CONSTRUCTION
PHOTO: NATURAL BUILDING TECHNOLOGIES

CLICK HERE TO VIEW

- **Insulation Data Sheet**

TIMBER FRAME BUILDING SYSTEMS

Timber frame is generally a fairly sustainable method of creating a structural envelope as long as the key principles of responsibly sourced timber and best practice detailing are followed. However, the sustainable credentials of timber frame construction may often be compromised by selection of insulation and / or membranes. Several timber-framed systems exist which are based around natural products used for these elements as well as the frame itself. Pavatex and Diffutherm are wood fibre insulants which form the basis of timber framed systems with U-values down to 0.18w/m^{2o}C. The Pavatex or Diffutherm is used in conjunction with other natural insulants such as hemp / cotton and OSB boards which provide racking and airtightness while avoiding the need for petrochemical produced membranes. The system itself can be sub-contractor designed to specific criteria such as preferred insulation or minimum heat loss level.

CROSS LAMINATED TIMBER (CLT)

CLT comprises layers or "lamellas," of graded softwood bonded at right angles to each other to create a structural material which can be used to form load-bearing walls in multi-storey buildings.Originally invented in the 1920s, a practical building material was not finally developed for the market until 1998 in Austria. This is now where most of the expertise lies and where the raw material is often grown. Although relying on a polyurethane structural adhesive, this is usually formaldehyde free and is of a very low VOC level.

Although take-up was initially slow by the construction industry, CLT buildings are now increasing in popularity and the number of tall multi-storey projects using CLT in lieu of steel or concrete as a structural solution is increasing. As a sustainable replacement for two of the most carbon-intense structural materials, its environmental advantages are obvious.

TIMBER AND TRANSPORT

Accurate figures relating to the transport of timber internationally is difficult to come by. There are some studies available on the movement of lumber internally in the USA but very little regarding shipping across the sea. This aspect is often leapt upon as drawback of using structural timber. However, it has to be borne in mind that the materials it is replacing also involve international transportation but without the carbon negative footprint of timber.

VINYL FLOORING IN PRODUCTION
PHOTO : POLYFLOR LTD

VINYL FLOORING IN USE
PHOTO : POLYFLOR

CLICK HERE TO VIEW

- **Vinyl Flooring Data Sheet**

2.34 VINYL FLOORING

Vinyl flooring and linoleum are often seen as being the same product. However, they are of disparate origins with quite different qualities. Linoleum is a natural product while vinyl is a petrochemical product. However, their sustainable credentials are usually considered as being almost equal. This is largely because vinyl flooring will last far longer than linoleum and the latter may actually take more energy to produce than the synthetic sheet.

There are however, several fundamental environmental inequalities between the two materials. Vinyl is a product of a process which can result in polluting emissions whereas linoleum is refined from flax (a natural crop.) Also (and perhaps most importantly), vinyl is non-degradable. Consigned to landfill, vinyl may take thousands of years to break down.

There is also the issue that, even if vinyl will possibly last longer, as an internal surface finish, it is most likely to be replaced well before the end of its life; a victim of the latest fit-out or redecoration. So it may be that the basis for considering vinyl to be environmentally equal to linoleum is flawed.

Several manufacturers offer a recycling service, often as part of the EU's "Recovinyl" initiative. Tarkett claim to recycle more than 130,000 tonnes of material annually and use an average of 25% recycled material in their vinyl flooring. Other companies such as Altro and Polyflor also have recycling schemes but figures are not available for the quantities involved in these products. The process of recycling is fairly straightforward but the main challenge is adequate collection of waste material during replacement.

As a plastic product, vinyl flooring is subject to the same environmental issues as most other PVC based materials (See section on Plastics). It may also require adhesives which may be toxic or contain VOC's. Despite these problems, vinyl flooring usually gets an 'A+' rating under the BRE Green Guide.

LINKS

Recycling
http://www.recovinyl.com/

Comparison with linoleum
http://www.sustainablefloors.co.uk/linoleum-vs-vinyl.html

2.35 STEEL VERSUS CONCRETE

The debate over which material is the most environmentally beneficial or the most cost-effective has raged for years and shows no sign of abating. The suppliers and proponents of the respective materials continually produce documents publicising further 'evidence' on why one technology is better than the other.

In terms of embodied energy, it is likely that steel is the overall winner. The cementitious components of concrete are products of an energy intensive process (although these can be substituted, often quite ironically with by-products of the steel production process [GGBS]). Furthermore, steel is more flexible in terms of reuse, recycling and potential for adaptation when considering end-of-life options. Reinforced concrete is essentially a composite material and almost impossible to recycle to perform a similar function as its original use. However, steel requires applied fire protection, usually through a chemically derived process, whereas concrete has an intrinsic degree of fire resistance.

Balanced against the embodied energy consideration, the performance of each system throughout its life has to be taken into account. The thermal mass offered by exposed concrete enables the building structure itself to become a climate modifier. By exploiting the thermal lag of concrete, night cooling can be introduced for commercial buildings or possibly thermal storage for domestic properties. The overall benefits of this, if exploited correctly, can greatly reduce the energy demand of a building over its lifetime.

In an effort to help resolve this debate, cost consultants Currie and Brown worked with environmental engineers Hoare Lea & Partners on a notional project which was the subject of an article in the 2006 issue 25 edition of 'Building' magazine. Obviously, the outcome greatly depended on the form of building being studied and the design parameters and assumptions adopted.

The article noted the following regarding financial impact:

"Over 30 years, the combined effects of a change from a steel-framed air-conditioned office to a building with in situ concrete frame and floors are:

Capital cost changes: +£42,000 +3.6%

Energy cost changes: -£3,800 a year = -£85,000 -4.1% (saving 57 tonnes of CO_2 a year)

Total change in net present cost: -£43,000"

So for the speculative developer, steel may be the cheapest option (although the cost of steel has risen dramatically since 2004), but for the building owner, concrete may be the most cost-effective long-term solution.

In terms of environmental benefit, the authors concluded:

"An article like this cannot analyse all environmental impacts. For example, there are many other types of gas emissions that should be considered, such as nitrous oxide (N2O). The best overview of the overall impact of these materials is the Ecopoint rating developed by BRE.

Structural steel has 11 Ecopoints per tonne Reinforced concrete to 35 N/mm^2 (including rebar at 100 kg/m^3) has 5.3 Ecopoints/m^3 (using a density of 2371 kg/m^3), or 12.57 Ecopoints per tonne."

(N.B. The higher the Ecopoint rating, the better).

And finally...

"If we ignore operational energy savings, the concrete option appears to be about 30% worse, but when operational energy is accounted for, this dwarfs the embodied energy and the appraisal is reversed showing a saving of 6% for the concrete option."

Any benefits are not overwhelming and are probably subject to the detailed form and use of the building in question. Riad Quadery of Faber Maunsell concluded as much in the 2007 report entitled **"Comparison Of Reinforced In-Situ Concrete And Structural Steel In Multi-Storey Building Framework Construction".**

He concluded that:

"...it is extremely difficult to conclude which material is the better framing option as both the options have their own advantages."

And that:

"Once the frame type is chosen the developer should maximise the benefits."

So the conclusion was that no-one really knows but you can get both systems to work for you if you are careful enough.

Since that study was released, of course both industries have redoubled their efforts to appear sustainable. The concrete industry in particular has come under fire for the size of carbon emissions involved in cement production. As detailed under our section on concrete, new developments such as carbon curing and use of cement substitutes are imminent or already becoming widespread. The steel industry finally has a viable method of reusing steel in a manner acceptable to funders and insurers.

Yet against all this has now to be considered the possibility of structural timber systems such as CLT, whose sustainable credentials probably dwarf either of its competitors.

LINKS

https://www.building.co.uk/whole-life-costs-concrete-vs-steel/3069406.article

https://core.ac.uk/download/pdf/4399726.pdf

https://www.architectmagazine.com/technology/concrete-steel-or-wood-searching-for-zero-net-carbon-structural-materials_o

DATA SHEETS

SECTION 3

ALUMINIUM

ADVANTAGES

- Easily recyclable with active programme
- Lightweight
- Durable
- Low maintenance

DISADVANTAGES

- Extremely high embodied energy
- Reactive against some other materials (i.e. bi-metallic corrosion, green concrete, cement plaster, some timber species and CCA treated timbers)
- Low Green Guide rating for windows

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Recycled Aluminium only uses 5% of the energy required for the raw material.
- Source high-content of recycled where possible.
- Design for recycling.
- Anodising is the most environmentally friendly surface treatment and does not affect recycling.
- Powder coatings require pre-treatments which can be toxic - Choose a supplier with ISO14001 accreditation.
- Powder coatings create toxic fumes if burnt off during recycling requiring specialised equipment.
- Anodised is preferable to powder-coating but powder-coating is preferable to paint.
- Aluminium windows of a lower mass will gain a higher BRE Green Guide rating.
- Only use in moderation and where there is no alternative.

SUSTAINABLE ALTERNATIVES

- Windows: Timber, steel
- Rainwater goods: Steel, cast iron, zinc
- Cladding: Steel, timber, zinc, lead
- Trims & flashings : steel, zinc, lead

CLICK HERE TO RETURN TO SECTION 2 - ALUMINIUM

ASPHALT

ADVANTAGES

- Naturally occurring material
- Monolithic
- Superb waterproofing characteristics
- Recyclable (though often isn't)
- Low embodied energy
- Durable

DISADVANTAGES

- Expensive
- Application by specialised trade
- Roofing has low Green Guide rating
- Porous asphalt may require increased winter maintenance

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Optimum material for paving and externally trafficked areas.
- Use over recycled aggregate sub-base for highest Green Guide rating (A).
- Unrivalled as a roofing membrane but will require specialist application.
- Highest Green Guide rating for roofing is currently 'B' & only achievable with certain specifications. Most likely to be 'E'.
- Whole UK mastic asphalt trade claims to be carbon neutral through offsetting.

SUSTAINABLE ALTERNATIVES

- Roofing: EPDM Membranes / Recycled Bitumen
- Tanking: Membranes (Limited sustainable information is available on this area. Asphalts reliability should be taken into account over adhesive membranes)
- Landscaping and paving: Grasscrete. Porous asphalt
- Varied and contradictory information regarding recyclability and recycled content

CLICK HERE TO RETURN TO SECTION 2 - ASPHALT

BAMBOO

ADVANTAGES

- Natural material
- Historically proven
- Usually grown without chemicals
- Carbon sink during cultivation

DISADVANTAGES

- Transported from Far East
- Engineered form will use toxic resins
- Raw form will be unsuitable for UK climate

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Although used structurally in traditional far eastern architecture, bamboo is unlikely to be suitable for this role in the UK.
- May not perform well in humid or wet climates.
- Recent growth in the UK is in internal and external cladding which is an engineered product.
- Laminated panels use formaldeyde resin but in relatively small quantities.
- Laminated bamboo can be used in numerous applications including flooring, furniture, ceilings and blinds.

SUSTAINABLE ALTERNATIVES

- Indigenous timber

CLICK HERE TO RETURN TO SECTION 2 - BAMBOO

BITUMEN

ADVANTAGES

- Proven waterproofing ability
- Low cost
- Easily applied roofing without specialist trades
- Less toxic than some plastic alternatives

DISADVANTAGES

- Petrochemical derived
- High embodied energy
- Relatively short lifespan (15-20 years)
- Unlikely to be recycled

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Capable of 'A+' Green Guide rating in correct specification. (Contradicts some other sources such as GreenSpec, which lists bitumen based roofing felt as material to be avoided).
- Try to specify versions with recycled content (E.g. EshaVironment).
- Can be a substitute for PVC materials in locations such as DPCs etc.
- Far higher embodied energy content than naturally occurring asphalt but less is likely to be used.

SUSTAINABLE ALTERNATIVES

- Roofing:*EPDM, Single-Ply *TPO membranes (Thermoplastic Polyolefin)
- Damp-proofing: Non-PVC plastics, lead, engineering brick
- *Varied and contradictory information regarding recyclability and recycled content

CLICK HERE TO RETURN TO SECTION SECTION 2 - BITUMEN

BRICKS

ADVANTAGES

- Proven waterproofing ability
- Low cost
- Easily applied roofing without specialist trades
- Less toxic than some plastic alternatives

DISADVANTAGES

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- *Varied and contradictory information regarding recyclability and recycled content

CLICK HERE TO RETURN TO SECTION 2 - CLAY: BRICKS

CARPET - NATURAL

ADVANTAGES

- Natural product
- Very low embodied energy
- Durable
- Biodegradable
- Sustainable Resources
- Natural dye is available
- Creates healthy interior environment – low toxicity as less chemical treatments are required

DISADVANTAGES

- Can be sensitive to damp, mildew, moths
- More expensive than synthetic options
- Natural dyes can fade

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Wool and Sisal pile carpets are susceptible to mildew and moths – do not use in potentially damp environment.
- For true sustainability source carpet using natural dyes.
- Avoid high VOC adhesives.
- Avoid high VOC dyes.
- Use carpet tiles instead of sheet for increased versatility and less waste.

SUSTAINABLE ALTERNATIVES

- Carpet made from recycled plastic bottles

CLICK HERE TO RETURN TO SECTION 2 - CARPET

CARPET - SYNTHETIC

ADVANTAGES

- Cheaper
- Colours will not fade
- Stain resistant
- Capable of A+ Green Guide

DISADVANTAGES

- Petrochemical derived
- Some synthetic fibres mat and crush easily
- Coated with a range of toxic substances to promote durability, fire resistance, prevention of colour fade etc
- Unhealthy interior environment through off-gassing of VOCs

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Synthetic carpets are manufactured from petrochemical sources at high cost to the environment and health risk to the end user.
- Be aware - carpet take back schemes in reality are limited to often only unused carpet tiles accepted. Soiled carpet tiles are sent for 'energy recovery' meaning incineration.
- Modular carpet tiles are more versatile and less wasteful than sheets.

SUSTAINABLE ALTERNATIVES

- Use carpet woven from sustainable, natural, biodegradable materials with natural dyes

CLICK HERE TO RETURN TO SECTION 2 - CARPET

CEMENT MORTARS & RENDERS

ADVANTAGES

- Robust
- Good weather-tightness
- High strength

DISADVANTAGES

- Inflexible – movement joints required
- Will prevent masonry being re-used
- Cement content ensures high embodied energy
- Ingredients won through mineral extraction
- Non-recyclable

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- The cement industry is estimated to be responsible for 7-10% of the world's CO_2 emissions.
- Only consider where alternatives are impractical.
- Negative impact of cement render can be mollified by self colouring or pigmentation to reduce painting, cleaning and maintenance.
- Use of cement mortars necessitates movement joints with their attendant toxic materials.
- Adherence and rigidity of cement mortars make masonry difficult to recycle.

SUSTAINABLE ALTERNATIVES

- Lime based materials are available for both render and mortar. (May be detailing, robustness or weatherproofing issues)
- Clay mortars and renders can be used over a suitable substrate
- Low carbon cement or cement free alternatives

CLICK HERE TO RETURN TO SECTION 2 - CONCRETE & CEMENT PRODUCTS

CERAMIC TILE

ADVANTAGES

- Inert
- Relatively low embodied energy compared to alternatives
- Can have recycled content as standard
- Can provide thermal mass
- Durable
- Robust
- Low whole life cost

DISADVANTAGES

- Generally non-reusable
- Glazes may be toxic during manufacture

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Select products with at least some recycled content.
- Examine packaging and transport policy of manufacturer.
- Production can use large amounts of water – study manufacturer's process for sustainability.
- Ancillary products may be environmentally harmful.
- Trims.
- Adhesives.
- Grouts.

SUSTAINABLE ALTERNATIVES

- Recycled glass tile
- Cork or grass matting
- Rubber flooring

CLICK HERE TO RETURN TO SECTION 2 - CERAMIC TILES

CLAY - UNFIRED BLOCKS

ADVANTAGES

- Extremely low embodied energy
- Natural material
- Can use recycled material as binder (gypsum / straw etc)
- Creates 'breathable' construction
- Can be cut with wood saw
- Significant thermal mass
- Recyclable

DISADVANTAGES

- May not be ideally suited for load-bearing structures
- Not weather-tolerant
- Require specialised clay mortars
- Easily damaged

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Can be used as internal loadbearing and non-loadbearing infill for framed structures.
- Will require weatherproof coating (render) if used for an external envelope.
- Do not tolerate contact with water.
- Usually used in conjunction with clay plasters and mortars (c/f).
- Usually fully supported at edges.
- Blocks are usually combined with material as a binder. 'Karphosit' blocks use straw. Some others use gypsum in the form of recycled plasterboard.
- Can be used to provide thermal mass.
- Can be produced via a portable compressing machine on site.
- Variants include mud brick, adobe and compressed earth block.

SUSTAINABLE ALTERNATIVES

- There are very few more sustainable alternatives to unfired clay
- Use instead of concrete / fired clay alternatives such as brick or block for partitioning or inner leaves

CLICK HERE TO RETURN TO SECTION 2 - CLAY

FIRED HOLLOW CLAY BLOCKS

ADVANTAGES

- Low embodied energy
- High U-values possible
- Solid wall construction for increased speed
- Often part of a walling system
- High acoustic properties
- Good thermal mass
- Recyclable

DISADVANTAGES

- Usually imported from France or Germany (but now available in the UK). Therefore non-UK modules
- Often only most suitable for domestic construction
- May be unfamiliar system
- Non-renewable product of mineral extraction

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Fired clay blocks are often known as 'Ziegel' blocks but these are only one type of hollow clay block. (Other types include 'Porotherm').
- Blocks are usually part of a system including reveal blocks, lintels and specialised mortars (sometimes applied 1mm thick via roller). Training may be required for site staff.
- Not suitable as a facing material – render or cladding required.
- Additional insulation may be required to bring up to minimum standards (depending on width selected).
- Can be used in cavity wall specification to reduce reliance on insulation.
- Can increase speed of construction by 3 or 4 times over traditional loadbearing masonry.
- BRE Green Guide A rating is achievable.
- Lime mortar will allow dismantling for re-use.

SUSTAINABLE ALTERNATIVES

- Fired hollow clay blocks are a sustainable alternative to traditional load-bearing masonry

CLICK HERE TO RETURN TO SECTION 2 - CLAY

CLAY BOARDS, PLASTERS & RENDERS

ADVANTAGES

- Natural materials
- Very low embodied energy
- Recyclable
- Non-toxic – reduced allergy risk
- Can control internal moisture content

DISADVANTAGES

- Easily eroded
- Not robust
- Synthetic additives in commercial production may reduce recyclability
- More expensive than gypsum alternatives

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Should only be used where adequately protected from moisture. Water will soften and reactivate its workability.
- Fibre additives (such as straw) can increase robustness and moisture resistance.
- Limewash can also increase moisture resistance.
- Clay plasters regulate air temperature and vapour content.
- Linseed oil as a surface treatment can make impermeable but negate its permeability.
- Commercially produced versions are available with synthetic additives and natural pigmentation.
- Cannot be used over gypsum plasterboards. Clay board can be used as a substitute in framed construction.
- Clay board has better acoustic properties than gypsum alternatives.
- Check fire resistance.
- Check acoustic properties.
- Clay boards are very heavy requiring additional fixings.

SUSTAINABLE ALTERNATIVES

- Clay plasters and renders are sustainable alternatives to cement-based products.
- However, they may not be robust enough for modern buildings
- Lime-based products may be more effective if this is an issue

CLICK HERE TO RETURN TO SECTION 2 - CLAY

CLAY DRAINAGE

ADVANTAGES

- Natural materials
- Recyclable
- Robust
- Long lifespan
- Potential reduction in materials over UPVC alternatives

DISADVANTAGES

- Product of mineral extraction
- Relatively high embodied energy content

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Sustainable alternatives for below ground drainage are limited. Vitrified clay can be used in preference to plastic.
- 100 year + lifespan works in favour of Whole Life Costing assessment.
- For maximum sustainability, follow the following guidelines.
- Specify from manufacturer with ISO14001 accreditation.
- Bed on recycled aggregate.
- Mains drainage is the most efficient method of dealing with foul waste.

SUSTAINABLE ALTERNATIVES

- Cast iron offers greater opportunities for recycling and use of recycled material
- Also less concrete encasement may be needed on site with C.I
- In areas isolated from mains infrastructure, on-site treatment may be an alternative

CLICK HERE TO RETURN TO SECTION 2 - CLAY

COMPOSITE CLADDING PANELS

ADVANTAGES

- Speed of construction on site
- Simplified build-up
- High U-values
- Airtight
- Re-use is possible

DISADVANTAGES

- Recycling depends on specialised processing
- May have plastic-based coatings
- Quicker site operations often offset by longer lead in times
- Cores may be petro-chemical derived

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Recycling of composite cladding panels is in its infancy.
- It may not always be economically feasible to separate out the core from the facing material.
- Wholesale re-use is possible, especially if secret fixing is used.
- The insulation used in cores may also be of a rigid type which has high embodied energy or involve toxic by-products.
- Recycling process of insulation cores is currently being developed but is not widespread at present.

SUSTAINABLE ALTERNATIVES

- Built-up steel or cladding with mineral fibre insulation
- Timber cladding
- Second hand composite cladding re-used

CLICK HERE TO RETURN TO SECTION 2 - COMPOSITE MATERIALS

COMPOSITE FLOORING & STRUCTURAL DECKS

ADVANTAGES

- Lightweight high strength solution
- Space saving – may result in reduced building height
- Less time on site

DISADVANTAGES

- Unrecyclable
- May require pumped concrete

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- A composite flooring system is one which works by laminating one material on to another and gaining strength from the two materials working together.
- The most common is profiled steel sheet with high strength con.crete topping bonded via shear connectors
- A+ Rating is available under BRE Green Guide; however, this does not take into account recyclability or end-of-life options.
- Composite steel / concrete flooring is unrecyclable. The concrete cannot economically be removed from the steel during demolition

SUSTAINABLE ALTERNATIVES

- Any alternative system incorporating similar materials (e.g. screed on pre-cast planks)
- This will allow recycling for aggregate at demolition

CLICK HERE TO RETURN TO SECTION 2 - COMPOSITE MATERIALS

CONCRETE BLOCKS

ADVANTAGES

- High thermal mass
- Use secondary aggregates
- Almost universal A+ Green Guide rating
- Good workability

DISADVANTAGES

- Aggregates won by mineral extraction
- Relatively high embodied energy
- Cement based mortar for fixing increases embodied energy further
- Dense version may be heavy to lift

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Care should be taken in selecting the block for optimum sustainability.
- Most incorporate a substantial amount of recycled material.
- Cement substitute and RCA content are often standard by default and may not even be advertised as such.
- Blocks are available which incorporate cement substitutes such as GGBS, FBA or PFA.
- Aerated blocks have less embodied energy than denser types and are easier to transport and lay.
- Aerated blocks use 50% cement substitute.
- Aerated blocks will improve U-value. Dense blocks will worsen.
- Fair-faced can be left exposed to exploit thermal mass.
- Use of lime mortar in laying will enable reuse at demolition.

SUSTAINABLE ALTERNATIVES

- Fired clay blocks
- Hemcrete (Hemp-lime) blocks
- Woodchip ICF Blocks (Durisol)
- Rammed Earth

CLICK HERE TO RETURN TO SECTION 2 - CONCRETE PRODUCTS

CONCRETE

ADVANTAGES

- High thermal mass
- Durability
- Potential for factory produced components
- Aggregates have low embodied energy
- Inherent fire resistance without chemical additives
- Reinforcement is usually 100% recycled steel

DISADVANTAGES

- Recyclablity usually does not include a reuse option ('downcycling' only).
- Cement has high embodied energy
- Aggregates won by mineral extraction

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Pre-cast elements may offer higher Green Guide ratings than cast-in-situ systems.
- With In-situ work, self-compacting concrete may offer better finishes and less time on site.
- In-situ mixes should be sourced locally as possible.
- A major advantage of using concrete is gained by exploiting its thermal mass. Therefore this should be exposed at an approximate rate of 1 square metre per metre of floor area.
- Specify highest proportion of cement substitute possible (Most commonly GGBS or Fly ash). Many companies will now offer 'Low-carbon concrete'. The concrete industry is working on many alternatives such as carbon-cured concrete.
- Take care specifying recycled aggregate. This may not always be the most sustainable solution due to size and shape requiring higher cement content.
- Concrete external cladding has poor ratings under the BRE Green Guide. High ratings are available for concrete flooring. There is no rating for structural concrete frames.

SUSTAINABLE ALTERNATIVES

- Steel will offer comparative benefits but may not offer thermal mass
- Timber and timber-based products (Glu-lam / Parallam etc.) can be used for framing, flooring and cladding but will require an alternative design approach
- CLT is a viable structural alternative where spans are relatively short
- See Section 2 - 'Steel versus Concrete'

CLICK HERE TO RETURN TO SECTION 2 - CONCRETE

COOPER

ADVANTAGES

- Traditional material
- Easily recycled
- Potential anti-bacterial qualities
- Durable and robust
- Can have high recycled content

DISADVANTAGES

- Won by mineral working
- Run-off may contaminate rainwater
- Finite resource
- High energy processing from ore
- Expensive

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Attempt to ensure high recycled content if specifying on large scale.
- Run-off from copper roofing or rainwater goods may be contaminated beyond potability.

EMBODIED ENERGY (MJ/KG)		
	Virgin	Recycled
Zinc	72	9
Copper	70	17.5 - 50
Lead	49	10
Source: Inventory of Carbon & Energy (ICE), University of Bath 2008		

CLICK HERE TO RETURN TO SECTION 2 - SHEET METALS

EARTH COB

ADVANTAGES

- Natural and renewable materials
- Extremely low embodied energy
- Can be produced on site

DISADVANTAGES

- Limited weather resistance
- More suitable for domestic level and self-build projects
- Limited bearing strength
- Heavy

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- A mixture of sand, clay, water and straw, traditionally mixed by letting cows walk through it.
- Will require additional weatherproofing and structural support. (Lime render and timber frame).
- Commercially produced Cob blocks are now available no rating for structural concrete frames.

SUSTAINABLE ALTERNATIVES

- Rammed earth
- Hemcrete
- Straw bale

CLICK HERE TO RETURN TO SECTION 2 - EARTH

GYPSUM PLASTER & PLASTERBOARD

ADVANTAGES

- Lightweight & easily worked
- Can cover 'shoddy' workmanship
- Raw material can be sourced as waste product
- Active recycling programme

DISADVANTAGES

- Natural material won by mineral extraction
- Synthetic material is of limited supply
- High embodied energy content
- Landfill can cause production of toxic gases & fluids – strict disposal laws

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Gypsum can be sourced from either natural mines or recovered as a by-product from power station flue-gas desulphurisation. However, other waste products from this process are not so easily disposed of.
- As power generation moves away from fossil fuel burning, the availability of FGD gypsum will become limited.
- Drylining can negate the usefulness of thermal mass within the building.
- Legislation has forced UK industry to create a collection and recycling programme for plasterboard.
- Board products now exist with high recycled content.

SUSTAINABLE ALTERNATIVES

- Clay plasters & boards
- Lime plasters
- Fair-faced or unlined surfaces (exploiting potential of thermal mass)

CLICK HERE TO RETURN TO SECTION 2 - GYPSUM

HEMP-LIME

ADVANTAGES

- Natural materials
- Carbon lock-up/sink
- High U-values possible
- High thermal inertia (similar to thermal ass)
- Breathable construction

DISADVANTAGES

- Specialised equipment required for in situ umping
- Wall thicknesses may be prohibitive
- Not water resistant
- Friable

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Tradical Hemcrete is a proprietary product therefore make up of its ingredients is not publicised. However, the mix does include some cement.
- Combine with lime based renders and plasters for a vapour permeable construction.
- Hempcrete may not be durable enough for commercial construction and will require protection. Lime render may not be robust enough to do this in say, a warehouse environment. The manufactures may even recommend a concrete inner leaf, further increasing the wall thickness which may need to be substantial already.
- K value ranges from 0.07 to 0.05 W/m2°C but the thermal performance of hempcrete is difficult to express by the U-value method, which is unsuited to thick materials with a high degree of thermal dynamism.
- To achieve improved u-values, walls may require considerable depth.
- Site applied Hempcrete may be limited in application due to seasonal conditions. Air temperature and humidity can adversely affect workability and curing.

SUSTAINABLE ALTERNATIVES

- Hemp-Lime is a sustainable alternative to traditional construction, particularly cavity walling or timber framing in housing and low-rise buildings
- Alternatives include:
  - Straw bale
  - Fired clay block
  - Rammed Earth

CLICK HERE TO RETURN TO SECTION 2 - HEMP LIME

ICF (INSULATED CONCRETE FORMWORK) BLOCKS

ADVANTAGES

- Speed of construction
- High U-values and airtightness
- Ease of use for self-builders
- High load-bearing capacity

DISADVANTAGES

- Use large amounts of cement based materials which have a very high embodied energy content
- Not easily recyclable
- No thermal mass
- Usually imported into UK
- Uses petrochemical derived formwork

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Usually formed from polystyrene based material and filled with concrete, variations exist which are made from recycled woodchip with a partial fill from mineral fibre.
- The insulation isolates the concrete's thermal mass potential so this cannot be exploited.
- Designs may be limited by the flexibility of the system adopted.
- Specify low carbon concrete fill with cement substitute such as PFA or GGBS.
- Recycled aggregate may not be feasible due to small gaps to be filled.
- Some products will have ties made from recycled plastic.
- Usually rendered but may be faced with other materials. Specify lime render or pigment to avoid painting.
- Composite nature means it may be difficult to recycle.

SUSTAINABLE ALTERNATIVES

- Woodchip version will have lower embodied energy than the polystyrene version
- Perforated clay blocks
- Timber-frame construction and /or cladding

CLICK HERE TO RETURN TO SECTION 2 - ICF

INSULATION - DATA

	MATERIAL	ORIGIN	EMBODIED ENERGY (MJ/KG)	CONDUCTIVITY (K VALUE- W/M°C)	BRE GREEN GUIDE	NOTES
ORGANIC SOURCES	Cellulose	Recycled newspaper	0.94 to 3.3	0.034-0.040	A+	• Blown into suitable cavity or void. • Chemical fire retardant treatment • Renewable • Grown – therefore Carbon sink
	Cork	Trees	4.0	0.037-0.040	A	• Potentially recyclable • Grown – therefore Carbon sink • Renewable
	Flax	Crops	39.50	0.037	?	• May use plastic binder and chemical fire / insect treatments • Grown – therefore Carbon sink • Renewable
	Hemp	Crops	?	0.037-0.039	?	• May use ammonium phosphate as fire retardant. • Some use 8-10% plastic binders • Grown – therefore Carbon sink • Renewable
	Sheep's wool	Sheep farming	20.90	0.036-0.040	A	• Chemical fire retardant and insecticide treatments • Renewable
	Straw	Crops	0.24	0.045	A	• Bales or used as part of modular walling system • Renewable • Grown – therefore Carbon sink
	Wood Based	Timber industry by-products	10.8 (Woodwool) 20.0 (Woodwool board)	0.038-0.040	?	• Wood fibre insulation uses woodchip with polyolefin binders
	Wood/Hemp	Timber industry with crops	?	0.038	?	• 55% Wood • 30% Hemp • 15% Polyurethane binders • Grown – therefore carbon sink • Renewable

	MATERIAL	ORIGIN	EMBODIED ENERGY (MJ/KG)	CONDUCTIVITY (K VALUE- W/M°C)	BRE GREEN GUIDE	NOTES
MINERAL EXTRACTION	Foamed glass	Recycled glass	27.00	0.042	A+ to C	• Rating dependent on density • Relatively low EE due to recycled content • Recyclable • High compressive strength
	Glass wool	30-60% recycled industrial waste	28.00	0.032-0.040	A+ to A	• Rating dependent on density • Potentially recyclable (if unsoiled) or re-usable • High recycled content • Binders may be toxic (formaldehyde) • Irritant
	Mineral/Rockwool	Up to 23% recycled industrial waste Mineral extraction	16.80	0.036	A+ to C	• Rating dependent on density • Potentially recyclable (if unsoiled) or re-usable • Binders may be toxic (formaldehyde) • Irritant • Product emissions include carbon-monoxide, formaldehyde & phenol
	Perlite	Mineral extraction	10.0	0.045-0.05	?	• Loose fill or blown into cavities & voids • Usually only domestic use
	Vermiculite	Mineral extraction	7.2	0.063	?	• Loose fill or blown into cavities & voids • Usually only domestic use
COMPOSITE	Multi-foil	Petro-chemicals & mineral extraction	?	1.69-1.71	?	• Manufacturer's claims difficult to prove • Very little independently verified data • Continuing controversy over performance

	MATERIAL	ORIGIN	EMBODIED ENERGY (MJ/KG)	CONDUCTIVITY (K VALUE- W/M°C)	BRE GREEN GUIDE	NOTES
PETRO-CHEMICAL DERIVED	Expanded Polystyrene (EPS)	Petro-chemical	88.60	0.033	A+	• Very high embodied energy • Petro-chemical derived • Toxic fire retardant treatment • Potentially recyclable (but not sually) • High compressive strength • Water resistant • Non-biodegradable
	Extruded Polystyrene (XPS)	Petro-chemical	109.20	0.032	E	• Extremely high embodied energy • Petro-chemical derived • Toxic fire retardant treatment • Potentially recyclable (but not usually) • High compressive strength • Water resistant • Non-biodegradable • May result in ozone depleting emissions (zero ODP version can cost extra)
	Phenolic Foam Board	Petro-chemical	87.00	0.018-0.025	?	• Very high embodied energy • Petro-chemical derived • Inherently flame resistant • Usually found in laminated elements • High compressive strength • Water resistant • Non-biodegradable • Not recyclable • Produced from toxic derivatives • Potentially shrinks over life causing uninsulated gaps

	MATERIAL	ORIGIN	EMBODIED ENERGY (MJ/KG)	CONDUCTIVITY (K VALUE- W/M°C)	BRE GREEN GUIDE	NOTES
PETRO-CHEMICAL DERIVED	Polyurethane (PUR/PIR)	Petro-chemical	72.10	0.019	A	• High embodied energy • Petro-chemical derived • High compressive strength • Water resistant • Non-biodegradable • Not recyclable • Hazardous emissions and wastes generated during production • Potentially shrinks over life causing uninsulated gaps
	Recycled Plastic / Eco-wool	85% recycled plastic bottles	?	0.040	?	• High embodied energy? • Ultimately petro-chemical derived • Rolls loose laid • Non-biodegradable • Non-toxic • Non-Irritant • Recyclable • Made from recycled material

CLICK HERE TO RETURN TO SECTION 2 - INSULATION

LEAD

ADVANTAGES

- Traditional material
- Easily recycled
- Relatively low energy in original processing
- Durable and robust
- Easily worked

DISADVANTAGES

- Won by mineral working
- Run-off may contaminate rainwater
- Finite resource
- Heavy - manual handling considerations
- Potential toxin. Historical evidence of widespread poisoning.
- Historical winning and processing has left contaminated landscape
- Attractive to thieves

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Attempt to ensure high recycled content if specifying on large scale.
- Avoid using any rainwater which has run-off from lead.

EMBODIED ENERGY (MJ/KG)		
	Virgin	Recycled
Zinc	72	9
Copper	70	17.5 - 50
Lead	49	10
Source: Inventory of Carbon & Energy (ICE), University of Bath 2008		

CLICK HERE TO RETURN TO SECTION 2 - SHEET METALS

LIME - MORTARS, RENDERS & PLASTERS

ADVANTAGES

- Lower embodied energy than cement or gypsum based products
- Carbon sink
- Flexible construction (less movement joints)
- Allows breathing construction'
- Recyclable

DISADVANTAGES

- Lower robustness than cement based alternatives
- Require protection from elements during construction
- Lower strength than alternatives
- Some categories of lime may have to be imported.
- Potentially harmful during mixing

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Widely used in conservation work, lime mortar may not be suitable for modern cavity walling due to its lower strength. There is very little guidance on this.
- A lime mortar of comparable compressive strength to a Portland cement bound mortar does not necessarily indicate that it has similar flexural strength, shear strength or durability. Some Continental hydraulic limes contain materials that make them more akin to Portland cement than traditional UK hydraulic limes.
- Fewer movement joints may be required but they probably cannot be excluded entirely.
- Lime cures by absorbing carbon dioxide. This therefore contributes to offsetting the emissions associated with slaking during production.
- Masonry built with lime mortar may be easier to recycle at demolition but the ease of this is dependant on the strength of the mix. Hydraulic varieties will be harder to remove.
- Lime based renders and plasters are softer than cement or gypsum based alternatives and therefore may be more prone to impact damage in industrial or commercial environments.
- In the UK, there may be a lack of sufficient experience in the use of lime for construction.
- High performance lime (NHL 5) will be imported from France.

SUSTAINABLE ALTERNATIVES

- Lime based products are considered a sustainable alternative to gypsum or cement based products but care should taken that if specified, they are fit for the purpose

CLICK HERE TO RETURN TO SECTION 2 - LIME

LINOLEUM

ADVANTAGES

- Natural material (Flax)
- Renewable resource
- Recyclable
- Biodegradable
- Non-toxic
- Water resistant

DISADVANTAGES

- High embodied energy content
- Flax cultivation uses fertilizers (nitrate runoff)

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Linoleum has a relatively high embodied energy content due to its manufacturing process but this is very small compared to PVC sheet and contains none of the toxins.
- Natural Rubber has a lower EE content but has to be imported from SE Asia.

SUSTAINABLE ALTERNATIVES

- Natural Rubber
- Cork flooring
- Ceramic tiles with recycled content

CLICK HERE TO RETURN TO SECTION 2 - LINOLEUM

LIVING ROOFS

ADVANTAGES

- Increased bio-diversity
- Improved rainwater attenuation
- Working carbon sink
- Help to reduce urban heat island effect.
- Reduced thermal stress on waterproofing medium

DISADVANTAGES

- Lightweight type may be monocultural
- Best bio-diversity comes with most unkempt appearance
- May hinder recycling of harvested rainwater
- Waterproofing and component materials usually of petro-chemical origin

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Two variants: Intensive & Extensive.
- Intensive is structurally heavy using a deep soil medium and often turf over a concrete slab.
- Extensive roofs are lightweight and may be as little as a pre-grown sedum mat laid over water-proofed steel sheeting.
- When costing a living roof, the increased capital expenditure should be offset against subsequent savings in cooling plant or surface water attenuation infrastructure. Make sure the QS & client understand this.
- Run-off from a living roof will be discoloured, limiting the opportunity for rainwater harvesting & re-use.
- Attempt to source low impact substructure & waterproofing materials (e.g. recycled bitumen sheet).
- Brown roofs offer increased bio-diversity. Demolition rubble from the existing site can be used for increased BREEAM points.
- Limit maintenance to removal of tree seedlings. Let brown roofs attract moss & lichen.

SUSTAINABLE ALTERNATIVES

- Living roofs are one of the most sustainable forms of construction. Despite using some high impact materials, the vegetation cover will offer a carbon negative solution over the life of the building which will probably offset any higher embodied carbon in the materials

CLICK HERE TO RETURN TO SECTION 2 - LIVING ROOFS

MARINE AGGREGATES

ADVANTAGES

- Low Carbon Footprint
- Minimal waste

DISADVANTAGES

- Can contribute to coastal erosion.
- Destructive to marine biosphere
- Marine operations are exempt from fuel emission legislation
- Finite resource

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Difficult to specify the origin of aggregates – question your suppliers.

SUSTAINABLE ALTERNATIVES

- Reduce requirement through efficiencies and alternative design strategies
- Greater use of secondary aggregates (by-products)
- Greater use of reclaimed resources

CLICK HERE TO RETURN TO SECTION 2 - MARINE AGGREGATES

PAINT - NATURAL

ADVANTAGES

- Low embodied energy
- Very low toxicity or non-toxic
- Made from low impact or renewable resources
- Biodegradable
- Very Low or No VOCs

DISADVANTAGES

- May not be suitable externally
- May not be as robust or durable as synthetic alternatives
- May require greater amount for decent coverage
- May be restricted in colour range or application
- May require longer drying times

ALTERNATIVES : LIMITATIONS AND USES

WATER-BORNE, PLANT BASED:

- Not suitable for external use
- Very low toxicity / Embodied Energy / VOC Content

SOLVENT-BORNE, PLANT-BASED:

- Incorporates VOC such as turpentine – Less toxic than synthetic types
- Suitable for external joinery
- Includes Linseed oil paint

MINERAL PAINT:

- No solvents
- Good durability, robustness and colour range
- External use
- Moderate embodied energy content†

DISTEMPER / CASEIN:

- Often called 'Protein paint' (Made from dairy products)
- From renewable resource
- May not be durable

CLAY PAINT:

- Low embodied energy content
- External use possible
- Extremely limited colour range

LIMEWASH:

- Non-toxic but care need during application (irritant)
- Product of mineral extraction
- Durability issues & limited colour range

SUSTAINABLE ALTERNATIVES

- Specify a material which doesn't require painting in the first place!

CLICK HERE TO RETURN TO SECTION 2 - PAINT

PAINT - SYNTHETIC

ADVANTAGES

- Robust & durable
- Colourfast
- Wide range of colours and specialist finishes and/or performances
- May offer intrinsic weather-protection

DISADVANTAGES

- Toxic
- May have high VOC content
- Hard to dispose of waste and containers without polluting the environment
- High embodied energy
- May 'off-gas' airborne pollutants, irritants and toxins
- Often petrochemical derived

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Just because a product is marketed as 'Zero VOC' doesn't mean it actually is – check the ingredients of the paint to be sure.
- If synthetic paint is unavoidable, specify Zero-VOC acrylic emulsion or a water-based product.
- Work with the contractor to ensure any waste or discarded container is disposed of correctly. Consider as being harmful chemical waste.
- Oil based paints are considered 'traditional' with low embodied energy but have a high VOC content and may be relatively toxic emitting irritant vapours.
- Acrylic paints are petrochemicals despite being water based.

SUSTAINABLE ALTERNATIVES

- Specify a material which doesn't require painting in the first place!
- Natural paints

CLICK HERE TO RETURN TO SECTION 2 - PAINT

PHASE CHANGE MATERIALS

ADVANTAGES

- Can be used as part of a passive heating & cooling strategy
- Can provide 'thermal mass' to a lightweight building
- Can be used as an applied finish rather than depending on exposure of dense materials such as concrete

DISADVANTAGES

- Potentially derived from petrochemicals
- Embodied energy unknown
- Probably unrecyclable
- Will add to the 'chemical cocktail'

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Suppliers will often be able to advise on the impact of using PCM through simulation software.
- When using board, specialist jointing procedures may have to be used.
- Board may also be able to act as a vapour barrier.
- Phase change materials are not suitable for every climate. Temperate offers the greatest opportunity. Use in other geographical climates should assessed with care.
- BRE Green Guide ratings are unknown.

SUSTAINABLE ALTERNATIVES

- Heavyweight materials such as exposed concrete or clay based materials.

CLICK HERE TO RETURN TO SECTION 2 - PCM

PLASTICS

ADVANTAGES

- Durable
- Robust
- May be recyclable
- Cheap

DISADVANTAGES

- Contain various toxins
- Non-biodegradable
- Usually a petrochemical product
- High embodied energy

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- There are countless varieties of plastic. All of these are products of an energy intensive petro-chemical refining process. Almost every type of plastic production involves emission of numerous toxins into the environment. This is also true of the disposal of plastic which although lasting thousands of years will leach and off-gas hazardous compounds in to the environment. These compounds include formaldehyde, ammonia, dioxin, mercury, phenol, chlorine and benzene (for which there is no known safe dose).
- PVC is often considered the worst of these types, incorporating chlorine, mercury and phthalates (plasticizers), which do not break down and can accumulate in water courses and wildlife.
- Despite publicity to the contrary, plastic is unlikely to be biodegradable.
- Where possible, plastic elements should be minimised and designed out of the building.
- Any unavoidable plastic elements should if possible include a recycled content as high as possible.
- Some companies are now recycling plastic elements into sheets available for use as interior elements or insulation.
- Recycled elements do not avoid the initial energy use of production nor the emissions associated with them.
- Bioplastics offer a non-petrochemical derived alternative.

SUSTAINABLE ALTERNATIVES

- Design out wherever possible and do not consider as primary option
- Where unavoidable, ensure high recycled content or biological origin (bioplastic)
- Consider recycling strategy at demolition

CLICK HERE TO RETURN TO SECTION 2 - PLASTICS

RAMMED EARTH - STABILISED

ADVANTAGES

- Largely natural materials
- Very low embodied energy content
- High thermal mass

DISADVANTAGES

- Very long process on site
- Weather protection needed during construction
- Sustainable credentials partially compromised by addition of cement based stabilisers
- Raw material may need to be imported from another area

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- The feasibility of a rammed earth structure may hinge on whether the local earth available on site is suitable. Assess this by survey first.
- Stabilisation will improve durability but will probably be cement based, increasing the overall embodied energy content of the construction.
- Stabilised rammed earth may be considered as a form of natural concrete due to the high cement content. (6-15%).
- Stabilisers will reduce the ability of the rammed earth to passively regulate the interior relative humidity but will marginally improve the U-value.
- Weather protection during construction is essential. May involve temporary structure. However, the finished structure can be exposed to the elements.
- Protracted curing period. Commercial scale walls may extend site works by up to 6 months.
- Limited number of practitioners (one!) reduce commercial and technical options.
- Consider formwork hire times; consider making specific formwork which may be more cost effective.

SUSTAINABLE ALTERNATIVES

- Unstabilised rammed earth
- Cob
- Hemcrete
- Straw Bale

CLICK HERE TO RETURN TO SECTION 2 - EARTH

RAMMED EARTH - UNSTABILISED

ADVANTAGES

- Completely natural material
- Extremely low embodied energy
- Provides passive thermal and humidity conditioning to interior spaces
- High thermal mass

DISADVANTAGES

- Low strength
- Not weather resistant
- High risk process
- Extremely long process on site
- Raw material may need to be imported from another area

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- The feasibility of a rammed earth structure may hinge on whether the local earth available on site is suitable. Assess this by survey and compression test first.
- Weather protection during construction and when complete is essential. May involve temporary structure. Structure should have “a good pair of boots and a hat.”
- Protracted curing period. Commercial scale walls may extend site works by up to 6 months.
- Consider making the formwork due to cost of hiring.
- Collapse during construction is a very real possibility
- Rain or water incursion (from leaks or flooding) will erode the material.
- Limited number of practitioners (one!) reduce commercial and technical options.

SUSTAINABLE ALTERNATIVES

- Stabilised rammed earth
- Cob
- Hemcrete
- Straw Bale

CLICK HERE TO RETURN TO SECTION 2 - EARTH

ROOF TILES 1: TIMBER SHAKES & SHINGLES

ADVANTAGES

- Natural product
- Very low embodied energy
- Reusable
- Biodegradable
- Renewable

DISADVANTAGES

- Longevity in wet climate
- Maintenance issues
- Fire spread concerns
- Acidic run-off from some timber species
- May be imported from North America

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Specify FSC / PEFC accredited timber.
- Consider in relation to context and location (fire risks?
- Select source as close to site as possible.
- If using, design according to the constraints of the material.

SUSTAINABLE ALTERNATIVES

- Timber shingles have the lowest embodied energy of any roofing material except thatch

CLICK HERE TO RETURN TO SECTION 2 - ROOF TILES

ROOF TILES 2: NATURAL SLATE

ADVANTAGES

- Natural product
- Low embodied energy
- Reusable
- Low toxicity
- Durable & robust
- Established second hand market

DISADVANTAGES

- May be transported over long distance
- Product of mineral extraction
- Expensive
- Large amount of waste associated with winning base material

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- May be 'Blue' or 'Grey' (Stone) slates.
- Attempt to source as locally as possible – avoid imported versions. Selection may depend on the traditional local vernacular.
- Lowest environmental footprint will come from reclaimed second hand units.
- May be an expensive option – look at offsets of whole life costing and examine life cycle analysis.

SUSTAINABLE ALTERNATIVES

- Reclaimed second hand slates are best option within this category
- Only timber offers a lower embodied energy content if locally sourced

CLICK HERE TO RETURN TO SECTION 2 - ROOF TILES

ROOF TILES 3: CLAY TILES

ADVANTAGES

- Natural product
- Reusable
- Low toxicity
- Durable & robust
- Established second hand market

DISADVANTAGES

- May be transported over long distance
- Product of mineral extraction
- Relatively high embodied energy

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Attempt to source as locally as possible – avoid imported versions. Selection may depend on the traditional local vernacular.
- Lowest environmental footprint will come from reclaimed second hand units.
- May be an expensive option – look at offsets of whole life costing and examine life cycle analysis.

SUSTAINABLE ALTERNATIVES

- Reclaimed second hand tiles are best option within this category
- Natural slates offer a lower carbon footprint
- Concrete tiles may have a lower embodied energy content but may contain more toxins

CLICK HERE TO RETURN TO SECTION 2 - ROOF TILES

ROOF TILES 4: ARTIFICIAL SLATE & TILES

ADVANTAGES

- Relatively low embodied energy
- Theoretically reusable
- Fairly durable
- Inexpensive alternative to natural products

DISADVANTAGES

- May have high toxicity
- May be transported over a long distance
- Heavy weight of concrete types will demand greater structure
- Production may generate greenhouse gases.
- Probably won't ever get reused

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Attempt to source as locally as possible – avoid imported versions.
- Although supposedly reuseable, in practice, this very rarely happens.
- Fibre cement tiles have a life expectancy of only about 30 years max. and a high toxicity level.
- Artificial slates may include concrete, fibre cement or resin-based reconstituted types.

SUSTAINABLE ALTERNATIVES

- Natural slates offer a lower carbon footprint however, clay tiles are higher in embodied energy than the manufactured alternative

CLICK HERE TO RETURN TO SECTION 2 - ROOF TILES

ROOFING MEMBRANES - SYNTHETIC RUBBER

ADVANTAGES

- Potentially recyclable (roofing)
- Robust
- Durable
- Relatively low toxicity

DISADVANTAGES

- Petro-chemical based
- High embodied energy
- Toxic run-off if consigned to landfill

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Synthetic rubber flat roofing is usually known as TPO (Thermoplastic Polyolefin) or EPDM (Elastomeric membranes).
- These are usually mechanically fixed with welded seams and so avoid many of the toxins associated with chemical adhesives.
- Achievable BRE Green Guide ratings range from D to A+ depending on the overall construction. The highest ratings are only achievable with a warm roof construction on steel framing rather than an inverted type or on concrete slabs.
- Usually are not recyclable but may be reusable if mechanically fixed and removed carefully.
- Their greatest contribution to sustainability may be as part of a green roof systems.

SUSTAINABLE ALTERNATIVES

- A pitched roof
- Green roofs

CLICK HERE TO RETURN TO SECTION 2 - ROOFING MEMBRANES

RUBBER FLOORING - (SYNTHETIC)

ADVANTAGES

- May have high recycled or natural rubber content
- Potentially reusable
- Durable
- Sound absorbing

DISADVANTAGES

- Petro-chemical
- Continuous off-gassing of chemicals
- Non-biodegrable
- Can include same toxins as PVC (c/f plastics)
- Generate toxic fumes when burnt
- High embodied energy

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Can be made largely from car tyres, the disposal of which is creating a worldwide problem.
- However, embodied energy is still high.
- Can be 'downcycled' for secondary use.
- Try and source products with a high proportion of natural rubber content - but ensure this is from a sustainable resource (Rubber cultivation has been linked to deforestation in SE Asia).
- BRE Green guide rating A.

SUSTAINABLE ALTERNATIVES

- Natural rubber
- Linoleum
- Cork

CLICK HERE TO RETURN TO SECTION 2 - RUBBER

SEALANTS, ADHESIVES & FILLERS

ADVANTAGES

- Essential to an air-tight design
- Only used in low quantities

DISADVANTAGES

- Potentially derived from petrochemicals
- Will probably contain VOC's
- Unrecyclable & difficult to dispose of
- Will add to the 'chemical cocktail'

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Attempt to specify low or zero content VOC types.
- Minimise use where possible.
- Attempt to source non-petrochemical derived types
- Specify types with low impact or recyclable packaging
- BRE Green Guide ratings are unknown.

SUSTAINABLE ALTERNATIVES

- Almost impossible to replace. Possibilities include: Coconut fibre, felt, sisal, lime but these probably are not suitable in a commercial environment

CLICK HERE TO RETURN TO SECTION 2 - SEALANTS ADHESIVES & FILLERS

SIPS & MODULAR SYSTEMS

ADVANTAGES

- High U-values
- High airtightness
- Factory quality control
- Extensive use of timber
- Greatly increased speed of construction
- Low embodied energy

DISADVANTAGES

- Extended lead-in period
- Earlier design freeze
- Design options may be curtailed by system
- Insulant and adhesives may incorporate toxins or petrochemicals
- Petrochemical insulation often used
- May be impossible to recycle

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- As part of a system such as Huf Haus, a weathertight shell can be erected within 15 days.
- Factory QA and skilled labour ensures high levels of airtightness and therefore energy efficiency. Often, a desired U-value is given as a brief to the supplier who will then design to that level.
- May be mostly suitable for domestic scale projects.
- European versions may use softwood staves as the outer material. OSB is also an option. In North America, ply is common but this should be avoided in the UK due to the possibility of including tropical hardwoods and formaldehyde based adhesives.

Note: Any factory produced prefabricated system will probably result in lower embodied energy and improved airtightness and therefore thermal performance.

SUSTAINABLE ALTERNATIVES

- SIPS are sustainable alternatives to traditional methods of envelope construction
- Avoid plywood
- Consider insulation alternatives – these are available on request

CLICK HERE TO RETURN TO SECTION 2 - PREFABRICATION

STEEL

ADVANTAGES

- Durability
- Construction grade steel may often have high recycled content
- Completely recyclable
- Speed of construction
- Potential for Modern Methods of Construction (pre-fab)
- Easier to adapt and alter when compared to concrete

DISADVANTAGES

- Additional fire protection may be required
- Weather protection may be chemical or plastic based coatings
- Some raw materials involve extensive transcontinental delivery
- Relatively lightweight – very little thermal mass

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Design for deconstruction. Can the elements be easily dismantled, reused or recycled?
- Avoid chemical weather or fire protection coatings.
- By combining with concrete floor elements, thermal mass can be introduced as a passive climate control mechanism.
- Reinforcement in the UK is likely to be from 100% recycled content but may be imported from Eastern Europe.

SUSTAINABLE ALTERNATIVES

- Concrete may offer some in-use advantages (see Section 2 - 'Steel versus Concrete')
- Timber and timber-based products (Glulam / Parallam etc) can be used for framing, flooring and cladding but will require an alternative design approach.
- Cross laminated timber (CLT) in low to medium rise projects
- Basalt based reinforcement and ties

CLICK HERE TO RETURN TO SECTION 2 - STEEL

STONE - NATURAL

ADVANTAGES

- Natural, largely inert material
- Low embodied energy
- Often contributes to the vernacular context
- May support local traditional trades and skills
- Heavyweight material
- Easily recycled
- Robust & durable

DISADVANTAGES

- Won by mineral working – causes disruption
- Quarrying often takes place in rural areas
- Potentially extensive transportation involved
- Expensive material
- Specialist trade required

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Only select local or at least indigenous varieties - do not import.
- Consider lime mortars (see 'Lime').
- Source second-hand reclaimed stone.

SUSTAINABLE ALTERNATIVES

Natural low-impact structural facing materials may include:

- Rammed earth
- Earth blocks
- Timber structure and / or cladding

CLICK HERE TO RETURN TO SECTION 2 - STONE

STONE - ARTIFICIAL

ADVANTAGES

- Semi-natural, largely inert material
- May use natural waste material from quarrying
- Heavyweight material
- Complex features possible relatively easily

DISADVANTAGES

- Weathering characteristics may not be a sufficient substitute for natural stone
- Cement based product with fairly high embodied carbon
- Less durable and robust than natural stone
- May look "cheap," if of low quality

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Ensure detailing takes into account its characteristics - this is not stone!
- Select on the basis of inspecting a physical sample prior to specification.
- Best used only for complex features rather than main walling.

SUSTAINABLE ALTERNATIVES

- Natural stone

CLICK HERE TO RETURN TO SECTION 2 - ART & CAST STONE

STRAW BALE

ADVANTAGES

- Natural material
- Biodegradable
- Renewable
- Carbon sink
- Extremely low embodied energy
- Excellent acoustic properties

DISADVANTAGES

- Wall thicknesses may be substantial
- May be expensive due to on-site 'flying factory' set up costs
- Limited design options

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Although used in self-build low-tech housing for a number of years, the commercially available version of straw bale walling is a system marketed by Mod-Cell.
- Cost and programme may depend on the local availability of straw.
- Straw bales are made on-site and fitted into a factory produced frame built to a set module.
- These frames may limit the design options available. Windows may have very deep reveals.
- The thermal performance of straw bales may be difficult to express by the U-value method which is unsuited to thick materials with a high degree of thermal inertia.
- Use in conjunction with lime render to create a breathing construction.
- Consider using only organic straw for improved sustainability.

SUSTAINABLE ALTERNATIVES

- Straw bales are a sustainable alternative to traditional construction, particularly cavity walling or timber framing in housing and low-rise buildings.
- Alternatives include:
  - Hemp-Lime
  - Fired clay block
  - Rammed Earth
  - SIPS

CLICK HERE TO RETURN TO SECTION 2 - CROPS

TIMBER CLADDING

TYPES

EUROPEAN OAK

- Durable
- Will leach tannin initially
- May be expensive

SWEET CHESTNUT

- Durable
- Will leach tannin initially
- May be expensive and in short supply

WESTERN RED CEDAR (EUROPEAN GROWN)

- Moderately durable

WESTERN RED CEDAR (UK GROWN)

- Moderately durable
- May be expensive and in short supply

LARCH (SIBERIAN NOT UK)

- Moderately durable
- UK larch grows too quickly to be durable.
- Siberian larch is commonly available

THERMOWOOD

- Heat treated softwood– no chemicals
- Different surface colour treatments available
- Higher embodied energy content due to processing
- Imported from Finland

ACCOYA

- Chemically treated softwood
- Different surface colour treatments available
- Higher embodied energy content due to processing
- Imported from Finland

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Always demand proof of origin and provenance (FSC / PEFC).
- Avoid using sapwood.
- 'Green' wood can be used and dries naturally. Allow sufficient fixings to absorb shrinkage.
- European Oak and Sweet Chestnut contain a great deal of tannin. This will initially stain but then wash off. Use corrosion resistant fixings (e.g. stainless steel) and protect surfaces from staining during this period.
- All durable and moderately durable timbers contain tannin, all tannin will leach from timber as it weathers, some staining / run off will occur. Detail appropriately and brief client accordingly.
- There is a relationship between cladding longevity and the depth of eaves. 600mm should be the optimum.
- Design a splash zone of no less than 150mm above the ground.
- Ventilate behind the cladding.
- Ensure the sawn ends are treated and/or well vented.
- Take great care in the detail design – do not abandon to site staff.

CLICK HERE TO RETURN TO SECTION 2 - TIMBER

TIMBER - COMPOSITE SHEETS

TYPES

OSB

- Uses off cuts from other processes (waste material)
- Uses phenol formaldehyde as binder but this is stable with no off-gassing
- Recyclable / Recycled content
- Robust
- Durable
- Viable alternative to plywood
- Plywood
- Robust
- Durable
- Hardwood faced variant usually bonded with Urea Formaldehyde – More off-gassing than OSB (Formaldehyde is carcinogenic and an irritant)
- Hardwood based plywoods are a major destination of illegally logged tropical timber

FIBREBOARDS (MDF / CHIPBOARD / HARDBOARD ETC)

- Stable and easily workable
- Usually for interior users only
- Bonded with formaldehydes or alternative resins.
- Create airborne particulates when worked. Most are carcinogenic and asthma inducing
- Strict restrictions on working and use relating to protective clothing and respirators
- Banned in some countries

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- OSB is the most environmentally friendly selection for timber based sheet materials (excluding raw timber).
- Pay attention to degree of material working required and likelihood of off-gassing or particle inhalation.
- If using ply is unavoidable, demand full FSC / PEFC documentation. This should be obtained for every constituent layer and not just the facing ply.
- Attempt to source boards which use non-formaldehyde glues.
- Phenol Formaldehyde is more stable than Urea formaldehyde and presents a lower threat to the environment and humans.

CLICK HERE TO RETURN TO SECTION 2 - TIMBER

TIMBER - PROCESSED & ENGINEERED

TYPES

GLULAM

- Alternative to steel or concrete but withreduced spans in some situations
- Equivalent glulam beam may have only 20-25% of the embodied energy of steel or concrete.
- Usually imported (possibly even from Canada). However, indigenous species can be used to produce glu-lam (e.g. Sweet Chestnut).
- Glue may be toxic
- Alternative products exist in the form of LVL (Laminated Veneer Lumber) and Parallam

THERMOWOOD

- Thermally treated softwood
- May include 'Lunawood' and Platowood'
- Stable
- Imported from Europe
- No chemical treatment
- May not require any further surface treatment
- Used mainly for cladding

ACCOYA

- Non-toxic chemically modified softwood
- Accoya can be used and/or machined for numerous applications (windows /cladding)
- Usually receives applied finish
- More durable than teak (virtually rot-proof)
- Suitable for use in freshwater immersion

CLT

- Multi-storey application possible
- High degree of inherent fire resistance
- Strength-to-weight ratio comparable to concrete, despite being five times lighter
- Considerable reduction in Global Warming Potential over steel or concrete
- High degree of off-site fabrication employed
- High speed of construction
- Suitable for seismically durable designs

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Always specify FSC or PEFC accredited timber components and demand certification or at least provenance if from a smaller supplier.
- Attempt to secure a timber source which is indigenous or at least requires the minimum amount of transportation.
- Timber products may require transportation or need chemical treatment for manufacture or weather / fire resistance - however, the embodied carbon and energy of timber is so much less than other materials, this becomes a secondary consideration.
- Timber from large scale industrial plantations such as those in the USA or Canada may involve monocultural practices and clear cut logging which is bad for bio-diversity. European and Scandinavian timber is grown on a smaller more ecologically sustainable scale.
- Timber is one of the few renewable materials.

CLICK HERE TO RETURN TO SECTION 2 - TIMBER

VINYL FLOORING

ADVANTAGES

- Hard-wearing & durable
- Longevity
- Recyclable
- Inert in use

DISADVANTAGES

- Petrochemical
- High embodied energy
- Manufacture may pollute
- Non-degradable
- Will add to the 'chemical cocktail'

CONSIDERATIONS, LIMITATIONS & BEST PRACTICE

- Whole life assessment can be comparable with linoleum.
- Use product with as high a recycled content as possible.
- If disposing of, ensure collection for recycling.
- BRE Green Guide A+ rating possible.

SUSTAINABLE ALTERNATIVES

- Linoleum
- Timber flooring
- Cork
- Natural Rubber (If available)
- Ceramic tiles

CLICK HERE TO RETURN TO SECTION 2 - VINYL FLOORING

WINDOWS 1: GENERAL & GLAZING

GENERAL

- Heat lost through the window frame in use is likely to have a much greater environmental impact than the embodied energy entailed in its production.
- Windows are the weak link in an insulated envelope. In commercial buildings, the optimum glazing ratio is approximately 40% of the external wall area, regardless of elevation (as long as solar shading is provided.) Under Building Regulations, the maximum U-value is 2.2W/m^{2o}C while for an external wall, it is 0.35W/m^{2o}C This means that almost half the envelope may be leaking heat at a rate of over six times as much as the rest! Therefore, although expensive to achieve, greater energy savings can be made by improving the window specification rather than just concentrating on the wall insulation.
- Heat is lost not only through the glazing but through the frame as well. U-values may be given for the centre pane, the frame or for the whole unit. Whole window values are expressed as Uw. Glazing values are Ug.
- For frames, it is important to choose a material with the least conductivity. Wood is the least conductive material followed by PVC and metal.
- Even with timber frames, the metal spacers between the glass panes act as cold bridges. Large panes have a shorter perimeter than lots of smaller panes and therefore are more thermally efficient. Warm edge spacers are available in high-spec windows.
- Frames can be thermally broken (even timber ones). But the material used for this may be a petro-chemical based insulation such as PUR. However, this will only be present in small quantities.
- Installation of the frames is just as important as the windows themselves. This is a weak link where air tightness should be maintained by good detailing and adequate site supervision.

GLAZING

- Glazing options include variations on double and triple glazing together with warm edge spacers, low-emissivity coatings and possibly inert gas fills. Without these additional last two items, the U value of the glazing may not be vastly improved.
- The minimum Building Regulations standard is currently (August 2009) 2.2W/m^{2o}C This is the approximate value of double glazing with no gas fill or low-e panes
- Double glazing with a low-e coating is typically 1.7W/m^{2o}C
- Passivhaus standards require 0.8W/m^{2o}C. This level can be achieved by triple glazed units with low-e panes and an argon fill.
- The lowest value possible from a high spec double-glazed unit is about 0.9W/m^{2}oC using low-e glass and a krypton fill.

CLICK HERE TO RETURN TO SECTION 2 - GLASS & GLAZING

WINDOWS 2: TEMPERATE HARDWOOD

ADVANTAGES

- Low embodied energy
- BRE Green Guide A+ rating
- Renewable resource
- Low maintenancea
- Durable
- Biodegradable
- Good thermal performance

DISADVANTAGES

- Structural limitations on design
- Not recyclable (other than as fuel)
- Left untreated may fade in UV light – Client / tenant taste issues

NOTES

- The UK has the greatest demand for tropical hardwood in Europe. Consequently Britain imports more illegally logged timber than any other country in the world. Most of this is Mahogany and Red Meranti and is used in garden furniture and domestic window production. Specifying temperate hardwood will not only reduce the market for illegal timber but also help prevent rain forest degradation.
- Some tropical hardwoods may be from proven sustainable sources and have FSC or PEFC accreditation but will still have a higher embodied energy content than temperate hardwoods due to transportation.
- Always specify FSC sourced timber if possible and ensure certificates are obtained.
- Treating and painting wood adds significantly to its environmental impact. Either specify a naturally durable species that doesn't need treating or select a low impact treatment.

CLICK HERE TO RETURN TO SECTION 2 - TIMBER

WINDOWS 3: TEMPERATE SOFTWOOD

ADVANTAGES

- Low embodied energy
- BRE Green Guide A or A+ rating
- Renewable resource
- Moderately durable with maintenance
- Biodegradable
- Good thermal performance

DISADVANTAGES

- Structural limitations on design
- Not recyclable (other than as fuel)
- aintenance (re-painting or staining) required on a regular basis
- Paint is often petrochemical derived, toxic in use, non-biodegradable and generates hazardous waste

NOTES

- UK grown softwood may be grown too quickly for maximum durability and strength. Timber from colder climates may perform better (E.g. Scandinavia or Siberia).
- Always specify FSC sourced timber if possible and ensure certificates are obtained.
- Treating and painting wood adds significantly to its environmental impact. Select a low impact treatment from plant based origins.
- Paint is a toxic chemical which is unrecyclable and causes high levels of hazardous waste.

CLICK HERE TO RETURN TO SECTION 2 - TIMBER

WINDOWS 4: ALUMINIUM / SOFTWOOD COMPOSITE

ADVANTAGES

- Partially renewable resource (timber)
- Extremely durable
- Long lifespan with minimum maintenance (up to 50 years)
- Good thermal performance

DISADVANTAGES

- Partially recyclable (Al)
- High embodied energy content in aluminium
- Coating to aluminium may have adverse environmental impact

NOTES

- Always specify FSC sourced timber if possible and ensure certificates are obtained.
- Try and source a high proportion of recycled aluminium.
- Natural or anodised finish is most sustainable to aluminium.
- When originally introduced, composite frames scored very low under the BRE Green Guide. (D rating). However, the latest version (2022) now shows an A or B rating. It is unclear whether this is due to an improvement in performance or measurement methods.

CLICK HERE TO RETURN TO SECTION 2 - ALUMINIUM

WINDOWS 5: ALUMINIUM

ADVANTAGES

- Recyclable
- Extremely durable
- Long lifespan with minimum maintenance (up to 50 years)
- Low maintenance
- BRE Green Guide B rating possible with profile of less than 0.88kg/m

DISADVANTAGES

- High Global warming potential
- High embodied energy content in aluminium
- Coating to aluminium may have adverse environmental impact
- BRE Green Guide rating drops to D with profile of greater than 1.08kg/m. Therefore, this may constrain design decisions

NOTES

- Try and source a high proportion of recycled aluminium.
- Natural or anodised finish is most sustainable form of finishing aluminium.
- Ratings under the BRE Green Guide can vary for aluminium windows. This can often depend on the weight of aluminium per metre used in the frames.

CLICK HERE TO RETURN TO SECTION 2 - ALUMINIUM

WINDOWS 5: COATED STEEL

ADVANTAGES

- Recyclable
- Durable
- Low maintenance
- BRE Green Guide B rating possible

DISADVANTAGES

- High Global warming potential
- High embodied energy content
- Coating may have adverse environmental impact
- Toxic by-products
- Poor thermal performance
- Heavy section

NOTES

- Most steel windows contain approx 20% recycled content.
- Galvanising is a preferable finish to paint as it facilitates easier recycling and is less toxic to the environment.
- Original (1930s) steel windows were thin in section but are unlikely to look like this today due to the requirement for double-glazing and thermal breaks.

CLICK HERE TO RETURN TO SECTION 2 - STEEL

WINDOWS 7: PVC

ADVANTAGES

- Potentially recyclable
- Moderately durable
- Low maintenance
- Good thermal performance
- BRE Green Guide A / A+ rating possible

DISADVANTAGES

- High embodied energy content
- Recycled content is still unusual
- Toxic by-products in manufacture
- Large sections often requiring reinforcement
- Can degrade in UV light
- Petrochemical derived
- Non-biodegradable

NOTES

- Refer to the section on plastics.
- PVC is a petrochemical which incorporates chlorine, phthalates and other toxins in its manufacture. Off-gassing and run-off from these enters the environment where their full impact is not yet fully understood.
- There is very little recycled content in PVC frames. Most PVC from windows is 'down-cycled' to lower grade plastic and used for other elements (such as drainage). The greatest advances are taking place in Germany. Rehau include a relatively high proportion of recycled content in their frames. Several UK recycling centres now exist with Veka claiming that their plant provides a "closed loop," system for PVC re-use.
- Despite the lengthy list of environmental disadvantages, PVC windows can achieve Green Guide ratings of A for domestic and A+ for commercial applications.

CLICK HERE TO RETURN TO SECTION 2 - PVC

ZINC

ADVANTAGES

- Low toxicity in use
- 100% recyclable at low energy input
- Low scrap value dissuades theft
- Durable and robust with extended lifespan
- Sheet or galvanised elements require no further coating

DISADVANTAGES

- High embodied energy for virgin material
- Product of mineral winning
- High energy production process
- Expensive

NOTES

- Attempt to ensure a high recycled content.
- Zinc sheet is preferable to galvanised steel as the material is recoverable.
- Galvanised steel may be a more sustainable alternative to anything requiring a plastic based coating.

EMBODIED ENERGY (MJ/KG)

	Virgin	Recycled
Zinc	72	9
Copper	70	17.5 - 50
Lead	49	10

Source: Inventory of Carbon & Energy (ICE), University of Bath 2008

CLICK HERE TO RETURN TO SECTION 2 - SHEET METALS

APPENDICES

SGP - AN INTRODUCTION

Stephen George + Partners (SGP) is an Architects' Journal AJ100 practice with offices in London, Leicester, Leeds, Birmingham and Solihull. Our award-winning teams are skilled and highly versatile, providing an exceptional level of expertise in masterplanning, design and delivery. We add value with our capability in digital, visualisation, interiors and health and safety services.

WE CARE + WE CHALLENGE + WE DELIVER

We believe that good architecture is built on strong relationships, and we work closely with clients in both the public and private sectors, listening to their needs and understanding their values and culture to deliver outstanding projects across a range of sectors.

We are known for our quality, reliability and integrity. We apply our technical expertise and commercial realism to resolve complex issues effectively and deliver well-designed, innovative buildings, creating better places for people to live, work and enjoy.

SUSTAINABLE DESIGN

Our interest in sustainable design spans the life of the Practice and we were commissioned to research passive solar energy collection by the European Commission back in 1978. In 2008 we were invited to join the UK-GBC Biodiversity Task Group and have been part of a dedicated workstream to develop a campaign strategy to provide clarity for the industry and promote best practice for the provision and means of assessment of biodiversity within the built environment.

SOCIAL RESPONSIBILITY

We are committed to nurturing an open, inclusive, fair and supportive business that promotes social value and embraces our duty of care to our community, the environment and society as a whole. We recognise these under the heading of Social Responsibility, a core value of our Practice, which our Social Responsibility Group leads through the Stephen George + You initiative, an award-winning programme, addressing Buildings (including our Better Buildings website SGP Better builds *(stephengeorge.co.uk)), Community, Planet and People & Training.*

Our Social Value programme extends to the support of several charities including the Trussell Trust (a UK Food Bank Charity), sponsorship of junior sports teams, our own honeybee hive, initiatives promoting health and wellbeing as part of Mental Health Week and our SGPID Group which promotes diversity, inclusion and equality across the Practice.

Our Thought Leadership programme includes published pieces entitled 'Beyond the Envelope – Biometric High-Rise', 'The Road to Sustainability in Architecture' and 'Designing with Authenticity'. We hold the ISO 14001:2015 Standard and are members of both the UKGBC and Planet Mark with whom we are embarking on our Net Zero Carbon route map.

FAIRNESS INTEGRITY QUALITY SERVICE DESIGN SOCIAL RESPONSIBILITY

NORSE CONSULTING - ABOUT US

Norse Consulting is the parent company for building consultancy services within the Norse Group, delivering integrated property solutions for communities nationwide. We bring passion, expertise, and a spirit of partnership to create places that work for people and the planet.

PLACES FOR PEOPLE AND THE PLANET

We are committed to sustainability and creating places that benefit people and the planet. Our energy specialists work alongside clients from conception to completion and beyond to support their net zero goals by implementing decarbonisation initiatives and delivering net zero (in use) homes and low-carbon public buildings.

CONTINUOUSLY BY YOUR SIDE

Our operational breadth and scale benefit our clients, partners, and their communities across the whole asset life cycle. With expertise across advisory, design, and estates, supported by a network of specialist services within the Norse Group, we are continuously by your side. Together, we deliver solutions to support local communities better, maintaining a purpose-driven approach to improving the places where people live, work, and receive health and care.

EXPERTISE DERIVED FROM PASSION

Our people are our greatest asset and are committed to delivering a consistently high-quality service to our clients. Leveraging a wealth of knowledge and experience across a broad range of building consultancy services, our team plays a pivotal role in enhancing Norse Consulting's ability to deliver comprehensive multidisciplinary solutions.

A RELIABLE PARTNER YOU CAN TRUST

With our wealth of experience supporting local government, housing sectors, education academies and health and care trusts, we understand that it takes collaboration to deliver the best results and make a truly positive impact.

We have developed and optimised a partnership model focussed on mutual long-term prosperity with the capability to deliver major projects at pace and scale. By helping local authorities move away from traditional outsourcing, we retain value in the local community by upskilling employees and developing in-house expertise while also returning money to the public purse.

ABOUT NORSE GROUP

As Britain's largest local authority trading company (LATCO), ensuring we put people at the heart of what we do is integral to the ethical value proposition for our stakeholders and shareholder.

Wholly owned by Norfolk County Council, our combination of business expertise and public service ethos offers an innovative alternative to traditional outsourcing. Each year we return many millions of pounds to the public purse through our joint venture partnerships, re-investing to ensure long-term success, creating jobs and protecting public services.

norse
CONSULTING

FURTHER READING & REFERENCES

WEBSITES

GREENSPEC
The definitive online source of information on the environmental impact of building materials.

Available at: http://www.greenspec.co.uk

FIRSTPLANIT
Comprehensive materials library and project specification system.

Available at: https://www.firstplanit.com/

2050 MATERIALS
Global database of materials.

Available at: https://2050-materials.com/

THE INVENTORY OF CARBON AND ENERGY (ICE)
The University of Bath's exhaustive database of the Embodied Energy and Carbon content of building materials. Includes the publication for download and an extensive list of references.

Available at: https://circularecology.com/embodied-carbon-footprint-database.html

SMARTWASTE
The BRE's programme to help industry reduce waste and meet the demands of WRAP.

Available at: http://www.smartwaste.co.uk/

THE GREEN GUIDE TO SPECIFICATION
The Building Research Establishments' online guide to environmental performance rating for building elements.

Available at: http://www.thegreenguide.org.uk/index.jsp

GREEN BOOK LIVE
BRE Online reference database of products and services purporting to be 'environmental'. Includes information on the Environmental.

Available at: http://www.greenbooklive.com/

RICS LOW CARBON TOOLKIT
Principles and supporting guidance for the interpretation and implementation of EN 15978 methodology.

Available at: Whole Life Carbon Assessment for the Built Environment

FURTHER READING & REFERENCES

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The Green Building Bible Volume 2 (4th Edition)
UK. Green Building Press 2009

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Strategies for Sustainable Architecture
Oxford, UK. Taylor & Francis – 2006

ELIZABETH L & ADAMS C (ED.)
Alternative Construction: Contemporary Natural Building Materials
Hoboken, New Jersey, USA. John Wiley & Sons – 2005

WALKER P, KEABLE R, MARTIN J, MANIATIDIS V.
Rammed Earth : Design & Construction Guidelines (EP62)
Watford UK. BRE – 2005

MORTON T.
Earth Masonry: Design & Construction Guidelines (EP80)
Watford UK. BRE – 2008

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Green Roofs & Facades (EP74)
Watford UK. BRE – 2006

BERGE B, (TRANS. BUTTERS C & HENLEY F)
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Oxford UK. Architectural Press – 2nd Ed. 2009.

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Designing for the Circular Economy
Routledge 2018

JUSTIN SALMINEN
Materials for a Sustainable Future
Royal Society of Chemistry. 2012

MICHAEL BRAUNGART
Cradle to Cradle. Remaking the Way We Make Things
Vintage 2009

GERNOT MINKE
Building with Earth: Design and Technology of a Sustainable Architecture
Birkhäuser 2021

WILLIAM STANWIX & ALEX SPARROW
The Hempcrete Book: Designing and Building with Hemp-Lime
Green Books 2014

BARBARA JONES
Building with Straw Bales: A Practical Manual for Self-Builders and Architects
Green Books 2015

SUSTAINABLE CONSTRUCTION

SECTION 1 - PACKAGING: PAGE 15

In September 2023, The Supply Chain Sustainabilty School published an extensive report entitled "Packaging Optimisation in the Housebuilding Sector."

More can be read about the the report and a copy downloaded from the link provided (right).

SECTION 2 - RE-USE: PAGE 18

The concept of re-using both materials and entire buildings continues to gain traction as a solution to finite resources and attempting to move away from an economic model which prioritises demolition and consumption. Links to two recent articles are provided (right).

LINKS

"Packaging Optimisation in the Housebuilding Sector."
Breakthrough Report Redefines Built Environment Packaging (supplychainschool.co.uk)

Material re-use
Future houses to become material 'banks,' experts explain (EURACTIV.com)

Building re-use
Demolish nothing: densifying the built environment through accretion - Architectural Review (architectural-review.com)

SUSTAINABLE CONSTRUCTION

SECTION 1 - RENEWABLE ENERGY GENERATION: PAGE 19

Photo-voltaic cells for renewable energy generation first started appearing in volume around the early 2000's. Most PV manufacturers estimate that, on average, a solar panel has a lifespan of 25 years. This means that over the next few years, the first generation of panels will start to be decommissioned. What happens to those old panels then?

Well... no-one is quite sure, given the potential scale of the issue. It is estimated that by 2050, up to 78 million tons of PV panels will have reached the end of their life while 6 million tons of new panels are being produced annually.

Although PV panels contain a lot of quite valuable materials such as silver and silicon, recovering these is far from easy. This requires a bespoke (and costly) process to separate the composite sandwich of materials and at the moment, it is far more economic to merely consign old panels to landfill than to try to recycle their components. In the USA, where there is no legislation covering PV cell recycling, it is estimated that recycling could cost up to 10 times more than any revenue obtained from those recovered materials.

Under EU law, producers are required to ensure their panels are recycled properly and through its Circular Business Models for the Solar Power Industry project is trying to formulate end of life solutions for solar panels. Japan, India and Australia are preparing to instigate similar programmes.

LINKS

News story overview
Solar Panels Are Starting to Die, Leaving Behind Toxic Trash | WIRED

CIRCUSOL
Homepage | Circusol

MIT Technology Review
Solar panels are a pain to recycle. These companies are trying to fix that. | MIT Technology Review

PLASTIC

SECTION 2 - PLASTIC WASTE AND RECYCLING: PAGE 81

One potential solution to plastic pollution currently being investigated is that of "Plastic-eating bacteria." Resulting from Japanese research, a form of bacteria has been discovered which appears to digest polyethylene terephthalate or PET. Much has been written in the media about the possible planet-saving potential of these microbes.

However, the truth is that the bacteria only seems to have a taste for one particular type of plastic and the research is in its very early stages. Also, as with most recycling, this solution of course addresses the symptom rather than the cause.

LINKS

News story overview
We are just getting started': the plastic-eating bacteria that could change the world | Plastics | The Guardian

Live Science
Plastic-eating bacteria: Engineering and impact | Live Science

CONCRETE AND CEMENT PRODUCTS

SECTION 2 - ALKALI ACTIVATED CEMENT: PAGE 42

While research and development of AAC continues in the UK, it remains to be seen what impact the demise of the HS2 project may have on its widespread introduction. In Australia, Geopolymer cement is being actively produced under the trade name "Earth Friendly Concrete." However, it is recognised that by using PFA or GGBS as a base for the cement substitute, the potential may be limited simply due to the availability of these constituents (c/f).

SECTION 2 - LIMESTONE CALCINED CLAY CEMENT: PAGE 43

Metakaolin or calcined kaolinite clay has been used a supplementary cementitious material for a number of years. Recently, an international consortium based in Switzerland has developed a product known as "LC3," which combines metakaolin with additional limestone. The manufacturing process leads to a chemical reaction which allows LC3 to reach a similar performance to OPC (CEM I).

As this reaction is a partial substitute for the burning process which gives cement its very high carbon footprint. It is claimed therefore that LC3 can save 30 -40% of CO^2 compared to OPC.

The most suitable kaolinite clays are typically found in tropical or subtropical climates, meaning that most efforts at marketing, production and use have been to date in India, South-East Asia and Latin America. However, there have been some notable projects.

LINKS

Geopolymer Concrete
Geopolymer Concrete, A Carbon-Neutral Alternative to Cement (the-possible.com)

Earth Friendly Concrete
Earth Friendly Concrete - Capital Concrete

AAC Description
What is Alkali-Activated Concrete (AAC)? - The Constructor

LC3
LC3 – Limestone Calcined Clay Cement

CONCRETE AND CEMENT PRODUCTS

SECTION 2 - BETOLAR GEOPRIME: PAGE 43

Geoprime is a low carbon concrete which employs hitherto under-utilised industrial by-products as a cement substitute. As a proprietary product, details of the actual process aren't readily available. However, Betolar's philosophy is to instigate manufacturing close to the source of these by-products. Geoprime is marketed as a raw material for manufacturers to introduce into often existing fabrication processes such as hollow-core floor slabs. It is claimed that the alternative process can be implemented within four months, without major investment and can result in up to an 80% reduction in the carbon footprint of raw materials from present.

LINKS

Betolar Geoprime
Solutions for construction | Betolar

CROPS

SECTION 2 - HEMP: PAGE 48

The Nova Institute in Germany has published a study on "Carbon Storage in Hemp and Wood raw materials for Construction Materials". This seeks to investigate the comparative potential of both hemp and timber as carbon sinks and in terms of emissions from their production. Like most science pertaining to the natural world, the answer isn't straightforward. A link for the report is provided right.

SECTION 2 - FUNGUS: PAGE 50

The potential of fungus to be used in construction and product fabrication has appeared in the media in recent years. Touted as a revolutionary organic and low carbon material, mycelium is the root network of a fungus of which the mushroom is a very small part. The basic raw material is already marketed for use in bespoke product design and in acoustic panels.

In Australia, RMIT University in Melbourne is, at the time of writing (November 2023) seeking methods of industrialising production of fire-retardant panels made from mycelium. The properties of fungal mycelium have been known for a number of years but the greatest challenge is developing a viable method of forming the raw material into a usable product. Apart from the non-structural items described above, the area which offers potentially the greatest impact, is the possibility of use as an envelope material. Researchers at Newcastle University are developing a composite material known as "Mycocrete," which is created by growing mycelium into textile based moulds. At present, this has not progressed past a proof-of-concept prototype and so is some time away from being a viable commercially available construction material.

LINKS

Carbon storage in hemp and wood raw materials for construction materials"
21-06-14_Carbon_Storage_in_Hemp_and_Wood (builtbn.org)

Fungal fireproofing
Fungi Make Safer Fireproofing Material - Scientific American

Mycelium products
MYCEEN

Mycocrete
Mycocrete: A New Sustainable Building Material Made from Fungi (azobuild.com)

NOTE

NO MONEY SHOULD EVER BE EXCHANGED FOR THIS PUBLICATION