The Stephen George & Partners Guide to:

Building Materials and the Environment

Joanne Denison and Chris Halligan

Second Edition v2.1

Copyrights & Acknowledgements

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.

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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 accept no responsibility whatsoever for any individual or company, for whatever reasons, selected from the weblinks held within this guide. Readers should obtain references and details of the companies' past projects prior to making any decision to employ.

The Authors

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Introduction

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

Part 1 is a short overview of sustainable construction;

Part 2 is a 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 also contains a useful bibliography and is fully interactive with many useful links to external sources of further information.

The foreword has kindly been provided by Richard Nicholls, author of *The Green Building Bible, Volume 2.*

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Revisions to the Second Edition v2.1

Part 1: Sustainable Construction

- Minor amendments to paragraph on Renewable Energy Generation and Building Orientation

- New paragraphs on:
  - Packaging,
  - Recycling
  - Transportation

Part 2: Materials Summary

Renumbered to account for new additions

2.2 Asphalt – Revised and expanded

2.3 Bamboo – New section

2.6 Ceramic Tile - New section

2.8 Composites – Substantially revised

2.9 ICF – Revised

2.10 Concrete and Cement Products
Substantial revisions throughout
New sections on
- Secondary Aggregate,
- Chemically Engineered Cement Substitutes,
- Fibre Reinforced Concrete
- Microsilica Concrete

2.11 Crops - Substantial revision to section on Hemp

2.13 Glass and Glazing – Amended for clarity

2.15 Insulation – Substantial revisions
U-value for Straw amended

2.16 Lime - Substantial revision to section on Hempcrete

2.18 Living Roofs – Amended

2.19 Paint – Amended

2.20 Plastic - Revised and expanded

2.22 Phase Change Materials – New section

2.23 Roofing Membranes – New section

2.26 Sealants, Adhesives and Fillers – New section

2.29 Steel - Substantially revised

2.31 Timber – Revised section on accredittion. FSC / PEFC comparison included

2.32 Vinyl Flooring – New section

Part 3 : Data Sheets

Asphalt – Amended

Bamboo –New addition

Cement Mortars & Renders – Revised

Ceramic Tile - New addition

Composite Cladding Panels – Substantially revised

Composite Flooring - Substantially revised

Concrete – Amended

Hempcrete – Substantially revised

Insulation Data – Straw U-value amended

Lime – Revised

Living Roof – Amended

Paint : Natural – Revised

Paint : Synthetic – Revised

Phase Change Materials – New addition

Plastics – Revised

Roofing Membranes : Synthetic Rubber – Amended

Sealants, Adhesives and Fillers – New addition

S.I.P.S – Amended

Straw Bale – Revised

Steel - Substantially revised

Vinyl Flooring – New addition

Bibliography

Additions made

Preface to the Second Edition

The first issue of the Stephen George & Partners Guide to Building Materials and the Environment has, since its issue, generated a great deal of discussion. Upon occasion, this seemed to us as if we had succeeded in the equivalent of poking a stick into a hornets nest. When we were compiling the first edition, it was often quite difficult to obtain the information we were looking for from suppliers and manufacturers. However, it seems that we needed to go "into print" in order to get people to contribute information for inclusion in future editions.

Inevitably, certain unintended discrepancies in the first edition have come to light – largely from the occasional misunderstanding of trade names or just from the way certain terms can be read in a number of varying ways. However, such instances, despite prompting us to re-visit our research, have all proved to be fairly minor. Overall, the Guide seems to have proved internationally popular (having found its' way to at least twenty other countries as far as we can tell) but most significantly, has provided a vehicle for collaboration with several academic institutions, professional bodies and manufacturers on the subject of low impact building materials. In fact, with the findings of our first edition as a starting point, during the course of our discussions, much more information on several materials has come to light; information which has served to confirm and expand many of our initial conclusions. We would like to express our special thanks to those companies and trade organisations who have taken the time to help us with the content for this latest edition.

Much of this newly acquired information has been included in this revised edition. As well as clarifications and qualifications, we have re-written or expanded certain sections (most notably that on concrete) in addition to including several new items.

We have always intended the Guide to Building Materials and the Environment to be an ongoing project subject to constant improvement and freely available to all. We would like to thank all those individuals and companies who have provided feedback, comments and additional information regarding the Guide and would continue to encourage any readers to contribute to this work whenever possible.

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Contents

Foreword by Richard Nicholls

Richard Nicholls -

is currently a senior lecturer in the Department of Architecture and 3D design at the University of Huddersfield. His book "The Green Building Bible: Volume 2" was runner up in the 2007 RIBA International Construction Book of the Year awards.

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The problem has now been identified – human activities cause damage to the environment. There is no bigger activity than the construction and operation of buildings and so this particular activity has a considerable detrimental effect on the environment. As a result legislators have legislated, clients have become concerned and research bodies have made recommendations. Generally, there is a consensus amongst all stakeholders in the construction industry that buildings now have to be designed and built to have minimal impact on the environment.

But how do we achieve this? Where does the knowledge come from to design sustainably? The curricula of degree courses are full of the basics; design, structures, construction, professional practice to name just a few of the subjects that are crammed into the profession. Even with this full timetable most degree courses now contain an element of sustainability too. However, this is not always explored as deeply as it should due to the pressure of meeting the other obligations of the course. Naturally, CPD courses and Masters level courses help after graduation. But what is not often identified is that much research activity also takes place at the level of the individual in practices up and down the country. Little of this practical research is published leaving other individuals to go through this process time and time again when encountering a similar need for information on sustainable principles on their own schemes.

It is in avoiding this replicated effort where this guide is of great use. It has been compiled by a practice with a deep interest in sustainability whilst researching options for the design, materials, components and services necessary to satisfy the requirements of a sustainable building. The information contained in it is based on visits to and discussions with manufacturers, attendance on courses and in-house research. It will be a great asset as a source of information to any practice interested in designing sustainable buildings. The information is presented in a simple and clear manner using interesting graphics and with adequate explanation for those new to a particular product. It also has links to further information should you wish to find out more.

To conclude, this guide is both timely, given the needs of the construction industry and relevant, given the practical nature of its content. It is also accessible, being freely available via the internet. It is now up to you to make use of the guide and feed back suggestions to the writing team as practical experience progresses.

Richard Nicholls,
November 2009.

Section 1
Sustainable Construction

Photo: Kjeuring (Wikimedia Commons)

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 important 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 practice 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 following thirty years of work in the field of sustainable architecture Stephen George and Partners were asked to design a Sustainable Construction Academy for the University of Kent. 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. We therefore set about investigating the sustainable credentials of every major element we wished to incorporate in the eventual design. This eventually covered those materials often perceived as being the most sustainable and those which are often considered 'run-of-the-mill'. 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 practical use to our colleagues in Stephen George and Partners, our clients and professional partners. 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.

This guide is based on our current knowledge and recent experience. The market for 'green' components is booming, with new companies jumping on the Eco bandwagon almost every week. This is very much a working document to be expanded as experience and time increase our knowledge base. It is not meant to be an exhaustive work, but merely a starting point for those professionals requiring an overview of materials and to provide a direction to further information if required.

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 (E.E)

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.

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.

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.

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
www.bath.ac.uk/mech-eng/sert/embodied.

Also instrumental in the research of embodied energy of building materials is the Centre for Building Performance Research at the University of Victoria in Wellington, New Zealand.
http://www.victoria.ac.nz/cbpr/documents/pdfs/ee-coefficients.pdf
http://www.victoria.ac.nz/cbpr/projects/embodied-energy.aspx

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.**

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 u-PVC windows, which despite being derived from petrochemicals, containing chlorides and (in common with most plastics) using phthalates, which are plasticisers suspected to be responsible for a whole range of damage to the bio-sphere, receive an A+ rating – the same as hardwood. Aluminium windows are rated as 'D'. It is far from clear why this should be so.

Some of the most inexplicable comparisons come when examining insulation. EPS insulation derived from petrochemicals scores higher than straw bale and sheep's wool under the Green Guide, yet has one of the highest embodied energy figures of all insulation materials:

Straw bale – 0.24MJ/Kg
Wool – 20.90MJ/Kg
Expanded Polystyrene – 88.60MJ/Kg

Similarly, end-of-life options seem to have a minor impact on the assessment process. Composite materials are almost impossible to recycle but often receive an A or A+ rating.

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

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 dependant 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.

Links

Mastic Asphalt Council:
http://www.carbon100.com/

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.

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. 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 80% of packaging of building materials could be recovered.

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 offloading. 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.

Links

WRAP Packaging:
http://www.wrap.org.uk/construction/construction_materials/packaging/index.html

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.

Builderscrap is an organisation formed to facilitate salvaging and re-use of materials. The scale and quantities involved however are not yet at a large commercial scale.

WRAP is a UK government sponsored initiative designed to help industry reduce the amount of waste generated in commerce and industry. WRAP produce a very useful guide to reclaimed building materials which is free to download from their website.

“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.

Many mainstream building materials now incorporate a percentage of recycled content. WRAP, as well as producing guidance on the recycling of building materials, have an interactive database on their website which provides information on the recycled content of a wide range of products.

Links

Builderscrap:
http://builderscrap.com/

WRAP Recycled Materials:
http://www.wrap.org.uk/construction/tools_and_guidance/recycled_content/

Recycled content database:
http://rcproducts.wrap.org.uk/

Reclaimed Building products guide:
http://rcproducts.wrap.org.uk/construction/reclaimed_building.html

Recycled Content guide
http://rcproducts.wrap.org.uk/document.rm?id=2962

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:
http://www.environment-agency.gov.uk/business/sectors/37543.aspx

Tyndall Centre Report
http://www.tyndall.ac.uk/sites/default/files/Shipping_and_climate_change.pdf

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.

The primary design consideration should be the minimising of energy 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, 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:
http://www.therenewableenergycentre.co.uk/

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; less 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.

Passive buildings require active users!

In other words, get up off your bum and either open a window or put a jumper on!

Sustainable Construction - 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. These can be summarised as follows:

- 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/can not 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.

Sustainable Architecture: 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

- Design the building to passively use natural day lighting and ventilation.

  - Limited width for cross ventilation and natural day lighting
  - Sufficient height for daylight penetration
  - Exposed thermal mass with night cooling (approx 1sq.m per square metre of floor area) for commercial projects
  - 35 – 40% of wall area glazed is optimum 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

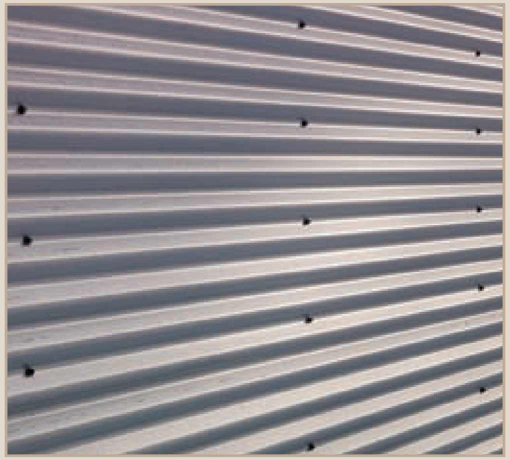
  - Is recycling or reuse possible?

- 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.

Photo: SecretLondon (Wikimedia Commons)

Section 2
Materials Summary



Aluminium Cladding
Photo: Photos.com website

Aluminium awaiting recycling
Photo: Norsk Resirk A/S

Click 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 ($A_{12}O_3$) 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

Links

Aluminium production:
http://www.powerofaluminium.com/html/bauxite.htm

Aluminium recycling:
http://www.snelsons.co.uk/aluminium_how.html

The Great Pitch Lake in Trinidad
Photo: Jw2c (Wikimedia Commons)

Mastic Asphalt being laid
Photo: Mastic Asphalt Council

Click to view:

Asphalt Data Sheet

2.2 Asphalt

Asphalt is a natural material, a sticky black matter of hydrocarbons, 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. Asphalt is a material that can be found, mined and collected in its natural state. 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 and Tobago, 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.

Tarmac and Aggregate Industries both produce porous asphalt (also known as pervious macadam), which can be used as part of a Sustainable Urban Drainage System. Porous asphalt is described as "open graded, angular aggregate with a thin binder coating of polymer modified bitumen," which 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 increased surface freezing, this is disputed by Tarmac but research from Holland where the system has been widely installed warrants additional investigation into how the material reacts to winter freeze / thaw cycles.

Asphalt, by virtue of its' colouration, has been associated with the urban heat island effect. Many cities have expanses of skyward facing, black asphalt used as roofing or hard surfacing. Under the LEED assessment system originating in the United States, extra points can be attained by applying a white surface treatment to partially temper the excessive heat absorption of these dark surfaces.

Practical Applications

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

Links

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

Mastic Asphalt Council:
http://www.carbon100.com
http://www.masticasphaltcouncil.co.uk

Porous Asphalt:
Winter maintenance study

2.3 Bamboo

Bamboo growing
Photo : Wikimedia Commons: annieo76

A bamboo building in northern China
Photo Wikimedia Commons

Click 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 virulent 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:

http://www.bcltimberprojects.co.uk/index.htm

http://www.buildingmaterialssupplies.co.uk/index.php/natural-materials/bamboo

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

www.bambooteam.com/pablo/2003%20JBR.pdf

http://www.inbar.int/

2.4 Bitumen

Peel n Stick tanking bitumen
Photo: Jo Denison, Stephen George & Partners

Cold Refined Bitumen
Photo: Burger (Wikimedia Commons)

Click 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. However one company is leading the way in recycling, extracting the bitumen content for reuse from a recycling plant in Holland and producing a membrane with a 44% recycled content - Esha Waterproofing.

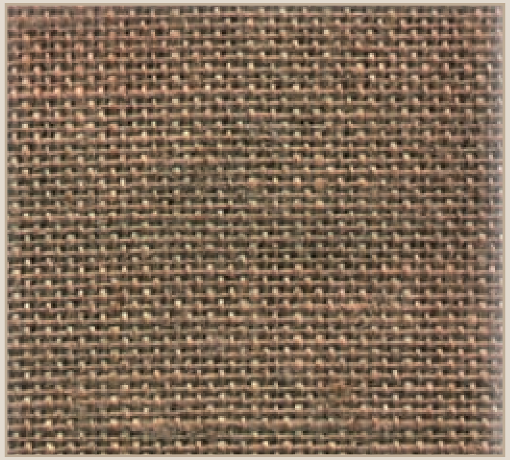
Practical Applications

Waterproofing, Roofing, Tanking, Road Surfacing

Links

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

Esha Waterproofing.
http://www.roofinfo.co.uk/Enhanced/esha.asp



Jute backing
Photo: Luigi Chiesa (Wikimedia Commons)

Looped pile carpet
Photo: Photos.com website

2.5 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.

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

2.5 Carpet continued

Synthetic yarn close-up 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 down cycle 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

Natural carpet materials do not feature in the Green Guide under the commercial section, which features petrochemical derived carpets achieving min A to A+, with only the bitumen backed tiles graded as B. 80/20% wool/polyamide carpets with recycled carpet backing achieve rating C under the domestic section.

Links

General Information:
http://www.sustainablefloors.co.uk/green-carpets.html
http://en.wikipedia.org/wiki/Carpet
http://en.wikipedia.org/wiki/Sustainable_flooring

Click to view:

Carpet - Natural Data Sheet
Carpet - Synthetic Data Sheet

2.6 Ceramic Tile

Ceramic tiles being laid
Photo : Wikimedia Commons - US NAVY

Ceramic wall tiles
Photo : Wikimedia Commons: Alexandre Mancini

Click 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 manufactring 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, Swimmng pools, Paving.

Links

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

General information.
http://www.edcmag.com/CDA/Archives/9d730e983b8fb010VgnVCM100000f932a8c0____

Lattice clay 'Thermoplan blocks
Photo: Natural Building Technologies

Naterra Block with Beeswax finish
Photo: Akristos

2.7 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, have become popular as alternatives to concrete.

Be aware: unfired material will absorb water and potentially wash away or slump when wet. 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, thereby reducing transportation. Unfired clay mixed with 50% recycled plasterboard has been developed by Akristos into the 'Naterra' block.

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 / Reed / Hessian Lining Boards

Clay boards are available as an alternative to plasterboards. They offer good sound absorption, thermal mass and vapour permeability. The boards cannot survive prolonged contact with water or damp conditions and are fairly thick and heavy, requiring additional fixing details. Clay board is not a financially viable option compared to plasterboard but exceeds plasterboard in thermal comfort performance and provides an alternative to those wanting to move away from gypsum.

Clay drains being laid
Photo: Naylor Drainage Ltd.

Naterra Blocks being laid
Photo: Akristos

Click to view:

Fired Hollow Clay Blocks Data Sheet
Unfired Clay Blocks Data Sheet
Clay Drainage Data Sheet
Clay Boards
Plasters & Renders Data Sheet

2.7 Clay continued

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 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

Links

General Information:
http://www.es.ucl.ac.uk/schools/UCL/bricks.htm
http://en.wikipedia.org/wiki/Brick

Brick Development Association:
http://www.brick.org.uk/aboutbrick.html

Naterra Blocks
http://www.backtoearth.co.uk/products.html

2.8 Composite Materials and Deconstruction

Composite Steel-Concrete Flooring being laid.
Photo: John Cooper, Stephen George & Partners

Click to view:

Composite Cladding Panels Data Sheet
Composite Flooring Data Sheet

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. Efforts are being made to investigate re-processing the rigid insulation cores for re-use in other products. However, this process is not widespread but this situation may be due to the relative newness of the material and therefore not common amongst recently demolished buildings.
There is some evidence for the recent wholesale re-use of panels on a limited scale. Such re-use is most appropriate to secretly fixed panels which avoids the need to use drilled holes.

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.

Links

Design for deconstruction:
http://www.lifecyclebuilding.org/files/Designing%20Structural%20Systems%20for%20Deconstruction.pdf

Recycling of composite steel panels
www.colorcoat-online.com/.../Colorcoat%20Technical%20Paper%20-%20End%20of%20life%20for%20pre-finished%20steel.pdf

The Green Guide to Composites:
http://www.netcomposites.com/composites-green-guide.asp?page=121&section=green-guide&ex=1&submenuheader=1

http://www.netcomposites.com/composites-green-guide.asp?page=89&section=green-guide

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

http://www.epic.uk.com/assets/epic_identification_and_disposal2.pdf

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 to view:

ICF Blocks Data Sheet

2.9 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/m^{2}°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:
http://www.concrete-home.com/
http://www.icfinfo.org.uk/index.php

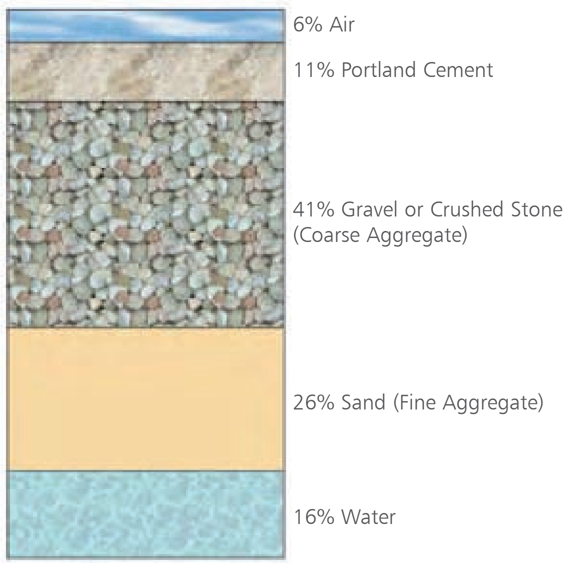
Demolished Insitu Concrete – Recycled Aggregate.
Photo: La Farge

Aggregate Quarry
Photo: La Farge

2.10 Concrete and Cement Products

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 of concrete, this can be

Limestone aggregate
Photo: La Farge

Limestone aggregate.
Photo: Emadrazo (Wikimedia Commons)

2.10 Concrete and Cement Products continued

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)
Silica Fume (by-product of silica production)
Metakaolin (from oil sand)
Rice husk ash (from rice paddy fields).

A cement factory looms over Monterrey, Mexico
Photo : Hector Martínez (Fotografía de)

Hope Cement works, Derbyshire
Photo: Dave Pape (Wikimedia Commons)

2.10 Concrete and Cement Products continued

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.

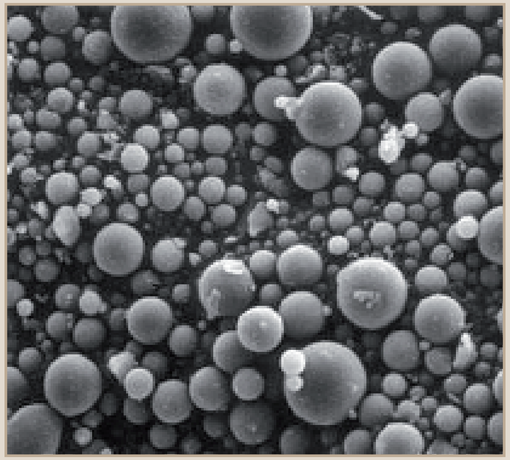
PFA (Pulverised Fuel Ash)

Ash is produced as a result of burning coal for the production of electricity. Coal is used to supply around 37% of the UK's electricity, and therefore fly ash is an abundant material. 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. Just over 1,000,000 tonnes of FBA are produced annually and 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

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. For a variety of reasons not all PFA is used, with about half of the annual production being land-filled. 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

2.10 Concrete and Cement Products continued



Fly Ash magnified 2000x
Photo: United States Department of Transportation - Federal Highway Administration

PFA Photo: La Farge

therefore wet) may not be suitable for use as a cement replacement. Rocktron have developed a method where a refining process reduces carbon content down to levels suitable for use by the cement industry. The remaining minerals are processed and used in other industrial products such as pastes and fillers. The pure extracted carbon is then sold back to the power station.

While this process offers a solution to deal with stockpiled PFA, (which continues to be produced in volume worldwide despite efforts being made to restrict the construction and use of coal fired power stations), it must be borne in mind that fly ash can be dangerous if not disposed of responsibly. 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 cement content, generally about 50% but sometimes up to 70%. 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. Unfortunately, it is not available for smaller scale concrete production because it can only be economically supplied in bulk. GGBS is not only used in concrete; other applications include the in situ stabilisation of soil.

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.

Fly Ash spillage from settling pond Photo: Brian Stansberry, Wikimedia Commons

Fly ash dumping in China
Photo: Zhao Gang / Greenpeace

2.10 Concrete and Cement Products continued

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.

In the past, we have found that while attempting to specify GGBS, sourcing this is not always easy. Surprisingly, even trade organisations may not be able to advise where it can be obtained. Even when used by major concrete and cement suppliers they may not be aware of the environmental benefits of GGBS as a low energy cement substitute. Some suppliers market GGBS as a specialist alternative beneficial only for its extended strength gain (56 days as opposed to 28 for OPC based concrete) and are seemingly oblivious to its potential as a low impact material.

GGBS based concrete may be marketed under a specific trade name (E.g. Tarmac LCC [Low Carbon Concrete]) and generally can be specified for most locations. However, there may be issues with certain elements such as exposed power-floated slabs which could be subject to excessive dusting or prove difficult to finish due to the higher strength attained.

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.

Another chemically engineered cement replacement currently under development is 'Novacem'. This uses magnesium silicate as a raw material, processed at relatively low temperatures (700ºC), to produce magnesium carbonate. Novacem estimate naturally occurring worldwide magnesium silicate reserves to be over 10,000 billion tonnes. However, the most significant claim for Novacem is that, 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. The manufacturers claim that the production process for 1 tonne of Novacem absorbs up to 100Kg


Concrete blockwork under construction
Photos.com website

2.10 Concrete and Cement Products continued

more CO_2 than it emits. At the time of writing (November 2010),

Novacem is still under development but scheduled to begin full production in 2014 – 2015.

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.

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 of 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

2.10 Concrete and Cement Products continued

site to the manufacturing plant. A more sustainable block from further away becomes less sustainable compared to a local product.

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.

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

2.10 Concrete and Cement Products continued

Links

Cement Production:
http://www.cement.org/basics/concretebasics_concrete-basics.asp

Sustainable Concrete:
http://www.sustainableconcrete.org.uk

http://www.cenin.co.uk/low-carbon-cement.php

http://novacem.com/

The Concrete Centre - Concrete Credentials
http://www.concretecentre.com/

The Concrete Centre:
http://www.concretecentre.com/main.asp?page=0

Aggregates:
http://www.sustainableaggregates.com/

GGBS:
http://www.mineralproducts.org/prod_slag01.htm

PFA:
http://www.greenpeace.org/china/en/press/reports/coal-ash-report-english-2010

http://rktron.com/

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

http://www.concrete.elkem.com/

Click to view:

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

The Cork Oak after harvesting
Photo: Fritz Geller-Grimm and Felix Grimm (Wikimedia Commons)

Flax flowers
Photo: Sten Porse (Wikimedia Commons)

Click to view:

Insulation Data Sheet

2.11 Crops

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 Finishes

Links

General information:
http://en.wikipedia.org/wiki/Cork_Oak

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 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/m^{2}°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.

Industrially grown Hemp
Photo: Markus Hagenlocher (Wikimedia Commons)

Hemp shive
Photo: Copyright © 2000-2009 Lime Technology Limited)

Click to view:

Linoleum Data Sheet

2.11 Crops continued

However, at 25MJ/kg, this is a fraction of that required for PVC sheet (65MJ/kg).

Practical Applications

Insulation, Lino Flooring

Links

General information:
http://en.wikipedia.org/wiki/Flax
http://www.jeffersoninstitute.org/pubs/flax.shtml
http://www.ag.ndsu.edu/agnic/flax/utilization.htm

Hemp

Hemp is an amazingly versatile plant.It is a non-hazardous biodegradable fibre from a renewable source and 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 claims 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, the most popular being chopped and combined with lime for wall construction. In this form (generically known as 'Hempcrete', commonly known by the trade name 'Tradical Hemcrete'), it can be cast in situ between formwork, sprayed onto a frame, pre cast as panels or made into blocks. 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

2.11 Crops continued

Hemcrete being spray applied
Photo: Copyright © 2000-2009 Lime Technology Limited)

ModCell panels under construction
Photo: ModCell (www.modcell.co.uk)

Click to view:

Hemp-Lime Data Sheet
Insulation Data Sheet

process.) 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 and provision must be taken to protect the finished material as it is not robust enough to withstand regular impact. Shive is also 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, Lime Technology market a proprietary system known as 'Tradical Hemcrete'. This 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. As the wet applied Hemcrete requires some time to dry and cure, the recent innovation of pre-cast panels (as 'Hemclad') widens the opportunities for commercial application. 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 $W/m^{2o}C$ ('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 $W/m^{2o}C$, the actual heat loss of the examined building equated to 0.11$W/m^{2o}C$. Lime Technology's own offices are constructed from Tradical Hemcrete and are being monitored to study the actual thermal performance of the material further

Practical Applications

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

Links

General information:
http://en.wikipedia.org/wiki/Hemp
http://www.hort.purdue.edu/newcrop/ncnu02/v5-284.html
http://hemp/Hemp_UK/Hemp.
html http://hempbuilding.com/
http://www.hemphasis.net/Building/building.htm

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

The finished building
Photo: ModCell (www.modcell.co.uk)

Click to view:

Straw Bale Data Sheet
Insulation Data Sheet

2.11 Crops continued

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.

Links

Modcell
http://www.modcell.co.uk/

Amazon Nails (UK straw building centre):
http://www.amazonails.org.uk/

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

Straw insulation values:
www.ienica.net/greentech/posters/Hohensinner.pdf

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.

2.11 Crops continued

A traditional thatched cottage in Ireland
Photos.com website

But today only three main thatching materials are used: water reed, wheat reed and long straw.

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

General information
http://thatch.org/

2.12 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 man.

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)

2.12 Earth continued

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.

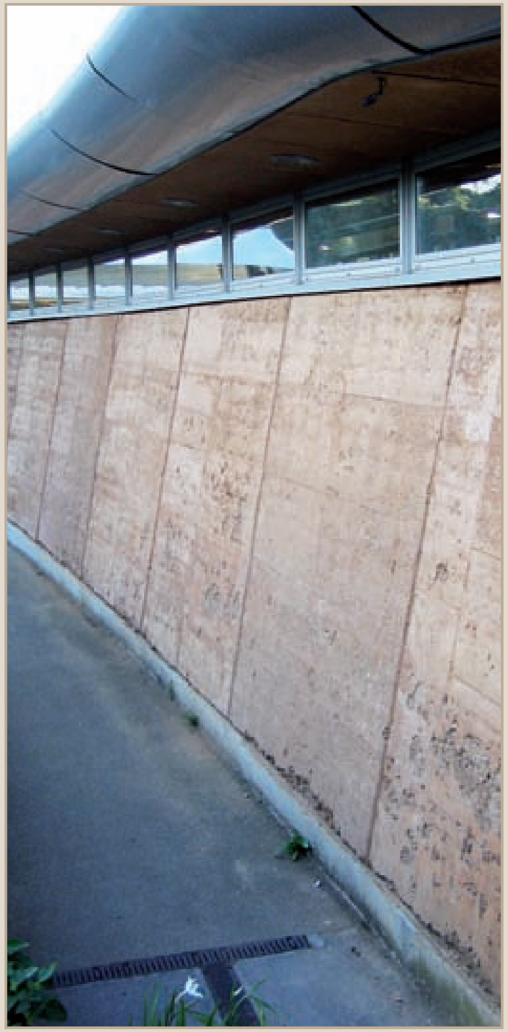
Some clarification of the industry has come from Paul Joaquin who wrote his PhD on the strength of rammed earth structures and now works for Ramboll. In this work, Paul impartially explained the difference between the two constructions and the organisations which advocate them. These can be summarised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

• Earth Structures UK 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.

• Ram Cast promote unstabilised structures and only operate on a consultancy basis. Ram Cast also offer advice and training to contractors.

• 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 contactors. (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 and

2.12 Earth continued



Rammed earth visitor centre at the Eden Project, UK
Photo: Andrew Dunn (Wikimedia Commons)

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.

Stabilised Rammed Earth is not perfect but it is the best environmental solution for building walls that is available at the moment.

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

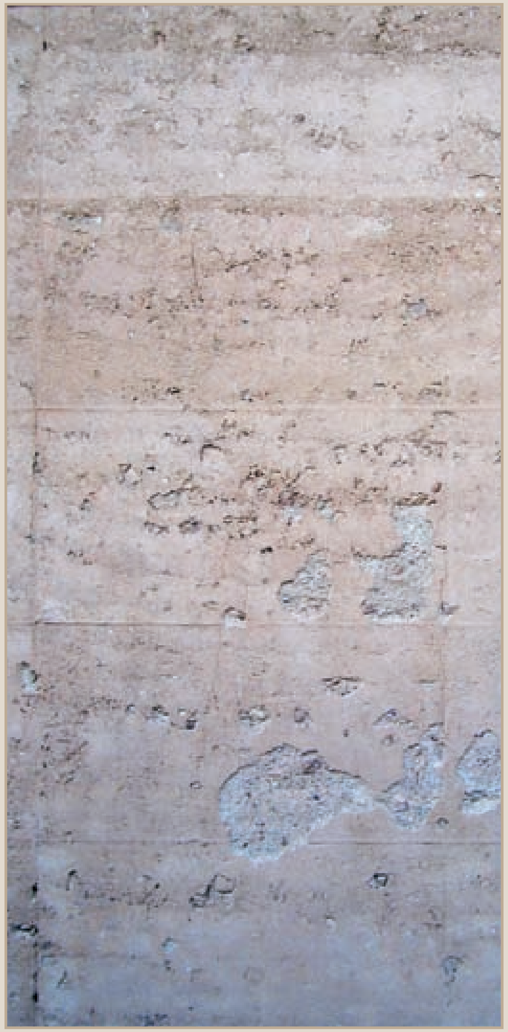
The Material

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.

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



Close up of a rammed earth wall
Photo: Andrew Dunn (Wikimedia Commons)

2.12 Earth continued

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 up to £500. 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/m^2°C for a 300mm thick wall and 1.6 W/m^2°C for 400mm. U-values of unstabilised walls are typically 3.3 W/m^2°C and 2.5 W/m^2°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'?

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


A traditional rammed earth building in China
Photo: Bolobolo (Wikimedia Commons)

Click to view:

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

2.12 Earth continued

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.

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)

Links

Ram Cast consultancy:
http://www.rammed-earth.info/

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

History:
http://www.dur.ac.uk/p.a.jaquin/rammed_earth.htm

Earth Building webring:
http://www.webring.com/t/Build-With-Earth-WebRing?sid=35

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

2.13 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 (Na_2CO_3), known as soda ash, to produce a mixture of 75% silica (SiO_2) and 25% sodium oxide (Na_2O), 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% SiO_2 (silica) 12% - 16% Na_2O (sodium oxide) 5% - 11% CaO (calcium oxide) 1% - 3% MgO (magnesium oxide) 1% - 3% Al_2O_3 (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.

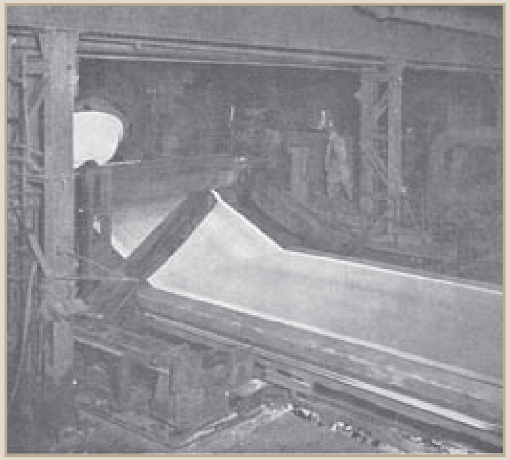
Foamed Glass

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 UK Building Regulations is 2.2 $W/m^{2}°C$. 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=0.35 $W/m^{2}°C$,) 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 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/



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 to view:

Windows 01 - General & Glazing Data Sheet

2.13 Glass & Glazing continued

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. However, under the BRE Green Guide to specification, the highest available rating for aluminium frames would seem to be 'B' (with the majority of this type being rated far lower than this). Curiously, Upvc frames get 'A+' which is higher than some timber systems.

Practical Applications

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

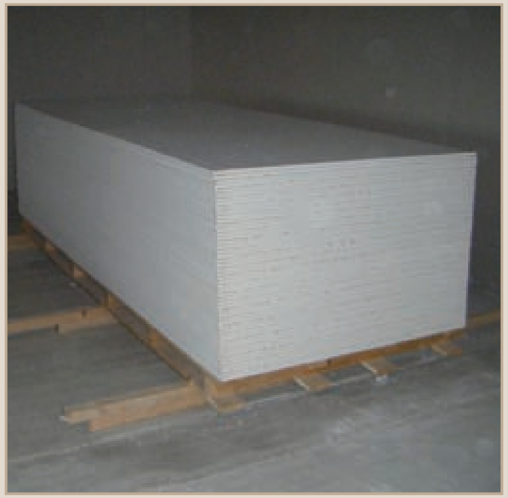
Links

General Information:
http://www.britglass.org.uk/AboutGlass/TypesofGlass.html

Recycled glass products:
http://www.glasseco.co.uk/
http://www.bottlealleyglass.co.uk/index.html

2.14 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 175°C, 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 ($CaSO_4$ $2H_2O$) 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 (Flu 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 ($CaSO_4$ $2H_2O$) 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.

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 the landfill.

Plasterboard is one of the most widely specified building materials
Photo: Sambach (Wikimedia Commons)

Naterra Block with beeswax finish
Photo: Akristos

Click to view:

Gypsum Data Sheet
Concrete Blocks Data Sheet

2.14 Gypsum continued

Hydrogen sulphide gas problems

In the US and in Europe, plasterboard waste disposed of in landfills have allegedly created the dangerous hydrogen sulphide gas (H_2S). 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 water-courses. Since the cost of sending plasterboard waste to landfill has risen considerably, many plasterboard manufacturers are implementing full recycling schemes.

The LaFarge Ferrybridge plant uses 100% FGD Gypsum (Fuel Gas Desulphurised) but cannot guarantee suppliers which plant the plasterboard comes from. They guarantee 44% of the raw material is recycled.

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

WRAP – Waste and Resources Action Program

The Ashdown Agreement was signed in March 2007 between the Gypsum Products Development Association (GPDA) representing the UK plasterboard manufacturers, and WRAP. The Agreement set two challenging and quantifiable targets:

1. to reduce the amount of waste sent to landfill from manufacturing operations in Great Britain to 10,000 tonnes per year by 2010; and
2. to increase the take back and recycling of plasterboard waste, for use in plasterboard manufacture, to 50% of new construction waste arisings (currently estimated at 300,000 tonnes) by 2010.

Between April 2007 and March 2008 nearly 54,000 tonnes of plasterboard waste from construction was recycled back into new plasterboard. Manufacturers have also reduced the waste sent to landfill from their production operations to only 6,000 tonnes.

WRAP helped develop the Naterra block, a clay unfired block with 50% recycled plasterboard. (See Clay Data Sheet.)

Practical Applications

Plaster, Plasterboard, Mouldings

Links

General Information:
http://www.british-gypsum.com/

Recycling:
http://www.gypsumrecycling.co.uk/6688-1_Whyrecycle/
http://www.gypsumrecycling.co.uk/

General Sustainability:
http://www.gypsumsustainability.org/miracle.html
http://www.british-gypsum.com/sustainability/environmental_sustainability.aspx

LaFarge FGD Gypsum
http://www.lafargeplasterboard.co.uk/wps/portal/SustainableDevelopment/LafargeWasteOffer

WRAP:
http://www.wrap.org.uk/wrap_corporate/news/plasterboard.html

Naterra Blocks:
www.backtoearth.co.uk

2.15 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 up to four times 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, 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 values and dynamic thermal performance

Heat loss through an element of a buildings' 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 materials' 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 also 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 lead 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. Lime Technology have monitored Tradical Hemcrete buildings as having a thermal performance which in real life is much improved over what may be expected from a standard heat loss calculation. Terming this "dynamic thermal performance" Lime Technology question whether the widespread method of measuring heat loss is adequate for natural materials such as hemp-lime.

Links

General Information:
http://en.wikiversity.org/wiki/DFE2008_Residential_Wall_Insulation

Warmcel Cellulose insulation (recycled newspaper) being spray applied
Photo: Excel Industries


Flax insulation rolls & batts
Photo: Isolina Oy

2.15 Insulation continued

Insulation Materials

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

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.

2.15 Insulation continued

Hemp insulation batt
Photo: Christian Gahle, nova-Institut GmbH

Sheep's wool insulation
Photo: Shadokat, Wikimedia Commons

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 insulation has been available for several years in the UK, mainly imported from Australia and New Zealand. We now have two UK manufacturers, Black Mountain from Wales and Thermafleece from Scotland.

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 farming has a much discussed controversial affect 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:
http://www.sheepwoolinsulation.com/#
http://www.cat.org.uk/information/pdf/SheepsWoolInsulation.pdf

Wood fibre insulation
Photo: thingermejig (Wikimedia Commons)

Glass wool rolls
Photo: Jo Denison, Stephen George & Partners

2.15 Insulation continued

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.

Links

General Information:
http://www.constructionresources.com/products/envelope/woodflex.asp?PageCategoryID=3
http://www.natureproinsulation.co.uk/woodfibre_main.htm
http://www.burdensenvironmental.com/insulation-boards-%E2%80%93-woodfibre

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:
http://isover.co.uk/about_glasswool.asp

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 com-

Rockwool
Photo: Jo Denison, Stephen George & Partners

Close-up of Foamglas
Photo: UNES (Wikimedia Commons)

2.15 Insulation continued

pressed 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%
Second Set of Raw Materials	Industrial Waste Material (i.e. cement and steel production pre-stone wool waste post-stone wool waste)	21%
Binder	Phenol Formaldehyde Urea	8%

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 activity; (during the age of the dinosaurs), Rockwool in the UK is produced in Wales.

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

Links

General Information:
http://www.rockwool.co.uk/sw58920.asp
http://www.rockwool.com/environment/production/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.'

Multifoil Insulation
Photo: Jo Denison, Stephen George & Partners

2.15 Insulation continued

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.

Links

General Information:
http://www.foamglas.co.uk/overview.htm

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 to their actual performance. In 2008, guidance notes on ‘their use in roofs’ was issued to Local Authority Building Control Officers and debate continues to rage on their efficiency.

Links

DCLG Report:
http://www.communities.gov.uk/publications/planningandbuilding/multifoil

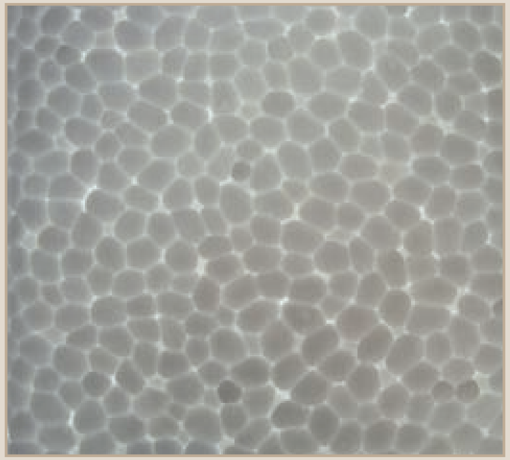
BRE Draft Report:
http://www.foam-insulation.co.uk/building-regulations/BRE-multi-foil-insulation-measured-u-values.pdf

4. Fossil

Polystyrene

Polystyrene can be recycled, and has the number “6” as its recycling symbol.

Currently, the majority of polystyrene products are not recycled because of a lack of consumer awareness regarding suitable recycling facilities and methods. Polystyrene “recycling” is not a closed loop, producing more polystyrene; 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.



Close-up of EPS board
Photo: Phyrexian (Wikimedia Commons)

2.15 Insulation continued

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.

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.

Recently manufacturers in the United States have begun making and marketing recycled EPS as building products.

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.

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:
http://www.eps.co.uk/downloads/index.html-
http://www.insultech-eps.com/
http://en.wikipedia.org/wiki/Polystyrene#Recycling

Recycling:
http://www.eps.co.uk/recycling/recycling_main.htm
http://www.eccleston.com/expanded-polystyrene-recycling.htm


Close-up of XPS board
Photo: Lyndon Johnson, Stephen George & Partners

2.15 Insulation continued

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 "Foamcore". "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. Styrofoam produce a variant designated 'Styrofoam 'A' which uses "Recycled CO_2" as a blowing agent. (Not quite sure where it is recycled from…). This results in its GWP rating being reduced from 1300 (for HFCs) to below 5. As yet, (mid-2009) this does not have a BRE rating.

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.

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.

PUR / PIR is often used within composite cladding panels as the insulating core. The options for recycling PUR / PIR materials are limited. They can be reused as similar chemical products (in adhesives or binders for example), although evidence for any programme offering this is scant. A manufacturer's website states that

"…the best currently available solution for the insulation core, if it can no longer be used as insulation, is by incineration with energy recovery, where incineration facilities are available, or land fill if not."

That's burn it or bury it to you and I. Pentane blown PU insulation has been given an "A+" Environmental Profile rating by the BRE.

Links

General Information:
http://www.brufma.co.uk/sustainability.htm
http://www.brufma.co.uk/properties.htm
http://en.wikipedia.org/wiki/Polyurethane#Raw_materials

Recycled plastic insulation being laid
Photo:YBS Insulation


Recycled Plastic Bottle Insulation
Photo: Jo Denison, Stephen George & Partners

Click to view:

Insulation Data Sheet

2.15 Insulation continued

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:
http://www.daviddarling.info/encyclopedia/P/AE_plastic_fiber_insulation.html

Lime mortar being mixed
Photo: JJ Sharpe

Lime mortar being applied
Photo: Copyright © 2000-2009 Lime Technology Limited

2.16 Lime

Lime products are made from limestone. Limestone is a sedimentary rock composed largely of the mineral calcite (calcium carbonate: $CaCO_3$). 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

Lime render being applied
Photo: Copyright © 2000-2009 Lime Technology Limited

Lime render being applied
Photo: Copyright © 2000-2009 Lime Technology Limited

2.16 Lime continued

varying characteristics. These can range from a pure 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 propriortary 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

Click to view:

Lime Data Sheet

2.16 Lime continued

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.

English Lime

Singleton Birch Ltd. are the only UK source of Lime. Currently, Singleton Birch do not produce a natural NHL 5. Pure NHL 5 Lime comes from France where they have a higher level of silicate in the raw material. Singleton Birch NHL 5 is manufactured with added pozzolan, (GGBS). Singleton Birch is working on providing a pure NHL 5 Lime in the UK, at the time of writing this is still 'under development'.

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 – Lime Mortars:
http://www.greenspec.co.uk/html/materials/limemortar.html
http://www.brick.org.uk/_resources/Use%20of%20Traditional%20Lime%20Mortars%20in%20Modern%20Brickwork.pdf

General Information – Lime
http://www.limes.us/about.php?id=1

Lime suppliers
http://www.jjsharpe.co.uk/material.html
http://www.naturalhydrauliclime.com/
http://www.limetechnology.co.uk/pages/hemcrete.php
http://www.lhoist.co.uk/tradical/hemp-lime.html

2.17 Linoleum

Linoleum is available in a very range of colours
Photo: Holger.Ellgaard (Wikimedia Commons)

Click to view:

Linoleum Data Sheet

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.

Linoleum is available in a very range of colours
Photo: Holger.Ellgaard (Wikimedia Commons)
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. Hence its rating under the BRE Green Guide to Specification has very little difference to some PVC floor coverings.

Links

General Information:
http://www.sustainablefloors.co.uk/linoleum-vs-vinyl.html
http://en.wikipedia.org/wiki/Linoleum

An established intensive green roof.
Photo: PNWRA (Wikimedia Commons)

An extensive green roof showing a range of sedum colours
Photo: Lamiot (Wikimedia Commons)

2.18 Living Roofs

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. One bitumen supplier with a green roof system uses a bitumen membrane with a 44% recycled content. (ESHA – See 'bitumen' above). 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

A brown roof
Photo: thingermejig (Wikimedia Commons)

Click to view:

Living Roofs Data Sheet

2.18 Living Roofs continued

cooling 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.

Links

General Information:
http://www.livingroofs.org/
http://www.thegreenroofcentre.co.uk/

Peeling paint
Photo: Photo: Daniel Schwen (Wikimedis Commons)

2.19 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 householders (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-biodegrad-

White primer
Photo: Photo: Daniel Case (Wikimedia Commons)

2.19 Paint continued

able and must be treated as chemical waste. In recent years, acrylic paint has become increasingly popular due to it being water based and is often even considered an enironmentally 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.

Click to view:

Synthetic Paint Data Sheet
Natural Paint Data Sheet

Plastic litter on the Hawaiian coast
Photo: U.S. National Oceanic and Atmospheric Administration

Melted squashed wellington boots
Photos: Smile Plastics www.smile-plastics.co.uk

2.20 Plastic

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.

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. As of August 2009, research teams headed out the Pacific to investigate the quantities of plastic and plan a clean up operation. It is thought that 80% of marine debris is blown from land to sea with much being transported by river.

In the UK the majority of plastic used is in packaging (35%) followed closely by the construction industry (23%)

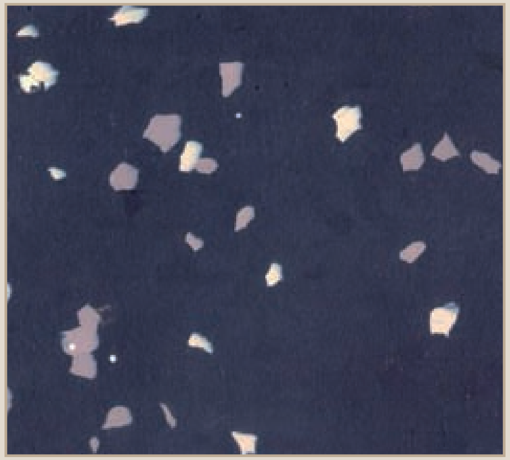
Links

General Information Plastic & Recycling:
http://www.wasteonline.org.uk/resources/InformationSheets/Plastics.htm

http://plasticpollutioncoalition.org/learn/common-misconceptions/

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:



A mixture of beige and dark grey Coffee Cup waste
Photos: Smile Plastics www.smile-plastics.co.uk

Shredded bank notes suspended in reject car headlamp lenses
Photos: Smile Plastics www.smile-plastics.co.uk

2.20 Plastic continued

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 boy 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 affect on the environment. Available information is conflicting.

Links

General Information PVC & Phthalates:
www.phthalates.com
http://www.healthybuilding.net/pvc/ThorntonPVCSummary.html
http://ec.europa.eu/environment/waste/pvc/index.htm

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

2.20 Plastic continued

a variety of applications such as cladding, partitioning or furniture. The PVC window industry is making efforts to increase the amount of recycled material in its products. Recycled PVC window systems are now available but these are not 100% re-used material and are usually faced with virgin material. At present, it is claimed that PVC can be recycled up to 10 times. It is unclear what happens to the material after that.

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.

Despite the growth in recycled plastic products, the UK still only recycles about 7% of its plastic waste. Given that the plastic waste generated annually in Britain is around 3 million tonnes, this leaves a vast amount of undegradable waste to be disposed of. 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.

Links

Recycled plastic supply

http://www.smile-plastics.co.uk/

http://www.recovinyl.com/

http://dekura.co.uk/

Bioplastics

The toxic nature of many of the constituent ingredients of conventional plastic, particularly PVC when used in childrens' toys, has lead 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

http://www.teamburg.de/bioplastics/

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

http://www.materialdatacenter.com/mb/index.php#loadPage0

Click to view:

Plastics Data Sheet

SIPS panels being erected in a domestic situation
Photos courtesy SIPS UK Ltd.

SIPS panels being erected in a domestic situation
Photos courtesy SIPS UK Ltd.

Click to view:

SIPS Data Sheet

2.21 Prefabrication

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 great 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.

Links

National Audit Office report on Modern Methods of Construction in Housing
http://www.nao.org.uk/our_work_by_sector/housing,_property/modern_methods_of_construction.aspx

SIPS General:
http://www.sipsindustries.com/sips/sips.php
http://www.sips.org/ (US website)

2.22 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 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 a 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
http://www.pcmproducts.net/home.htm

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

http://www.thefreelibrary.com/Phase+Change+Material+(PCM)+Eutectic+Solutions+Used+for+Passive...-a01073963942

Products:
http://energain.co.uk/Energain/en_GB/index.html

http://www.micronal.de/portal/basf/ien/dt.jsp?setCursor=1_290798

EPDM Foil
Photo : Wikimedia Commons : KVDP

A finished EPDM roof
Photo: Wikimedia Commons : KVDP

2.23 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
- Concrete membranes

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

Mainly used on large commercial buildings and 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 having 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.

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 either 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 wind-borne 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

2.23 Roofing Membranes continued

Roofkrete in-situ on a completed building
Photo: Sustain Construction

necessarily dependent on high standards of workmanship. BRE Green Guide ratings are unknown.

Concrete Membranes

Roofkrete is a proprietary product which has been produced on a very small scale for a number of years. It consists of a galvanised steel mesh to which is applied a 5mm flexible concrete membrane. It can be used for numerous applications in addition to roofing - such as tanking, waterproofing and even boat building. Recently, the production of Roofkrete has been acquired by KreteSustain Systems Ltd. who are now making attempts to widen the commercial use of this material. The malleability of Roofkrete allows it to be adapted to organic forms. Roofkrete, controversially advertises itself as "The World's most sustainable flat roof, green roof, balcony and terrace waterproofing system." Although this rather sweeping assessment is subject to debate, a Master thesis study originating from Hogeschool-Universiteit Brussel concluded that Roofkrete had the lowest embodied energy of any waterproofing system available to the UK construction industry. The total embodied energy for Roofkrete is quoted as being 600kWh/m^3 while PVC single ply membranes are shown to be 126,000 kWh/m3. Lifespan is claimed to be 100+ years and although claims are made for recyclability, this in fact would be in the form of hardcore fill. No BRE Green Guide rating exists at present for Roofkrete.

Links

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

Roofkrete:
https://docs.google.com/document/edit?id=1SVEgMhb8DCk3iKYiYgJQWVqBhv-b0dRKnffREI1Qu8g&hl=en&pli=1#

http://krete.co.uk/home

Click to view:

Roofing membranes – synthetic rubber Data Sheet
Bitumen Data Sheet
Concrete Data Sheet
Plastics Data Sheet

2.24 Roof Tiles

Timber roofing shingles
Photo: Camster 2 (Wikimedia Commons)

Natural slate is common on many European historic buildings
Photo: Photos.com

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 used 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 Delabole Slate quarry in Cornwall
Photo: Lynda Poulter (Wikimedia Commons)

Natural clay roofing tiles Clay tiles
Photo: Photos.com website

Click 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

2.24 Roof Tiles continued

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.

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 lead 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.

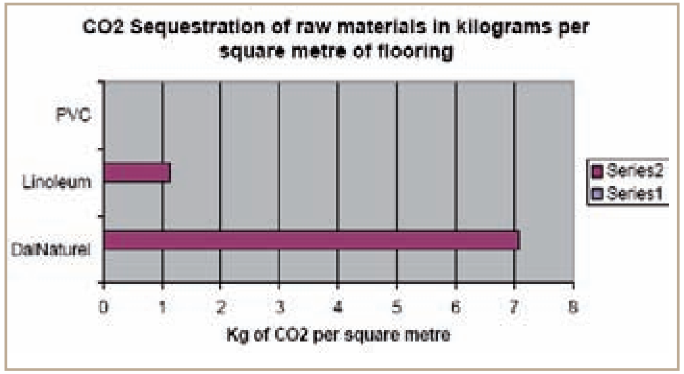
All artificial slates and tiles can be reclaimed and reused but in practice very rarely are and more often than not may be reduced to rubble to be used as fill etc.

Rubber trees being tapped on a plantation Photo: Joe Zachs (Wikimedia Commons)

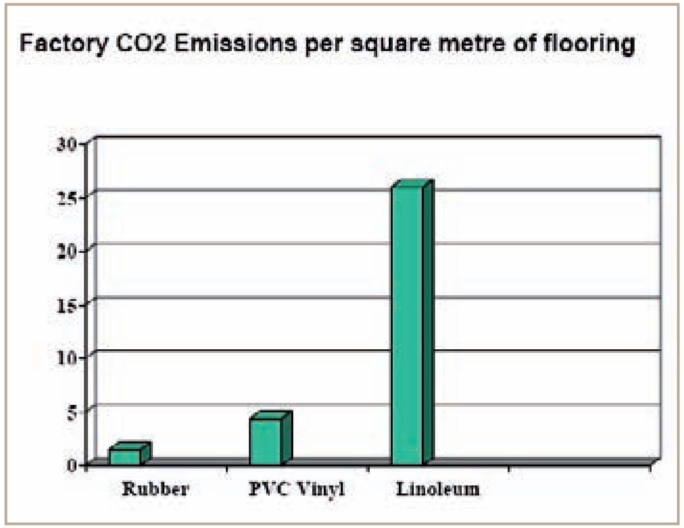
2.25 Rubber

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 petro-chemical 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 has recently become available for flooring once again. Although produced in tropical climates and therefore subject to transportation, the environmental impact from CO_2 emissions and embodied energy is far superior to either vinyl or linoleum flooring. Being a product of trees, CO_2 is actually sequestered during growth and therefore production. However, rubber plantations are mono-cultural and possibly detrimental to biodiversity, 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

Natural Rubber Supply:
http://www.dalsouple.com/Commercial-DalNaturel.php

Click to view:

Natural Rubber Flooring Data Sheet
Synthetic Rubber Flooring Data Sheet

2.26 Sealants, Adhesives and 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 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.

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

2.26 Sealants, Adhesives and Fillers continued

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 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 bio-sphere if allowed to enter the environment.

Links

General Information:
http://www.adhesivesmag.com/Articles/Construction/BNP_GUID_9-5-2006_A_10000000000000145627

Reduced Packaging:
http://www.geocel.co.uk/prodrange.aspx?r=eseal

Click to view:

Sealants Data Sheet

2.27 Shellac

Three different colours of shellac
Photo: LivingShadow (Wikimedia Commons)

Mealy Bug - Lac Insect
Photo: CSIRO Wikimedia Commons

Shellac is a resin secreted by the female Lac insect as it forms its cocoon on certain trees. The colour of the cocoon/shellac depends which tree the insect chooses to make its cocoon on. The insect drinks the sap of the tree and secretes the shellac, which is scraped from the bark of the tree processed and sold as dry flakes, then mixed with alcohol to form a liquid stain used for food glaze and timber colourant.

Shellac dries to a naturally high gloss sheen. Shellac is a natural polymer and can be considered a natural plastic; with the addition of wood flour, it can be used as a moulding compound and thus described as a thermo set plastic. It was widely used as sealant/varnish prior to the invention of polyurethane and it is UV resistant. It is not very tolerant to modern day solvents but is excellent as a water vapour barrier and odour barrier and as such is used in the aftermath of fire damage.

Links

General Information:
www.wikipedia.org/shellac

Copper roofing
Photos.com website

Tin can
Photo: Donar Reiskoffer (Wikimedia Commons)

2.28 Sheet Metals

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

Curved zinc roofing
Photo: KVDP (Wikimedia Commons)

The Statue of Liberty – possibly the world's best known copper clad building
Photos.com website

2.28 Sheet Metals continued

with possible toxic run-off to watercourses, it should be 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."

However, the Inventory of Carbon & Energy (ICEv.1.6a) from the University of Bath gives the following embodied energy figures:

- Copper – 40.55 MJ/Kg
- Lead – 25 MJ/Kg
- Zinc – 61 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

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 are finite resources with limited virgin stocks remaining in the world, particularly 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 metal

Links

Tin
http://en.wikipedia.org/wiki/Tin_can

Copper
http://en.wikipedia.org/wiki/Copper
www.copperconcept.org/publicationdownload.asp?pid=145

Lead
http://en.wikipedia.org/wiki/Lead_ore

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

Molten Steel being recycled from the World Trade Centre
Photo: United States Navy

Stainless steel is used extensively in catering applications
Photos.com website

2.29 Steel

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 is 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.

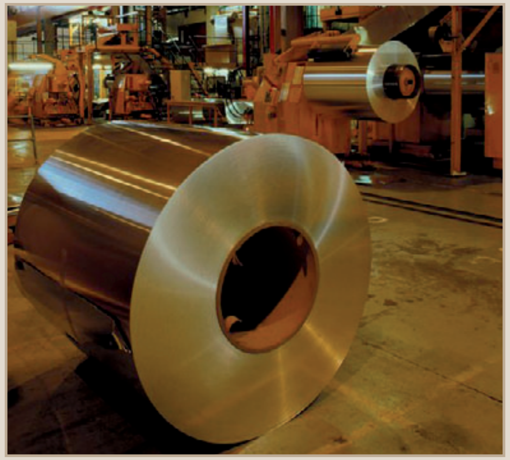
Steel is also manufactured through Electric Arc Furnaces, EAF's use 100% recycled material, the electric arc current melts the steel and lime, other fluxes are added and carbon and oxygen are blown into the mix, impurities combine to make slag (EAFS). This material is tapped into a ladle furnace, alloy additions can be made now or at the secondary steelmaking stage.

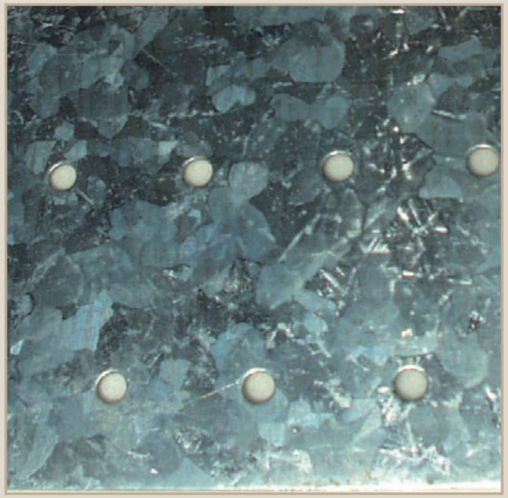
Secondary steelmaking occurs in ladle (arc) furnaces using both material from BOS and EA Furnaces where it receives extra treatments to create high grade steels.

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 favored 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 himself successfully employed this process on one of his early


Stainless steel coil being produced
Photos.com website


Galvanised steel plate
Photo: Splarka (Wikimedia Commons)

Click to view:

Steel Data Sheet
Zinc Data Sheet

2.29 Steel continued

commercial projects at the Phoenix Theatre in Leicester in 1963. However, in today's climate, legal requirements often demand stringent 'fitness for purpose' testing for reused elements. Unfortunately such testing is not widely available within the UK and is expensive. The elements within Bill Dunster's BedZed, for example, were moved over a substantial distance by road transport in order to be reconditioned and tested to the required standard. When one compares this against the fact that the steel in a structural element will be largely recycled anyway, combined with the efforts and resources needed to locate members of a suitable size, reuse of elements offers questionable benefits.

The above information is largely from the Corus publication 'Making and Rolling Steel' (2008).

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.

Steel v Concrete

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

Links

Steel:
http://www.steel-sci.org/

Steel Sustainability
http://www.corusconstruction.com/en/sustainability/
http://www.corusconstruction.com/en/reference/publications/sustainability_and_environment/
http://www.corusconstruction.com/en/reference/teaching_resources/building_in_steel/

Steel recycling:
http://ecosteelbuildings.co.uk/steel_recycling_environmental_policy.htm

Stainless Steel Recycling:
http://www.worldstainless.org/ISSF/Files/Recycling/Flash.html

Galvanised steel – General:
http://en.wikipedia.org/wiki/Galvanised

Galvanised steel – Sustainability:
http://www.hdg.org.uk/?cms_id=148

Stone is used extensively in many historic cities and upland locations
Photos.com website

Quarried Stone.
Photo: La Farge

Click to view:

Stone Data Sheet

2.30 Stone

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.

Links

Stone masonry - general:
http://www.sustainablebuild.co.uk/ConstructionStone.html

Quarrying impacts:
http://www.sustainablefloors.co.uk/the-impact-of-quarrying.html

Centre for sustainable minerals development (Strategic Stone Study):
http://www.bgs.ac.uk/mineralsuk/minequar/stones/EH_safeguarding_stone.html

BRE Stone types list
http://projects.bre.co.uk/ConDiv/stonelist/stonelist.html

2.31 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).

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

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.


Treated Siberian Larch
Photo: Vincent Timber (www.vincenttimber.co.uk)


Untreated Sweet Chestnut
Photo: Jo Denison, Stephen George & Partners

2.31 Timber continued

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.

Over the past 13 years, over 90 million hectares in more than 70 countries have been certified according to FSC standards and several thousand products are produced using FSC-certified wood carrying the FSC trademark. FSC operates through its network of National Initiatives in 45 countries.

PEFC
Founded in Geneva, Switzerland in 1999, the Programme for the Endorsement of Forest Certification (PEFC) is a non-governmental, non-profit organisation promoting sustainable forests through independent third party certification. PEFC bases its criteria on regionally accepted inter-governmental 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:
http://www.fsc-uk.org/

PEFC:
http://www.pefc.co.uk/

Illegal timber importation:
www.ppe.uk.net/documents/Illegal.pdf
http://www.greenpeace.org/international/press/reports/lawless-illegal-timber

2.31 Timber continued

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 Exectutive Summary that *"...FSC remains the only credible scheme."*

Link: http://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	
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

2.31 Timber continued

Durability

Timber Research and Development Organisation (TRADA) Classification
TRADA are a not-for-profit organisation which aims is 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

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.

Untreated Western Red Cedar
Photo: Jo Denison, Stephen George & Partners

2.31 Timber continued

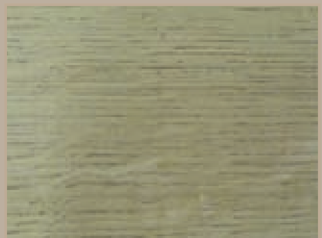
Unfinished External Joinery

Suitable Species

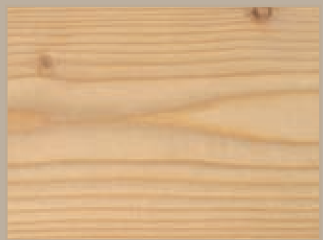
- European Oak (durable)
- Sweet Chestnut (durable)
- Western Red Cedar (European grown) (moderately durable)
- European (not UK) Larch (Moderately durable)
- Douglas Fir (Moderately durable)

Guidance:

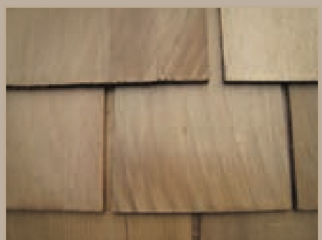
- Use seasoned wood
- Avoid using sapwood, especially when using moderately durable wood
- European Oak and Sweet Chestnut contain a great deal of tannin. This will initially stain but then wash off. Use corrosion resistant fixings (e.g. stainless steel) and protect surfaces from staining during this period.
- All unpainted wood regardless of species will gradually lose its original colour and fade to a light grey.



OAK
Photo: Mnemosine (Wikimedia Commons)



Siberian Larch
Photo: Vincent Timber (www.vincenttimber.co.uk)



Untreated Cedar Shingles
Photo: Vincent Timber (www.vincenttimber.co.uk)

Western Red Cedar
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)

2.31 Timber continued

Platowood Spruce
Photo: Jo Denison, Stephen George & Partners

Lunawood cladding
Photo: Oy Lunawood Ltd

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.

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.

Accoya in close up
Photo: © Titan Wood Ltd'

Accoya as cladding
Photo: © Titan Wood Ltd'

Click to view:

Processed/Engineered Timber Data Sheet
Composite Timber Sheets Data Sheet

2.31 Timber continued

Links

TRADA
http://www.trada.co.uk/

Wood preservation – general
http://www.greenspec.co.uk/html/materials/woodpresevtn.html
http://en.wikipedia.org/wiki/Wood_preservation#Wood_acetylation

Thermowood
http://www.finnforest.co.uk/products/exteriorcladdings/Pages/ThermoWood.aspx

Acoya
http://www.accoya.info/accoya.html

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.

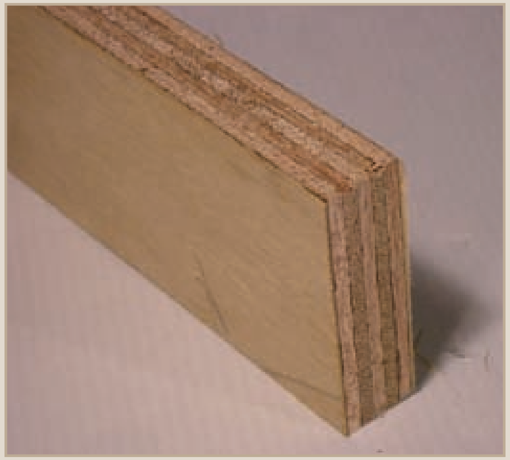
Composite Timber Material Types

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 diisoynate 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.



Plywood
Photo: Rotor DB (Wikimedia Commons)

OSB
Photo: Elke Wetzig (Wikimedia Commons)

2.31 Timber continued

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.

• 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.

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 the UK is Europe’s largest user of plywood. Ply consists of thin layers of tropical hardwood veneers glued and compressed into sheets. There is no technical reason why unsustainable tropical hardwood plywood cannot be replaced with alternatives such as FSC Oriented Strand Board (OSB), which is locally sourced, competitively priced, and readily available on the UK market.

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.

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.

Thermowood cladding
Photo: Finnforest Ltd - www.finnforest.co.uk

Accoya used as Glu-lam
Photo: © Titan Wood Ltd'

Click to view:

Processed/Engineered Timber Data Sheet
Composite Timber Sheets Data Sheet

2.31 Timber continued

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.

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

Plywood general
http://www.greenspec.co.uk/html/materials/boards.html

Plywood vs. OSB
http://www.greenpeace.org.uk/tags/plywood

OSB
http://www.osbguide.com/osb.html

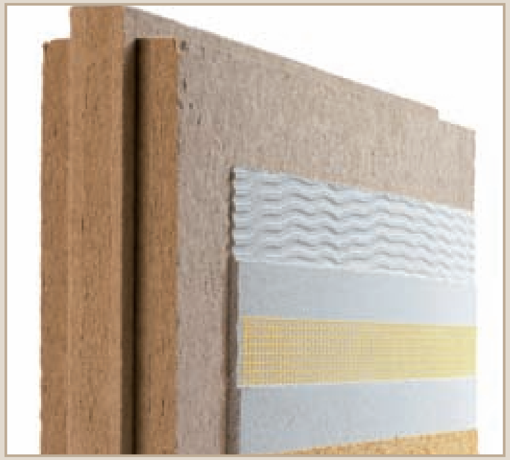
Glue in composite boards
http://www.polyurethane.org/s_api/sec.asp?CID=915&DID=3628

Glulam
http://www.glulam.co.uk/

LVL
http://www.timber.org.au/NTEP/menu.asp?id=103

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



Diffutherm board
Photo: Natural Building Technologies

Pavaclad system under construction
Photo: Natural Building Technologies

Click to view:

Insulation Data Sheet

2.31 Timber continued

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.

Links

Pavatex & Diffutherm
http://www.natural-building.co.uk/pavatex_pavatherm_plus_timber_frame.htm

2.32 Vinyl Flooring

Vinyl flooring in production
Photo : Polyflor Ltd

Vinyl flooring in use
Photo : Polyflor

Click to view:

Vinyl Flooring Data Sheet

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 straight forward 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

2.33 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 (NO_4). 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).

2.33 Steel versus Concrete continued

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 upshot is that no-one really knows but you can get both systems to work for you if you are careful enough.

Links

http://www.building.co.uk/story.asp?storycode=3069406

Section 3
Data Sheets

Photo: Copyright - Greenpeace / Alex Hoffard

Click to return to section 2 - Aluminium

Element / Material

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 effect 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 to return to section 2 - Asphalt

Element / Material

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
- 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 to return to section 2 - 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

Element / Material

Bamboo

Considerations, Limitations & Best Practice

- Although used structurallly 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 to return to section 2 - 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

Element / Material

Bitumen

Considerations, Limitations & Best Practice

- Capable of 'A+' Green Guide rating in correct specification. (Contradicts NGS 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 to return to section 2 - Clay : Bricks

Element / Material

Bricks

Advantages

- Durable
- Reusable when used with lime mortar
- Recyclable
- Non-toxic
- Often locally produced in lowland UK

Disadvantages

- High embodied energy in production
- Transportation can be excessive
- Clay won by mineral extraction

Considerations, Limitations & Best Practice

- Almost universal A+ rating under BRE Green Guide. (Debatable assessments?)
- Flettons use less energy in firing than solid ‘stocks’
- Source on basis of local availability rather than pure aesthetics
- Recycled bricks are the ‘greenest’ option but often expensive
- Lime mortar will allow reuse at demolition and reduce requirement for movement joints. However, check the required bearing capacity as lime mortar may not be robust enough in non-domestic situations.
- As U-value requirements increase, overall wall thicknesses increase as well in order to incorporate enough insulation. Therefore, thinner materials than brickwork may be desirable.

Sustainable Alternatives

- Reused and reconditioned bricks if brickwork faced elevations are required

If not, other walling materials may include:

- Perforated clay blocks with render finish
- Timber frame and cladding
- Straw bale & timber frame modules
- SIPS panels or factory produced modular system
- Rammed Earth
- Thin clay facing tiles on steel frame

Click to return to section 2 - Carpet

Element / Material

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 to return to section 2 - Carpet

Element / Material

Carpet - Synthetic

Advantages

- Cheaper
- Colours will not fade
- Stain resistant
- Capable of A+ Green Guide Rating

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, bio degradable materials with natural dyes.

Click to return to section 2 - Concrete & Cement Products

Element / Material

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 to return to section 2 - Ceramic Tile

Element / Material

Ceramic Tile

Advantages

- Inert
- Relatively low embodied energy compared to alternatives
- Can have recyced content as standard
- Can provide thermal mass
- Durable
- Robust
- Low whole life cost

Disadvantages

- Generally non-reusable
- Glazes may be toxic during maufacture

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 to return to section 2 - Clay

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

Element / Material

Clay - Unfired Blocks

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.
- Now available with 50% recycled plasterboard content. (‘Naterra’ block) – Higher compressive strength for commercial application,
- 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 to return to section 2 - Clay

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

Element / Material

Fired Hollow Clay Blocks

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 to return to section 2 - Clay

Element / Material

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 to return to section 2 - Clay

Element / Material

Clay Drainage

Advantages

- Natural material
- 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 use in preference to plastic.
- 100 year + lifespan works in favour of Whole Life Costing assessment
- For maximum sustainability, follow the following guidelines
  - o Specify from manufacturer with ISO14001 accreditation
  - o 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 to return to section 2 - Composite Materials

Element / Material

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 to return to section 2 - Composite Materials

Element / Material

Composite Flooring

Advantages

- Lightweight high strength solution
- Space saving – may result in reduced building height
- Less time on site

Disadvantages

- Steel shuttering may prevent exploitation of soffit level thermal mass
- May require pumped concrete

Considerations, Limitations & Best Practice

- A composite flooring system is one which works by two adjacent materials acting together. A system with structural steel sheet can enable the amount of concrete in the slab to be substantially reduced.
- The most common is profiled steel sheet as shuttering with high strength concrete topping over. Bonding can vary according to the system
- The structural steel decking can incorporate up to 79% recycled material.
- A+ Rating is available under BRE Green Guide.

Sustainable Alternatives

- Pre-cast system allowing exploitation of thermal mass through an exposed soffit. However, this will be a heavier system.

Click to return to section 2 - Timber

Element / Material

Composite Timber 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 carcinogen and 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 to return to section 2 - Concrete Blocks

Element / Material

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:
- Some, such as the 'Enviroblock,' have a 90% recycled content.
- 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
- "Naterra" Blocks with 50% recycled plasterboard content
- Hemcrete (Hemp-lime) blocks
- Woodchip ICF Blocks (Durisol)
- Rammed Earth
- SIPS Panels or timber framed system

Click to return to section 2 - Concrete

Element / Material

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 insitu work, self-compacting concrete may offer better finishes and less time on site.
- In-situ mixes should be as 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'.
- 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 both framing, flooring and cladding but will require an alternative design approach.
- See Section 2 - 'Steel versus Concrete'

Click to return to section 2 - Sheet Metals

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

Element / Material

Copper

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.

Sustainable Alternatives

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 to return to section 2 - Earth

Element / Material

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

Sustainable Alternatives

- Rammed earth
- Hemcrete
- Straw bale

Click to return to section 2 - Gypsum

Element / Material

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 to return to section 2 - Crops : Hemp

Element / Material

Hemp-Lime

Advantages

- Natural materials
- Carbon lock-up/sink
- High U-values possible
- High thermal inertia (similar to thermal mass)
- Breathable construction

Disadvantages

- Specialised equipment required for in situ pumping
- Wall thicknesses may be prohibitive
- Not water resistant
- Friable

Considerations, Limitations & Best Practice

- Tradical Hemcrete is a proprietary product therefore the ingredients of its make up are 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 $W/m^{2\circ}C$ 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.

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
- SIPS

Click to return to section 2 - ICF

Element / Material

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 to return to section 2 - Insulation

Element / Material

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
Mineral Extraction	Foamed glass	Recycled glass	27.00	0.042	A+ to C	• Rating dependant 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 dependant 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 dependant on density • Potentially recyclable (if unsoiled) or re-usable • Binders may be toxic (formaldehyde) • Irritant • Production 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
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 usually) • 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 un-insulated gaps
	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 un-insulated 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 to return to section 2 - Sheet Metals

Advantages

- Traditional material
- Easily recycled
- Relatively low energy in orginal 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

Element / Material

Lead

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.

Sustainable Alternatives

Embodied energy (MJ/kg)		
	Virgin	Recycled
	72	9
Copper	70	17.5 - 50
Lead	49	10

Source: Inventory of Carbon & Energy (ICE), University of Bath 2008

Click to return to section 2 - Lime

Element / Material

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) may 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 to return to section 2 - Linoleum

Advantages

- Natural material (Flax)
- Renewable resource
- Recyclable
- Biodegradable
- Non-toxic
- Water resistant

Disadvantages

- High embodied energy content
- Flax cultivation uses fertilizers (nitrate runoff)

Element / Material

Linoleum

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
- Timber flooring

Click to return to section 2 - Living Roofs

Element / Material

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 to return to section 2 - Paint

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

Element / Material

Paint - Natural

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 to return to section 2 - Paint

Element / Material

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, iritants and toxins
- Often petro-chemical 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 to return to section 2 - Phase Change Materials

Element / Material

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 to return to section 2 - Plastics

Advantages

- Durable
- Robust
- May be recyclable
- Cheap

Disadvantages

- Contain various toxins
- Non-biodegradable
- Usually a petrochemical product
- High embodied energy

Element / Material

Plastics

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 phlatates (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 high as possible recycled content.
- 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 to return to section 2 - Timber

Element / Material

Processed & Engineered Timber

Types

Glulam

- Alternative to steel or concrete but with reduced 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

Acoya

- Non-toxic chemically modified softwood
- Acoya 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

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 to return to section 2 - Rammed Earth

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.

Element / Material

Rammed Earth - Stabilised

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 to return to section 2 - Rammed Earth

Element / Material

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 to return to section 2 - Roof Tiles

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

Element / Material

Roof Tiles 1: Timber Shakes & Shingles

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 to return to section 2 - Roof Tiles

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

Element / Material

Roof Tiles 2: Natural Slates

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 to return to section 2 - Roof Tiles

Element / Material

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 to return to section 2 - Roof Tiles

Element / Material

Roof Tiles 4: Artificial Slates & 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 to return to section 2 - Roofing Membranes

Advantages

- Potentially recyclable (roofing)
- Robust
- Durable
- Relatively low toxicity

Disadvantages

- Petro-chemical based
- High embodied energy
- Toxic run-off if consigned to landfill

Element / Material

Roofing Membranes - Synthetic Rubber

Considerations, Limitations & Best Practice

- Synthetic rubber flat roofing is usually know 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 system

Sustainable Alternatives

- A pitched roof
- Green roofs
- Concrete membrane

Click to return to section 2 - Rubber

Element / Material

Rubber Flooring - Natural

Advantages

- Low embodied energy
- Renewable resource
- Non-toxic
- Sound absorbing
- Natural material
- Crop produce therefore carbon sink

Disadvantages

- Some products can include same additive toxins as PVC (c/f plastics)
- Generates toxic fumes when burnt
- Extensive transportation
- Monocultural plantation system may not enhance biodiversity

Considerations, Limitations & Best Practice

- Can be 'downcycled' for secondary use.
- BRE Green guide unrated
- Compared to alternatives such as linoleum and PVC, natural rubber has the lowest factory emissions of CO_2 per square metre
- Raw material is a planted product therefore absorbs CO_2 during growth. Comparative figures for CO_2 sequestration are:

  Natural rubber – 7kgCO_2/m^2

  Linoleum – 1.25 kgCO_2/m^2

  PVC - 0 kgCO_2/m^2

Sustainable Alternatives

- Linoleum
- Cork

Click to return to section 2 - Rubber

Element / Material

Rubber Flooring - Synthetic

Advantages

- May have high recycled 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.
- BRE Green guide rating A

Sustainable Alternatives

- Natural rubber
- Linoleum
- Cork

Click to return to section 2 - Sealants, Adhesives & Fillers

Element / Material

Sealants, Adhesives and 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 to return to section 2 - Prefabrication

Element / Material

S.I.P.S. & 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 petro-chemicals
- Petrochemical insulation often used.

Considerations, Limitations & Best Practice

- As part of a system such as Huf Haus, a weathertight shell can be erected within 15 days.
- Many systems originate in Germany and have to be imported. Despite this, speed of construction using skilled apprentice-trained labour vastly reduces embodied energy content when compared to traditional envelope systems.
- 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 to return to Section 2 - Steel

Element / Material

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 both framing, flooring and cladding but will require an alternative design approach.

Click to return to section 2 - Stone

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

Element / Material

Stone

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 to return to section 2 - Straw

Element / Material

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.

Sustainable Alternatives

- Straw bales are a sustainable alternative to traditional construction, particularly cavity walling or timber framing in housing and low-rise buildings.
- Consider using only organic straw for improved sustainability.

Alternatives include:

- Hemp-Lime
- Fired clay block
- Rammed Earth
- SIPS

Click to return to section 2 - Timber

Element / Material

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

Acoya

- 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 to return to section 2 - 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'.

Element / Material

Vinyl Flooring

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
- Ceramic tiles

Click to return to section 2 - Glass & Glazing

Element / Material

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^2°C while for an external wall, it is 0.35W/m^2°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^2°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^2°C
- Passivhaus standards require 0.8W/m^2°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°C using low-e glass and a krypton fill.

Click to return to section 2 - Timber

Element / Material

Windows 2 : Temperate Hardwood

Advantages

- Low embodied energy
- BRE Green Guide A+ rating
- Renewable resource
- Low maintenance
- 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 to return to section 2 - Timber

Element / Material

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)
- Maintenance (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 to return to section 2 - Aluminium

Element / Material

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
- Low BRE Green Guide rating (D)

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
- Despite the longer lifespan, increased durability and recycled content of aluminium, these frames are rated very low under the BRE Green Guide (D). However, Passivhaus standard composite windows are available from Germany which again calls into question the rating system under the Green Guide.

Click to return to section 2 - Aluminium

Element / Material

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
- A higher BRE Green Guide rating is possible with aluminium frames than with aluminium softwood composite types. This is despite having a far higher embodied energy content and global warming potential. It is difficult to ascertain why this should be.

Click to return to section 2 - Steel

Element / Material

Windows 6 : 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 to return to section 2 - Plastics : 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

Element / Material

Windows 7 : PVC

Notes

- Refer to the section on plastics.
- PVC is a petrochemical which incorporates chlorine, phlatates 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. The VEKA Umwelttechnik factory is the only 'closed loop' PVC window recycling plant in the world which re-uses discarded PVC frames in new windows. **http://www.vekauk.com/environment.php**
- Despite the lengthy list of environmental disadvantages, PVC windows can achieve Green Guide ratings of A for domestic and A+ for commercial applications.

Click to return to section 2 - Sheet Metals

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

Element / Material

Zinc

Considerations, Limitations & Best Practice

- 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.

Sustainable Alternatives

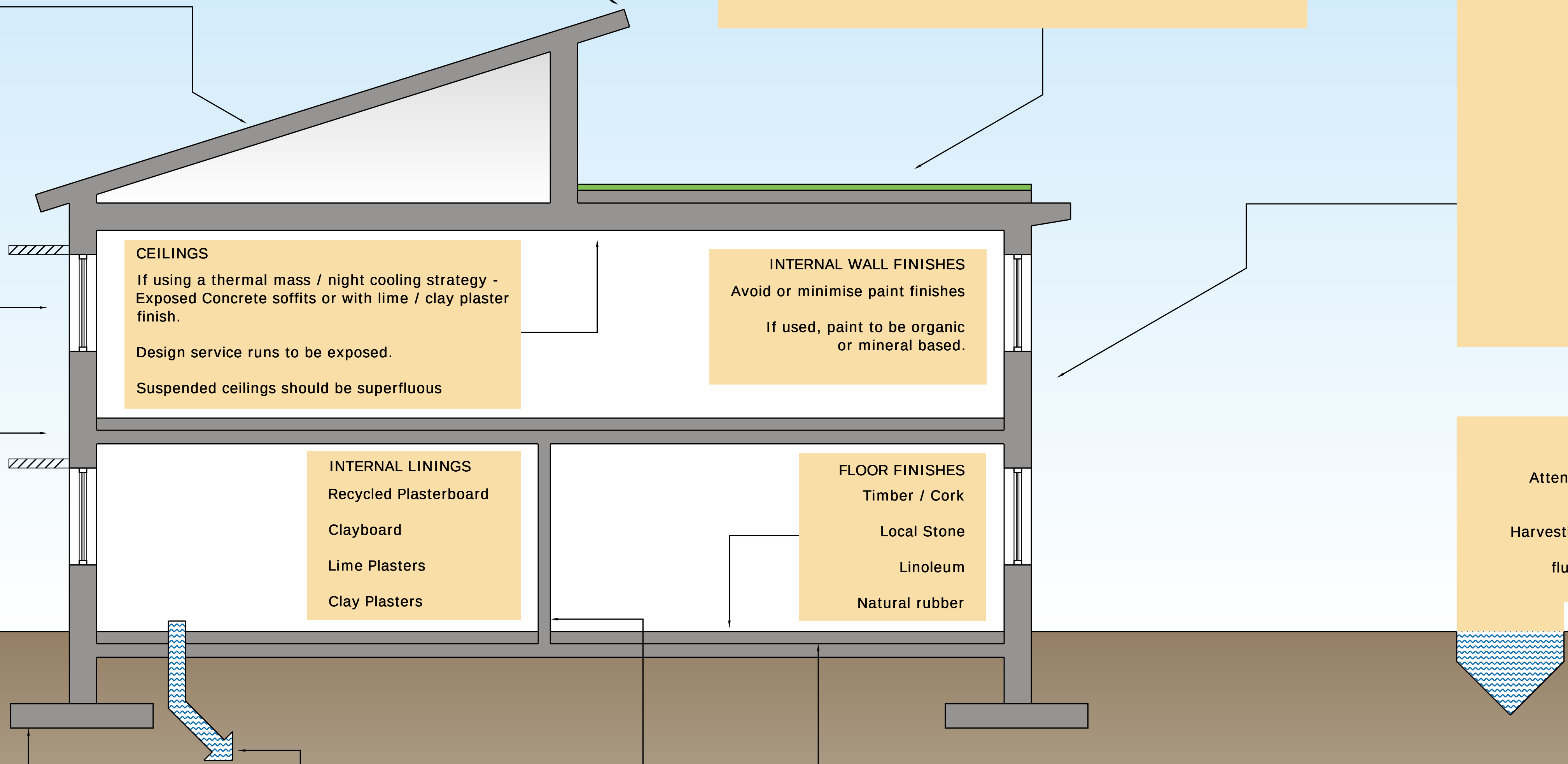
Embodied energy (MJ/kg)		
	Virgin	Recycled
Zinc	72	9
Copper	70	17.5 - 50
Lead	49	10

Source: Inventory of Carbon & Energy (ICE), University of Bath 2008

Appendices

Photo: Carribean Hermit Crab (Wikimedia Commons)

Sustainable Materials : Typical Applications



PITCHED ROOF

STRUCTURAL

Timber / Engineered timber with OSB decking

SIPS

PC Concrete with high recycled aggregate content and cement substitute.
N.B. Only if used as part of a thermal mass exploiting energy strategy

COVERINGS

Indigenous timber shingles or shakes

Natural slate - locally sourced if possible; preferably reclaimed

Zinc sheet

INSULATION

Cork

Cellulose

Hemp

Wood based

Sheep's Wool

RAINWATER GOODS

Zinc

Aluminium

FLAT ROOF

STRUCTURAL

Engineered timber with OSB Decking

PC Concrete with high recycled aggregate content and cement substitute.
N.B. Only if used as part of a thermal mass exploiting energy strategy

INSULATION

Foamglass

EPS

Rigid Mineral fibre

COVERINGS

Green Roof on recycled bitumen sheet

Zinc Sheet

EXTERNAL WALLS

STRUCTURAL

Straw Bale

SIPS

Timber Frame

Hemcrete

Clay Blocks

Rammed Earth / Cob / Earth Blocks

Concrete Elements with high level of recycled content & cement substitute

CLADDINGS & FACINGS

Timber

Lime Render

Reclaimed brick

Local Stone

INSULATION

Cork

Cellulose

Hemp

Wood based

Sheep's Wool

WINDOWS

FSC / PEFC Hardwood frames

Triple-glazed or double-glazed with Argon fill

CEILINGS

If using a thermal mass / night cooling strategy - Exposed Concrete soffits or with lime / clay plaster finish.

Design service runs to be exposed.

Suspended ceilings should be superfluous

INTERNAL WALL FINISHES

Avoid or minimise paint finishes

If used, paint to be organic or mineral based.

INTERMEDIATE FLOORS

Engineered timber with OSB Decking

PC Concrete with high recycled aggregate content and cement substitute.
N.B. Only if used as part of a thermal mass exploiting energy strategy

INTERNAL LININGS

Recycled Plasterboard

Clayboard

Lime Plasters

Clay Plasters

FLOOR FINISHES

Timber / Cork

Local Stone

Linoleum

Natural rubber

RAINWATER DRAINAGE

Attenuation via green roofs or permeable paving

Harvesting for grey water re-use in WC flushing and / or landscape irrigation

FOUNDATIONS

PC Concrete with high recycled aggregate content and cement substitute.

BELOW GROUND DRAINAGE

Clay pipework

Mains connection

PARTITIONS

Earth blocks

Clay blocks

Concrete blocks with high recycled content

FSC Timber studwork

FLOOR SLABS

Concrete with optimum recycled aggregate content and cement substitute.

NOTE:
The materials shown here are merely sugestions for the most sustainable materials available for each element. An alternative solution not listed here should not be taken as negating that material in terms of sustainability. Each project should be assessed individually.Not every material may be suitable for every situation and constraints in durability and / or availability may result in a material usually considered less sustainable being more suitable.

Introduction to Stephen George & Partners LLP

Stephen George & Partners LLP believe that a commitment to sustainable design and sustainability within our own company is an essential part of our business in the 21st Century. All aspects of this commitment are formulated and coordinated by our Sustainability & Technical Steering Group composed of suitably experienced personnel from across the company.

We have extensive experience within both the private and public sectors, offering quality architectural design services supported by technical expertise. Commitment to quality, service and innovation are the basis of our practice philosophy and working closely with our clients is a key element of our success. We believe that the foundations of good design lie in strong relationships.

Our interest in sustainable design is equally life-long; we were commissioned to research passive solar energy collection by the European Commission back in 1978. Recognising the need to adhere strictly to budgets, we have developed strategies for sustainable design that are cost-effective for our clients to implement.

In August 2008 we were invited to join the UK-GBC Biodiversity Task Group. Joining a wide group of experts we 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.

At Stephen George & Partners LLP, we are accredited BREEAM Assessors. As well as providing a service for our-projects, they also carry out an important advisory role for clients and designers. Any projects which require a BREEAM assessment can be studied at a very early stage and the design team briefed on the best approach of achieving the target rating. Obviously, having assessors within the practice allows access to useful guidance and avoids those 'nasty surprises' at a later date.

To help us in our housing projects, Stephen George & Partners LLP have a qualified assessor accredited to carry out Standard Assessment Procedures. Again, not only does this make life easier in terms of communication within the design team, but ensures that our staff have easy access to informal advice through every stage of a project.

UK GREEN BUILDING COUNCIL
Member

Sustainable Design - Our Experience

Suscon (Sustainable Construction) Academy, Dartford, Kent

- Extensive passive heating and cooling systems
- Minimal energy use
- Low embodied energy, low carbon and low toxicity materials.

Woodstone Primary School, Ravenstone, Leicester

- Natural ventilation
- Photovoltaic cells
- Grey water harvesting

Magistrates' Court, Loughborough, Leicester

- BREEAM 'Excellent'
- Winner of the RIBA, Leicestershire & Rutland Society of Architects 2009 Design Award for Large Projects

Sustainable Design - Our Experience

Probation Centre, Cobden Street, Leicester

- Passive cooling and ventilation systems
- Maximised daylighting
- Predicted energy consumption 50 per cent of a typical office building

Littlecombe, Dursley, Gloucestershire

- 37.5 hectare Sustainable Urban Community
- One of the largest biomass district heating systems in the UK

Mountsorrel, Leicestershire

- One of the first Code Level 6, Zero carbon homes in the UK.
- Completed January 2010

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Available at - https://wiki.bath.ac.uk/display/ICE/Home+Page

The Green Guide To Specification

The Building Research Establishments' online guide to environmental performance rating for building elements.
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Green Book Live

BRE Online reference database of products and services purporting to be 'environmental'. Includes information on the Environmental
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SMARTWaste

The BRE's programme to help industry reduce waste and meet the demands of WRAP .
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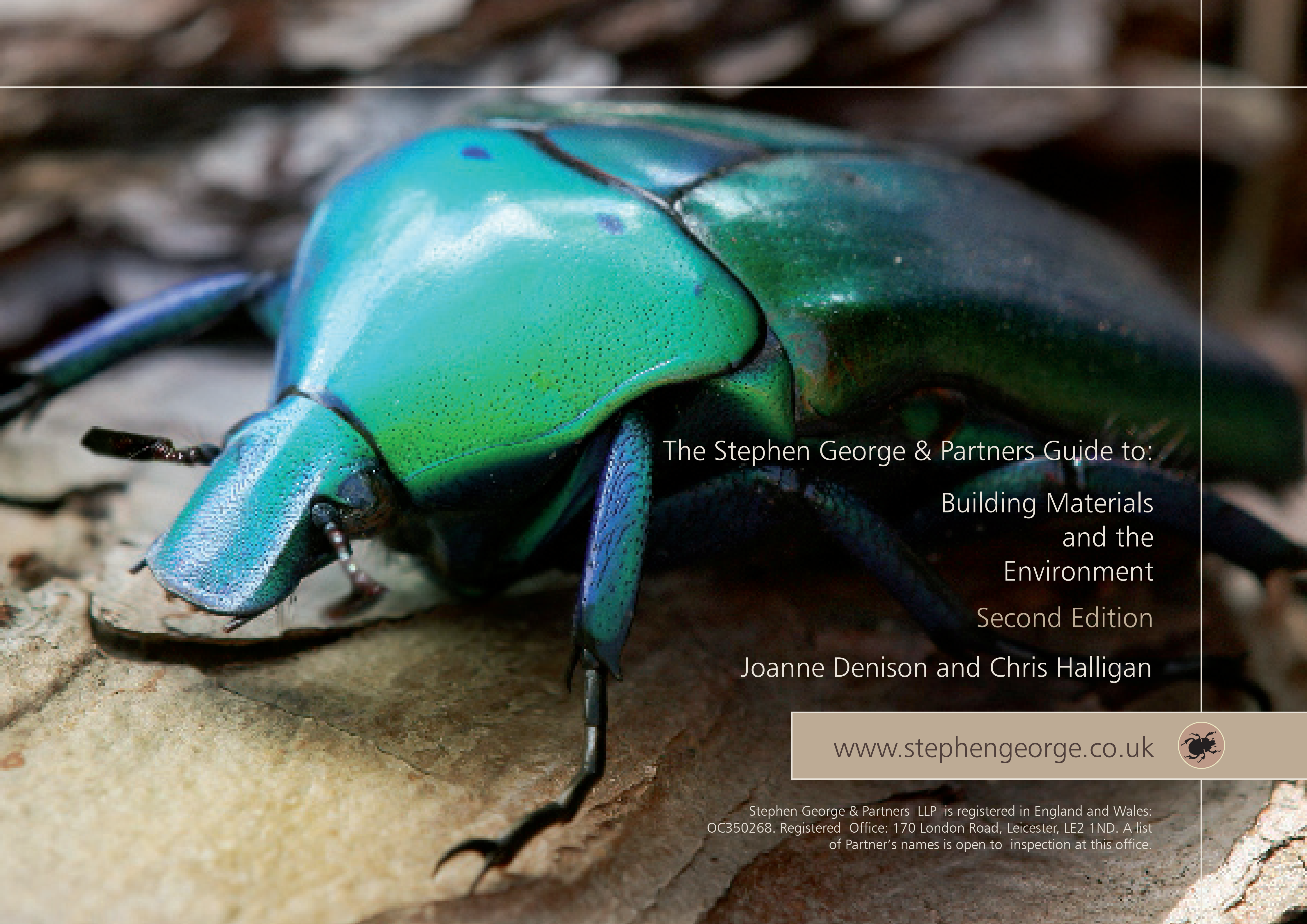

The Stephen George & Partners Guide to:

Building Materials and the Environment

Second Edition

Joanne Denison and Chris Halligan

www.stephengeorge.co.uk

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