A GUIDE TO

SUSTAINABLE MATERIALS

FOR

THEATRE DESIGN

THE SOCIETY OF BRITISH THEATRE DESIGNERS

SBTD

Contents

Introduction

Preface
What is a Sustainable Material?
Making Sustainable Design Decisions
How to Read this Guide

Part One: Sheet and Foam Materials

Introduction
Eco-board
Hemp-board and Hemp-canvas
Cardboard
Engineered Woods: Plywood
Engineered Woods: OSB (Oriented Strand Board)
Engineered Woods: MDF
Søuld Acoustic Boards (Eelgrass Panel)
Recycled Plastic Board
Cellulose Wallboard
Corn-based Foam
Corn-based Board
Wood-wool Board

Part Two: Other Building Materials

Introduction
Glulam
Cork
Bamboo
Straw
Repurposed Rubber
Waste-based Bricks
Recycled Paper Brick Part 1
Recycled Paper Brick Part 2
CompostaBlock
Cob

Part Three: Sustainable Processes and Manufacturing

Introduction
Sustainable Procurement Processes
Tools for Supporting Sustainable Procurement
Initiating Alternative Material Loops
Reclaiming Existing Materials - Sleeping Bag Case Study
Circular Economy Design
Sustainable Connections
Forest Stewardship Council (FSC)
Fireproofing
Toxic Materials
Toxicity and Natural Materials
Working with Metals
Working with HDPE Plastics
Working with Plants
Working with Waste
Touring Materials Sustainably
Storing Materials Sustainably
Modularity and Adaptability
Illusionary and Minimal Materials
Technology and Sustainable Materials
Site Specific Materials

Contents contd.

Part Four: Paints, Glues, Varnishes and Textures

Introduction
Ecopaint (low VOC)
A Comparison of Homemade Casein Paints
Biodegradable Glue
Natural Dyes
Structural Wood-based Colours: Cellulose Nanocrystals
Bacterial Dye 1: Serratia Marcescens
Bacterial Dye 2: Janthinobacterium Lividum
Cellulose Varnish and Stain
Cork Crumb
Bio-beads
Dekozell
Beeswax
Introduction to the Sustainability of Oils
Linseed Oil
Tung Oil
Using Oil on Other Materials Part 1
Using Oil on Other Materials Part 2

Part Five: Materials for Costumes and Props

Introduction
Cellulose Bio-plastic Part 1
Cellulose Bio-plastic Part 2
Agar Bio-plastic Part 1
Agar Bio-plastic Part 2
Cardboard Clay Part 1
Cardboard Clay Part 2
Barkcloth
Seaweed
Wool
Mycelium
Red Osier Dogwood
Nettle
Recycled Ceramics
Flax (linen)
Recycled Paper

Appendix

List of Useful Links
List of Manufacturers and Suppliers
Glossary of Terminology

Introduction

Preface

A Guide to Sustainable Materials for Theatre Design is produced by the Society of British Theatre Designer's Sustainability Working Group.

The working group started in 2020. The group established ongoing projects, including carbon literacy training and sustainable costume management across the theatre sector in the UK. Each project was motivated by helping the theatre industry to become more environmentally sustainable, given the importance to find modes of working that limit the effects of climate change. For example, processes that do not heavily rely on fossil fuels, excessive material extraction or the production of large quantities of material waste.

Research into sustainable materials was another project established at the inception of the working group. Given the time pressures on setting up a theatre production and designers often being thrown into unfamiliar surroundings on a job by job basis, many designers do not have the time to research and test new and experimental materials within their work. This guide seeks to respond to this issue and be a place of reference that collects together pragmatic, aesthetic and ecological information about materials which have been investigated by theatre designers for theatre designers. In this sense, the guide hopes to bridge the gap between material science and theatre practice in order to give designers the agency to advocate for sustainability and to develop a critical eye as to how we define and measure sustainability in a qualitative sense.

Sustainability can sometimes come with the connotations of limiting artistic practice because material abundance and some material processes have large environmental costs. The guidebook wants to challenge that notion as research into new materials and ways of using materials can be framed as an exciting, and often thrifty area for theatre design. It opens more doors than it closes. The guide has been written in the spirit of positioning sustainability as a creative opportunity to make theatre in ways that have not yet been done before.

Hamish Muir
Guide Editor

We would like to thank all of the contributors to this guidebook. It has been produced by set designers and members of the SBTD on a voluntary basis who have spent the time to research and collate work to help inspire the industry.

List of contributors:

Arianna Mengarelli
Hamish Muir
Urs Dierker
Paul Burgess
Kira Curtis
Deborah Piffer
Simon Daw
Max Goodman
Alison Neighbour
Ruth Stringer
Maria Terry
Ian McFarlane
John Winters
Adam Washiyama Shulman
Karen Hood
Andrea Carr
Lucy Bridger
Gretchen Maynard-Hahn
Mathias Peitersen
Lea Hedeskov
Frederik Larsen

What is a Sustainable Material?

Unfortunately, there is no such thing as a sustainable material, which may be an odd way to begin a guide to sustainable materials! However, what is meant by this statement is that no material is inherently sustainable, as it is dependent on how it is used. For instance, a piece of timber may have a low embodied energy as a raw material but if it is transported across the globe, conglomerated with other substances, and thrown into landfill without reuse or recycling, it quickly becomes a less environmentally friendly option. This means the sustainability of a piece of material has to be assessed using several different metrics, and is specific to the individual object and the relationship it has with its user.

The metrics which we have come up with to assess the sustainability of the materials are as follows:

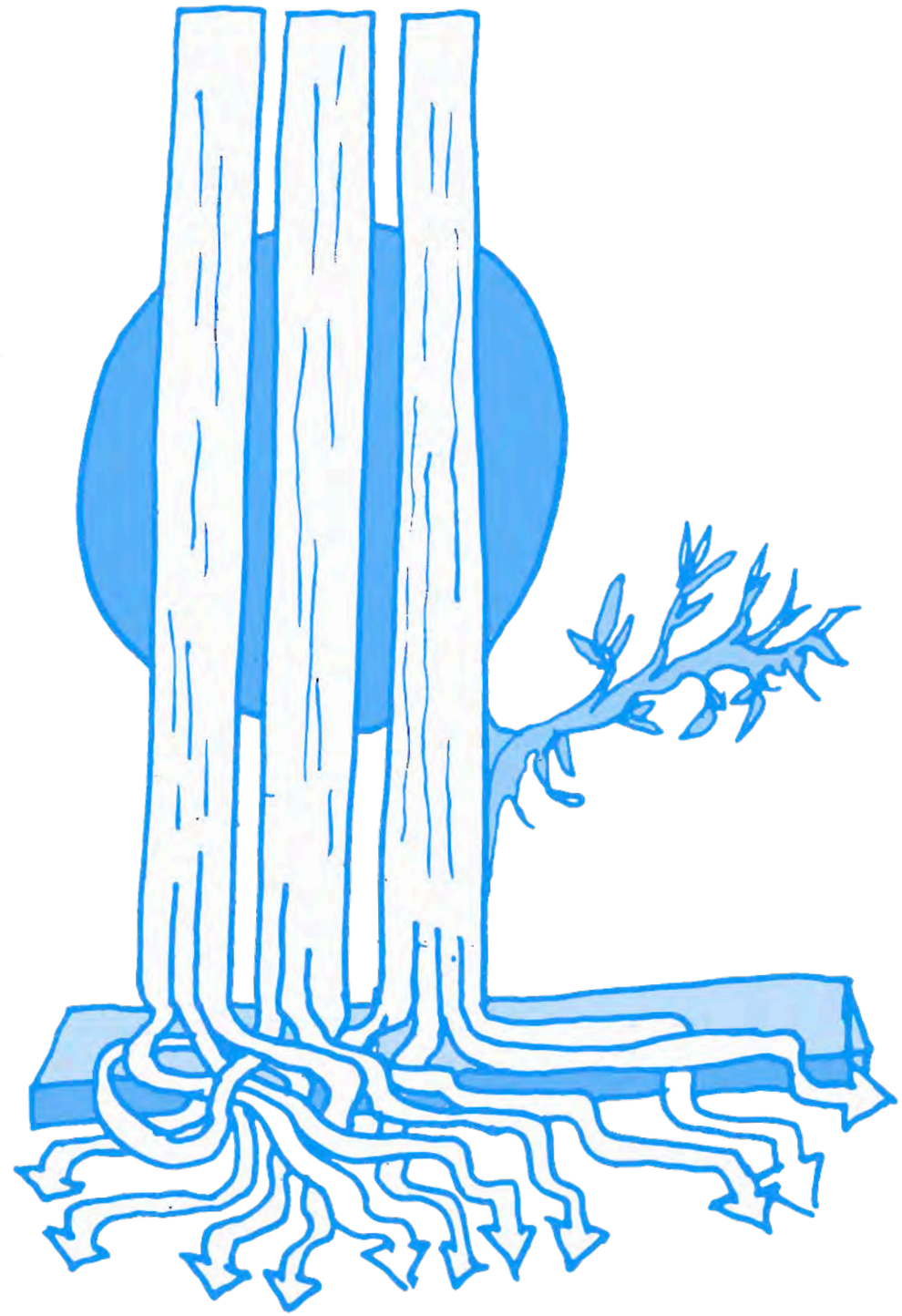
- Does it contain chemicals which are harmful to the environment (For instance, is it corrosive or toxic)?
- Is the material reusable and recyclable (This depends on its versatility, strength and whether it can be reduced back to its raw form to be re-manufactured)?
- Is the material bio-degradable (This is partly related to the first two questions in terms of the durability and toxicity of the substance.)?
- Does it have a high embodied energy? (Embodied energy is the energy required to make, transport, use and dispose of a material from cradle to grave. Some materials, like steel, have a high embodied energy to manufacture, other materials have a high embodied energy because they travel far to get to the theatre which uses them.)
- Where is it quarried and manufactured? (Embodied energy can be difficult to calculate quantitatively but knowing where a material is made compared to where it will be used gives a good indication if the embodied energy is high or low, because embodied energy is dependent on how far a material travels.)

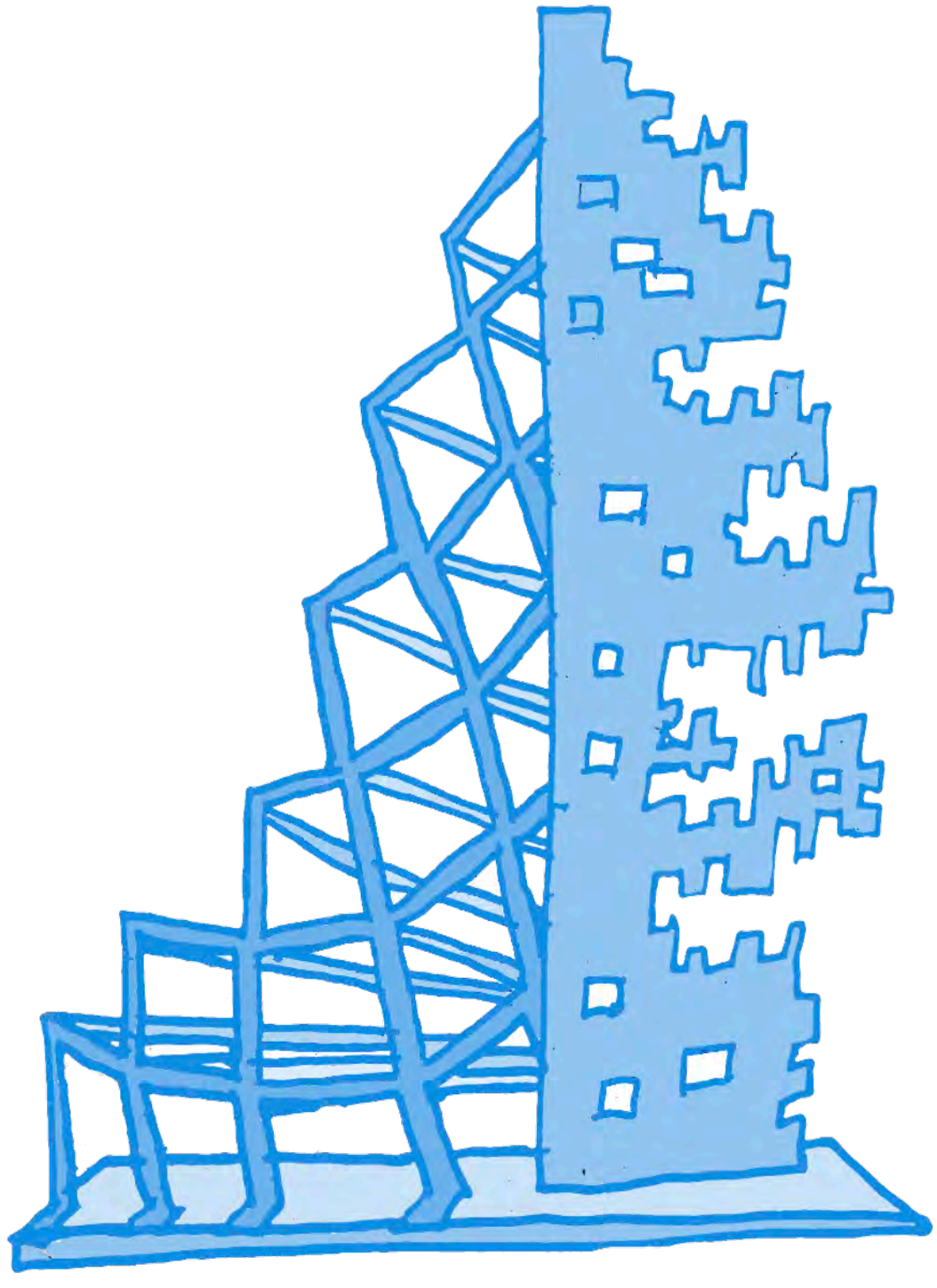
Making Sustainable Design Decisions

Given the many different ways we can measure the sustainability of a material, making choices about materials can be very difficult and is a major reason why greening the theatre has been slow to establish. For example, a piece of steel has a high embodied energy but if it is used many times by a production company, it may become more sustainable in the long term compared to materials which are routinely bought new and thrown away for every production.

The time it takes to investigate and unpick all of the trade routes, manufacturing processes, embodied energies and carbon costs can be long and the answers unclear or misleading. However, in this guide, we want to demystify the research process. We have attempted to assess materials as a set designer would for any theatre production and present the pros, cons, facts and fictions that we find along the way. Not only do we want to present some interesting materials, we want to show our methods so that set designers can learn from the approach we have taken and ask similar questions of materials when it comes to making decisions for their own designs. We want to show what we have found out and what remains unclear so that designers can build on our work and save time repeating investigations.

We have selected a variety of materials including alternatives to existing materials used in theatre, new materials that could add a different aesthetic and interesting processes of making and using materials that aim to give more autonomy to the designer as to how they go about making and using sustainable materials.





Broadly speaking, the materials chosen can be split into two categories: Those which have been designed for reuse and longevity, and those that can be recycled or biodegraded without significant impact on the environment. These are the two objectives which we would like to suggest to designers to think about when considering material options. Is the material going to be versatile and robust to be used again in a future show? Or is it something that can be created and disposed of within the duration of the show that minimises the carbon footprint and wastage?

These two objectives help to ask questions of the material in terms of its sustainability. A robust material might be more expensive initially but it might pay for itself over several productions. An ephemeral material does not need to be robust and so it can be optimised in terms of its weight and strength.

Making the right decisions can be difficult but it can also enrich the use of materials in theatre. The decisions that set designers make about the material palette of the stage can embrace the interesting narratives of where materials have come from, the history and cultural meanings of materiality in theatre, the human and non-human systems that materials are formed by and the usage of materials at the end of the production run.

How to Read this Guide

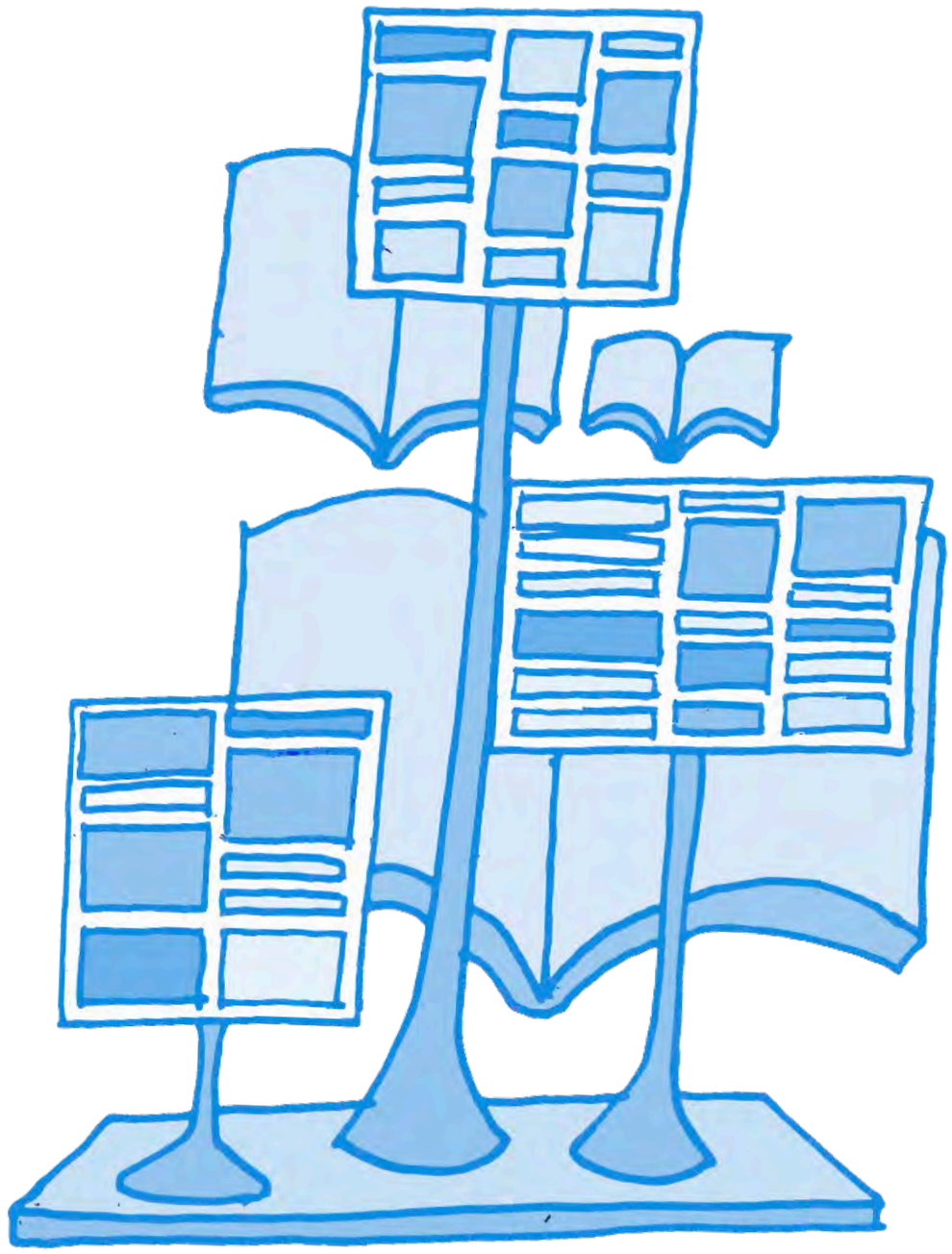
This guidebook is not presenting materials that are inherently better for the environment because sustainability is not as simple as giving a green seal of approval to some materials over others. Instead, the guide reviews a variety of materials and properties, showing both the advantages and disadvantages in relation to its use in theatre and its sustainability. Some materials will not be applicable to some productions but given the wide variety of different forms of performance in the world, there will likely be some productions or companies that find the materials suit their practice.

In each of the pages presented, there is a table called *Material Matters*. This summarises the properties, the potential uses of the material in theatre and its environmental sustainability so that a set designer can easily compare different materials based on a variety of factors rather than a simple binary between being sustainable or unsustainable.

The guide has been made as visual as possible so that the materials can speak for themselves and that the form and processes presented are as tangible as possible to the reader.

We have avoided focusing on specific manufacturers as much as possible in the review as we don't want to endorse some companies over others and we need to maintain an impartial and critical eye towards sustainability information given about products to avoid greenwashing. We also want to avoid the guide going quickly out of date based on new products becoming available and so the majority of information has been written to discuss the material, rather than the brand. However, a list of useful links and manufacturers can be found at the end of the guide if you wish to do some further investigation yourself and try out some of these materials in practice.

Note: Images have been sourced and credited assuming fair use copyright as the guide is a free resource for educational purposes created by multiple volunteer authors. We are happy to remove images if you notice anything that should be changed.



Part One: Sheet and Foam Materials

This first section of the guide presents a variety of sheet materials that can be used on stage. Materials in sheet form are used ubiquitously for structural, sculptural, architectural and cladding purposes on the stage. This section looks at the sustainability of some familiar materials whilst also presenting some alternatives to the products which dominate the industry. The majority of the sheet materials do not require a different way of working with, though some may be best suited to specific purposes or aesthetics which a theatre company may wish to achieve.

Eco-board

researched by Paul Burgess

Material Matters

Properties	Is it fire and/or water proof?	Up to a point
	Can it be cut and/or painted on?	Yes
	Is it strong, durable, soft, brittle or flexible?	It is rigid and fairly strong
Uses	What is the price bracket (at time of publication)?	£20-30 per 1220mm x 2440mm sheet
	What could it be used for in theatre design?	To replace some current sheet materials
Sustainability	Does it contain toxins?	No
	Is it recyclable?	Yes
	Does it have a high embodied energy?	No, compared to similar products
	Is it biodegradable?	Yes
	Where is it manufactured?	The Netherlands

General Information

Eco-board is made from agricultural waste (straw, reeds, wheat, rice, corn, cotton stalks, soybean, sorghum, flax, fruit tree twigs, branches, and trimmings). The manufacturer describes it as ‘an ecological alternative to chipboard, MDF, OSB, and Plywood with the benefit of a negative carbon footprint.’ It does not replace all uses of those, but it does replace several, particularly the more load-bearing uses of high-grade ply. It is available in standard 1220mm by 2400mm sheets, in 9mm and 18mm thicknesses.

Use

It is rigid and fairly strong, and could be used as general sheet material - floors, walls, furniture etc. - apart from situations that need significant load-bearing, where it can’t really replace plywood. It is lighter-weight than some alternative boards. According to the manufacturer, Eco-board is ‘resistant to water and naturally fire-retardant’, although we found no further detail on this provided in the documentation.

Cutting and Painting

It can be cut fairly precisely, but as the grain is bigger than MDF, probably not with as much precision. In terms of painting, it is quite absorbent so may need a few coats. In both respects, it is somewhat similar to chipboard. As it is made from seasonal agricultural waste, its colour may vary.

Recycling

It can be returned to the factory to be recycled into new Eco-board, although no information is given on the minimum amounts accepted. And it is reusable if the design allows it to be salvaged. Regarding other environmental concerns, the manufacturers provide detailed information on embodied energy, raw materials and carbon sequestration. Its embodied energy is considerably less than plywood. However, they don’t say how far from the factory the raw materials are sourced.

Hemp-board and Hemp-canvas

researched by Hamish Muir

Material Matters

Properties	Is it fire and/or water proof?	It is water proof, fire rating is unclear
	Can it be cut and/or painted on?	It is not easily cut or painted on
	Is it strong, durable, soft, brittle or flexible?	It is a strong material for interior and exterior usage
Uses	What is the price bracket (at time of publication)?	£55.50 per metre squared at time of researching
	What could it be used for in theatre design?	External cladding
Sustainability	Does it contain toxins?	It is unclear
	Is it recyclable?	Yes
	Does it have a high embodied energy?	Moderate - it is made in the UK but requires some manufacturing
	Is it biodegradable?	Yes
	Where is it manufactured?	UK

Hemp is a hardy crop and is fast-growing. Generally, it is ready to harvest after 90-140 days at which point it can be processed into usable construction products.

Like most crops, it is susceptible to diseases and is dependent on its growing conditions.

There are still some controls around the use of hemp because it contains compounds that are used to produce drugs but the compound is small in comparison to the plant it often gets mistaken for - marijuana.

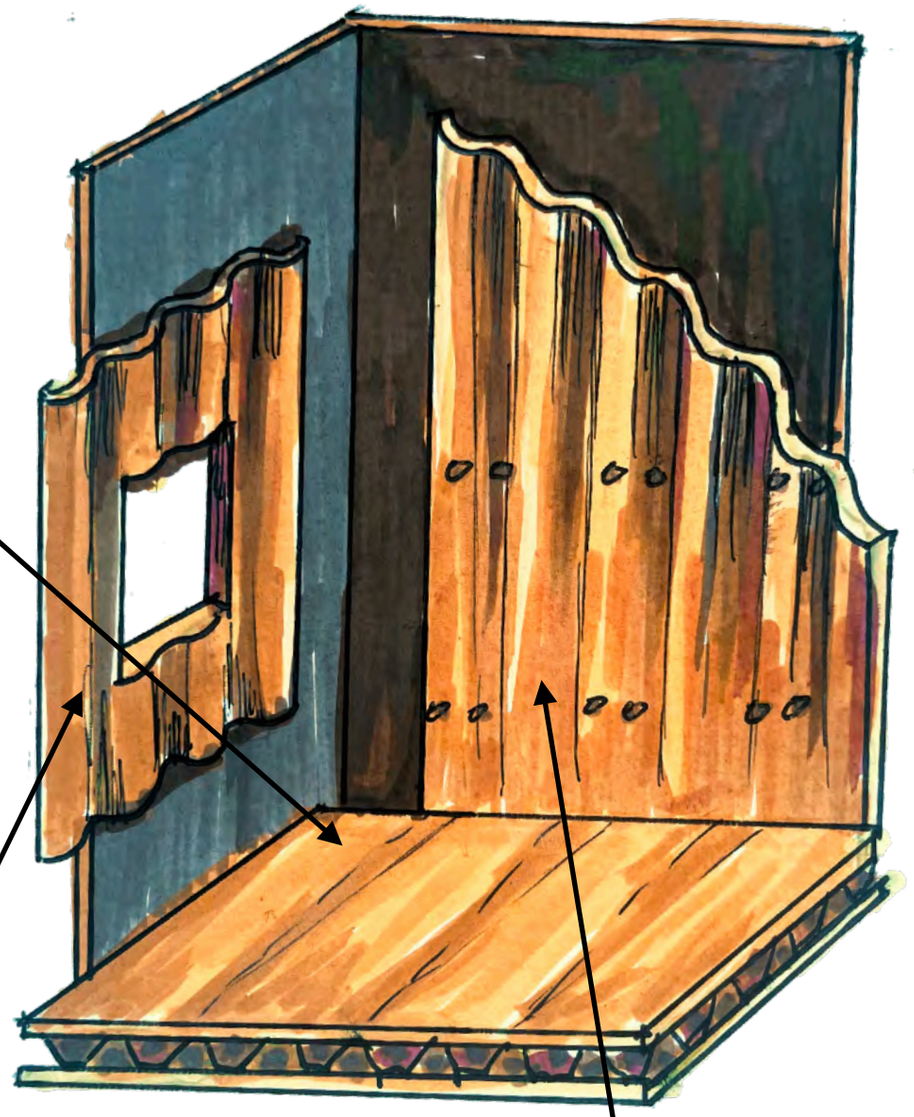
Embodied Energy and Captured Carbon

The material is processed to be given strength meaning its carbon footprint increases, however, it captures carbon, and is relatively lightweight for its strength meaning it is a more sustainable alternative to metal equivalents, which have a high embodied energy to manufacture.

Non-structural hemp

As a base material, hemp can be used in other contexts, such as a light weight fabric or canvas. This means it could be used for costume or cladding.

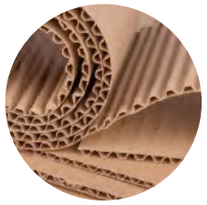
Margent Farm are a UK based producer of hempboard https://www.margentfarm.com/about-us/hemp-fibre-corrugated-panels



The corrugated hemp material is robust and can be used structurally.

Theatre Architecture

The material is expensive for theatre design but it offers a possibility to be used as a statement piece of design and for stage design to be at the cutting edge of sustainable architecture. The barrier between a temporary set design and a more permanent performance space can blend through the use of this material. The material can offer an honest and stark aesthetic to a scenic backdrop. As it is strong and versatile, it can be used multiple times, meaning the initial cost can be spread across several production budgets. This is a sketch of how hemp board could be used to build a versatile small-scale stage space.

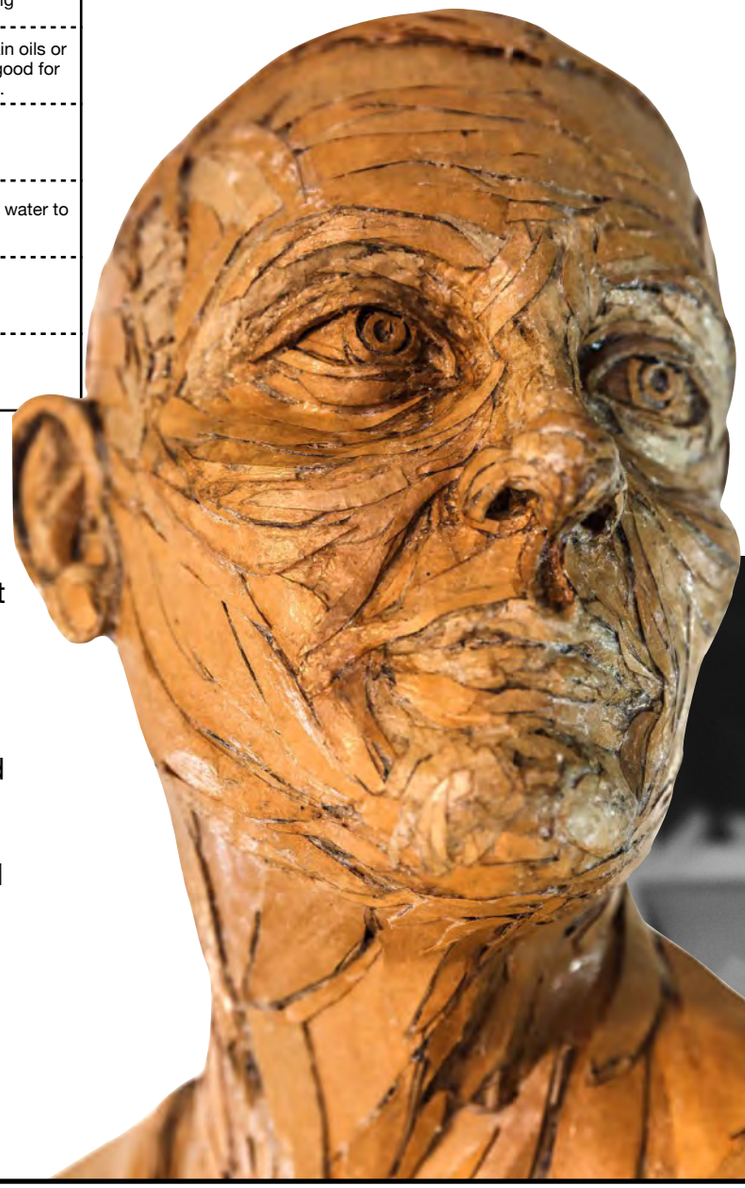


Cardboard

researched by Hamish Muir

Material Matters

Properties	Is it fire and/or water proof?	No
	Can it be cut and/or painted on?	Yes
	Is it strong, durable, soft, brittle or flexible?	It is flexible and strong but not for load bearing, corrugated versions are stronger
Uses	What is the price bracket (at time of publication)?	very economical and free if reused
	What could it be used for in theatre design?	non-structural sculptural pieces and some cladding
Sustainability	Does it contain toxins?	Some cardboards contain oils or laminates that are not good for the environment.
	Is it recyclable?	Yes
	Does it have a high embodied energy?	Medium - it uses a lot of water to manufacture.
	Is it biodegradable?	Yes
	Where is it manufactured?	UK



Sculpting Cardboard

Cardboard is already being used in the design of film and theatre in different capacities. Cardboard has its own properties and aesthetic. It can be used in ambitious new ways, such as in the sculptures depicted. It is a lightweight material to transport meaning it would be great for low-carbon touring, as long as it is carefully secured, avoiding damage.

Sculptures produced by artist James Lake https://jameslakesculpture.co.uk/

Set images from: https://news.sky.com/story/cardboard-could-be-a-game-changer-as-film-and-tv-industry-looks-to-clean-up-its-act-12527779 and https://www.vectarproject.co.uk/
Other images by Remon Geo and Stefan Cosma

Up-cycling Packaging

Cardboard is a major contributor to landfill and is a ubiquitous waste product as a material used for transport packaging. It means that every household and every business has a significant amount of waste cardboard.

If theatre can up-cycle cardboard, it would save a significant amount of waste and be able to use a free and versatile material for sculptures, light-weight cladding, back drops, props and puppetry. Cardboard may need some additional support and, in some cases, it may need to be combined with adhesives, which would make it harder to recycle, however, it is fairly durable in indoor usages without the addition of fire or water proofing or stiffeners.

Cardboard is a simple material but the most sustainable solution is often a simple solution.

Engineered Woods: Plywood

researched by Kira Curtis

Material Matters

Properties	Is it fire and/or water proof?	It needs to be treated for fire and water proofing
	Can it be cut and/or painted on?	Yes
	Is it strong, durable, soft, brittle or flexible?	It is a hardwood product making it lighter and less dense than natural wood
Uses	What is the price bracket (at time of publication)?	Standard 8'x4' plywood sheet starts at about £20 for a 5mm thickness.
	What could it be used for in theatre design?	Flats, decking stage block - anywhere sheet material may be needed.
Sustainability	Does it contain toxins?	Yes, but not a harmful amount.
	Is it recyclable?	Yes, but better to reuse.
	Does it have a high embodied energy?	While the manufacturing process does require energy, it is more energy-efficient than other building materials.
	Is it biodegradable?	No, plywood is generally considered non-biodegradable; the adhesives used in plywood production prevent it from fully biodegrading.
	Where is it manufactured?	China is the largest exporter (40% of the UK's supply). Ensuring that the wood supply is traceable is key. Look for the FSC logos.

Advantages

- The waste from making plywood can be recycled for other purposes or even used as biofuel.
- Whilst the manufacturing process requires energy, this process remains more energy-efficient than many other building materials.
- It is a strong and durable material. It is made to last and can be reused in other projects.
- It is more energy efficient than most other building materials.
- Different versions, sizes and thicknesses are available for flexible usage.
- It is lighter and less dense than solid wood but can look the same with added grain.
- It can be cut easily and customised with paints and oils. Note: you will need to ensure that the surface is well prepared to take on paint.
- It can be recycled but not in a household recycling bin. You can hire a skip or take it to a recycling centre where it can be used for things such as animal bedding. Also note, plywood is a class B wood that has been treated, so it has to be recycled separately from class A untreated timber. There are many local organisations that will take donations, eg. Leeds Wood Recycling.

Disadvantages

- Formaldehyde glue is used to seal the veneers together. Any emissions from the plywood are at their highest immediately after the manufacturing process but do eventually subside after a few weeks. A phenolic coating is often applied to each sheet to help reduce emission levels further. When this building material reaches the supplier, the boards typically emit very low levels of formaldehyde which is considered far too low to have any significant impact by US and European regulators.
- The majority of UK plywood suppliers still get their sheets shipped in from overseas and the raw materials used by manufacturers come from outside of the UK.
- It requires additional coatings for waterproofing and fire-retardancy.

How Plywood is made

Plywood is made using dried wood veneers which are layered together and sealed with heat and pressure.

Top Tip

Use a Birch plywood because it is more readily available in the northern hemisphere, and uses almost every part of the tree.

Engineered Woods: OSB (Oriented Strand Board)

researched by Kira Curtis

Material Matters

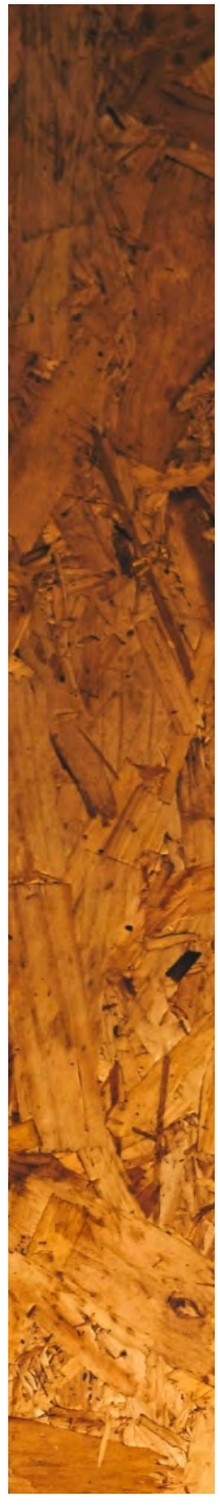
Properties	Is it fire and/or water proof?	Treatments can be added to reduce its flammability - it's not fully waterproof but more resistant than plywood
	Can it be cut and/or painted on?	Painting is a little trickier due to the texture. Recommend sanding down first, then priming
	Is it strong, durable, soft, brittle or flexible?	It is strong and durable
Uses	What is the price bracket (at time of publication)?	£15-20 for 8 x 4 board
	What could it be used for in theatre design?	Anything similar to plywood and MDF. When left untouched, it can give a more natural wood appearance
Sustainability	Does it contain toxins?	yes - same as plywood & MDF
	Is it recyclable?	same as plywood & MDF
	Does it have a high embodied energy?	same as plywood & MDF, however it makes use of wood shavings
	Is it biodegradable?	same as plywood & MDF
	Where is it manufactured?	same as plywood & MDF

Advantages

- New trees are not necessarily needed to create the wood shavings and uses recycled wood as a constituent material
- It is more moisture resistant, lighter, and generally cheaper than plywood

Disadvantages

- Some formaldehyde glue is still used in the production process although uses less than plywood
- It has no grain and so looks less like real wood
- It is heavier than plywood and warps more easily
- It tends to loosen at the strands and can degrade over time
- It is more difficult to work with in a theatrical setting because of its rough texture



Top Tip

Always have a look at reusing sheet materials that are available at wood recycling centres before buying new.

How OSB is made

OSB is made by layering together large wooden shavings. It is then sealed with wax and resin glue before being pressed under heat and pressure.

Engineered Woods: MDF

researched by Kira Curtis

Material Matters

Properties	Is it fire and/or water proof?	FR rated MDF can be purchased at a cost - it is not waterproof but moisture resistant MDF is available
	Can it be cut and/or painted on?	Very easy to cut. Painting usually requires priming first otherwise paint will seep into material
	Is it strong, durable, soft, brittle or flexible?	Strong and durable
Uses	What is the price bracket (at time of publication)?	8 x 4 sheets typically. Different thicknesses available. 6-12mm thickness is between £20-25 a board
	What could it be used for in theatre design?	Commonly used for panelling, flats, and fixed structures. Good for stage cladding
Sustainability	Does it contain toxins?	Yes but minimal - only in manufacturing. Not harmful for user
	Is it recyclable?	MDF can be repainted and reused but not easily recyclable - eg. same as plywood
	Does it have a high embodied energy?	Medium, energy used during manufacturing and shipping from suppliers
	Is it biodegradable?	Not easily due to glues used in manufacture
	Where is it manufactured?	UK suppliers are available but majority is imported. Shipping from China is becoming more common

Advantages

- It is a cheaper sheet material option
- Its smooth surface is ideal for painting
- It has a dense and durable structure
- Moisture resistant and fire retardant versions are more readily available

Disadvantages

- Formaldehyde glue is used in the production process meaning it has the same issues as plywood
- It has no grain and so does not look like wood if that was a desired aesthetic
- It is heavier than plywood and warps more easily

How MDF is made

MDF has a similar production process to plywood however the timber used comes from wood fibres. These wood fibres are made from broken down hardwood and softwood residuals meaning it is typically using waste or recycled wood. Once mixed with wax and formaldehyde resin glue, they are then pressed into flat sheets using high heat and pressure.

Top Tip

Find ways to use the sawdust created when cutting. Mix with a glue fill in holes or create and mend props.

MDF, OSB and Plywood comparison

Most commonly, MDF is used in theatre due to its cheaper cost and its ability to be painted and customised more easily. However, if a natural wood look is desired, plywood may be the better option, as it can help to reduce waste and is more durable for secondary use. In general, OSB is the best sustainability option because it contains the highest proportion of recycled content but more time may be required to transform OSB into theatre scenography because of its rough texture.

Søuld Acoustic Boards (Eelgrass Panel)

researched by Simon Daw

Material Matters

Properties	Is it fire and/or water proof?	Both a FR (Class I or A rating) and non-FR version is available. It is not waterproof.
	Can it be cut and/or painted on?	They can be dyed and cut.
	Is it strong, durable, soft, brittle or flexible?	Rigid panels which are lightweight with some compression and flex when under pressure.
Uses	What is the price bracket (at time of publication)?	High at time of researching - £90 for 600 x 1100 mm board
	What could it be used for in theatre design?	Scenic surfaces and flattage
Sustainability	Does it contain toxins?	No
	Is it recyclable?	Yes
	Does it have a high embodied energy?	Low
	Is it biodegradable?	No
	Where is it manufactured?	Denmark

Overview of the Material

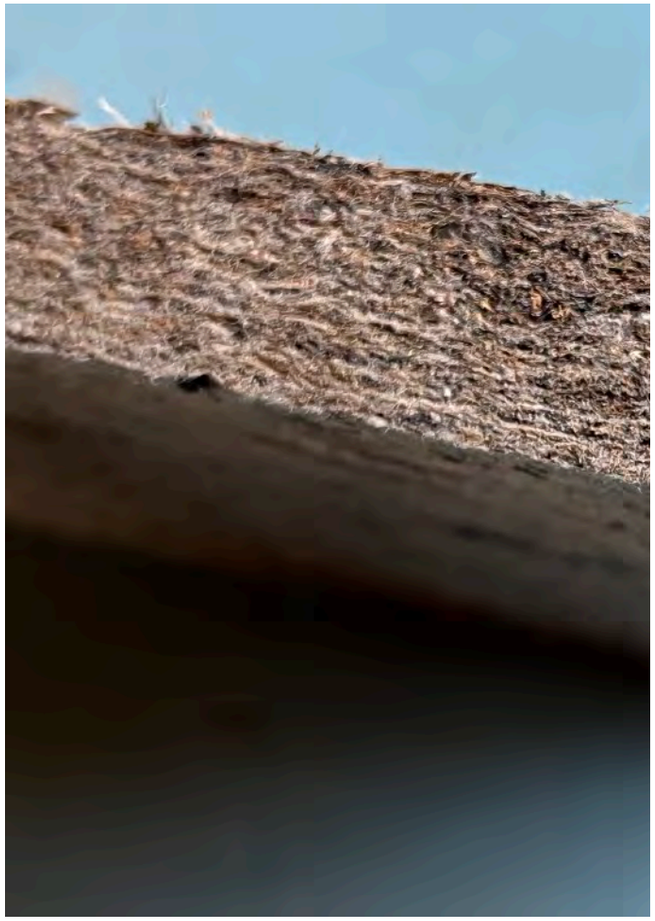
Eelgrass is a natural resource which reproduces itself annually in the sea, washes ashore without any human intervention, and is dried on nearby fields by the sun and wind. When manufactured, the eelgrass is mixed with a non toxic binder and compressed to form boards. The binder means that eelgrass board is not biodegradable.

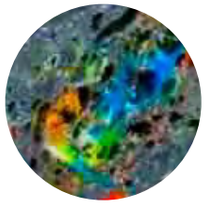
It has a natural composite texture. This texture lights well with tones of muted greens and warm browns. It is lightweight, which is good for touring. It has a pleasant natural smell of dried grass and is engineered to absorb sound across a wide range of frequencies. They can be dyed using natural stains, linseed oil, pigments made from bricks, or other natural pigments. The material is made from natural eelgrass fibres which are highly absorbent, making them an ideal canvas for dyeing. Søuld Acoustic Boards are easy to cut using a table saw or circular saw. CNC-cutting is also possible with a drag-knife or an oscillating knife.

When eelgrass grows, it stores large amounts of carbon dioxide. If it is left to decompose at shore, the CO_2 will be released back into the atmosphere. By transforming it into a product, the CO_2 is stored in Søuld. The emissions from Søuld's products are extremely low (Cradle to Cradle certified - Platinum level in Material Health).

When they reach their end-of-life they can be returned to the factory, re-shredded and either blended into standard products or used to create a base for second-generation growth. Søuld products that are not returned to the factory can be sent for combustion at heating plants.

The Acoustic Boards FR are 18 mm thick and the Acoustic Mats and Acoustic Mats FR are 35 and 40 mm thick. The available sizes are:
1100 x 600 mm
1100 x 1500 mm
1100 x 3000 mm





Recycled Plastic Board

researched by Hamish Muir

Material Matters

Properties	Is it fire and/or water proof?	It is water proof, and has a moderate level of fire resistance (Euroclass B)
	Can it be cut and/or painted on?	It can be cut and can be painted
	Is it strong, durable, soft, brittle or flexible?	It is a strong material for interior and exterior usage
Uses	What is the price bracket (at time of publication)?	price varies - £10 or more per unit
	What could it be used for in theatre design?	Structural usages and cladding
Sustainability	Does it contain toxins?	The plastic content varies - it may contain some content that is harmful
	Is it recyclable?	No
	Does it have a high embodied energy?	Moderate - it is made in the UK but requires some manufacturing
	Is it biodegradable?	No
	Where is it manufactured?	UK

Properties and Form

Recycled plastic board comes in different forms, including planks, sheet material or posts and is an alternative to wooden structures.

It is a robust material that doesn't rot meaning it does not need to be replaced often and can handle outdoor conditions. Its ability to be reused without loss in strength means it would be an option for modular set designs and outdoor theatre.

It is made from waste plastic which is diverted from going to landfill. However, the moulding of the plastic into board form requires energy and the types of plastics it contains are hard to trace, meaning the chemical content can be unclear. It is difficult to recycle again after the initial remanufacturing has taken place.

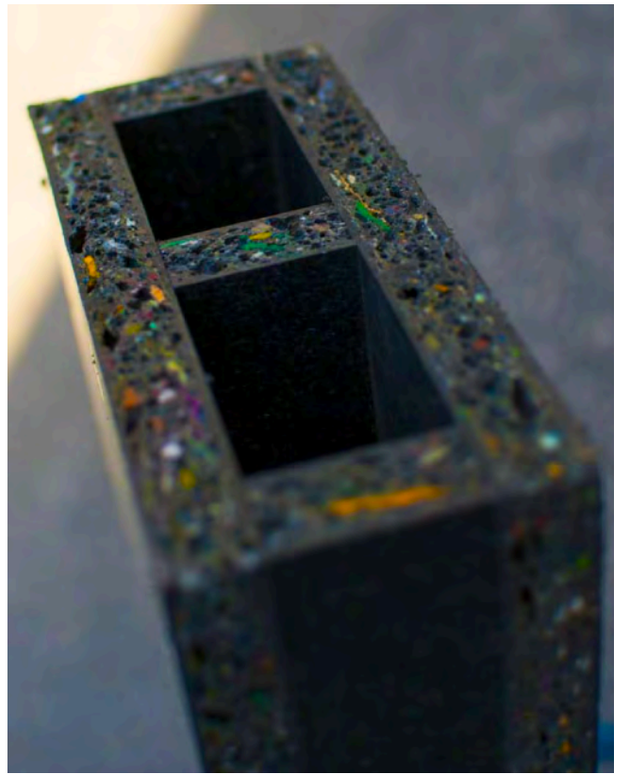
Sources: https://slpw.co.uk/product/ekoply/
and https://www.kedel.co.uk/mixed-plastic-lumber/recycled-mixed-plastic-boards-100-x-35-hanit-ultra.html

Using Recycled Plastics

Designers should think carefully about using recycled plastics in any form as they can derive from plastics which contain harmful chemicals. There are a lot of plastics already in the world and diverting them from landfill and giving them a second life will certainly help, but we need to know what to look for.

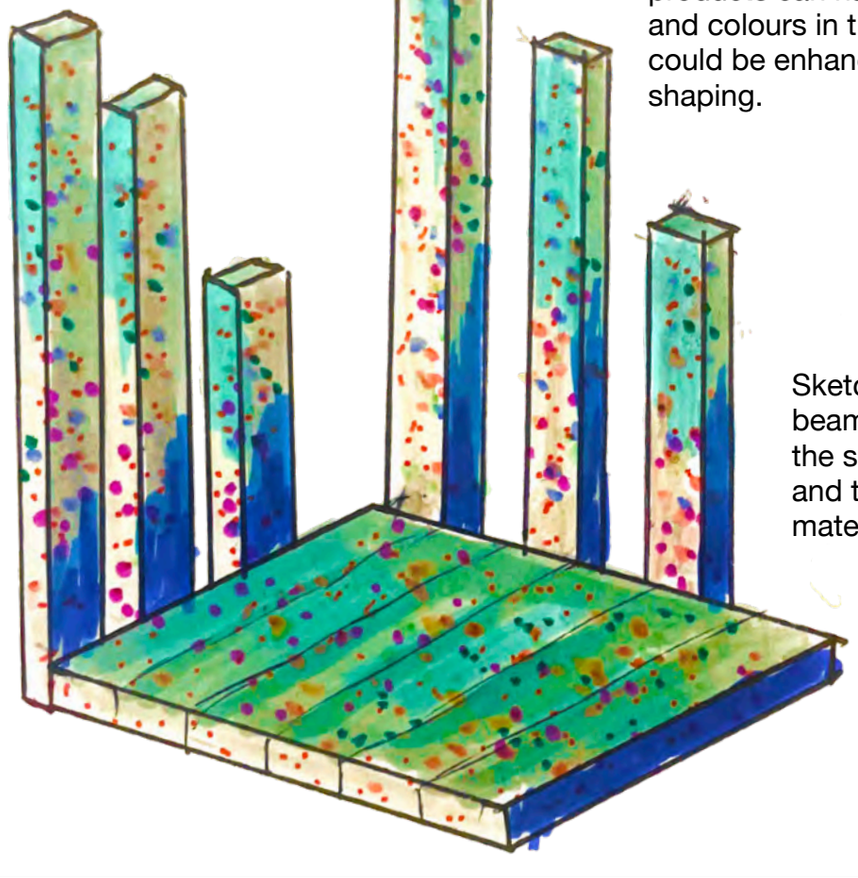
What to look for?

High density polyethylene (HDPE), low density polyethylene (LDPE) and polypropylene (PP) are considered the safest plastics but vary in terms of recyclability. If the plastic contains toxins, it will likely come from particular flame retardants, such as brominated chlorinated and organophosphorus retardants. See Section 3 for more information on working with HDPE plastics.



Texture

Aesthetically, recycled plastic board products can have interesting textures and colours in their cross-section which could be enhanced with lighting or shaping.



Sketch of plastic beam stage showing the speckled colours and texture of the material.

Cellulose Wallboard

researched by Deborah Piffer

👍 Made from recycled materials

👍 Good soundproofing

👎 Limited availability

👎 Can be exposed to cellulose dust

Material Matters

Properties	Is it fire and/or water proof?	It is fire, mould and moisture resistant but not waterproof
	Can it be cut and/or painted on?	It can be cut and painted on but may need to be coated with primer
	Is it strong, durable, soft, brittle or flexible?	It is strong, durable and soft. It is not brittle and has great resistance to bending
Uses	What is the price bracket (at time of publication)?	It has a medium price bracket but varies ($20-$40 per 4x8 sheet)
	What could it be used for in theatre design?	large scale - flooring, masking flats, scenery; small scale - model making
Sustainability	Does it contain toxins?	non-toxic (Homasote is formaldehyde free but contains a small amount of paraffin)
	Is it recyclable?	Yes
	Does it have a high embodied energy?	No
	Is it biodegradable?	Yes
	Where is it manufactured?	USA (Homasote is from New Jersey) and in Europe

Image reference: homasote | Scott W. Bartholomew Architecture
Text references: 2023 - first nine months | homasote, 3D wall panels italia - cellulosic waster board, materials-13-01303-v2 - cellulose fibreboard.pdf

The Wallboard

Cellulose wallboard, or fibreboard, was introduced in building construction in the 20th Century. The wood waste and plant fibre components enhance the mechanical properties of the panel, providing a stronger and more durable material at a lower price. Cellulose fibreboard is an alternative to traditional materials, such as plywood, MDF or drywall. Fibreboard manufacturers (such as Homasote) use a high recycled content in their products (Homasote use 98% recycled cellulose fibre from post-consumer paper waste). Wax-emulsion binders are used to make the board moisture-resistant. The high density, fibrous and porous structure absorbs sounds waves and dissipates their energy reducing echo and reverberation within a space.

Sustainability

Some manufacturers like Homasote use closed loop water processing systems and recycle local paper waste. Compared to virgin wood pulp manufacturing, the fibreboard decreases air pollution by half and significantly reduces water and energy consumption. Some cellulose fibreboard manufacturers may use petroleum-based adhesives and binders containing formaldehyde, resulting in a cheaper but toxic and non-biodegradable product. Eco-friendly alternatives are produced in Europe and are made from recycled wood waste and plant fibres.

Uses in Theatre Design

Cellulose wallboard can be applied in theatre design as a structural element to create scenery, rehearsal spaces with good soundproofing, stage flooring/deck or masking flats. Zooming into this material, considering its features and texture, damaged boards can be repurposed for model-making, white-card design, or model-boxes, to substitute foam board. It is stiff but easy to cut through and has a neutral grey colour that can be easily painted. Manipulation of this fibreboard during manufacturing and post-production can be a hazard due to wood dust. As an example, the image on the left shows an architectural model made by Scott W. Bartholomew, using chipboard, foam core and Homasote wallboard

The images above show the three main stages of cellulose fibreboard making process. It starts with paper waste being shredded cellulose fibre, which is then mixed with water binder and fire retardant. Finally the mixture is compressed to form a compact solid board.

Corn-based Foam

researched by Paul Burgess

Material Matters

Properties	Is it fire and/or water proof?	No
	Can it be cut and/or painted on?	It can be cut, but it is hard to be carved precisely. It will take paint, but the paint will partially dissolve it.
	Is it strong, durable, soft, brittle or flexible?	It is fairly tough (hard to tear) but very soft
Uses	What is the price bracket (at time of publication)?	Not known
	What could it be used for in theatre design?	Bulking, or packaging fragile items when touring.
Sustainability	Does it contain toxins?	No
	Is it recyclable?	No
	Does it have a high embodied energy?	Medium - depending on shipping
	Is it biodegradable?	Yes
	Where is it manufactured?	Virginia, USA

What is it made from?

The foam is made from corn starch, derived from corn crops, which are a relatively fast-growing crop source. Starch-based foams are generally more eco-friendly than fossil-based ones. However, there is not enough detail available from the manufacturer to make a direct comparison. Though it is non-toxic and biodegradable, it is best not to be disposed of in large quantities as it can affect salinity of soil.

As well as being available from some manufacturers or found in existing packaging, some corn-based foam can be manufactured at home using household products. This means it can be made to the quantities required, it can be moulded to the desired shape, and there is no additional embodied energy required to ship the product before usage.

A detailed recipe and further discussion of corn-based foam can be found at: https://www.greencompostables.com/blog/cornstarch-foam-packaging

What can it be used for?

According to the manufacturer, it's fully biodegradable, safe to handle, quickly dissolvable in water, and burns without giving off problematic chemicals.

Though it can be easily and cleanly disposed of, its water solubility makes it impractical to use in some situations, such as uses that require painting or fire-proofing.

It could be used to bulk out costumes or package fragile items for touring.

Alternatively, it may be an interesting substance to experiment with if a dissolving or melting effect was desired as part of a set design.

Corn-based Board

researched by Hamish Muir

Material Matters

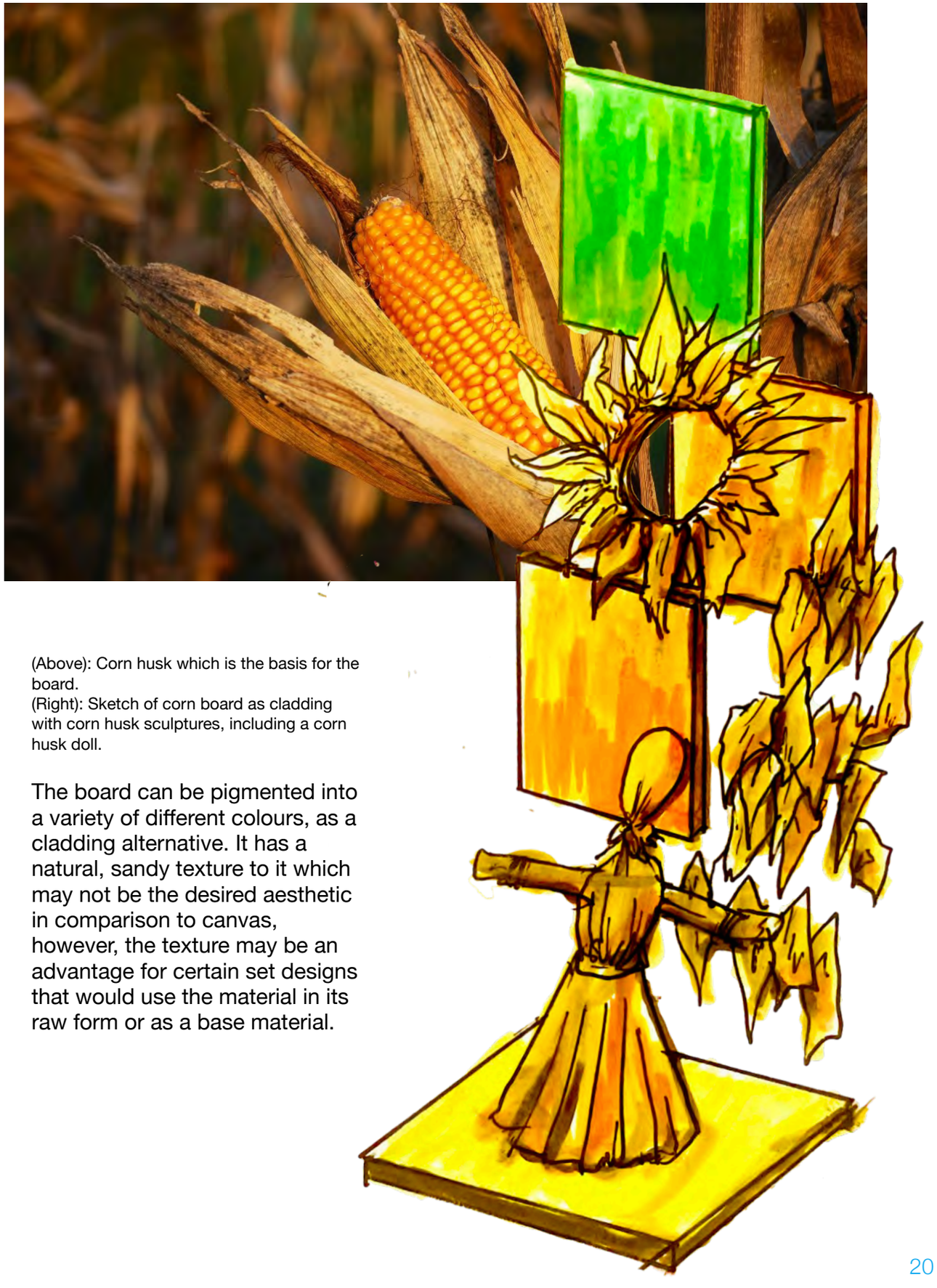
Properties	Is it fire and/or water proof?	No
	Can it be cut and/or painted on?	It can be cut but not easily painted on
	Is it strong, durable, soft, brittle or flexible?	Varies depending on manufacturer - some boards are more rigid than others
Uses	What is the price bracket (at time of publication)?	High for architectural purposes
	What could it be used for in theatre design?	Wall and furniture cladding, panelling, insulation
Sustainability	Does it contain toxins?	No
	Is it recyclable?	Yes
	Does it have a high embodied energy?	Low - some manufacturers are carbon neutral
	Is it biodegradable?	Yes
	Where is it manufactured?	The Netherlands, Belgium, USA, Thailand

When we eat corn on the cob, we throw away the husks which is a large amount of waste compared to how much is consumed. A large amount of energy and water is required to farm corn and so it is a great waste of that energy to throw a lot of the material away.

Corn board derives from corn husks. Several manufacturers of building materials are working with this waste by-product to produce a range of materials, including hard board as an alternative to OSB or as a softer board for insulation or furniture cladding.

The wall insulation has the advantage of not having any added resins and it doesn't require an energy intensive manufacturing process to make. By using husks and other biomass materials in the board, the material retains the carbon dioxide it has captured until the point where it biodegrades.

Sources: https://www.designboom.com/design/cornwall-discarded-corn-cobs-upcycle-reusable-walls-carbon-dioxide-stonecycling-circular-matters-11-24-2023/ https://www.futurematerialsbank.com/material/corn-husks-corn-cobs/ and photo by Christophe Maertens on Unsplash



(Above): Corn husk which is the basis for the board.
(Right): Sketch of corn board as cladding with corn husk sculptures, including a corn husk doll.

The board can be pigmented into a variety of different colours, as a cladding alternative. It has a natural, sandy texture to it which may not be the desired aesthetic in comparison to canvas, however, the texture may be an advantage for certain set designs that would use the material in its raw form or as a base material.

Wood-wool Board

researched by Hamish Muir

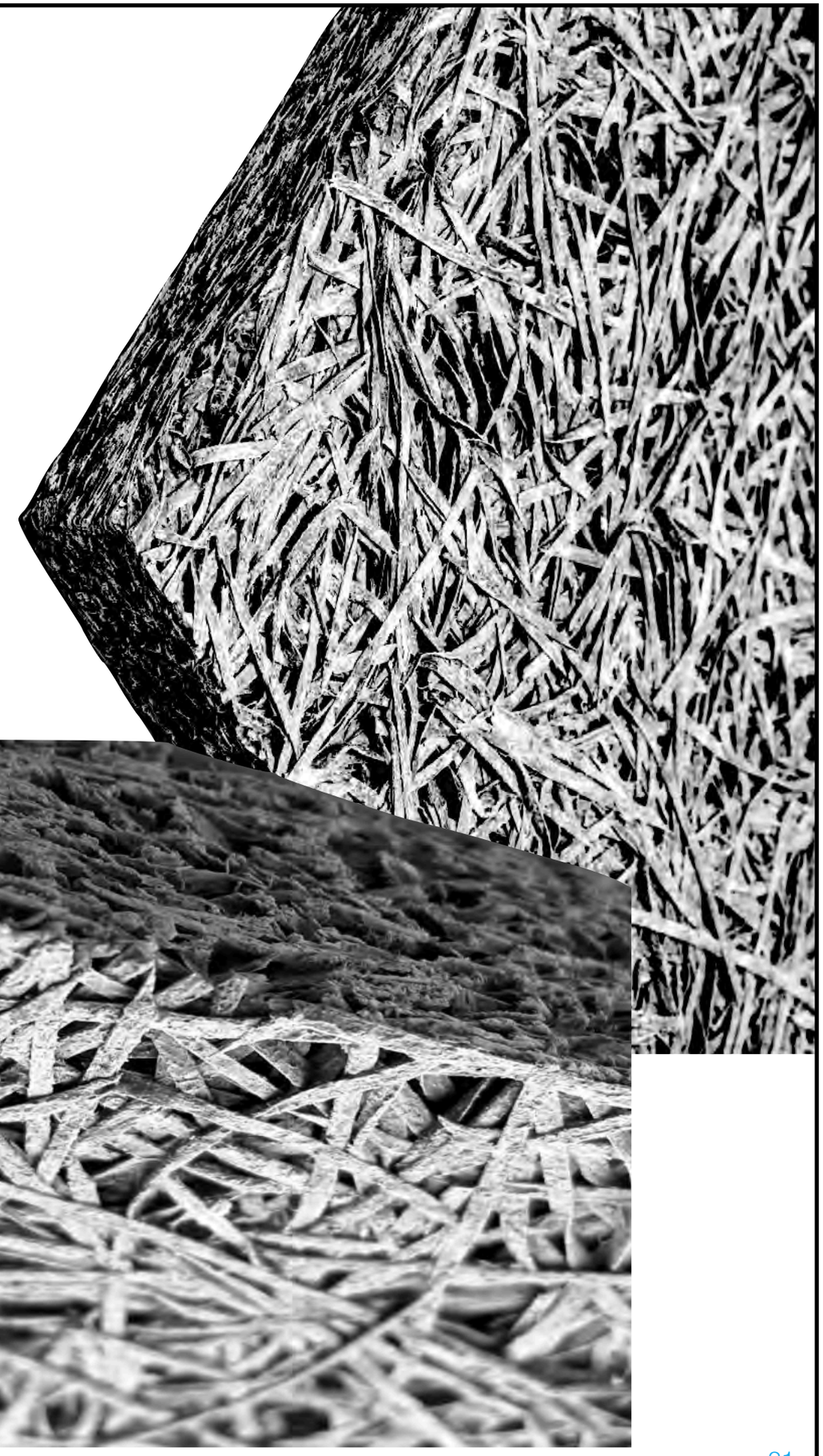
Material Matters

Properties	Is it fire and/or water proof?	It is breathable but is not waterproof and it has a good fire rating of B-s1, d0 meaning it has a limited fire risk
	Can it be cut and/or painted on?	It can be cut though not precisely and it can be painted or plastered on
	Is it strong, durable, soft, brittle or flexible?	It is strong but it is best for internal usage
Uses	What is the price bracket (at time of publication)?	£7.80 per m^3 (excluding VAT)
	What could it be used for in theatre design?	Alternative to insulation and non-structural, acoustic cladding
Sustainability	Does it contain toxins?	It is inert but contains some cement so can cause water leachate
	Is it recyclable?	No
	Does it have a high embodied energy?	Moderate - some manufacturing required
	Is it biodegradable?	Partially - the cement content means it cannot biodegrade fully
	Where is it manufactured?	Various - UK, Scandanavia

Wood-wool board is an interesting material, mainly because of its striking appearance and distinctive aesthetic in its natural appearance.

It is made by combing wood waste strands (often a waste by-product) with a binding agent.

For the design of scenography and theatre architecture, its good for acoustic insulation and so would offer sound benefits without using plastic foam equivalents.



It is important to say that wood-wool board is not the most sustainable material in this guidebook because some manufacturers use cement to bind the wood strands together and cement has a high carbon footprint. However, wood-wool has been included in this guide to highlight this point and to suggest that if a cemented material is fundamental to a design concept, such as to increase fireproofing, this probably is one of the better options because it does not use cement in excess.

It may be possible to make wood wool with a different binding agent, such as a natural glue, that does not involve cement. This would improve its recyclability and biodegradability.

Image source: https://www.ecologicalbuildingsystems.com/product/cewood-wood-wool-board?srsltid=AfmBOortaVUc-oXClFfRGwj3xDVyQP6t09CtwJCozk9jPIRbmhKiSL74

Part Two: Other Building Materials

In this section, construction materials that are not in sheet form will be presented. This includes block-work, stage flooring and structural components. Unlike the first section, many of these materials, such as straw or bamboo, can be used in their raw state after they are farmed. This means they have a lower embodied energy than materials such as sheet plywood or steel that require a significant amount of energy to be manufactured and formed into usable, sheet products on stage.

Glulam

researched by Deborah Piffer

Material Matters

Properties	Is it fire and/or water proof?	It has enhanced fire resistance but is not waterproof
	Can it be cut and/or painted on?	Yes, it is easy to cut, stain and paint
	Is it strong, durable, soft, brittle or flexible?	It is strong, resisting torsional stress and warping
Uses	What is the price bracket (at time of publication)?	High - Price varies depending on the type of wood
	What could it be used for in theatre design?	Architectural elements and structural scenery
Sustainability	Does it contain toxins?	Adhesive synthetic glue is less than 1% by weight of the product
	Is it recyclable?	Yes
	Does it have a high embodied energy?	Medium - it is heavy to transport
	Is it biodegradable?	Yes
	Where is it manufactured?	Germany, Austria, Switzerland and there are CE certified companies in the UK

Above: Temporary theatre space by David Rockwell. See https://www.ingenio-web.it/articoli/il-legno-per-un-teatro-temporaneo/

👍 Strong structural abilities and flexible to create shapes

👍 It can be recycled or repurposed for non-structural uses

👎 It has a low moisture resistance

👎 The beams are sometimes difficult to repair

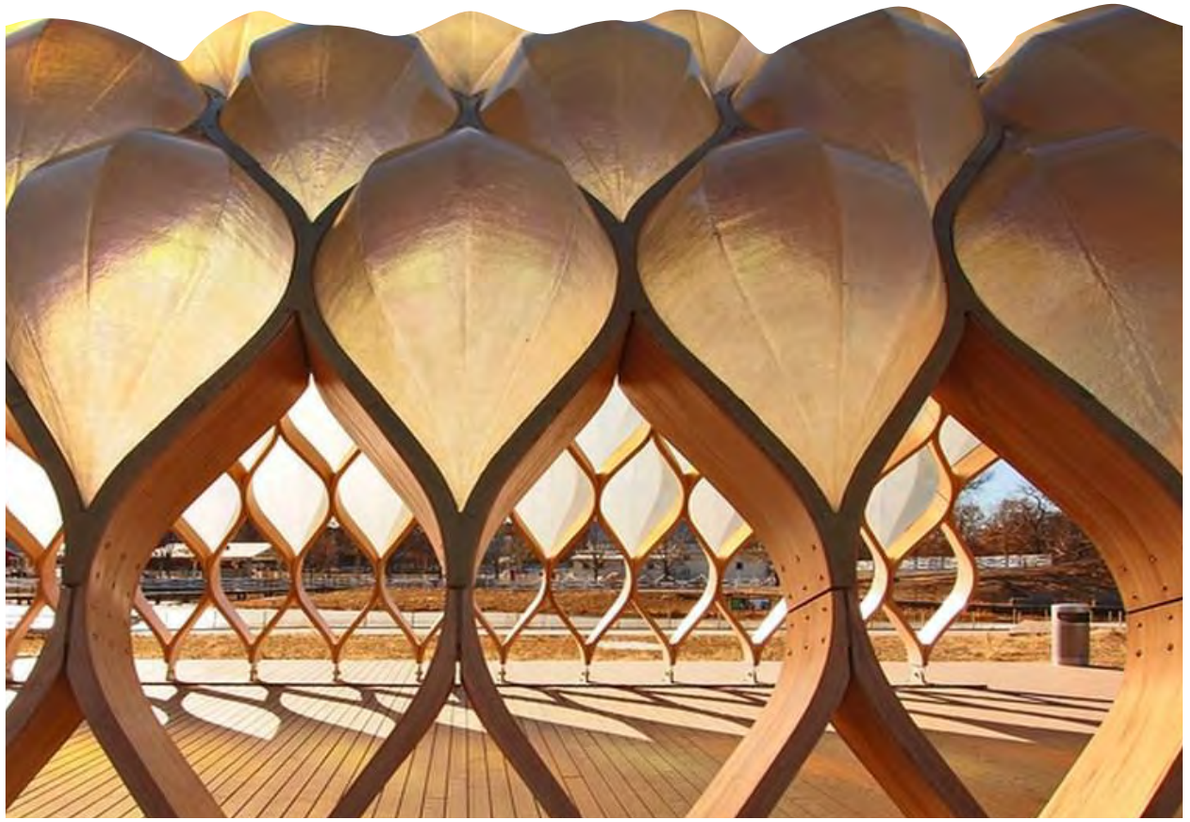


Image Source: Nature Boardwalk at Lincoln Park Zoo - photo by Jeanne Gang https://www.ds-design.in/post/future-materials-the-architecture-of-biocomposites

GLU-LAM (Glue laminated timber) is a bent structural material, patented by O. Hetzer in the early 20th Century in Switzerland. It is created by layering timber with a durable adhesive, applying pressure and applying heat to create long length laminations. According to Glulam LTD, the beams manufacturing process uses one tenth of the energy to manufacture an equivalent steel beam. It can produce wood dust so an FFP2 dust mask is advised when using.

Manipulation of Glulam during post-production can be a hazard due to the adhesives it contains such as:

- melanine-resin (used indoors, light brown colour, contains *formaldehyde)
- phenal-resorcinol-resin (used outdoors, dark brown colour, contains formaldehyde)
- polyurethane (light transparent colour, non-toxic alternative)

*Formaldehyde is a colourless, flammable gas. Fomaldehyde-based resins are used as a bonding agent in the manufacturing of wood-based panels. This substance becomes toxic when it crosses the emission limit of 0.124 mg/m^3.

It is a good solution for scenery staged at large venues and for building temporary open-air theatres. Damaged beams can be used to make props, furniture, carved frames etc, which would help to develop a circular economy. The sustainability of Glulam relies on sourcing wood from sustainable forests which respect a logging rhythm that preserves the environment and biodiversity. Glulam beams are most commonly made from Spruce, Redwood or Siberian Larch wood.

This data was sourced from ‘Commission Regulation (EU) 2023/1464 of 14th July 2023’. See also: EWP training https://www.youtube.com/watch?v=kdmHaCV_1DU & https://woodcampus.co.uk/

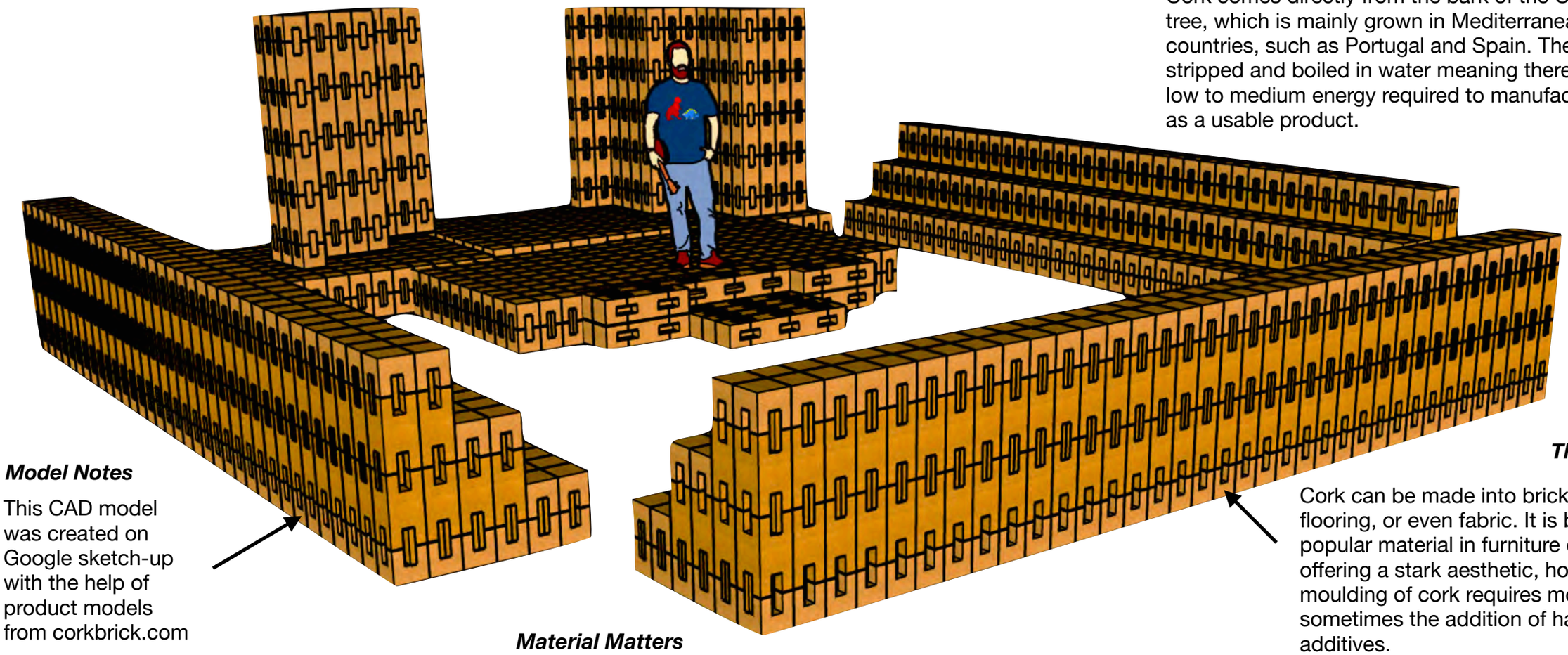
Cork

researched by Hamish Muir

Cork can be made into a variety of shapes, including modular, glue-less bricks that can be built into numerous configurations. In its un-clad state, it offers a unique aesthetic and texture but can compromise, aesthetically, in the rain. Cork is light-weight, fairly durable and can be used for small to mid scale theatre stage infrastructure.

How Cork is Made

Cork comes directly from the bark of the Cork Oak tree, which is mainly grown in Mediterranean countries, such as Portugal and Spain. The bark is stripped and boiled in water meaning there is some low to medium energy required to manufacture cork as a usable product.



Model Notes

This CAD model was created on Google sketch-up with the help of product models from corkbrick.com

Theatre Use

Cork can be made into bricks, boards, flooring, or even fabric. It is becoming a popular material in furniture design, offering a stark aesthetic, however, specific moulding of cork requires more energy and sometimes the addition of harmful additives.

Material Matters

The structure may be compromised if individual bricks are cut out of their original, modular shapes. This is so they can remain like Lego bricks and be reused multiple times.

Properties	Is it fire and/or water proof?	It is flammable at a low-medium rating. It resists water to an extent.
	Can it be cut and/or painted on?	It can be painted on or covered in tissue.
	Is it strong, durable, soft, brittle or flexible?	It is strong but better for interiors than exteriors. It can be walked on.
Uses	What is the price bracket	Varies
	What could it be used for in theatre design?	stage or set building
Sustainability	Does it contain toxins?	It is certified against chemicals e.g. formaldehyde. It may contain glue.
	Is it recyclable?	Yes
	Does it have a high embodied energy?	Medium - it is industrially manufactured and it is made outside the UK
	Is it biodegradable?	Yes
	Where is it manufactured?	Various

Bamboo

researched by Hamish Muir

Material Matters

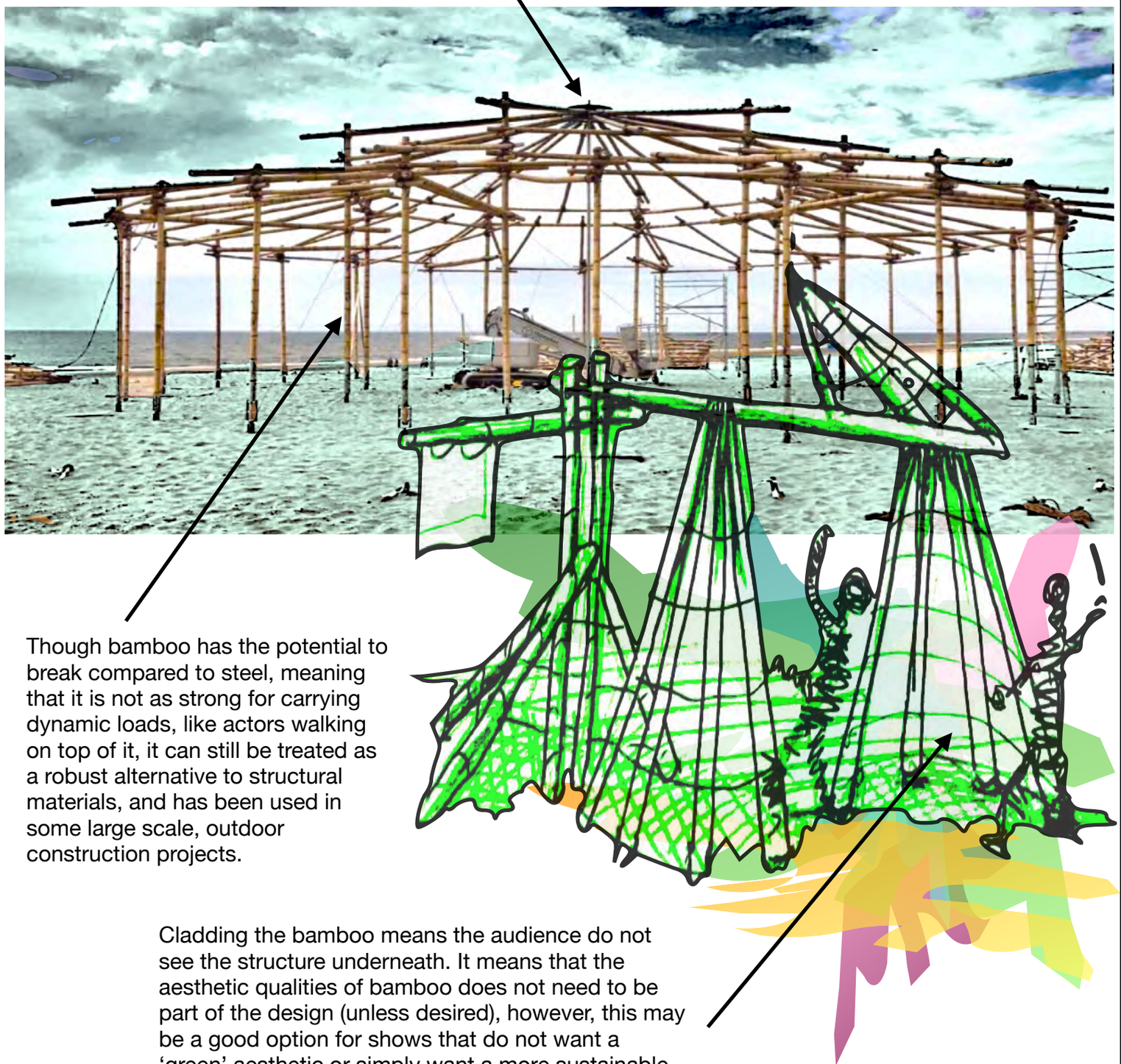
Properties	Is it fire and/or water proof?	Waterproof, not fireproof
	Can it be cut and/or painted on?	It can be cut easily
	Is it strong, durable, soft, brittle or flexible?	It is strong, and can be flexible depending on circumference
Uses	What is the price bracket (at time of publication)?	Varies but can be home-grown
	What could it be used for in theatre design?	Small to large structures
Sustainability	Does it contain toxins?	No
	Is it recyclable?	No but it can be composted
	Does it have a high embodied energy?	High if shipped from Asia
	Is it biodegradable?	Yes
	Where is it manufactured?	Asia for large quantities

The connections between bamboo struts is critical and some training may be required to understand the configurations. However, it means that the material can be constructed and de-constructed by hand.

Source of all images: Open Air bamboo theatre by Studio Akkerhuis - https://www.domusweb.it/en/architecture/2017/10/18/The-open-air-theatre-by-Studio-akkerhuis-uses-bamboo-and-ropes.html

Bamboo is a strong and versatile material to work with. It can be bound together to make truss-like structures. These can be clad with canvas, fabrics or a variety of other materials to produce set designs that are robust, lighter-weight than metal counter-parts and can be built into a range of bespoke configurations.

Bamboo is fast growing, and can be composted making it a fantastic crop to grow and supply material to theatres. Theatres could grow, harvest and compost their own bamboo, reducing air miles and creating a circular economy.



Though bamboo has the potential to break compared to steel, meaning that it is not as strong for carrying dynamic loads, like actors walking on top of it, it can still be treated as a robust alternative to structural materials, and has been used in some large scale, outdoor construction projects.

Cladding the bamboo means the audience do not see the structure underneath. It means that the aesthetic qualities of bamboo does not need to be part of the design (unless desired), however, this may be a good option for shows that do not want a ‘green’ aesthetic or simply want a more sustainable alternative to a steel frame.

Straw

researched by Adam Washiyama Shulman

Material Matters

Properties	Is it fire and/or water proof?	Flammable on its own, fireproof when compressed and covered with mud/ plaster
	Can it be cut and/or painted on?	It can be cut and painted on
	Is it strong, durable, soft, brittle or flexible?	It can be made to have any of these properties, depending on application
Uses	What is the price bracket (at time of publication)?	Inexpensive, source from local farms
	What could it be used for in theatre design?	Scenic structures, costumes
Sustainability	Does it contain toxins?	Non toxic, contains zero VOC
	Is it recyclable?	To some extent
	Does it have a high embodied energy?	No, though it can require time and effort to assemble
	Is it biodegradable?	Yes
	Where is it manufactured?	Wherever cereals can be harvested

👍 Cheap and easy to way to fill space

👍 Low embodied energy

👎 Can be messy

👎 Some labour intensive processes

Overview: Straw is the stem of cereal crops such as wheat, barley, oats, rice, and rye. As an agricultural product, straw is a versatile building block in cultures around the world. By referencing vernacular architecture and craft, scenographers can employ reliable traditions for quickly assembled structures.

1. Wattle and daub is a mixture of clay, dung and mud binded by fibrous straw to create a natural mortar that is pressed into a grooved wood lattice. Consider this a biodegradable predecessor to lathe and plaster, and drywall: a fast way to erect flat surfaces. It has been practiced in prehistoric Europe, Asia, Africa, Mesoamerica, and North America. Little specialised knowledge is required.

2. Cob is also a mixture of subsoil, sand, water, and straw, but is constructed much like handbuilding clay with/without an armature. These materials can be mixed on a tarp to form moldable bricks. While labour intensive, the product is an inhabitable sculpture from earthen materials with little carbon footprint. Some specialised knowledge is required.

3. Straw bale construction: By stacking straw bales then covering the exterior with a layer of plaster (or daub), one can quickly create thick walls. The light materials are compressed by high-pressure wires and recycled wood. Specialised knowledge needed.

4. Bale gardens: A less intensive method of defining space is to simply stack and arrange straw bales as above-ground gardens. No specialised knowledge required.

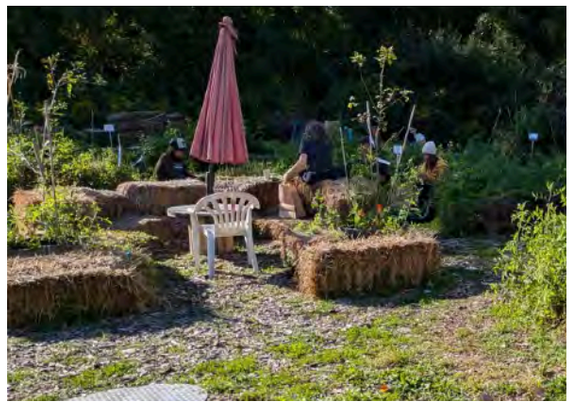
5. Other functions: Straw is a reliable stuffing, and its pokey form can be softened by compression and a layer of cotton. While more intensive and often requiring specialised experience, straw is woven into durable hats, baskets, and shoes around the world. The fibres can be beaten into paper pulp, or layered into thatched roofing.

Source of Images: https://commons.wikimedia.org/wiki/File:Straw_of_the_rice.08Oct9.jpg, https://thesoilfactory.org/, https://www.dezeen.com/2011/06/19/teahouse-by-takeshi-hayatsu-and-kristin-trommler/, https://ecobnb.com/blog/2023/01/cob-houses/, https://www.yourhome.gov.au/materials/straw-bale, https://commons.wikimedia.org/wiki/File:Straw_hats_and_baskets.jpg

Wattle and Daub

Cob

Straw Bale Construction



Bale Gardens

Repurposed Rubber

researched by Hamish Muir

Material Matters

Properties	Is it fire and/or water proof?	Waterproof but not fireproof
	Can it be cut and/or painted on?	Yes
	Is it strong, durable, soft, brittle or flexible?	Strong and flexible
Uses	What is the price bracket (at time of publication)?	If second-hand, it can be free or low cost
	What could it be used for in theatre design?	Set structure, acoustic material or costume product
Sustainability	Does it contain toxins?	Yes, if burned or left for chemicals to leach into the environment
	Is it recyclable?	Yes
	Does it have a high embodied energy?	If second-hand then it has a low EE unless further processing and transportation is required
	Is it biodegradable?	No
	Where is it manufactured?	Various

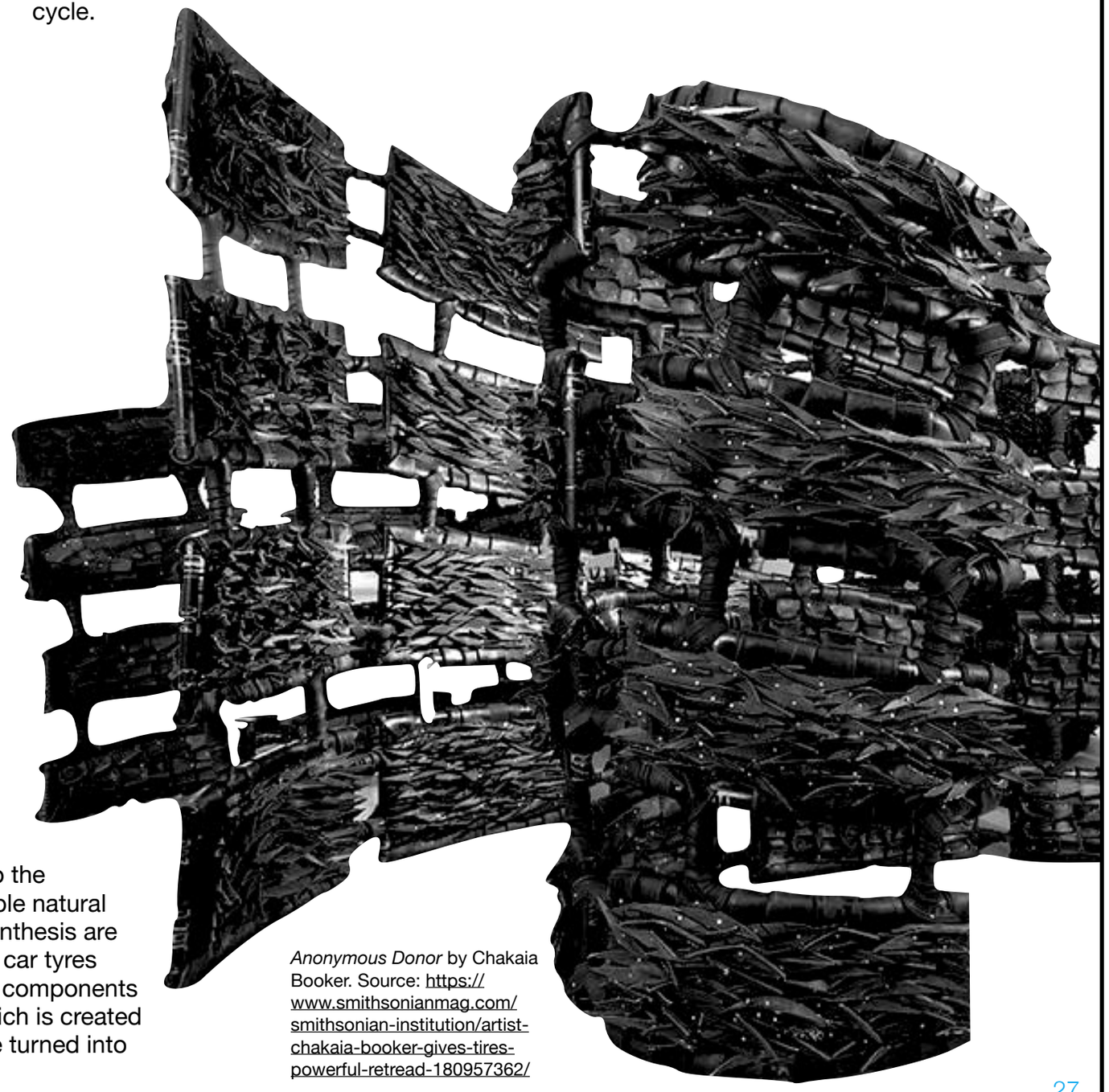
Reused Rubber

Rubber products, like tyres, are flexible and durable but they can be harmful to the environment if they are disposed of or burned. Whilst moving towards renewable natural rubber sources, such as those derived from sugars, plant oils and microbial synthesis are important, finding purposes for existing rubber can be a good way of avoiding car tyres going to landfill. Second-hand tyres can be used for soft play areas, structural components and can be made into elaborate sculptures such as the image on the right, which is created by artist Chakaia Booker. This shows the potential for repurposed rubber to be turned into ambitious artwork and scenography that masks its original function.

Recycled Rubber

Recycled rubber is created by grinding rubber into a crumb. Rubber crumb has multiple uses which often entails being combined with more synthetic materials with a high recycled content. Recycled rubber crumb can be made into sheet material, moulded products, acoustic underlay, such as Regupol 6010BA, bags, and costumes that can be used on stage or back-stage.

The recycling process has an embodied energy associated with it as the rubber is heated and moulded into a new form. By no means is rubber the most sustainable material in this guide but if a long-term purpose is found for it that avoids it breaking down into micro-plastics, burning or leaching chemicals then it can be a durable and versatile material to up-cycle.



Anonymous Donor by Chakaia Booker. Source: https://www.smithsonianmag.com/smithsonian-institution/artist-chakaia-booker-gives-tires-powerful-retread-180957362/

Waste-based Bricks and DIY Bricks

researched by Hamish Muir

Material Matters

Properties	Is it fire and/or water proof?	Fireproof and low water absorption
	Can it be cut and/or painted on?	Not easily but possible
	Is it strong, durable, soft, brittle or flexible?	It is strong, durable and brittle
Uses	What is the price bracket (at time of publication)?	Varies - many are more expensive than average brick price but some could be second hand
	What could it be used for in theatre design?	Structural elements and temporary modular structures
Sustainability	Does it contain toxins?	No - though some may have traces of chemicals from lime or mortar
	Is it recyclable?	Not fully, but the majority can be recycled
	Does it have a high embodied energy?	Medium - bricks require firing though some companies offset
	Is it biodegradable?	No
	Where is it manufactured?	The Netherlands

Making your own Bricks

Brick-making is an ancient practice used for construction. Natural clay, sand and aggregate are combined together in wooden moulds. Bricks can then be left to dry out before being fired. The firing process uses energy though some mud brick recipes, which use straw for reinforcement, or recycled paper brick recipes (which are discussed in this guide) don't require firing to be used. Firing is predominantly for structural or outdoor uses, which may not be necessary for theatre scenography. A long time is required to cure the bricks properly, a large space is required to make and store bricks and a large work force is required as it is an intensive process. However, small scale artisanal brick making can be a really interesting craft and employing more people in a making process often reduces the carbon footprint of a manufacturing process.

The Circularity of Bricks

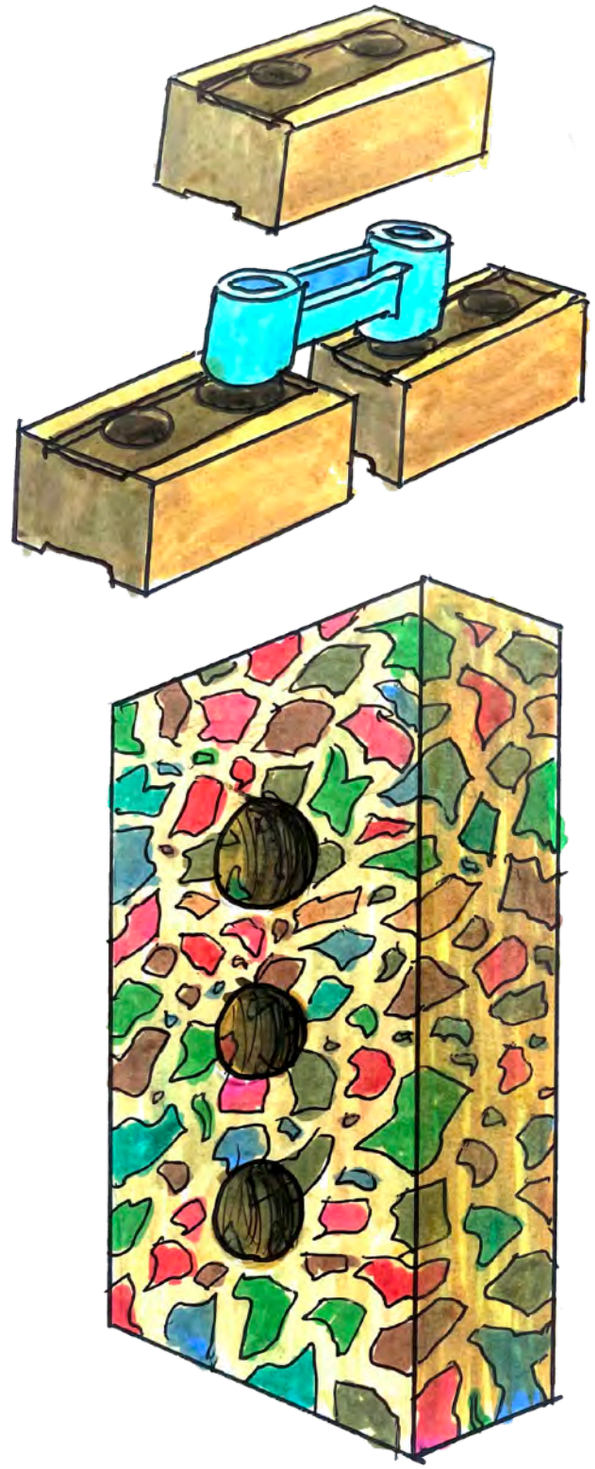
In architectural practices, there is a move away from making new building materials and using what we already have. This is in order to avoid high energy manufacturing processes and avoid excessive amounts of waste. Many brick manufacturers use recycled content in their products. There are some companies which are actively diverting construction waste clay from landfill to be made into waste-based bricks. The addition of waste creates interesting textures and forms that the bricks can take, meaning that they offer different aesthetic qualities than regular bricks. There are also many possibilities for using second-hand bricks that still retain their strength and form.

Some bricks contain traces of mortar or plastic content. In general, this is very low and most bricks are inert, but it is worth checking as a manufacturer may use a variety of waste streams as raw materials. Additionally, make sure that the raw materials are not travelling far. Clay and sand are heavy and so increase the embodied energy if they have travelled far.

Use in Theatre

Bricks tend not to be used in theatre because they are more structural, heavier, and are better for permanent, long-term wall structures, however, outdoor theatre and some complex sculptural forms that require a strong base could consider the use of bricks. The number of bricks required in theatre is likely to be low in comparison to architectural scales so the intensive making of bricks would be more feasible.

The main sustainability and feasibility issue with bricks is the use of mortar, which has a high embodied energy and fixes the bricks in place. However, it is possible to use bricks that have been designed to interlock without the use of adhesives. Additionally, connectors have been designed, such as Linko (see top right sketch), which is made from waste plastic. These connectors can join bricks together without cement being involved in the process. It also means the bricks can be constructed and deconstructed for different purposes.



Sources: front-materials.com
https://www.ineltec.net/news/construction/the-brick-that-builds-walls-faster-and-without-concrete
https://www.youtube.com/watch?v=mzJolmT__xc&t=175s
https://localworksstudio.com/projects/making-bricks-from-construction-waste/

Recycled Paper Brick Part 1

researched by Arianna Mengarelli

👍 Cheap and easy to make

👍 Biodegradable

👎 Long drying time in a damp environment

Making recycled paper bricks is a relatively simple process, but it requires some preparation and patience. The basic idea is to turn used paper into a pulp, compress it into brick-shaped moulds, and dry it to create solid, usable bricks. They of course can be pressed into any mould to be turned into a variety of shapes. A full step by step guide to making recycled paper bricks is given overleaf.

Materials Needed

- Used paper (newspapers, old books, cardboard, or scrap paper)
- Water
- Blender or food processor
- Mould (brick-shaped or any desired form)
- Mesh or cloth (optional, for extra drying)
- Strainer or sieve
- Wooden board or tray for drying
- Optional: Flour paste or starch (for binding, if needed)

Top Tips

Shredded Paper: The more finely shredded your paper is, the smoother and more consistent the final brick will be.

Drying Time: Don't rush the drying process. Slow drying results in a more stable, stronger brick.

Size of the Mould: If you want to make larger bricks, use a bigger mould or several smaller moulds. Make sure they are not too thick, as thicker bricks take longer to dry and may crack.

Alternative Moulds: You could use cardboard boxes, wooden frames, or any rectangular shape that suits your needs.

Material Matters

Properties	Is it fire and/or water proof?	Yes, if brushed with beeswax
	Can it be cut and/or painted on?	It is hard to cut once moulded
	Is it strong, durable, soft, brittle or flexible?	Hard, light and fairly durable
Uses	What is the price bracket	It is made from waste cardboard so free
	What could it be used for in theatre design?	Could be used to create wall panels/feature textures and/or sculptures
Sustainability	Does it contain toxins?	Non-toxic
	Is it recyclable?	It is hard to recycle many times over but it already is a form of up-cycling
	Does it have a high embodied energy?	No
	Is it biodegradable?	Yes
	Where is it manufactured?	Can be made by the designer

Recycled Paper Brick Part 2

researched by Arianna Mengarelli

Instructions

1. Prepare the Paper
Gather up your used paper. Old newspapers, junk mail, scrap paper, and even cardboard can work well. The more shredded or torn, the better, as it will break down more easily. Remove any non-paper items (e.g. plastic windows from envelopes) and cut the paper into smaller pieces. This will help it break down more efficiently in the next step.

2. Soak the Paper
Place the cut-up paper into a large container and add enough water to completely submerge it. Let it soak for several hours, ideally overnight, to soften the paper fibers.

3. Blend into a Pulp
After the paper has soaked, drain the excess water (but keep it on the wet side). Use a blender, food processor, or an immersion blender to break down the soaked paper into a smooth pulp. If you don't have a blender, you can try mashing the paper by hand or using a mortar and pestle, though it will take longer. Add small amounts of water as needed to help the process.

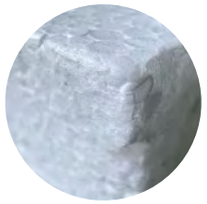
4. Optional Binding (Flour Paste or Starch)
If you want to improve the brick's strength and durability, mix a small amount of flour and water (about 1:4 ratio) or starch to make a paste. Stir this paste into the paper pulp until it is evenly distributed. This will help the fibres stick together more effectively.

5. Form the Bricks
Take your pulp and press it into a brick mould (you can use any rectangular mould, or even an old brick as a form). Press the pulp down firmly to eliminate air pockets. You may need to use a spoon or your hands to compact it. For extra moisture control, you can place a cloth or mesh underneath the mould to help with drainage.

6. Drying the Bricks
Once the pulp is in the mould, you'll need to let it dry completely. For the best results, place the brick mould on a wooden tray or board and let it air dry in a well-ventilated area. You can also place the bricks in the sun or use a fan to speed up drying. Drying can take anywhere from several days to a week depending on the thickness and humidity.

7. Removing from the Mould
Once the brick has dried and hardened, carefully remove it from the mould. You can sand the edges lightly if needed to smooth out any rough spots.

Once you've made your paper bricks, you can use them for a variety of purposes in your stage design, from building walls to props, depending on how durable you want them to be. If the bricks need to be more robust you might want to use a stronger binding agent like glue or starch.

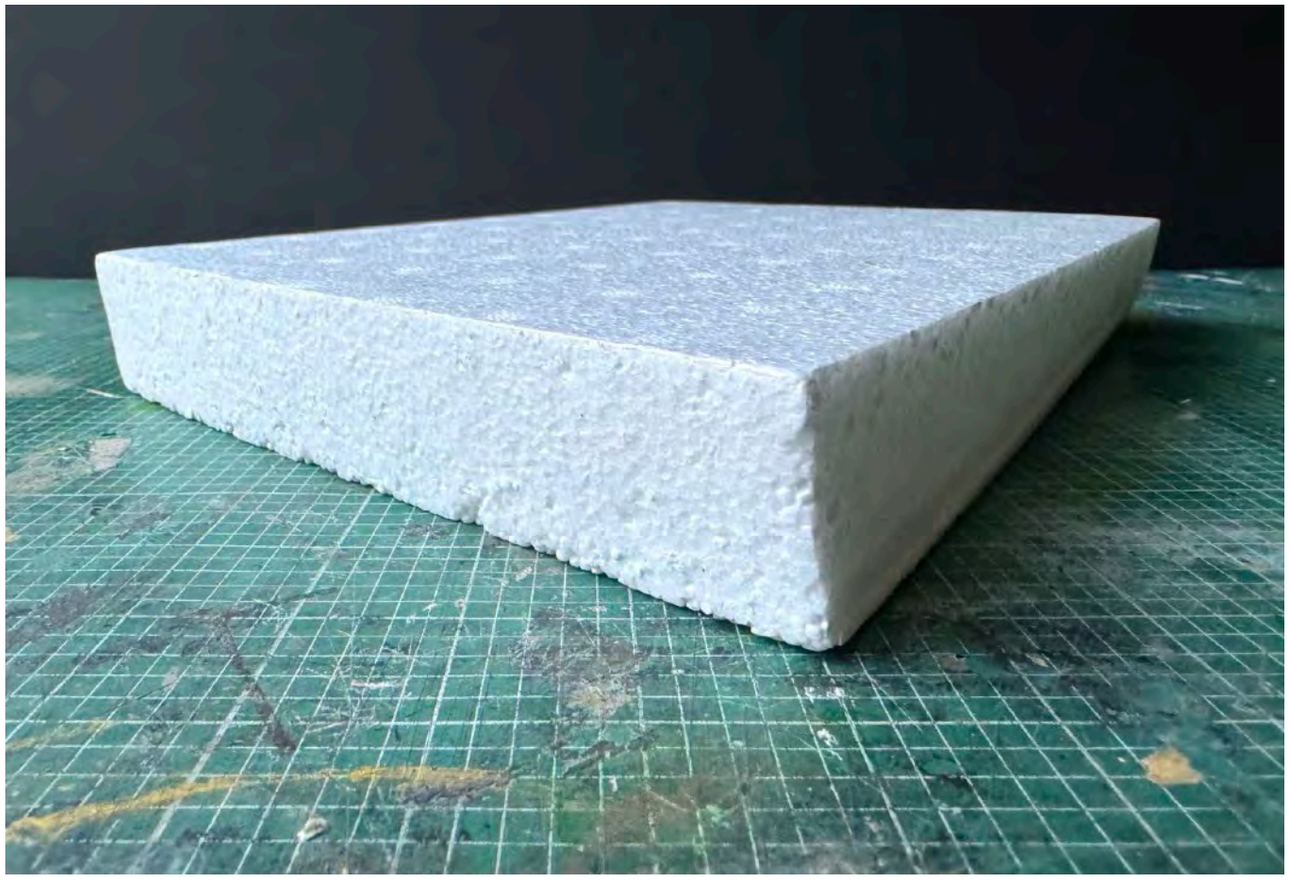


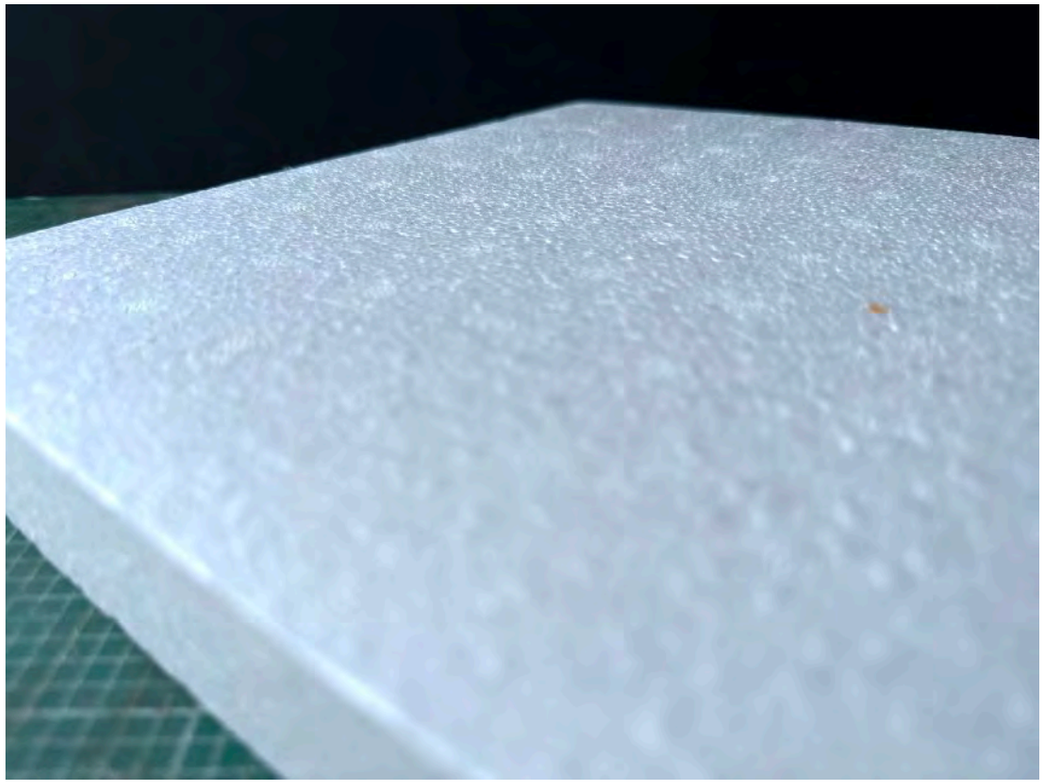
CompostaBlock

researched by Paul Burgess

Material Matters

Properties	Is it fire and/or water proof?	It is sufficiently waterproof. It is fire retardant to Euro Class E and will melt rather than combust.
	Can it be cut and/or painted on?	Yes, but it's more difficult to carve than polystyrene and would benefit from some kind of primer
	Is it strong, durable, soft, brittle or flexible?	Very similar to polystyrene
Uses	What is the price bracket (at time of publication)?	£50 for 855mm x 565mm x 40mm
	What could it be used for in theatre design?	As an alternative to polystyrene for carved objects.
Sustainability	Does it contain toxins?	No
	Is it recyclable?	Yes, but through a specialist process.
	Does it have a high embodied energy?	It is 100% carbon neutral, which implies low embodied energy
	Is it biodegradable?	Yes, in a hot compost.
	Where is it manufactured?	It's made by a UK-based company





CompostaBlock is an alternative to one of the most unpleasant materials used in theatre design: polystyrene. Polystyrene has a high embodied energy, contains substances that are very harmful to the environment and to health, is messy and breaks down into components that can find their way into water systems, and takes a long time to biodegrade.

Unfortunately, polystyrene is very hard to replace in theatre design because it is lightweight and can be sculpted into any possible shape.

CompostaBlock is a great alternative that has the same properties as polystyrene. It is denser but still fairly lightweight and it can be cut with accuracy.

It derives from annually renewing biomass feedstock crops such as corn starch and sugarcane. Though this is a sustainable source, it is reliant on large-scale agriculture, so it is worth checking with the supplier about the farms where the raw materials come from. It is not the cheapest material, but it is an excellent material to champion design that is not reliant on plastics, yet can still achieve the sculptural quality of using polystyrene. As plastics get phased out, CompostaBlock and its equivalents will become more popular and more affordable in the future.

Cob

researched by Deborah Piffer

Material Matters

Properties	Is it fire and/or water proof?	It is naturally fire-resistant, not waterproof
	Can it be cut and/or painted on?	Yes, primer can be applied when painting
	Is it strong, durable, soft, brittle or flexible?	It is strong, durable when mixed correctly; it is malleable when wet and can be brittle when dry
Uses	What is the price bracket (at time of publication)?	Low-medium (Atp £2.25 +VAT per block, £211.60 per full pallet)
	What could it be used for in theatre design?	Scenery and props texturing; architectural elements such as platforms, columns, arches etc
Sustainability	Does it contain toxins?	No
	Is it recyclable?	Yes
	Does it have a high embodied energy?	Low embodied energy
	Is it biodegradable?	Yes
	Where is it manufactured?	It is mixed on site using locally sourced materials, however it can be purchased from Cob Block Sales UK and Eurocob

Images (above) show different stages of a cob brick creation.

👍 Biodegradable

👍 Versatile sculpting material

👎 Moisture sensitivity

👎 Dense and heavy material

Reference images and sources: Building & Sculpting with Cob - Artisan Structures; Bioconstrucción, construimos utilizando materiales naturales; Curved Cob Bricks – Earth Blocks UK ; Cob House: 8 Cob Buildings & Design Ideas Plus Cost Estimates & How to Build | Architecture & Design; Delcy Morelos – EARTH ARCHITECTURE

What is Cob?

Cob is a natural building material composed of:

- Soil: High in clay content and low in organic matter or stones.
- Sand and Clay: Mixed in a ratio of 1:1 or 1:2, depending on soil properties.
- Straw or Fibres: Evenly distributed throughout the mixture to enhance binding.
- Water: Gradually added until the cob reaches a dough-like consistency.

Cob bricks requires several weeks to dry, depending on the climate, composition ratio, and thickness. Proper drying and maintenance are crucial to prevent cracking and ensure durability. To protect the surface and extend its lifespan, it is recommended to apply a suitable coating finish.

While cob structures are labour-intensive to create, and their drying time may limit their practicality for productions with tight schedules, cob remains a sustainable and versatile choice. As a biodegradable material, it aligns with eco-friendly practices and can be broken down and reused. Cob offers a harmonious balance of aesthetic appeal, functionality, and environmental consciousness.

Aesthetic Potential of Cob

Artists have long explored the expressive potential of soil and cob-like materials to evoke themes of nature, sustainability, and human connection. On the right is an image of Delci Morelos' Earthly Paradise, exhibited at the Biennale di Venezia 2022. This installation, made from soil and spices, invited visitors to walk around a 'breathing construction,' offering a sensory experience. The work reflects concepts similar to cob-making, emphasising texture, organic form, and the transformative interaction between humans and materials.

Application to Theatre Design

Cob's pliable nature allows it to be sculpted, carved, or shaped into brick blocks. Once dry, it hardens to a concrete-like state, offering both stability and texture. It is particularly suited for creating rustic, historical, or naturalistic stage sets and props. Cob can also be used for temporary installations and experimental theatre, where its sculptural qualities enhance creativity.

Part Three: Sustainable Processes and Manufacturing

Part Three addresses the way in which materials are used because this is as important to the sustainability as the chemistry of the material itself. There are uses of materials which are more sustainable than others. For instance, being able to return materials back into their raw state can help with reuse and recycling, and the way in which materials are stored, transported, tested, conglomerated and constructed can have an impact on their longevity and versatility.

Sustainable Procurement Processes

researched by Mathias Peitersen, Lea Hedeskov, and Frederik Larsen

When purchasing materials, elements, and equipment for scenographic use, it may be challenging to know which sustainable and circular economy initiatives to prioritise. This model suggests a decision flow, that puts priority to the initiatives with highest potential for minimising the adverse environmental impact of your scenography.

The tool incites informed decisions on which sustainable initiatives to prioritise in the design and procurement process. While there are trade-offs for each initiative, the tool ranks them according to what is typically most effective, following a reduce, reuse, recycle mind set. Start on the left side of the model and use the headings to determine how much you can minimise the negative impact by asking: "How much of the scenography can we build with elements we already have? How much can we borrow? And how about renting or leasing?" And so on. Every time you go one step further to the right, the sustainability potential decreases. While priority is given to initiatives to the left, you can also combine sustainability initiatives (i.e. second-hand mono materials that are recycled and certified).

Assessment criteria

The steps in the decision flow have been assessed according to these criteria.

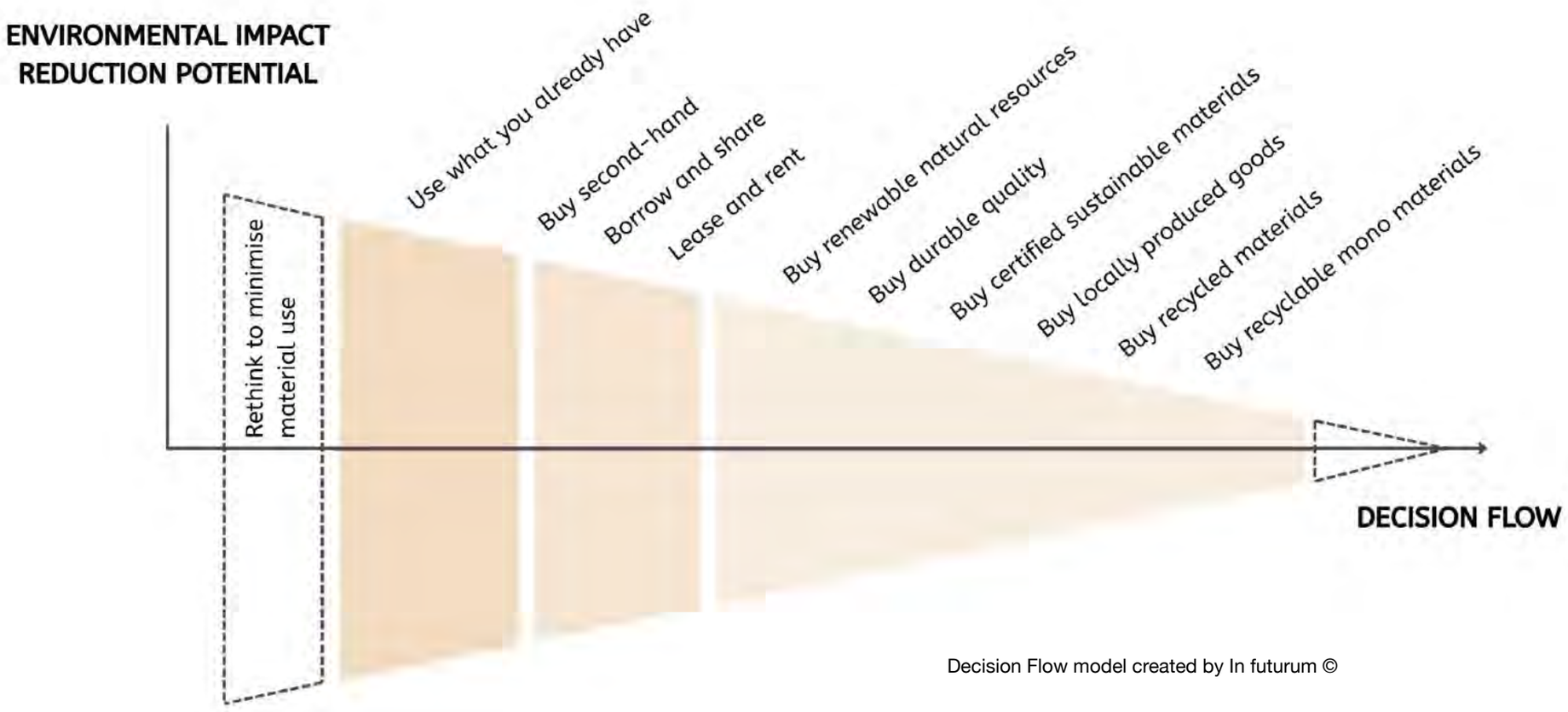
Use-phase extension: the biggest environmental contribution comes from making better use of existing materials and components instead of purchasing new.

Ownership: Ownership may increase motivation for future reuse.
Recyclability: Ensure the potential for closing material loops when it can no longer be reused.

Sustainability certifications: An easy indicator of initiatives to decrease environmental effects.

Additional resource consumption: Minimise use of additional resources for packaging, transportation, etc.

Transparency: Knowing the full supply chain of your materials increases your chances of assessing their sustainability implications.



Decision Flow model created by In futurum ©

Tools for Supporting Sustainable Procurement

researched by Mathias Peitersen

Sustainable procurement processes and value chain collaboration is key to achieve greater impact in sustainability efforts of cultural productions. Through value chain collaboration and strategic procurement, you can strengthen commitment to the sustainability goals of the production, find new and better solutions and materials, and positively impact their value chain by showing initiative, sharing knowledge, and starting a dialogue. These tools may help achieving this even if production periods are busy and you often need to act fast to meet the production deadlines.

The optimal level of detail in the tools may vary depending on the size of your theatre. Large theatres may benefit from more advanced measures, while simple tool may be enough for small groups and organisations. Start experimenting and see what works for you.

Supplier Dialogue

Open and honest dialogue can be a tool to improve collaboration and bring diverse experiences into play. By being vocal to suppliers about your sustainability goals, you can collaborate on finding the right solution. This can be to find the least damaging material for a given purpose or to discuss potential take-back agreements or similar.

Green Riders

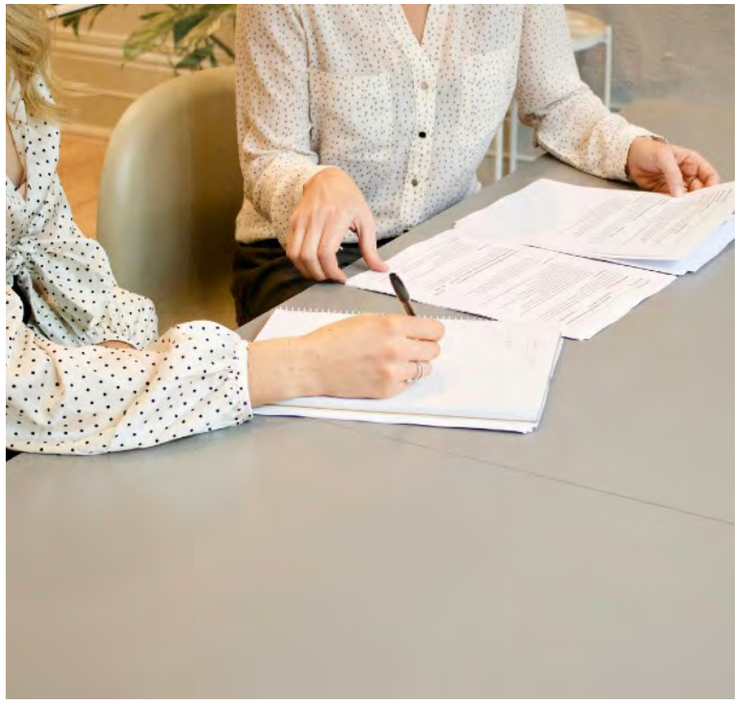
A green rider can structure your sustainability efforts when co-producing, touring or working with external partners where you do not have direct agency. It sets the tone for the collaboration, draws attention to your wishes, but is often not as specific as a technical rider. They come in many shapes and sizes and in varying degrees of detail.

Procurement Policy and Principles

Using a shared document to list criteria for material procurement, may be a way to continuously improves the sustainability performance and share initiatives across personnel and departments. It may also free mental capacity to focus on your creative tasks rather than administration. It may be an internal document aiming to secure internal alignment or an official policy communicating for a wider audience outside your organisation.

Sustainable Legal Processes

Through legal processes you can set base level and show that sustainability and resource management is a priority in the fulfilment of collaborative tasks in your theatre or organisation. This includes tenders, contracts, and official cross-organisational collaboration agreements. This is especially useful for large projects, long-term collaborations and leases and can be key to make sustainability performance a priority throughout the collaboration. Consider using flexible criteria instigating that the supplier brings suggestions to the table, or specific criteria that the supplier must adhere to meeting your sustainability standards.



Initiating Alternative Material Loops

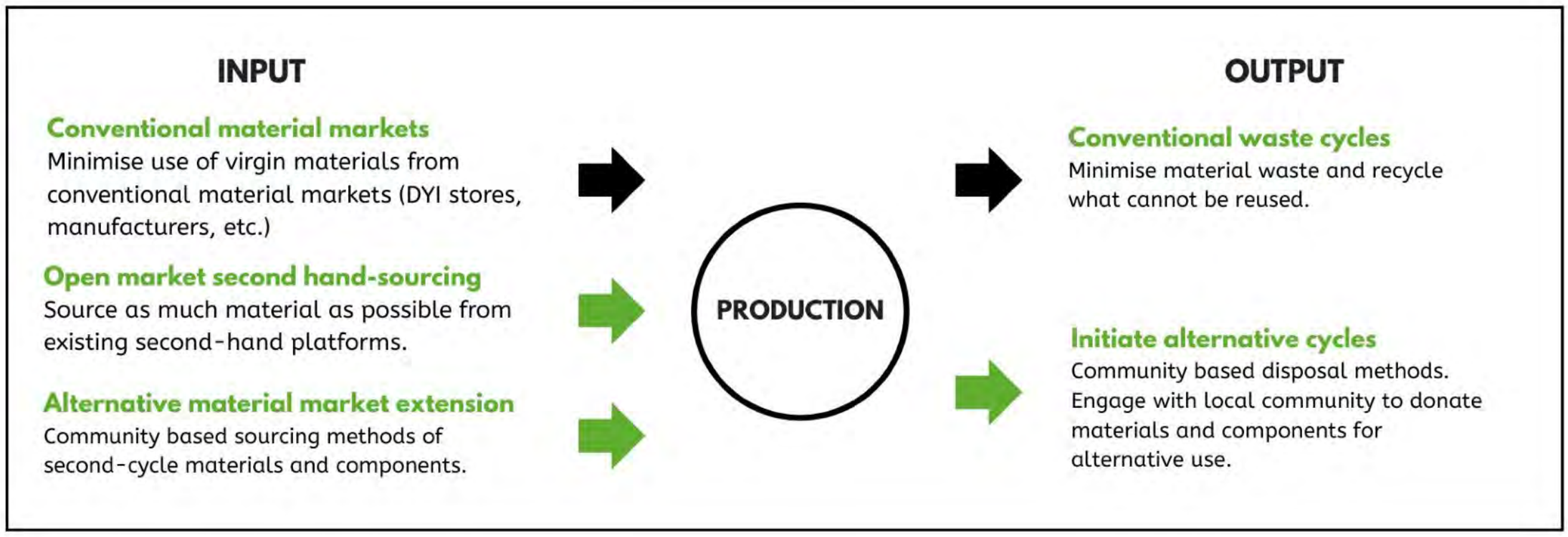
researched by Mathias Peitersen

To minimise consumption of virgin materials from conventional material markets in your scenography, it may be beneficial to consider alternative material loops. Where in your neighbourhood can you source second-hand materials? Who can you talk to about exploring alternative materials? Consider actors outside the traditional cultural industry, such as the building industry. Do local craftspeople have spare rafts and sheet materials from a project? Or are there scrap batches of textile from the local factory?

The cultural industry, and particularly the smaller theatres, has a difference in scale compared to other industries. Amounts of left-over or scrap materials that may be insignificant in one sector, can be enough to be used in making theatre scenography.

Similarly, it may also be relevant to consider where materials can flow after end production. Can you donate props, costumes or scenography that cannot be reused by other organisations? Are there any smaller cultural institutions or theatre schools for whom it may be useful? Could you donate it to a sharing network or a local second-hand shop? Are there any local workshops, maker spaces or small-scale production companies, that may be able to upcycle it?

Initiating such alternative material flow may be time consuming at first. However, once the collaboration is established, you can enter agreements to automise things to minimise coordination. You can create long term collaboration agreements with an organisation that deliver or receive certain second-hand material types or components for reuse to make material circularity easier in the future.



Reclaiming Existing Materials - Sleeping Bag Case Study

researched by Andrea Carr

Reclaiming materials is a major way that designers can improve the sustainability of their practice. By sourcing an unusual material, such as a waste byproduct, working with it and getting to know its strengths and weaknesses over time, will offer possibilities of how it can be reinterpreted and remade as a scenographic object. In this case study, we look at reclaiming old sleeping bags and tents.

What are Tents and Sleeping Bags made from?

Sleeping bags and tents are made from composite materials that are strong, very durable, light weight, compactable, and flexible. Polyester (PES) is, next to polyamide, an important basic material for the construction of the tent skin. Sleeping bags have natural or synthetic insulating fillers. The world's first commercially produced sleeping bag with an insulating filling was actually made in 1890 by a Norwegian company called Fuglesangs Sønner. All modern tent fabrics are fire-retardant under EN5912 European Safety Laws. Caution with fire must always be used, as flame retardant fabrics, will still catch fire given the right circumstances.

The Unsustainability of Tents and Sleeping Bags

Camping equipment is now derived chiefly from the petro-chemical industry and cheap prices have turned it into a throw away commodity rather than a one in a life time purchase. It takes a long time to biodegrade, between 20-200 years! They are not recyclable but reusable because of their durability. Like other man made materials, the embodied energy of polyester encompasses many power sources, machinery, and manufacturing processes, which includes the production of raw resources, most importantly petroleum. The materials are not very sustainable which means that how we use them is important. Reclaiming used tent and sleeping bag materials is cheaper and avoids tents going in the bin and into landfill.

Sourcing the Materials

Ecoscenographer Andrea Carr sourced and recycled tents and sleeping bags from a festival for a theatre show, as there are many tents left over from large festivals that go to waste. It's a material we have a lot of and does not degrade easily so it needs re-purposing. As tents are shelter structures consisting of sheets of fabric or other material draped over or attached to a frame of poles or a supporting rope, they can be deconstructed and different parts used in different ways.

Andrea mindfully deconstructed and repurposed the found materials. It takes time to unpick and restitch but this is part of getting to know the material. It was amazing to see how many materials and resources go into a sleeping bag and camping equipment in general, from metals to plastics to zips. It is rewarding and humbling to deconstruct an existing object to repurpose it. This brings a new perspective on the materials we use and take for granted, and therefore brings a deeper respect and awareness about how we use them.

Tents offer a creative challenge due to their mutability. They are light weight, and come in pre-existing shapes to play with and add or subtract together. They can go large in scale without incurring weight. They can be draped, stitched, stretched, flown, used with other structures, such a poles, and they can be projected on. They also offer a unique colour palette if stitched together. The material can be used as basic fabric for costume and set as it can be cut and unpicked. Tents might be able to be painted on but not easily.

Tents pack right down and expand out allowing for different scales of vision and production. It can be compacted easily for transportation without causing damage or creasing and is designed to be a lightweight material, ideal for touring.

Images from: Reading Festival Clean-up and Stuck by Hoax Theatre, designed by Andrea Carr

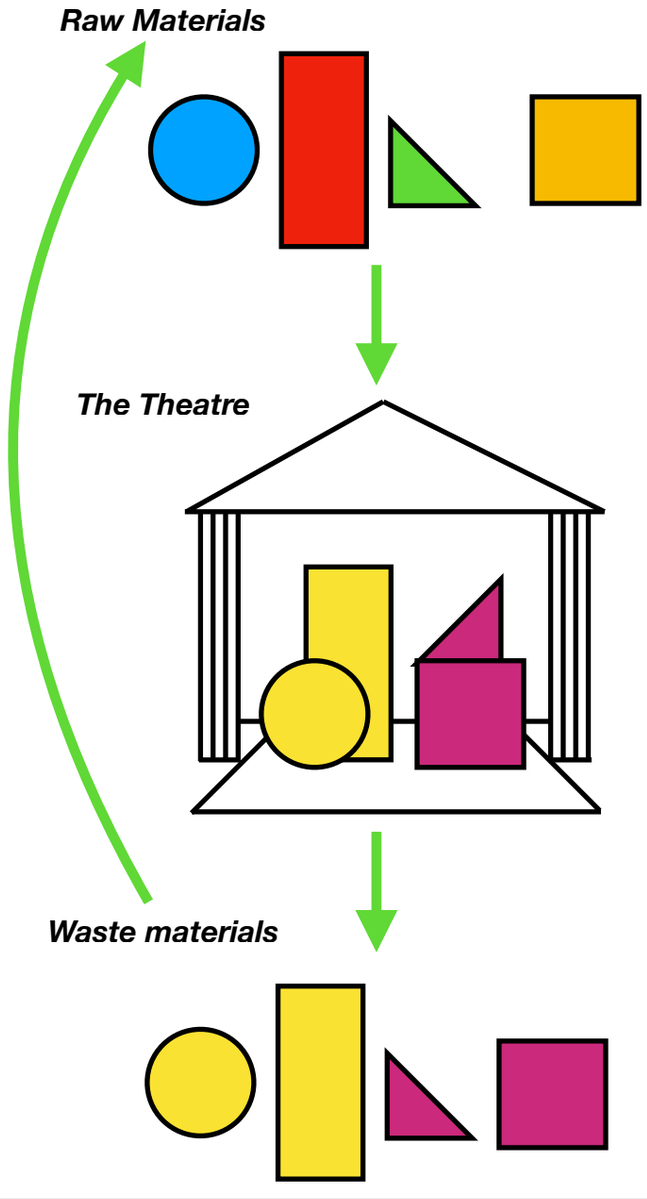
Circular Economy Design

researched by Hamish Muir

The circular economy is about avoiding material waste. In its purest form, the waste materials from one theatre production would become the raw materials for another theatre production. There are three main strategies for avoiding material going to landfill as explained through these diagrams.

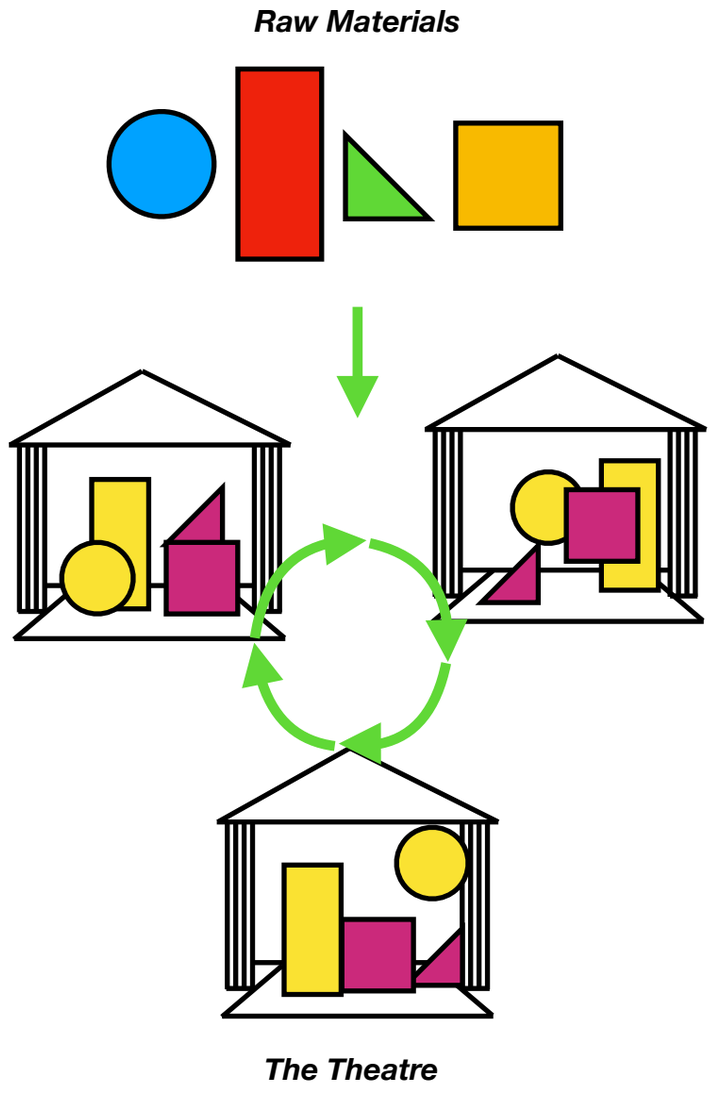
1. DECONSTRUCTABLE DESIGN

This is about designing the set so that each element be returned, as much as possible, to the original form it was before its use in theatre, for instance, designing the set so paint or fasteners can be removed.



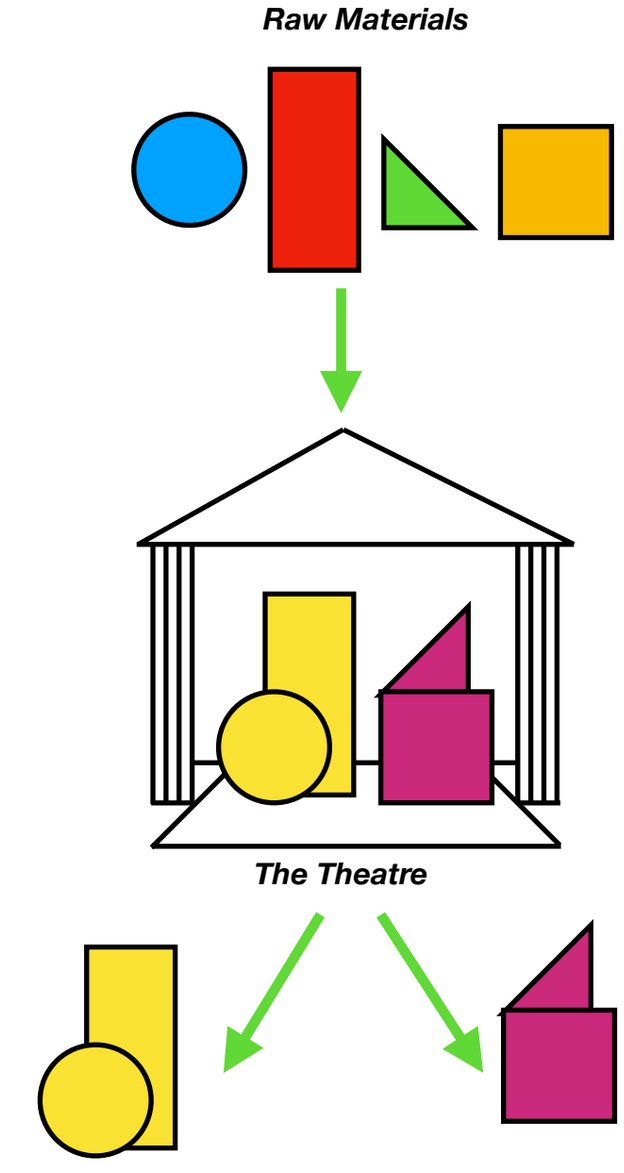
2. ELONGATE THE CIRCLE

Elongating the circle is about finding different ways of using the material for several productions. Essentially, this is about creating a culture of reuse, repair and adaptability. Designing for longevity may be an important factor also.



3. CASCADE USE

Cascade use is about finding partners and business inside our outside of theatre who will find the waste materials produced by theatre useful e.g. schools, workshops etc.



Sustainable Connections

researched by Hamish Muir

Connecting materials together can be a major contributor to the sustainability of theatre sets, regardless of the materials that are being connected. Glues and adhesives can permanently affect how a material is used and reused in the future. Most glues don't biodegrade and contain chemicals that can harm the environment if they go to landfill. This page explores different connection technologies and what they may offer to a set designer.

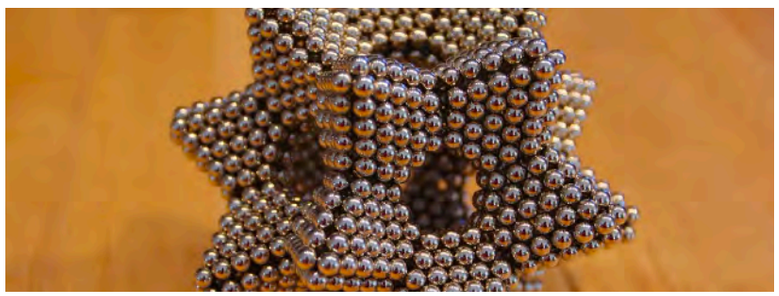
Rope

Rope is already a strong material used in theatre production. Its sustainability is more dependent on how well it is kept and what material it is made from. Used in conjunction with magnets, rope could be a good system for hanging materials that can be deconstructed, stored, transported and reconfigured easily, such as hanging removable cladding materials onto other structures.

Ties

Some ties are single use or are made of plastic, but metal ties can be used multiple times in different configurations. Well designed clips, such as the paper clip, are efficient and effective because of the form they have been moulded into, allowing the materials they connect to be unaffected by the connection itself.

Source: https://www.cableties-online.co.uk/blog/all-about-metal-cable-ties



Magnets

Magnets can offer versatility to a light weight, non-structural modular set which can be deconstructed and reconstructed in different ways. How the magnet is connected to the material is important to consider for strength reasons but a permanent magnet fixture might allow different temporary materials to be connected and disconnected with ease.

Metal and Wooden Fasteners

If a material is connected using metal fasteners, the material can be permanently damaged, particularly when using nails that are harder to remove than nuts and bolts. Choosing where to drill a hole can mean strong, durable and versatile connections can aid in materials being used multiple times or for a very long time. Wooden nails are weaker but are significantly better for reuse, recycling and deconstruction.

Tape

Whilst tape is not a structural connector and can create waste, there are emerging brands that are strong and durable meaning that the tape can be used to stick and (re)stick materials together several times. There are also biodegradable alternatives.

Designed fittings

An elegant solution for making sustainable connections are products that are shaped into forms that can be bound together, as inspired by Japanese joinery. Tongue and groove joints are an example of how the ends of a strut can be designed so that they fit together without introducing binding materials. There is room for creativity when designing unique connections suited to theatre sets, similar to how Lego bricks fit together.

source: https://www.designboom.com/technology/free-interactive-software-easily-complex-japanese-wooden-joints-furniture-04-13-2021/

Forest Stewardship Council (FSC)

researched by Kira Curtis

Who are FSC?

The Forest Stewardship Council (FSC) are an organisation who promote responsible forestry, ensuring our world's forests can continue to play a vital role in our environment, communities, and economy.

What is it?

FSC is a certification which signposts the materials being used and where they are from. This offers the designer a trackable process, from beginning to end, ensuring responsible forest management.

When offering FSC certified materials, the company have to provide clear, trackable detail of the materials source so that you can be certain about the sustainability of the product.

Where will Theatre Designers find the FSC tree logo?

- Costumes and fabrics
- Timber and other construction materials
- Books, scripts, paper products
- Furniture, home décor and props
- Craft materials and art supplies

Photo by Dominik Van Opdenbosch on Unsplash

Key Areas FSC support

- Zero deforestation
- Fair wage and work environment
- Support the change from preservation to conservation
- Community rights

The Licence Code

Three different labels (right) indicate how a product has been used.

The numbers at the bottom of the label allow you to research the materials back to their original source. The licence code is in the form 'FSC-CXXXXXX'.

The FSC website has a certificate database of all valid licences. A new database is being updated but a public certificate dashboard is currently available. Using the licence code from the label, you can check the code is valid, and find details about the supplier, the tree species and important locations

Certification types

FSC offer different types of licences which are given as abbreviations and will mean different information is available depending on the type of licence. The different types are as follows:

FM = Forest Management
COC = Chain of Custody
CW = Controlled Wood
FM/COC = combined Forest Management and Chain of Custody

The Labels

All materials used come from FSC-certified forests.

The product is made from 100% recycled materials.

The product is made with a mixture of materials from FSC-certified forests, recycled materials, and/or FSC-controlled wood.

Fireproofing

researched by Urs Dierker and Hamish Muir

Coating

Fireproofing in live performances is a common practice in the set department to prevent devastating destruction in the event of fire.

Common chemicals used for fireproofing in theatre include ammonium sulfate and ammonium phosphate, which are commonly applied to fabrics and set materials to reduce flammability. Boric acid and borax are used as flame retardants for wood and textiles, forming a protective layer that prevents combustion. Intumescent coatings, which expand when exposed to heat, often contain phosphates, sodium silicates, and expandable graphite, providing insulation and delaying fire spread. For foam and plastics, melamine-based compounds and aluminum hydroxide are used to suppress flames and reduce smoke production. These chemicals help ensure that stage curtains, costumes, and set pieces meet UK fire safety standards.

The issue with fire proofing is that additional coatings are added to a base material (which may, in its raw state, be a sustainable material) but due to the addition of fire or water proofing, the overall sustainability of the material reduces because the proofing material may contain toxins, it may be harder to biodegrade, or it may make the material less easy to recycle.

Non-toxic options

There are some low-toxicity fireproofing products such as Flame Check Spray. However, the product data sheet suggests that it can be an eye irritant and it should not be allowed in drains and the wider water system, and that some aspects of its properties, such as its biodegradability, have not been proven. Whilst the toxic content may be low, it still needs to be handled with care.

Thinking outside of the box

Though regulations must be consulted, thinking about how and where fire risk is apportioned is important in assessing how best to efficiently fireproof a set design. For instance, if an object is designed so that throughout the course of the production it remains behind a separate fireproof barrier wall, the object itself may not need to be fireproofed. The design of the barrier wall could be semi-permeant and serve multiple productions. Alternatively, considering the location of the scenographic object in relation to what would happen in a fire test may have some consequence on its design requirements. If the scenographic object was put in a vacuum or it was designed to be in a pool of water at all times, how would this affect the fireproofing design of the overall theatre? Of course, this may not apply to all circumstances and fireproofing adhesives may be unavoidable in the near future but thinking about the behaviour of fire and how the scenography interfaces with the architecture of the performance venue, can help to define a fire strategy that can lower the risk of individual objects catching fire.

Borax which is used in wood and textile flame retardants.

Ammonium sulfate with colouring, as used by aerial fire brigades for forest fires.

Expandable graphite, which is used in intumescent coatings.

Fire simulation software can model how materials and architectures behave in fire conditions and aid in the design of a fire strategy.

Sources:
https://www.fireprotectiononline.co.uk/fire-retardant-spray?attribute_values%5B225%5D=567&gad_source=1&gclid=CjwKCAiAqfe8BhBwEiwAsne6gclgxrjcV-lxk12ktzxn3SKk1dM5KC_Yr1cZv4QMWy8w2c9wJMWfZxoC_1MQAvD_BwE#product-details-tab-description
https://paverpol.co.uk/
https://www.draeger.com/en_seeur/Products/Fire-simulation-trailer-mobile

Toxic Materials

researched by Urs Dierker and Hamish Muir

Toxic materials in theatre set and costume productions is a well-established topic, and many toxic materials are documented. Frameworks are in place to prevent harm to people and the environment. Information can be accessed through the Health and Safety Executive for instance. This short text focuses on toxicity and natural materials.

Defining toxicity

Toxicity refers to the degree to which a substance can cause harm to living organisms. In theatre, toxicity is commonly focused on two subjects: harm of people who handle and are exposed to harmful substances like chemicals, and the negative consequences the use of these substances can have on the environment. For the purposes of this publication, toxicity is defined as substances poisonous or harmful to the environment in the form of chemicals and materials. Working with natural materials (for example natural dyes or living specimens such as mycelium) can increase the risk of biological toxicity. Current theatre workplace toxicity prevention focuses on non-living materials (chemicals, dust) to prevent acute toxicity from short-term exposure and environmental toxicity affecting ecosystems.

Current standards

It can sometimes be difficult to identify qualitatively and holistically whether a material contains toxic content. However, the international Globally Harmonized System of Classification and Labelling of Chemicals (GHS) has a series of pictograms (as shown) that identify quickly the hazards related to certain materials. Additionally, many material products have a data sheet that will give this information.

GHS standards and levels of severity indicates how harmful a material is for the environment. Materials that irritate the skin or the eyes, or that cause respiratory issues, or health problems if ingested or exposed, need to be considered both for their usage on stage and for safe disposal after their use. Ideally, many such materials that contain harmful chemicals, such as adhesives, glazes and plastic textures, should be phased out of use to create safer environments.

STOT (Specific Target Organ Toxicity) is a standard that presents the non-lethal health impacts of a substance, Category 1 being the most severe. This may be referenced on a data sheet or product label.

Wider Natural Implications

More broadly, toxicity can be measured in terms of a chemical's lethal content and the acronym LC50 is a standard used to identify this. LC50 refers to the concentration in water of the chemical that would be lethal to 50% of the population it was exposed to. This indicates the severity if certain chemicals were to find their way into the water systems. Mobility in soil is also important in this sense, as chemicals can leach from landfill and move through the soil into water systems, which cause environmental harm. If a chemical has a high mobility in soil and an LC50 rating that would cause harm, then it should be avoided and cannot be disposed of down the drain.

The acronym PBT (meaning persistent bioaccumulative and toxic) or vPvB (very persistent and very bioaccumulative) are also important to look for on a material datasheet. Bioaccumulation refers to whether a material is absorbed faster than it can be eliminated by an organism, which relates to its danger in the natural environment and its biodegradability.

Explosive

Flammable

Oxidising

Compressed Gas

Corrosive

Toxic

Health Hazard/Hazardous to the Ozone layer

Serious Health Hazard

Hazardous to the Environment

Toxicity and Natural Materials

researched by Urs Dierker

Natural materials can be harmful, either when mixed with substances that are non-biodegradable or on their own. This text introduces three specific aspects of toxicity in relation to natural materials:

1. Harm caused by chemicals used to enhance the properties of natural materials
2. Harm from hybrid materials combining natural and non-biodegradable substances
3. Harm to people from handling or being exposed to certain natural materials

1. Harm caused by chemicals

Chemicals such as alum (potassium aluminium sulphate) are traditionally used in natural dyeing to strengthen the bond between the colourant and the textile fibre in the dye bath. While alum is generally considered less harmful than other metal-based mordants when used in small amounts, higher concentrations can contribute to environmental toxicity. Other common mordants, such as aluminium trisulphate, iron, copper, or other metal-based compounds, are known to negatively impact aquatic ecosystems. This highlights that natural materials do not always stay harmless when becoming hybrid materials. Bio-mordants, which are derived from plants, fungi, or food waste, are increasingly being explored as sustainable alternatives. Bio-mordants are made from tannin-rich plant extracts, such as pomegranate peel (right), gall nuts, and sumac, myrobalan, and certain algae-based compounds. They have shown promise in binding dyes to textiles without introducing heavy metals into the environment.

2. Harm from hybrid materials

Mixing natural materials, for example, cellulose, with non-biodegradable additives (e.g., plasticisers, resins, and polymers) to enhance properties like physical strength can create hybrid materials that give the illusion of being sustainable. While cellulose decomposes naturally, synthetic additives can lead to persistent pollution. Over time, these hybrid materials break into harmful residues, like micro plastics (right) rather than fully degrading. This can contaminate soil and water. The misconception of partial biodegradability can also encourage improper disposal.

To reduce toxic environmental impact:
• Develop fully biodegradable mixtures, ensuring all components degrade without leaving harmful residues.
• Understand how to recycle hybrid materials and recognise greenwashing claims through breaking down products into their material components.

3. Harm to people

Natural materials are not harmless by default. It is important to understand which materials you are handling and how to do so safely. This is especially true when working with living biomaterials such as bacteria or fungi (right) or dried plant and animal materials used in natural dyeing.

Safety Tips:
• Inform yourself about the toxicity of the products you are using. Read Material Safety Data Sheets (MSDS).
• Wear appropriate protective gear, especially safety glasses for eye protection, a respirator for lung protection, and protective clothing and boots.
• Prevent cross-contamination by sterilising tools and keeping food away from workspaces.
• Be aware of allergic reactions, especially with plant-based materials.
• Ensure proper storage and disposal to avoid environmental harm—hazardous waste should be disposed of responsibly.
• Keep a first aid kit accessible and know emergency procedures for eye exposure, inhalation, or skin contact.

Images from: https://hsph.harvard.edu/news/microplastics-a-growing-challenge-to-health-and-the-environment/

Working with Metals

researched by John Winters

Material Matters

Properties	Is it fire and/or water proof?	Does not burn but will weaken when heated - does not absorb water, but steel will rust
	Can it be cut and/or painted on?	It can be cut with the correct blade/ tools - It can be painted, but requires priming/special paints
	Is it strong, durable, soft, brittle or flexible?	Steel – strong, durable & slightly flexible; Aluminium – less strong, less durable & more brittle
Uses	What is the price bracket (at time of publication)?	£7.14 per metre (20 x40 x 2mm)[1]
	What could it be used for in theatre design?	Structures, mechanisms & small intricate items
Sustainability	Does it contain toxins?	Welding gases and particulates are harmful
	Is it recyclable?	Very, but energy-intensive
	Does it have a high embodied energy?	Yes 1.6[2] – 6.9[3] kg CO2e / kg
	Is it biodegradable?	No
	Where is it manufactured?	Worldwide, but raw material is often produced and finished in different locations

[1] Metals4U – 20 x 40 x 2mm Mild Steel Box Section (inc. VAT, 2025)
[2] Worldsteel, 2023 – Steel sections, Europe; Stages A1-A3 (upfront carbon)
[3] ICE V4.0 Database, 2024 – Aluminum profile, Europe; Stages A1-A3 (upfront carbon)
[4] Unusual Rigging – https://www.unusual.co.uk
[5] Steeldeck – https://www.steeldeck.co.uk
[6] Triple E BEEEM – https://buildit.triplee.ltd
[7] https://www.phillips.com/detail/antony-gormley/UK010615/33

There are libraries of books written about metals, so only so much can be written here, but in theatre, the most common form is mild steel and, in some countries, aluminium alloy.

What is interesting about the material from a theatre design perspective?

Metal allows large structural spans to be achieved with a compactness suitable for transport and fit-up. The Romans could make large concrete domes that relied on compression, but steel's tensile strength lends it to beams and trusses.

What is the material's best quality?

Mild steel can be welded, and the weld can be as strong as the steel. A bracket welded onto steel adds material compared to a screw or bolt into timber, which removes material and might reduce its strength.

What is the material's worst quality?

It can be difficult to work without specialist skills and tools. Cutting or drilling metal isn't as difficult as welding, but the carpenters will prefer a wooden door frame to drill hinges into than a steel one. Aluminium alloy can be welded, but will lose strength at the welded joints. Truss manufacturers overcome this problem, but your typical scenery contractor does not have the required facilities.

What is interesting about the material from a sustainability perspective?

While it can be recycled using renewable electricity in electric arc furnaces, recycling is energy-intensive. Designers should advocate for metal reuse over recycling and avoid landfill or incineration at all costs. Steel-framed decks are a perfect example of metal's versatility. Other modular products that include metal (available for hire or reuse) include lighting trusses, tab track, castors, scaffolding, handrails, staircases, and modular structural systems.

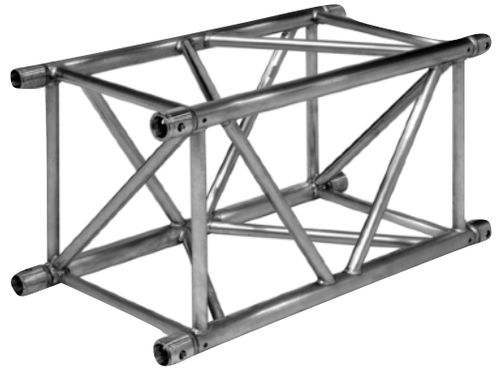
What about weight?

It is easy to make things too heavy with steel, but a well-designed steel structure can be lighter than the equivalent timber structure. However, facing a structure with sheet steel would be very heavy, so plywood is usually used for the final facing and scenic finishes. Those two materials must be disassembled at end-of-life so the steel can be recycled.

Reusable metal products and services

The linear nature of most scenery procurement (see circular economy section) makes it hard to use reusable products outside of producing theatres. Part of the solution is to work with contractors who will take back their hardware; some rigging companies have circular business practices; some rigging companies already have circular business practices and recover installed hardware for reuse.[4]

'Designers should advocate for metal reuse'



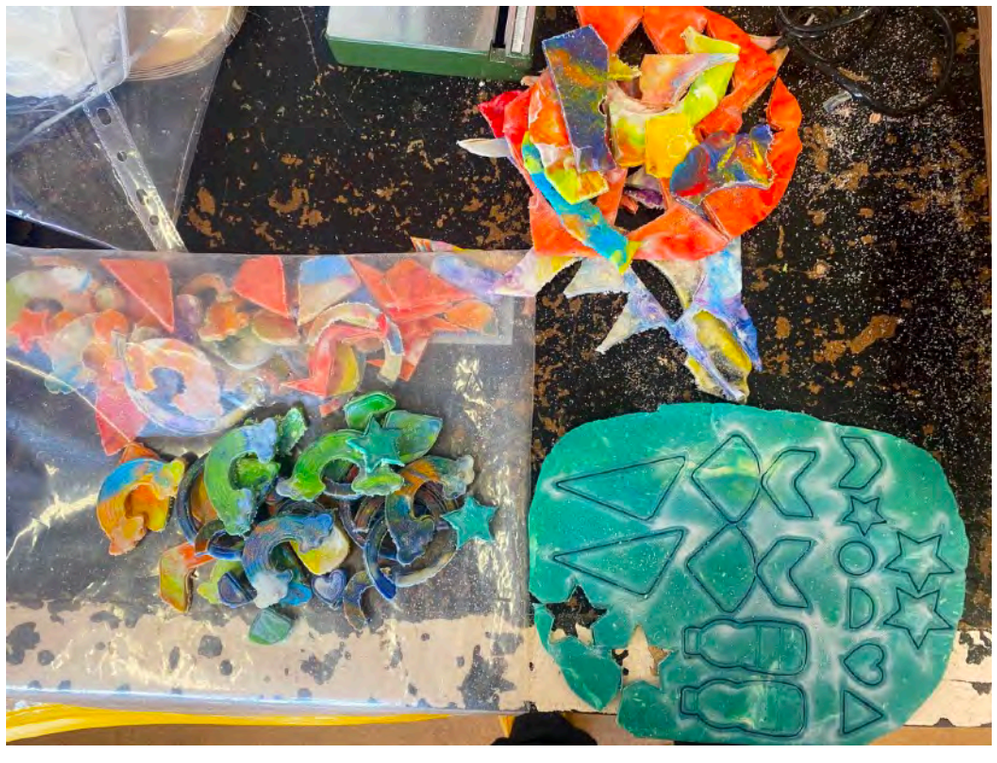
An aluminium truss can support scenery, but competent technicians are needed to design a lifting plan.[4]

Steel-framed decking is a fantastic modular scenery product all designers should be familiar with. The wooden top is replaceable during the lifetime of the frame.[5]

Modular structural systems can bolt together to make larger structures (left). The weldability of metal lends itself to intricate sculptures, such as 'Domain XV' by Antony Gormley (right).[6][7]

Working with HDPE Plastics

researched by Maria Terry



Experiments in melting and moulding by Maria Terry to create accessories. For more info see ‘Pretty Rubbish’ from Maria Terry Design: https://mariaterrydesign.co.uk/shop/

Though plastics should be phased out of usage in theatre design due to their high embodied energy, the health and environmental risks they pose, and the lengthy time they take to biodegrade, it is important to know what to look for when using plastics and how to use them carefully within theatre design as some plastics are significantly better than others. Choosing the right plastics, up-cycling them and reusing them multiple times, can be part of a sustainable design strategy.

HDPE Plastic (High density polyethylene) is 100% recyclable and is less harmful than other plastics in terms of toxic content, however it still would act as a pollutant if disposed to landfill and finds its way into the water system.

A good way of taking HDPE out of circulation is to collect any plastic bottles or caps with a ‘2’ inside the recycling logo on the base. Once melted down and pressed at 180-200° the plastic becomes a very versatile, sandable, cuttable, waterproof, colourful sheet material. Note that when sanding, plastic particles can get into the air unless extracted and collected.

It can be made into props, homewares and accessories with a variety of forms and colours. It can range from simple baking in the oven to more specialist moulding and tooling for more complex shapes.

‘Brothers Make’ and Peter Brown have useful youtube channels showing tutorials for melting and remaking HDPE plastic. They blend the plastic into a mixture before baking or microwaving. Protective gloves should be worn when melting and baking parchment should be used on top of oven trays. There are also courses available where you can learn how to make with recycled plastics, such as Derby Museum of Making.

Channels referenced: https://www.youtube.com/watch?v=-igxhoGEQFU and https://www.youtube.com/watch?v=kUR6_bQLU-E

Plastic Recycling Resin Symbols Explained

1 PETE
- Polyethylene terephthalate
- recyclable

2 HDPE
- High-density polyethylene
- recyclable

3 V
- Polyvinyl chloride
- not easily recycled

4 LDPE
- Low-density polyethylene
- only recycled by specialist companies

5 PP
- Polypropylene
- recyclable

6 PS
- Polystyrene
- not easily recycled

7 OTHER
- Other plastics including acrylic and polycarbonate, nylon and fibreglass
- not easily recycled

Types 2, 4 and 5 are considered the safest to use though all plastics have potential health and environmental risks.

Working with Plants

researched by Adam Washiyama Shulman

Overview

Live and harvested plants possess a visceral materiality serving far beyond decorative set dressing. Bringing a representative of the outdoors onto the stage presents a lively encounter beyond the brief timescale of a performance. A design with a “plant's-eye-view” can present living organisms as additional characters with their own needs. The tangible aroma, taste, touch, and sound of raw materials enhance a play world while eliminating the wasted energy of metal/foam/processed wood structures.

Trees from the Adirondack Mountains in Upstate New York driven down to Broadway (Come From Away, 2017)

Ethical Harvest

Which plants are renewable resources? Which require high embodied energy to incorporate? Byproducts of agriculture (corn stalks, straw), stewardship (thinned trees, uprooted invasive species), and climate (wind-snapped limbs, flowers picked before frost) are all non-disruptive sources of material with distinct onstage presence. Consider the cultural and economic implications of chosen species while engaging their distinct material qualities – if Birnam Wood needs to march toward Dunsinane, fast-growing invasive shrubs could provide a thick cover; vines can be woven structurally; or perhaps “pest” plants in the theatre’s region might be a source of medicine in their original habitat. The downsides of harvesting plants - the theatre may require spraying insect repellent; leaves dry quickly and crumble; wilting limits flowers to shorter runs; transporting heavy tree trunks demands energy. Positives: nature does beauty better.

Source of Images: Adam Shulman, BIOphelia, 2024, https://adamshulman.art/theatrical-design;
Henriette Hübschmann, Your Palaces Are Empty (All We Ever Wanted), 2024, https://www.hansottotheater.de/spielplan/monatsplan/eure-palaeste-sind-leer-all-we-ever-wanted/3072/;
Beowulf Borrit, Come From Away, 2017 https://www.beowulfborittdesign.com/broadway/come-from-away ;
Max Reinhardt, A Midsummer Night’s Dream, 1934, https://www.latimes.com/entertainment-arts/story/2022-06-02/midsummer-nights-dream-history-hollywood-bowl-2022

Reused plastic sheets pierced by an ivy: a focused vision of nature reclaiming a human world (Your Palaces Are Empty, 2024)

Life Onstage

The living plant presents an opportunity to extend the supportive reach of a theatrical production through collaboration with a local florist or botanic institution. Depending on the duration and season of a production, the limitations on a plant’s health is critical. A potted plant implies the need for a caretaker’s active interaction with the set, either during the performance or by the crew. Aesthetic considerations include hiding the pot and incorporating growth lights into the lighting design: see the 2024 carbon-neutral production of Your Palaces Are Empty (All We Ever Wanted) featured a single striking cultivated curtain of ivy illuminated by clean energy. But be careful when choosing scale over specificity: consider the classic 1934 Midsummer Night's Dream, when massive oak trees, sod, and foliage were transported 30 km to the Hollywood Bowl for a week’s spectacle. An ideal alternative is to bring the work outdoors toward longer-term site-specific garden design as public art!

The pastoral set of 1934’s A Midsummer Night’s Dream was illuminated by 30k fairy lights, with a special transistor to bear the power

Working with Waste

researched by Hamish Muir

Working with waste as waste can equally be a creative and powerful way to use scenography to make comment on the issues of global waste management and pollution on land and in the oceans, such as the 2017 work of Fabrice Monterio (above.)

Scavenging

Designers often have to be scavengers. Building relationships with businesses that have a desirable waste by-product can offer a free supply of material to be used in design work. Much as this might avoid materials going to landfill, making sure materials can be reused or deconstructed back to their raw state after they have been up-cycled will avoid them being disposed of in the future.

Aesthetics of Waste

There are a variety of different aesthetics that can be achieved with waste materials, ranging from scenic elements that have a patchwork, conglomerated quality, to those which mimic the original form of the material before it was disposed of. The combination of materials can make for some unexpected and imaginative designs. The second-hand aesthetic can sometimes be undesirable but we would suggest that embracing the materials for what they are can help to change what is meant by ‘high production value’. Much of scenic art is about making new materials look old or making materials mimic other materials and so those processes can breath new life into waste by-products.

Source of images: The Wave, installation by Maria Phillips. source: https://www.heraldnet.com/life/trash-gets-an-artistic-transformation-at-schack-art-center/ and Enza by Jan Hopkins, Art of Recycling exhibition at the Schack Art Center source: https://www.heraldnet.com/life/trash-gets-an-artistic-transformation-at-schack-art-center/ and Fabrice Monteiro - The Prophecy source: https://www.theguardian.com/artanddesign/gallery/2017/jun/16/gods-of-garbage-fabrice-monteiro-the-prophecy-polluted-environment-in-pictures

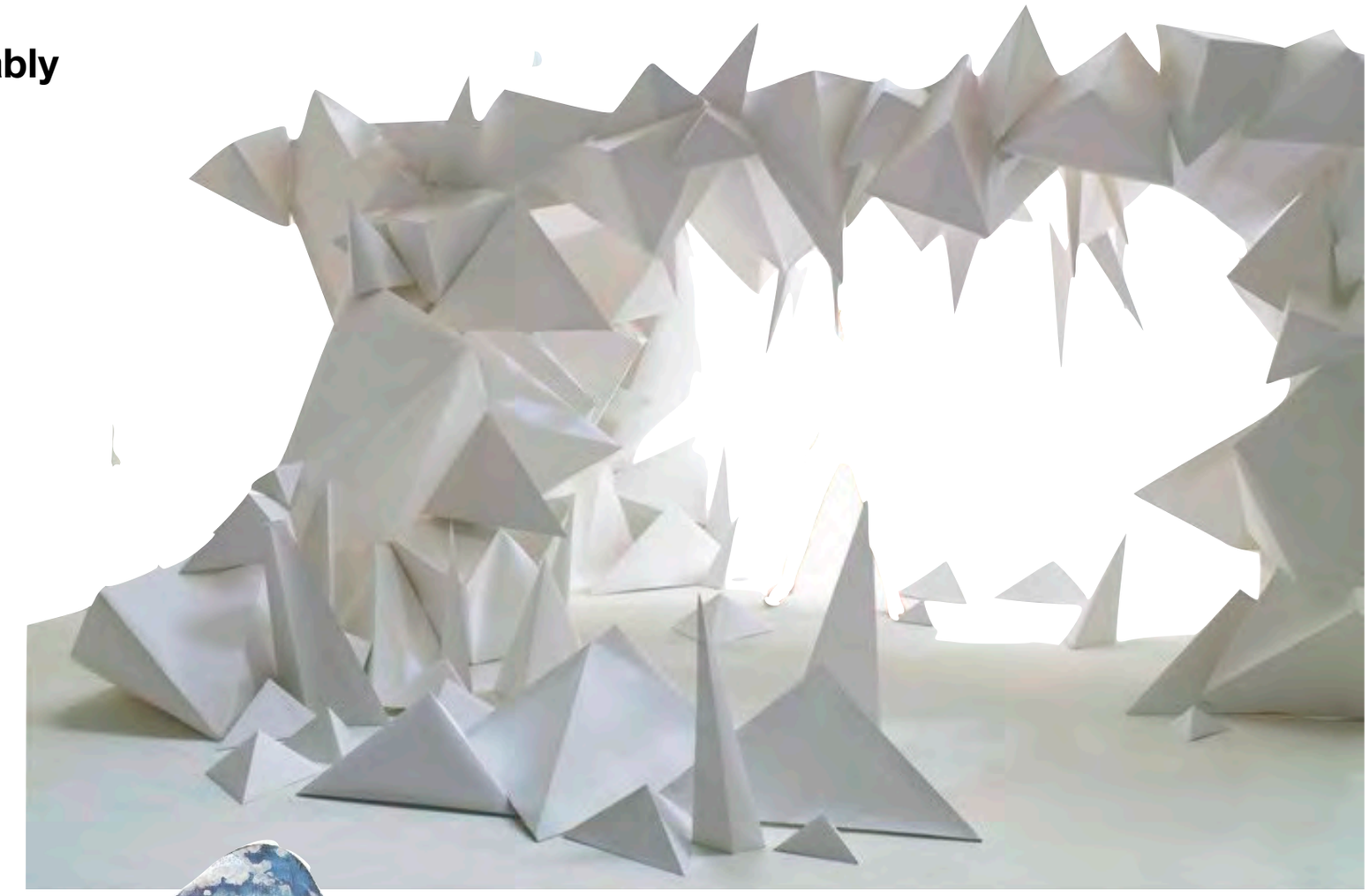
Touring Materials Sustainably

researched by Hamish Muir

Ideally a designer would plan their design based on the transport available to take their materials and equipment. For example, if a design was made to collapse into the cuboid shape of a van, then it would optimise the use of the space. This is sometimes not possible and so thinking about making the set design collapsible can help with conserving space for both storage and transport.

John Byrne's set design for 'The Cheviot, the Stag and the Black, Black Oil' (below), was in the form of a pop-up book, meaning it could hold multiple sets whilst being easy to transport. The way the set was constructed fitted with the storytelling of the performance. A set design with a built-in deconstructive mechanism can be an interesting way to tour set designs, but also for the set designs to be performative elements in theatre themselves.

Source of images: origami design - https://designformankind.com/wp-content/uploads/2010/11/origami-fashion-2.jpg https://designformankind.com/2010/11/inspired-by-22/origami-fashion-2-2/ and John Byrne stage set of The Cheviot, the Stag and the Black, Black Oil (1973) source: https://www.bbc.co.uk/news/uk-scotland-tayside-central-44453100 and https://www.creativeboom.com/news/scottish-artist-john-byrnes-giant-pop-up-book-sets-the-stage-for-va-dundee/



Folded forms, such as origami, can produce interesting scenic shapes on stage. Paper, card, and wood products are the materials used most often for these sorts of designs as they need to be light-weight to be moved but also robust enough to remain undamaged. Tent or balloon structures are also a good means of using materials that can fill a large space but also are collapsible.

If folding mechanisms are not possible, other techniques for touring materials sustainably include researching materials that are available at each venue so they can be used when on site without transportation between venues; projecting augmented reality elements can reduce the amount of physical material transported; and using materials that disappear, such as dissolvable (or even edible!) structures avoids materials being transported between venues.

Storing Materials Sustainably

researched by Hamish Muir

There are four principles that we would like to suggest for making an efficient storage work sustainably.

Separating

When materials are conglomerated together, this is when they become less versatile and often end up being disposed of. Keeping material streams separate can help to manage what materials are used more than others. This goes for waste streams as well. Separating waste by-products will mean they are more likely to be reused than if contaminated with other substances.

Cataloguing

Many theatres are now employing systems of cataloguing their material assets. Simply giving materials a name raises their value. This is important for a range of reasons (economic, logistical and environmental). In terms of sustainability, it can mean that other theatres can borrow items more easily and designers can draw on existing materials for inspiration or direct use in their own stage designs. One of the issues with reusing set design elements is that they tend to be very bespoke and specific to the production they were made for, however, by categorising materials, similar items can be grouped together, which means that shared properties will become more apparent.

Locating

Defining specific locations and infrastructures for different types of materials can encourage reuse networks to grow organically and designate, purposeful space to store and manage materials. Making sure that materials are accessible to different makers within the theatre production process (such as locating spare wood in the carpentry workshop or spare cardboard near property or model makers) will avoid many materials being thrown away. The location and its environmental conditions are also important to make sure that materials don't degrade and become unusable whilst in storage.

Curating

Unfortunately, we can't keep everything. It is better to have a working storage of items that are accessible and reusable than an overflowing scrapheap of items that are hard to identify. The level of material abundance and ordering will differ depending on preference and available storage space. The design of the store itself can be an interesting creative opportunity, designing theatre's own cabinet of curiosities.

Formafantasma produced a timber storage as an art installation at the Serpentine Galleries in 2020, celebrating the materials in their raw state.

Photo credit: George Darrell source: https://www.serpentinegalleries.org/whats-on/formafantasma-cambio/#art-and-ideas

The new Green Store initiative set up by the National Theatre to encourage the reuse of sets and props in theatre industry.

Photo credit: https://www.nationaltheatre.org.uk/news/welcome-to-the-green-store/

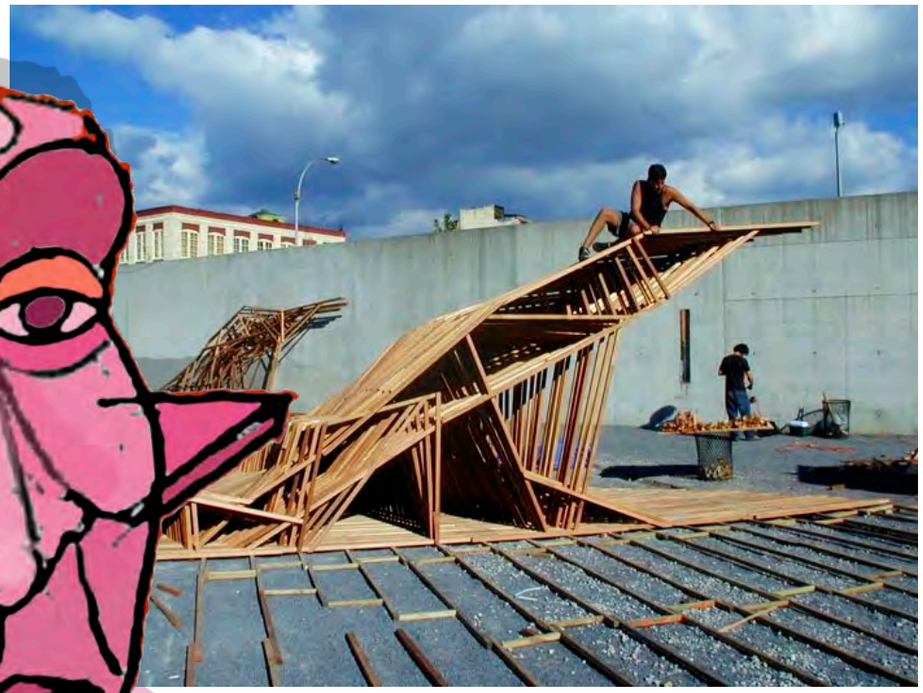
Modularity and Adaptability

researched by Hamish Muir

Modularity

An important part of modular design is making sure that different material systems remain separate (or at least separable) from each other. For example, keeping lighting and electric leads unattached or detachable using mechanical fasteners would be important for use and reuse. A clear and strong method statement for deconstruction needs to be in place at the beginning of the process alongside the preservation of the original construction drawings.

Parametric design is an approach used in architecture which can help designers to find a modular unit which is repeatable (such as the structure made from the same repeating element in the images on the right). It's important to find a simple shape that can be duplicated many times and constructed together to make a complex structure, like a jigsaw or tessellation pattern. The Beijing Olympic Stadium, the Bird's Nest, was designed using these principles. Like Lego bricks, the advantage of this design approach is that different sets can be made from the same constituents meaning that a designer can create different sculptural shapes for the stage from the same material components.



Adaptability

Adaptability is a similar but distinct approach to modularity. Using lightweight, movable materials with a simple geometry can help with building versatile structures. A scenic element that can be folded out so that it looks and behaves differently depending on its orientations and its level of assembly can offer a variety of scene changes to a production. The sketch on the left shows a scenic element of a totemic face that has multiple purposes depending on its orientation on the stage and if certain parts are folded or unfolded to reveal new interior spaces to the audience. The set design is treated almost like a children's toy set with different elements that can be added or subtracted depending on the particular production.

Source of images: MOMA Dunescape by Shop Architects, source: https://www.shoparc.com/projects/dunescape/ and collapsible bamboo structures http://thesis.arch.hku.hk/2015/2015/12/22/the-folding-bamboo-archtecture/

Illusionary and Minimal Materials

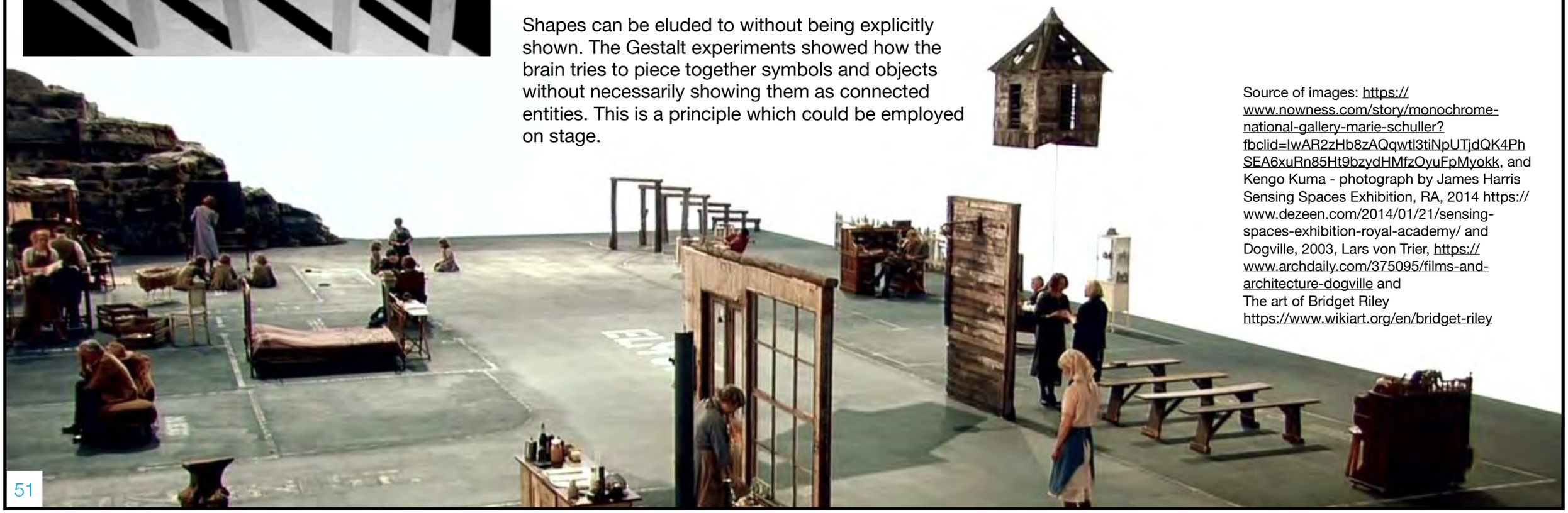
researched by Hamish Muir

Thinking about the stage space in terms of focal points, suggestions, and the relationship with the audience's perception can help to minimise the amount of scenographic materials without the theatre production seeming sparse. Establishing a real or suggested horizon line is a good place to start as designers can then play with how an audience receives that horizon using shadow, mirrors, contrasting colours, and curved surfaces. Two dimensional images which are incongruent with the horizon line can be perceived as being three dimensional, such as the image of the wooden posts on the left, however this depends on the angle that the audience are looking at the performance. Depth can also be created by making objects smaller than they are in reality. This is an illusion known as 'Shepard's terror'.

Colour tones are perceived in relation to each other which can be played with in terms of background and foreground and how colours are overlaid on each other. Highly contrasting colours can give a sense of movement or undulation.

Shapes can be eluded to without being explicitly shown. The Gestalt experiments showed how the brain tries to piece together symbols and objects without necessarily showing them as connected entities. This is a principle which could be employed on stage.

Minimal materials does not need to mean low production value. Thin, wire-like materials (such as the installation above) can fill a space using a limited amount of material. Minimal materials may also be a stylistic choice by a designer or director, such as Lars von Trier's 2003 film 'Dogville' which is set on a theatre-like stage. The illusion of the location is part of the thematic content of the film.



Source of images: https://www.nowness.com/story/monochrome-national-gallery-marie-schuller?fbclid=IwAR2zHb8zAQqwtl3tiNpUTjdQK4PhSEA6xuRn85Ht9bzydHMfzOyuFpMyokk, and Kengo Kuma - photograph by James Harris Sensing Spaces Exhibition, RA, 2014 https://www.dezeen.com/2014/01/21/sensing-spaces-exhibition-royal-academy/ and Dogville, 2003, Lars von Trier, https://www.archdaily.com/375095/films-and-architecture-dogville and
The art of Bridget Riley
https://www.wikiart.org/en/bridget-riley

Technology and Sustainable Materials

researched by Hamish Muir

Whilst a lot of high tech solutions come with energy demands and material extraction for making hardware, there are existing and emerging technologies that can help designers to optimise and improve the sustainable efficiency of their work and material choices. These technologies should not replace the craft of practical scenic effects, puppetry, lighting, matt painting and miniature model making etc. but they can compliment a hybrid approach between digital and material design.

Pre-visualisation programs, LIDAR, and building information modelling (BIM) can be useful tools for planning construction and deconstruction sequences and retaining spatial data about materials, including carbon footprints. LIDAR can retain spatial and material information about a performance, which would be a useful archive to learn from.

Image and video editing software and CAD programs, such as Blender or Sketch-up, can also be useful tools to offer quick virtual spaces to play with the aesthetic of a design or express the atmosphere of an environment without having to build separate physical models. Artificial intelligence programming is increasingly becoming ubiquitous in many industries. It can speed up processes but it cannot replace them. A.I. poses many issues regarding intellectual property, particularly in the creative industries, so it must be used with care, but it can be a tool for generating additional information that may help inform design decisions, alongside traditional methods.

Augmented or virtual reality equipment can help to make a minimalist stage look materially abundant. ‘The Tempest’ produced by the RSC in 2016 used motion capture technology. However, the issue with this sort of production is the interface between digital material and real material. There is an issue with tangibility and realism. Whilst theatre need not always be naturalistic, projecting images on to different materials or using real materials alongside virtual or augmented realities is an interesting area for experimentation as it could mean the same materials are reused many times over and can minimise transportation footprints for touring.

3D printing has the potential to be a sustainable option (albeit it still requires a lot of energy to run). If the constituent materials used to make models in 3D printers become more environmentally friendly and can be broken back down into pellet form to be remanufactured into another set design, then the same materials could be used many times over to produce different forms on stage. Prop Shop at Pinewood Studios specialise in using 3D printers for props and sets.

3D printing, Virtual Realities and Artificial Intelligent Design come with their own aesthetics which would not suit many forms of theatre and they are far from being a catch-all solution to environmental problems in theatre but designers can build them into their process to help with choosing, minimising, optimising, reusing, refining and archiving materials.

Source of images: ‘Zauberflöte' computational architecture set design, Michael Hansmeyer http://www.michael-hansmeyer.com and ‘The Tempest’ RSC, 2016, https://www.nytimes.com/2017/01/04/theater/at-this-tempest-digital-wizardry-makes-rough-magic.html

Site Specific Materials

researched by Hamish Muir

Regenerative Design

In terms of using materials on a site, designers should consider how materials affect their surroundings and can be used to enhance and regenerate the site. This can be through adding new long term, non-toxic structures that improve biodiversity like bird and bat houses, clearing harmful materials from the site, using materials to conserve parts of the site, or planting or cultivating new materials. Ecoscenographer Tanja Beer's 'The Living Stage' project in 2017 cultivated a new community garden during the course of her production, which left a positive legacy. As mentioned in the Introduction, sets should either be designed for longevity and reuse or ephemerality, leaving no trace behind. Letting materials be materials, as they are, in their raw state can celebrate that material in its own right.

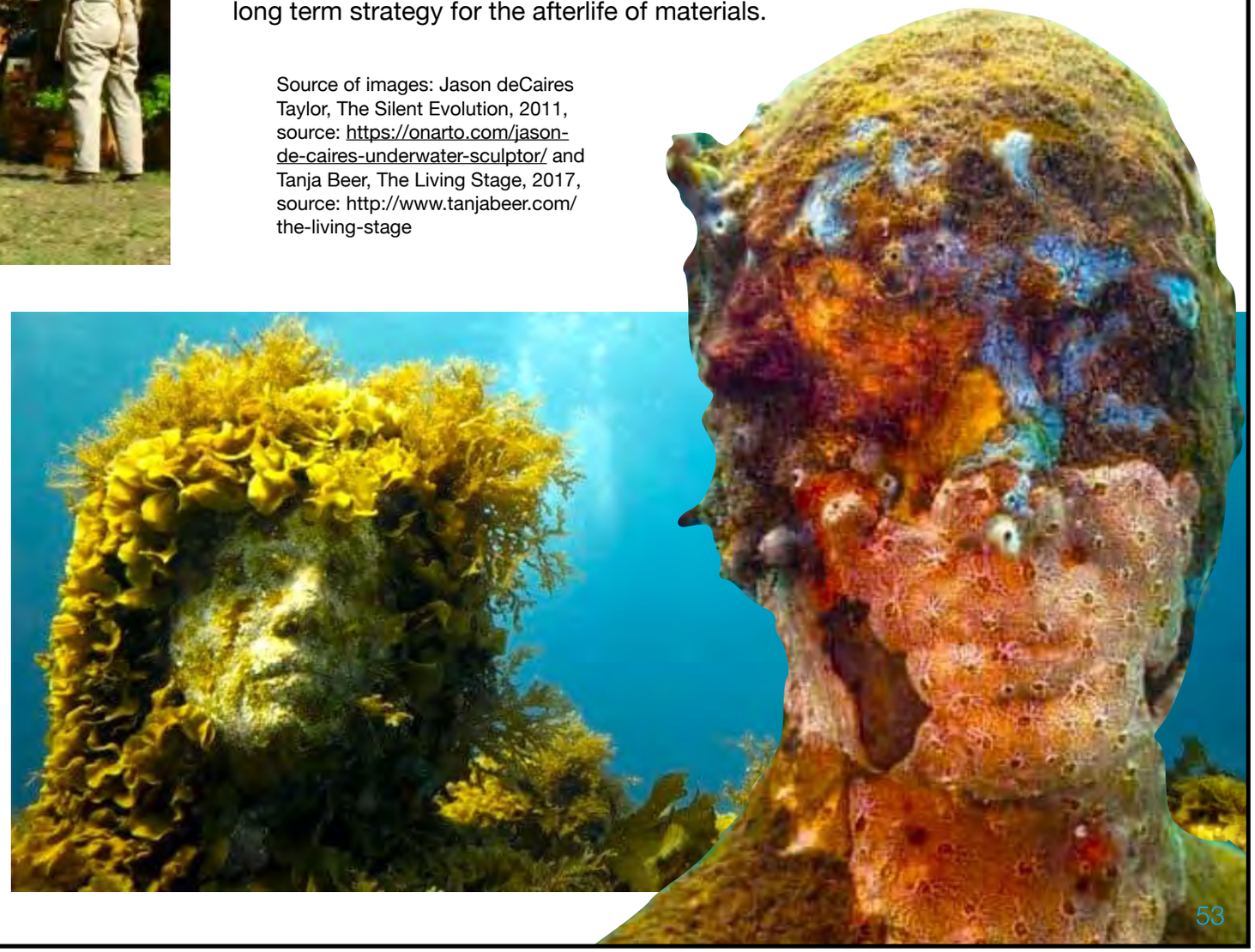
The Sustainability of Site-specific Theatre

Site specific theatre is inherently quite a sustainable form of performance because it can utilise materials without the need for extraction, transportation, storage or the creation of artificial environmental conditions. Furthermore, site specific theatre can make the environment more of an integral part of the performance, meaning that nature is not excluded from the art of theatre. However, site specific theatre is not always the most environmentally friendly option as sites can be damaged by performance, artificial set elements can still be used that poorly interface with their surroundings, and carbon costs can be hidden amongst a site that looks 'natural'.

Unexpected Sites

Unusual locations and environments might offer an interesting scenographic challenge to a designer. Jason deCaires Taylor's 2011 project 'The Silent Evolution' involved placing human sculptures on the sea bed. This acted as a very striking scenographic installation and it encouraged the growth of plants and animals in the long term. Designers may not always have the opportunity to work on the seabed but thinking about how scenography would behave in different environmental conditions can help to work out a long term strategy for the afterlife of materials.

Source of images: Jason deCaires Taylor, The Silent Evolution, 2011, source: https://onarto.com/jason-de-caires-underwater-sculptor/ and Tanja Beer, The Living Stage, 2017, source: http://www.tanjabeer.com/the-living-stage



Part Four: Paints, Glues, Varnishes and Textures

Paints and varnishes are critical when considering sustainability as they can affect the recyclability, toxicity, and biodegradability of the material they are combined with. For instance, it is a necessity to add fireproofing varnishes to some scenic materials. As with all of the materials presented so far, it is important to find a strategy of use that considers the conditions in which varnishes are applied, if they can be washed off, removed or redesigned, where and when they don't need to be used and what material source they are derived from.

Ecopaint (low VOC)

researched by Karen Hood

Material Matters

Properties	Is it fire and/or water proof?	No
	Can it be cut and/or painted on?	N/A
	Is it strong, durable, soft, brittle or flexible?	Durable and washable, interior and exterior quality
Uses	What is the price bracket (at time of publication)?	£23.99 per litre for white £29.99 per litre for colours
	What could it be used for in theatre design?	Paint finish
Sustainability	Does it contain toxins?	Some silicates can be mild irritants so handling and disposal are important
	Is it recyclable?	Yes in theory, as it contains no micro beads - pots are also recyclable
	Does it have a high embodied energy?	Medium - it requires some energy to manufacture but some limestone based paints absorb carbon during curing
	Is it biodegradable?	Not completely
	Where is it manufactured?	UK suppliers but some raw materials may be imported

Material Composition

Ecopaints currently on the market contain silicates, graphene and limestone or chalkstone. Many of these materials are better alternatives to the plastic based raw materials used in other paints. However, checking how certain stones are quarried is important for sustainability in terms of the amount quarried, the energy required to quarry and the distance raw materials have travelled to the manufacturer.

Volatile Organic Compounds (VOC)

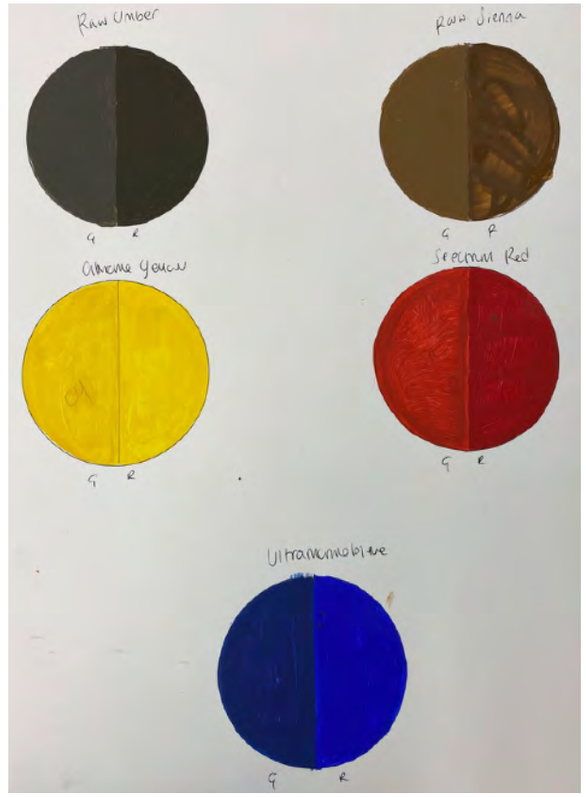
Low VOC paint is an important signifier to look for when thinking about sustainable paint alternatives. Volatile organic compounds are chemicals present in certain materials that evaporate in air. They can cause respiratory health issues. VOCs can be found in paints and fossil fuels. They also occur naturally, such as those produced by household moulds. VOCs are found in the solvent material in paint (the material which is used to dissolve in the paint-making process). Water based paints have low or no VOCs. Information concerning low VOC is certified to the brand so this can be checked.

Limestone based paints

Some paints which use limestone as a raw material can absorb carbon dioxide during the curing process. Limestone releases carbon dioxide when it is heated for paint production but it absorbs carbon dioxide in the atmosphere when it is drying, which reduces its overall carbon footprint. This means the footprint is significantly less compared to other paints.

Usage in theatre

Limestone based paint is a great alternative to 'off the shelf' coloured emulsions that contain plastic and other harmful chemicals but some of the colours are not as vibrant to popular brands of scenic paints, though this may change in the future.



Colour testing showing pigment strengths of eco-paint compared to other brands, showing that eco-paint is fainter

A Comparison of Homemade Casein Paints

researched by Paul Burgess

Why mix your own?

Some casein paints come ready-mixed in tubs to a consistency for immediate use. These tend to produce a consistent matt, waterproof finish. Various ranges of artists' casein paints are also available in tubes, although they come in quantities too small for most scenic painting.

None of these paints are cheap, however, and they also tend to contain additives, which sometimes cause irritation.

As many scenic uses do not have to last long, additives to protect from, for example, mould may not be required. This means they can be produced with non-toxic ingredients at home at a much lower cost than buying ready-made products, and with better biodegradability. Three mixes were tested for the guide.

The pigment used in the tests is from Florence Mine, Egremont, Cumbria.

Left to right: ammonium carbonate, bicarbonate of soda and borax, with a silk glaze applied to the top half of each sample.

Comparison

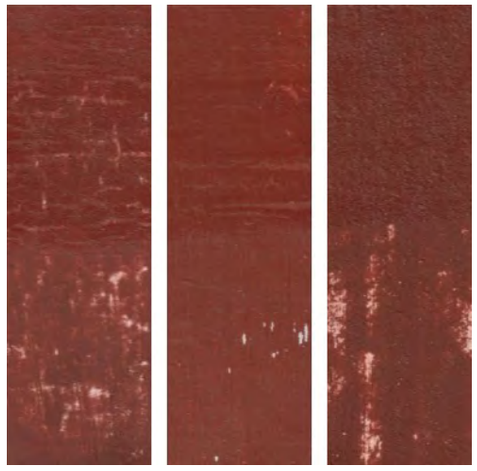
Ammonium carbonate is unpleasant to work with and requires ventilation, so it is not ideal. It can also be a skin irritant. It was easy, if unpleasant, to mix. A few grains were still present even after vigorous mixing and leaving it to stand. Also, the ammonia smell is retained; it should only be used in well-ventilated spaces. The recipe was from Cornelssen & Son, which is also where the Ammonium carbonate was sourced. More experimentation on ratios of ammonium carbonate to casein could create a very usable paint.

The **bicarbonate of soda** was very hard to mix. The first recipe, which was found on Pinterest, was too dry and rose slightly, like an apologetic muffin. With water added, it didn't smooth out; it just became lumpy and was initially impossible to paint with. After leaving it standing for a couple of days, however, it settled into quite a smooth, usable paint. It delivered the lightest hue of the three. It is worth further experimentation as it's also the cheapest and has no irritation or toxicity issues.

The **borax** needs to be mixed with hot water and allowed to stand for an hour. It mixes well but settles slightly over time, so it needs remixing before use. The recipe, which came from caseinpainting.blogspot.com, is not quite right yet, as some of the borax formed lumps that had to be removed. But it was not unpleasant to mix and easy to paint with. It needed to be painted quite thickly, one layer at a time, to get a good opaque finish, and it is darker and more matte than the others, with a slight glitter. Borax is toxic to humans, but only in large quantities.

Waterproofness

They all had sufficient water resistance to be over-painted after a few hours, when they were touch-dry. I also tried cleaning them with a wet cloth, but this took a lot of the paint off. The glazed sections fared much better. After a couple of days of further drying, however, even the unglazed sections stood up to cleaning much better, with only a small amount of paint loss (see picture). The bicarbonate of soda mix seemed most robust. With a bit of work improving the recipe, perhaps waterproofness can be increased. Note that there was some cracking in the glaze, perhaps because a heater was used to speed up the drying process.



The same samples as shown on the left after being scrubbed with a wet cloth.

Conclusion

Overall, commercial versions are a potential replacement for acrylic paints for detailed work but are too expensive to replace mineral paints as an alternative for area coverage. There's also an argument about whether replacing petroleum-based paints with dairy-based paint is much of an ecological improvement, given dairy's impact on the environment. And they're not necessarily toxin-free. However, home-made versions are affordable and fine for less robust requirements.

However, there is a lot of potential for toxin-free homemade versions. This guide cannot yet confidently provide a recipe that is robust without using a glaze, but watch this space…!

Biodegradable Glue

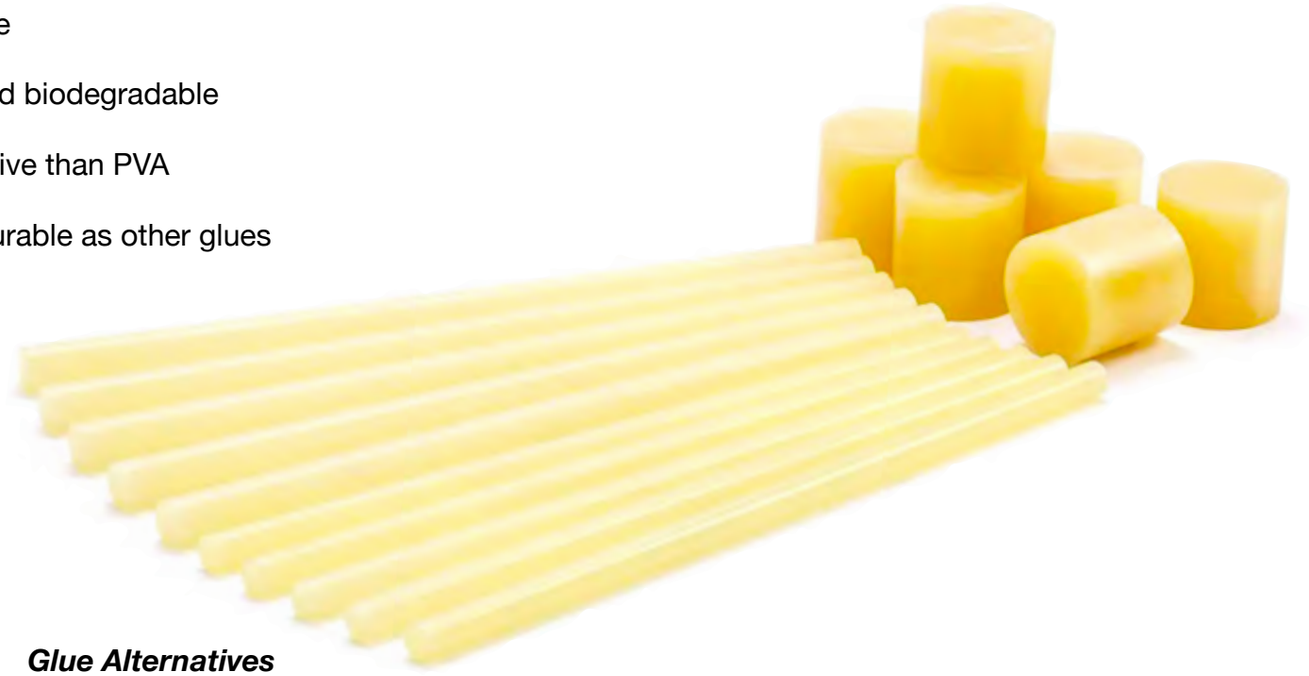
researched by Arianna Mengarelli

👍 Ready for use

👍 Non-toxic and biodegradable

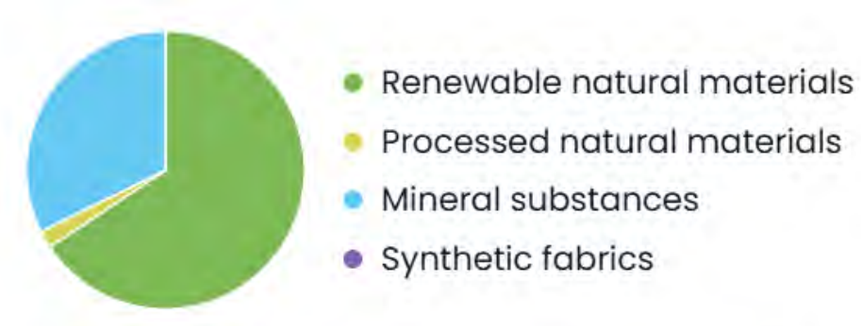
👎 More expensive than PVA

👎 It is not as durable as other glues



Material Matters

Properties	Is it fire and/or water proof?	It is water resistant
	Can it be cut and/or painted on?	N/A
	Is it strong, durable, soft, brittle or flexible?	N/A
Uses	What is the price bracket (at time of publication)?	1 kg = 23.90 € 5 kg = 82.90 € (17.18 € / kg) 10 kg = 155.90 € (15.50 € / kg)
	What could it be used for in theatre design?	Glueing: carpet, wood, moldings, fabrics, sheet materials, tiles
Sustainability	Does it contain toxins?	Non-toxic
	Is it recyclable?	No
	Does it have a high embodied energy?	No
	Is it biodegradable?	Yes
	Where is it manufactured?	Germany



Auro 380 Glue Ingredients

This particular glue product includes water, mineral fillers, natural rubber milk, rosin glycerin ester, linseed oil, milk casein, cellulose, swelling clays, potash, benzisothiazolinone, and sodium pyrithione. Above is a pie chart showing the proportion of material sources, ranging from raw natural materials to synthetic fabrics.

Glue Alternatives

Changing the types and uses of adhesives in scenographic design will be a useful method for improving sustainability as it avoids harmful chemicals entering the water system when leached from landfill and it can bond materials together without destroying the potential for reuse and in some cases recycling.

Hot Melt Adhesives

There are a variety of products being developed including hot melt adhesives, which can be used for lamination or gluing. Current examples include Kiilto Biomelt and Power Adhesives tecbond 214B (as pictured).

See https://packagingeurope.com/news/worlds-first-certified-biodegradable-hot-melt-adhesive-produced-by-power-adhesives/11599.article and https://www.kiilto.com/industry/kiilto-biomelt/, and https://news.cision.com/kiilto/r/global-interest-in-biomelt--kiilto-s-innovative-biodegradable-adhesive,c3449805

Auro 380

Auro 380 is a biodegradable, non toxic adhesive.
The natural ingredients are from renewable sources such as natural resin and rubber. This adhesive is a sustainable alternative to conventional glues which can rely on petroleum based ingredients, and contribute to poor indoor air quality.

Auro is a German manufacturer that produces sustainable paints, varnishes and glues. Available online at https://greenshoppaints.co.uk/products/auro-380-universal-adhesive?srsltid=AfmBOooqaTDqyRf55l7nYqlh0fjdQkLfrt70aCFg-9Kpwf4wcy1tuoNQ

Other natural glue producers include: https://www.greatart.co.uk/collall-nature-glue-100-ml-bottles.html and https://gurit-resins.com/wp-content/uploads/bsk-pdf-manager/2024/06/PDS-AMPRO-BIO-1-0124.pdf

Natural Dyes

researched by Max Goodman

Material Matters

Properties	Is it fire and/or water proof?	Dye should not be affected by water and the fire proofing will depend on the material being used.
	Can it be cut and/or painted on?	Natural dyes can be used as a paint substitute
	Is it strong, durable, soft, brittle or flexible?	N/A
Uses	What is the price bracket (at time of publication)?	Natural dyes can be extracted from many plants, flowers and vegetables. The prices will depend on what you are using.
	What could it be used for in theatre design?	Natural dye could be used for colouring fabrics and other soft materials which could be used for set dressing and costumes
Sustainability	Does it contain toxins?	Any mordents used to help enhance the colour can be toxic, but miner in small quantities.
	Is it recyclable?	N/A
	Does it have a high embodied energy?	low embodied energy, this process is most often done by hand using only a small amount of energy to heat the dye.
	Is it biodegradable?	left over raw dye (without any additives) is biodegradable
	Where is it manufactured?	N/A

Natural dyes were the first way in which colour was brought to life. Before the creating of synthetic dyes, natural dyes were used to create all colour for furnishing in homes (like curtains and rugs) as well as all clothing.

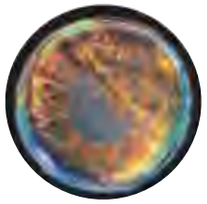
Creating colour naturally for theatre design allows for the same end result as using synthetic colours. This process allows for the negative toxins and manufacturing processes of synthetic dyes (with uses a lot of energy and creates a lot of carbon) to be removed from the design.

Image sources: https://lacreativemama.com/the-ultimate-guide-natural-dyeing/ and https://rebeccadesnos.com/blogs/journal/flower-dyes-summer-2021/

Natural dyes allow for you to explore colours through a new lens. Being able to create your own colour from scratch means you can cultivate exact shades which are unique and one of a kind. This is often not possible when working with pre-made synthetic dye as it is very concentrated and made to create one colour.

The process of making and using the dye can take time. Using natural dyes may not be possible in a theatre production with a quick turn around due to it being a slow process. Small amount of energy will need to be used to extract the colour from the chosen matter. Natural dye mordants allow for dyes to 'fix' onto a material. examples of these include alum and iron. When using these to support the dye process, toxins are added although this step is not always essential to creating colour naturally and when used in small quantities, its impact is very miner.

When done correctly, dye should not be affected by water once it has been transferred onto a material. Using natural dye to colour material does not increase how flammable the material is, weather it is fire proof will depend on the material being used.



Structural Wood-based Colours: Cellulose Nanocrystals

researched by Urs Dierker

Material Matters

Properties	Do CNCs fade?	good in indoor conditions but can degrade under prolonged UV exposure or high humidity
	What materials do CNCs work best with?	They work best on scorched wood and dark, smooth, rigid surfaces like wood, glass, or pretreated textiles
Uses	What is the price bracket (at time of publication)?	currently $200 - $1000 per kg depending on purity and preparation
	What could it be used for in theatre design?	They can enhance costumes, and props vibrant effects, ideal for close-up indoor performance
Sustainability	Does it contain toxins?	They are non-toxic but their processing may involve chemicals that require careful handling
	Does it have a high embodied energy?	CNCs have a moderate embodied energy but lower than synthetic alternatives
	Is it biodegradable?	Yes
	Where is it manufactured?	Canada, Finland, USA

Images show work completed as part of the Naturally Dramatic Project (2019-2020) by Urs Dierker at Aalto University in Finland in collaboration with the BiCMat research group led by Prof. Orlando Rojas at the Department of Bioproducts and Biosystems. The work extended to a course on biomaterials in the Department of Costume Design taught by Urs Dierker (2021) at Aalto Univeristy. All photos © Urs Dierker | Circular Costume Design

Current research suggests ***Structural colours*** from dried, wood-based **cellulose nanocrystals (CNCs)** are a non-toxic, pigment free, non-fading alternative to plastic-based iridescent colourants. The colours are pigment free because they create microstructures that refract light into a rainbow of vibrant shades.

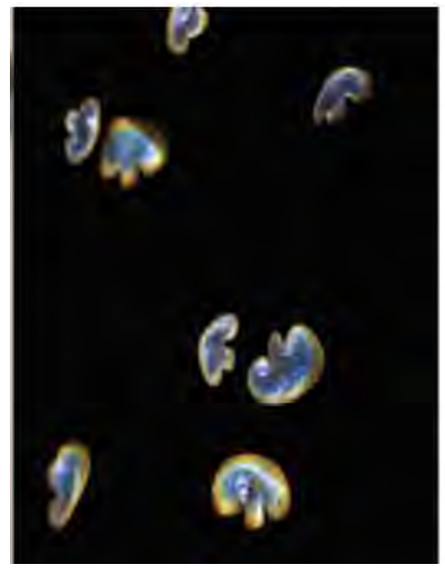
CNC based colours are a relatively new field of sustainable material research, although wood-based cellulose diffraction has been known since the 1990s. Wood pulp can be divided into cellulose-based derivates, such as Microfibrillar cellulose (MFC), Micro-crystalline cellulose (NFC) and Cellulose nanocrystals (CNCs). These can be used to create beautiful, soft, and rigid wood-based materials for sets, props and costume design.

CNCs can be made into a never dried slurry or powder. From experience, the slurry works better. CNCs are prepared using ultrasound sonication (a process that uses ultrasound to agitate particles). This process improves the diffraction process.

If not treated, CNCs can become dry and brittle. Adding glycerol can help to avoid this.

Due to the technical process to condition and create CNCs, they are not widely available as consumer products. However, it is useful to know what is being developed and what may be available in the near future. Additionally, some specialist and research groups are developing this work including Sparxell, Radiant Matter, Structural Colour Studio and CelluForce.

For more information see The Chemarts Cookbook from Aalto University (2020) and The Bloomsbury Encyclopaedia of World Textiles, Volume 4.

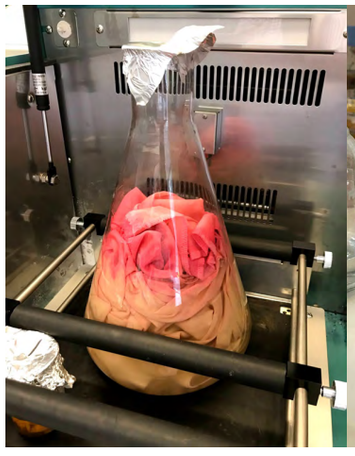


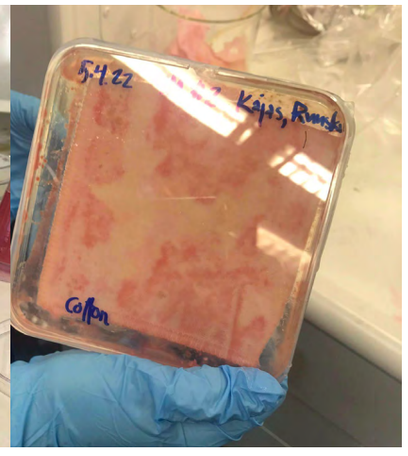
Bacterial Dye 1: Serratia Marcescens

researched by Urs Dierker

Material Matters

Properties	Does it fade?	The color fastness is relatively low, particularly in terms of lightfastness
	On what textiles does it grow best?	Serratia marcescens grows best on natural fibres, particularly those that are porous and can hold moisture
Uses	What is the price bracket (at time of publication)?	It is costly due to quality control requirements and the need for a controlled lab environment
	What could it be used for in theatre design?	It could be used as a dye for costumes, ideal for indoor or short-term applications
Sustainability	Does it contain toxins?	It can produce toxins and poses infection risks, requiring careful handling in controlled environments
	Does it have a high embodied energy?	It has a relatively high embodied energy, due to the specific environmental controls and sterilisation
	Is it biodegradable?	The pigment prodigiosin produced by Serratia marcescens is biodegradable
	Where is it manufactured?	It is typically cultured, rather than mass-manufactured, in specialised laboratory settings





Images show work completed as part of the Naturally Dramatic Project (2019-2020) by Urs Dierker at Aalto University in Finland in collaboration with the BiCMat research group led by Prof. Orlando Rojas at the Department of Bioproducts and Biosystems. The work extended to a course on biomaterials in the Department of Costume Design taught by Urs Dierker (2021) at Aalto Univeristy. All photos © Urs Dierker | Circular Costume Design

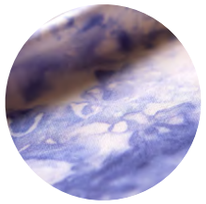
Serratia marcescens is a rod-shaped, gram-negative bacterium commonly found in diverse environments, including soil, water, plants, and animals. Known for its distinct red-pigmented colonies, produced by the pigment **prodigiosin**, S. marcescens has attracted scientific attention for its unique characteristics and its role as an opportunistic pathogen. Prodigiosin, the red pigment produced by S. marcescens, has strong dyeing properties that bond well with natural fibres. This naturally occurring red pigment belongs to a group of compounds called pyrrole pigments. One challenge with prodigiosin is its limited lightfastness. Although it produces a vibrant red to pinkish hue on textiles, this colour tends to fade with prolonged sunlight exposure.

Prodigiosin can shift depending on the pH level, showing different shades of red under acidic and alkaline conditions. This makes prodigiosin a pH-sensitive dye, allowing it to change colour when adjusting the pH of the dye bath or post-treating the fabric with a mild acid (such as vinegar) or a mild base (like a baking soda solution). In acidic environments, prodigiosin appears in shades of bright red to reddish-pink, maintaining its characteristic vibrancy. Under alkaline conditions, prodigiosin's hue shifts toward a duller, purple or brownish-red tone.

While S. marcescens naturally occurs in various habitats, including moist environments like bathrooms, it is associated with hospital-acquired infections. Handling S. marcescens requires strict safety protocols due to its association with infections and antimicrobial resistance. Essential protective measures include using personal protective equipment (PPE) such as gloves, lab coats, and face masks to prevent direct contact and inhalation. Work should be conducted in a sterile environment with surfaces disinfected using bleach or ethanol to minimise contamination. Waste materials must be treated as biohazardous and disposed of appropriately, followed by thorough handwashing.

To use S. marcescens in textile dyeing, natural fibres are pre-sterilised and inoculated with the bacterium in a nutrient-rich environment, allowing it to grow and produce prodigiosin directly on the fabric. After 24–48 hours, the fabric is treated to kill the bacteria. This leaves the red pigment and removes the health risk. Applying a mordant, like alum or vinegar, can improve pigment retention on the fibres.

Though this is a material that can only be handled in controlled laboratory settings and is not widely available, it is useful designers if they wish to collaborate with material scientists and to be aware of experiments in this area of research.

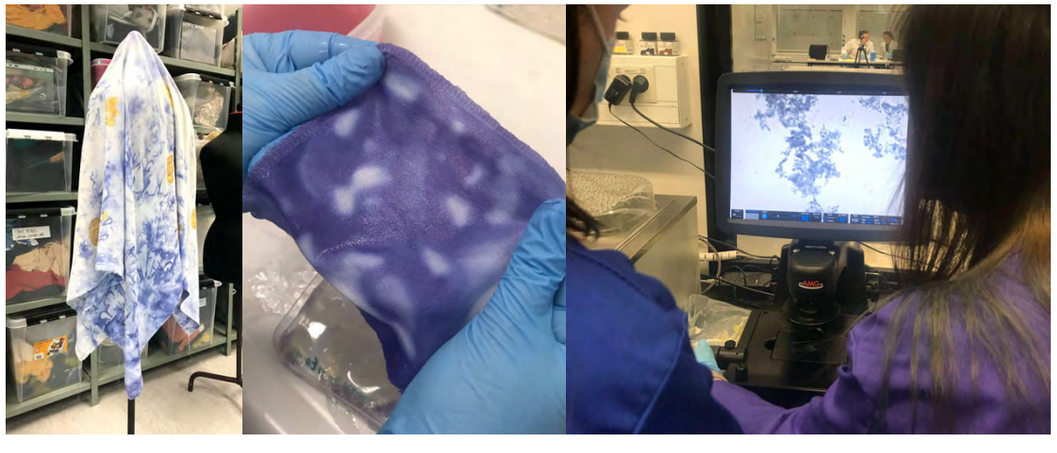


Bacterial Dye 2: Janthinobacterium Lividum

researched by Urs Dierker

Material Matters

Properties	Does it fade?	It has moderate colourfastness on fabrics like silk, wool, and cotton
	On what textiles does it grow best?	It is particularly effective for dyeing textiles like silk, wool, cotton, nylon, and polyamide
Uses	What is the price bracket (at time of publication)?	Using J. lividum for dyeing textiles is relatively costly, primarily due to the expenses of cultivating and extracting its violacein pigment in sufficient quantities
	What could it be used for in theatre design?	J. lividum could support a sustainable approach to costume and set design
Sustainability	Does it contain toxins?	Violacein, can be toxic under specific laboratory conditions. However, in textiles or controlled applications, violacein's toxicity is minimal
	Does it have a high embodied energy?	Low - it can be cultivated at relatively low temperatures and doesn't demand harsh chemical processes
	Is it biodegradable?	Violacein, the pigment produced by J. lividum, is biodegradable
	Where is it manufactured?	It is not readily available - companies like Vienna Textile Lab and Colorifix work with bacterial pigments



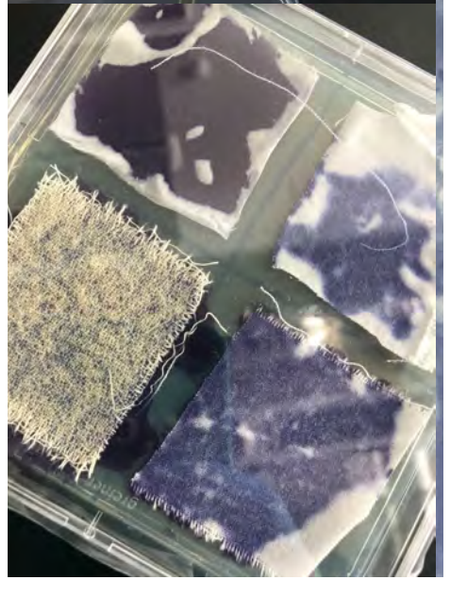
Images show work completed as part of the Naturally Dramatic Project (2019-2020) by Urs Dierker at Aalto University in Finland in collaboration with the BiCMat research group led by Prof. Orlando Rojas at the Department of Bioproducts and Biosystems. The work extended to a course on biomaterials in the Department of Costume Design taught by Urs Dierker (2021) at Aalto Univeristy. All photos © Urs Dierker | Circular Costume Design

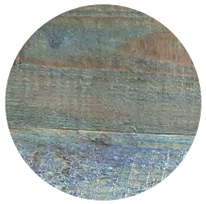
Janthinobacterium lividum (J. lividum) is a Gram-negative bacterium known for its distinctive purple color, produced by a pigment called **violacein**. This pigment is particularly effective for dyeing textiles like silk, wool, cotton, nylon, and polyamide, though it has moderate colourfastness and does not achieve high durability, especially in terms of resistance to washing and UV exposure. J. lividum is commonly found in soil, freshwater, and on amphibians. Violacein is typically a shade of deep blue or purple, depending on concentration and context, and it has antibacterial, antiviral, anti-fungal, and anti-tumour properties.

Creating textile dyes from pigments produced by J. lividum is still in the research and development phase. Currently, J. lividum is not produced on a large, industrial scale but rather in research labs, often at universities or small biotech companies focused on sustainable bio-dyeing and microbial pigment research.

Research is underway to scale up J. lividum dye production in bioreactor systems. A **bioreactor** is a controlled container used to grow microorganisms under optimal conditions. During **fermentation** in a bioreactor, bacteria grow and produce useful substances like violacein. Current studies focus on optimising pigment yield; however, the work remains largely experimental. Given the challenges in scaling production, a commercially viable J. lividum-based dye for textiles may be available within the next 5–10 years. This timeline allows for continued optimisation to ensure stability, colorfastness, and affordability in line with commercial textile standards.

Though this material is not readily available, it has been presented here to give designers a brief look behind the scenes of some of the processes and experiments used in material science. This will help designers know what to look for and some of the questions to ask of bacteria dyed fabric manufacturers.





Cellulose Varnish and Stain

researched by Arianna Mengarelli

👍 Cheap and easy to make

👍 Biodegradable

👎 Long drying time in damp environments

👎 It might be hard to achieve full coverage

Material Matters

Properties	Is it fire and/or water proof?	It is water resistant but can suffer from water damage - it doesn't catch fire when lit
	Can it be cut and/or painted on?	N/A
	Is it strong, durable, soft, brittle or flexible?	It can be hard or flexible depending on the amount of glycerine added
Uses	What is the price bracket (at time of publication)?	40p x 1kg
	What could it be used for in theatre design?	Varnishing or staining sets and props
Sustainability	Does it contain toxins?	No
	Is it recyclable?	Not once applied
	Does it have a high embodied energy?	CMC takes a fair amount of energy to be synthesised out of trees but is as sustainable as paper
	Is it biodegradable?	Yes
	Where is it manufactured?	UK and other pharmaceutical companies all over the world

Varnish Recipe

Cellulose varnish is very simple to make and only requires two ingredients: Carboxymethyl cellulose (CMC) and water.

The recipe for a cellulose based DIY biodegradable varnish is as follows:

1. Mix CMC with water. It need only be 2% CMC to water.
2. Allow to stand overnight.
3. The following day the varnish will be ready to use.
4. You can add natural pigments to turn it into a stain. Examples include blue/green spirulina, spinach, turmeric, beetroot, paprika powders.

Example Usages

(Right) The stain was unevenly brushed over cardboard clay creating a water effect.

(Left) The blue cellulose varnish was applied to a wooden floor giving a clear colour without losing the texture of the wood.

Cork Crumb

researched by Paul Burgess

Material Matters

Properties	Is it fire and/or water proof?	Flammable. It will absorb water, but this won't affect its integrity unless it's left to rot.
	Can it be cut and/or painted on?	Cutting is limited as it is crumb for texture. It can be painted.
	Is it strong, durable, soft, brittle or flexible?	It is strong and durable for normal usage when glued/painted, but will break with force.
Uses	What is the price bracket (at time of publication)?	£20 for 12L
	What could it be used for in theatre design?	Adding texture to a surface. Available in different sizes.
Sustainability	Does it contain toxins?	No
	Is it recyclable?	No
	Does it have a high embodied energy?	No
	Is it biodegradable?	Yes
	Where is it manufactured?	Various

Cork crumb is a waste material from the production of wine cork stoppers. Much of the circular economy is dependent on the waste of one industry becoming the resource of another and cork crumb is a prime example of how the waste of the wine industry can be diverted from landfill and used productively by the theatre industry.

It is a great texture for creating rough surfaces within scenic design and comes in three sizes: 2-3mm, 3-7mm and 5-15mm. Flints Hire and Supply sell it in 12L tubs.

Cork is a good substance to work with because of its non-toxicity and low embodied energy. It is a much more sustainable alternative to fossil-fuel-based textures. It is a relatively robust substance, though once added to a textured surface, it may need some protection for transit and storage.

Consideration of how the cork is combined with other materials, such as paints and resins, should be considered, so that it can continue to be reinvented beyond its life on the stage.

Bio-Beads

researched by Paul Burgess

Material Matters

Properties	Is it fire and/or water proof?	not fireproof, but appears to be waterproof after a short test (1 hour)
	Can it be cut and/or painted on?	It can be cut. It takes paint if not too watery
	Is it strong, durable, soft, brittle or flexible?	It can be squeezed but returns to its original shape
Uses	What is the price bracket (at time of publication)?	£38.70 + VAT for 60 litres
	What could it be used for in theatre design?	Texture, filling gaps, padding, etc
Sustainability	Does it contain toxins?	No
	Is it recyclable?	In theory, but not through household recycling
	Does it have a high embodied energy?	No data is available, but generally, bioplastics have 50% less embodied energy than conventional plastics
	Is it biodegradable?	Yes
	Where is it manufactured?	Not specified

More info: https://www.flints.com/product/All/FHSBB60L?proddesc=Flints-Bio-Beads-60L&category=eco-textures-and-materials&catdesc=Eco-Textures-and-Materials

Origins

Bio-beads are made from natural materials - corn starch and sugar cane.

They are a more sustainable alternative to polystyrene for prop-making and texturing, etc. Polystyrene is a particularly unpleasant and polluting material that is in widespread use. Polystyrene is not good for the environment because it doesn't biodegrade, it easily breaks apart, meaning it readily can work its way into water systems, and it contains toxins. Bio-beads and materials like Compostablock (see Part One) would be a good alternative to help theatres reduce or remove the use of polystyrene in the production of scenography.

What are the advantages of bio-beads?

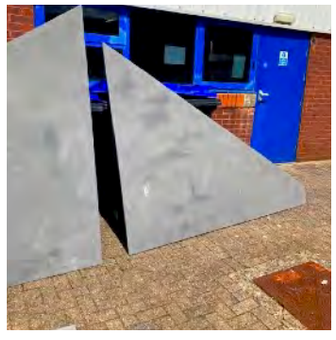
Their greatest asset from a sustainability point of view is compostability. From a prop-making point of view, they hold their shape well and take paint and glue.

What are the disadvantages of bio-beads?

Like polystyrene, they have an electrostatic charge, which can make the individual beads tricky to handle. They require a complex manufacturing process, so their embodied energy is significant even if it is lower than that of conventional plastics.

Dekozell

researched by Ruth Stringer



Above: In this trial, it was used as a exterior wall surface, like a fine house render.

Dekozell can be mixed with water, paint and PVA to create different scenic textures e.g. brickwork, concrete, weathering, sandstone, bark, rust effects. It can be used as a modelling paste, essentially as a substitute to idenden. Like idenden, it is versatile in its texture and application. It can be mixed with different amounts of water, paint, and materials such as sawdust to give a smoother or coarser texture. Once dry, the surface can be repainted and reworked easily, by wetting it again. In theory, this might mean you could thoroughly dampen the surface and remove the dekozell layer completely, making it easier to reuse and recycle the component parts. Depending on what type of paint/adhesive is added to it, this might also mean that the afterlife of the set itself has more possibilities, for instance, if breaking down the materials completely and using them in other industries. If stored properly, the dry, unused fibre can be kept for minimum 10 years.

‘You've Got Dragons’ photo by Kirsten McTernan - design by Ruth Stringer

Dekozell is a bi-product of wood fibre. It is made from dry cellulose fibre. It is a bi-product of sustainable timber according to the manufacturer and has had nothing else added to it, such as resins, toxins or preservatives. It is shipped as a dry fibre, meaning it is very lightweight as a raw material.

It is best for indoor sets because of how it is affected by water. It uses a lot of water in the mixing stage (at least 16litres for a 1.9kg bag) and if mixed, is harder to recycle. It is also has a long drying time which would need to be factored into the schedule of the project.

Material Matters

Properties	Is it fire and/or water proof?	It is not water of fireproof unless applied with varnish or FR treated substrate
	Can it be cut and/or painted on?	it can be painted or have paint added to it in the mixing/application stage
	Is it strong, durable, soft, brittle or flexible?	soft and mouldable on application, it 'sets' when it is dry but is still slightly
Uses	What is the price bracket	£68.50 ex. VAT for a 1.9kg bag (Flints)
	What could it be used for in theatre design?	As an alternative to idenden
Sustainability	Does it contain toxins?	No - it is 100% pure cellulose, a bi-product of wood fibre.
	Is it recyclable?	not once it's been applied as it will likely have had paint and PVA added
	Does it have a high embodied energy?	likely low - it's a pure bi-product of sustainable timber
	Is it biodegradable?	Not when paint and adhesives have been added
	Where is it manufactured?	Flints supply it - possibly Germany

Beeswax

researched by Lucy Bridger

Material Matters

Properties	Is it fire and/or water proof?	It is highly flammable but does provide a slight degree of water proofing
	Can it be cut and/or painted on?	It can be cut, though sometimes tricky, and it isn't recommended to paint over beeswax, especially on wood
	Is it strong, durable, soft, brittle or flexible?	Beeswax is quite strong and stiff
Uses	What is the price bracket (at time of publication)?	500g is £16.50 to 700g at £23.00
	What could it be used for in theatre design?	waterproofing leather costumes, lubricant, candles
Sustainability	Does it contain toxins?	As beeswax is a natural material, it does not contain toxins
	Is it recyclable?	Yes
	Does it have a high embodied energy?	Low
	Is it biodegradable?	Yes, it takes up to 28 days
	Where is it manufactured?	UK

Origins

Beeswax is a naturally occurring animal wax, that has been used since the seventh millennium. It also has a long standing usage in the design industry. There is an art form known as encaustic painting, which is created from beeswax that has been mixed with damar resin and pigments. This is an ancient art form where wax was melted onto wooden panels. However it needs constant heat when applied and it is difficult to revise when cooled.

It has a high melting point of 62 degrees Celsius and is able to be manipulated at around 33-35 degrees Celsius. The bees maintain a temperature of 33 degrees Celsius inside the hive, which allows them to manipulate the wax into the right consistency. It discolours if heated beyond 85 degrees Celsius.

Applications to Theatre

Beeswax can make leather waterproof, so it would be ideal for costumes if the production requires scenes with water. It can be used to refurbish old joints as a lubricant and it prevents wood from splintering when coated on nails. It can create candles that do not drip and smoke.

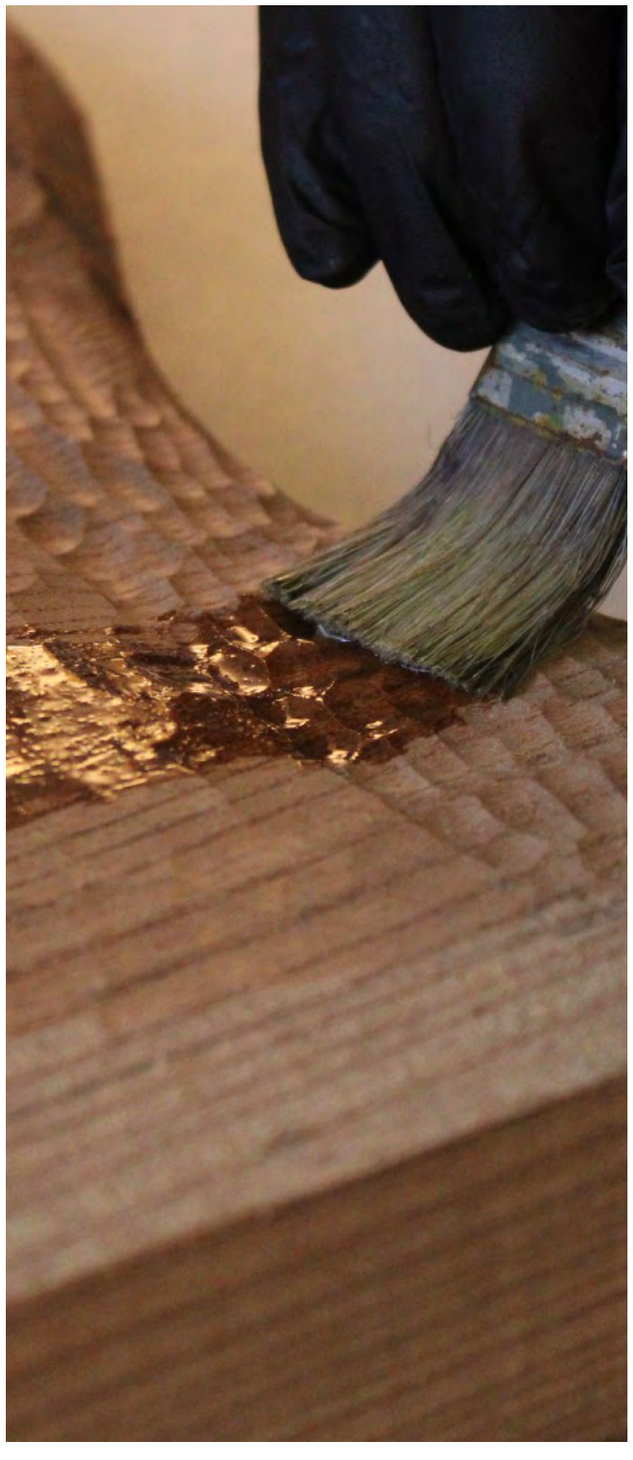
Beeswax is a natural material that can be harvested sustainably from hives. It has no toxins added so it is naturally biodegradable, and is versatile because it can easily be morphed between solid and liquid states.

The main issue with beeswax is that it is highly flammable, so it may not suit all productions. The other issue with using beeswax for waxing wood and any furniture or flooring is that it needs to be reapplied quite frequently as the finishing wears down quickly. This may mean it is expensive in the long run to use this material for that purpose.

Example of Encaustic painting, Egypt 2nd Century, Source: https://www.britannica.com/art/encaustic-painting

Introduction to the Sustainability of Oils

researched by Gretchen Maynard-Hahn



The Origins of Oils

Vegetable, animal, and mineral oils have served a variety of purposes across cultures and industries for millennia. Oils were often used as anointing liquids in religious ceremonies and offerings representing purification. Today, they serve as lubricants and biodegradable plastics.

Vegetable oils are derived from seeds, nuts and fruits. Vegetable oils are commonly used as moisturisers, massage oils, and in soap-making (e.g, coconut oil, palm oil).

Animal oils and fats have been used in cooking (e.g. lard, fish oil) and as a preservative. There have also been many industrial uses for animal oils including the unsustainable farming of whale oil which was a major fuel source for lamps before petroleum. Another example is lanolin from sheep's wool, which is used in skin treatments.

Mineral oils are extracted from petroleum amongst other sources, meaning some mineral oils are directly related to the fossil fuel industry. Machine oils and hydraulic fluids have been used in industrial processes. Mineral oils are also commonly used for the preservation and waterproofing of wood, leather, and machinery.

One of the most unsustainable aspects of oil (animal, mineral and vegetable) have to do with sourcing of the materials. Major oil producers are grown and processed in locations that require large areas of land which in many cases contributes to irresponsible land use and deforestation. There are also social and ethical issues surrounding industrial farming where exploitative labour practices have been documented. Many oil crops are also very water-intensive which leads to a depletion of freshwater resources and often require pesticides and fertilisers which can lead to soil degradation and water pollution. Many oil processing techniques are very energy-intensive and create large amounts of waste and chemical byproducts. Most oils found in the UK must also be imported from large scale producers, leading to high transportation emissions. We are going to compare the embodied energy of some different oils, looking at how they are derived and where they can be found.

Comparing the Embodied Energy of Oils

Walnut Oil – Moderate – Cold-pressed from walnuts (low-energy) but it requires solvent extraction. Walnuts are grown in temperate regions including parts of the UK but are primarily imported from France, USA or China.

Jojoba Oil – High – From the Simmondsia chinensis plant, native to SW USA and NW Mexico. It is also cultivated in Argentina, Australia, Israel and Peru, which requires shipping. Extraction and refinement are also energy-intensive.

Coconut Oil – High – Coconuts are grown in tropical and sub-tropical regions. Coconut oil is typically imported from Southeast Asia or the Pacific which requires shipping. Processing also involves significant energy use.

Neatsfoot Oil – Moderate to High – Neatsfoot oil is derived from cattle and processed at facilities such as slaughterhouses or rendering plants. Local sourcing is possible but the processing raises the embodied energy.

Hemp Oil – Low to Moderate – Extracted from Cannabis sativa plant seeds. Hemp is a hardy plant that can be grown in the UK. Cold-pressing is relatively low-energy when compared with solvent extraction.

Camelia Oil – High – Camelia oil is extracted from the seeds of the Camelia oleifera plant. Camelia oil is sourced from China and Japan, leading to transport related energy costs. Processing methods also add to its embodied energy.

Olive Oil – Moderate to High – Olive oil is mainly imported from countries in the Mediterranean Basin. Other olive oil producers include USA, South America, and Australia. Mechanical extraction is moderately energy intensive.

Sunflower Oil – Moderate – Sunflowers are cold-pressed (low-energy) and refined (higher-energy). Sunflowers are grown in the UK and locally available.

Soybean Oil – High – Solvent Extraction (hexane extraction) is energy intensive. Farming practices require heavy irrigation, pesticides and fertilisers (high agricultural footprint).

Castor Oil – High – Castor oil is a vegetable oil extracted from the castor plant. Castor oil is primarily sourced from India, requiring long-distance transport. Extraction is energy-intensive, especially for refined versions.

Linseed Oil

researched by Gretchen Maynard-Hahn

Material Matters

Properties	Is it fire and/or water proof?	It is flammable but can be used for waterproofing
	Can it be cut and/or painted on?	N/A
	Is it strong, durable, soft, brittle or flexible?	N/A
Uses	What is the price bracket (at time of publication)?	£6.00 (75ml) - £35.00 (1L)
	What could it be used for in theatre design?	preservation, waterproofing, finish
Sustainability	Does it contain toxins?	Boiled Linseed oil often contains heavy metal drying agents that can be toxic Raw or natural linseed oil is non-toxic
	Is it recyclable?	Depends on the material it is used on
	Does it have a high embodied energy?	Moderate – Cold-pressed from flax seeds
	Is it biodegradable?	raw or natural linseed oil is biodegradable
	Where is it manufactured?	UK, USA, Russia, Canada, India, China

Raw linseed oils are natural, non-toxic and biodegradable finishing oils. It is derived from flax, a renewable crop which can be extracted sustainably. Flax is can grow in cooler climates such as the UK but the major producers are Canada, Russia, India, China and the USA. Natural Danish Oil (Polymerised linseed oil) is VOC free, organic, and does not contain harmful solvents or metal dryers like commercially produced Danish oils. Boiled linseed oil and some commercial wood finishes contain toxic drying agents like lead, cobalt or manganese. Choose low-VOC, non-toxic linseed oils and avoid metal-based drying agents.

Puppet from Norwich Puppet Theatre's 'The Frog and The Princess' with oil finish

Usage in Theatre

In a theatre environment, oils are a valuable and incredibly diverse material that can be used for finishing and preservation, lubrication, waterproofing, and as a pigment binder. Natural oils like linseed, tung, Danish or walnut oil can be used to seal and protect wooden puppets, props and are also used in the construction of wooden set pieces to ensure longevity and to prevent cracking or warping under stage conditions. They are also used as lubrication for various joints, hinges, sliding or rotating elements and mechanisms. Oils are often mixed with pigments or stains to create textures, patinas, weathering and faux finishes like aged leather or rust for historical props and puppets as well as being used on costumes to stain or darken and give them a worn look. Some oil and wax mixtures can be applied to fabrics or porous materials to make them water resistant. Oils are essential to condition leather elements and keep them soft and flexible and to prevent cracks. Oils like castor oil can be used as a release agent in latex or silicone moulding. Naturally derived glycerin or glycerol is a sugar alcohol compound derived from plant or animal oils and is used on stage for effects such as in blood recipes. This makes the material look realistic, have the proper viscosity and to stop them from drying. 'Drying' oils takes time to cure and may remain tacky if not applied correctly.

Tung Oil

researched by Gretchen Maynard-Hahn

Material Matters

Properties	Is it fire and/or water proof?	It is flammable but can be used for waterproofing
	Can it be cut and/or painted on?	N/A
	Is it strong, durable, soft, brittle or flexible?	N/A
Uses	What is the price bracket (at time of publication)?	£10.00 - £50.00 (1L)
	What could it be used for in theatre design?	preservation, waterproofing, finish
Sustainability	Does it contain toxins?	Pure tung oil is non-toxic but modified tung oils may contain solvents that release harmful fumes
	Is it recyclable?	It depends on the material it is applied to
	Does it have a high embodied energy?	Moderate to High – Requires pressing and refining
	Is it biodegradable?	Yes
	Where is it manufactured?	China, Argentina,or Paraguay

Tung tree nuts, which tung oil derives from, are native to China. Other major producers include Paraguay and Argentina. For UK based designers, this means tung products have travelled, increasing their embodied energy.

Test of different oils, (Danish oil, Beeswax Oil and pure Tung oil) on oak block

Properties of Oils

In some cases, oils increase the durability, flexibility and softness of materials. However, oils can weaken the fibres of some fabrics and paper and corrode some metals which affects durability. It is important to consider how oil can be used to give materials a longer life, avoiding certain materials going to landfill.

Most oils are not fireproof and are in fact extremely flammable. However there are some exceptions where oils can contribute to fire resistance under controlled conditions. Flammable Vegetable oils and petroleum-based mineral oils are flammable and can even self ignite if left on rags due to oxidation. When using vegetable or mineral oils, always store used rags in a sealed metal container.

Some oil-based paints and sealers release harmful fumes that require proper ventilation. Pure tung oil has no volatile organic compounds, it is biodegradable, it is non-toxic and is grown from a renewable crop which makes them a more sustainable alternative to many synthetic wood finishes. It also has a long lifespan meaning that it does not need to be used regularly. Some products say ‘made with tung oil’, which contains additives. Pure tung oil or 100% tung oil should be marked on the label.

Using Oil on Other Materials Part 1

researched by Gretchen Maynard-Hahn

Paper and Cardboard

Plain cardboard and paper are fully recyclable. If these products come into contact with oils they are no longer recyclable as the oils weaken the fibres, making them unsuitable for pulping. If paper or cardboard becomes lightly exposed to natural oils, consider composting.

Wood

Linseed, tung, and Danish oils as well as wax and oil blends can be used on wood to create a water-resistant barrier, protecting sets from humidity and spills. Oil-based paints and sealers can provide both colour and waterproofing for set elements, backdrops and stage floors. Untreated wood is easily recyclable or compostable. Once oils are used it becomes difficult to recycle as it repels water which makes it difficult to break down in wood processing recycling. Many wood recyclers will also reject oil-finished wood due to potential chemical contamination from additives. In addition, burning treated wood in incinerators may release toxic fumes depending on the oils used. If composting is an option for your materials, be sure to use natural oils that do not contain any additives.

Puppets and Leather

Leather used for puppets, props or costumes can be treated with neatsfoot, jojoba, coconut or sunflower oil to keep it flexible and water-resistant. Jojoba oil is a natural leather conditioner alternative to mineral oil which is a petrochemical derivative. Jojoba oil is derived from a drought resistant plant that does not usually require pesticides, herbicides or fungicides and can be extracted sustainably through supercritical CO_2 extraction. Coconut and sunflower oils are a plant-based alternative to oils such as mink oil that are used for waterproofing and conditioning. Sustainable coconut oil options that prioritise minimising environmental impact are available and can be identified by Fair Trade and Rainforest Alliance certifications. Sunflower oil may be considered more sustainable if it is certified organic, reducing pesticide and herbicide use, and grown and processed domestically. The sustainability of neatsfoot oil which is rendered from the bones and feet of cattle, depends on it’s sourcing and other ethical considerations. As a byproduct of the farming industry, it may be considered a sustainable use of resources but the environmental impacts of farming practices should be taken into consideration when purchasing a neatsfoot product.

Using Oil on Other Materials Part 2

researched by Gretchen Maynard-Hahn

Metal Props

Light coats of biodegradable machine oil or mineral oil can prevent rust or corrosion on metal props exposed to water and humidity. In some instances, a light coating of vegetable oils such as olive oil can also be used though vegetable oils remain tacky and need to be removed and reapplied regularly. Metals (steel, aluminium, brass) are highly recyclable but once they are oiled can cause recycling issues as oil residues may contaminate recycling batches. Some lubricating oils or oils containing toxins are considered hazardous waste and must be removed before recycling and disposed of properly. Metals that have been cleaned may still be recycled.

Fabrics

Soybean or jojoba oil and wax blends can waterproof certain fabrics useful for period costumes or water effects. Clean fabrics (cotton, wool, polyester) are recyclable. Oils make fabrics hydrophobic which prevents proper breakdown in textile recycling. When oiled cloth is mixed with other fabrics, it may contaminate entire batches and cause them to be discarded instead of recycled. If a costume has been oiled and is no longer needed, it is best to repurpose it rather than attempting to recycle it. Soybean oil wax blends are used for natural waterproofing on wax canvas costumes and props. This is a plant-based alternative to paraffin or petroleum waxes. Soybean oils face significant sustainability challenges including deforestation, biodiversity loss and land rights issues. Certifications on soybean oil products including Round Table on Responsible Soy (RTRS) and ProTerra help identify ethical and sustainable soy products.

Plastics

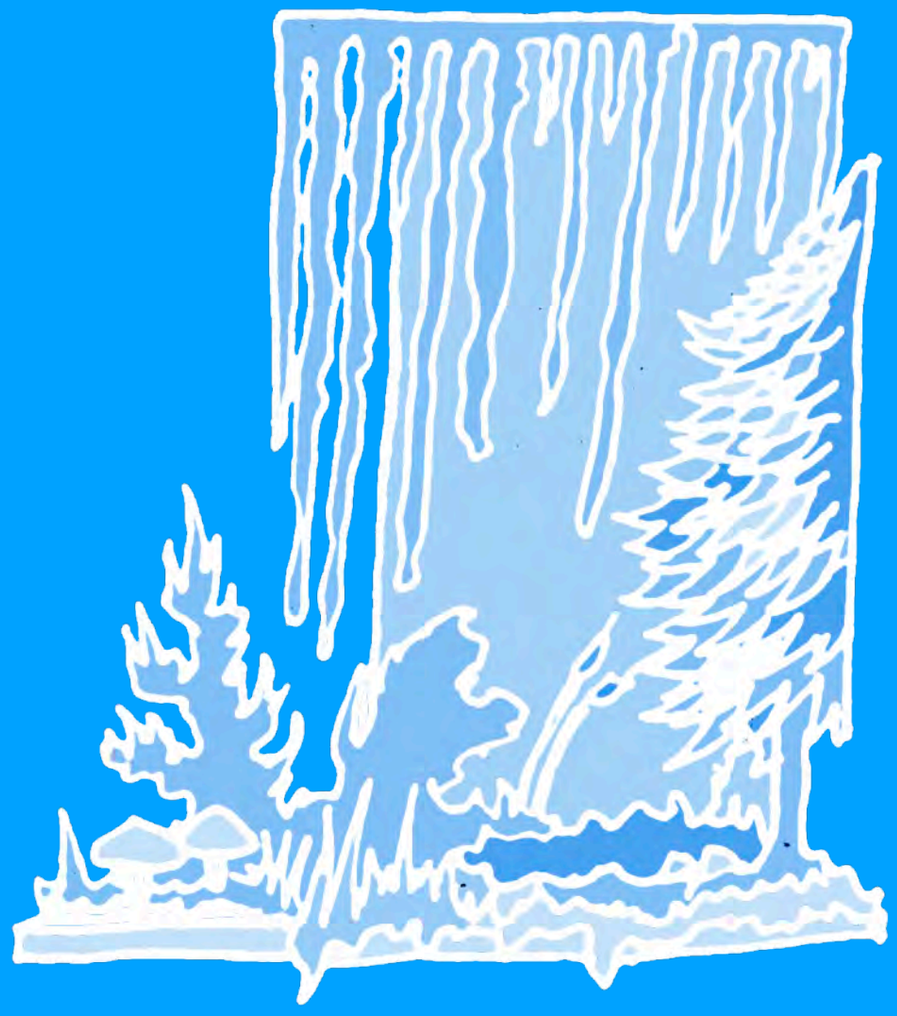
Many plastics are recyclable but once they are oiled, residues can contaminate recycling batches. Oils prevent proper melting in the recycling process or chemically react with plastics which degrade their structure. Plastics that have been washed thoroughly may still be recycled.

Paints and Finishes

D-Limonene from the oils of citrus peels is the key component of citrus-based solvents and is a biodegradable, natural alternative to petroleum-based solvents often used in oil paints, degreasers and cleaners. As citrus peels are a byproduct of the citrus industry, D-Limonene is considered a sustainable and renewable product. Hemp oil is a ‘drying’ oil used in non-toxic, VOC-free and biodegradable paints and wood finishes. Hemp is a fast growing and renewable crop that can be grown without pesticides or herbicides.

Natural Danish oil applied on birch ply (comparing with and without oil)

Part Five: Materials for Costumes and Props



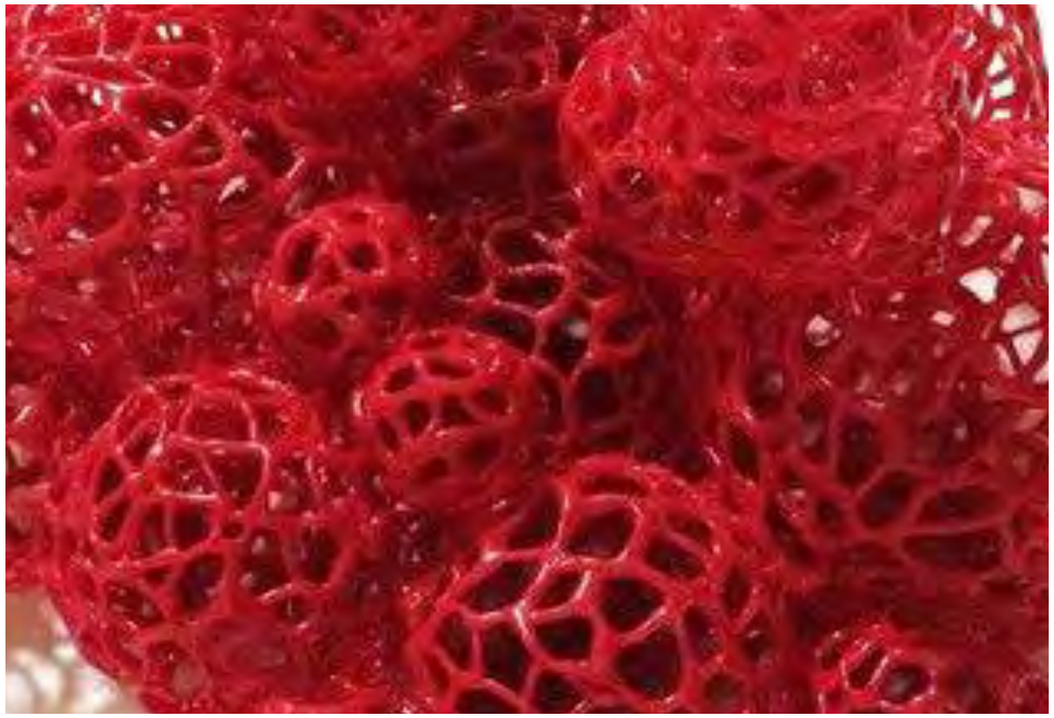
This final section is written in the spirit of DIY - using natural materials or foraged materials found in the household or in nature to produce interesting effects and designs. Though nothing is impossible, most of the materials presented are delicate or difficult to produce in large quantities on the scale needed for set designs, but they are very applicable to the design of costumes and props.

Cellulose Bio-plastic Part 1

researched by Arianna Mengarelli

Material Matters

Properties	Is it fire and/or water proof?	It is water resistant but can suffer from water damage over time - It doesn't catch fire when lit
	Can it be cut and/or painted on?	Yes
	Is it strong, durable, soft, brittle or flexible?	It can be hard or flexible, depending on the amount of glycerine added
Uses	What is the price bracket (at time of publication)?	30p x 100g of material
	What could it be used for in theatre design?	It can be used instead of thermoplastics for mask making, props and puppet making
Sustainability	Does it contain toxins?	No
	Is it recyclable?	Yes it could be cut up and re-cooked for future crafts
	Does it have a high embodied energy?	MFC does take a fair amount of energy to be synthesised out of trees but it is as sustainable as paper
	Is it biodegradable?	Yes
	Where is it manufactured?	MCC and CMC are manufactured from pharmaceutical companies all over the world - Agar can be purchased in the UK



Working with the Material

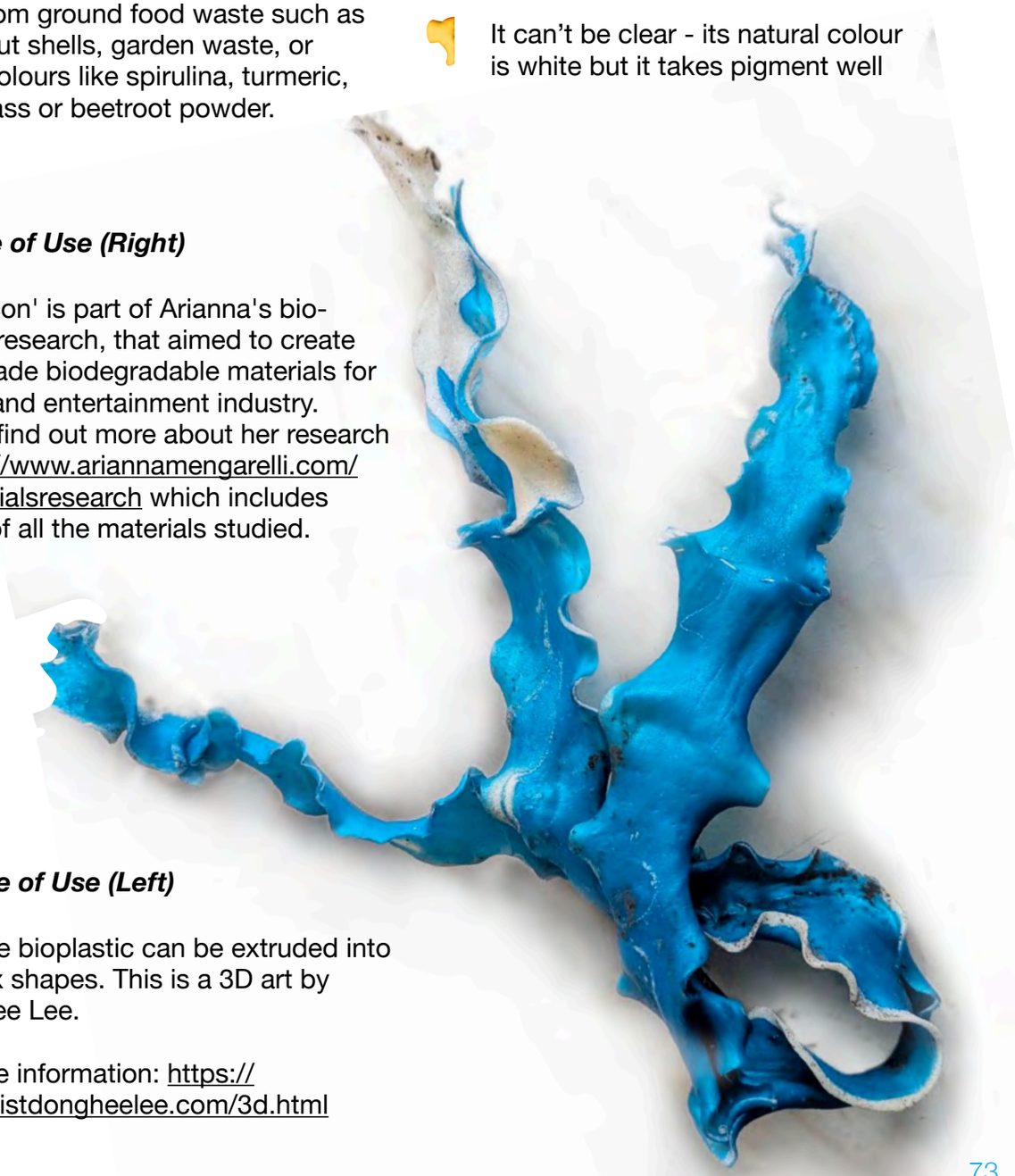
The Cellulose bio-plastic recipe (on the following page) is easy to cook on a hob, with affordable ingredients. The result is a strong, durable, bio-degradable and versatile material.

Pouring 1-2mm thickness resembles latex. Pouring 3mm thickness resembles pliable plastic. This material could be re-heated to change shape. To this recipe, you can add ingredients for texture and colour from ground food waste such as coffee, nut shells, garden waste, or natural colours like spirulina, turmeric, wheatgrass or beetroot powder.

- 👍 Strong, cheap, easy to make
- 👍 Injectable/pourable in a mould
- 👍 Workable with electric saws and drills
- 👍 Can be reshaped through heat, after it has dried, like a thermoplastic
- 👎 Long drying time in damp environments
- 👎 It can't be clear - its natural colour is white but it takes pigment well

Example of Use (Right)

'Sea Bacon' is part of Arianna's bio-material research, that aimed to create home-made biodegradable materials for the arts and entertainment industry.
You can find out more about her research at https://www.ariannamengarelli.com/biomaterialsresearch which includes recipes of all the materials studied.



Example of Use (Left)

Cellulose bioplastic can be extruded into complex shapes. This is a 3D art by Dong Hee Lee.

For more information: https://www.artistdongheelee.com/3d.html

Cellulose Bio-plastic Part 2

researched by Arianna Mengarelli

STEPS	INGREDIENTS
1 Prepare the 2% CMC solution one day ahead. 2 Mix well the ingredients in a pot 3 Bring to a boil on a hob and keep stirring 4 Leave to boil for a few minutes until it thickens 5 Remove from the hob and wait a few minutes for it to cool 6 Pour or inject as desired	250g 2% CMC (Carboxymethyl cellulose) to water Mix 15g Agar Agar 7g Glycerine (added for flexibility, leave out if desired) 2g Distilled Vinegar 11g MCC (Mycrocrystalline Cellulose)

Variations and Additional Information

To create a wavy, thin surface, pigments were mixed and brushed using a spatula on the surface whilst it was still hot to create an uneven surface and crackled edges.

To create some negative space, the mix was injected with a large syringe when it was still hot.

Because glycerine was added to the recipe, the bioplastic has some flexibility and it can return to its shape after being scrunched. If this level of flexibility is not required, glycerine does not need to be added.

This is the same sample but once it has dried out.

This is the same sample but once it has dried out.

Agar Bio-plastic Part 1

researched by Arianna Mengarelli

Material Matters

Properties	Is it fire and/or water proof?	It is water resistant but can rot and loose its strenght if affected by moisture over a long period of time
	Can it be cut and/or painted on?	yes
	Is it strong, durable, soft, brittle or flexible?	It is very hard, solid and light If glycerine is added to the recipe it could be flexible and leathery
Uses	What is the price bracket (at time of publication)?	20p x 100g of bioplastic (dry weight)
	What could it be used for in theatre design?	Costumes, masks, props, puppet, set
Sustainability	Does it contain toxins?	No
	Is it recyclable?	yes, it could be cut up and re-cooked for future crafts
	Does it have a high embodied energy?	No
	Is it biodegradable?	Yes
	Where is it manufactured?	You can purchase Agar made in UK

Making your own Bio-plastic

On the following page is is a quick recipe to make a bioplastic on a hob. The main ingredient is Agar, or agar-agar. It is a jelly-like substance consisting of polysaccharides obtained from the cell walls of some species of red algae.

The basic recipe dries into a hard plastic. You can add Glycerine of up to 4% of the water content if you require the material to be flexible.

You can also add to the wet mix ground food waste such as coffee, nut shells, garden waste, or natural colours, like spirulina, turmeric or wheatgrass powder.

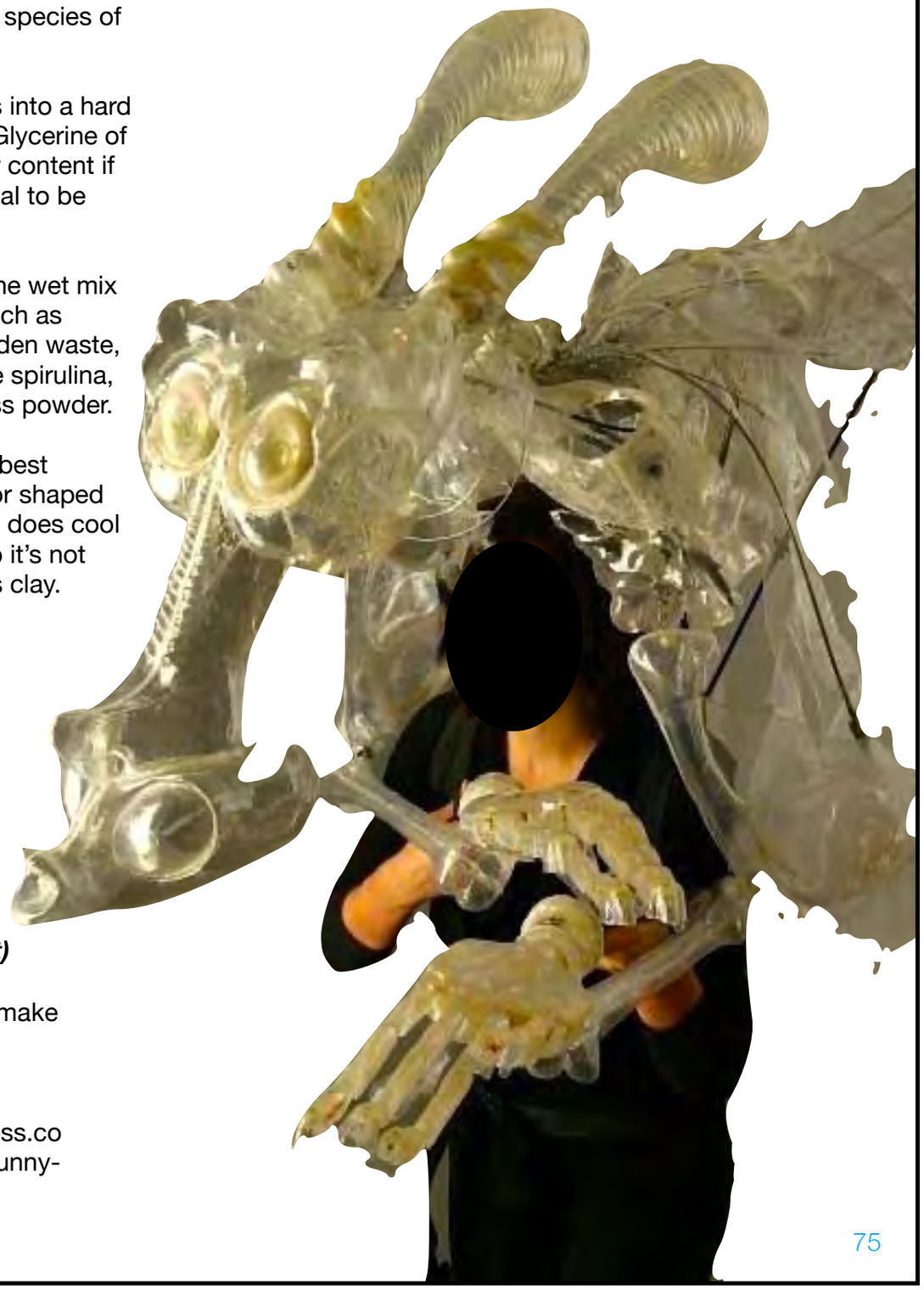
This kind of plastic is best poured into a mould or shaped with tools while hot. It does cool and harden quickly so it's not suitable to be used as clay.

👍 Sustainable, cheap, easy to make

👍 Recyclable

👍 Workable with electric saws and drills

👎 It shrinks up to 1/3rd of its size while dying



Example of use (right)

An example used to make a puppet from the Tolosa's International Puppet Centre

Example of use (left)

An example used to make elements of a light installation. Source: https://lightartnews.wordpress.com/2013/06/09/soo-sunny-park-unwoven-light/

Agar Bio-plastic Part 2

researched by Arianna Mengarelli

STEPS	INGREDIENTS
1 Measure the ingredients in a pot. 2 Bring to boil on a hob, stir continuously. 3 Simmer for 3 minutes until thickened. 4 Set aside to cool slightly. 5 Pour on your mould. 6 Wait a few hours before de-moulding (Keep in the mould to dry if you are looking to cast a specific shape, as it might warp while drying.)	250g Water 15g Agar Agar 2g Distilled Vinegar You could add Glycerine for flexibility, up to 4% of water content

Variations and Additional Information

This is how the coral looked after the mix was poured and it was worked while hot. The edges of the branches were spread to achieve the desired look.

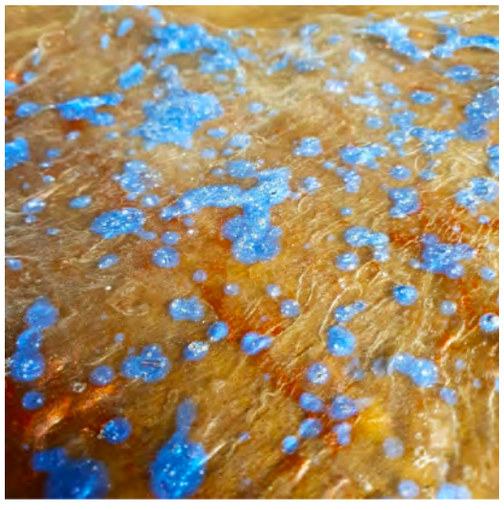
To make flexible PVC - like leather, use:
250g Water,
15g Agar,
10g Glycerine,

Leave it to dry for a 2-3 days.

Pour 2/3 mm thick on a glass surface.

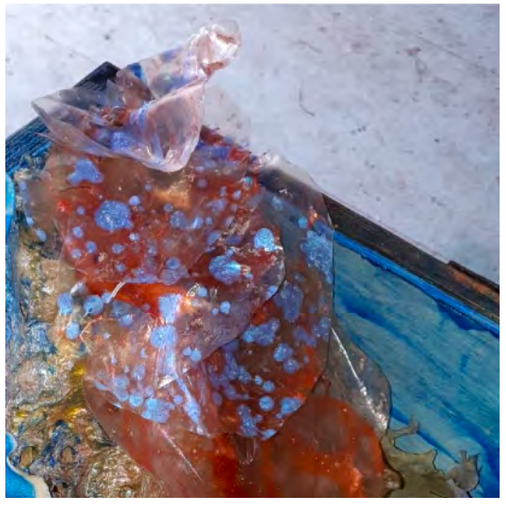
Leave to dry for a 2/3 days.

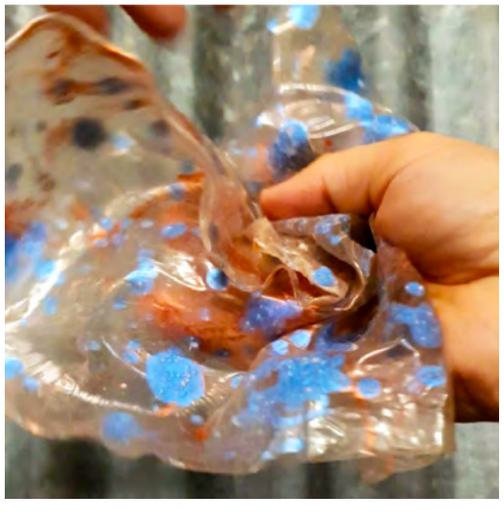
The leather can be sewn and/or ironed to melt pieces together (use parchment paper as protection)



It produces a flexible and versatile leather surface.

It can be cut easily and cleanly.





Cardboard Clay Part 1

researched by Arianna Mengarelli

Material Matters

Properties	Is it fire and/or water proof?	It is water resistant but can suffer damage over time
	Can it be cut and/or painted on?	Yes
	Is it strong, durable, soft, brittle or flexible?	It is very hard, sturdy and light
Uses	What is the price bracket (at time of publication)?	40p x 100g of clay (dry weight)
	What could it be used for in theatre design?	Sculpting, mask making, props and puppet making
Sustainability	Does it contain toxins?	No
	Is it recyclable?	Yes, it can be cut up and re-cooked for future crafts
	Does it have a high embodied energy?	MFC does take a fair amount of energy to be synthesised out of trees but is as sustainable as paper
	Is it biodegradable?	Yes
	Where is it manufactured?	Depends on carboard manufacturer - MCC is made by pharmaceutical companies all over the world

Example use for the Clay

On stage and screen, we would normally use polystyrene and/or fibreglass to make organic pieces of set. Cardboard clay could be sculpted on a chicken wire armature and it could replace the plastic polymers that are toxic and will never decompose.

👍 Strong, cheap, easy to make and to sculpt

👍 Recycled and recyclable

👍 Workable with electric saws and drills

👎 Long drying time in damp environments

Recipe

Recycled cardboard clay can be easily cooked on any hob. It can be used as a regular air dry clay or as an alternative to paper mache that doesn't contain any harmful glues and chemicals.

The recipe is presented on the following page. To this recipe, you can add ground food waste, such as coffee, nut shells, garden waste, or natural colours like spirulina, turmeric or wheatgrass powder.

Example of cardboard clay on wire armature

MCC

Microcrystalline cellulose (MCC) is a term for refined wood pulp and is used as a texturizer, an anti-caking agent, a fat substitute, an emulsifier, and extender, and a bulking agent in food production. The most common form is used in vitamin supplements or tablets. It is also used in plaque assays for counting viruses, and as an alternative to carboxymethylcellulose. Online retail price is £34 for a 5kg bag that will be enough to make a life-size human sculpture.

Cardboard Clay Part 2

researched by Arianna Mengarelli

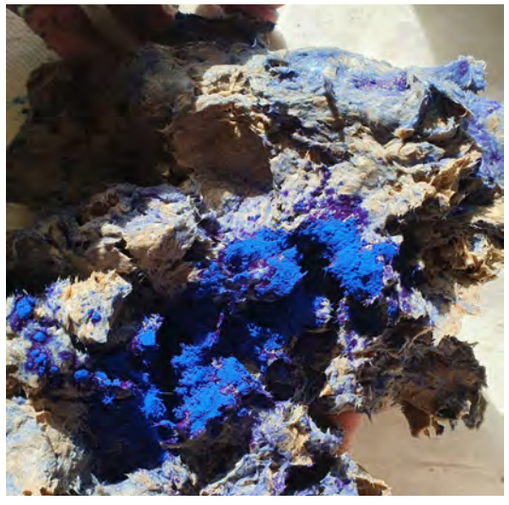
STEPS	INGREDIENTS
1 Cut up pieces of cardboard, immerse in warm water until they fall apart easily when teared. 2 Mush the cardboard with your hands and use a blender to make a finer mix. 3 Drain as much water out of the pulp as possible. 4 Mix the MCC into the cardboard crumble. 5 Fill a cooking pot with water, agar and vinegar and boil for 3 minutes. 6 Pour on the cardboard pulp and mould it with your hands or apply to an armature. 7 Dry in a dry space for a few days or in a dehydrator for several hours depending on volume.	400g of dry cardboard, cut into small pieces (turned into 700g of wet cardboard pulp) 250g Water 15g Agar Agar 2g Distilled Vinegar 60g MCC - Mycrocrystalline Cellulose

Variations and Additional Information

The rough cut cardboard pieces.

It is turned into pulp after pouring hot water over it and squeezing most of the liquid out.

It then is turned into soft workable clay after adding the rest of the ingredients.



Natural pigment can be added to the mix.

The clay is easy to sculpt.

It's ideal for making rock or coral effects.

Barkcloth

researched by Hamish Muir

Material Matters

Properties	Is it fire and/or water proof?	It is not fire or water proof
	Can it be cut and/or painted on?	Yes, it can be dyed or printed on
	Is it strong, durable, soft, brittle or flexible?	It is fairly durable for fabric but prone to some surface damage
Uses	What is the price bracket (at time of publication)?	The cost varies
	What could it be used for in theatre design?	costume, fabrics, headdress
Sustainability	Does it contain toxins?	No, in its traditional form
	Is it recyclable?	Yes, depending exactly how it is processed.
	Does it have a high embodied energy?	Low - it is created directly from bark
	Is it biodegradable?	Yes
	Where is it manufactured?	worldwide: Uganda, Indonesia, Japan, Pacific Islands

History of Barkcloth

Barkcloth is a non-woven heritage fabric material that is made from the inner lining of Moraceae trees. Traditionally, the inner-bark, which is a fibrous material, is soaked in water and then stretched and hammered into sheets.

Modern barkcloth involves a different technique entirely and is more to do with the way fabric is processed.

Making barkcloth is a heritage technique that has been ongoing in Uganda, Vietnam and Papua New Guinea. The National Gallery of Scotland have a collection of Eharo masks used for dance from Papua New Guinea which are made from barkcloth.

Source: https://www.nms.ac.uk/explore-our-collections/stories/global-arts-cultures-and-design/understanding-barkcloth-at-national-museums-scotland/sub-pages/masks-from-papua-new-guinea/

Different patterns and uses have been developed in historical and contemporary examples.

Image: back-strap loom © National Museums Scotland. More information: https://www.nms.ac.uk/explore-our-collections/stories/global-arts-cultures-and-design/understanding-barkcloth-at-national-museums-scotland/

Armour and 'The Green Knight'

Barkcloth was used to create the cloak for the titular character in David Lowery's film, 'The Green Knight' (2021), to avoid using animal products, like fur or leather. When oiled, it can be malleable and be a lightweight alternative. The use of bark and the plant-based objective of the production also had a thematic resonance because the Green Knight is part-tree himself!

More information: https://observer.com/2021/08/the-green-knight-costume-designer-interview/

Seaweed

researched by Max Goodman

Seaweed is the biggest plant species in the ocean. It has many benefits to the watery ecosystems as it creates homes and food for marine animals. It also removes carbon dioxide from the atmosphere. The plant is being used more frequently to create replacements for harmful materials like plastics and materials with microplastics. The plants durability and versatility means it is a great sustainable material to create with.

Material Matters

Properties	Is it fire and/or water proof?	It is water resistant and flammable when dried
	Can it be cut and/or painted on?	It can be cut, when raw or dried - It can be painted on when dry
	Is it strong, durable, soft, brittle or flexible?	Dried seaweed is brittle - Raw seaweed is flexible
Uses	What is the price bracket (at time of publication)?	N/A
	What could it be used for in theatre design?	Stage fabrics, props and costumes
Sustainability	Does it contain toxins?	No
	Is it recyclable?	No
	Does it have a high embodied energy?	Low depending how far it has travelled
	Is it biodegradable?	Yes
	Where is it manufactured?	N/A

Where can Seaweed by sourced?

Seaweed can be easily foraged on beaches across the country. It is easiest to collect after a high tide as this time is when the fresh seaweed will wash up onto the shore. There are many different species which all have their differences in terms of shapes and size, although this should not negatively affect any making projects you want to use it for. What species you find will depend on what part of the country you are looking in.

How to use Seaweed for Theatre Design

When experimenting with seaweed, consider how the different forms of the plant can work alongside the ‘traditional’ theatre elements to create one cohesive design.

The image (left) is an experimentation exploring how seaweed can be used to create shadows when intersecting with light.

Seaweed Textiles

Dried or raw seaweed can be sewn within other materials to create different textures and patterns. In this example, the seaweed has been sewn together with thread to create patterns and textural pieces. These could be used to add detail to the set design of costume elements.

Seaweed Paper

Seaweed can be used to add texture to paper structures. Through a process of combining the plant with recycled paper, it creates a durable and sustainable alternative that could be used to add texture and details to a set and as a foundation for props.

Wool

researched by Max Goodman

Material Matters

Properties	Is it fire and/or water proof?	No
	Can it be cut and/or painted on?	It can be easily cut
	Is it strong, durable, soft, brittle or flexible?	When tied, it is relatively strong and durable
Uses	What is the price bracket (at time of publication)?	£4 - £20
	What could it be used for in theatre design?	Costume, props
Sustainability	Does it contain toxins?	Synthetic wool does, other wools are dependent on the dye
	Is it recyclable?	No
	Does it have a high embodied energy?	Moderate - depending how far it has travelled
	Is it biodegradable?	Plant and animal wools are
	Where is it manufactured?	Across the UK

Traditionally used for hand crafting, wool is a versatile material that can be used in many different ways to add layers of texture to a design. There are multiple way wool is manufactured, with each having their pros and cons for both creating with and sustainability.

Design Use

With simple crafting techniques like knitting, crochet and knot tying, wool is an easy way to create pieces of material. This could include clothing items as additions to costuming, or as a way to dress a space through creating draping or ceiling canopies.

All wool types are able to be dyed either naturally or synthetically, meaning that you can dye any wool to the colour that you require.

Plant Based Wool

- Made by spinning fibres from plants
- Wool examples include linen from flax plants and cotton from gossypium
- In its natural state (without any chemical colouring dye) the wool is biodegradable
- Rough texture - when knitted/tied together it is ideal for elements that require durability and strength
- It is not the most cost efficient, hand spun wool does cost more due to the time it takes to make
- Consider how you can reduce any negative environmental impact when sourcing the wool

A linen wool made from flax plant

Animal Fur Based Wool

- Made by spinning fibres from animal fur
- Wool examples are most commonly sheep or alpaca
- In its natural state (without any chemical colouring dye) the wool is biodegradable
- Soft/fluffy texture - ideal for costume elements or adding soft detailing to a set design
- The wool has a positive environmental impact if sourced locally
- It is not the most cost efficient, hand spun wool does cost more due to the time it takes to make
- Consider how you can reduce any negative environmental impact when sourcing the wool

A wool made from sheep fur

Synthetic Based Wool

- Usually made from a mix of polyester (a synthetic fibre derived from coal and petroleum) and acrylic fibres
- Filled with microplastics that end up in our environment when the wool is used
- No way of disposing of it sustainably - the wool must be mechanically melted down
- Textures vary depending on the wools exact ingredients
- Synthetic wool is ideal if you want to use a large quantity, as it is easily accessible and inexpensive
- Synthetic wool has a negative environmental impact

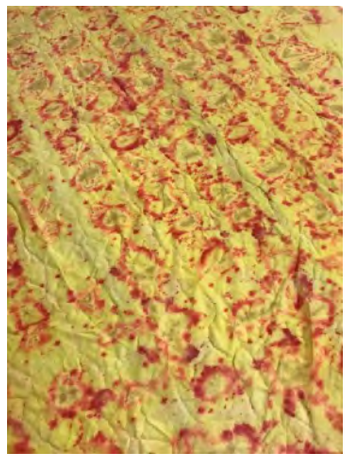
A synthetic wool

Mycelium

researched by Urs Dierker

Material Matters

Properties	Does it fade?	It does not produce stable colours, but pigments extracted from certain fungi can have moderate to good colour fastness when processed correctly.
	On what textiles does it grow best?	It grows best on organic substrates such as cellulose-based fabrics, natural fibres, and agricultural byproducts like sawdust or straw.
Uses	What is the price bracket (at time of publication)?	The cost of mycelium products ranges widely, from $20–$100 per square meter for raw materials to higher prices for specialised or processed designs.
	What could it be used for in theatre design?	It can be used for creating lightweight, biodegradable props, textured set elements, and sculptural costumes with organic, sustainable aesthetics.
Sustainability	Does it contain toxins?	Mycelium itself is non-toxic, but its substrate or treatments may contain residues requiring proper handling.
	Does it have a high embodied energy?	Mycelium production has low embodied energy, though sterilisation and controlled growth environments add some environmental costs.
	Is it biodegradable?	Yes, mycelium is fully biodegradable and decomposes naturally in the environment.
	Where is it manufactured?	Mycelium is typically grown in specialised labs or facilities worldwide, with significant production hubs in Europe, North America, and Asia.



Images show work completed as part of the Naturally Dramatic Project (2019-2020) by Urs Dierker at Aalto University in Finland in collaboration with the BiCMat research group led by Prof. Orlando Rojas at the Department of Bioproducts and Biosystems. The work extended to a course on biomaterials in the Department of Costume Design taught by Urs Dierker (2021) at Aalto Univeristy. All photos © Urs Dierker | Circular Costume Design

Mycelium, the root-like network of fungi, is a versatile and sustainable biomaterial that has captivated designers and scientists with its potential. It grows by extending its thread-like filaments, called hyphae, through organic matter, forming a dense and fibrous structure. This living material can be cultivated, shaped, and processed into various forms, making it an innovative candidate for theatre applications, ranging from set design to costumes and props.

In theatre, mycelium provides a medium for creating environmentally conscious and visually compelling designs. For instance, mycelium-based panels can serve as lightweight, biodegradable alternatives to traditional materials like polystyrene or MDF. These panels are not only structurally robust but also compostable, supporting sustainability objectives. Designers have explored growing mycelium directly into moulds to produce organic shapes and textures, ideal for fantastical or naturalistic set pieces. Costume designers are also experimenting with mycelium as a material for wearable art. By growing mycelium on fabrics or moulding it into accessory components, they create avant-garde costumes that are both visually striking and biodegradable.

Urs Dierker and the BiCMat research group at Aalto University conducted experiments growing three fungal strains directly on textiles and cellulose-based soft materials: Pleurotus pulmonarius (Oyster mushroom), Ganoderma lucidum (lingzhi or reishi mushroom), and Fomes fomentarius (tinder or hoof fungus). Among these, Ganoderma lucidum produced the most distinct results, forming reddish to brownish tones that added depth and texture to the materials. To ensure safety and stability, the textiles were autoclaved to stop further growth and eliminate any risks to handlers or wearers. Over time, the mycelium dried but remained flexible if thick enough, while edges took on a paper-like texture. The adhesion of the mycelium to the textiles and soft materials was moderately strong. The resulting materials could not be washed but could be rinsed; when dry, they were odourless but developed a musty, fungi-like scent when damp.

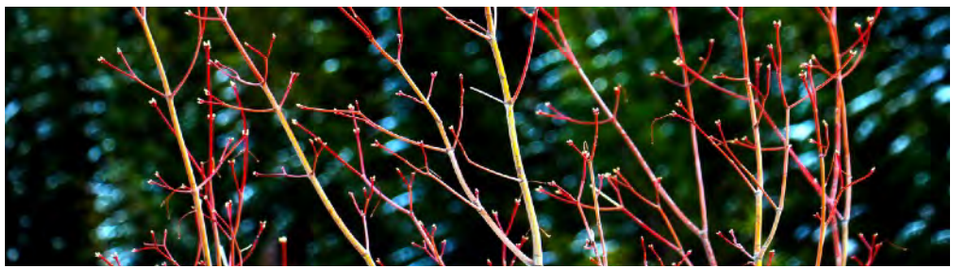
At Newcastle University's Hub for Biotechnology in the Built Environment (HBBE), researchers have explored mycelium's architectural potential through projects like BioKnit, which incorporates mycocrete into textile frameworks to create durable, eco-friendly materials. Similarly, MycoColors, a Berlin-based initiative, focuses on fungal-based dyes as sustainable alternatives to synthetic colorants, offering vibrant and ecological solutions for various applications. By integrating mycelium into theatre design, artists can challenge traditional production methods and embrace sustainability. Mycelium adaptability, unique visual properties, and eco-friendly characteristics make it a powerful tool for reimagining the theatrical landscape.

Red Osier Dogwood

researched by Ian McFarlane

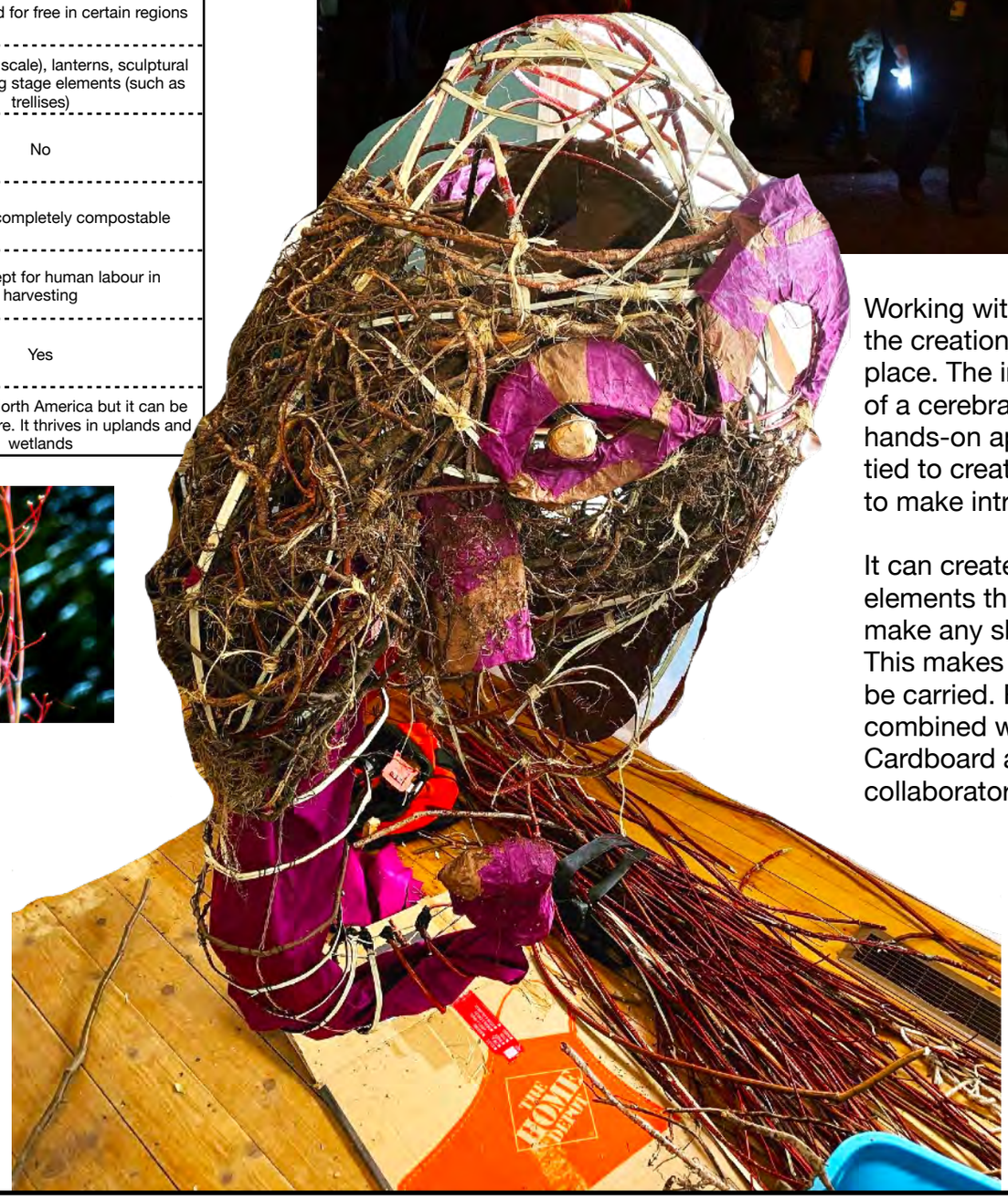
Material Matters

Properties	Is it fire and/or water proof?	It is water proof but not fire proof
	Can it be cut and/or painted on?	Yes
	Is it strong, durable, soft, brittle or flexible?	Very flexible and soft
Uses	What is the price bracket (at time of publication)?	Can be foraged for free in certain regions
	What could it be used for in theatre design?	Puppets (large scale), lanterns, sculptural elements, living stage elements (such as trellises)
Sustainability	Does it contain toxins?	No
	Is it recyclable?	No but it is completely compostable
	Does it have a high embodied energy?	None, except for human labour in harvesting
	Is it biodegradable?	Yes
	Where is it manufactured?	It is native to North America but it can be grown elsewhere. It thrives in uplands and wetlands



Red Osier Dogwood has been used for thousands of years as a weaving material and can be harvested on location in a sustainable manner. If growing your own supply, it is also advantageous for pollinators and birds. If a design process takes the growing and harvesting into account, it radically localises production. If the material is left raw, it is completely biodegradable, making the environmental impact almost completely at net zero, if not regenerative.

It will dry up or decompose after a few years and requires time and labour like most sustainable practices, but this could match the lifespan of many theatre productions.



Working with red osier dogwood encourages the creation of designs that are specific to place. The irregular shapes force designers out of a cerebral approach to a more haptic or hands-on approach. The rods may be split and tied to create large, abstract shapes, or woven to make intricate objects.

It can create solid structures or sculptural elements through weaving techniques. It can make any shape and is extremely light weight. This makes it ideal for anything that needs to be carried. Red osier dogwood can easily be combined with other building materials. Cardboard and paper-mache are ideal collaborators, as well as any other wood.

See also youtube.com/watch?v=JiwPAZXLzz0 for a tutorial on how to use it.

(Top) Animated lanterns made from red osier dogwood, designed by Ian McFarlane and Laura Stinson. Part of *The River Clyde Solstice Walk*, New Glasgow, PEI, 2022. Photo credit: Robert van Waarden.
(Left) Large-scale sculpture of a mammoth made from red osier dogwood, spruce root, cardboard mache and fabric. Designed by Ian McFarlane.

Nettle

researched by Alison Neighbour

Material Matters

Properties	Is it fire and/or water proof?	Yes it is inherently fireproof. It is not waterproof unless treated.
	Can it be cut and/or painted on?	As a fabric or string, it can be cut and painted on, similar to linen or cotton. It can be dyed but with mixed results.
	Is it strong, durable, soft, brittle or flexible?	The fabric is strong and durable, and surprisingly soft, but it depends on the weave. It usually has a bit of a sheen.
Uses	What is the price bracket (at time of publication)?	Nettles themselves are freely available -Fabric is available for around £20-30/m, it can also be bought as yarn
	What could it be used for in theatre design?	Costume, upholstery, string, regular cups of tea...
Sustainability	Does it contain toxins?	No
	Is it recyclable?	Yes
	Does it have a high embodied energy?	No - only human energy.
	Is it biodegradable?	Yes
	Where is it manufactured?	UK, Nepal

Where is nettle fabric made?

Whilst researching the material, mass-produced nettle fabric was only found in Nepal. This claims to be hand-produced by artisans but you would of course need to do due diligence on any suppliers. There is a cottage industry in the UK of growers and weavers mainly making small amounts for themselves. You can make string or raw fibre really easily in an hour or so from foraged nettles. A company called Camira based in Huddersfield have created a nettle and wool blend upholstery fabric, but at the time of writing this doesn't seem to be available to the public. Also, the human labour to create fabric from nettles is quite intensive.

History and Sustainability

Nettle is one of the oldest fibres used for making fabrics - dating back at least to the Bronze age. The plants are native, quick growing, great for wildlife habitat, and an important part of our ecosystem.

It comes from a plant that is freely available throughout the UK and is considered a weed. Not only can you make fabric and string out of it, you can also make a cup of tea, and allegedly it alleviates arthritis - handling a lot of raw nettle definitely gives your hands a nice fizzy feeling! When you're done, just put it back where you got it from and it will return to the earth. Nettles need no artificial help to grow, and they like to grow in the areas nothing else does.

Nettle fabric is sometimes called Ramie. It is soft and really durable. The string is really strong - one of the strongest natural fibres there is. A costume made of nettle would last a long time and it's also fire retardant, and cool and comfortable to wear. Nettle fabric would be especially well suited to the rigours of outdoor performance and touring. It is also anti-microbial and resistant to wrinkling. The natural colour is quite a dull grey. It can be dyed. The recommendation is to add citric acid to penetrate the fibres.

Further reading:

Nettle growing for upholstery in Yorkshire, supported by Defra
https://atworkwithcamira.com/files/[08-27-2013]Sting%20brochure.pdf

Nettles for Textiles- a site run by Allan Brown, hub for all nettle based fibre research https://www.nettlesfortextiles.org.uk/wp/about-us/

The Nettle Dress directed by Dylan Howitt - beautiful and inspiring film as an antidote to fast fashion https://www.nettledress.org/

Images (top to bottom): garment by Catherine Hutchinson; Nettle fabric weaving - both images from https://www.nettlesfortextiles.org.uk/wp/;
The Nettle Dress documentary film poster

Recycled Ceramics

researched by Hamish Muir

Material Matters

Properties	Is it fire and/or water proof?	It is fireproof and waterproof
	Can it be cut and/or painted on?	It can be painted or glazed
	Is it strong, durable, soft, brittle or flexible?	Strong but breakable
Uses	What is the price bracket (at time of publication)?	low or free if salvaged
	What could it be used for in theatre design?	can be used as textures, decorations, props or remade into new sculptures
Sustainability	Does it contain toxins?	No, unless adhesives are added
	Is it recyclable?	Yes, though it may be difficult to recycle many times
	Does it have a high embodied energy?	No, but the initial process of firing ceramics does use a lot of energy
	Is it biodegradable?	No
	Where is it manufactured?	used pottery can be found in the UK and Europe

Unsustainable ceramics

The mining, transportation and firing of pottery and glassware is extractive on the environment and has a high embodied energy. Additionally, a lot of ceramics use metal glazes that are not good for the environment if left in landfill, and so finding ways to get the most out of ceramics, even when broken, can be a really good way of reducing the impact of these materials on the environment.

Luckily recycled ceramics can be processed and re-manufactured in lots of different and creative ways.

Sources: https://www.craftscouncil.org.uk/stories/7-makers-and-studios-turning-ceramics-green
https://www.futurematerialsbank.com/material/ceramic-waste/
https://granbyworkshop.co.uk/
https://www.notonthehighstreet.com/littlebrickhouseceramics/product/recycled-glass-decorative-ceramic-bowl
https://amudlarksdiary.com/2019/07/20/pottery-from-the-foreshore/
www/shutterstock.com

Salvaging

The interesting aspect of ceramic waste is how and where to find it. Sourcing recycled ceramics can range from using broken household materials, to working directly with a pottery or glassmaker that have ceramic waste streams, to using construction waste materials, to finding fragments through activities like mudlarking. The history and context of the ceramic pieces that are salvaged can add a layer of meaning to the materials that are used for making props and decorations which could resonate thematically with a theatre production.

Decorating

If the fragments of ceramics are kept untouched, they can be used as light decoration, either to create textures or to build mosaic-like patterns. The quality of light differs when shining against ceramic fragments, which can produce interesting theatrical effects and atmospheres.

Remaking

Ceramic waste can be ground down and used as a raw material to make new stone and earthenware objects. Water, paper fibres and sometimes a proportion of new clay like bentonite or sodium silicate are added together to form new objects. Sodium silicate needs to be handled with care as it is an irritant and therefore not good for the environment, however, it may only be needed for 3D printing ceramic objects. Various creative solutions to glazes have been developed including using condensed urine, which at first glance might not seem very palatable, but it is a good alternative to metal based glazes.

Flax (linen)

researched by Alison Neighbour

Material Matters

Properties	Is it fire and/or water proof?	It is not fireproof, it will burn rather than melt; it can be waterproof
	Can it be cut and/or painted on?	Yes. Cuts really easily and is a joy to work with as a fabric.
	Is it strong, durable, soft, brittle or flexible?	The woven fabric and raw fibre are strong and soft. Flax is also available as a twine
Uses	What is the price bracket (at time of publication)?	£20-50/m for 150cm wide fabric; £3 for 100m of string; £2 for a square metre of seeds to grow your own.
	What could it be used for in theatre design?	Costume, or anywhere using light duty canvas or string
Sustainability	Does it contain toxins?	The retting process for flax produces naturally occurring toxins
	Is it recyclable?	Yes
	Does it have a high embodied energy?	No, as fibre goes this is really light on embodied energy
	Is it biodegradable?	Yes - You can put it in your home compost. If it's been dyed then check what chemicals have been used.
	Where is it manufactured?	France and Belgium are our closest places to have a linen flax industry.

Water vs Dew Retting

If flax linen is retted in a body of water or a tub, the water will be polluted and not suitable for discharge into a watercourse. This issue killed off Ireland's flax industry as the water pollution got so bad it was banned.

However the flax can also be dew retted on grass, meaning no toxins are discharged. If you are growing your own then aim to dew ret it; if buying from elsewhere then ask how it has been retted and what has happened to the water used. Some linens may be dyed so this would need to be checked with the individual supplier. On the plus side, very little water is needed to grow flax - much less than for cotton. Processing requires no water at all if it is dew retted.

Origins

The linen comes from flax, which is a plant. It's been used for many years historically for clothing, bed linen, vegetable sacks etc... It is one of the original circular materials that was grown on farms and used in any part of the farm that required fabric. There are different grades of fabric that can be produced from different parts of the flax depending how it is grown. Flax seeds can be planted in April-June and the stems harvested 100 days later. With some simple tools you can process it yourself into a raw spinnable fibre or string. There is a growing network of UK flax growers so you may find a cottage supply, but not on an industrial scale.

Working with Flax

It has a beautiful floaty quality to it as a fabric and lets the light through. The raw fibres have a texture and sheen like human hair which could be a great natural substitute for wigs and other hair pieces, or for puppet work to create hair and horses tails for example. The woven fabric can be painted on, but this will depend on the tightness of the weave.
 It is truly beautiful at all stages of its life, from plant to fabric, and (whilst time consuming), the processes involved in transforming it from plant to fabric involve a series of simple steps and can be done in your own home and garden. The processing lends itself to being done in community with others. It is also available fairly locally. It takes a lot of labour to get from plant to fabric - whilst simple, it will take more time than the average theatre designer has to do this. However you could just buy the linen already made from a supplier with good ethics.

Waterproofing

A tight weave fabric can be naturally waterproofed to an extent using washed-in and/or painted on lanolin. Washing in the lanolin keeps the fabric fairly soft and offers some water resistance. Painting it on as a thicker paste means that the lanolin may re-melt in high temperatures and become sticky, but it does give an effect similar to a waxed jacket when set in with a hairdryer. A boiled pine resin paste can be used if you're happy with a more solid finish like a varnish - be aware that both these options increase flammability!

Further reading: https://www.bertas-flachs.at/en/ - reference for all things Flax and the craft around creating linen from it; https://www.linenfabrics.co.uk/fabrics - supplier of natural fabrics (including French & Belgian flax) in Canterbury. Additional images from https://www.etsy.com/uk/listing/604456027/natural-linen-fabric-100-soft-washed

Recycled Paper

researched by Kira Curtis

Material Matters

Properties	Is it fire and/or water proof?	No and no
	Can it be cut and/or painted on?	Yes and Yes - like normal paper
	Is it strong, durable, soft, brittle or flexible?	soft, brittle/flexible - it is a bit thicker than normal paper
Uses	What is the price bracket (at time of publication)?	Typically looking at £1 per A4 sheet to buy
	What could it be used for in theatre design?	Props, decorating flats, programmes, flyers and other marketing materials
Sustainability	Does it contain toxins?	The process can sometimes include bleaching or chemical washing
	Is it recyclable?	Yes
	Does it have a high embodied energy?	No
	Is it biodegradable?	Not always
	Where is it manufactured?	Can be made at home - raw materials can be purchased in Europe

DIY Recycled Paper

A sustainable way of making paper is to make your own from scraps of paper and card. To make your own:
1 tear paper into small pieces
2 let it soak in hot water overnight to soften
3 blend the pulp together
4 fill a shallow dishpan with water and add the pulp
5 make a screen, such as a fine mesh fabric stretched over a picture frame
6 dip the screen into the milky mixture and lift out horizontally
7 carefully flip the thin layer of pulp from the screen onto a cloth
8 press the water out by applying pressure
9 leave to dry under a heavy weight, such as a book

Recycling process

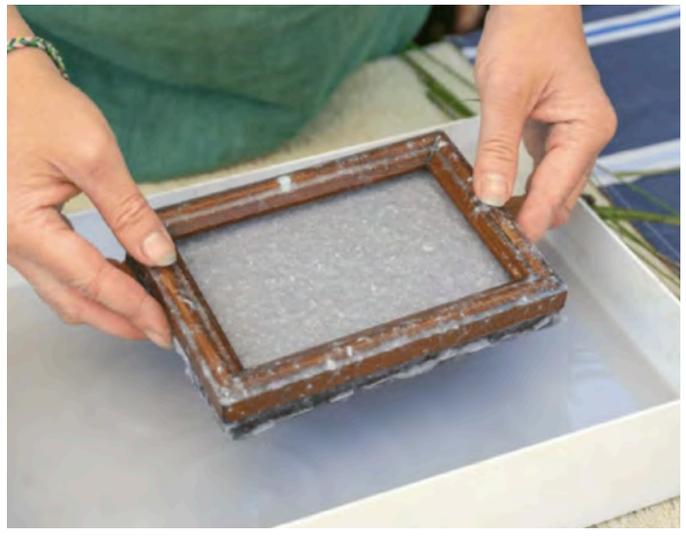
Recycled paper is made from paper scraps that are mixed with water (and sometimes chemicals to bleach or remove ink). This makes a pulp which is pressed together to make new paper.

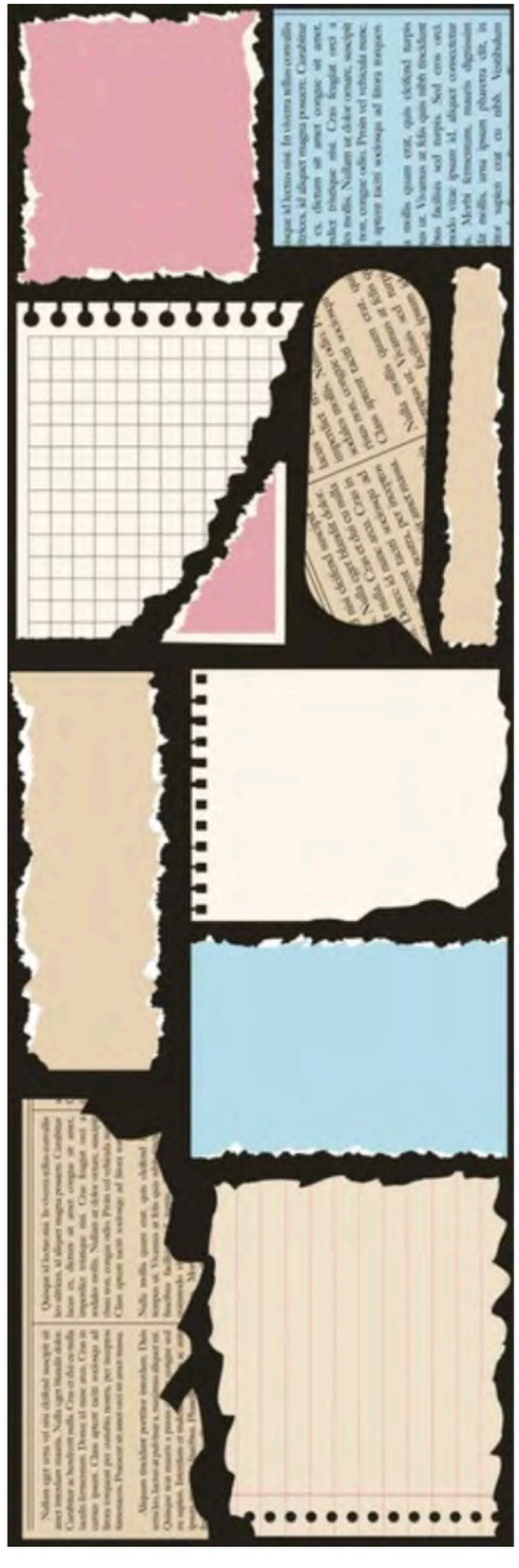
Environmental Benefits

The main benefit of using recycled paper is that it saves more trees being cut down to create virgin paper. Trees are important as absorbers of carbon dioxide in the atmosphere and so avoiding deforestation is a major part of helping to conserve the environment. Making recycled paper also uses less water and energy than virgin paper meaning it has a lower carbon footprint. Recycling also diverts paper and its byproducts from becoming waste.

Types of Recycled Paper

There are a variety of different recycled papers. The differences include how much recycled content there is, the quality of the waste paper used, where the waste paper is sourced (e.g. it can be waste paper created during the manufacturing process or it can be paper that has been used), and the type of fibres used, such as recycled cotton based fibres.





Images from: Shutterstock showing how to make your own paper and paper scraps

Appendix

List of Useful Links

Mo'olelo Performing Arts company Green theatre Choices Toolkit:
https://www.sustainablepractice.org/wp-content/uploads/2010/11/Toolkit.pdf

Future Materials Bank:
https://www.futurematerialsbank.com/

The Institute of Making:
https://www.instituteofmaking.org.uk/

Better Building Materials (USGBC):
https://www.greence.com/sites/default/files/Better_Building_Materials_Guide.pdf

Cradle to Cradle Certified Products:
https://c2ccertified.org/certified-products

Green Seal Directory:
https://certified.greenseal.org/directory

Database of Sustainable Building Materials:
https://ukgbc.org/resources/2050-materials/

Make/Works Sustainable Fabricators:
https://make.works/

International Trade Fair for Sustainable Textiles:
https://innatex.de/?lang=en

Fibershed (developers of regional fibre systems):
https://fibershed.org/affiliate-directory/

Danish Design Guide for Circular Economy Exhibition Practices:
https://static1.squarespace.com/static/5beabf7c4611a0f681fb5e98/t/6788feb8160bc7078ca032a8/1737031354882/Designguide_Cirkul%C3%A6re-udstillingspraksiser_digital.pdf

Stuff in Cycles Material Database
https://www.stuffincycles.com/

List of Manufacturers and Suppliers

What follows is a list of manufacturers for Parts 1,2,4 and 5. We have provided this as an appendix at the back rather than included it throughout the guidebook for two main reasons.

Firstly, specific products will be superseded in the future as more become available and others stop being manufactured. We want the guidebook to be as future proof as possible and so we have primarily focused on the materials themselves rather than products derived from those materials. This applies to the vast majority of the case studies presented but it does not apply to all of them as the type of product and sustainability of the product can be inextricably linked to the manufacturers process. Different variations, innovations and products will become available and these variations will affect the overall sustainability but the indexes we have used to measure sustainability within this guide (eg embodied energy, toxicity, recyclability etc) will remain the same and help assess the environmental impact of materials as more products become available.

The second reason is that this list of manufacturers is a starting point. Most of the websites given are examples rather than preferences. We do not endorse these companies over others as it is difficult to build a clear picture of the full manufacturing process and this is subject to change as new suppliers and practices are developed. We have tried to present a fair assessment of the materials, both in terms of their advantages and disadvantages. We encourage you to look for similar products sold in your area and consider how they are sourced, how far they travel, and what happens to them when they are disposed of.

List of Manufacturers and Suppliers - Sheet and Foam Materials

MATERIAL	MANUFACTURER/RETAILER	WEBSITE
Eco-board	Geaves Surfaces	https://www.geaves.com/eco18
Hemp-board and Hemp-canvas	Margent Farm	https://www.margentfarm.com/
Cardboard	Staples	https://tinyurl.com/2fu9mb8p
Plyboard/OSB/MDF	Hanson	https://hanson-plywood.co.uk/products/poplar-plywood-theatre-stage-sets-scenery-props/
Eelgrass Panel	Søuld	https://www.sould.dk/
Recycled Plastic Board	Plasteco Wood and Kedel	www.plastecowood.com www.kedel.co.uk
Cellulose Wallboard	Homasote	https://www.homasote.com
Corn-based Foam	TemperPack	https://www.temperpack.com
Corn-based Board	FRONT formerly StoneCycling	https://www.front-materials.com
Wood-wool Board	Savolit and Troldtekt	https://www.savolit.co.uk https://www.troldtekt.co.uk

List of Manufacturers and Suppliers - Other Building Materials

MATERIAL	MANUFACTURER/RETAILER	WEBSITE
Glulam	Buckland Timber	https://www.bucklandtimber.co.uk/
Cork	CorkBrick	corkbrick.com
Bamboo	UK Bamboo Suppliers	www.ukbamboo.com
Straw	Baled	https://baled.co.uk
Repurposed Rubber	Martin's Rubber company (processing rather than raw material purchase)	https://www.martins-rubber.co.uk/
Waste-based Brick	FRONT Formerly StoneCycling	https://www.front-materials.com
Recycled Paper Brick	DIY (from household materials)	N/A
CompostaBlock	Flints	https://www.flints.co.uk/product/All/PROBPB4?proddesc=CompostaBlock-855-x-565-x-40-mm
Cob	Cornish Lime	https://cornishlime.co.uk/products/associated-products/cob-blocks/

List of Manufacturers and Suppliers - Paints, Glues, Varnishes and Textures

MATERIAL	MANUFACTURER/RETAILER	WEBSITE
Ecopaint	Graphenstones	https://graphenstone-ecopaints.store/
Casein Paints	Auro	https://organicnaturalpaint.co.uk/
Biodegradable Glue	Power Adhesives, Auro or Kiilto Biomelt	https://www.poweradhesives.com/adhesives/tecbond-214b/
Natural Dyes	Wingham Wool	https://www.winghamwoolwork.co.uk/natural-dyes-mordants.html
Structural Wood-based colours	Specialist Producers	N/A
Bacterial Dyes	Specialist Producers	N/A
Cellulose Varnish	CMC is stocked by various art suppliers	https://www.georgeweil.com/
Cork Crumb	Flints	https://www.flints.co.uk/products/eco-textures-and-materials
Bio-beads	Flints	https://www.flints.co.uk/product/expanded-polystyrene-balls--be/FHSBB60L
Dekozell	Flints	https://userresources.prospect365.com/library/view/EMf1xkFmAd37XPVy18ErZg==/855/PRODEK19.pdf
Beeswaxes	Local Honey Man	https://localhoneyman.co.uk/products/pure-beeswax-bars
Linseed Oil	For linseed paint: Swedish Linseed Paint For oil: Brouns	https://swedishlinseedpaint.co.uk/ https://linseedpaint.com/product/oils/raw-linseed-oil/
Tung Oil	Various UK suppliers	https://tungoil.co.uk/

List of Manufacturers and Suppliers - Materials for Costumes and Props

MATERIAL	MANUFACTURER/RETAILER	WEBSITE
Cellulose Bio-plastic	CMC is stocked by various art suppliers	https://www.georgeweil.com/
Agar Bio-plastic	Agar Agar can be bought from several supermarkets	Various
Cardboard Clay	DIY	N/A
Barkcloth	Craft and Fabric suppliers	https://www.georgeweil.com/
Seaweed	DIY	N/A
Wool	Wingham Wool	https://www.winghamwoolwork.co.uk/
Mycelium	Gardening suppliers	https://www.meritmushrooms.co.uk/
Red Osier Dogwood	DIY	N/A
Nettle	Nettles for Textiles (info and how to make guides)	https://www.nettlesfortextiles.org.uk/wp/
Recycled Ceramics	Granbyware	https://granbyworkshop.co.uk/
Flax	Various fabric suppliers	https://www.worldofwool.co.uk/
Recycled Paper	Recycled Paper Company	https://www.recycledpapercompany.co.uk/

Glossary of Terminology Part 1.

Biodegradable: A material that can naturally break down over time through biological processes, without causing environmental harm.

Biobased: A bio-based material is a material intentionally made, either wholly or partially, from substances derived from living (or once-living) organisms, such as plants, animals, enzymes, and microorganisms, including bacteria, fungi and yeast.

Biodegradable Plastics: Plastics are made from renewable materials that can break down faster than conventional plastics when exposed to environmental conditions. However, their biodegradability depends on the specific conditions.

Bioinspired: Design inspired by or based on biological structures or processes.

Bioplastics: Plastics made from renewable resources, such as plant starch or algae, as opposed to petroleum-based plastics. Some bioplastics are biodegradable, though not all are.

BPI Certified: The BPI Certification Mark indicates third-party verification of compostability for manufacturers and brand owners to use on products and packaging and for consumers, end-users, and composters to use when determining whether or not a product or package is compostable. BPI is the leading third-party verification of ASTM standards for compostable products in North America.

Carbon Footprint: The total amount of greenhouse gases (mainly carbon dioxide) emitted during the lifecycle of a product, activity, or service, including production, transportation, use, and disposal.

Carbon Sequestration: The process of capturing carbon dioxide from the atmosphere and storing it in plants, soil, oceans etc.

Closed-Loop System: A system where products or materials are continuously reused, repaired, or recycled, reducing waste and the need for new resources.

Compostable: This means that not only are materials broken down in the environment but they can be turned - alongside food and other organic waste - into a soil-like material called compost. Composting is a natural way of recycling and compost can be used in soil to help things grow. But, not all plastic packaging labelled as "compostable" is home compostable and won't break down in a household compost bin.

Cradle to Cradle: A design philosophy that emphasises creating products that can be fully recycled or safely biodegraded, eliminating waste and ensuring that materials are continuously reused.

Cradle to Grave: The lifecycle approach of assessing the environmental impact of a product, from production through to disposal, focusing on resource use, emissions, and waste generation.

Embodied Carbon: The total carbon emissions associated with the production and transportation of materials used in construction or manufacturing, from raw material extraction to the final product.

Embodied energy: The sum of all the energy required to produce any goods or services, considered as if that energy were incorporated or 'embodied' in the product itself. The concept can be useful in determining the effectiveness of energy-producing or energy saving devices, or the "real" replacement cost of a building, and, because energy-inputs usually entail greenhouse gas emissions, in deciding whether a product contributes to or mitigates global warming. (Source: Wikipedia)

Energy Efficiency: The practice of using less energy to perform the same task, typically through improved technologies or practices that reduce energy consumption and waste.

Glossary of Terminology Part 2.

Environmental Impact: The effect that the production, use, or disposal of a product or service has on the environment, including resource depletion, pollution, and ecosystem disruption.

Ethical Consumption: The practice of making purchasing decisions that prioritise social, environmental, and ethical concerns, such as buying from fair trade companies or supporting businesses with sustainable practices.

Fair Trade: A certification for products that ensures workers in developing countries are paid fair wages, work in safe conditions, and use environmentally sustainable production methods.

Greenwashing: The practice of making false or exaggerated claims about the environmental benefits of a product or service to attract eco-conscious consumers, without substantial evidence to support such claims.

Life Cycle Assessment (LCA): A method of evaluating the environmental impact of a product or service over its entire life cycle, from raw material extraction to production, transportation, use, and disposal.

Low VOC (Volatile Organic Compounds): Products (such as paints, adhesives, and coatings) that release minimal harmful chemicals into the air, which can have a lower environmental and health impact.

Natural Fibres: Fibres derived from plant or animal sources, such as cotton, wool, hemp, or silk. These are often biodegradable and more sustainable compared to synthetic fibres like polyester.

Non-toxic: Referring to products or materials that do not contain harmful chemicals and do not pose a risk to human health or the environment.

Organic: Products made from materials grown without the use of synthetic pesticides, herbicides, or genetically modified organisms (GMOs). Organic farming practices tend to be more sustainable due to their minimal environmental impact.

Post-consumer Recycled (PCR): Materials that have been recycled from products that have already been used and discarded by consumers, such as recycled paper or plastic.

Renewable Resources: Natural resources that can be replenished naturally on a human timescale, such as sunlight, wind, and sustainably managed forests.

Sustainably Sourced: Materials or products obtained through methods that do not deplete natural resources or harm the environment, often certified by organisations like the FSC (Forest Stewardship Council) or MSC (Marine Stewardship Council).

Upcycling: The process of converting waste materials or old products into new, higher-value products, often by adding creative or artistic value.

Water Footprint: The total amount of water required to produce a product or service, including water used for growing materials, manufacturing, and transportation.

Zero Waste: A lifestyle and philosophy aimed at reducing waste to the minimum, by reusing, recycling, and composting materials to avoid sending anything to landfill.