C. Dove: Exploring the use of seaweed biopolymers in construction materials
Alginate

Fucus Vesculosis

Laminaria Hyperborea

Ascophyllum Nodosum
Alginate
Alginate - Use in construction

Unfired Clay Bricks - Seville University
Galan-Marin & Riveria (2010)

Lightweight concrete
Alginate Industries (1964)
PhD Programme

1: Earth Masonry
Unfired earth masonry units - alginate used as stabilising additive to improve strength

2: Insulation Products
Aerogel/low density foam - alginate used to improve mechanical properties of clay-based aerogel

3: Alginate Residue (by-product)
Biocomposite material incorporating fibrous residue product
1: Earth Masonry

**MBL (~20 samples)**
- ALGINATE
- Characterisation

**IBSTOCK (4 soils)**
- SOIL
- Characterisation

**Small Scale Specimens**

**Phase 1a: Brick Specimens**
- Batch 1
- Batch 2
- Batch 3

**Phase 1a Testing**

**Phase 1b: Brick Specimens**
- Batch 4

**Phase 1b Testing**

**Phase 1c**

- Do samples meet the minimal strength requirements?
- Assess feasibility as a masonry product?

**Characterisation**
- Workability
- Homogeneity
- Drying Shrinkage
- Density
- Mechanical Strength
- Water Absorption
- Drip Erosion Test
- Abrasive Strength
- Porosity
- Microstructure
- Thermal Conductivity

**LCA (Life Cycle Analysis)**
- Embodied Energy
- Cost Analysis

**Seaweed Source**
- Soil Source

**Sample No.**
- PR30U
- 1
1: Earth Masonry

Energy Consumption in Brick Production

Total Fuel
- Kiln (83%)
- Dryer (15%)
- Other (2%)

Heat Recovery

Embodied Energy of Masonry Products (MJ /kg)

Organic Additives used in Earth Masonry

- Oil derived
- Plant derived
- Animal derived
- Agro-Industrial Wastes
- Synthetic Polymers

Asphalt /Bitumen
- Synthetic polymers
- Synthetic fibres

Polysaccharides
- Oils
- Resins
- Organic Acids
- Fibres /Husks
- Hairs /feathers
- Excrement /Urine
- Animal fats
- Blood
- Casein
- Food waste
- Molasses
- Lignosulfonate
- Whey
- Spent grains
- Sewage Sludge
- Other organic wastes
- Thermosets
- Thermoplastics
- Synthetic Fibres
1: Earth Masonry - Mechanical Strength

Strength Improvement compared to control mix

- Compressive Strength (%) ▲ Flexural Strength (%)

Average Strength Values: Soil Y & U (N/mm²)

0.1% alginate
1: Earth Masonry - Other properties

1: Abrasion resistance
Improved by products PR38 & PR22

2: Water absorption/resistance
Improved by most alginate products when using high clay content soil

3: Scanning Electron Microscope
Higher mechanical strength, denser structure
1: Earth Masonry - Energy benefits

- Bricks are oven-dried rather than kiln fired leading to significant reductions in the energy consumed during production.

- The stabilising additive used (alginate) is obtained from a natural renewable source compared to high embodied energy/carbon alternatives such as cement and lime.

- Unfired clay offers good hygrothermal properties which can help to regulate humidity, provide thermal mass within the building structure and improve the quality of the internal environment.
2: Insulation Products

MBL samples or commercial Na-Alg
ALGinate
Characterisation

MMT Clay
CLAY
Characterisation

Phase 2a
Freezing / freeze-drying optimisation
Trial batch
1 commercial alginate, 5 mix ratios

Phase 2a Testing

Phase 2b
Batch 1
Batch 2
3 - 5 MBL alginate products at 5 mix ratios

Phase 2b Testing

Phase 2c
Comparison with other commercially available products

Homogeneity
Density
Drying Shrinkage
Compressive Strength

N2 adsorption (Porosity)
SEM (Microstructure)
Thermal Conductivity
Fire performance
Biodegradation

LCA (Life Cycle Analysis)
Embodied Energy
Cost Analysis
2: Insulation products - Energy benefits

- Highly porous material with low thermal conductivity
- Produced using natural constituents (alginate and clay)
- Offers alternative to other high performance insulation products such as silica aerogels.

Thickness required to achieve U-value of 0.2 W/m²K
2. Insulation products - Energy benefits

- Highly porous material with low thermal conductivity
- Produced using natural constituents (alginate and clay)
- Offers alternative to other high performance insulation products such as silica aerogels.

### Embodied Energy of Insulation Products (MJ/kg)

<table>
<thead>
<tr>
<th>Material</th>
<th>Embodied Energy (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expanded PS</td>
<td>110</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>120</td>
</tr>
<tr>
<td>Phenolic Foams</td>
<td>100</td>
</tr>
<tr>
<td>Glass Mineral Wool</td>
<td>80</td>
</tr>
<tr>
<td>Sheep's Wool</td>
<td>35</td>
</tr>
<tr>
<td>Cellulose</td>
<td>20</td>
</tr>
<tr>
<td>Vacuum Insulation Panels</td>
<td>50</td>
</tr>
<tr>
<td>Silica Aerogel</td>
<td>40</td>
</tr>
<tr>
<td>Clay Aerogel</td>
<td>30</td>
</tr>
</tbody>
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Overall objectives/contributions

1: Establish whether seaweed derived alginates (and their associated by-products) produced in the Scotland, can be successfully used in the development on environmentally-friendly composite materials for use in construction.

2: Investigate the mechanisms surrounding alginate-clay interactions and assess whether the type of alginate used has an influence upon the properties of the product properties.

3: Establish the optimum form(s) of alginate (based on technical performance, availability and cost-efficiency) for use in each of the case study materials.

4: Establish whether the proposed construction materials are technically and economically viable to produce at an industrial scale and assess their potential energy savings in comparison to conventional materials.