Assessing the potential of hemp hurd (*Cannabis sativa* L.) for the production of environmentally friendly lightweight panels

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+ Cheers & GA & GTBH
+ research study → part of MSc by research degree → Uni Melbourne.

- background
- aim and Objectives
- progress update & remaining tasks

**Sustainable and Renewable Forest Products Group**
1. BACKGROUND

Current situation:
growing global population → drives demand for wood fibre products (EWPs → PB, Ply, FB) & increasingly wood energy sector

contasted by 1 decline of sustainable timber resources
2 instability of crude oil/gas prices (context: precursor for chemicals/polymers used for adhesives to manufacture EWPs)

This discrepancy has led to concerns about the future supply of wood fibres
Concerns about:
1 the sustainability of our material systems,
2 the dependency on finite, petroleum-based resources
3 deficiencies in existing waste management structures

→ Motivate efforts to develop safer materials with improved environmental credentials
→ DEVELOPMENT of composites from non-wood fibres such as agricultural and vegetal residues (by-product of agricultural food production)
Emerging hemp industry in Australia focuses on grain production

- Hemp seeds/oil for human consumption
- Value adding potential for residual biomass
- Hurd/fibre crop

This is where hemp might help us to address at least some of these challenges.

Australia: hemp mainly grown for grain at this stage → leaves substantial biomass behind for further value adding

Alternative approach: grow directly for hurd/fibre
AIM & OBJECTIVES

Aim: Develop lightweight panels manufactured with hemp hurd and evaluate their performance characteristics

Objective 1: Characterise ground hemp hurd using granulometry measurements (digital image analysis)

Objective 2: Assess interfacial bonding capacity of manufactured panels

Objective 3: Identify optimal adhesive application, pressing parameters, and panel compositions

Aim of this study is to develop composite panels with hemp hurd and evaluate their properties.

- composite materials ➔ important understand and describe its constituents and this is what the first objective addresses:
  - Shape (Particle Geometry) influences the properties of the whole composite ➔ analyse particles (aka granulometry)

Obj2. addresses the fact that hemp hurd is known to be a highly absorbent material ➔ This might affect the bond quality as less adhesive remains available for bonding on the particle surface ➔ resulting in weaker bonds ➔ and poorer material performance

Obj3. to identify an OPTIMAL adhesive loading ➔ achieve satisfactory performance characteristics and avoid excess adhesive (concept: resin efficiency) ➔ Establish successful processing parameters.

So, in order to meet objectives 2-3...
2. METHODOLOGY & CUTTING PATTERN

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Cutting pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing to Australian particle board standard AS/NZS 4266.1:2017</td>
<td></td>
</tr>
<tr>
<td>• Bending strength/stiffness (MOR/MOE)</td>
<td>MOE/MOR_1 (220 x 50)</td>
</tr>
<tr>
<td>• Internal bond strength (IB) and Density (D)</td>
<td>IB &amp; D 1 (50 x 50)</td>
</tr>
<tr>
<td>• Screw withdrawal strength (SWR)</td>
<td>IB &amp; D 2 (50 x 50)</td>
</tr>
<tr>
<td>• Water absorption (WA) and Thickness swelling (TS)</td>
<td>TS &amp; WA 1 (50 x 50)</td>
</tr>
</tbody>
</table>

... I suggest to perform a range of critical tests → based on Australian particleboard standard + cutting pattern shows the panels and illustrates where exactly the specimens are extracted from

[+ majority of these tests are destructive → we bend or pulled apart in various ways → measure the force that is required to do that. + also tests such as WA and TS where we record the behaviour of the specimen in response to intense exposure to moisture]
### Study design

<table>
<thead>
<tr>
<th>Factors</th>
<th>Panel configuration</th>
<th>Adhesive type</th>
<th>Unique panels</th>
<th>Replicates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coarse</td>
<td>Medium</td>
<td>Fine</td>
<td>Type</td>
</tr>
<tr>
<td></td>
<td>&gt; 2.0 - 4.0 mm</td>
<td>&gt; 1.0 - 2.0 mm</td>
<td>&gt; 0.6 - 1.0 mm</td>
<td>homogeneous</td>
</tr>
<tr>
<td>1</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>250%</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>100%</td>
<td>-</td>
<td>homogeneous</td>
</tr>
<tr>
<td>3</td>
<td>50%</td>
<td>50%</td>
<td>-</td>
<td>mixed</td>
</tr>
<tr>
<td>4</td>
<td>25%</td>
<td>50%</td>
<td>25%</td>
<td>mixed</td>
</tr>
</tbody>
</table>

*quantity conditional to adhesive type

How are the panels constructed?

**Overview of study design (manufacturing template)**

+ 3x particle size categories coarse, medium and fine
+ 4x panel configurations
+ Each panel config will be manufactured with one of 3 adhesive at 2 compactions rates and 2 different amount of adhesive
+ This whole process is one repetition and will results 48 unique panels
+ replicated 3 times ➔ generate sufficient test specimen and data to perform a statistical analysis
Ok, what has been done so far?

+ received hemp hurd chips (Australian Hemp Manufacturing Company)
+ pitched the project idea 3 adhesive manufacturers → 3 adhesives
  building/construction industry based on
  - MC resistance
  - cure without any extra heat
  - formaldehyde-free / non-formaldehyde releasing
A crucial first step was to reduce hemp hurd chips into finer material (aka furnish) with a cutting mill.

+ quite basic process  \(\rightarrow\) **essential feature** are the sieve inserts located at the bottom of the cutting chamber.
- homogenize the furnish  \(\rightarrow\) only particles matching the opening sizes pass through into the receptacle.
- Purchased range sieve inserts of varying sizes, produced furnish with each insert and then followed up with a granulometry analysis.
in this next step - mechanical screening - the furnish from each sieve insert was separated into respective particle size categories.

Laboratory test sieves with mesh sizes of 4.0, 2.0, 1.0 and 0.6 mm were stacked inside a plastic container and placed on top a mechanical shaker...with the furnish placed on the top sieve ... the shaker was then set to run for 1 min.

This distributed the particles according to mesh opening size as displayed in the fig at the bottom
+ Particles left on each mesh were collected, weighed and expressed as percentage of total weight.
+ Results are presented as Particle size distribution in this chart
+ Each bar represents the distribution per sieve insert
+ Which inserts produced the most favorable distribution for subsequent manufacturing
Particle geometry - Digital image analysis

+ 100 particles particle left on 4, 2 and 1 mm mesh was scanned with a flatbed scanner and processed with digital image analysis software (ImageJ).
+ This Figure shows the scanned, original particles on the left and subsequent stages after rendering with ImageJ.
+ The software measured particle dimensions and calculated important shape descriptors.
3. PROGRESS OVERVIEW – Particle geometry – Aspect ratio

Particle geometry
Aspect ratio/Slenderness

+ This chart shows Aspect Ratio for each sieve insert and grouped by particle size
+ The higher the number the more elongated or slender the particle is.

→ Results illustrate the wide spread of the data and an irregular tendency for elongated shapes.
→ It also indicates it is not a highly homogenized material.

Box plot: compare range and distribution of data
[Smaller particles: higher IB, less swelling (higher compactness), compression strength and SWR
Elongated shape increases MOE/MOR]
To understand equipment requirements and processing parameters → range of prototype panels

+ moulding frame and lid/spacer combination → leaves a 12 mm gap at the bottom → forms panel as resinated mix is compacted in the press
+ Later stage: introduced an aluminum mould for PRF → pressed at elevated temperate of 80 °C to accelerate curing process → aluminum mold for heat transfer
Specimens preparation

+ visually assessed for cohesion, brittleness and edge integrity.
+ prepared specimen for a preliminary assessment.
3. PROGRESS OVERVIEW – Adhesion (pull-off)

Preliminary testing: Pull-off (Adhesion)

+ The specimens were subjected to a modified adhesion (pull-off) test (ASTM D4541-17)
+ metal dolly is glued to one face of the specimen and a hydraulic press is used to pull the dolly away from the surface.
+ This test was developed to assess the adhesion of surface coatings of concrete
+ in this context: screening method to establish adhesive ratios and densities for the main manufacturing stage.
Preliminary testing: Internal bond strength

+ Internal bond (IB) test (AS/NZS 4266.1:2017) using an Instron universal testing machine.
+ similar principle → measure force required to pull the specimen of known dimension apart
+ With the exception that the pulling force is directed to the middle of specimen and exposes the weakest bonds
4. Future work

1. Preliminary trial
   Complete technical preparation with MDI adhesive

2. Main trial
   Manufacture hurd composite panels based on results of preliminary trials

3. Specimen preparation and testing → data analysis → thesis
   • insight into possible applications and potential products
   • inform choices for further investigation

So, what is left to do?
Quite a lot actually...
+MDI → very different sprayed using compressed air
5. References


Thank you

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