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

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Introduction

The demand for wood fibre products for a growing population and competing industries is contrasted by a decline of sustainable timber resources [1]. This discrepancy raises concerns about future supply for lignocellulosic fibres and motivates research into finding alternative sources. The 2017 legalisation of hemp seeds/oil for human consumption suggests a strong focus on grain production of Australia's emerging hemp industry. The enthusiasm about the 'food' aspect of hemp presents an opportunity for the valorisation of fibre by-products from residual biomass. Hemp stems consist of xylemic, lignified core tissue (hurd) and long fibre bundles situated in the bast. The excellent tensile strength characteristics of hemp bast fibres made them a popular choice for many natural fibre composites (NFCs)[2]. Less explored, hemp hurd comprises shorter fibres and is a porous, highly absorbent material used as animal bedding, spill absorbent and soil amendment. Several research studies aimed to improve the mechanical, thermal and hygric properties of alternative lightweight construction materials mixed from hurd and cementitious binders (hemp concrete) [3]. Further studies explored hurd as main constituent or additive in traditional particleboards [4, 5]. The aim of the present study is to develop lightweight panels manufactured with Australian hemp hurd and evaluate their performance characteristics. Objectives are to a) characterise ground hemp hurd using granulometry measurements via digital image analysis, b) assess the interfacial bonding capacity of manufactured panels, and c) identify optimal adhesive application, pressing parameters, and panel composition.

Material and Methods

Hemp hurd chips have been conditioned at 23 °C and 65 % relative humidity to 12 % equilibrium moisture content (EMC). A cutting mill (Fritsch Pulverisette 15) incorporating sieve inserts of 8.0 x 8.0, 6.0 x 6.0, 4.0 x 4.0 and 2.0 x 2.0 mm was used to reduce the size of the chips into smaller particles (furnish). Particle size distributions for each batch have been recorded after the furnish was fractionated with mesh sizes of 6.3, 4.0, 2.0, 1.0 and 0.6 mm. Particles left on the 6.3 mm mesh and particles smaller than 0.6 mm were deemed too coarse and too small, respectively, and therefore excluded from the study. Fifty particles of furnish left on the 4.0, 2.0 and 1.0 mm mesh were scanned and digitally analysed (ImageJ) to determine aspect ratio (slenderness), length and best fitting ellipse. Particles left on the 0.6 mm mesh were too small to be scanned but still considered in the panel manufacturing. Bulk densities of uncompacted furnish were determined at 12 % EMC for each particle size category.

A methylene diphenyl diisocyanate adhesive (MDI), a bio-epoxy adhesive and a phenolic resorcinol formaldehyde (PRF) adhesive were selected for their improved resistance to moisture and ability to cure at room temperature (cold setting). The adhesives are formaldehyde-free (MDI, bio-epoxy) or suitable for exterior structural use with waterproof bonds that do not release formaldehyde (PRF). Single-layered prototype panels were manufactured with PRF and bio-epoxy adhesive using a laboratory press to establish appropriate processing parameters for each adhesive. Two different adhesive loading levels and compaction ratios (i.e., "high" and "low") have been identified for the main trial based on current preliminary trials. The prototype panels were visually assessed for cohesion, brittleness and edge integrity. Three specimens of 85 x 85 mm and 50 x 50 mm were cut per panel for a preliminary assessment of interfacial bonding capacity. The specimens were subjected to a modified pull-off (adhesion) test (ASTM D4541-17) and an internal bond (IB) test (AS/NZS 4266.1:2017) using an Instron universal testing machine.

Future Work

Single-layered, low density (<300 kg/m^3) homogenous and mixed hemp hurd composite (HHC) panels will be manufactured targeting a 12-mm thickness based on results of preliminary trials. The HHCs will comprise variations of three particle size categories (i.e. coarse: ⩾ 2 to 4 mm, medium: ⩾ 1 to 2 mm and fine: ⩾ 0.6 to 1 mm) at two different compaction ratios (200 % and 250 %) and two adhesive ratios (high/low). Extended mechanical and physical property testing will be performed with HHC specimens from the main trial (to AS/NZS 4266.1:2017). Selected tests will include: bending strength (MOR) and stiffness (MOE), internal bond strength (IB), screw withdrawal strength (SWR), density (D), water absorption (WA) and thickness swelling (TS). Statistical analysis will be performed to analyse the obtained data and identify optimal HHC panel configurations for each adhesive. The results will allow identifying appropriate adhesive ratios, favourable particle size combinations and compaction ratios in relation to performance characteristics. The findings of the study will provide insight into possible applications and potential products manufactured from hemp hurd such as core layer for a lightweight sandwich or structural insulated panel, and inform choices for further investigation.

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