Biocomp 2016

The 13th Pacific Rim Bio-Based Composites Symposium
Bio-based composites for a sustainable future
November 13th to 15th, 2016 - Concepción - Chile

Study of Macroalgae and Mollusc Wastes as Secondary Fillers in Novel Wood-Plastic Bio-composite Particleboard

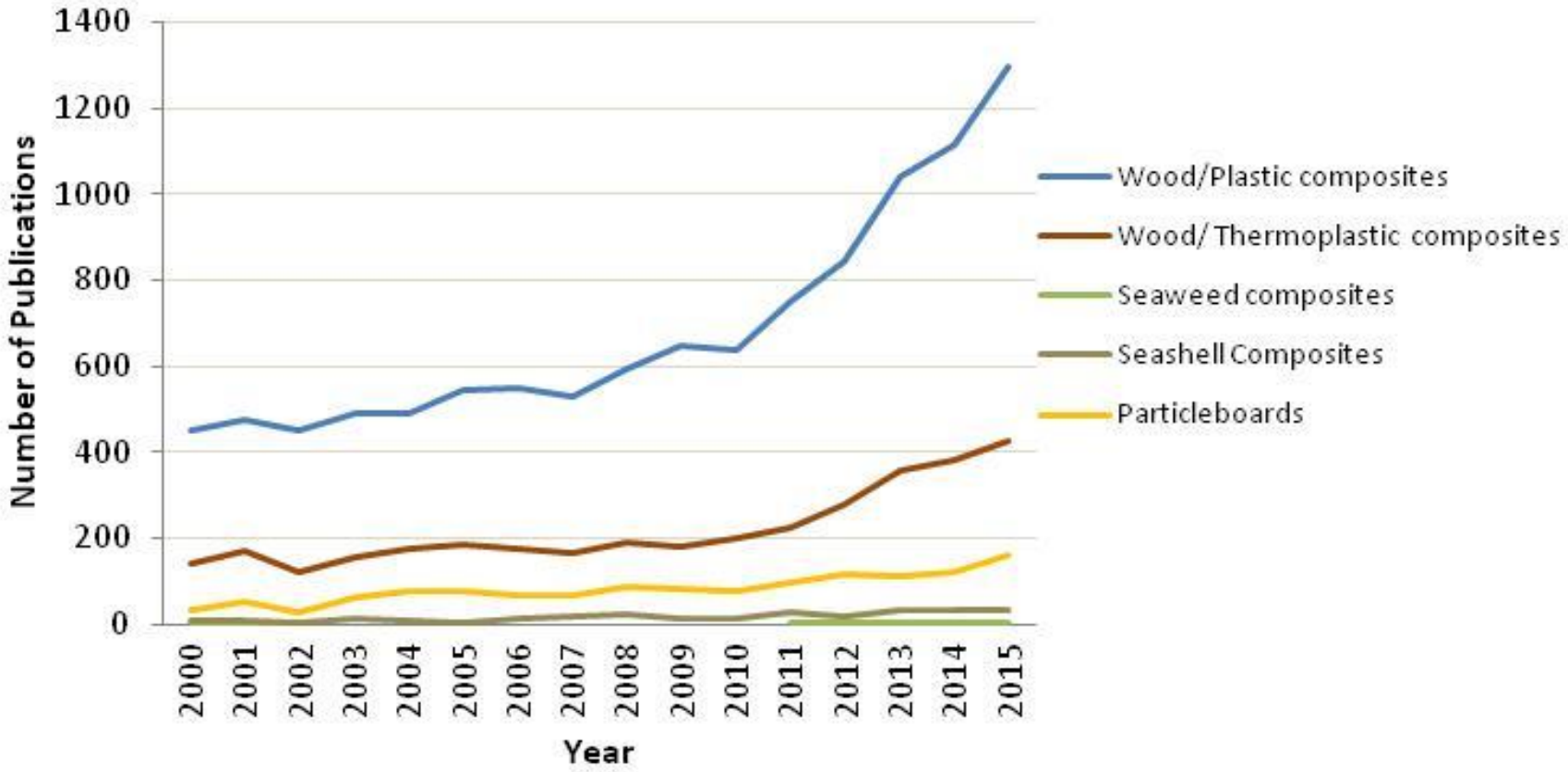
Claudia Echeverria*, Farshid Pahlevani, Vaibhav Gaikwad, Veena Sahajwalla

Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering, - Faculty of Science
University of New South Wales
Sydney , Australia

SMaRT@UNSW
Sustainable Materials Research & Technology

UNSW AUSTRALIA

Wood/Plastic Composites (WPC) Published Research



Number of WPC publications in the last 15 years. Source: Science direct database

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

Project and Research scope

Industrial Ecology

Waste Recovery

Regenerative Design

Wood-Plastic Bio-composite

Low-carbon Building material

Marine Bio-filler

From Waste to Novel Green Materials

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

Problem Statement

• End of Life & Post-consumer timber as well as mixed plastics were listed as Environmental Priority Wastes in 2015 by the NSW Environment Protection Authority (EPA)

Opportunity

• Waste as resource for sustainable building materials

Relevance of the subject

• Transfer waste into resources, addressing simultaneously key social, environmental, political and economic factors through an integrated ethical strategy

• Recovery of low-cost 'latent' materials for high value applications as well as for novel commercially viable end-product

Barriers & Considerations for WPBC sourced from wastes

- **Waste stream reliability of consistent supply of quality raw materials**
- **Cross-contamination with other materials or chemical treatments**
- **Technological barriers, cost effectiveness to clean or segregate waste materials**
- **Minimizing transport costs by capturing and/or processing waste materials closer to the first source of generation**

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

Abstract

In this research locally sourced waste materials from the Sydney Metropolitan Area have been used for the development of a novel environmentally sensitive hybrid bio-composite particulate panel, for a low-carbon environmentally sensitive end-product, for building applications.

For this purpose four highly available materials are examined as raw materials, which mixture it is unprecedented until date.

Macroalgae and bivalve mollusc shells are examined as reinforcement in their function of secondary bio-fillers. The effect on mechanical performance and moisture absorption of the particle size and particle reduction method are reported.

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

1-Introduction

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

Marine waste as resources

Approximately 1,800 species of brown algae have been classified worldwide. The majority develops predominantly, in intertidal underwater forests from temperate cold water marine ecosystems. Similarly, bivalve molluscs are found in saltwater as well as freshwater intertidal habitats.

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

Marine industrial wastes global overview

Table 1. World top 5 aquaculture producers according to Food and Agriculture Organization in 2013

Molluscs – mariculture	t/yr	%	Seaweeds – mariculture	t/yr	%
China	12,728,046	83.4	**China**	13,479,355	50.1
Japan	332,460	2.2	**Indonesia**	9,298,474	34.6
Republic of Korea	291,024	1.9	**Republic of Korea**	1,575,605	5.9
Chile	252,528	1.7	**Philippines**	1,558,378	5.8
Thailand	217,467	1.4	**Japan**	418,365	1.6

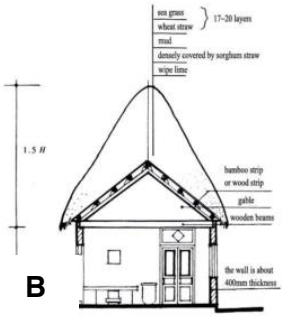
- **China accounted for approximately the 54% for seaweed and 83.4% for molluscs; altogether with total of 26.2 million tonnes per year.**

- **China produces 10 million tons of shell biological wastes each year which remains greatly underutilized, disposed of in landfills presenting major environmental hazards (Yao et al., 2014)**

Marine waste as building materials

They have been traditionally used in vernacular architecture, to provide thermal insulation and impermeability- in countries such as Denmark and China for thousands of years. They were highly valued bio-materials mostly for their consistent availability, low cost, hand layered feasibility, light weight and remarkable thermal and fire-retardant properties. With a life span expectancy of more than 150 years (Widera 2014)

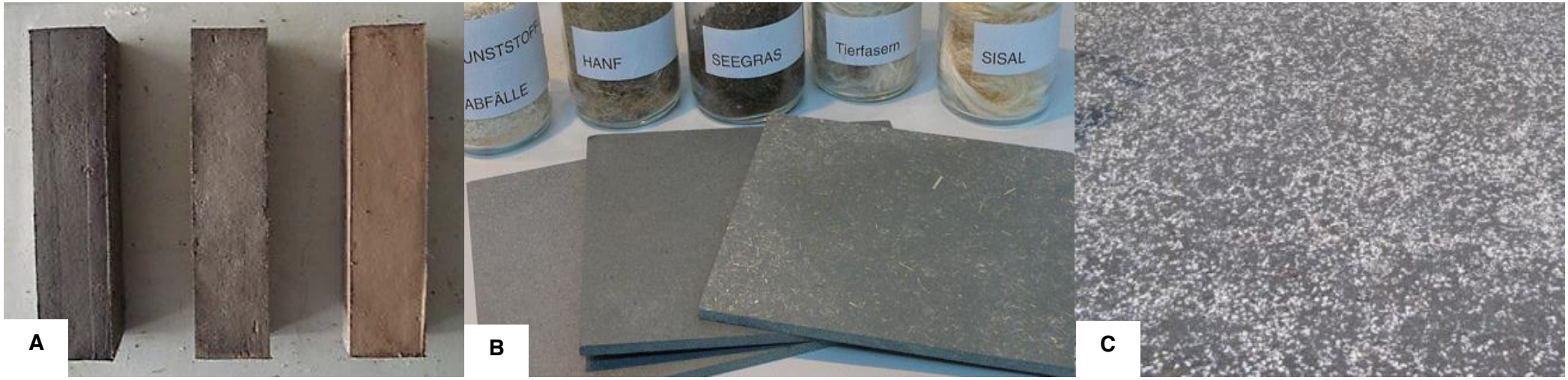
- **Seaweed (SW) was mainly used as roof thatching or mud reinforcement.**
- **SW ashes was used for glass manufacturing in England and Scotland until XVIII.**
- **Seashells (SS) where used as wall infill or as replacement for cement.**



A)Traditional Seaweed thatch homes of Læsø, Denmark (Widera 2014)
B)-D) Roofs of seaweed houses in Shandong, China (Kuang and Yu 2013)
E) Oyster houses in Xunpu, China (Wang and Tong 2013)

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

Marine waste Hybrid Bio-composites



A)Sw-Wool Mudbricks, Spain (Rivera-Gómez et al. 2014 B) Engineering FR Panels at Hannove Fair, 2007 C) Recycled oyster shells wastes as aggregate in permeable concrete (University of Florida)

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

2- Materials and Methods

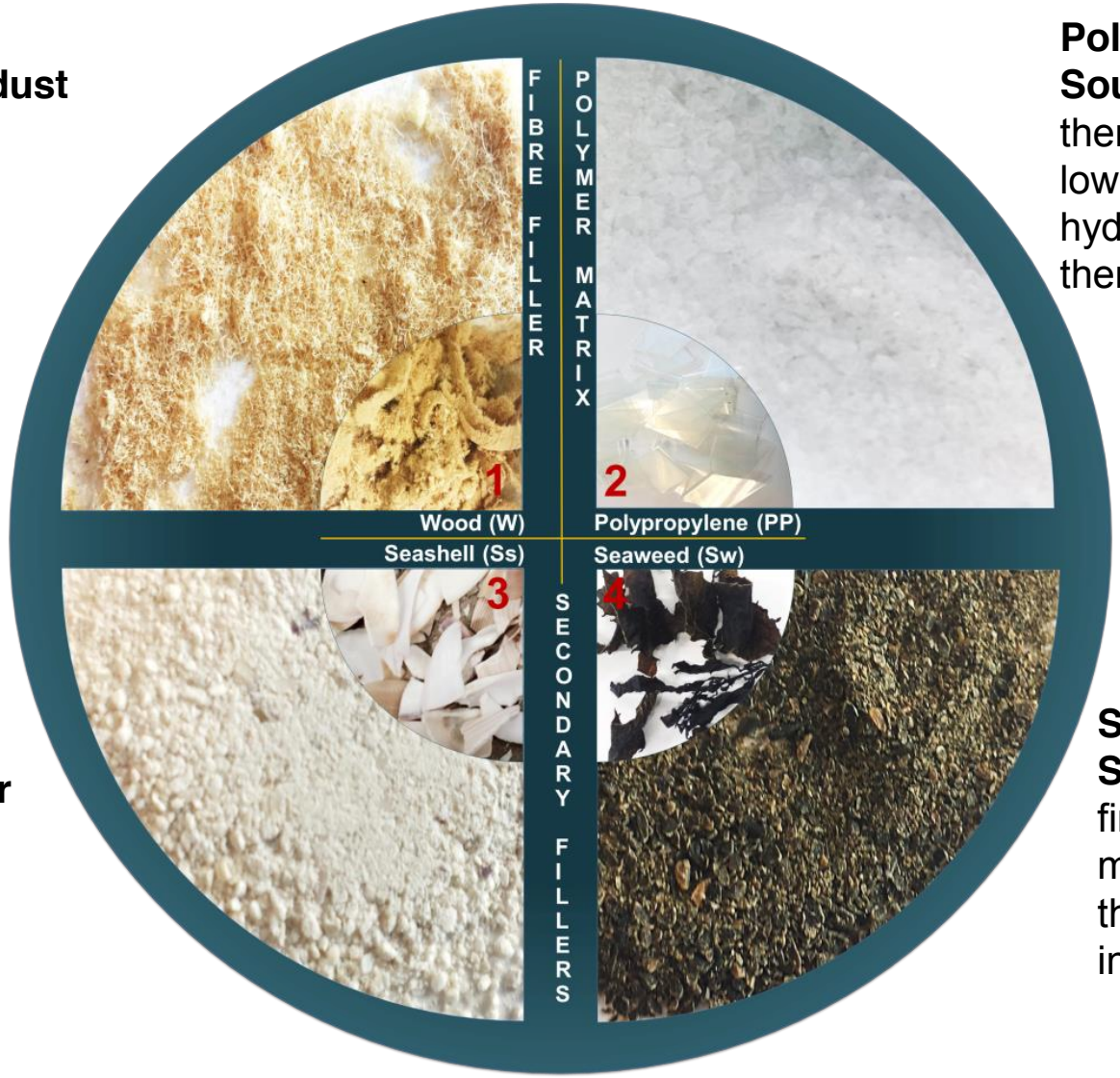
Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

Materials selection criteria

Biocomp 2016

Wood (W)
Source: mixed sawdust
structural strength
thermal and acoustic insulation

Polypropylene (PP)
Source: food containers
thermoplastic polymer
low toxicity
hydrophobic
thermal insulation



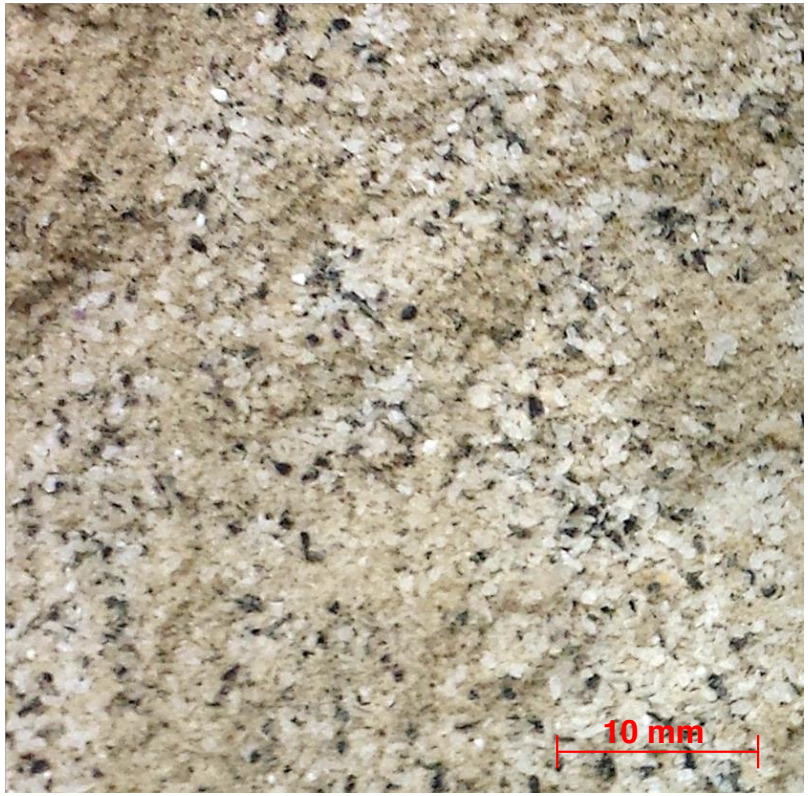
Seaweed (SW)
Source: marine litter
mechanical strength
fire retardancy

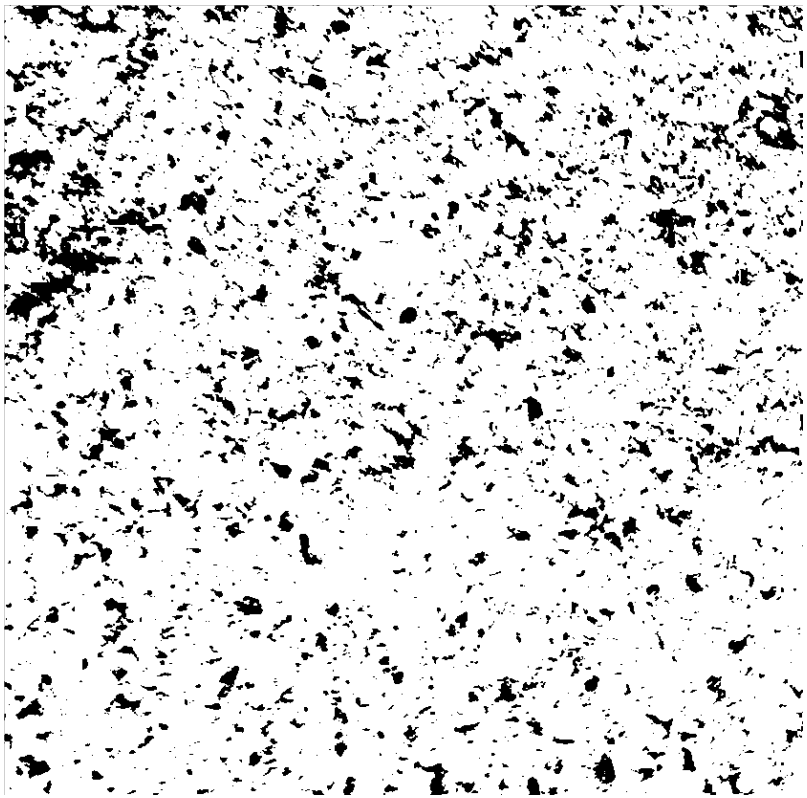
Seashell (SS)
Source: marine litter
fire retardancy
mould resistance
thermal and acoustic insulation

Fillers as multi-functional bio materials

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

Dry mixture characteristics





Bio-composite particulate 60/40 wt% mixture forms an isotropic heterogeneous disperse phase randomly oriented with particles size between 32-850 µm.

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

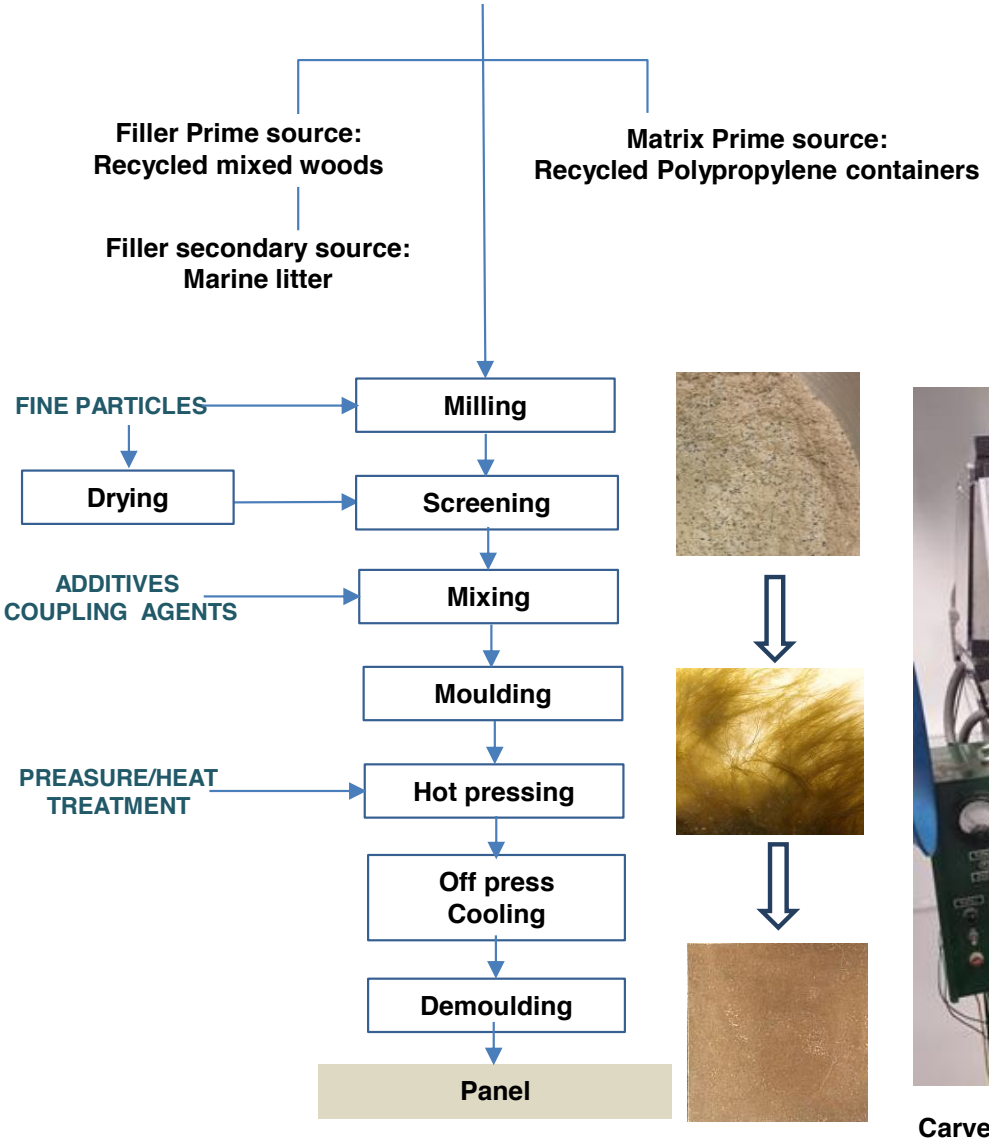
Panel Manufacturing

Biocomp 2016

Retch Cutting Mill SM100

Rocklabs Ring mill

WPC Process



Carver Hydraulic Hot press

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

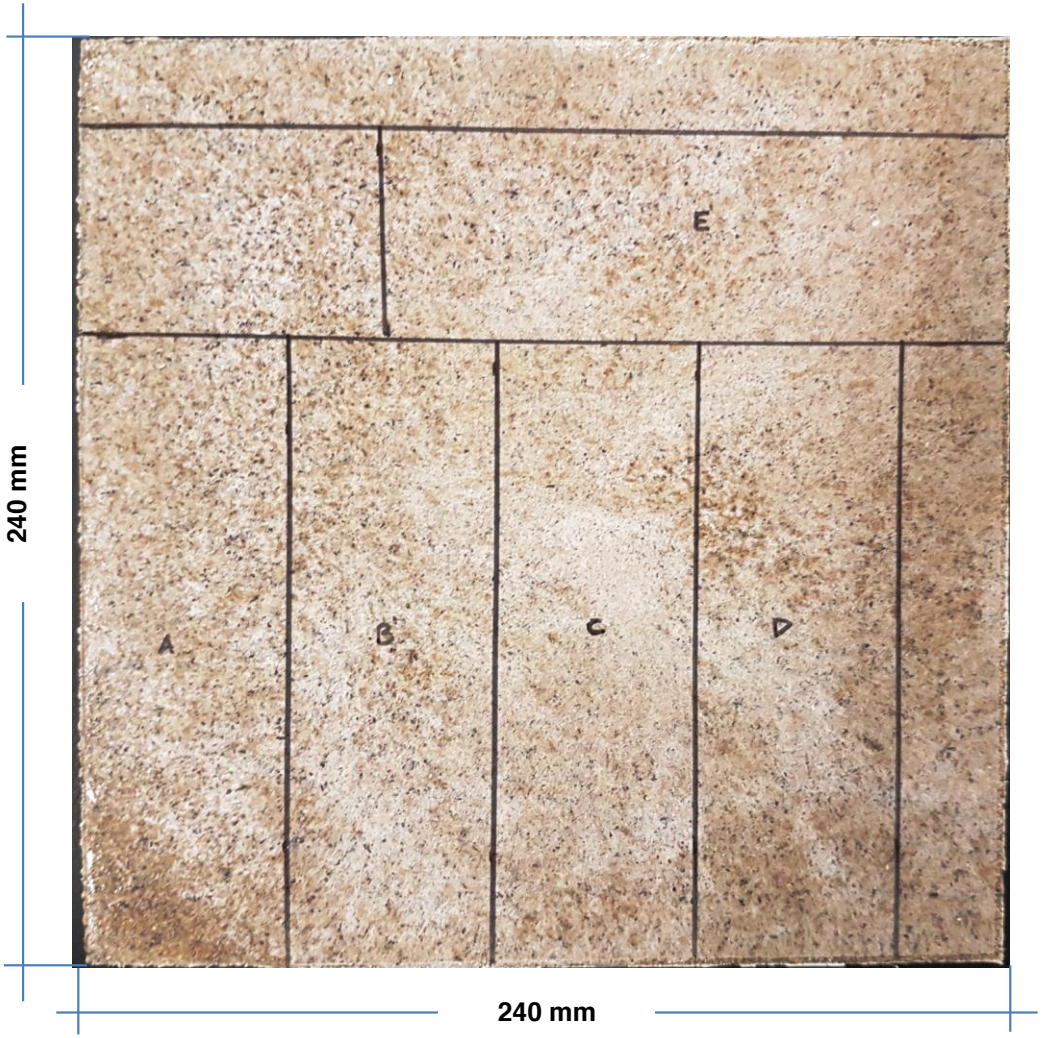
3- Experimental

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

Static bending Test ASTM D1037

Biocomp 2016

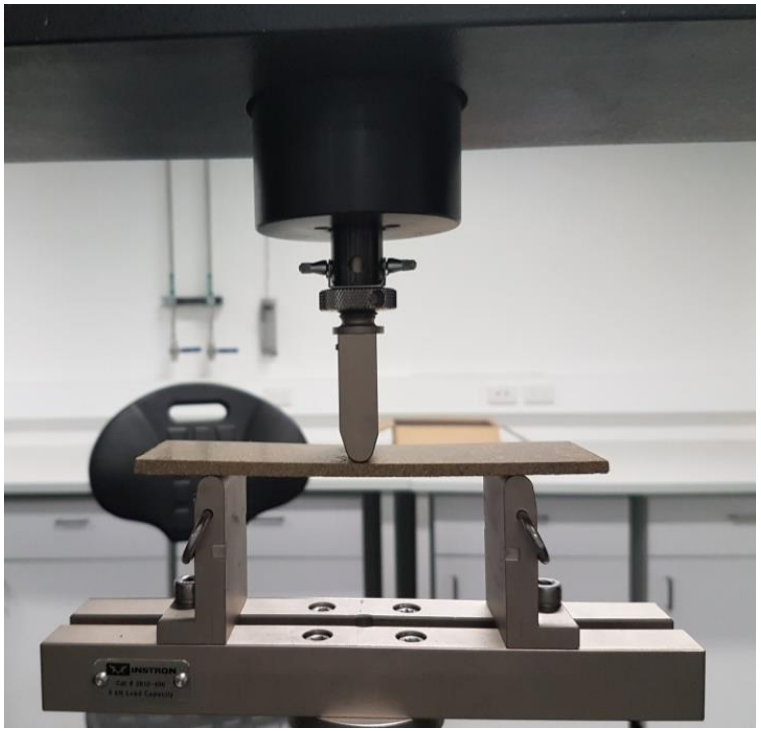
Five specimens were produced from each panel sample to be tested individually.



Panel dimension: 240 x 240 mm

5 specimens of 160 x 51 x 4.5 mm approx.

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES



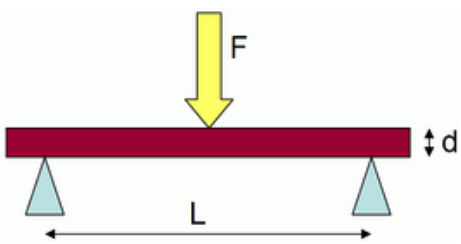
Instron 5565 static testing machine

Modulus of Rupture

$$MOR \quad \frac{3FL}{2bd^2}$$

Modulus of Elasticity

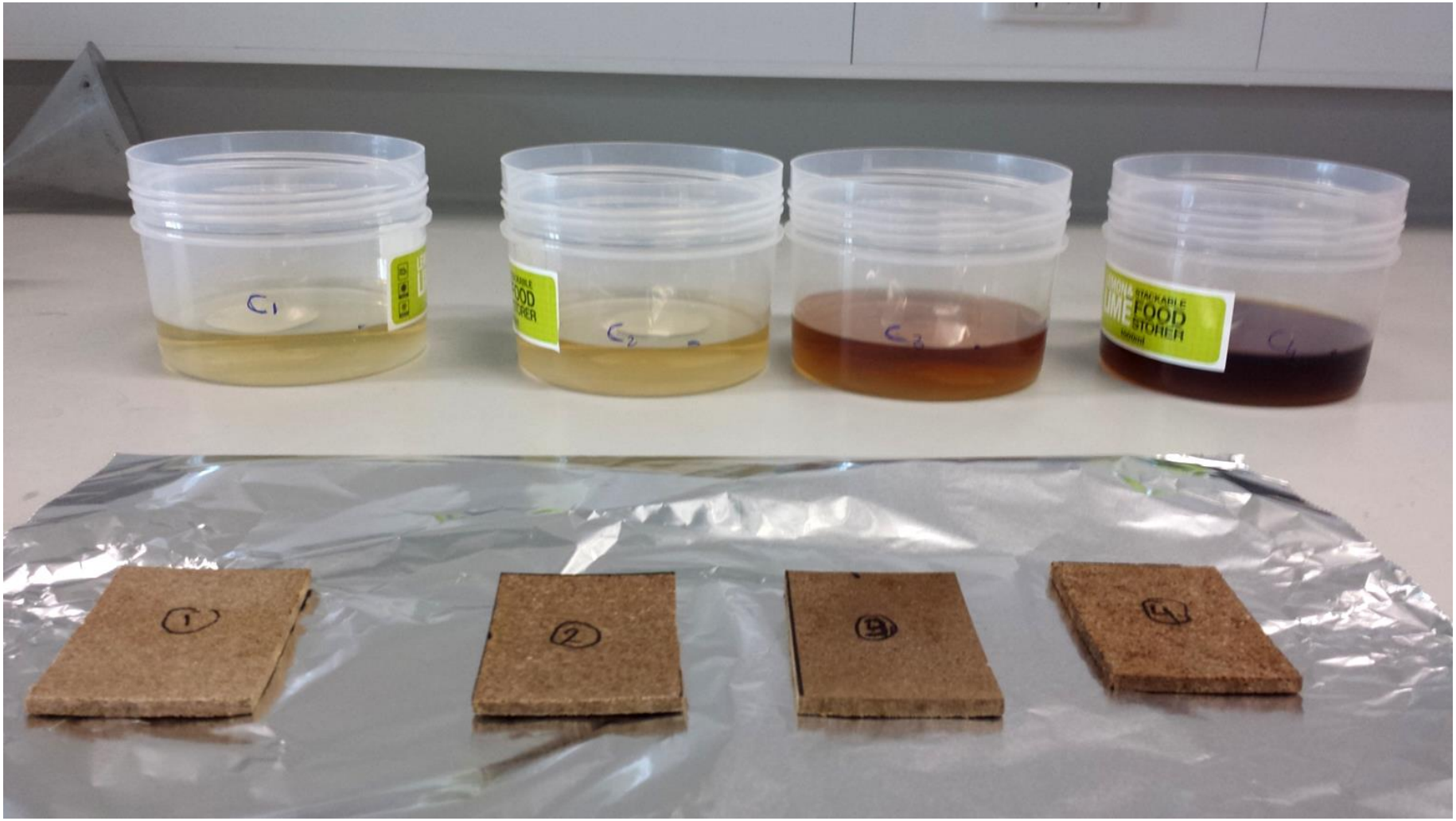
$$MOE \quad \frac{L^3}{4bd^3} \frac{\Delta P}{\Delta y}$$



F = maximum load at failure
b = length of the specimen in dry condition
L = span between supports
d = thickness of specimen in dry conditions
ΔP/Δy = slope of straight line portion of load deformation curve

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

24 h Water absorption



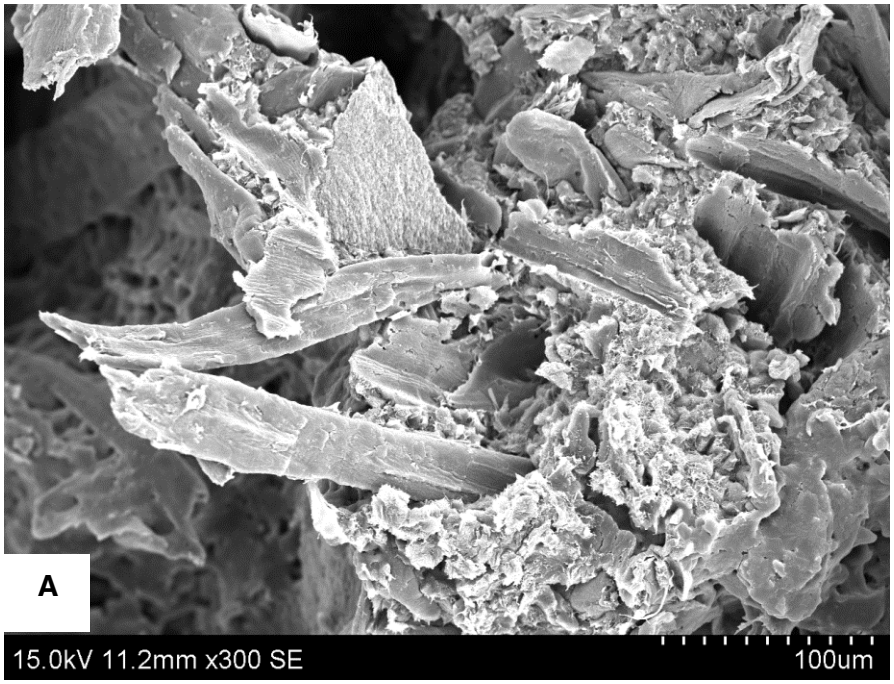
Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW
THE UNIVERSITY OF NEW SOUTH WALES

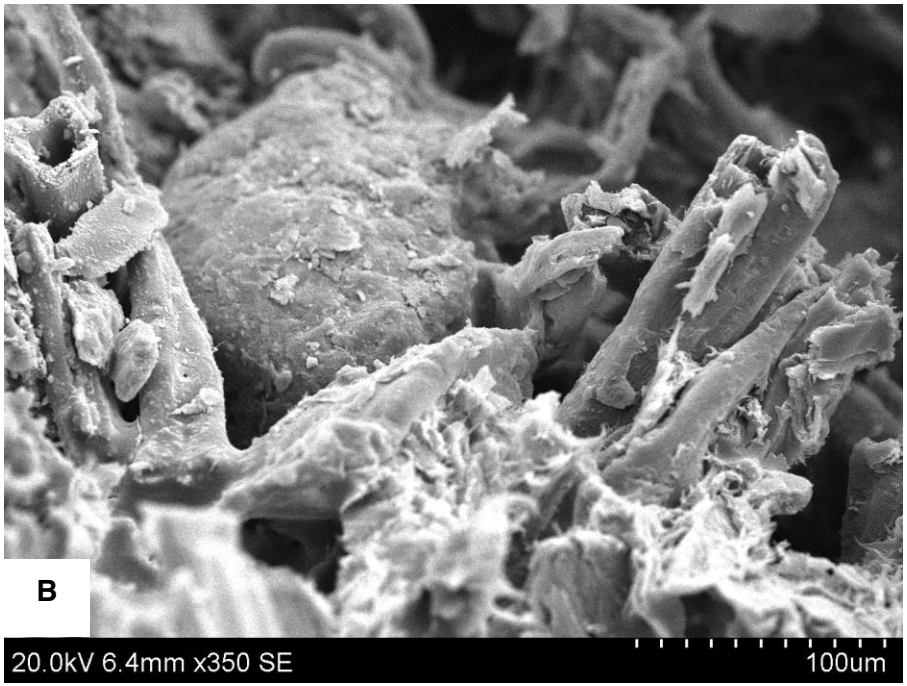
4- Results and discussion

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

SEM Fracture Surface Analysis

SEM micrographs were captured from the fracture surfaces after performing the mechanical test. The sample panels were mounted on a 25mm stud and kept in a desiccator for 24 hours. Samples were gold coated, before the analysis





WPBC Matrix/Fillers interface Fracture Surface SEM micrograph.
WPBC Panel A, 20 mesh; B) WPBC Panel B, 40 mesh

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

Cross section

From the SEM micrographs as well as the cross section analysis panel (B) presented a consistent encapsulation of the fibres. Therefore reducing micro pores and internal cracks, resulting in an increased physical bonding as well as internal cohesiveness between the hydrophobic matrix and hydrophilic fillers

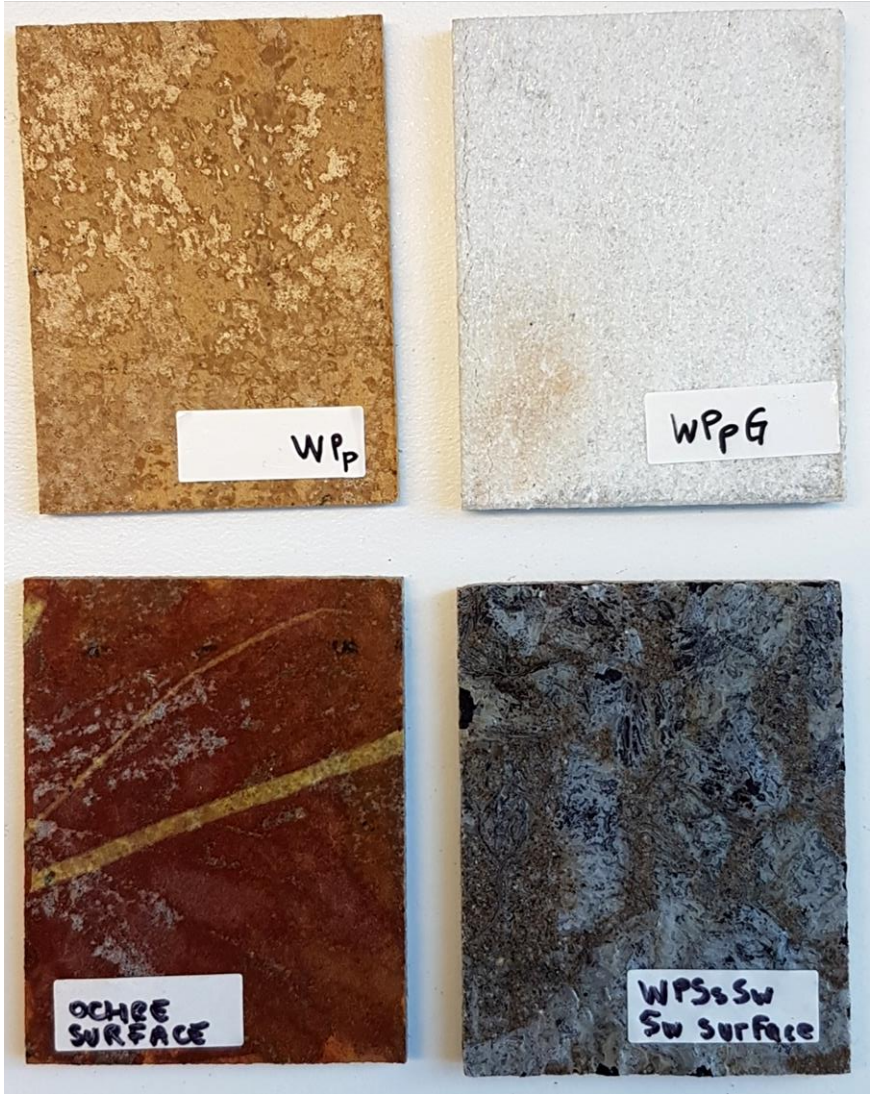
A) WPBC
20 mesh
-850 µm
Manually processed

B) WPBC
40 mesh
-425 µm
Mechanically processed

Cross-sectional image of the grain size detail of WPBC panels

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

Advancement on Design and Applications



Interior Architecture

Cabinetry & furniture

Acoustic/Insulating Panels

Division panels & Screens

Architectural linings

Ceiling Panels

- **Functional Bio-composite material series**
- **Formula and source of materials optimization for high-performance**
- **Design for disassembly and recycling**
- **Long term consistent non-toxicity**

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES

Conclusions

•Incorporation of the secondary marine bio-fillers improved the moisture resistance properties of the prototype panels

•These results suggest the proposed novel bio-composite is being suitable for high moisture environments applications.

•From the MOR and MOE values the peak mechanical performance was achieved by the specimens obtained from panels with particle size of -425 μm as well as by panels with particles made from mechanical pulverization.

•Panel can be optimized by the incorporation of 3 wt% MAPP into the formula

Claudia A. Echeverria PhD (c)
Centre for Sustainable Materials Research and Technology (SM@RT)
School of Materials Science & Engineering - Faculty of Science
UNSW THE UNIVERSITY OF NEW SOUTH WALES