Polymeric Waste Glass Composites

RP1022u1

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Peer Review Statement

The CRCLCL recognises the value of knowledge exchange and the importance of objective peer review. It is committed to encouraging and supporting its research teams in this regard.

The author(s) confirm(s) that this document has been reviewed and approved by the project's steering committee and by its program leader. These reviewers evaluated its:

- originality
- methodology
- rigour
- compliance with ethical guidelines
- conclusions against results
- conformity with the principles of the Australian Code for the Responsible Conduct of Research (NHMRC 2007),

and provided constructive feedback which was considered and addressed by the author(s).

Contents

Introduction

This report presents the productionisation of the processes developed in CRCLCL RP1022, the investigation of innovative sustainable low carbon products from waste materials for the built environment.

The aims of the project were to deliver an innovative solution for industrial scale production of glass composite panels. By leveraging the expertise and process for developing of a new generation of high-performance engineered stone for building, furniture and architectural applications (RP1022), we propose processing and production of glass composite panel at an industrial scale.

In this project, processing parameters from lab-scale to industrial-scale production will be fine-tuned. We will then investigate the design, properties and production trial with end users to support commercialisation.

In the long term, this project represents a significant advance in reducing the carbon generation during production of building materials as it overcomes the costly need for extraction of raw materials, transportation and production of already existing products in the market.

The success on this project will provide a cost-effective, technically viable new solution that supports the goal of producing low carbon and sustainable products with high performance at compatible price. To help to achieve this goal, the SMaRT centre will also initiate the partnerships with local waste management's facilities for providing the input materials and local manufacturer to manufacture the final product.

The products developed at lab scale have the performance standards at least equal to existing engineered stone products, particularly those used in the benchtop market. The project will also establish the feasibility of producing the product and will support and facilitate its industrial scale production and commercialisation.

The proposal was made to purchase a hot press and moulding tools (die) to prepare a prototype 300 mm x 300 mm engineered stone at an industrial site, Terrazzo Australian Marble. Under this, we have procured and installed the Hot press at TAM on 2nd June 2019.

Utilisation and commercialisation strategy

- Use of up to 300T of waste per year
- Reduction of waste going to landfill.
- The use of the waste materials reduced the carbon footprint of the end product and the manufacturing and distribution system.
- The product is sustainable as it is 100% recyclable at the end of its life.
- Replacing imported product with locally produced produce with a recycled waste content of more than 50%.
- End product can be used in various markets from commercial fit out and refurbishment to domestic refurbishment and installation.
- The product is cost competitive with current engineered stone systems.
- The product has similar technical capabilities as the current engineered stone systems.
- The unique product has generated a large interest form the fit-out market and specifiers.
- The process is available to current and potential industry partners.
- This setup is run as a demonstration setup to show potential partners what can be achieved.
- Partners with the inhouse skill sets to run the process using a compatible production system as proven on the test press will be sort.

Case Study Report

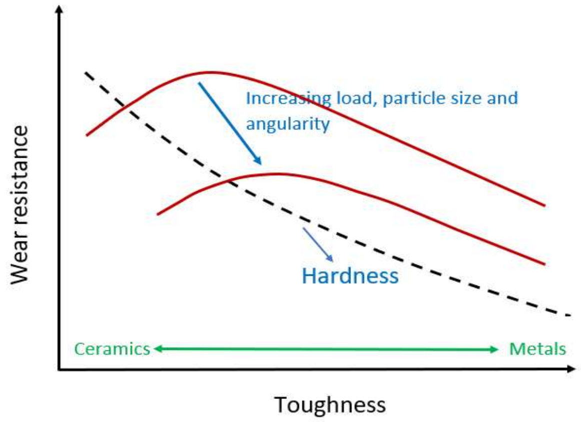
The study reports a novel approach to synthesize glass- resin composite tiles by utilizing end-of-life mixed waste glass as valuable raw materials.

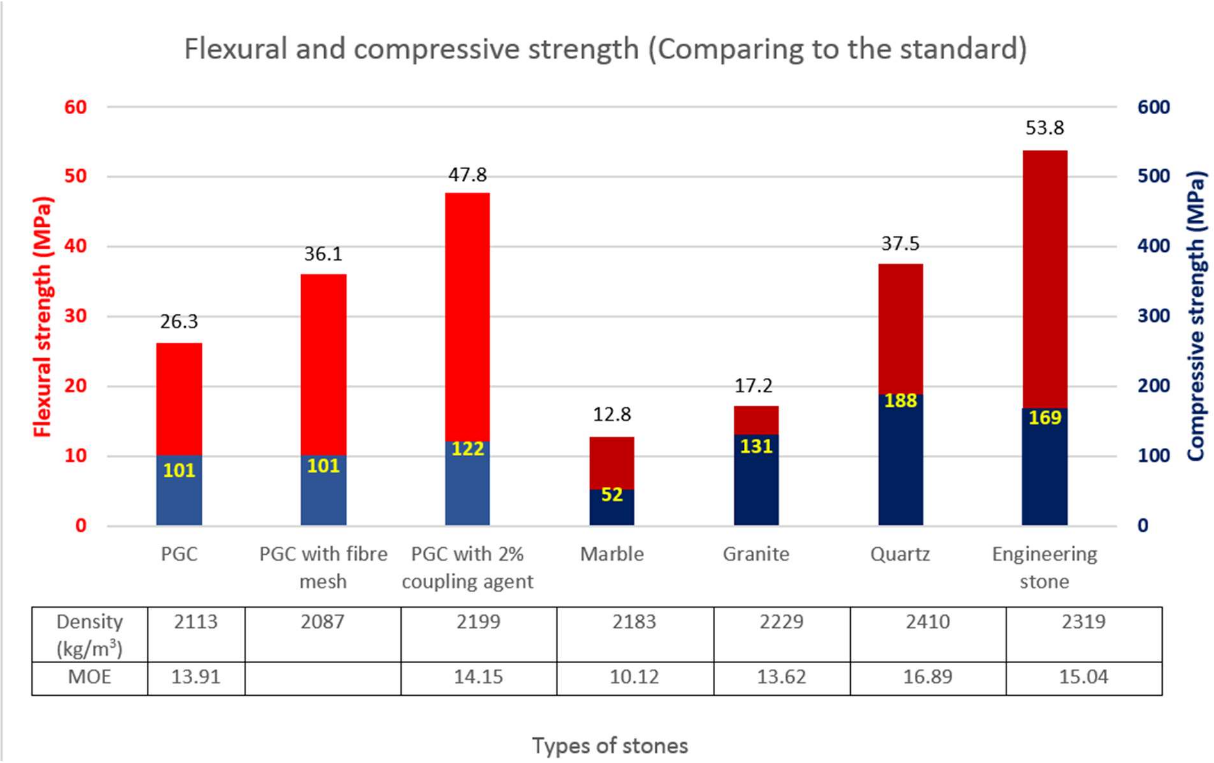
Waste glass is one of the fastest growing solid waste streams around the world today. High consumer demand especially in architecture, construction and packaging have risen sharply for the past decade. Its role has evolved from humble beginning as window panes in luxury house to sophisticated structural load-bearing element for canopies, staircase, masonry glass blocks, beam and floor. Global demand for flat glass in architecture/construction is expected to double from the year 2013 to 2023 with total usage of flat glass increase from 72,000 to 139900 million dollars (The Freedonia group, 2015). The increase in consumption, however, is linearly correlated with the increasing volume of waste. Recycling technology to drive the recovery of resources have failed to keep pace with this accelerating consumption, resulting in ever-increasing volumes of waste to landfill (EPA, 2017). Despite its recyclability, end-of-life building glass is almost never recycled into new glass products. It is very often crushed together with other building materials and put into landfills (Glass for Europe, 2014). In Europe, approximately 1.5 million tonnes of waste glass are generated every year due to building demolition and renovation (Hestin et al., 2016). Similarly, in Australia, the glass consumption increases but the national recycling rate fell from 49 to 42% (Industry Edge Pty Ltd and Equilibrium OMG Pty Ltd, 2016; Adaway et al., 2015), leaving almost 800,000 tonnes of waste glass requiring disposal every year (FEVE, 2017).

Conventional glass recycling technologies are limited by the need to separate waste glass into different types. Some speciality glasses like window panes, tempered glass, Pyrex, borosilicate glass and any type of broken glass are usually not considered recyclable. As the melting points and characteristics of different glass types are precisely matched to their uses, mixed glass cannot be remelted in one batch. If heat treated glass are mixed with bottle and jar recycling process, it can result in different viscosity of the glass melt and prevent the molten glass to extrude properly. Forming, cooling rate and annealing temperature of mixed glass are also harder to control. Additionally, different types of glass have different coefficient of thermal expansion which might expand and contract at different rate. Mixing these glass cause cracking or shattering of the piece during cooling. Contamination are also the major problem in conventional glass recycling. Demolition sites are a major source of waste window glass, but effort to recycle old window glass cullets to new glass has not been done. Unlike container glass which allow small amount of impurities of 20- 50 ppm, production of flat window glass tolerate no ceramic and ferrous metal impurities (ref3). Also, various types of window glass ranging from standard, tempered, silver based varnish (mirror) to laminated glass have different chemical composition and impurities, preventing conventional recycling to be done. To increase glass recycling rates, alternatives means of reprocessing waste glass without remelting are needed. In this study, we demonstrated that mixed broken glass could be used as primary input to produce high-value composite tiles.

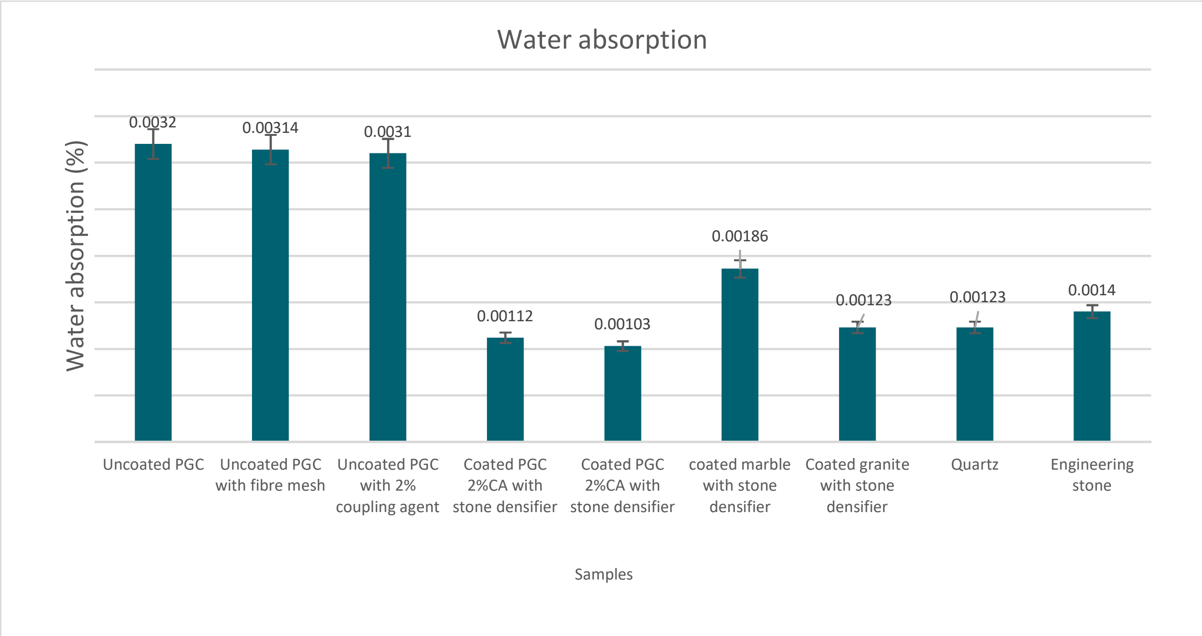
Based on Heriyanto's Ph.D. study, the optimum composite tiles (i.e. PGC – polymeric glass composite) achieved a flexural strength of 48 MPa, water absorption below 0.002%, a density of 2.113 kg/m3, compressive strength of 101 MPa with high scratch and wear resistant. It's excellency in the mechanical value stand in parallel with engineering stone but, with cheaper and efficient process.

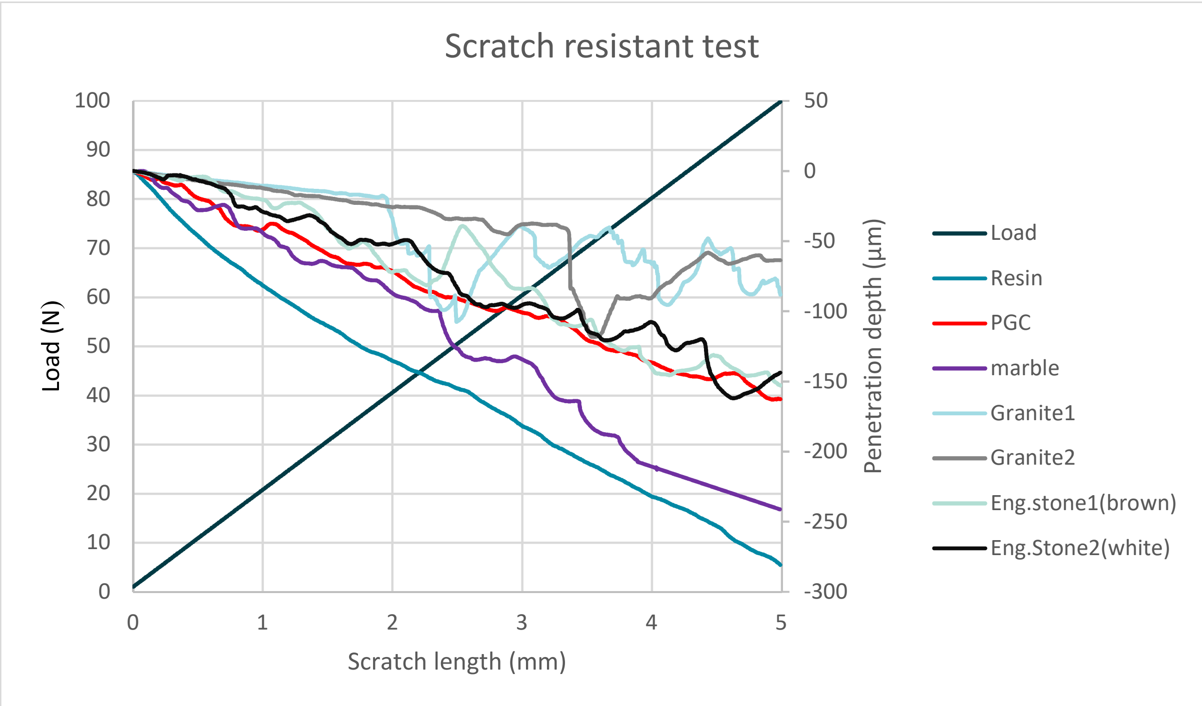
The data were outlined as followed:



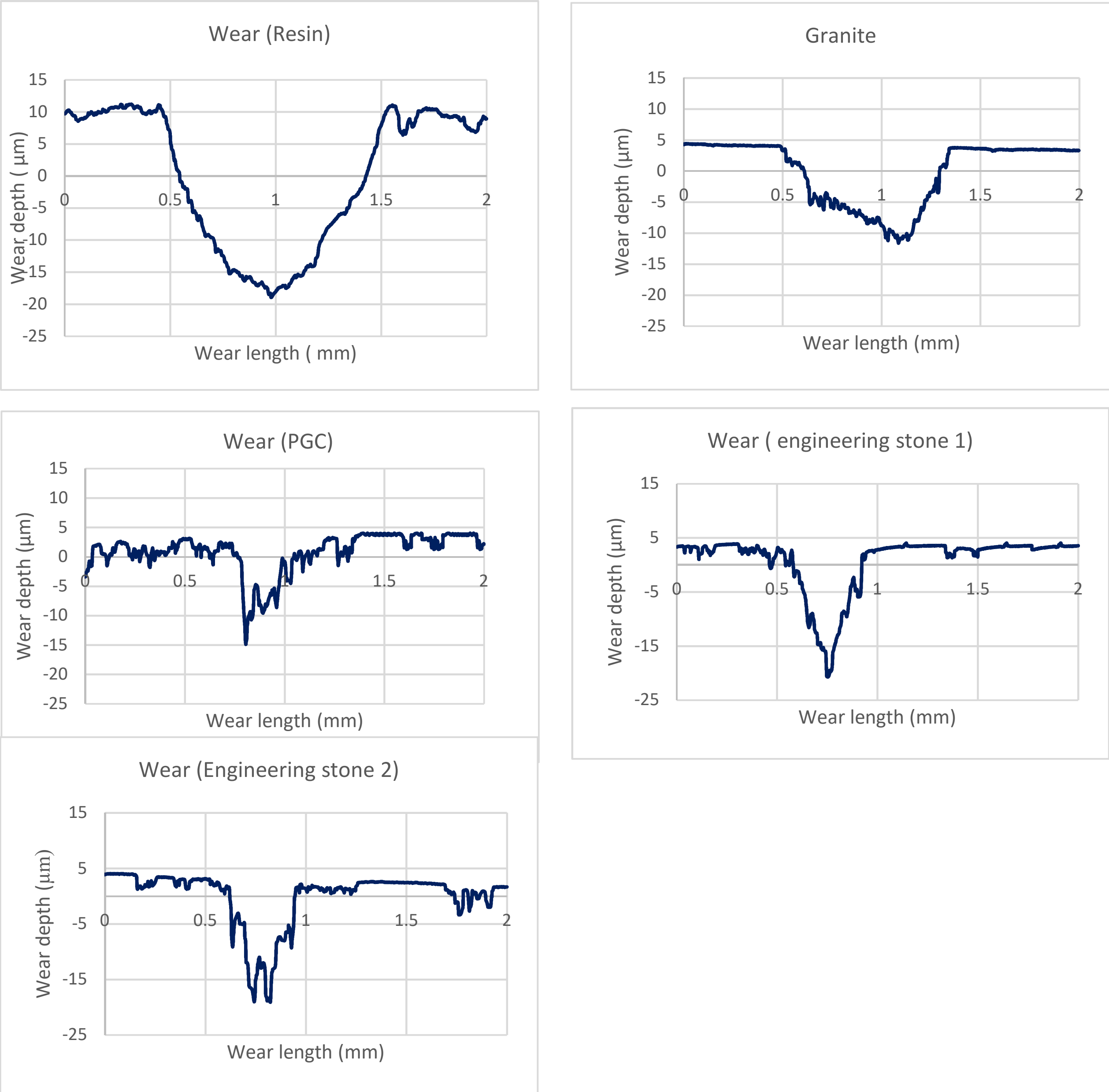


Density (kg/m^3)	2113	2087	2199	2183	2229	2410	2319
MOE	13.91		14.15	10.12	13.62	16.89	15.04


Water absorption
Water absorption (%)
0.0032
0.00314
0.0031
0.00112
0.00103
0.00186
0.00123
0.00123
0.0014
Uncoated PGC
Uncoated PGC with fibre mesh
Uncoated PGC with 2% coupling agent
Coated PGC 2%CA with stone densifier
Coated PGC 2%CA with stone densifier
coated marble with stone densifier
Coated granite with stone densifier
Quartz
Engineering stone
Samples

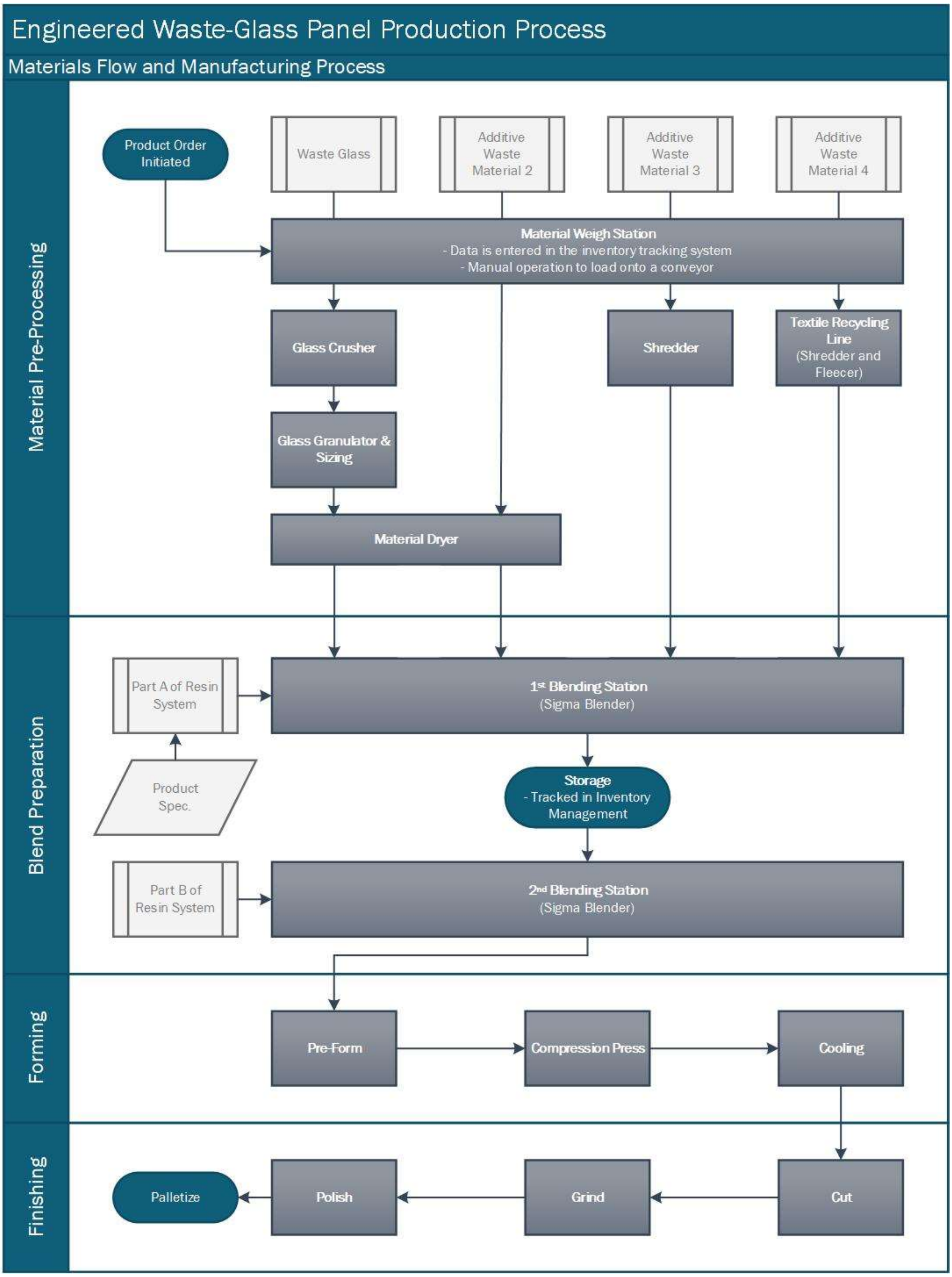

Scratch resistant test
Load (N)
100
90
80
70
60
50
40
30
20
10
0
Penetration depth (μm)
50
0
-50
-100
-150
-200
-250
-300
0
1
2
3
4
5
Scratch length (mm)
Load
Resin
PGC
marble
Granite1
Granite2
Eng.stone1(brown)
Eng.Stone2(white)

Wear profile of tested samples (A-E); (F) Correlation of wear resistant with hardness



Monitoring and evaluation plan

- Finding a cost-effective resin that exhibits a UV resistant capability.
- Finding an appropriate procedure to safely operate variety of machines, equipment, and raw materials in the laboratory
- Developing a suitable processing condition and composition with the new resin.
- Minimizing the production cost by eliminating the grinding process from glass to powder. This were done by using readily available waste glass aggregates (Minus 5 mm and minus 2 mm size).
- Incorporate various waste i.e. Textile, coffee cups and coffee grounds in the glass-resin panels.
- Adding silane coupling agent to improve the mechanical properties of the modified glass-resin composite where needed.


Engineered Waste-Glass Panel Production Process
Materials Flow and Manufacturing Process
Material Pre-Processing
Product Order Initiated
Waste Glass
Additive Waste Material 2
Additive Waste Material 3
Additive Waste Material 4
Material Weigh Station
- Data is entered in the inventory tracking system
- Manual operation to load onto a conveyor
Glass Crusher
Shredder
Textile Recycling Line (Shredder and Fleecer)
Glass Granulator & Sizing
Material Dryer
Blend Preparation
Part A of Resin System
1st Blending Station (Sigma Blender)
Product Spec.
Storage - Tracked in Inventory Management
Part B of Resin System
2nd Blending Station (Sigma Blender)
Forming
Pre-Form
Compression Press
Cooling
Finishing
Palletize
Polish
Grind
Cut

Product Description

The UNSW-SMaRT will manufacture a range of Engineered Waste-Glass flat panel products. Engineered Waste-Glass is a patented blend of resin systems with waste glass, and other waste materials developed at the SMaRT Centre, UNSW Sydney. Each panel has a minimum of 50% waste material, with many of the materials being diverted from landfill.

SMaRT will tailor flat panel products to customer specifications, such as the appearance, size and properties. Some applications of Engineered Waste-Glass flat panels are counter/tabletops, partitions, and cladding.

The Technology

Engineered Waste-Glass panel products have been developed from IP researched at the SMaRT Centre UNSW Sydney, directed by Professor Veena Sahajwalla. A seminal paper was published on the technology in 2018 in the Journal of Cleaner Production proving the science of the process; https://doi.org/10.1016/j.jclepro.2018.04.214.

UNSW-SMaRT has developed two commercial resin systems to produce panels in a range of sizes, appearances and properties. SMaRT currently can produce panels of 300 mm in length by 300 mm in width and 6 to 25 mm in thickness. The panels are created by blending waste glass, single use coffee cups, used coffee grounds, and waste textiles. Each panel has a minimum of 50% waste materials.

The material system has been tested at the SMaRT Centre UNSW Sydney. The waste materials have been sourced from representative waste aggregators, recyclers, community groups, and companies. A multi-step material testing process has been developed at the Centre to verify that properties are within specification. This will continue as part of the process to ensure a high-quality product. The resin systems have also been tested from a variety of suppliers, and unique blends have been developed to allow customers to request a variety of performance specifications. The products can be tested for bending/compression strength, moisture absorbance, stain resistance, slip resistance etc.

The Process

The manufacturing process is outlined in the included figure. All the equipment listed in the line is currently available through manufactures around the world. The material handling systems to integrate the equipment and create a process are also available off the shelf. Each of the modules has been tested in UNSW's SMaRT centre as a proof of concept. By locating the new Engineered Waste-Glass Panel process at Terrazzo Australian Marble, many of the existing processes, networks, and facilities can be leveraged to reduce risk and increase viability of having a technically sound production process.

A technical risk analysis has been conducted. The blending and processing of waste materials has been carefully researched over the past 4 years at the SMaRT Centre and novel methodologies have been published. This technology builds from that foundation to de-risk the variability of input materials and processing parameters. The materials have been analysed in 3rd party labs to demonstrate their compliance to safe operating levels in Australia.

The process requires three operators who are moving through different roles. A manager is required to task the line operators and manage the material input and output streams. The management, sales, and logistics will be managed through existing personal in UNSW-SMaRT and TAM.

Material Supply and Handling

UNSW-SMaRT will be responsible for managing the material supply chain. An in-house system will be used to track inventory, supply, quality, and cost. Some of the key materials have been explained in further detail below:

Material/Product	Logistics	Safety	Tracking
Waste Glass	**Primary Supplier: IQ Renew** IQ Renew is currently collecting over 1 million yellow bins across Australia's east coast. Their facilities can separate, grind, and wash waste glass. They are currently producing 3 glass fractions, 2 mm minus, 5 mm minus, and 10 mm minus. Each of these fractions is usable in the Engineered Waste-Glass panel. The waste glass will be transported using IQ Renew's existing logistics network. The glass will be transported in bulka bags.	The loading of the glass material will be the responsibility of IQ Renew. Safety testing for silicosis and asbestos has been conducted. The reports have declared the material safe. The datasheets are included in the appendix for reference.	IQ Renew will notify UNSW-SMaRT on dispatch and quantity of material, after receipt of the order. This will be captured in the inventory tracking system. The material will be unloaded at TAM. The correct unloading procedure, PPE, and storage are the responsibility of TAM. TAM will weigh the received material and log the data in the tracking system. A sample of the material will be sent to UNSW in a sealed plastic bin for contamination, and quality testing.
Specified Epoxy Resin Blend	**Primary Supplier:** *Currently Under Tender* The tailored resin system is a readily available through a variety of vendors.	The resin system comes with its own MSDS and safety process.	Resin systems will be tracked in the inventory tracking system.
Specified Polyester Resin Blend	**Primary Supplier:** *Currently Under Tender* The tailored resin system is a readily available through a variety of vendors.	The resin system comes with its own MSDS and safety process.	Resin systems will be tracked in the inventory tracking system.
Consumables	Basic consumables, such as silicon release, tools, PPE etc are covered by UNSW-SMaRT and TAM.	N/A	Consumables will be tracked in the inventory tracking system.
Packaging	Existing System at TAM	Responsibility of TAM	The final quantity will be tracked by UNSW-SMaRT. The delivery will be handed over to the TAM system.

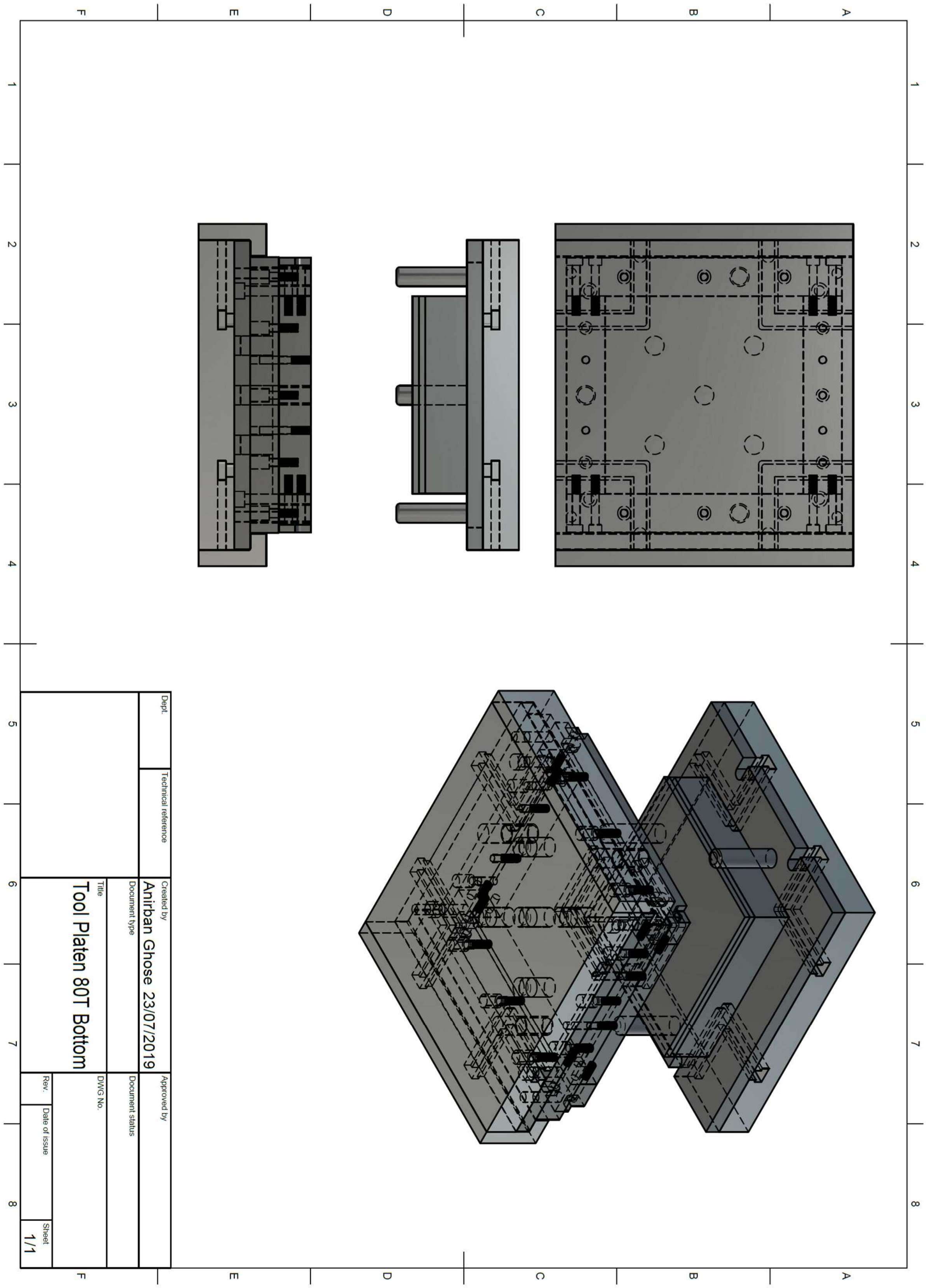
Location of Manufacturing Facilities

The manufacturing process will be co-located across two sites; Terrazzo Australia Marble and UNSW Sydney. Terrazzo Australia Marble is a key industry partner where downstream processing equipment and distribution networks are already existing. SMaRT will leverage these assets to reduce the friction in getting products to market. Terrazzo Australia Marble is well connected to freight routes to enable waste material delivery and product export across Australia and globally.

UNSW Sydney has been nominated as one of the waste material testing and preparation sites. This is due to its proximity to researchers and testing equipment. SMaRT at UNSW Sydney will form part of the material supply chain to provide quality assurances to the input materials and the output products. The patented material blends will be trialled at SMaRT Centre to remain agile to market demands and waste material quality, before being introduced into the production at the at Terrazzo Australia Marble.

Address of Terrazzo Australia Marble:
4 Holbeche Rd, Arndell Park NSW 2148

Tool Design



Dept.
Technical reference
Created by
Anirban Ghose 23/07/2019
Approved by
Document type
Document status
Title
Tool Platen 80T Bottom
DWG No.
Rev.
Date of issue
Sheet
1/1

Demonstration Study Report

Milestone completed to produce glass based-engineered stones:

- Heat activated unsaturated Polyester resin was selected to replace the general epoxy. The resin is proved to be cheaper and have better UV stability.
- Adjusting the ratio of waste glass aggregate (5mm minus and 2 mm minus) with polyester resin to achieve a technical acceptable product.
- The ratio between polyester, glass, catalyst etc are adjusted to produce the optimum product.
- Production rate were improved by hot-pressing the engineered stone mixture. The use of heat activated polyester resin, the process time for 240x240x20 mm panels decreases significantly from 1 hours to only 11 minutes.
- Purchase and installation of hot-press.

Initially it was purchased for RRA, Belambi. Due to unforeseen reason by their administration, the project did not continue.

Another partner was sort and the variation were made to install the hot press at Terrazzo Australian Marble