University of Southern Queensland

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EVALUATION OF ISSUES FOR SMALL AND MEDIUM-SIZED ENTERPRISES IN THE USE OF ADVANCED AND GREEN ENGINEERING MATERIALS

A dissertation submitted by

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ABSTRACT

The aim of the research is to identify and evaluate the issues for Small and Medium-sized Enterprise's (SMEs) with the use of Advanced and Green Engineering Materials (AGEMs); determine if the issues are linked to the previous use of an AGEM, or restricting the uptake of AGEMs; and investigate the issues with 5 individual AGEMs. The research identified trends by surveying firms from the construction industry. An online survey tool, Survey Monkey, was used to distribute and collect the survey. From the survey results, the leading issues for: AGEMs in general; AGEMs previously used by SMEs; and AGEMs not previously used by SMEs, was found to be a made up of seven common issues, with the leading issues changing depending on the category examined. The leading seven issues were: "Experience", "Cost of Materials", "Standards or Codes", "Availability", "Material Properties", "Evaluation Methods" and "Perception". The assortment of issues tended to depend on whether SMEs had used an AGEM before or not; with intangible issues decreasing and tangible issues increasing with use. Experience appears to be the leading issue to restrict the uptake of AGEMs and should be the first issue Manufactures consider correcting. Which could reduce the length of awareness time prior to use of AGEMs and decrease a number of other intangible issues. The examination of individual AGEMs agreed with the cumulative picture of issues with AGEMs and would require further research for more in depth analysis.

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NOMENCLATURE AND ACRONYMS (OR ABBREVIATIONS)

The following abbreviations have been used throughout the text and bibliography: -

AAI	Average Age of Inventory
ACP	Average Collection Period
AGEM	Advanced and Green Engineering Material
CEB	Compressed Earth Block
CLT	Cross Laminated Timber
DSCC	Ductile Self Compacting Concrete
EOQ	Economic Order Quantity
ERP	Enterprise Resource Planning
FA	Fly Ash
FRP	Fibre Reinforced Polymers
FV	Future Value
GGBFS	Ground Granular Blast Furnace Slag
Glulam	Glued-Laminated Timber
Glubam	Glued-Laminated Bamboo
HREC	Human Research Ethics Committee
IAQ	Indoor Air Quality
IRR	Internal Rate of Return
JIT	Just-In-Time
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LVL	Laminated Veneer Lumber
MIRHA	Microwave Incinerated Rice Husk Ash
MRP	Materials Requirement Planning
MRP II	Manufacturing Resource Planning II
NPV	Net Present Value
NSM	Near-Surface Mounted
NS	Net Savings
OC	Operation Cycle
PB	Payback Period
PIS	Participant Information Sheet
POFA	Palm Oil Fuel Ash
PV	Present Value
SDA	Sawdust Ash
SF	Silica Fume
SIR	Savings-to-Investment Ratio
SME	Small and Medium-sized Enterprise.
USQ	University of Southern Queensland
WACC	Weight Average Cost of Capital
CEEFC	Centre of Excellence in Engineering Fibre Composites

CHAPTER 1 - INTRODUCTION

1. Problem Statement

This research is to evaluate issues for Small and Medium Enterprise's (SME) in the use of advanced and green engineering materials (AGEMs). The research, design and innovation involved in creating advanced and green materials can take sizable resources and investment to develop. SMEs play a large part in the construction market and therefore their adoption of new materials can be crucial to the success of advanced and green engineering material products.

2. Background

Universities, and other developers and manufactures of advanced and green engineering materials, can benefit from the knowledge of issues perceived by SME's with the selection and use of their product. The research has been initiated to identify issues affecting SMEs demand for AGEMs currently developed by USQ. USQs Centre of Excellence in Engineering Fibre Composites (CEEFC) which is "one of the key research centre in Australia" is thought to be a possible beneficiary of the knowledge that can be gained through this research.

3. Objectives

- To undertake a survey of SMEs to identify their perceived issues in the use of AGEMs.
- To evaluate the issues for SMEs in the use of AGEMs.
- To provide a comprehensive list of the main findings so that manufacturers can improve their marketing, communication and delivery of advanced and green material products.

Refer to Project Specification which can be found in Appendix A.

4. Potential Implications and Consequential Effects of this Project

The University of Southern Queensland's Human Research Ethics Committee (HREC) was consulted in regards to the survey that, once approved, was dispersed to SMEs as part of this research project. The acceptance ensured that the survey had considered ethical requirements for human research, and any risks were identified and mitigated.

For privacy of the surveyed companies, their company names will not be included in the report. Instead, they will be referred to by their discipline, for example 'architect'.

5. Resources Requirement

This research was constrained by the time taken to receive acceptance from USQ's HREC and for the invited firms to respond to the survey, and the tool used to distribute and collect survey results.

USQ's HREC was engaged with a month allowance in the time frame, to allow for changes to be made to the survey and accompanying documents. The survey was left open for three weeks to allow time for the invited participants to respond, weekly digestion of location, firm size and discipline distribution results were used to encourage undecided participants to participate in the research. An online survey tool, Survey Monkey, was used to distribute the survey and collect results.

CHAPTER 2 - LITERATURE REVIEW

2.1. Introduction

AGEMs are developed to extend the boundaries of conventional materials and help in the provision of an environment that can be enjoyed by future generations. The research, design and innovation involved in creating AGEMs can take sizable resources and investment to develop.

Small and medium-sized enterprises (SME) play a large part in the construction market and therefore their adoption of new materials can be crucial to the success of advanced and green engineering material products.

The aim of evaluating issues for SMEs in the use of AGEMs is to produce a comprehensive list of the perceived issues with these materials. This research could provide manufacturers with the information required to improve their marketing, communication and delivery of advanced and green material products.

2.2. Small and Medium Enterprise

Small and medium-sized enterprises (SME) are distinguished from larger firms by the number of staff employed and legal forms of business.

SME classifications have different thresholds around the world. In New Zealand firms with up 20 employees, and in Australia firms with less than 200 employees are considered to be SME. SMEs account for 97.2% (Ministry of Business, Innovation & Employment, 2014) and 95% (SME Association of Australia, 2014) of all enterprises in New Zealand and Australia respectively.

Legal forms of business for SMEs can include, sole proprietorship, partnerships or corporation. The benefits of each legal form of business are applicable to different business situations. Sole proprietorships and partnership benefit from the simplicity of their creation, the owners are legally responsible for the action of the firm and tax is taken at personal tax rates. Corporations are more complicated to set up, and result in a form of double taxation for owner managers. Corporations form separate legal entity

and owners benefit from the limited liability to the extent of their investment into the firm (Brooks, 2010).

2.3. Advanced Materials

Advanced materials are an improvement on conventional materials. They are developed to enhance strengths, or mitigate weaknesses of conventional materials.

Post-tensioned timber combines timber's flexibility, aesthetic and environmentally friendly properties, with the ductile properties of steel to improve the ductility and strength of timber (Symons, 2014). Ductile self-compacting concrete (DSCC) minimises the need for skilled labour as levelling and compaction occurs under self-weight. (Nuruddin, Chang, & Azmee, 2014)

New Zealand company XLam Ltd (Symons, 2014), is manufacturing an advanced heavy timber material, cross-laminated timber (CLT). This product has a large demand in Europe, and XLam anticipate entering the Australasian market. Manufactures such as Xlam face challenges in introducing new materials, as engineers, architects, quantity surveyors and clients tend to be conservative in the adoption of relatively unknown products.

2.4. Green Materials

Green materials are an alternative to conventional materials. They can contain recycled and nontoxic material, and can provide a more energy efficient alternative to conventional materials. Green materials fit into six identifiable categories: green process; improved sustainability; recycled content; recyclability; low toxicity; and biodegradable (RSMeans, 2002, pp. 232-234).

Green materials rarely appear any different than conventional materials, the workmanship and level of finish generally have much more influence on aesthetics (Spiegel & Meadows, 1999). Sustainable timber looks no different than timber managed in an unsustainable way. Resources managed sustainably are replenished at a rate faster than they are consumed. Concrete containing cement replacement materials appears no different than conventional concrete.

The perception of green material can impact adoption. The use of the term 'green' often leads to perception of low-tech, uncontrolled and unprofitable to SMEs. With some manufacturers reluctant to advertise the use of green processes for fear of prejudice (Spiegel & Meadows, 1999).

There are few standards and guidelines for the 'greenness' of green materials, with those that are available being performance rather than prescriptive (Spiegel & Meadows, 1999). Standards and guidelines are used heavily in the construction industry as a means to demonstrate work is satisfactory. Green materials can suffer from requirements to use the standards of the conventional materials they are replacing, as well as a green standard, e.g., LEED, Energy Star, BREEAM, and ISCA, to demonstrate the greenness of the material.

2.5. Issues for Small and Medium Enterprises

The research of literature found no articles specifically relating to the 'issues for SMEs in the use of advanced and green materials'. The issues found focused on either businesses or materials.

SMEs are generally younger (Abdullah & Manan, 2011) and likely to be in experiencing higher growth than larger mature firms. Issues for SMEs in the use of AGEMs include the growth of the firm and the community, the cost of materials, experience, inefficient standards or codes, methods used for investigation and evaluation and compatibility with inventory management practises.

Materials issues are unique to the material. Materials are discussed in Section 2.3. The common issues include material properties, the perception, environmental impact and the selection of materials available.

2.5.1. Growth

Growth affects the use of advanced and green materials. Unprofitable materials have a negative effect on the growth of firms. Population growth requires infrastructure created by the construction industry.

Firms raise capital to fund projects through short and long term (equity and debt) financing. Short term and debt financing requires the firm to pay interest on the capital raised or borrowed and repay the amount in the future. Equity financing sells a share of the firm to the investor. For a firm to repay the financing required to fund project, it seeks growth by earning a net profit on the projects undertaken. The profit is then used to payback capital borrowed and increase the wealth of shareholders to the company (Gitman, Juchau, & Flanagan, 2008).

The construction industry is responsible for the provision if infrastructure to facilitate population growth. The construction industry is one of the largest and most active sectors throughout the world. In Europe annual turnover of 1200 billion Euros, with 52% market share of exports result from the construction industry. China will need 40 billion square meters of residential and commercial floor space over the next 20 years (Pacheco-Torgal & Jalali, 2012).

2.5.2. Cost

SME have less access to capital. Investigation and evaluation of materials increase the cost. Cost is the easiest component of a material to be evaluated. The intangibility of some benefits can lead to current cost constraints can outweigh the future benefits of materials.

AGEMs tend to be more expensive by face value. Conventional 30 MPa concrete tends to cost less than 30 MPa lightweight concrete (Simons, 2012). The percentage increase in price between conventional materials and advanced and green materials is called a premium. The premium is to cover externalities, compensate for research and development or specialist knowledge and labour required. Externalities can include improved future sustainability. Forestry operations have the choice when producing timber whether to manage the resource sustainably. Sustainable management in a 'price taking' environment leads to less profit for forestry. (Mankiw, 2009)

2.5.3. Identification and Evaluation Methods

Identification of materials is made more challenging due to the number of alternatives. Investigation and evaluation of materials increase the cost. SME avoid

the cost of identification and evaluation by using familiar materials. Excluding some advanced and green materials due to lack of experience.

Evaluation methods include the use of financial tools. Financial tools are affected by premiums. The premium increases the cost and risk. Higher returns are required by firms to justify increasing risk levels.

2.5.4. Experience

The construction industry relies on previous experiences to guide future decisions. SME have less access to experts. When uncertainty exists the industry can rely on expert opinion. Advanced and green materials carry more risk to SME with less experience.

The risk of using advanced and green materials by less experienced firm's increases the risk premium used in their evaluation.

2.5.5. Lack or Inefficient Industry Standards or Codes

The construction industry relies on standards and codes to justify decisions. There is a general lack of standards and codes for environmentally effectiveness of green materials (Spiegel & Meadows, 1999). Advanced and green materials suffer from poor coverage in standards and codes when there is need for further research on the material.

The structurally properties for advanced and green materials are determined use of codes. Materials until thorough research is undertaken on material properties, insufficient standards and codes can lead to under or over design of structures.

2.5.6. Inventory Management

Inventory management is closely tied to working capital and current asset management. Firms require working capital to operate. Working capital is the net of current assets and liabilities. Solvency of a company is judged by the ability of the current assets to cover the current liabilities. Maintaining positive working capital is an issue to firms of any size. (Brooks, 2010)

2.6. Evaluation Methods

Aesthetical, financial and ethical considerations affect evaluation methods. Materials have different properties; though can perform the same task. Aesthetics is subjective, the client or designer likes the material or they do not. Aesthetics eliminates materials in the selection process. Financial evaluation methods are used to select the most economical from the alternatives. Ethical evaluation is challenging. Ethical evaluation can include externalities. Externalities are challenging to evaluate and quantify. Externalities are unsolicited effects to others by firm's decisions. Positive externality of using green material is improved air quality. Negative externality of using concrete is the green house gases created in the production. (Spiegel & Meadows, 1999; Brooks, 2010; Mankiw, 2009)

2.6.1. Financial Evaluation

Financial evaluation considers the costs to firms (Brooks, 2010; Gitman, Juchau, & Flanagan, 2008). Principles of time value of money, or more straightforward comparison are used. Time value of money works on the basis that money is more valuable today than in the future. To compare like for like, cash flows must be discounted to present value (PV) or compounded to future value (FV).

Financial evaluation although the easiest to quantify can be challenging for SME. The determination of risk to the firm and project affects the quality of results.

There are many methods of financial evaluation used by firms. Commonly used methods, discussed below, include payback period (PB), net present value (NPV) and internal rate of return (IRR).

2.6.1.1. Discounting/ Compounding

Time value of money states that money is more valuable today than in the future. $1 dollar gives you the option to spend or invest. Money that is not spent or invested depreciates due to inflation. If the dollar is invested at a return of 4%, the $1 will be $1.04 in one year time. Equation 2-3 and 2-4 below are used to determine the PV and FV of a single cash flow.

$$PV = FV * (1 + i/100)^{-n} \quad \textit{(EQ.1-1)}$$

$$FV = PV * (1 + i/100)^{n} \quad \textit{(EQ.1-2)}$$

Where: $i = \text{rate of return (\%)}$

$n = \text{period of time (year)}$

To compare financial options cash flows must be compared in the same time period. Discounting is used to determine the PV future cash flows. For example if FV = \$1.04, i = 4% and n=1, then PV = $1.04*(1+ 4/100)^{-1} = 1$. Compounding is used to find the FV of cash flows. (Gitman, Juchau, & Flanagan, 2008)

Rate of return represents the risk of the cash flow. Firms commonly use weight average cost of capital (WACC) as the required rate of return. WACC represents the risk market places on the firm. (Brooks, 2010)

2.6.1.2. Payback Period (PB)

Payback period is a straightforward method of financial evaluation. Payback period determines the time taken to recoup investment. Payback period works on the principle that the projects that recoup investment quick are better. The material with the shortest PB is selected, provided the length of PB is less that maximum period decided my management of the firm.

PB fails to consider the time value of money. Any cash flows earnt after the payback period are neglected. This can lead to selection of options that appear less than optimum using NPV and IRR.

An example of PB is shown in Table 2-1, is used to demonstrate the PB of \$1.00 investment with \$0.33 cash flows for the next four years. PB will be three years. (Brooks, 2010)

Table 2-1: PB Example

Cash Flow	Amount	Cumulative
CF_0	($1.00)	($1.00)
CF_1	$0.33	($0.67)
CF_2	$0.33	($0.33)
CF_3	$0.33	$0.00
CF_4	$0.33	$0.33

2.6.1.3. Net Present Value (NPV)

NPV is the sum of all cash flows discounted to PV. NPV uses the principle of time value of money. Positive NPV mean the project will return more money than in costs, negative NPV indicates expected loss. Discount rate is typically the WACC for a firm. Using the WACC is beneficial to determine if the selection will increase the wealth of the firm.

An example of NPV is shown in Table 2-2, is used to demonstrate the NVP of $1.00 investment with $0.33 cash flows for the next four years, i of 4%. NPV=$0.20 with the current cash flow over the four years. (Brooks, 2010)

Table 2-2: NVP Example

Cash Flow	Amount	PV (i=4%)
CF_0	($1.00)	($1.00)
CF_1	$0.33	$0.32
CF_2	$0.33	$0.31
CF_3	$0.33	$0.29
CF_4	$0.33	$0.28
	NPV =	$0.20

2.6.1.4. Internal Rate of Return (IRR)

IRR determine the rate of return required for the sum of the cash flows to equal the initial investment. IRR is recorded as a percentage. The IRR is easily compared to

WACC. Projects are accepted if the IRR is greater than the WACC. IRR greater to WACC means the firm will earn more than it costs to undertake the option evaluated.

An example of NPV is shown in Table 2-3, is used to demonstrate the NVP of $1.00 investment with $0.33 cash flows for the next four years, WACC of 4%, IRR of approximately 12%. As the IRR is greater than the WACC the firm would expect to make ≈8% on the option evaluated.

Table 2-3: IRR Example

Cash Flow	Amount	PV (i≈12%)
CF_0	($1.00)	($1.00)
CF_1	$0.33	$0.29
CF_2	$0.33	$0.26
CF_3	$0.33	$0.23
CF_4	$0.33	$0.21
	NPV ≈	$0

2.7. Materials

Concrete is the most commonly used construction material in the world, and there are numerous advanced concrete materials (Nuruddin, Chang, & Azmee, 2014). Earthen is one of the oldest materials, a large proportion of the world's population live in earthen buildings. The collection and then return of earthen material to the earth promotes it as a green material. Timber products benefit from high strength to weight ratio, "visual and tactile attractiveness, high energy efficiency, quick erection time and a low carbon footprint" (Werther, et al., 2012).

2.7.1. Concrete

Concrete is conventionally made up of cement, water, sand and aggregate. Concrete has a high compressive strength, but has poor tensile strength and is prone to brittle material failure. Because of this, the tensile strength of concrete is generally neglected during the calculation of material strength.

Cement undergoes hydrolysis to act as a binder. Concrete strength is dependent on the cement-water ratio of concrete. Cement production is a major emitter of green house gases due to the energy demand to crush and fire limestone.

Improvements in technology over the past 20 years have resulted in the development of advanced and green concrete (Naik, Kumar, Ramme, & Canpolat, 2012). Ductile self-compacting concrete (DSCC), high strength concrete, light weight concrete, fibre reinforced concrete and concretes utilising cement replacement materials are discussed below.

2.7.1.1. Ductile Self Compacting Concrete (DSCC)

DSCC reduces the need for skilled labour in the construction of concrete structures. Compaction and levelling of conventional concrete is crucial to achieve concrete strength. DSCC compacts under the materials self weight, and spreads into every corner of the formwork.

DSCC can suffer from blockage of the aggregates when pouring into heavily reinforced sections. There is more investigation and testing required when using DSCC due to low tolerances. A 1% increase in water content has a noticeable effect in the performance of the DSCC. (Naik, Kumar, Ramme, & Canpolat, 2012)

2.7.1.2. High Strength Concrete

High strength concrete uses admixtures to increase the concrete strength (f_c'). Increase in concrete strength results in lower cost to clients due to reduced section sizes. (Nuruddin, Chang, & Azmee, 2014)

An increase in concrete flexural capacity (M_n) is directly proportional to increases in concrete strength (f_c') refer to EQ.2-1 (AS 3600:2009). Increased flexural capacity allows for a reduction in the section size of concrete member, subsequently lowering the design load on supporting members and decreasing the design moment (M^*). Reducing section sizes affects both sides of EQ.2-2 (AS 3600:2009). An iterative approach is employed to find the optimum section size.

$$M_n = \alpha_2 * f'_c * \gamma * d * b * \left(d - \frac{\gamma d_n}{2}\right) \quad \textit{(EQ.1-3)}$$

$$M^* \leq \phi M_n \quad \textit{(EQ.1-4)}$$

Concrete brittleness increases with strength; due to this advanced concretes have been developed. Conventional concrete has low tensile strength and experiences brittle failure. High strength concrete is shown to benefit from fibre reinforcement to address these deficiencies.

2.7.1.3. Lightweight Concrete

Lightweight concrete is created using lightweight aggregate or aerated concrete. The use of lightweight concrete reduces the deadweight in a structure. Lower dead weights require smaller section sizes and consequently reduce the quantity of material required to carry the loads (Green, Brooke, & McSaveney , 2008).

Lightweight concrete can suffer shrinkage problems due to the porosity of its aggregates. Lower density lightweight aggregates are weaker than conventional aggregate; AS 3600:2009 Concrete Structures and NZS 3101:2006 Concrete Structures, provide coefficients for the design of lightweight concrete using conventional concrete calculations.

2.7.1.4. Fibre Reinforcement

Concrete fibre reinforced by the addition of short discontinuous metallic, non-metallic or hybrid fibres primarily controls the propagation of cracks and limits the crack width (Sivakumar & Santhanam, 2007). Fibre provides ductility and reduces the brittleness of concrete, by acting as a bridge between adjacent surfaces of existing micro-cracks.

Metallic fibres are generally short discontinuous steel strands. They can reduce micro cracking and permeability. The fibres increase the flexural strength of concrete, and provide fatigue, impact and abrasion resistance. Excessive quantities of metallic fibres are not desired as they add costs and reduce the concrete workability.

Non-metallic fibres can be glass, synthetic or organic fibres. Non-metallic fibres reduce the micro cracks in concrete but do not provide any noticeable gain in the flexural strength of concrete.

Hybrid fibre reinforcement is a combination of metallic and non-metallic fibres. Hybrid fibre reinforcing has been found to perform better in all aspects than metallic fibre alone, except flexural toughness. To achieve enhanced flexural toughness the mix of metallic to non-metallic fibres need to be selected carefully. (Sivakumar & Santhanam, 2007)

2.7.1.5. Cement replacement materials

Cement replacement materials replace a portion of the cement content in concrete (Massazza, 1993). Cement replacement materials are pozzolanic. Pozzolanas are a material that contains siliceous or siliceous and aluminous material by composition. Pozzolanic materials alone provide little or no cementing property but can provide cementing property when combined with calcium hydroxide due to a chemical reaction between silica and calcium hydroxide.

Cement replacement materials have been investigated as a way to reduce the volume of cement required while still achieving the desired structural capacity.

The pozzolanas identified below include fly ash (FA), microwave incinerated rice husk ash (MIRHA), silica fume (SF), sawdust ash (SDA), ground granular blast furnace slag (GGBFS) and palm oil fuel ash (POFA). These materials are recycled waste products from manufacturing plants (Nuruddin, Chang, & Azmee, 2014; Naik, Kumar, Ramme, & Canpolat, 2012; Elinwa & Mahmood, 2002; Dehuai & Zhaoyuan, 1997; Tangchirapat, Saeting, Jaturapitakkul, Kiattikomol, & Siripanichgorn, 2007).

FA is by-product of coal fired electric generating plants. Due to its spherical shape and rheology properties, FA increases the workability and flowability of concrete. The use of FA results in lower cement, superplasticier and viscosity modifier requirements while maintaining 28-day concrete strength.

MIRHA is a manufactured by controlled microwave burning of rice husks. MIRHA improves the strength and reduces the porosity of concrete.

SF is a by-product of alloy production in arc furnaces. SF consists of ultra fine particles, which fill voids present in conventional concrete and provide higher bond strength between cement paste and aggregates.

SDA is a by-product from the timber industry. SDA enhances the performance of concrete in respect to setting time, workability and compressive strength.

GGBFS is a bi-product of iron production from ore. The use of GGBFS is contributed to higher strength gains of concrete allowing high early strength, which is noticed to maintain higher strength than conventional concrete.

POFA is a by-product from the palm oil industry. It is predominantly disposed of in landfills leading to environmental concerns. POFA improves the sulphate resistance of concrete.

2.7.2. Earthen Materials

Earthen materials (Miccoli, Müller , & Fontana, 2014) are one of the oldest materials in use today. There is evidence of earthen buildings lasting hundreds of years. Earth used in earthen materials is not considered renewable. The materials are predominantly extracted from the building site during earthworks. This differs from other building materials such as steel where metal ore and other materials are extracted from the earth, processed and then delivered to site. Earthen materials can be stabilised with lime to enhance its properties. Commonly used earthen materials are adobe bricks, rammed earth and cob.

The research into earthen materials lacks depth and consistency compared to research of other engineering materials. There is need for further knowledge of failure mechanisms and materials properties. Standards and codes used by the building industry tend to treat all earthen materials the same. New Zealand is one of the few countries with seismic consideration in the use of earthen material.

2.7.2.1. Adobe brick

Adobe bricks are created by air-drying earthen material in a mould. Adobe bricks are also referred to as ‘earth block’, ‘mud brick’, ‘sun baked brick’ and ‘unfired brick’. Adobe bricks are used throughout the world. The earthen materials required to manufacture adobe bricks are obtainable in most countries. The typical compressive strength of adobe brick is in the order of 1.0-5.0 MPa (Miccoli, Müller , & Fontana, 2014).

Adobe brick is a modular construction method, unlike rammed earth and cob, which are monolithic. There have been few improvements to adobe brick since prehistoric times. Strength improvements have been achieved through compressed earth blocks (CEB), reinforcement with straw and stabilisation with lime.

2.7.2.2. Rammed Earth

Rammed earth is created in-situ using formwork to restrain the earth as it is compacted. Compaction of earth in rammed earth walls is undertaken in lifts. Lifts are the term for layers of material. The compacting the layers in lifts allows full compaction of the material.

Compressive strength of rammed earth is dependent on many factors: soil properties, moisture content, compaction, fibre content and additives. The use of fibre is rare. The typical compressive strength of unstabilised rammed earth is 1.5-4.5 MPa. The monolithic nature of rammed earth is advantageous in seismic regions. (Miccoli, Müller , & Fontana, 2014)

2.7.2.3. Cob

Cob is a mixture of earth, water and plant fibres. The particle size of earth used is restricted to sand fraction. Cob is mixed to a plastic consistency by hand, machine or working animals. The mixed cob is then stacked in-situ 1.0-1.2m high and left to dry. Dry cob is trimmed and another stack of cob is applied on top. Cob walls are time consuming and are slowed considerably by poor weather.

Cob has lower compressive strength than the previous earthen materials, in the range of 0.5-1.5 MPa. The fibre content of cob enhances the shear capability and enhances ductility of the material. Cob can undergo elastic deformations. The fibrous content of cob is organic in nature and can putrefy if water is allowed to infiltrate the material. (Miccoli, Müller , & Fontana, 2014)

2.7.3. Timber

Timber is an engineering material created from wood. Currently there is an increasing demand around the world for timber as a construction material. Timber and wood products are a renewable resource, when managed sustainably. The material properties of timber have high variability including variations in moisture content, density and modulus of elasticity. Timber members behave differently in each loading direction. Perpendicular to grain its strength and stiffness properties are much lower than in the fibre direction. Timber also has weakness in the cross grain direction where highly brittle tensile failure can occur. (Mohamad, Ahmad, & Jalil, 2014)

Timber undergoes brittle failure when overstressed. Standard and codes adopt extensive strength reduction factors to account for this and the large variations in timber properties. Structural engineers use strength reduction factors as a way to reduce the calculated section capacity of materials. (Ferrier, Agbossou, & Michel, 2014)

Wood products are increasingly used over plain sawn and treated timber. The defects in timber are removed where possible in the manufacturing process. Advanced wood products commonly used include glue-laminated lumber (Glulam), laminated veneer lumber (LVL), and cross-laminated timber (CLT). Recent wood and wood-like products include hybrid wood with post tensioning or fibre reinforced polymer reinforcing, and glue-laminated bamboo (Glubam) (Ferrier, Agbossou, & Michel, 2014; Mohamad, Ahmad, & Jalil, 2014; Symons, 2014; Xiao, Chen, & Feng, 2013).

2.7.3.1. Glued-Laminated Lumber (Glulam)

Glulam is manufactured by gluing together individual pieces of strength-graded timber. The grain direction of individual pieces is alternated. Glulam achieves better

structural performance than plain sawn timber. Section size can be made to vary with member length. The size of the original tree does not limit section size of glulam. (Symons, 2014)

2.7.3.2. Laminated Veneer Lumber (LVL)

LVL is manufactured by gluing multiple layers of veneer together under heat and pressure. The veneer is approximately 3.5 mm thick, peeled from logs. Defects are cut from the veneer during the gluing process. (Symons, 2014)

LVL can be made into walls, floors, frames, beams or columns.

2.7.3.3. Cross Laminated Timber (CLT)

CLT, which goes under the trademarked name of XLam in New Zealand, is made up of boards lined up with alternating grains joined by finger joints and edge glued. The CLT is sealed inside a membrane and vacuum pressure around 90 kPa is applied for 2.5 hours.

CLT panels can be manufactured to incorporate large openings such as doors and windows, with minor openings cut out after the panel has cured. (Symons, 2014)

2.7.3.4. Glued-Laminated Bamboo (Glubam)

Glubam is manufactured from strips of bamboo. Bamboo is a wood-like species of grass. Bamboo exhibits equal of better physical and mechanical properties compared to wood and grows much faster (Xiao, Chen, & Feng, 2013). Bamboo is harvested after four years growth and can grow back without requiring replanting.

2.7.3.5. Hybrid Timber with Post-Tension Reinforcing

Timber post-tensioning has led to the development of low-damage seismic design of timber multi-storey buildings. Post-tension rods act as energy dissipaters. The ductile nature of steel can be used to reduce the brittle failure mechanism of timber. (Symons, 2014)

2.7.3.6. Hybrid Timber with Fibre Reinforced Polymers (FRP)

FRP is made from fibres, carbon and glass. Fibres are sealed in a polymer with the fibres aligned in one direction. This creates a material that is very strong in tension and very light.

2.8. Conclusion

The literature reviewed demonstrates that there are many material and business issues associated with SMEs in the use of AGEMs. The main business issues found are growth, cost, identification and evaluation of materials, experience, lack or inadequate standard and codes, and inventory management. The main material issues of AGEMs were found to be their material properties, perception by SMEs, environmental impact and the selection of materials available.

It is important for manufactures of advanced and green materials to understand the issues of SMEs because they comprise a large part of the construction market. SMEs are therefore highly influential on the success of advanced and green material products, and the issues they experience differ from that of larger organisations.

The project objectives include developing a comprehensive list of the main issues perceived by SMEs through evaluating the responses of a business survey. This information could help manufacturers to improve the utility of their advanced and green material products through marketing, communication and delivery tailored to customer needs.

CHAPTER 3 - RESEARCH DESIGN AND METHODOLOGY

3.1. Methodology

1. Produce a survey for SME engineering design and construction firms regarding their perceived issues in the use of advanced and green materials.
2. Gain approval of the survey from the University of Southern Queensland's Human Research Ethics Committee (HREC).
3. Form a list of email and phone contact details for a statistically valid sample of SMEs.
4. Administer the survey to the identified SMEs.
5. Follow up with slow respondents to the survey if required.
6. Select up to five suitable materials for further investigation.
7. Evaluate the responses to the survey and develop conclusions.

3.2. Survey

The survey questions were formulated, and then sent to USQ's HREC for acceptance with the ethical guidelines. While the HREC was reviewing the documentation an email list was created for potential firms to invite to participate in the survey. Upon acceptance the survey was distributed using an online survey tool, Survey Monkey, and three collector methods were used over the three-week period of the survey. A copy of the survey questions is attached in Appendix B.

The objective of the survey was to collect data to allow issues with AGEMs to be identified and evaluated, with five AGEMs to be evaluated further and for conclusions to be developed. To ensure that there was enough data to achieve the objectives a minimum number of desired responses for the survey was 30. This number of responses fits with central limit theorem sample size selection.

3.2.1. Formation

The survey questions were formulated to: collect generic firm details; evaluate issues with AGEMs; identify AGEMs previously used and unused by SME, and whether the

use would continue (for used AGEMs), or start (for unused AGEMs) with or without perceived issues being addressed.

The questions were split into four sections. The generic information about the firm allowed for the comparison between firms while maintaining anonymity for participants. Then three issue categories for SMEs to answer: issues with AGEMs in general; AGEMs previously used by the firm; as well as AGEMs not previously adopted.

3.2.2. Ethical Acceptance

The survey was required to be accepted by the USQ's HREC prior to release to selected firms who were invited to participate. The HREC acceptance ensured that the risk for the participants was identified and mitigated. This project maintained anonymity for respondents and gathered data on firms rather than the individual responding to the question, much like a business case study. There were very low levels of risk with this project.

Appendix C, contains the ethics committee submission and approval.

3.2.3. Selection of firms

The firms invited to participate in the survey were identified from the New Zealand and Australia business directory, Yellow Pages. The Yellow Pages directory was accessed through the company's websites, www.yellow.co.nz and www.yellowpages.com.au.

The list of participants to invite was collected from the 16 regions of New Zealand, and 6 states of Australia. Each of the 22 combined locations was divided further into three disciplines, 'Architect', 'Engineer', 'Contractor'. For the New Zealand firms there were more locations (regions) and fewer firms meeting the search criteria, the first ten firms identified from each discipline providing email addresses details were collected. With less locations (states) and a higher number of firms meeting the search criteria in Australia, email addresses of 20 firms for each discipline from each location were collected. This resulted in an email list of 749 firms from the

construction industry. The breakdown of discipline and country is shown in Table 3-2.

Table 3-1: Firms identified by discipline and country

	Architect	Engineer	Contractor	Total
New Zealand	674	1,043	3,907	**5,624**
Australia	4,672	1,633	62,546	**68,851**
Total	**5,346**	**2,676**	**66,453**	**74,475**

Table 3-2: Firms invited to participate by discipline and country

	Architect	Engineer	Contractor	Total
New Zealand	116	124	157	**397**
Australia	118	114	120	**352**
Total	**234**	**238**	**277**	**749**

Table 3-3: Percentage of Firms invited by discipline and country

	Architect	Engineer	Contractor	Total
New Zealand	17%	12%	4.0%	**7.1%**
Australia	2.5%	7.0%	0.19%	**0.51%**
Total	**4.3%**	**8.9%**	**0.42%**	

3.2.4. Distribution

The online survey tool, Survey Monkey, was used to create and distribute the survey. The survey was distributed by three methods, Survey tool generated email with direct link, a personal email with Facebook link to the survey, and a personal email with web link to survey.

Initially the invitation to participate was distributed using the online survey tool's email distributor and collector function. This generated an email with the required

links to participate or withdraw from further receipt of survey requests, in which a message was entered to explain the survey to the firms invited to participate and key information for the participant information sheet (PIS). The weakness of this method was the inability to add attachments and the fact the survey became locked to the email address that received the email. If the employee that received the email invitation did not have the authority to participate it could not be emailed to another employee that could complete the survey.

Due to the reduction of responses to from 4 responses per day, to none within days of the survey release, far short of the required number of participants, the firms yet to responded with either participation or to withdraw were contacted via personal email. The personal email contained a link to a Facebook page created for the research; a break down on the percentage of each discipline to respond, their location and firm size; and a second copy of the USQ HREC PIS.

Week three of the survey a final email was sent to the firms yet to respond through participation or withdrawal. The email contained a web link, which could be forwarded to other email addresses; a second break down of firm distributions; and stated the survey would be drawing to a close shortly.

3.2.5. Collection

The research survey was collected using three methods available with Survey Monkey. The collectors methods that were employed included, Email Invitation, Facebook Post and Web Link.

Email Invitation provided facility for a list of invited participants to be loaded, a message added and sent with a few clicks. When emailing large lists this method got past the limits in place to prevent malware attacks, e.g., the provider of our university email accounts, Gmail, allows a maximum of 100 recipients to an email, accounts that attempt to send emails with greater than 500 recipients face potential of account being closed on suspicion of ill intent. The disadvantage of Email Invitation is that only the recipient to the email may complete the survey.

Facebook Post allows a link to be posted on a Facebook page. Providing the benefit that any firm that can find the page can participate. Though this requires the link to the Facebook page to be distributed. The link to the Facebook page, set up for the research survey, was sent using personal email this required sending multiple emails to the remaining 650+ invited firms that had neither participated or withdrawn from the research, as mentioned above to avoid the anti-malware restrictions.

Web Link was the last method employed to collect responses. This method similarly to the Facebook post above required the distribution of the link via personal email. The advantage of this method, from the original method, was the ability for the email to be forwarded on to another employee if the initial contact didn't have the authority; and from the Facebook method, by removing the ability for Facebook users (non-construction industry firms) finding the page and filling the survey out themselves.

3.3. Limitations

The following limitations have been identified for the research to be considered with the results, discussions and conclusions. The AGEMs surveyed, distribution of disciplines that actually responded, quantity of participants, differentiation of personal vs. firm issues with AGEMs, reasons for each issue, completeness of the survey and ability to follow up with respondents.

The AGEMs that were covered by the survey were from a broad list created prior to the release of the survey document, and other materials mentioned by the respondents. There were only a couple of materials offered by participants under the option of "other". This meant that those options did not have enough respondents to evaluate the material, and the firms that provided responses on those materials did not provide input on another potentially equally used or unused AGEM by the firm. The decision of 5 or more AGEMs for SMEs to answer questions about may have provided better individual AGEM issue results, and potentially lower quality cumulative issue results.

The survey invited responses from three disciplines, 'Architect', 'Engineer' and 'Contractor' as an attempt to achieve a cross section of the construction industry. There may have been better methods of achieving the desired cross section. The

distribution of respondent's discipline is potentially a limitation for the result. The 'Architect' discipline contained the less number of firms for the industry, however provided the greatest percentage of responses. This could potentially incorporate a basis into the results. Further research could look at achieving equal volume responses from each discipline or look at achieving similar distribution as is experience in the industry. Inclusion of further numbers of each discipline will also allow for the breakdown of the results further by discipline, which was not possible with this research.

Increasing the quantity of participants will improve results, up to a point according to central limit theorem. The survey goal was to achieve 30 participants for the survey, which was met. This number has not allowed for some of the desired trends to be developed. This research may have benefited from increasing any of, but not limited to, the following: the number of respondents to each country; the number of respondents form each state and region; the number of responses for each discipline; the number of responses for each material. However the number of responses that was received by the survey was hard work to achieve as it is, in the time frame of the project there is little chance further responses could have been achieved. An example of where response volume may have affected result is with the unused AGEM responses. I feel that the volume of responses for each of the materials restricts the trends that can be examined for each material individually. Table 4-4 and Table 4-5, contain the list of common issues for the individual AGEMs, there is a trend that with increasing number of responses there was an increasing number of issues indicated. The materials in, Table 4-4, received a differing number of responses for each material from three to 12 responses for previously used AGEMs. Whereas, the materials listed in, Table 4-5, received only three to four responses for each material, just above the minimum examined.

The survey has assumed that the responses are the Firms issues with AGEMs. However there is no way of determining whether the respondent, on behalf of the firm, indicated personal or firm issues with AGEMs.

The survey did not collect the reason for each issue with AGEMs; and due to anonymity for survey respondents, methods of communicating with the participants either to discuss findings, or for follow up interview, are not available. In conjunction with the limitation discussed above about personal vs. firm issues, it is difficult to determine definitely the reasons for the issue resulting in multiple possible reasons for each issue discussed, rather than highlighting exactly how, e.g., "Cost of Materials", affects the firm.

Completeness of the survey was another limitation with the results. The survey received 30 respondents; each participant was given between 26 and 44 questions. The number of questions was dependent on whether the firm has used AGEMs in the past. Some questions were mandatory to move onto the next section. Some of the participants did not answer all the questions, this was obvious when looking at the volume of respondents from each use category, "Yes, frequently", "Yes, occasionally", "Yes, rarely" and "No". There was an obvious drop in the "rarely" respondents between used and unused materials; also the respondent's indicating "No" previous use of AGEMs, did not answer the questions on issues preventing the use of AGEMs.

All survey was conducted using online survey tool, to achieve responses from the areas examined. The use of phone or personal interviews could have increased the depth of questions, and allowed for deviation from script to clarify any uncertainties in understanding for participants or to gather more detailed reasons for issues.

CHAPTER 4 - RESULTS

4.1. Survey Participants

The research survey received 30 responses from SMEs in the construction industry. The discipline type (Architect, Contractor or Engineer), location and firm size of each survey participant was collected to assist with the analysis of data collected. The survey was distributed to a roughly even number of SMEs in each discipline and location, i.e., approximately 20 Engineering, Contracting and Architecture firms from each of the six Australian states and 10 of each discipline from each region of New Zealand. The survey was sent to 749 firms in total, refer to Table 3-2 for the breakdown of discipline and location. The size of each firm invited to participant was unknown prior to the collection of survey results. Table 4-1, below shows the split of respondents across discipline and location.

Table 4-1: Response location and discipline

	Architect	**Engineer**	**Contractor**	**Total**
New Zealand	11	2	6	**19**
Australia	4	4	3	**11**
Total	**15**	**6**	**9**	**30**

Table 4-2, shows the percentage of discipline and location of respondents. The highest percentage of respondents was of: the discipline of Architect with 6.4% of the invited Architect firms responding; and the location of New Zealand with 4.7% of the invited New Zealand firms responding. The discipline of Engineer received the smallest percentage of responses at 2.5% of the invited firms responding. The responses came from 4.0% of the total firms invited to participate. Only one subcategory achieved greater than 4.0% responses, which was New Zealand Architects with 9.4% of the invited firms responding.

Table 4-2: Percentage of response location and discipline

	Architect	Engineer	Contractor	Total
New Zealand	9.4%	1.6%	3.8%	**4.7%**
Australia	3.4%	3.5%	2.5%	**3.1%**
Total	**6.4%**	**2.5%**	**3.2%**	**4.0%**

4.1.1. Participants Discipline

The distribution of participants by discipline is shown in Figure 4-1. The total number of Architects that participated was equal to the number of Engineers and Contractors participants combined.

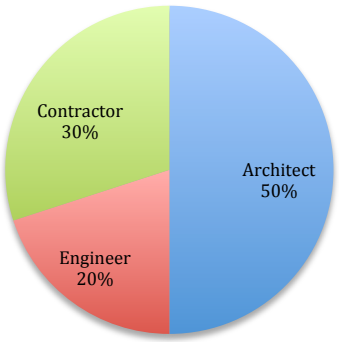


Figure 4-1: Discipline distribution from participating SMEs responses

Architect firms represented 12% and 7% of the total number of firms identified in the construction industry for New Zealand and Australia respectively, Table 3-3. Architects made up 29% and 34% of the firms invited to participate in the survey from New Zealand and Australia, or 31% of the total number of firms invited to participate. The response rate of Architects outperformed both of the other two disciplines, with the survey receiving 50% of the total number of responses from Architects.

Contractor firms represented 69% and 91% of the total number of firms identified in the construction industry for New Zealand and Australia respectively, Table 3-3. Contractors made up 40% and 34% of the firms invited to participate in the survey from New Zealand and Australia, or 37% of the total number of firms invited to

participate. The response rate of Contractor was lower than their share of the total number of firms invited to participate.

Engineer firms represented 19% and 2% of the total number of firms identified in the construction industry for New Zealand and Australia respectively, Table 3-3. Engineering made up 31% and 32% of the firms invited to participate in the survey from New Zealand and Australia, or 32% of the total number of firms invited to participate. The response of Engineer was lower than their share of the total number of firms invited to participate.

4.1.2. Participants Location

The survey was distributed to firms across New Zealand and Australia. The distribution of responses is shown in Figure 4-2. The survey asked where the firm operates. The location receiving the largest number of firms indicating it as an area of operation, with 20% of the participants, was Canterbury region of New Zealand. The only region of New Zealand or state of Australia not to be indicated by participants, as a region they operate in, was the Southland region of New Zealand.

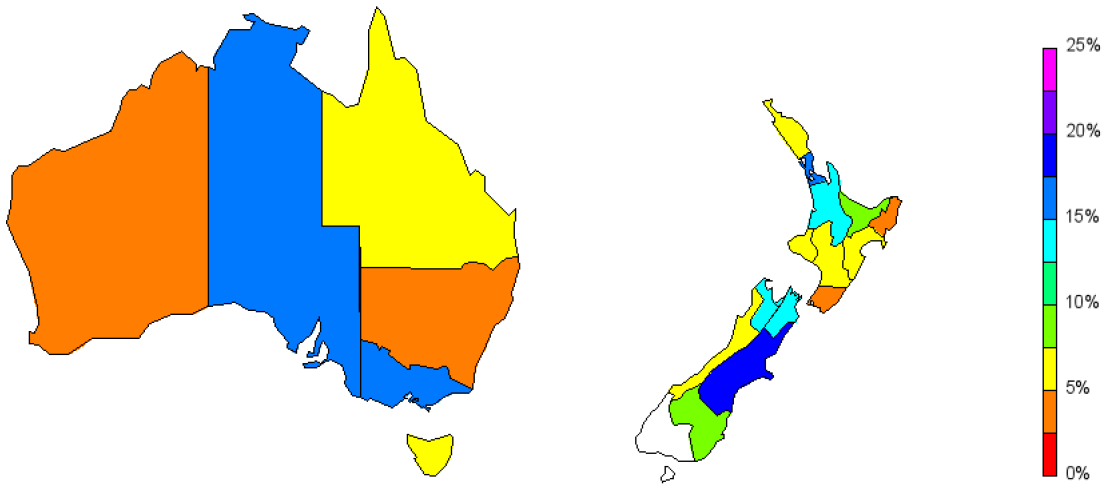


Figure 4-2: Location distribution of participating SMEs

4.1.3. Participants Firm Size

Figure 4-3, contains the size of firm, by number of employees, responses from each participant. The number of firms in each firm size decreased as the number of

employees increased. The survey was directed towards SME's with one of the New Zealand respondents responding in the range of 20-200, which is larger than a SME in New Zealand, but inside the range for SME in Australia.

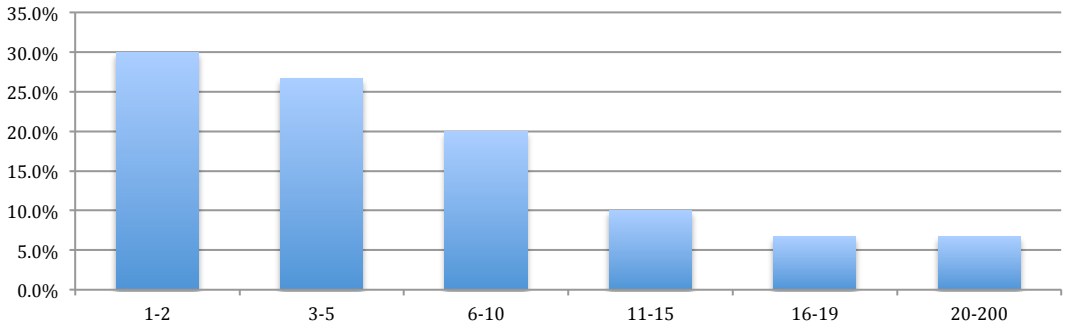


Figure 4-3: Size distribution of participating SMEs

The trend downward for the number of firms in each size range, with the lowest volume of responses for 16-19 full time employees, which is the maximum size for a SME in New Zealand, and increased slightly for firms with 20-200 employees. The 20-200 group contains the one New Zealand firm that is not considered an SME in New Zealand, but will be kept inside the same as the survey contains data from New Zealand and Australia, were 20-200 is the largest firm size categorised SME.

4.1.4. Participant Discipline, Size and Country

Figure 4-4, Figure 4-5 & Figure 4-6 contains the split of firm size by discipline and location.

Architect firm size and location responses in Figure 4-4, shows the majority of participants have less than 10 employees. Three quarters of the responses were from New Zealand.

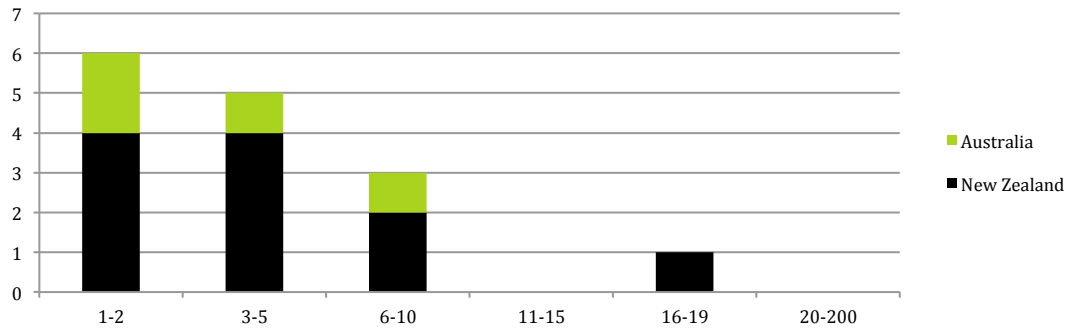


Figure 4-4: Architect, firm size and country responses

Figure 4-5, contains the Engineer firm size and location responses. There are less half the number of respondents for Engineer discipline than Architect. The firms that have participated indicate, a similar trend as to Figure 4-4, a downward trend with the majority with less than 10 employees. There were twice as many responses from Australia than New Zealand for Engineer. Further New Zealand and Australian Engineer responses are needed to produce a clearer picture of the distribution in firm size.

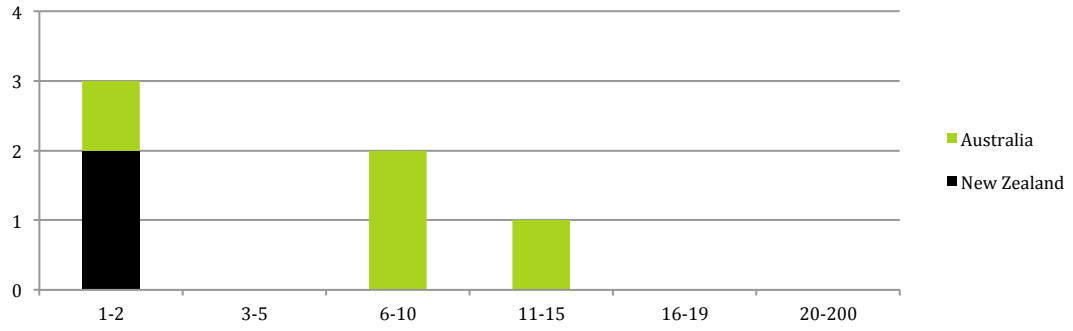


Figure 4-5: Engineer, firm size and country responses

Figure 4-6, below contains the Contractor discipline firm size and location responses. The contractor discipline received responses from just over half the number of those indicating Architect. The difference between Contractor discipline and that of Engineer and Architect is the number of firms with higher number of employees, and the lack of downward trend as the number of employees increased. There were twice as many responses from New Zealand than Australia for the Contractor discipline.

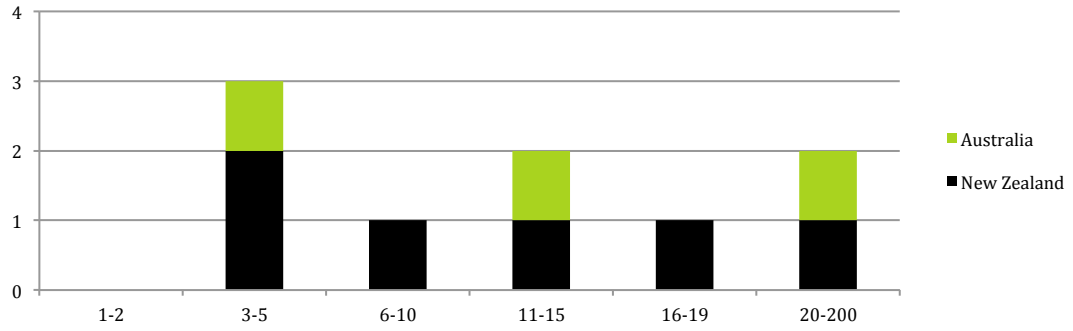


Figure 4-6: Contractor, firm size and country responses

4.1.5. Participants Use of AGEMs

The participants indicated their use of AGEMs as shown in Figure 4-7, by the response to the question 'Has the firm use AGEMs?'. In the survey participants were directed to different questions due to whether they indicated they had previously used AGEMs or not. The firms that indicated they had previously used AGEM were directed initially to questions about the three AGEM most prevalently used by the firm; before the questions about what materials the firm were aware of, but had not used due to the perceived issues. The firms that indicated no previous use of AGEM were directed past questions about their most commonly used AGEMs, to the questions about the issues preventing the use of AGEMs by the firm.

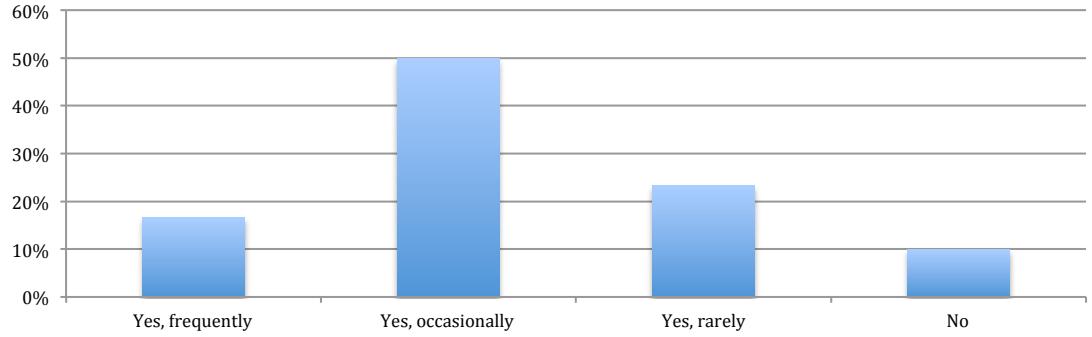


Figure 4-7: Frequency of AGEM use by SMEs

Figure 4-9 & Figure 4-8, show the distribution of firms that answered "Yes, frequently", "Yes, occasionally", "Yes, rarely" and "No" to questions about the AGEMs used and not used by the firm.

Figure 4-9, shows the distribution of responses to 'Has the firm used AGEMs?', for questions about the AGEM most commonly used by the firm. There were no firms that answered "No", as these firms were not given these questions. The distributions of the "Yes" respondents more close resemble the distribution that participated in the survey Figure 4-7, without the "No" respondents.

Figure 4-8, shows the distribution of responses to 'Has the firm used AGEMs?', that answered questions about the AGEMs the firm do not use due to the issues with the material. All survey participants were asked the questions about what AGEM the firm do not use due to the materials perceived issues. Participants that answered "No" to 'Has the firm used AGEMs?' did not go on and answer the questions about AGEMs they were aware of but did not use due to the issues related to them. There was a higher percentage of firms that answered "Yes, frequently" than "Yes, rarely", which differs from Figure 4-7 indicating that there were some "Yes, rarely" firms that did not answer the question about previously unused AGEMs.

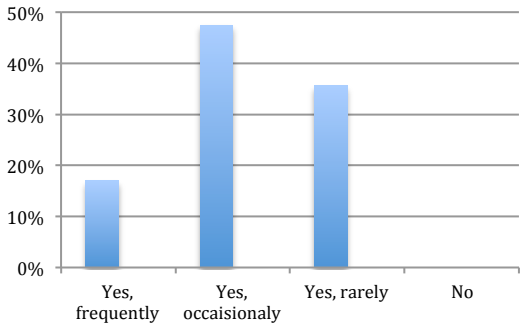


Figure 4-8: Frequency of use for previously used AGEMs

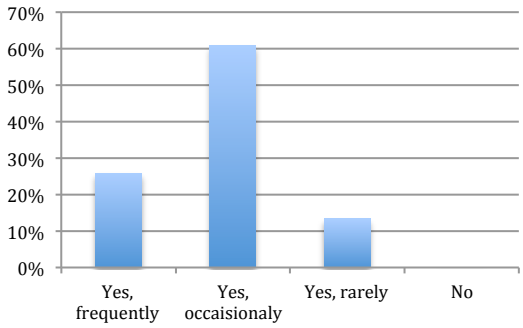


Figure 4-9: Frequency of use for previously unused AGEMs

4.2. Identification and Evaluation of AGEMS

The participants were asked 'How does the firm identify potential materials for use?' and 'How does the firm evaluate alternative materials?' on the page for general issues with AGEMs. Table 4-3 below contains the open-ended responses. The only alterations to the responses have been the addition of "*(beside in this table)"* where participants have referred to an answer that was above in the survey, but is shown beside the comment in the table below.

Table 4-3: Results for Methods of Identification and Evaluation

How does the firm identify potential materials for use?	How does the firm evaluate alternative materials?
Discussion with Client re cost savings	Compliance with standards and workability.
We look at specification of products, use other experts in the product, network with peers, use internet or other publications for information talk to others who have used/recommended the product.	as above *(beside in this table)*
Reading information, obtaining actual samples and testing in house, (e.g. where possible: we drill holes in, nail it, burn it, submerse in water, test with glues and chemicals, and use it:) industry feedback and other users, our own experience of the material. Cost/value. Is it a good solution?	Same as above. Policy being to become 'expert' in any new product which often means phoning the manufacturer to get greater technical detail and advice or limitations of use. *(beside in this table)*
Experience	We don't
research	research and investigation
Mostly supplier and customer feedback.	1. Customer acceptance 2. Cost 3. Improvement on existing material
Often it is suggested by the client. It depends on how "green" the client is. Also through reps, websites, advertising, seminars etc,	Through talking with other professionals and experienced users and manufacturers, research through the internet
General research based upon client request. Industry publications	Google for problems
Research, samples and speaking with manufacturers	As above and also built examples *(beside in this table)*
design factors, strength, look of the product, ability to be used for a specific task.	we look at what the product can do and the costs involved. The products availability and skills required to use it.
Mainly reading trade literature	Rely on others. Providing evaluating body is reputable
Research	Identify where and when has been previously used
Seminars and publications- what is out there? Book/ Internet browsing	Research- Mainly Internet and querying peers Check availability and Matching with projects- are they the best option- cost/ availability/ relevancy
inovation cost and aplication	research, and specific design requirements

4.3. SMEs issues with AGEMs

The research survey collected issues for SMEs with the use of AGEMs across three broad categories. General issues with AGEMs; issues for SMEs with the use of AGEMs commonly adopted by the firm; and issues for SMEs with the use of AGEMs not previously adopted by the firm.

The results for issues have not been broken down by discipline, as there is not enough data to compare from some disciplines (this is discussed in the limitations, Section 3.3).

4.3.1. General issues with AGEMs for SMEs

The SMEs that participated in the survey were asked to score a selection of issues with a sliding scale: "Strongly Disagree", "Disagree", "Neither Agree or Disagree", "Agree", and "Strongly Agree". Each choice was assigned a corresponding score of 1-5, with a score of 1 as "Strongly Disagree" and 5 as "Strongly Agree", the results from the survey are shown in Figure 4-10 below. The issues that scored higher than "Neither Agree or Disagree" are as follows:

1. Experience, with a score of 4.13;
2. Perception, with a score of 3.88;
3. Cost of Material, with a score of 3.73;
4. Standards or Codes, with a score of 3.67;
5. Evaluation Methods, with a score of 3.33;
6. Identification of alternatives, with a score of 3.27; and
7. Material Properties, with a score of 3.20.

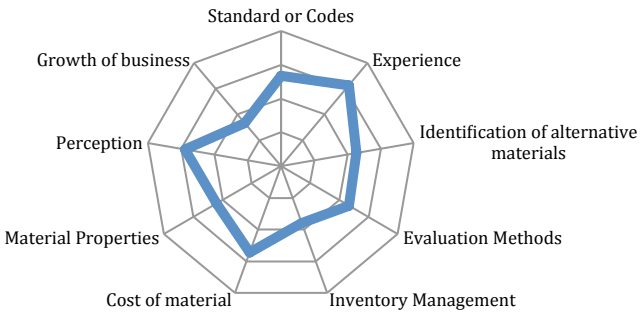


Figure 4-10: Survey results for general issues with use of AGEMs by SMEs

Experience was the highest scoring general issue for SMEs with the use of AGEMs, and the only issue that scored between "Agree" and "Strongly Agree". Scores above 3 indicate that there are more firms experiencing the issue than not, and highlights issues that could be addressed to improve the use of AGEMs in general. From the selection of general issues with AGEMs only "Growth of business" and "Inventory Management" scored "Disagree".

4.3.2. The issues with AGEMs previously adopted by SMEs

The SMEs that participated in the survey were split into firms that have used AGEMs in the past and those that have not. The SMEs that have used AGEMs were given questions about the three AGEMs most commonly used by the firm, included were questions about the issues related to the AGEMs. Figure 4-11, shows the issues for all AGEMs identified by SMEs as materials that are currently used by the firms. The leading four issues are:

1. Cost of Materials;
2. Material Properties;
3. Availability; and
4. Experience.

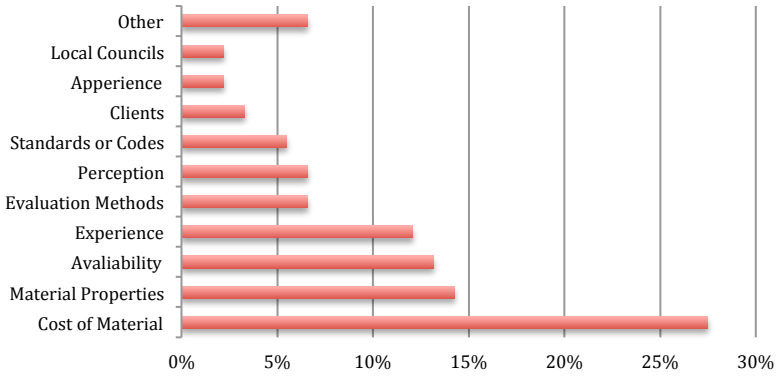


Figure 4-11: Survey results of issues with AGEMs previously adopted by SMEs

'Other' issues shown in Figure 4-11 above include, "Consistency", "Different Finishes Available", "Detailing/shop drawings", "Climate", "Absence of robust in-ground insulation" and "Structure of foundations and Parapit", which were given by a

participant using option of "Other" and typing in each issue. The individual issues for the most commonly used AGEM are shown in Section 4.4.1.1.

4.3.3. The issues with AGEMs not previously adopted by SMEs

The SMEs that participated in the survey were split into firms that have used AGEMs in the past and those that have not. All participants were asked questions about two AGEMs that have not been used by the firm due to issues with the material, included were questions about the particular issues preventing the use of these AGEMs. Figure 4-11, shows the issues for all AGEMs identified by SMEs as materials not previously used by the firm. The leading four issues are:

1. Experience;
2. Standards or Codes;
3. Evaluation Methods; and
4. Cost of Materials.

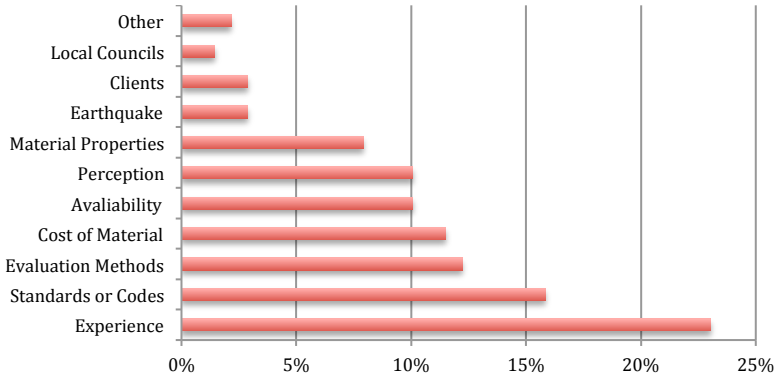


Figure 4-12: Survey results of issues with previous unused AGEMs

'Other' issues shown in Figure 4-12 above include, "Weather Conditions" and "Inventory Management", which were given under the option of "Other" by a single participate for each issue. The individual issues for the most commonly used AGEM are shown in Section 4.4.1.2.

4.4. Responses for individual AGEMs

Each participating SMEs were asked questions about two to five AGEMs. The firms that indicated previous use of AGEMs were given questions about the three most

commonly used AGEMs, and two AGEMs not used by the firm due to the perceived issues with their use. Whereas the SMEs indicating "No" previous use of AGEMs were directed to the latter questions about two AGEMs not used.

The materials that have been evaluated individually were the materials identified in the survey with at least 10% of the participants indicating either previous use of the material, or reluctance to use the material due to the issues perceived by the firm with their use.

4.4.1. Individual AGEMs Issues

The questions about each material included issues for both used and unused AGEMs. The following two sections introduce the results for each individual material's issues.

4.4.1.1. AGEMs commonly adopted by SMEs

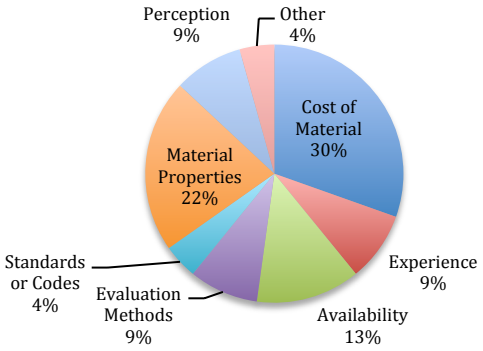
There were six AGEMs commonly adopted by at least 10% of the SMEs respondents that indicated prior use of AGEM, which were:

(a) LVL
(b) Glulam
(c) Rammed Earth
(d) High Strength Concrete
(e) Lightweight Concrete
(f) Adobe Brick

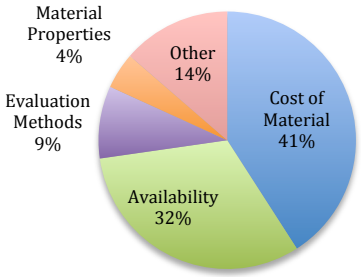
The materials have been listed above and shown below in the order of most responses, with indicated preference used to separate materials with identical number of responses, e.g., LVL was the most common AGEM from the survey responses; with Lightweight Concrete and Adobe Brick receiving the least number of participants, with 10% of participant indicating previous use. Lightweight Concrete was shown ahead of Adobe Brick since it received higher use preference as indicated in Section 4.4.7.

Figure 4-13 (a) – (f), contains pie charts showing the percentage each issue was indicated of the total recorded for each material. The most prevalent issue for each

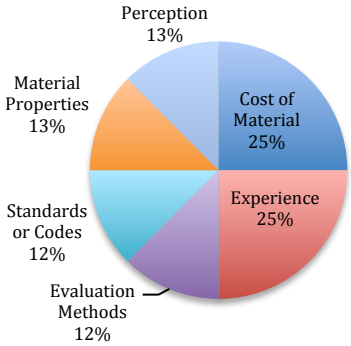
material tends to be "Cost of Material", Adobe Brick is the only material shown below that is an exception to this observation. Cost of Material was also identified in Section 4.3.2, as the leading issue for AGEMs that have been previously used by SMEs. The other top four issues identified in Section 4.3.2, "Experience", "Availability" and "Material Properties" were also present for the majority of the material below.



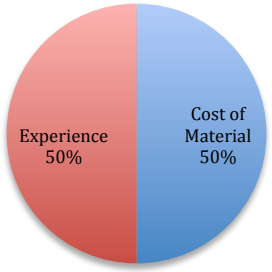
(a) LVL



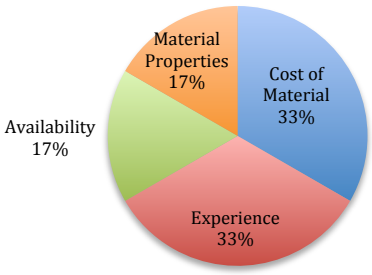
(b) Glulam



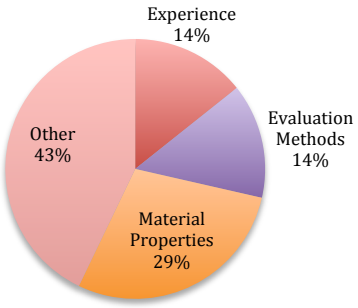
(c) Rammed Earth



(d) High Strength Concrete



(e) Lightweight Concrete



(f) Adobe Brick

Figure 4-13: Issues for SME with used AGEMs

Table 4-4, below indicates which materials had which issues, each letter corresponds to the material list above and the numbering in Figure 4-13. The table compares the issues recorded for each material, and ranks the issues. The four leading issues, "Cost of Material", "Material Properties", "Experience" and "Availability", have been ranked by the number of the most commonly used AGEMs indicating the issue, without considering the percentage of each issue to for each AGEM. There is a downward trend in the number of issues for each material, with the decrease in firms indicating their use, e.g., the most commonly used material (a) LVL, total of 8 issues (including "Other"), whereas (e) Lightweight Concrete and (f) Adobe Brick each indicate 4 issues. The decreasing trend is discussed further in limitations.

Table 4-4: Ranked and number of issues with previously used AGEMs

Issue	(a)	(b)	(c)	(d)	(e)	(f)	Total
Cost of Material	✓	✓	✓	✓	✓		**5**
Material Properties	✓	✓	✓		✓	✓	**5**
Experience	✓		✓	✓	✓	✓	**5**
Availability	✓	✓			✓	✓	**4**
Evaluation Methods	✓	✓	✓				**3**
Standards or Codes	✓		✓				**2**

Perception	✓		✓				**2**
Other	✓	✓				✓	**3**
Total	**8**	**5**	**6**	**2**	**4**	**4**	

"Other" issues contains a collection of issues indicated infrequently and have been grouped together to reduce the congestion. They contain "Local Council", "Climate", "Earthquake" and other issues reported by participants through the use of the comment box provided for "Other" issues.

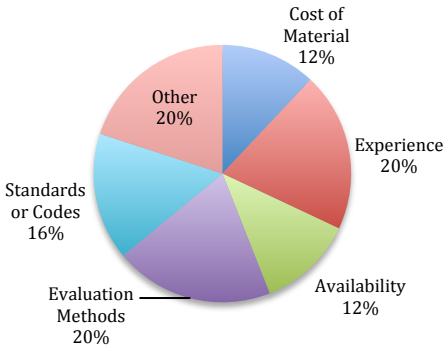
4.4.1.2. AGEMs commonly not adopted by SMEs

There are six AGEMs commonly not adopted by at least 10% of the SMEs respondents to the research survey due to the related issues are:

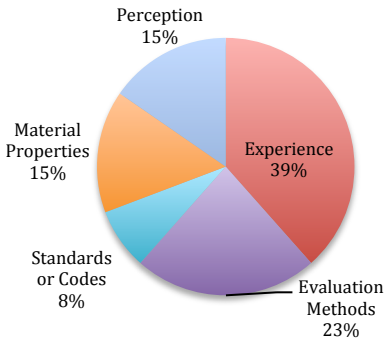
(a) Post-Tensioned Timber
(b) Cement Replacement Materials
(c) Cob
(d) Cross-Laminated Timber (CLT)
(e) Ductile Self Compacting Concrete (DSCC)
(a) Rammed Earth

The materials have been listed above, shown below in the order of most responses, e.g., Post-Tensioned Timber was the most commonly unused AGEM due to perceived issue for SMEs from the survey responses; with DSCC and Rammed Earth receiving the least number of responses, though still receiving at least 10% of participant indicating the material as unused due to related issues.

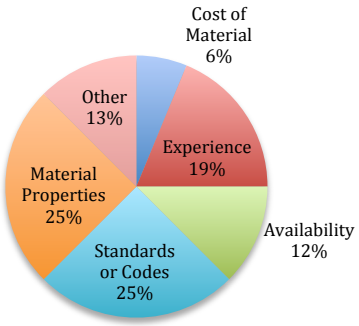
Figure 4-14 (a) – (f), contains pie charts showing the percentage each issue was indicated of the total recorded for each material. The most prevalent issue tends to be "Experience". "Experience" was also identified in Section 4.3.2, as the leading issue for AGEMs that have been not been previously used by SMEs. The other top four issues identified in Section 4.3.2, "Standards or Codes", "Evaluation Methods" and "Cost of Materials" were also present for the majority of the material below.



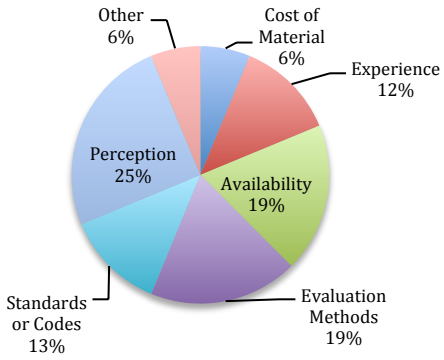
(a) Post-Tensioned Timber



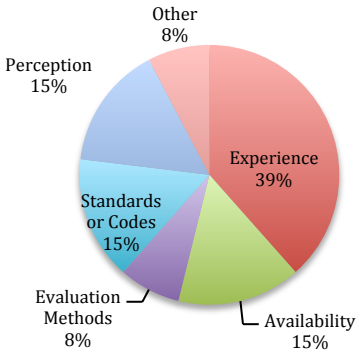
(b) Cement Replacement Materials



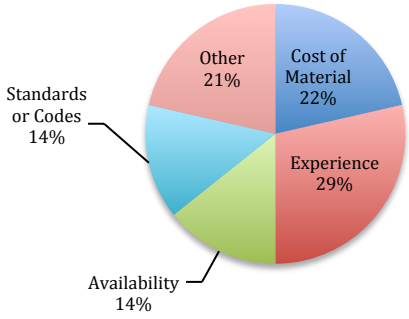
(c) Cob



(d) CLT



(e) DSCC



(f) Rammed Earth

Figure 4-14: Issues for SME with previously unused AGEMs

Table 4-5, below indicates which materials had which issues, each letter corresponds to the material list above and the numbering in Figure 4-14. The table compares the

issues recorded for each material, and ranks the issues. The five leading issues, "Experience", "Standards or Codes", "Availability" "Evaluation Methods" and "Cost of Material", differ from the top four listed in Section 4.3.3 by the inclusion of "Availability". Issues are ranked by the number of the unused AGEMs indicating the issue, without considering the percentage of each issue for each AGEM. Unlike the results for previously used materials in the section above, there is a flat trend for the number of issues indicated for each material. Also there are two issues that are common across by all the materials examined that are unused due to related issues, the common issues are "Experience" and "Standards or Codes".

Table 4-5: Ranked and number of issues for previously unused AGEMs

Issue	**(a)**	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**Total**
Experience	✓	✓	✓	✓	✓	✓	**6**
Standards or Codes	✓	✓	✓	✓	✓	✓	**6**
Availability	✓		✓	✓	✓	✓	**5**
Evaluation Methods	✓	✓		✓	✓		**4**
Cost of Material	✓		✓	✓		✓	**4**
Perception		✓		✓	✓		**3**
Material Properties		✓	✓				**2**
Other	✓		✓	✓	✓	✓	**5**
Total	**6**	**5**	**6**	**7**	**6**	**5**	

"Other" issues contains a collection of issues indicated infrequently and have been grouped together to reduce the congestion. They contain "Local Council", "Climate", "Earthquake" and other issues reported by participants through the use of the comment box provided for "Other" issues.

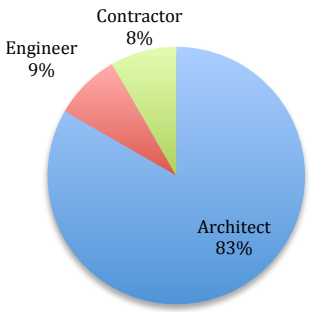
4.4.2. Discipline using individual AGEMs

The discipline of each respondent for questions about individual AGEMs was recorded, as acknowledged earlier. The discipline distribution is shown in the next

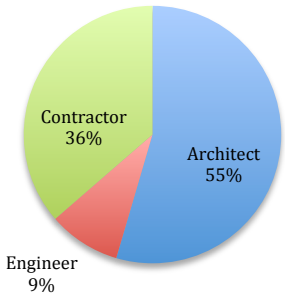
two subsections for each material receiving at least 10% of the participants indicating either previous use of the material, or reluctance to use the material due to the issues perceived by the firm with their use.

4.4.2.1. AGEMs commonly adopted by SMEs

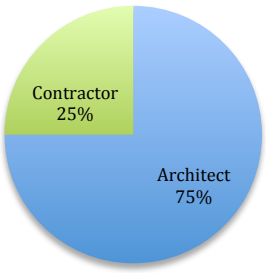
Figure 4-15 (a) – (f), below contains the discipline distribution of responses for the commonly used AGEMs. The Architect discipline indicted they use all 6 of the AGEMs examined further, their response represented greater than or equal to 55% of the responses to questions about individual AGEMs. The Engineer discipline indicated the use of only three of the AGEMs examined individually, LVL, Glulam and Adobe Brick, with generally low response rates. The Contractor discipline indicated the use of four of the AGEMs examined individually, LVL, Glulam, Rammed Earth and High Strength Concrete, however provided generally higher responses rates than the Engineering discipline. The use of Lightweight Concrete was indicated by only one discipline, Architect, a further three materials received responses from only two of the three disciplines.



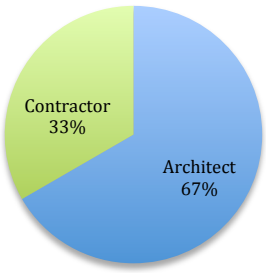
(a) LVL



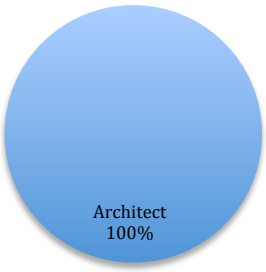
(b) Glulam



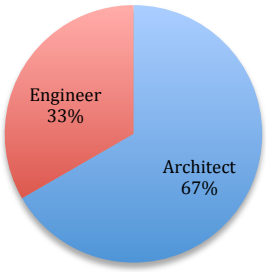
(c) Rammed Earth



(d) High Strength Concrete



(e) Lightweight Concrete

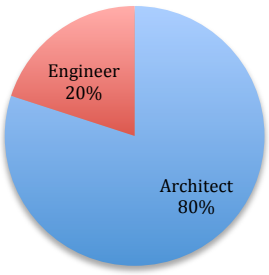


(f) Adobe Brick

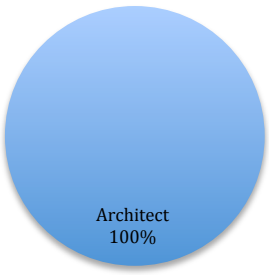
Figure 4-15: Distribution of SMEs discipline for previously used AGEMs

4.4.2.2. AGEMs commonly not adopted by SMEs

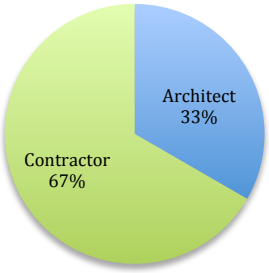
Figure 4-16 (a) – (f), below contains the discipline distribution of responses for the commonly unused AGEMs. The Architect discipline indicted issues with the use of all six AGEMs examined individually. The Engineer discipline provided issues restricting the use of two of the AGEMs examined individually, Post-Tensioned Timber and CLT. The Contractor discipline indicated issues preventing use of three AGEMs examined individually, Cob, DSCC and Rammed Earth. The issues relating to the use of Cement Replacement Materials were indicated by only one discipline, Architect. None of the AGEMs identified as materials with issues preventing their use received responses from all three disciplines.



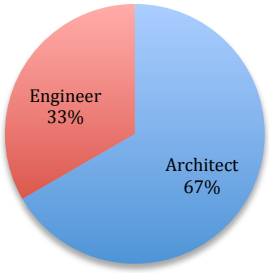
(a) Post-Tensioned Timber



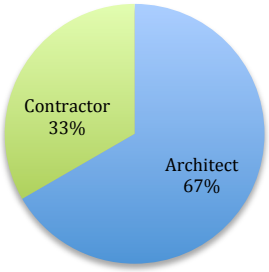
(b) Cement Replacement Materials



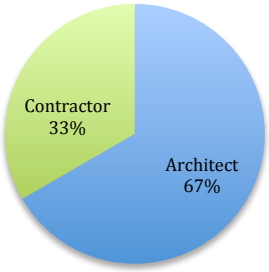
(c) Cob



(d) CLT



(e) DSCC, Discipline of SMEs



(f) Rammed Earth

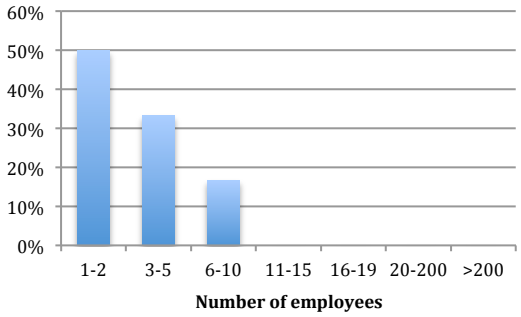
Figure 4-16: Distribution of SMEs discipline for previously unused AGEMs

4.4.3. Distribution of SMEs firm size using individual AGEMs

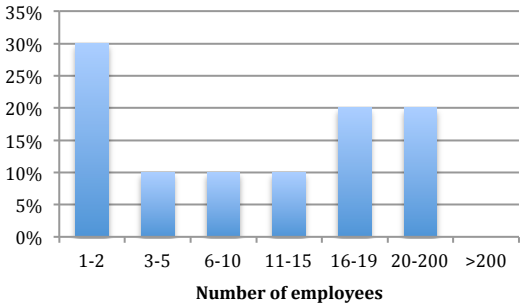
The firm sizes for SMEs indicating which AGEMs that the firm use, or have not used due to the perceived issues, has been collected and displayed in the following two subsections.

4.4.3.1. AGEMs commonly adopted by SMEs

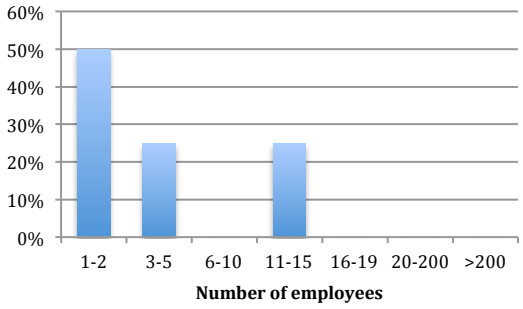
Figure 4-17 (a) – (f), below shows the firm size of SMEs who indicated previous use of each AGEM exceeding the 10% of participant response threshold. This can be examined in conjunction with Section 4.4.2 and 4.1.3. The materials that received responses from firms with 6-10 employees and greater tended to also have Contractor responses. The greater the percentage of Contractor responses the flatter the trend was.



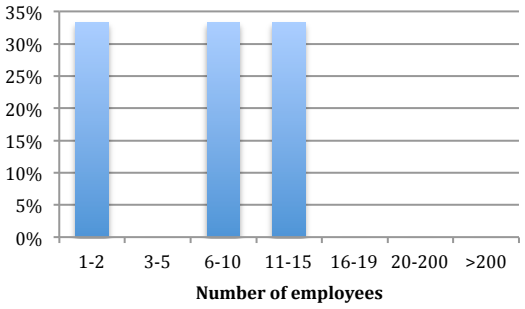
(a) LVL



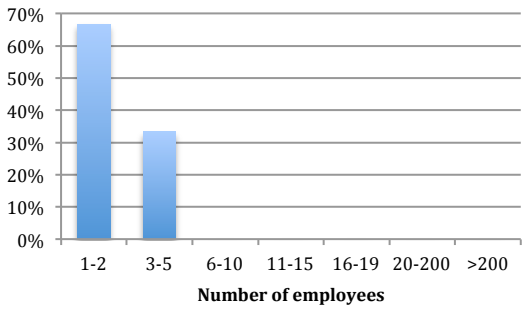
(b) Glulam



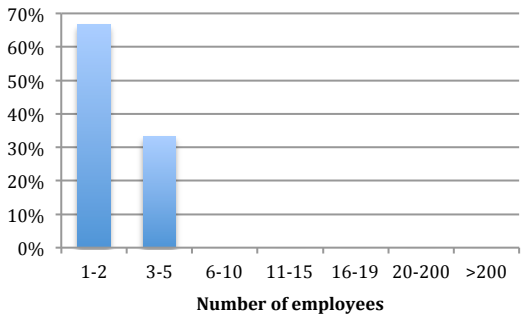
(c) Rammed Earth



(d) High Strength Concrete



(e) Lightweight Concrete

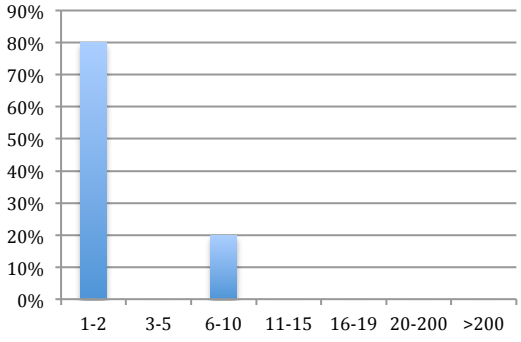


(f) Adobe Brick

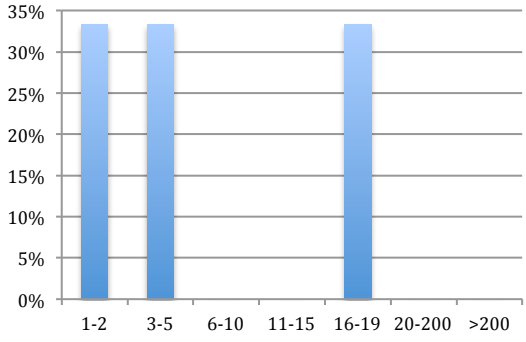
Figure 4-17: Distribution of firm size responding for used AGEMs

4.4.3.2. AGEMs commonly not adopted by SMEs

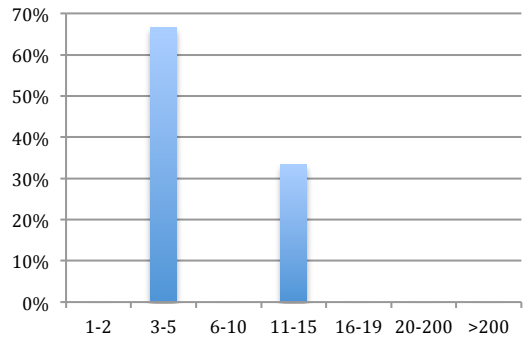
Figure 4-18 (a) – (f), below shows the firm size of SMEs indicating AGEMs that are not used by the firms due to perceived issues with the materials. This can be examined in conjunction with Section 4.4.2 and 4.1.3. This information could benefit from further responses and does not provide any apparent trends with the current amount of information. Unlike the AGEMs that are currently used by SMEs, the materials that are not currently use by SMEs received a wider range of responses with lower number for each.



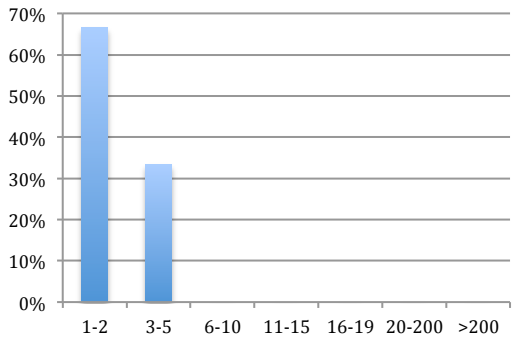
(a) Post-Tensioned Timber



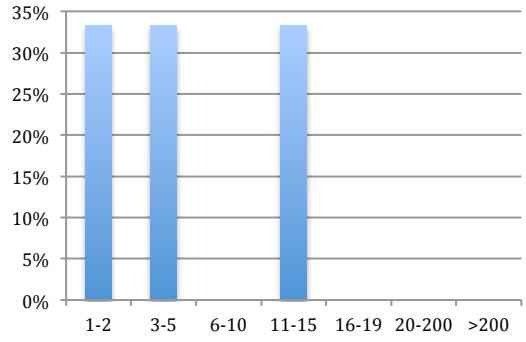
(b) Cement Replacement Materials



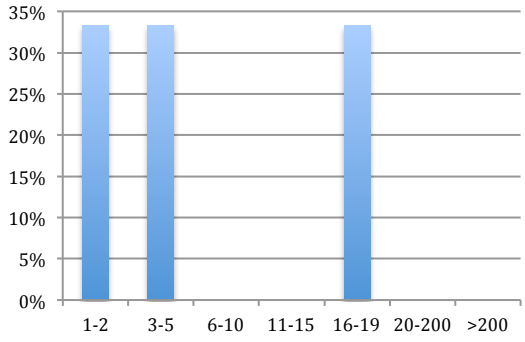
(c) Cob



(d) CLT



(e) DSCC



(f) Rammed Earth

Figure 4-18: Distribution of firm size responding for previously unused AGEMs

4.4.4. Awareness length of Individual AGEMs

Each of the two to five pages of questions about AGEMs contained a question about the length of time the firm had been aware of the material – There was a page of questions for each AGEM, with all participants receiving a page of questions for each of the two 'AGEMs not used by the firm due to the related issues' and previous users of AGEMs also received a page of questions for each of the three 'AGEMs commonly used by the firm' as mention above.

The results have been cumulated for used and unused materials and presented in the following two subsections, with the used graphed with the unused in the third subsection.

4.4.4.1. *AGEMs commonly adopted by SMEs*

Figure 4-19, shows the distribution of awareness length for the commonly used AGEMs. There is a trend towards awareness length greater than 5 years for the AGEMs commonly used by SMEs. 80% of the awareness length was found to be greater than 5 years, with the number of responses below 5 years far less than that greater than 5 years for the few AGEMs receiving responses in multiple awareness lengths periods, e.g., Glulam received eight responses greater than 5 years, two responses between 3 and 5 years, and finally one responses between 1 and 2 years.

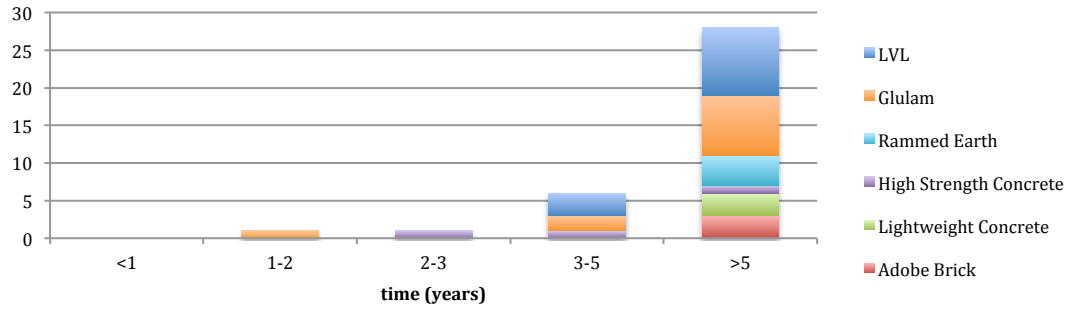


Figure 4-19: Length of awareness for previously used AGEMs

4.4.4.2. *AGEMs most commonly not adopted due issues by SMEs*

Figure 4-20, shows the distribution of awareness length for the AGEMs unused due to the related issues. There is an approximately even distribution across the awareness lengths, with approximately 80% with length of awareness less than 5 years.

Cob is an earthen material that has been used for hundreds of years which is interesting that it received a response of awareness length less than 1 year from one participant.

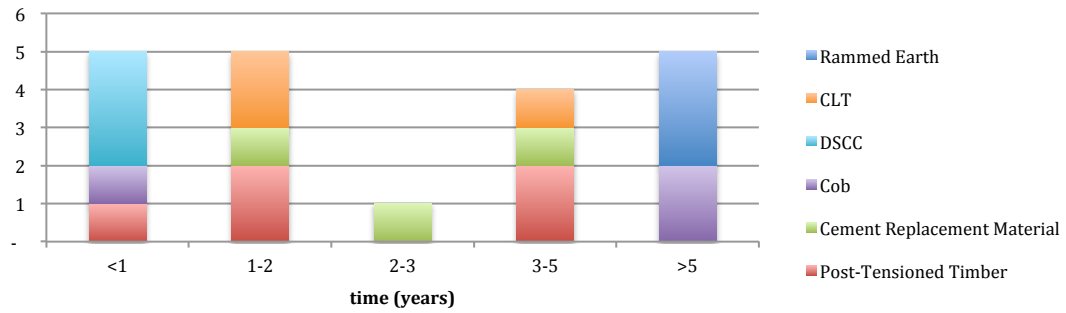


Figure 4-20: Length of awareness for previously unused AGEMs

4.4.4.3. Duration of awareness comparison

Figure 4-21, shows a comparison between the length of awareness for the AGEMs that have and have not been previously adopted by firms. There is a noticeable difference in the length of duration, where the previously used materials predominately fall into the greater that 5 years length of awareness. AGEMs that have not been adopted by SMEs tend to have been noticed by the firm for less than 5 years.

There was a very low percentage of responses indicating between 2 and 3 years for either used of unused AGEMs.

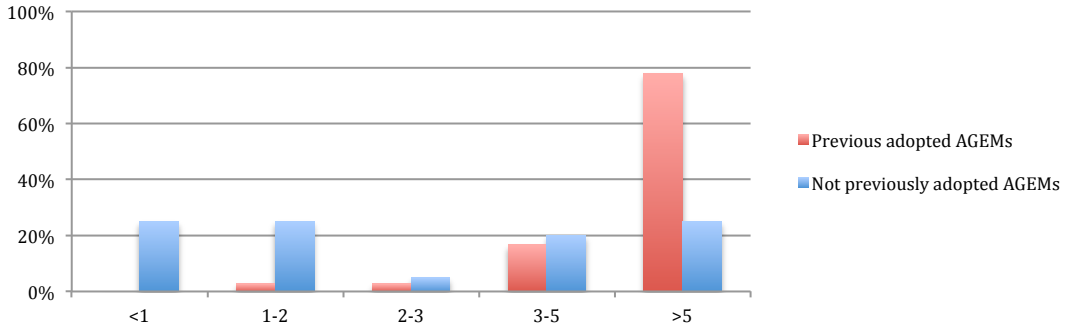


Figure 4-21: Comparison of length of awareness

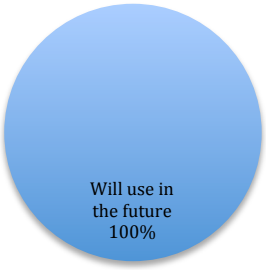
4.4.5. SMEs indication for future use of AGEMs

Participants were asked for an indication of future use for the AGEMs that they currently use, or whether they would adopt a currently unused AGEM if the perceived

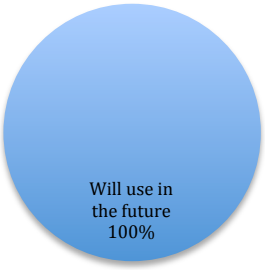
issues were addressed. The responses have been shown in the following two subsections.

4.4.5.1. AGEMs commonly adopted by SMEs

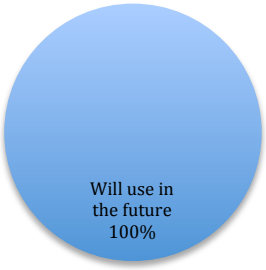
Figure 4-22 (a) – (f), below contains the indication of future use of AGEMs currently used by SMEs. Four of the six AGEMs received indication of 100% use in the future by SMEs currently using the materials. Two AGEMs received indication that 66% of current users of the materials will continue in the future, with 33% indicating they may use in the future. None of the six individual AGEMs examine that are currently used received indication of future use ceasing due to the current issues with the materials.



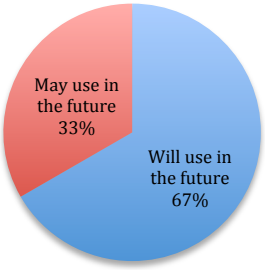
(a) LVL



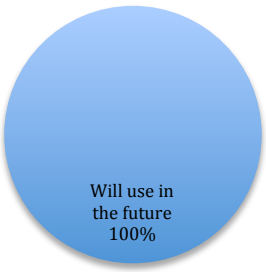
(b) Glulam



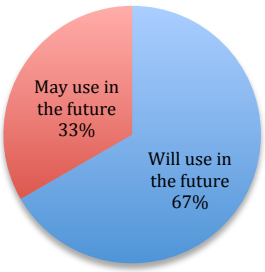
(c) Rammed Earth



(d) High Strength Concrete



(e) Lightweight Concrete

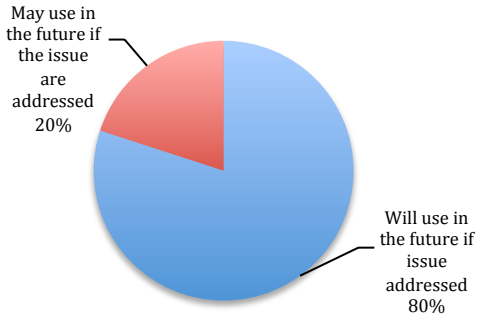


(f) Adobe Brick

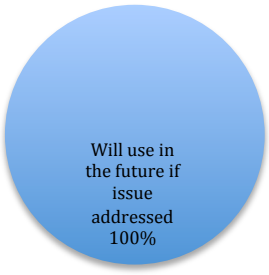
Figure 4-22: Indication of future use for previously used AGEMs

4.4.5.2. AGEMs commonly not adopted by SMEs

Figure 4-23 (a) – (f), below contains the indication of future use of AGEMs currently unused by SMEs, if current issues are addressed. One of the six AGEMs, Cement Replacement Materials, received indication of 100% use in the future by SMEs if the current issues are address. Two of the six AGEMs, Post-Tensioned Timber and CLT, received indication that between 66% and 80% of currently non-users of the materials will use in the future, and between 20 and 33% indicating they may use in the future. One of the six AGEMs, DSCC, received indication that 100% may use the material in the future. The final two materials, Cod and Rammed Earth, are the only materials that received indication that some of the firms would still not consider using the material if the current issue are addressed.



(a) Post-Tensioned Timber



(b) Cement Replacement Materials

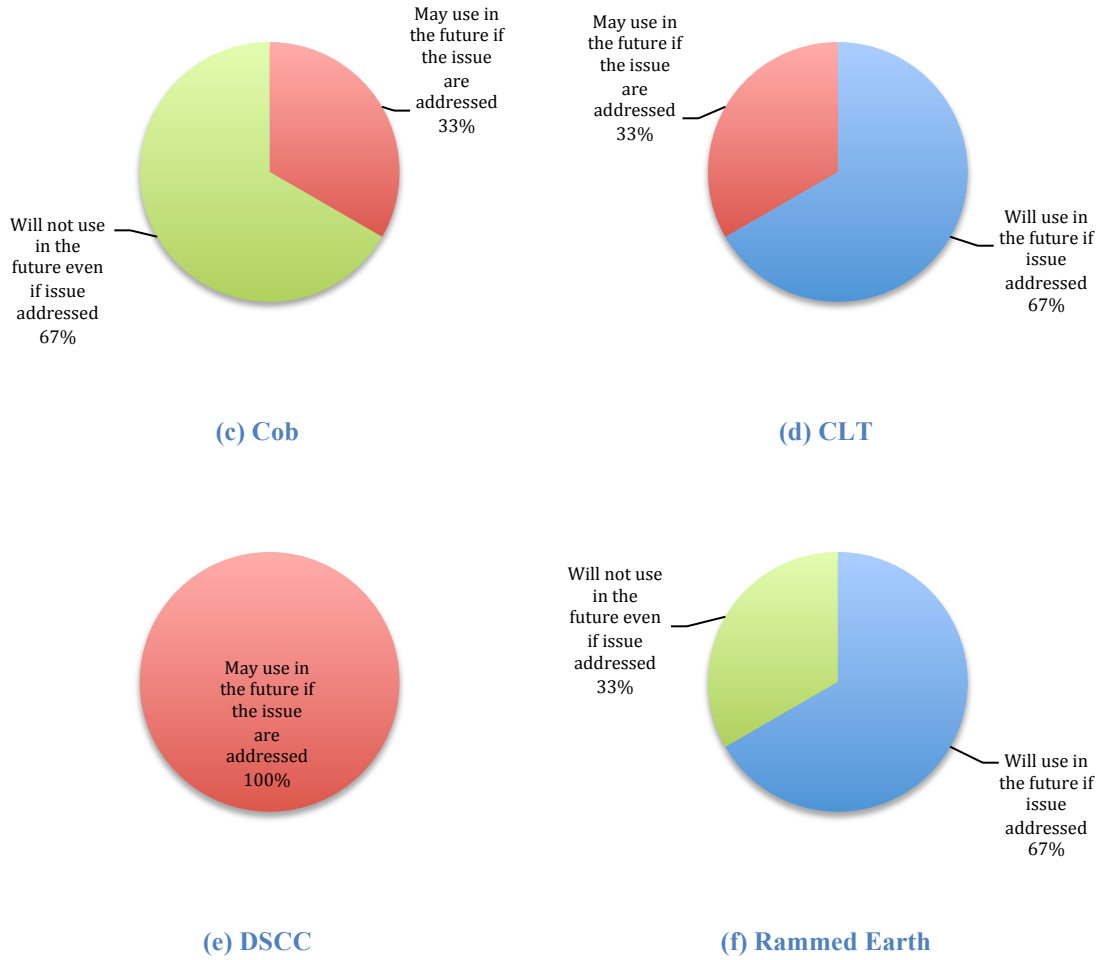


Figure 4-23: Indication of future use for previously unused AGEMs

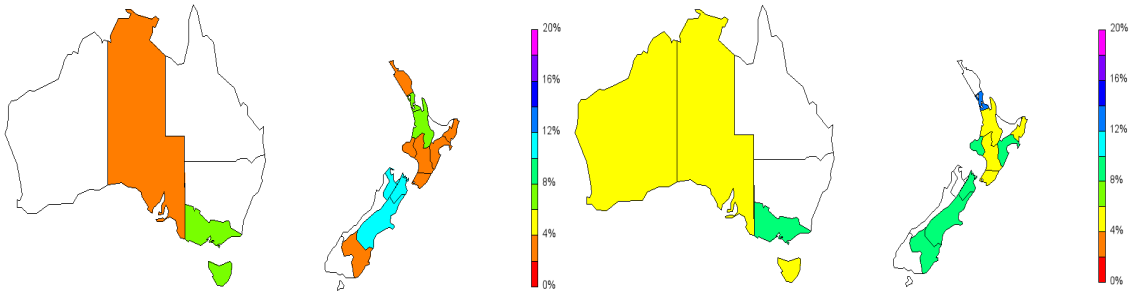
4.4.6. Distribution of SMEs location for AGEMs

The location of firms responding to questions about individual AGEMs and there use or lack of use has been recorded and shown in the next two subsections. For most individual materials examined there are respondents from both New Zealand and Australia. No single material, either used of unused, has received responses from all states of Australia and regions of New Zealand.

4.4.6.1. AGEMs commonly adopted by SMEs

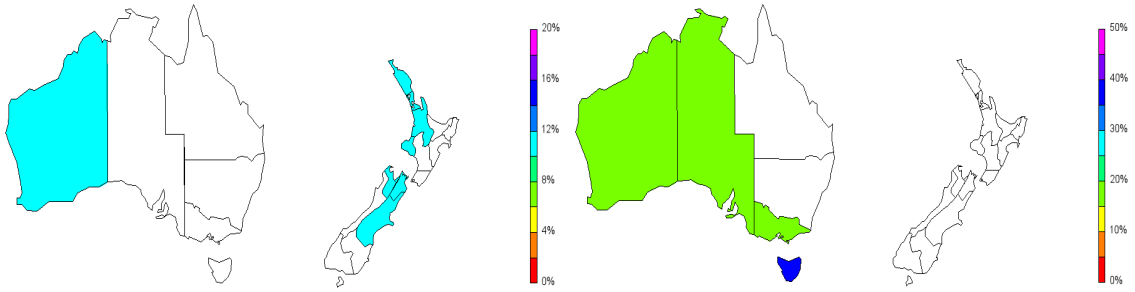
Figure 4-24, below shows the location of firms using the individual AGEMs. There was a greater spread for (a) LVL and (b) Glulam, which received the greatest number of responses. Two of the individual AGEM received responses from a single country. High Strength Concrete and Adobe Brick only received responses from Australia and

New Zealand respectively. There were no responses from QLD and NSW states of Australia; and Bay of Plenty, West Coast and Southland regions of New Zealand, for any of the commonly used AGEMs.



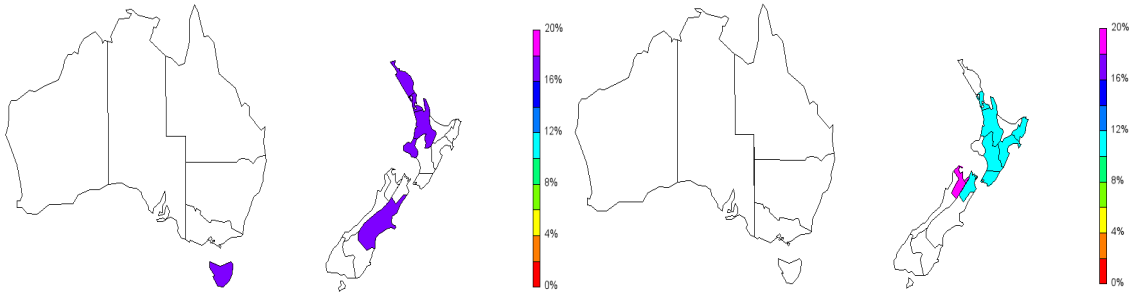
(a) LVL

(b) Glulam



(c) Rammed Earth

(d) High Strength Concrete



(e) Lightweight Concrete

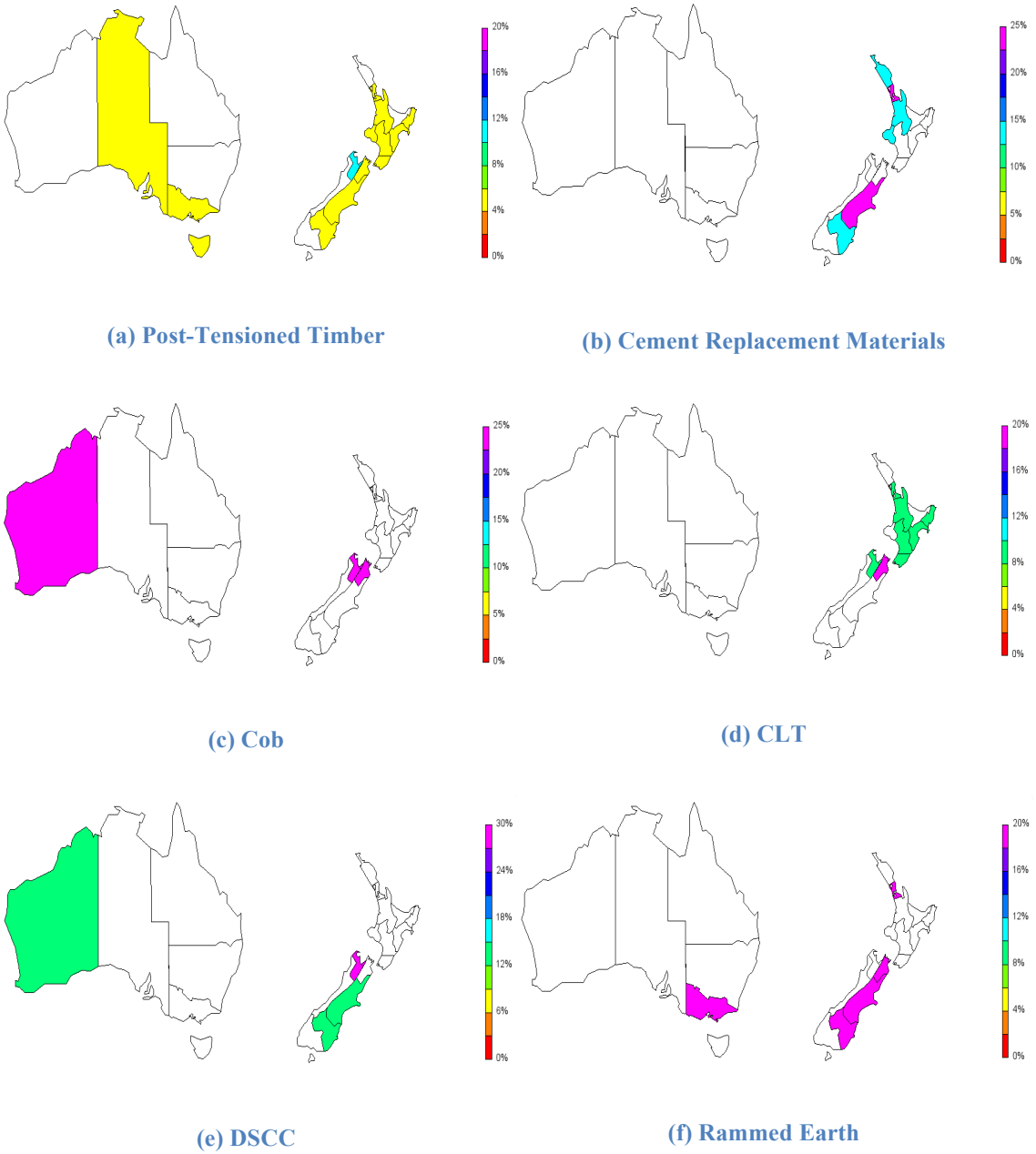
(f) Adobe Brick

Figure 4-24: Location of responses for previously used AGEMs

4.4.6.2. AGEMs commonly not adopted by SMEs

Figure 4-25 (a) – (f), below shows the locations of respondents answering questions about AGEMs with issues preventing the use. There were fewer responses for each

unused AGEM compared to the used AGEMs in the subsection above. The spread of regions responding to each unused AGEM was lower than experienced with used AGEMs. Two of the individual AGEMs received responses from a single country. Cement Replacement Materials and CLT received responses from New Zealand only. There were no responses from QLD and NSW states of Australia; and Bay of Plenty, West Coast and Southland regions of New Zealand.



(a) Post-Tensioned Timber

(b) Cement Replacement Materials

(c) Cob

(d) CLT

(e) DSCC

(f) Rammed Earth

Figure 4-25: Location of responses for previously unused AGEMs

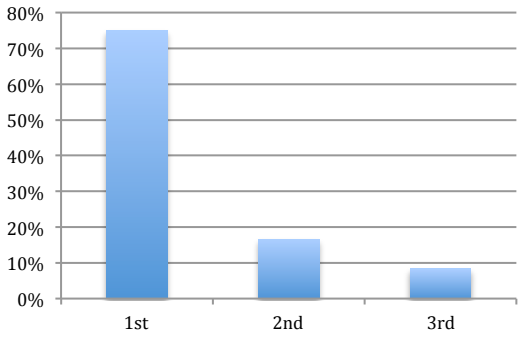
4.4.7. Preference for used individual AGEMs

The survey sections for AGEMs firms have used before were three pages of identical questions. The pages were for the three most commonly used AGEMs by the firm, the preference was recorded for each individual AGEM. There was a trend for the SMEs with LVL as first preference to have Glulam at the second preference. Each individual AGEMs that received responses from 10% of the participants, except Adobe Brick, was a most commonly used AGEM for at least one SME.

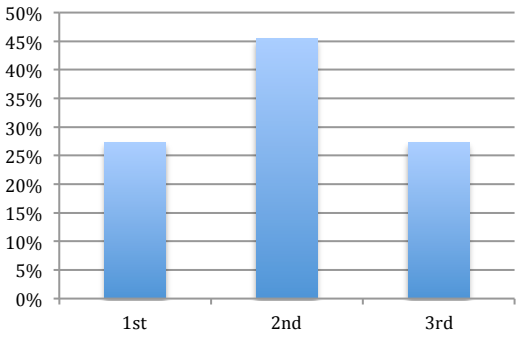
SMEs AGEM preference was used to determine the order they appeared on the list. The number of participants indicating their use separated LVL, Glulam, Rammed Earth and High Strength Concrete. Lightweight Concrete and Adobe Brick received the same number of responses, though Lightweight concrete received 1st, 2nd and 3rd preference votes that ranked it ahead of Adobe Brick, which was a 2nd and 3rd preference material.

4.4.7.1. AGEMs commonly adopted by SMEs

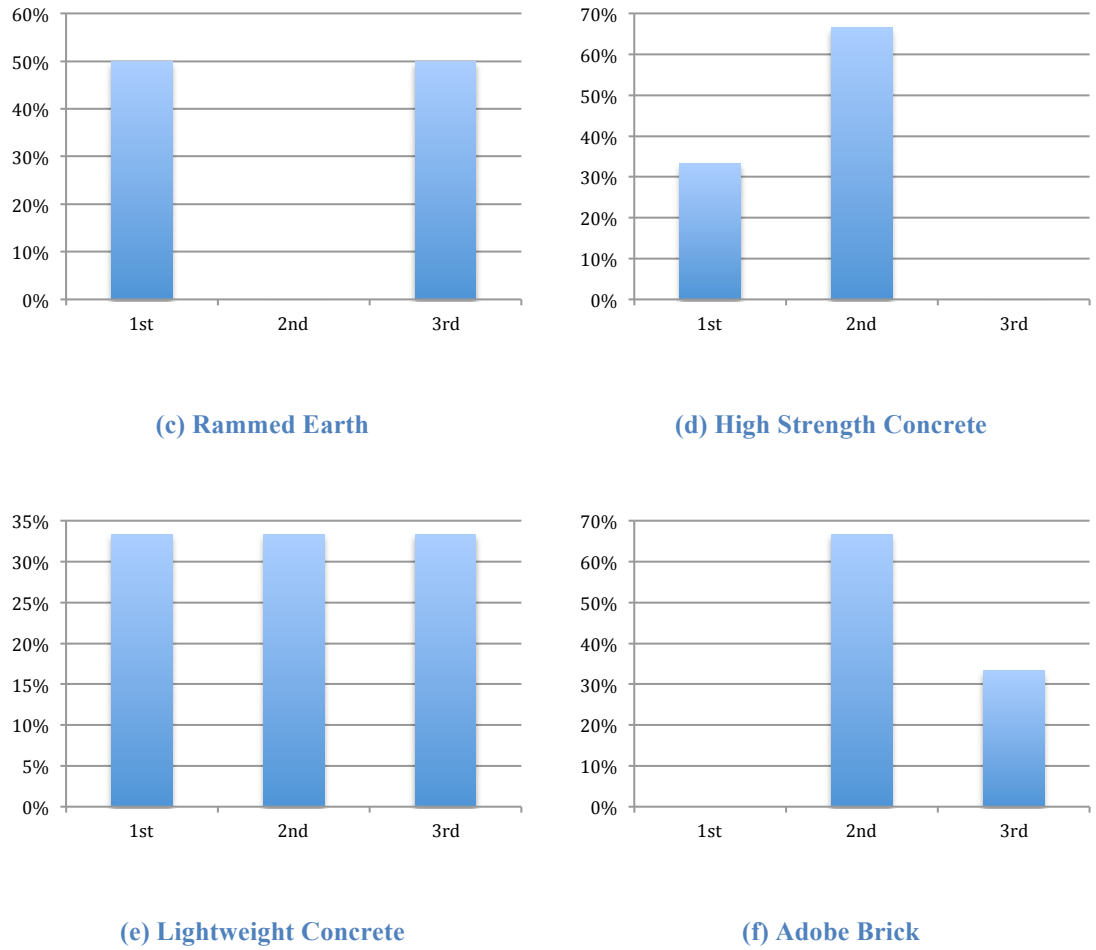
Figure 4-26 (a) – (f), below contains the participating SMEs preference for use of individual AGEMs.



(a) LVL



(b) Glulam



(c) Rammed Earth **(d) High Strength Concrete**

(e) Lightweight Concrete **(f) Adobe Brick**

Figure 4-26: SMEs preference of previously used AGEMs

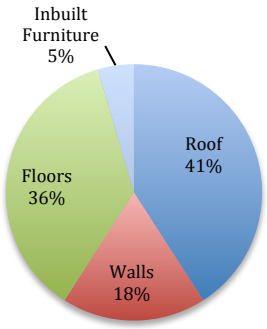
4.4.8. SMEs typical use of AGEMs

Contained with the questions about AGEMs the participants had previously used was a question about what the material was used for. This question was only collected for materials that had been previously used by SMEs. Building materials were the most common with the AGEMs used in roading and other civil projects not receiving enough responses to cross the 10% threshold.

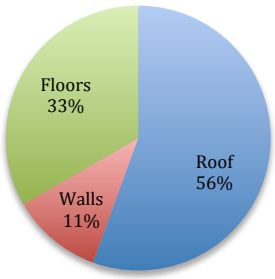
4.4.8.1. AGEMs commonly adopted by SMEs

Figure 4-27 (a) – (f), below contains the typical use of previously used AGEMs. There is a trend for building materials over roading and other civil uses. Five of the materials are commonly used in "Walls"; four in the construction of "Floors" and

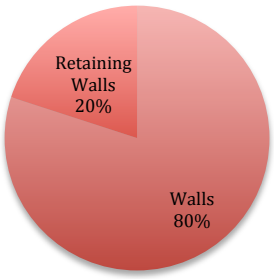
other uses include: “Roof”, “Inbuilt Furniture”, “Retaining Walls”, “Foundations” and “Road Pavement”.



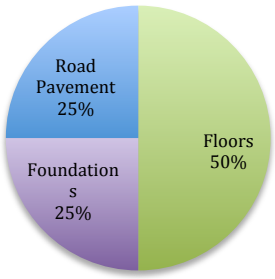
(a) LVL



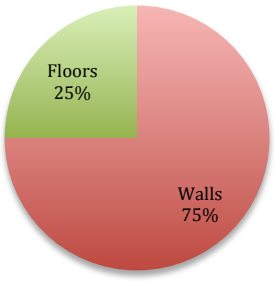
(b) Glulam



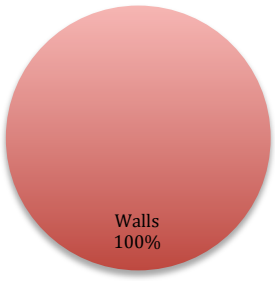
(c) Rammed Earth



(d) High Strength Concrete



(e) Lightweight Concrete



(f) Adobe Brick

Figure 4-27: Typical use for previously used AGEMs

CHAPTER 5 - DISCUSSION

5.1. Survey Participants

The objective of the survey was to achieve a minimum of 30 responses from the construction industry, with responses from New Zealand and Australian SMEs to identify trends for issues with AGEMs. This objective was meet by the responses with representation from all three disciplines engaged, also receiving representation for all six states of Australia and 15 of the 16 regions of New Zealand. The research was focused on the issues for SMEs and would have disregarded firms that were too large to be considered a SME. There was an instance were a participating firm that was larger than what is considered a SME in New Zealand was included, as it was within the bound for SMEs in Australia and the results are merged in the end.

The achievement of 30 responses was achieved with more coercion then initially expected. 749 firms were initially engaged to participate in the research survey, 30 responses represents 4% of those invited to participate. There was a lack of interest to participate in a survey, which hampered the final results, potentially due to the busy schedules in current work-life environment. Some disciplines have responded more positively to the survey; potentially due to the education each discipline has undertaken, or the size of firm invited to participate. The invited firms that neither responded to the survey nor opted out of further communication were sent weekly digests of the results including, firm sizes, locations and disciplines, for the three-week period of the survey to entice further responses. There was a spike of responses the 12hours following distribution of digested results.

Each participant was asked to indicate which discipline the firm classes itself as. The options were, “Architect”, “Engineer”, “Contractor” or “Manufacturer”. Each discipline undertakes operates at different stages of construction, it was predicated they would experience different issue with the AGEMs. The Manufacturer discipline was not actively targeted as they are considered to participate in the manufacturing industry rather than construction, which was the target industry.

The Architect discipline was over represented in the survey. This discipline is a design-oriented discipline as such is expected to be heavily involved in the selection of materials, which could be one of the reasons they responded positively to the survey. The education involved in becoming an Architect requires completion of a Master degree and the research that goes with it, this could have helped firms to relate to the research and increase their responses. Architect firm size tended to be less than 10 employees; this may have reduced the response due to the increase roles each member needs to undertake in smaller firms.

The Engineer discipline was the lease represented in the survey. This discipline can be solely design or construction, work across the full range of construction activities or partake to an extend somewhere in between. It is expected that if they didn't actively select materials, they could rule materials out, e.g., due to the unsatisfactory material properties. This potential ability to affect the materials used in construction projects did not lead to increasing respondent from this discipline. The education involved in becoming an Engineer generally requires a Bachelor's degree with research of a certain extent, however the New Zealand degrees have a significantly lower research component to that of Australian degrees, and with New Zealand Engineer the lowest respondent this could be a factor that reduces their belief of the importance of responding. Engineer firm size tended to be less than 10 employees, which may have reduced the response due to the increase roles each member needs to undertake in a smaller firm.

The Contractor discipline responded close to the percentage of invitations the discipline received, 30% response compared to 34% of total number of firms invited. This discipline is engaged primarily in the construction of projects and can be engaged due to the materials they specialise in, this is expected to reducing their potential to dismiss AGEMs or select materials for a project. There less specified required education required for the Contractor discipline, with a number of the firms run employees with trade training rather than tertiary degrees requiring research, this is expected to reduce the potential responses from the Contractor discipline. Contractor firm size tended to be larger than Architect or Engineer, this may have increased the ability for the firm to respond to survey questions.

There were responses to the survey from all states of Australia and most regions of New Zealand. The leading area of response was Canterbury, which is recovering from a set of devastating earthquakes that has resulted in firms who normally operate outside the region establishing offices in the region. Auckland region of New Zealand and the SA and NT state, and VIC state of Australia were the next leading areas for survey responses. Each state of Australia or region of New Zealand, received 20 invites or 10 invites, for each the three disciplines respectively. There were different levels responses from each location for each discipline. New Zealand received almost three times the number of Architect responses then Australia and twice the number of Contractor responses, with Australia providing twice the number of Engineer responses. Australia's construction industry is experiencing tough economic time currently which could have lowered the response rate across the board. The variance in Engineer could be partly down to the research extent of their education. These tough economic conditions could be affecting all three of the disciplines in Australia, which highlights further the lack of response from New Zealand Engineers.

SMEs were also asked if they had previous used AGEMs, with 90% responding "Yes" to varying degrees. The results for previous use of AGEMs were used to split the participants.

The "Yes" respondents were given questions about both previously used AGEMs and AGEMs that are not used due to the related issues. With the "No" respondent only receiving questions about AGEMs the firm have not used due to related issues. Therefore all SMEs were asked to identify two AGEMs they had not used due to the related issues. There was a drop off in the rate of firms that 'rarely' used AGEMs answering the questions, from the questions for AGEMs they used to the AGEMs they haven't used. None of the SMEs that answered "No" to previous use of AGEMs answered questions about the issues preventing the firm from using AGEMs. This indicates that most firms use AGEMs to a certain extent, however it is the firms that regularly use AGEMs that consider using other AGEMs, which allows them to identify issues with AGEMs they have not yet used. The firms that are not using AGEMs or are 'rarely' using AGEMs are not actively considering using AGEM they have not yet used.

Available time is assumed to reduce the responses to the survey for both New Zealand and Australian SMEs. Tougher economic conditions in Australia are assumed to reduce the rate of Australian firms responding to the survey. Education differences is assumed to have promoted the responses from architects, and provided the difference in the levels between New Zealand and Australian Engineers. Increased firm size appears to increase the responses with members required to manage a smaller range of responsibilities as the size of the firm increases, this is assumed to increase the responses for Contractors.

5.2. SMEs issues with AGEMs

The research survey collected issues for SMEs with the use of AGEMs across three broad categories. General issues with AGEMs; issues for SMEs with the use of AGEMs commonly adopted by the firm; and issues for SMEs with the use of AGEMs not previous adopted by the firm.

5.2.1. General issues with AGEMs for SMEs

The SMEs that participated in the survey were asked to score a selection of issues on a sliding scale. “Strongly Disagree”, “Disagree”, “Neither Agree or Disagree”, “Agree”, and “Strongly Agree”. Each choice was assigned a corresponding score of 1-5, the results from the survey are shown in Figure 4-10, Section 4.3.1. With the top seven issues for AGEM in general found to be:

1. Experience,
2. Perception,
3. Cost of Material,
4. Standards or Codes,
5. Evaluation Methods,
6. Identification of alternatives, and
7. Material Properties.

The list of top seven issues with AGEMs in general compare with the issues for green materials discussed by Spiegel & Meadows (1999). The six of the seven, omitting "Identification of Alternatives", and including "Availability" appear in the results for used and unused AGEM when examined collectively and individually.

The issues are a collection of tangible and intangible issues. With tangible issues including "Cost of Materials", "Availability" and "Material Properties"; and intangible issues including "Experience", "Perception", "Standards or Codes" and "Evaluation Methods". Whether an AGEM's leading four issues are predominately tangible or intangible issues depending on if the AGEM has or has not been previously used by the SME considering the AGEM.

When considering the results for AGEMs in general, the leading four issues are predominately intangible issues. This indicates that when a firm is asked, what are your issues with AGEMs in general? They think of materials they have not used before and rank the issues with that level of uncertainty.

Experience is the leading issue for AGEMs in general. This measure of experience issue is not linked to any one AGEM, but AGEMs in general, e.g., SMEs have indicated that if any one particular AGEM was selected at random, and the firm was required to use the selected material, they feel that their experience with the material; or the lack of previous use of the material by the construction industry, would be their leading issue with the use of the AGEM. Experience is followed by perception as an issue with the SME with the use of AGEMs.

Perception is intangible as it attached to the idea of the material and what people think of the material. There is no way to measure or allow for perception; the issue includes the idea that AGEMs in general are not perceived as well as conventional materials. This idea of the way that the market perceives the material reduces SMEs desire to start to use an unfamiliar AGEM. As such it is also apparent that perception drops down the list of issues once a firm has used the material.

Cost of Materials ranks third as an issue for AGEMs in general. Cost of Materials is a tangible issue when dealing with individual materials, however in the case of AGEMs

in general it is possible that the Cost issue is related to a perception of AGEMs to be costly. There is a stigma that anything that helps the environment cost more (Spiegel & Meadows, 1999), which appears to be similar to the idea that is formed when imagining any advanced materials or collectively AGEMs in general.

Standards or Codes issues are related to the idea that a firm will have issues with the design complying with relevant standards, or providing evidence the material is sufficient for the desired purpose. When dealing with the idea of general AGEMs it is easy to see why firms rank this as an issue, if an AGEM was randomly selected for the firm to use, which is the assumption of firms' judgement of AGEMs in general, the firm has no idea beforehand whether the standards will cover the selected material.

General AGEM issues are predominantly intangible issues, which as is discuss below, aligns closely with issues experienced with unused AGEMs. The analysis of general AGEM assumes that, SMEs responses are for the issues perceived by the firm if it was required to use any AGEM that was selected at random. Issues with previously used AGEM discuss next and issues with previously unused AGEM following it examine the accumulation of issues for individual materials.

5.2.2. The issues with AGEMs previously adopted by SMEs

The SMEs that participated in the survey were split into firms that have used AGEMs in the past and those that have not. The SMEs that have used AGEMs were given questions about the three AGEMs most commonly used by the firm, included were questions about the issues related to the individual AGEMs. Figure 4-11, shows the cumulative issues for all AGEMs identified by SMEs as materials that are currently used by the firms. The leading four issues are:

1. Cost of Materials;
2. Material Properties;
3. Availability; and
4. Experience.

Issues with AGEMs previously adopted by the firm differ from the issues for AGEMs in general in two ways. Firstly they accumulation of issues that are tied to actual AGEM, not the first idea of AGEMs; Secondly, they tend to be predominately tangible issues.

The first point is important as, with the leading issues of "Cost of Materials" differs from "Cost of Materials" for AGEMs in general. The results for previously used AGEMs indicated that firms have used and paid for, or encouraged clients to pay for these materials, and then indicated cost provides the largest issue. This issue is tangible, the SMEs know that 'X' dollars would be easier to justify that the 'Y' dollars the material costs. Cost can also become an issue with AGEMs that gain in popularity. With the use of supply and demand curve below it is possible to see how cost issues can be related to increased popularity. Figure 5-1, below shows the original supply curve in dashed purple and demand curve in dashed blue. When a material increases in popularity the demand curve moves to the right (with all thing assumed to remain the same) to the dashed red line. The equilibrium cost will increase and there will be an increase in the volume demanded Q_1 to Q_2. There is now an increase in the number of firms that would have wanted to pay the old price, this results in the firms after Q_2 to Q_3 to miss out on the material and to experience an issue with the Cost of Material.

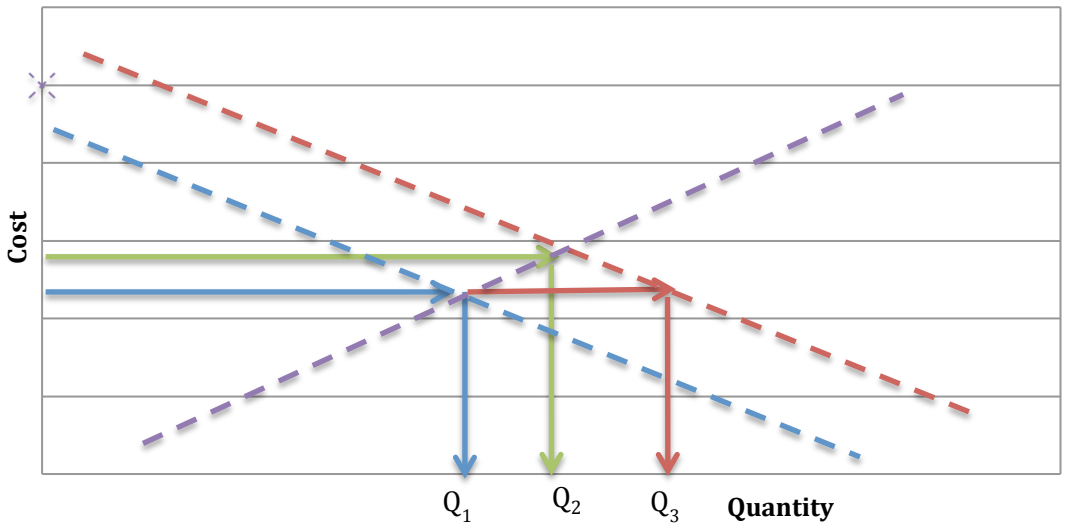


Figure 5-1: Supply vs Demand Curve

“Material Properties” is the second ranked issue with previously used AGEMs. It is a tangible issue, material properties are measurable and quantifiable generally, e.g., a high strength concrete beam will need to be certain dimensions to sustain certain loads, or may not be physically able to economically sustain the required loads. This allows for AGEM and conventional materials to be compared like for like, similar to apples with apples. AGEMs have either modified properties, to enhance strengths of mitigate weakness, or are greener than conventional materials. Material Properties may be an issue if the effectiveness of the material is relatively unproven, there may not be research to know how a material will perform in the long term. In saying that “Material Properties” should be the leading issue manufacturers of AGEM aim to achieve, if so that is to say that AGEMs are competing with convention materials by properties, rather that cost or intangible issues like “Standards or Codes”. This is an issues were AGEMs should have a competitive advantage over conventional materials.

“Availability” was the third ranked issue with previous used AGEMs. AGEMs tend to be a more specialised product with fewer manufacturers producing the material and therefore I assume that the AGEMs can suffer by not making their products as available to SMEs. SMEs tend to be working on smaller projects, they may not be able to justify ordering large enough quantities of materials directly for manufacturers, and may rely more heavily on the local building merchants for supplies. I believe that this issue would decrease as materials popularity increased and the manufacturers produce more and distribute to more locations.

“Experience” was the fourth major issues for AGEMs cumulatively. This issue differs from the three other leading issues due to the intangibility of the issue. This issue drops from the main issue for AGEMs in general, and as discussed below the main issue for unused AGEMs, either: due to lessons learnt from the use of the material in the past; the firm has obtained training or been educated in the use of the material; or the knowledge of the material in the industry has improved (as the construction industry relies heavily on the industries best practices and experience). With the decrease of Experience as the leading issue, as noted for AGEMs in general, there is a marked reduction with the other intangible issues, including “Standards or Codes”,

“Perception” and “Evaluation Methods”. These other intangible issues appear to be directly linked to the firm and industries “Experience” with an AGEM.

SMEs tended to be aware of the previously used AGEMs identified in the survey for equal to or greater than 5 years. This length of time could aid in the increase of Experience in the industry (reducing the issue with it). From increased experience there are the knock on effects of improvements to the other intangible issues, e.g., leading to further research updates of “Standards or Codes”, or identification of how to apply them for the given material; and improved “Perception” for the users of AGEMs. With the improvement of intangible issues, the tangible issues take their place. There is very little chance that issues will ever be completely removed, only replaced by more preferable ones.

The leading AGEMs all received high scores for indication of continued use in the future, by the SMEs that have previously used the materials. It was found with the leading six AGEMs, once a firm has taken the chance and used a material, very little are indicating they would not do so again in the future.

Location of respondents for leading AGEMs previously used requires more responses for each material to develop a better picture of preferences by location. The leading two AGEMs identified received responses from majority of locations that actively answered questions about the leading AGEM. This could use further research to establish if trends exist.

Intangible issues tend to decrease with the use of an AGEM and the length of time SMEs are aware of potential replacements for conventional materials. With time and use throughout the industry firms become aware of the material, the industry and members of SME who have used in the past and develop a better understanding of the advantages and disadvantages, how it will comply with building legislative requirements, and how the community will react to the material. The decrease in intangible issues appears to increased use, and possibly increase popularity. It appears to be an almost perpetual cycle, increase in use decreases intangible issues, and decrease in intangible issues increases use, the uptake is limited by the increase of tangible issues. The results of increased use can lead to greater demand and an

increase of tangible issues, e.g., “Cost of Material” increases with demand shifts until it is a leading issue for the material. Demand increase can also lead to firms finding issues with availability. Positive outcome is the increase of the issue with “Material Properties” as this indicates that the material is measured up by what it can do, against conventional materials.

5.2.3. The issues with AGEMs not previously adopted by SMEs

The SMEs that participated in the survey were split into firms that have used AGEMs in the past and those that have not. All participants were asked questions about two AGEMs that have not been used by the firm due to issues with the material, included were questions about the particular issues preventing the use of these AGEMs. Figure 4-11, shows the issues for all AGEMs identified by SMEs as materials not previously used by the firm. The leading four issues are:

1. Experience;
2. Standards or Codes;
3. Evaluation Methods; and
4. Cost of Materials.

Though all participants were given questions about the AGEMs the firm have not used due to the related issues with the material, there was a drop off in responses for firms that “rarely” use AGEMs and no responses from firms that indicated “No” to ‘Has the firm previously used AGEMs?’

“Experience” was the leading issue for previously unused AGEMs. This is an intangible issue; which is also the leading issue for AGEMs in general, and in the top four for previously used AGEMs. SMEs are indicating that either the firms personal or the industry does not feel that they know enough about the material; their lack of experience through previous use of examples of successful use is the leading obstacle. “Experience” is a difficult issue to deal with, as firms are reluctant to use a material without previous experience with it; and without firms using the material or being educated in the advantages and disadvantages, there is no improvement to the level of “Experience” either in the firm or the industry.

“Standards or Codes” is an intangible issue with the firm’s knowledge of how the AGEM fits with existing Standards or Codes. “Standards or Codes” appears to be an issue due to either; the perceived of effort for an SME to demonstrate compliance with regulations, or a lack of adequate coverage for some AGEMs with the current standards or codes. Standards or Codes appears to be a greater issue for unused AGEMs for which SMEs tend to be aware of for less than 5 years, than the used AGEMs for which SMEs tended to indicate awareness of greater than 5 years. There would need to be further research to identify if the time lapse provides time for the standards and code to be amended or if the SMEs identify ways for the AGEMs to comply with the existing standards and codes.

“Evaluation Method” is an intangible issue for AGEMs. The participants were asked to comment on their evaluation methods used to evaluate alternative materials, Section 4.2. The methods commonly stated included but not limited to: researching the material to improve expertise; using Google’s search engine for information on the material; discussing with contacts in the firms network; and some not even evaluating alternative materials. There is no set method for the evaluation, and issue with it appears to be an indication of how effective firms feel their evaluation methods are at identifying the best materials for each situation.

“Cost of Materials” is the fourth ranked issue for unused AGEMs. Along with “Experience” is one of the leading issues indicated for both used and unused AGEMs. “Cost of Materials” is generally a tangible issue, however like mentioned in the general issues I believe this could be, for at least some participants, an intangible issue when considering unused AGEMs. Where they have not conducted a thorough enough investigation to establish the cost compared to using alternative materials, e.g., for the use of High Strength Concrete, which may cost more per cubic metre, the volume of material saved using it may not be considered in the cost calculations (further research is required to prove this). The argument may be that the extra cost in designing a material is thought to balance out the inclusion of saving in the cost calculations.

There was not the same volume of responses for each unused AGEMs as for the used counterparts, though there was a similar number overall for used and unused. Figure 4-21 compared the duration of awareness firm indicated for the leading used and unused AGEMs. There is a difference in the length of time firms have been aware of AGEMs and whether they are used. Unused AGEMs indicated 80% of responses were less than 5 years. I believe the length of awareness of a material has a marked effect on the intangible issues with AGEMs. This has been touched on with discussion of "Standards or Codes" issue above.

Indication of uptake, there were less responses for each of the unused than used AGEMs. It is easy for firms to consider but not use any number of AGEMs. The results showed that most materials would be considered for use if the identifies issues are addressed. The two earthen materials were the only materials of the six AGEMs examined individually to have expressions of "Will not use in the future, even is issues are addressed". These materials have been around for centuries this clarifies that the length of awareness is a major factor for modern AGEMs.

Location of respondents for leading AGEMs previously unused requires more responses for each material to develop a better picture of preferences by location. This could use further research to establish if trends exist.

Unused AGEMs is affected predominately by intangible issues, and the length of awareness in the materials. "Experience" was the leading issue, which appears to affect all the other intangible issues and should be targeted for improvement to make the greatest difference in the uptake of unused AGEMs.

5.2.4. Comparison of the issues identified across categories

The survey collected issues for AGEMs across three categories of familiarity: AGEMs in general; AGEMs previously used by SMEs; and AGEMs not previously used by SMEs due to the issues related to the material. Each category has been discussed in the sections above. The four leading issues expressed in each of the three categories of AGEM issues are shown in Table 5-1. There are six issues which reoccur across the different categories; with a seventh, "Perception", top four in

general and failing just outside the top four in the used and unused categories. AGEMs will always have issues, as people are very rarely completely satisfied, the idea is to correct the issues that imped use of materials. Thus leaving issues where AGEMs can compete equally with conventional materials.

Table 5-1 Comparison of issue for familiarity categories

General AGEM Issues	Unused AGEM Issues	Used AGEM Issues
• Experience; • Perception; • Cost of material; and • Standards or Codes.	• Experience; • Standards or Codes; • Evaluation methods; • Cost of material.	• Cost of material; • Material Properties; • Availability; • Experience.

"Experience" and "Cost of Materials" is common to all three categories regardless of familiarity (used, unused or general). The difference between the categories is apparent with the ranking of these two issues. The 'general' and 'not previous adopted' categories rank "Experience" as the leading issue; the firm has not gain the experience from previous use of the material and is relying on industries examples, which may also be light or non-existent. SMEs tend to rank Cost of Material as the leading issue for 'previous adopted' AGEMs. "Cost of Material" appears to increase as an issue with the increased use or popularity of an AGEM.

"Perception" is linked to the idea of the material, whether it is thought of as a 'good', 'bad', 'clean', 'junk', etc. This issue was one of the leading four issues for AGEMs in general and ranked highly, though below the top four, for used and unused AGEMS.

"Standards or Codes" issues are common to 'general' and 'not previously adopted (unused)' categories. This issue tends to be more prevalent when there is a lack of perceived "Experience" with a material. The issue appears to be linked to either: an actual lack in the research or currentness of "Standards or Codes" to cover the material adequately; or due to SMEs lack of experience using the material, which could help the firm understand how well the current "Standards or Codes" apply to the material. This issue is considered to be intangible.

“Material Properties” appears in the extended list of general and unused materials issues, and as a top four issue for used AGEMs. This appears to be the best issue for an AGEM, one that manufacturers should be striving for. For Material properties to be a leading issue SMEs have dispelled a number of the intangible issues, and it indicates that the AGEMs are competing against conventional materials by their properties, rather that firms ideas of the material. AGEM are created with the material properties in mind, either to improve strength and mitigate weakness, or to provide a greener alternative to conventional. Material Properties was evident for the majority of the individual AGEMs previously used, Figure 4-13, though only two of the individual unused AGEMs, Figure 4-14. Some materials will never be suitable for some situations, e.g., you won’t use conventional timber for flooring where vibrations will be an issue. A material that is ruled out by “Material Properties” is generally in the toolbox of materials a firm will call on to complete projects.

“Evaluation Methods” make the top four for unused AGEMs solely. It is an intangible issue for materials. Table 4-3, contains responses about how firms evaluate materials, there is little consistency. There is a reduction in the issue with use of the material, indicating that use (or gaining experience) is the best way to reduce the issue with evaluation of materials. This agrees with idea of “Experience” as the leading issue to target to reduce intangible issues.

“Availability” is an issue typically identified with previously used AGEMs. SMEs are indicating that they want to use the material and the ability to source it is an issue for them. Though this issue ranked as a leading issue for the cumulative used AGEM issues, it is more prevalent for the six unused individual AGEMs. This issue tends to increase with the decrease of intangible issues. It can increase as an issue with the increase of use of popularity of a material, before manufacturers manage to increase production to satisfy the demand.

“Experience” and “Cost of Material” issues tend to identify if a material will be faced with predominantly intangible or tangible issues. “Experience” issues appear to be linked to all the intangible issues. With an increase in the firms’ perceived experience there are decreases in the leading issues that appear to prevent uptake of AGEMs:

"Experience", "Standards & Codes", "Evaluation Methods" and "Perception". The other side of increasing experience, and decreasing the "Experience" and other intangible issues, is the increase of tangible issues. There is never a time when someone does not want the current situation improved: if it's free, its not strong enough; if its invincible, there is too much demand and you can not get enough, etc. "Cost of Materials", as well as other tangible issues, increase to replace "Experience" and the other intangible issues that are reduced with it. It if believed that this is because the increased use will push the demand curve to the right (assuming supply is held constant), increasing the price some firms are willing to pay, and in some case this increase is above the amount current users are willing to pay. With the increased demand there is a decrease in readily available materials. Manufactures then are required to increase supply to prevent competitors entering the market. Increases in demand and supply lead to "Material Properties" limiting further increase in use of a material, when the material is used in all instances where it is best suited. This is why "Material Properties" is possible the best issue for AGEMs. There are issues for materials that do not follow the nice progression, e.g., "Standards or Codes" could specifically restrict the use of the material; the material might be developed in such a way that there is no means to improve "Perception"; limits on natural resource crucial to the development may be controlled by a few entities, creating monologies or oligopolies, which may prevent the increases in supply to elevate "Cost of Material" issues; etc.

5.3. Responses for individual AGEMs

Each participating SME was asked questions about two to five AGEMs. The firms that indicated previous use of AGEMs were given questions about the three most commonly used AGEMs, and two AGEMs not used by the firm due to the perceived issues with their use. Whereas the SMEs indicating "No" previous use of AGEMs were directed to only the latter questions about two AGEMs not used.

The materials that have been evaluated individually were the materials identified in the survey with at least 10% of the participants indicating either previous use of the material, or reluctance to use the material due to the issues perceived by the firm with

their use. Table 5-2, contains the list of materials examined individual. Rammed Earth was the only material that appeared on both lists and will be discussed further below.

Table 5-2: List of individually examined AGEMs

Used AGEMs	Unused AGEMs
(a) LVL	(a) Post-Tensioned Timber
(b) Glulam	(b) Cement Replacement Materials
(c) Rammed Earth	(c) Cob
(d) High Strength Concrete	(d) CLT
(e) Lightweight Concrete	(e) DSCC
(f) Adobe Brick	(f) Rammed Earth

The volume of responses for each of the materials is insufficient to develop trends that can be examined for each material individually. Table 4-4 and Table 4-5, contain the list of common issues for the individual AGEMs, there is a trend that with increasing number of responses there was an increasing number of issues indicated. The materials in, Table 4-4, received a differing number of responses for each material and an increasing number of issues with volume of responses. Whereas, the materials listed in, Table 4-5, received only three to four responses for each material, just above the minimum to be examined, with a relatively constant number of issues identified for each individual material.

The leading issues for the individually assessed AGEMs tended to follow what was identified from the cumulative. With tangible issues predominant for the previously used AGEMs, and intangible issues predominant for the previously unused AGEMs. The only difference was the inclusion of "Availability" as a top four issue for unused AGEMs, pushing the previously ranked 3rd and 4th issues down a spot. Rammed Earth was the only material that appeared on both lists. Due to this we can compare the responses from SMEs that use Rammed Earth, and those that have yet to due to the

issues they perceive with the material. Table 5-3, below contains the percentage each issue received, the difference between the used and unused responses, and whether the issue is assumed to be tangible or intangible. Due to the volume of responses we will ignore the issues that received 0% for either used or unused, e.g., "Material Properties" since it received 0% for unused responses. That leaves the top three issues, "Cost of Materials", "Experience" and "Standards or Codes". Throughout the discussion above we have proposed that Tangible issues increase with use, and decreases in Intangible issues increase use (decrease "Experience" issues particularly). The results for Rammed Earth showed increase in tangible issues and decrease in intangible, as expected. As standards or codes for Rammed Earth have not changed recently, we can also link the decrease of "Standards or Codes" issues to increase in experience, rather than research and development.

Table 5-3: Issues with Rammed Earth, unused vs used responses

Issue	Unused	Used	Δ	Tangible/Intangible
Cost of Material	22%	25%	+3%	Tangible
Experience	29%	25%	-4%	Intangible
Standards or Codes	14%	12%	-2%	Intangible
Material Properties	0%	13%	+13%	Tangible
Availability	14%	0%	-14%	Tangible
Evaluation Methods	0%	12%	+12%	Intangible
Perception	0	13%	+13%	Intangible
Other	21%	0%	-21%	NA

The Architect discipline, which provided 50% of the total responses, provided greater than their survey percentage share for each of the individual materials, e.g., 83% of responses for LVL came from Architects; this could have been attributed to Architects preferring one material over the other disciplines, however they were the leading respondents for all the material examined individually except Cob. The Contractor

discipline provided near to similar levels of responses to their overall survey participation for majority of the individual materials, indicating that they tended to answer all the questions. The Engineer discipline responses to the leading materials was far lower than they survey participation levels, indicating they skipped questions about individual materials, or used AGEM and had issues with different AGEMs than Architects and Contractors.

Further results could also help to indicate where firm size affected the material selection. From the results only LVL and Glulam show signs to firm size affecting material selection. LVL appears to be used by smaller firms, with a decreasing volume of responses with increase in firm size. Glulam appears to be used by a cross section of firm sizes, and one of the few individual materials receiving responses from the larger SMEs. Glulam received an almost 'bathtub' shaped graph, with high number of small SME then dropping off and gaining in number again at the larger end of the spectrum. The unused AGEMs firm size data has too few responses to represent anything of any interest.

The awareness length, as discussed in previous sections, indicated that the materials that are previously used by SMEs tended to be materials, which the firms have awareness of for greater of 5 years. Unused AGEMs helped to confirm this observation with 80% receiving indication of awareness from the participants of less than 5 years. There were a very low percentage of responses indicating between 2 and 3 years for either used of unused AGEMs.

Similar to Firm Size for used and unused AGEMs, likelihood of future use, and location results is lacking the volume of responses for each material to accurately develop trends. SMEs response to likelihood of using AGEMs in the future found that majority of used AGEMs would continue to be used; whereas there was indication that some of the unused AGEMs would not be adopted in the future, even if the identified issues were addressed. The materials that received "Will not use…" responses tended to be the earthen materials. The location of responses aim was to identify if there are any areas of New Zealand or Australia where a material is prevalent. The results for LVL and Glulam (which received the largest number of

responses), responses indicated use in all the areas that responded to questions about individual AGEMs. Northern areas of the South Island, New Zealand, were the leading users of LVL; and Auckland, New Zealand, received the highest volume of responses for Glulam. Far more responses would be required for each material before any trends could be developed or relied on.

All aspects of the individually examined AGEMs would benefit from greater volume of responses. Firm Size, Likelihood of future use, and Location results require more responses to develop trends. However Issues with AGEMs, and Length of Awareness appears to display trends with the volume of responses received. The issues for individual AGEMs tended to match the cumulative results in the section previous, with the addition of "Availability" issue for the unused AGEMs. Rammed Earth provided results for a single material that was in lists for both six used and unused examined individually, and the results tended to agree with statements that tangible issues tend to increase with use, and intangible issues tend to decrease. Also that some of the intangible issues are linked with "Experience", with decreases in "Standards or Codes" issues without further development of the standards or codes. Length of SMEs awareness of an AGEM tends to affect the use of the material, with 5 years of awareness appearing to be the divide between used and unused materials.

5.4. Summary

Available time is assumed to reduce responses to the survey for both New Zealand and Australian SMEs. Tougher economic conditions in Australia are assumed to reduce the rate of Australian firms responding to the survey. Education differences is assumed to have promoted the responses from architects, and provided the difference in the volume of responses between New Zealand and Australian Engineers. Increased firm size appears to increase the responses with members required to manage a smaller range of responsibilities as the size of the firm increases, this is assumed to increase the responses for Contractors.

"Experience" or "Cost of Material" as the leading issue tend to identify if a material will be faced with predominantly intangible or tangible issues. "Experience" issues appear to be linked to all the intangible issues. With an increase in the firms'

perceived experience there are decreases in the leading issues that appear to prevent uptake of AGEMs: “Experience”, “Standards & Codes”, “Evaluation Methods” and “Perception”. The other side of increasing a firms’ experience, and decreasing the “Experience” issue, and other intangible issues, is the increase of tangible issues. There is never a time when someone does not want the current situation improved: if it’s free, it’s not strong enough; if it’s invincible, there is too much demand and you can not get enough, etc. “Cost of Materials”, as well as other tangible issues, increase to replace “Experience” and the other intangible issues that are reduced with it. This could be due to the increased use will push the demand curve to the right (assuming supply is held constant), increasing the price some firms are willing to pay, and in some cases this increase is above the amount current users are willing to pay. With the increased demand there is a decrease in readily available materials. Manufactures then are required to increase supply to prevent competitors entering the market. Increases in demand and supply lead to “Material Properties” limiting further increases in use of a material, when the material is used in all instances were it is best suited. This is why “Material Properties” could be the ‘best’ issue for AGEMs. There are issues for materials that do not follow the nice progression, e.g., “Standards or Codes” could specifically restrict the use of the material; the material might be developed in such a way that there is no means to improve “Perception”; limits on natural resource crucial to the development may be controlled by a few entities, creating monologies or oligopolies, which may prevent the increases in supply to elevate “Cost of Material” issues; etc.

All aspects of the individually examined AGEMs would benefit from greater volume of responses. Firm Size, Likelihood of future use, and Location results require more responses to develop trends. However Issues with AGEMs, and Length of Awareness appears to display trends with the volume of responses received. The issues for individual AGEMs tended to match the cumulative results in the section previous, with the addition of “Availability” issue for the unused AGEMs. Rammed Earth provided results for a single material that was in lists for both six used and unused examined individually, and the results tended to agree with statements that tangible issues tend to increase with use, and intangible issues tend to decrease. Also that some of the intangible issues are linked with “Experience”, e.g., decreases in “Standards or

Codes" issues without further development of the standards or codes. Length of SMEs awareness of an AGEM tends to affect the use of the material, with 5 years of awareness appearing to be the divide between used and unused materials.

CHAPTER 6 - CONCLUSIONS

The research was set out to identify the leading issues for SMEs with the use of AGEMs, and evaluate issue with the hope of finding the leading issue for the uptake of AGEMs by SMEs. The aim of identifying and evaluating issues is so manufacturers of AGEMs can concentrate on improving the issues that pose the greatest restriction to the use of AGEMs by SMEs. The study also hoped to examine five individual AGEMs in further depth. The research sought to answer these questions:

1. What are the leading issue for SMEs with the use of AGEMs?
2. Do the issues change depending on whether the material has been used previously by the firm, or are some issues preventing the use of AGEMs?
3. How did five individual AGEMs compare to the leading issues.

The main empirical findings are discussed in Chapter 5 - Sections 5.1, 5.2, 5.3 and 5.4. This section will collate the findings to answers for the research questions.

1. What are the leading issue for SMEs with the use of AGEMs?

a. Experience: This tends to be the leading issue for unused AGEMs, and commonly indicated in the top four across all categories (used, unused and general issues). Experience is an intangible issue. This issue is linked to either the firm or industries previous use, or lack of use of a material; and the knowledge of how to use a particular material.

b. Cost of Material: This issue tends to be the leading issue for previously used AGEMs, and commonly indicated in the top four across all categories (used, unused and general issues). Cost of Material is a tangible issue. This issue tends to increase with use, possibly due to increase of cost attributed to increase in demand without increase in supply.

c. Standards or Codes: This issue is more prevalent for general issues with AGEMs and for previously unused materials. This is an intangible issue that appears to be linked with “Experience”. Standards or Codes appears to be an issue either due to inadequate coverage in the standards or codes, or due to lack of experience in

applying the current standards or codes to the materials. As such this issue can decrease with decreases in "Experience" issues.

d. **Availability:** This issue appears to be a top four issue for the cumulative results of previously used AGEMs, though it also appears in the individually examined previously unused AGEMs. This issue is considered a tangible issue, potentially linked to "Cost of Materials" and "Experience". With decrease in "Experience" issue and the accompanying increase in use, supply does not necessarily have a chance to meet the increased demand. This appears to increase the "Availability" issue and push cost of material up.

e. **Material Properties:** This issue appears as a top four issue with previously used AGEMs, also as a leading issue with some individually examined AGEMs. This issue is considered a tangible issue, linked to "Experience" and demand. Material Properties appears to be an issue for either lack experience with how the material can perform, or by not being the right material for the job. Though it is believed that the second issue, and potentially this issue in general, is a good issue. For an AGEM to receive "Material Properties" as an issue it is either inherently not for the job required or has measured up against conventional materials on all other issues and for the particular use it is not considered as proficient as another material. This appears to be an indicator issue that the industry has a good grasp on how to use the material.

f. **Evaluation Methods:** This issue appears as a top for issue with previously unused AGEMs. This is considered an intangible issue, linked with "Experience". The survey found that there were a varying number of ways that firms evaluated materials; discussion with peers was a common practise. It is believe that this issue dissipates with an increase in the firm's networks experience with the material, or through use of the material by the firm it's self.

g. **Perception:** This issue is the only issue that ranked top four with AGEMs in general and not with either the previously used or unused AGEMs. This issue is an intangible issue. Perception ranks highly for the idea of AGEMs, rather than for a material in particular. This issue appears to drop down the list when individual AGEMs are examined.

2. **Do the issues change depending on whether the material has been used previously by the firm, or are some issues preventing the use of AGEMs?**

The ranking of each issue tended to vary for each material, however there was a general trend that: SMEs indicated intangible issues, as the leading issues for AGEMs previously unused by the firm; and SMEs indicated tangible issues as the leading issues with AGEMs the firm has previously used.

a. **Intangible Issues:** Include issues that are hard to measure: "Experience", "Standards or Codes", "Evaluation Methods" and "Perception". These issues are an idea more than a direct measure. All AGEMs tended to have intangible issues, however whether they where a leading issue or more of a background issue tended to depend on whether the SME indicating the issue had previously used the material before. A lot of the intangible issues appear to be linked to "Experience", changes in experience only could result with changes in other intangible issues. Intangible issues appeared to be linked with the demand of a material, with decreases in intangible issues there appear to be increase in use.
b. **Tangible Issues:** Include issues that are measureable: "Cost of Materials", "Availability" and "Material Properties". Similar to the intangible issues, all AGEMs indicated tangible issues, and the ranking of the issue depended on whether the SME indicating the issue had previously used the AGEM or not. "Cost of Material" was a included in the top four issues for each category. With an increase in demand or decrease in experience issues, the cost of materials appears to be the first issue to replace the intangible issues. With economics dictating whether "Availability" or "Material Properties" rise in prominence.
c. **Length of Awareness:** There was also a distinct difference in the length of awareness SMEs indicated for previously used and unused AGEMs. The switch for predominately used or unused AGEMs appears to be with an awareness length of 5 years.

3. How did five individual AGEMs compare to the leading issues?

To establishing a criteria to select AGEMs for individual examination, that encapsulated at least five AGEMs from the survey required a minimum of three participants indicating the AGEMs to be previously used or unused. Using three or 10% of participants resulted in the inclusion of six AGEMs from both the used and unused results. Eleven AGEMs in total, as Rammed Earth was indicated on both lists. The low level of responses prevented a few trend to be developed, though there was sufficient information on the issues for comparison with the cumulative AGEMs issues examined.

There was no literature into the issues for SMEs with AGEMs discovered in the process of this research. Spiegel & Meadows (1999) indicated the issues that firm can experience with Green Materials. The research found similar issues to the work of Spiegel & Meadows, though went further to identify which issues are the most commonly experienced, and to proposed the balance of intangible and tangible issues. "Experience" appears to the leading issue restricting the use of AGEMs by SMEs, developing methods to increase SMEs experience though education, and other means, could lead to increase in use by SMEs. The issue with the firm and industries "Experience" appears to affect the majority of intangible issues (issues that appear to limit the uptake of AGEMs). If Manufacturers plan to implement processed to decrease the "Experience" issues for SMEs, they should consider means of increasing supply to: protect from new entrances; and reduce "Availability" and "Cost of Material" issues which tend to increase with a decrease in "Experience" related issues.

Introducing programmes to increase SMEs experience, through education or other means, could lead to not only increased demand for AGEMs but also earlier use of AGEMs. Currently AGEMs appear to be embraced to a greater degree after 5 years. By reducing this length of awareness prior to use, developers of AGEMs could see cash flow far earlier. Using the principles of time value of Money, a dollar today is worth more than a dollar tomorrow. Developers and Manufacturers gain more financially the earlier there is a uptake of the materials they are producing.

The following limitations have been identified for the research:

- Choice of AGEMs to respond to in the survey limited the trend that could be developed for individual materials. - a small number of responses for a large cross section of materials;
- The selection of material provided to choice from, may have restricted the AGEMs indicated by SMEs;
- Inviting equal number of firms from each discipline type, rather that based on the share of the industry, gave the Architect discipline (the smallest section of the industry) the ability to achieve the largest response rate, potentially introducing a basis;
- Volume of responses limited the depth of some analysis. For example, further participants could allow for analysis by country, or area;
- The survey does not have any way of confirming the responses are those expressed by the firm, or the personal issues of the employee responding;
- The survey did not collect the reason for each issue with AGEMs;
- Some participants completed less of the survey than others, an increased the number of compulsory questions may have increased or decreased the survey completeness; and
- The survey method prevented explanation of questions, or expansion of replies, to gain more in depth knowledge.

The future works that could be examined to further explore ideas for this research include the following:

- Widen survey reach
- Identify the benefits of educating SME in the benefits of AGEM
- Identify means of increasing SME Experience
- Investigate whether enough is done to keep Standards or Codes up to date with development of AGEMs
- Development of evaluation methods for AGEMs
- Collaboration with SMEs and manufacturers to identify ways of reducing the issues with AGEMs

The issues for SMEs with the use of AGEMs, differs for each material and each firm. There leading issues include: “Experience”, “Cost of Materials”, “Standards or Codes”, “Availability”, “Material Properties”, “Evaluation Methods” and “Perception”. The assortment of issues tended to depend on whether SMEs had used an AGEM before or not, with intangible issues decreasing and tangible issues increasing with use. Experience appears to be the leading issue to restrict the uptake of AGEMs and should be the first issue Manufactures consider correcting. Which could reduce the length of awareness time prior to use of AGEMs and decrease a number of other intangible issues. The examination of individual AGEMs agreed with the cumulative picture of issues with AGEMs and would require further research for more in depth analysis.

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APPENDIX A

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: **Christopher John Brockway WRIGHT**

TOPIC: EVALUATION OF ISSUES FOR SMALL AND MEDIUM-SIZED ENTERPRISES IN THE USE OF ADVANCED AND GREEN ENGINEERING MATERIALS

SUPERVISOR: Dr. David Thorpe

PROJECT AIM: Determine the major issues affecting the use of advance and green engineering materials by small and medium enterprises

PROGRAMME: **(Issue D, 29 July 2014)**

1. From literature, identify a range of advanced and green engineering materials.
2. From literature, identify issues in the use of advanced and green engineering materials.
3. Produce a survey for SME engineering design and construction firms regarding their perceived issues in the use of the selected five advanced and green materials.
4. Gain approval of the survey from the University of Southern Queensland's Ethical Committee.
5. Form a list of email and phone contact details for a statistically valid sample of SME's.
6. Administer the survey to the identified SME's.
7. Follow up with slow respondents to the survey if required.
8. Select up to five suitable materials for further investigation.
9. Evaluate the responses to the survey and develop conclusions.

AGREED:

 (Student)

29 / 07 / 2014

APPENDIX B

University of Southern Queensland

The University of Southern Queensland

Participant Information Sheet

HREC Approval Number: H14REA134

Full Project Title: EVALUATION OF ISSUES FOR SMALL AND MEDIUM-SIZED ENTERPRISES IN THE USE OF ADVANCED AND GREEN ENGINEERING MATERIALS

Principal Researcher: Christopher J. B. Wright

I would like to invite you to take part in this research project.

This research is to evaluate issues for Small and Medium Enterprise's (SME) in the use of advanced and green engineering materials. The research, design and innovation involved in creating advanced and green materials can take sizable resources and investment to develop. SME's play a large part in the construction market and therefore their adoption of new materials can be crucial to the success of advanced and green engineering material products.

Objectives

- To undertake a survey of SME's to identify their perceived issues in the use of advanced and green engineering materials.
- To evaluate the issues for SME's in the use of advanced and green engineering materials.
- To provide a comprehensive list of the main findings so that manufacturers can improve their marketing, communication and delivery of advanced and green material products.

1. Procedures

Participation in this project will involve

- ***The survey is an anonymous survey, conducted using Survey Monkey, which is expected to take approximately 15 minutes to complete.***
- ***The completion of the survey will be seen as giving consent to the use of the surveyed material.***
- ***The information submitted will be received in real time and monitored by the Principal Researcher.***
- ***The desired benefits of this research is to find issues SME's experience with using advanced and green engineering materials, information of issues is hoped to help identify ways to elevate issues with use of advanced and green engineering materials.***
- ***There have been no risks identified with the Research.***

2. Voluntary Participation

Participation is entirely voluntary. **If you do not wish to take part you are not obliged to.** The survey is anonymous, therefore once the survey has been completed it is impossible to identify the participant or the information provided by the participant.

Your decision whether to take part or not to take part, will not affect your relationship with the University of Southern Queensland.

Should you have any queries regarding the progress or conduct of this research, you can contact the principal researcher:

Christopher J. B. Wright
Bachelor of Engineering with Honours in Civil Engineering Student, Faculty of Engineering and Surveying.
Ph: +64 21 819 444
Email: u1035949@umail.usq.edu.au

If you have any ethical concerns with how the research is being conducted or any queries about your rights as a participant please feel free to contact the University of Southern Queensland Ethics Officer on the following details.

Ethics and Research Integrity Officer
Office of Research and Higher Degrees
University of Southern Queensland
West Street, Toowoomba 4350
Ph: +61 7 4631 2690
Email: ethics@usq.edu.au

Engineering Honours Project - Evaluation of issue for small and medium-

Welcome to My Survey

University of Southern Queensland

The University of Southern Queensland
Participant Information Sheet

HREC Approval Number:
Full Project Title: EVALUATION OF ISSUES FOR SMALL AND MEDIUM-SIZED ENTERPRISES IN THE USE OF ADVANCED AND GREEN ENGINEERING MATERIALS
Principal Researcher: Christopher J. B. Wright

I would like to invite you to take part in this research project.

1. Procedures Participation in this project will involve
• The survey is an anonymous survey, conducted using Survey Monkey, which is expected to take approximately 15 minutes to complete.
• The completion of the survey will be seen as giving consent to the use of the surveyed material.
• The information submitted will be received in real time and monitored by the Principal Researcher.
• The desired benefits of this research is to find issues SME's experience with using advanced and green engineering materials, information of issues is hoped to help identify ways to elevate issues with use of advanced and green engineering materials.
• There have been no risks identified with the Research.

2. Voluntary Participation
Participation is entirely voluntary. **If you do not wish to take part you are not obliged to.** The survey is anonymous, therefore once the survey has been completed it is impossible to identify the participant or the information provided by the participant.

Your decision whether to take part or not to take part, will not affect your relationship with the University of Southern Queensland.

Should you have any queries regarding the progress or conduct of this research, you can contact the principal researcher:

Christopher J. B. Wright
Bachelor of Engineering with Honours in Civil Engineering Student, Faculty of Engineering and Surveying.
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Engineering Honours Project - Evaluation of issue for small and medium-

Firm Information

***Type of firm?**

- [ ] Architect
- [ ] Engineer
- [ ] Contractor

***How many staff are employed by the firm?**

***What area(s) of the construction industry does the firm operate?**

- [ ] Residential
- [ ] Commerical
- [ ] Industrial
- [ ] Health
- [ ] Social
- [ ] Educational
- [ ] Rural
- [ ] Other (please specify)

Engineering Honours Project - Evaluation of issue for small and medium-

*Which regions/states of New Zealand or Australia does the firm operate?

- [ ] Northland Region
- [ ] Auckland Region
- [ ] Waikato Region
- [ ] Bay of Plenty Region
- [ ] Gisborne Region
- [ ] Hawke's Bay Region
- [ ] Manawatu-Wanganui Region
- [ ] Taranaki Region
- [ ] Wellington Region
- [ ] Tasman Region
- [ ] Nelson Region
- [ ] Marlborough Region
- [ ] West Coast Region
- [ ] Canterbury Region
- [ ] Otargo Region
- [ ] Southland Region
- [ ] Australian Capital Territory, New South Wales
- [ ] Victoria
- [ ] Queensland
- [ ] South Australia, Northern Territory
- [ ] Western Australia
- [ ] Tasmania
- [ ] Other (please specify)

*Has the firm used advanced and green engineering materials?

Engineering Honours Project - Evaluation of issue for small and medium-

Advanced and Green Engineering Material #1

To get a feel of the materials used in the past by the firm, the issues experienced and location of use, we have five identical pages of questions about advance and/or green engineering meterials. There are three pages for most used materials and two pages for materials not used (due to issues) by the firm.

Most used advanced and/or green engineering material.

***What is the most commonly used advanced and/or green engineering material by the firm?**

(The list of options provided is no way exhaustive, the use of "Other" is invited where applicable)

***Where does the firm typically use the material?**

- [ ] Roof
- [ ] Walls
- [ ] Floors
- [ ] Foundations
- [ ] Entrance/Driveways
- [ ] Fences
- [ ] Other (please specify)

***How long has the firm been using the material?**

Has the material benefited the firm?

and how?

Engineering Honours Project - Evaluation of issue for small and medium-

What is the most prevelent issue for the firm in the use of this material? (what could be improved to enhance the use of the material by the firm)

What is the second most prevelent issue for the firm in the use of this material? (what could be improved to enhance the use of the material by the firm)

***Is it likely the firm will continue using the material in the future?**

Engineering Honours Project - Evaluation of issue for small and medium-

Advanced and Green Engineering Material #2

To get a feel of the materials used in the past by the firm, the issues experienced and location of use, we have five identical pages of questions about advance and/or green engineering meterials. There are three pages for most used materials and two pages for materials not used (due to issues) by the firm.

Second most used advanced and/or green engineering material.

What is the second most commonly used advanced and/or green engineering material by the firm?

(The list of options provided is no way exhaustive, the use of "Other" is invited where applicable)

Where does the firm typically use the material?

- [ ] Roof
- [ ] Walls
- [ ] Floors
- [ ] Foundations
- [ ] Entrance/Driveways
- [ ] Fences
- [ ] Other (please specify)

How long has the firm been using the material?

Has the material benefited the firm?

and how?

What is the most prevelent issue for the firm in the use of this material? (what could be improved to enhance the use of the material by the firm)

What is the second most prevelent issue for the firm in the use of this material? (what could be improved to enhance the use of the material by the firm)

Is it likely the firm will continue using the material in the future?

Engineering Honours Project - Evaluation of issue for small and medium-

Advanced and Green Engineering Material #3

To get a feel of the materials used in the past by the firm, the issues experienced and location of use, we have five identical pages of questions about advance and/or green engineering meterials. There are three pages for most used materials and two pages for materials not used (due to issues) by the firm.

Third most used advanced and/or green engineering material.

What is the third most commonly used advanced and/or green engineering material by the firm?

(The list of options provided is no way exhaustive, the use of "Other" is invited where applicable)

Where does the firm typically use the material?

- [ ] Roof
- [ ] Walls
- [ ] Floors
- [ ] Foundations
- [ ] Entrance/Driveways
- [ ] Fences
- [ ] Other (please specify)

How long has the firm been using the material?

Has the material benefited the firm?

and how?

Engineering Honours Project - Evaluation of issue for small and medium-

What is the most prevelent issue for the firm in the use of this material? (what could be improved to enhance the use of the material by the firm)

What is the second most prevelent issue for the firm in the use of this material? (what could be improved to enhance the use of the material by the firm)

Is it likely the firm will continue using the material in the future?

Engineering Honours Project - Evaluation of issue for small and medium-

Advanced and Green Engineering Material #4

To get a feel of the materials used in the past by the firm, the issues experienced and location of use, we have five identical pages of questions about advance and/or green engineering meterials. There are three pages for most used materials and two pages for materials not used (due to issues) by the firm.

An unused advanced and/or green engineering material due to issues with the material.

***What is an unused advanced and/or green engineering material by the firm?**

(The list of options provided is no way exhaustive, the use of "Other" is invited where applicable)

***What are some issues preventing the use of this material?**

- [ ] Standards or Codes
- [ ] Experience
- [ ] Evaluation Methods
- [ ] Inventory Management
- [ ] Availability
- [ ] Cost of Material
- [ ] Material Properties
- [ ] Perception
- [ ] Other (please specify)

What is the most prevelent issue for the firm in the use of this material? (what could be improved to enhance the use of the material by the firm)

What is the second most prevelent issue for the firm in the use of this material? (what could be improved to enhance the use of the material by the firm)

***How long has the firm been aware of the material?**

***If the issues are addressed, is it likely the firm will use the material in the future?**

Engineering Honours Project - Evaluation of issue for small and medium-

Advanced and Green Engineering Material #5

To get a feel of the materials used in the past by the firm, the issues experienced and location of use, we have five identical pages of questions about advance and/or green engineering meterials. There are three pages for most used materials and two pages for materials not used (due to issues) by the firm.

An unused advanced and/or green engineering material due to issues with the material.

***What is an unused advanced and/or green engineering material by the firm?**

(The list of options provided is no way exhaustive, the use of "Other" is invited where applicable)

***What are some issues preventing the use of this material?**

- [ ] Standards or Codes
- [ ] Experience
- [ ] Evaluation Methods
- [ ] Inventory Management
- [ ] Availability
- [ ] Cost of Material
- [ ] Material Properties
- [ ] Perception
- [ ] Other (please specify)

What is the most prevelent issue for the firm in the use of this material? (what could be improved to enhance the use of the material by the firm)

What is the second most prevelent issue for the firm in the use of this material? (what could be improved to enhance the use of the material by the firm)

***How long has the firm been aware of the material?**

***If the issues are addressed, is it likely the firm will use the material in the future?**

Engineering Honours Project - Evaluation of issue for small and medium-

General Issues with Advanced and Green Engineering Materials

*Issues with using advanced and green engineering materials?

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
Standard or Codes	◯	◯	◯	◯	◯
Experience	◯	◯	◯	◯	◯
Identification of alternative materials	◯	◯	◯	◯	◯
Evaluation Methods	◯	◯	◯	◯	◯
Inventory Management	◯	◯	◯	◯	◯
Cost of material	◯	◯	◯	◯	◯
Material Properties	◯	◯	◯	◯	◯
Perception	◯	◯	◯	◯	◯
Growth of business	◯	◯	◯	◯	◯

Other (please specify)

How does the firm identify potential materials for use?

How does the firm evaluate alternate materials?

APPENDIX C

OFFICE OF RESEARCH
Human Research Ethics Committee
PHONE +61 7 4631 2690| FAX +61 7 4631 5555
EMAIL ethics@usq.edu.au

22 July 2014

Mr Christopher Wright
67 Brisbane Street
Sydenham
Christchurch 8032
New Zealand

Dear Christopher

The USQ Human Research Ethics Committee has recently reviewed your responses to the conditions placed upon the ethical approval for the project outlined below. Your proposal is now deemed to meet the requirements of the *National Statement on Ethical Conduct in Human Research (2007)* and full ethical approval has been granted.

Approval No.	**H14REA134**
Project Title	Evaluation of issues for small and medium -sized enterprises in the use of advances and green engineering materials
Approval date	22 July 2014
Expiry date	22 July 2017
HREC Decision	**Approved**

The standard conditions of this approval are:

(a) conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal required by the HREC
(b) advise (email: ethics@usq.edu.au) immediately of any complaints or other issues in relation to the project which may warrant review of the ethical approval of the project
(c) make submission for approval of amendments to the approved project before implementing such changes
(d) provide a 'progress report' for every year of approval
(e) provide a 'final report' when the project is complete
(f) advise in writing if the project has been discontinued.

For (c) to (e) forms are available on the USQ ethics website:
http://www.usq.edu.au/research/ethicsbio/human

Please note that failure to comply with the conditions of approval and the *National Statement (2007)* may result in withdrawal of approval for the project.

You may now commence your project. I wish you all the best for the conduct of the project.

Annmaree Jackson
Ethics Coordinator

Copies to: u1035949@umail.usq.edu.au

University of Southern Queensland

Human Research Ethics Application Form

To complete this form

- This form should be completed electronically.
- Do not remove or alter formatting – please include your response to each question in the allocated space.
- Answers should be provided in plain, everyday language. This means, that you should avoid using discipline-specific jargon, or acronyms throughout this application. If you must use discipline-specific terms, please ensure that you include a definition so that a person outside of the University could read and understand what your research is about, and what you propose to do.
- **Please read each question carefully and ensure that you provide the requested information.**
- Left-click the check boxes to select appropriate answers and complete text boxes by typing your answers in the space provided underneath each question. The frame will expand to accommodate the text.
- If your research design is utilising a range of methods, ensure that you address all approaches and stages of the research project for each question asked.

Submission

- Please forward the finalised application including supporting documentation via email to ethics@usq.edu.au. You do not need to forward a hard copy.
- Ensure all nominated investigators (i.e. Chief Investigator, Supervisor (if a student research project) and Additional Investigators) sign the signatures page and forward electronically to ethics@usq.edu.au (scan and email). Please note that your application will not be approved until all signatures have been received by the Ethics Office.

Project Duration

The commencement date of the project will be the approval date of the application by the USQ Human Research Ethics Committee.

Ethical approval will be granted for a period of three (3) years (maximum). Ethical approval will cease at either (a) the expiry date nominated in the approval notice, or (b) upon receipt of a final report (if submitted prior to the nominated expiry date).

Please note that in accordance with the Australian Code for the Responsible Conduct of Research, the National Statement on Ethical Conduct in Human Research, 2007, and USQ's Code of Conduct in Research Policy and Procedure, research must not commence until ethical approval has been granted by the University of Southern Queensland (USQ) Human Research Ethics Committee (HREC).

1. Investigator details

1.1 Chief investigator *(This is the person who will primarily be conducting the research and with whom we will correspond about this application.)*

USQ staff/student ID *(10 digits)*	0061035949			
Title (e.g. Prof, A/Prof, Dr, Mr)	Mr			
First Name	Christopher			
Other Names *(e.g. middle name/s)*	John Brockway			
Family Name	WRIGHT			
School	University of Southern Queensland			
Faculty or Centre	Faculty of Engineering and Surveying			
Campus	External			
Address for Correspondence *(please include a postal address, rather than your School or Faculty.)*	67 Brisbane Street			
	Sydenham			
	City	Christchurch	State	N/A
	Postcode	8032	Country	New Zealand
Email	U1035949@umail.usq.edu.au			
Telephone *(during business hours)*	+64 21 819 444			
Mobile	+64 21 819 444			

1.2 Supervisor *(This is the Principal Supervisor of a student project and the person who will be providing guidance to a student researcher.)*

Leave blank if not applicable

USQ Staff ID *(10 digits)*	102881
Title (e.g.Dr, Mr, Mrs, Ms)	Dr
First Name	David
Other Names *(e.g. middle name/s)*	Stuart
Family Name	THORPE
School	School of Civil Engineering and Surveying
Faculty or Centre	HES
Campus	Springfield
Address for Correspondence	PO Box 4196

(please include a postal address, rather than your School or Faculty.)				
	City	Springfield Central	State	Qld
	Postcode	4300	Country	Australia
Email				
Telephone				

1.3 Additional investigator/s

(Add more rows for additional researchers if required)

USQ Staff / Student ID	Full Name *(Include title e.g. Dr)*	Email	Telephone

2. Student project details

Note: If the proposed research is for the purpose of staff research only, go to Section 3.

2.1 Please check the box (choose one only) for the degree which this research will contribute to

- ☐ Doctor of Philosophy (DPHD)
- ☐ Doctor of Education (DEDU)
- ☐ Doctor of Professional Studies (DPST)
- ☐ Masters of Business Research (MBSR)
- ☐ Masters of Spatial Science Research (MSSR)
- ☐ Masters of Psychology (Clinical) (MPCL)
- ☐ Bachelor of Science (Honours) (BSCI)
- ☐ Bachelor of Education (Honours) (BEDH)
- ☐ Other: please specify
- ☐ Doctor of Business Administration (DBAR)
- ☐ Engineering Doctorate
- ☐ Doctor of Psychology (Clinical) (DPCL)
- ☐ Masters of Engineering Research (MENR)
- ☐ Masters of Science Research (MSCR)
- ☐ Master of Education (MED1)
- ☐ Bachelor of Arts (Honours) (BARH)
- ☐ Bachelor of Engineering (Honours) (BENH)

2.2 Have you successfully obtained confirmation of your candidature?

☐ Yes ☐ No

Note: Student research projects will not be reviewed by the Human Research Ethics Committee until evidence has been received that the student is a) a confirmed candidate in a USQ research project, or b) written notification has been received from either the Head of School, or the Director of the research centre in which the student is enrolled, confirming that the enrolling school/centre has undertaken a thorough review of the proposed research project methodology, and that they deem it is acceptable to proceed with the research.

☐ Copy of confirmation of candidature statement (not covering letter) attached; OR

☐ Copy of notification from the Head of School/Director, Research Centre attached

2.3 Will your research be conducted outside of Australia?

☐ Yes ☐ No

If Yes, please refer to Chapter 4.8 People in other countries of the *National Statement on Ethical Conduct in Human Research, 2007*; and:

- outline what arrangements you have made with your supervisor whilst outside of Australia to ensure that participants are duly respected and protected. This includes, but is not limited to an individual participant or group of participant's beliefs, customs, and cultural heritage
- provide detail of any ethical approval processes in the country that you need to obtain, and whether these are mandatory or voluntary
- provide detail of any local academic or institutional affiliations you have established to assist you

Note: It is your responsibility, as the research, to ensure that the research you plan to undertake is lawful in that country. Please ensure that you review this aspect of your research thoroughly, and discuss with your supervisor.

The Ethics for Human Research manuals from the leading civil engineering universities in New Zealand have been used to insure participants are respected and protected. The Principle Researcher is a New Zealander, which will help in navigating local beliefs, customs and cultural heritage.

Inspection of University of Canterbury and Auckland Human Research guideline gives the impression that there is not an equivalent National Statement of Human Research. Research needs to respect Acts of Parliament, including Privacy Act and Treaty of Waitangi.

Information will be collected anonymously and will have no affect on matters of the treaty of Waitangi.

I will not be using any other academic institutions to assist in the process.

3. Project details

3.1 Project title

Evaluation of issues for small and medium-sized enterprises in the use of advanced and green engineering materials.

Note: Ensure that the title is appropriate for this research and would make it easy to identify the project. This is the title that will be used for correspondence about this application and the resulting clearance, and would normally be the title you would use in recruitment and informed consent materials. If the title is very long or difficult to understand for the lay person, a lay version can be used in informed consent documents. A title such as 'Master of Education project' is inappropriate as it does not provide sufficient information about what this research is about. However, the title should not create the impression that the scope or likely impact of the research is broader than it actually is - for example, a project that

describes experiences of teachers in Brisbane with a new science curriculum should not be described as "Australian educational programs".

3.2 Using 'everyday language', provide a summary of the project (300 words max) outlining the projects broad aims, participant group(s), and possible outcomes

Project broad aims:

This research is to evaluate issues for Small and Medium Enterprise's (SME) in the use of advanced and green engineering materials. The research, design and innovation involved in creating advanced and green materials can take sizable resources and investment to develop. SME's play a large part in the construction market and therefore their adoption of new materials can be crucial to the success of advanced and green engineering material products.

- To undertake a survey of SME's to identify their perceived issues in the use of advanced and green engineering materials.
- To evaluate the issues for SME's in the use of advanced and green engineering materials.
- To provide a comprehensive list of the main findings so that manufacturers can improve their marketing, communication and delivery of advanced and green material products.

Participant groups:

Small and medium-sized enterprises from the construction industry in New Zealand and Australia.

Possible outcomes:

Identification of key issues for SME in the use of advanced and green engineering materials.
Determination of areas of further research into the issues with advanced and green engineering materials for SME.

Note: The response to this question must provide in clear lay terms, the objectives of the research, research questions, hypotheses and / or problems. This may need to include a review of the literature or otherwise to establish the need for the research. Next there should be a discussion of the selected research design and how this will enable the research objectives to be achieved. Once again, it may be important to review the literature to explain why this research design was selected and why the researchers believe the selected design will be successful. Section 1.1(b) and (c) of the National Statement (2007) establishes that these matters are an important ethical consideration for proposed research. Lastly, the response to this question should outline what participants will actually experience. It is important to remember that the audience for the application includes people with community and lay perspectives, so copying text from a grant proposal, PhD proposal, etc is not appropriate for this purpose. The length of the response to this question must be at least 100 words and no longer than 300 words. The length of the response should be reflective of the complexity and sensitivity of the research.

3.3 Is this project supported by an external competitive grant/s?

☐ Yes ☐ No

If Yes,

- please state the name of the funding organisation
- include the title as it appears on the grant application
- include the status of the funding application.

Funding organisation	**Title of project** *(as it appears on the grant application)*	**Status** *(e.g. pending, approved)*

3.4 Research Categories

Please check as many categories that are relevant to this research.

- ☐ Anonymous questionnaire/ survey
  (Participants are not personally identified and cannot be re-identified from collected data)
- ☐ Coded (potentially identifiable) questionnaire/ survey
- ☐ Identified questionnaire/ survey
- ☐ Examination of student work, educational instructional techniques etc.
- ☐ Examination of medical, education, personnel or other confidential records
- ☐ Observation (Overt with participant's knowledge)
- ☐ Observation (Covert without participant's knowledge)
- ☐ Focus Groups
- ☐ Interviews (Structure or unstructured)
- ☐ Telephone interviews
- ☐ Recordings (video)
- ☐ Recordings (audio)
- ☐ Procedures involving physical experiments (e.g. exercise)
- ☐ Procedures involving administration of substances (e.g. drugs, alcohol, food)
- ☐ Physical examination of participants (e.g. blood glucose, blood pressure and temperature monitoring)
- ☐ Surgical Procedures
- ☐ Other (please provide details)

3.5 Research Design

Outline the proposed research design (300 words), including:

- data collection technique/s and instruments
- task/s participants will be asked to complete
- estimated time commitment required of participants per technique
- the procedure associated with the project
- how data will be analysed.

Note: If you are using more than one data collection technique (identified in Section 3.4.) and/or participant group, please provide specific details for all techniques/groups.

- data collection technique/s and instruments

The data will be collected via online survey. The online survey tool, Survey Monkey, is the proposed tool for collection of data.

- task/s participants will be asked to complete

Participants will be asked to answer a selection of questions on behalf of their firm. The questions hope to identify the issues perceived by the firm in using advanced and green engineering materials.

- estimated time commitment required of participants per technique

The survey questions are hoped to take less that 15min to complete.

- the procedure associated with the project

Survey will be non-identifiable, firms will be asked to comment on the region they are located and type of firm.

- how data will be analysed.

Issues will be assessed on their own and in terms of region and types of firm.

4. Participants and Recruitment Methods

The *National Statement on Ethical Conduct in Human Research, 2007* has identified particular groups of research participants which require special ethical consideration. These groups include:

- Pregnant women and the foetus (Chapter 4.1)
- Children and young people (Chapter 4.2)*
- People in dependent or unequal relationships (Chapter 4.3)*
- People highly dependent on medical care (Chapter 4.4)
- People with cognitive impairment, intellectual disability, or mental illness (Chapter 4.5)
- People who may be involved in illegal activities (Chapter 4.6)
- Aboriginal and Torres Strait Islander peoples (Chapter 4.7)

  See also: *NHMRC Values and Ethics: Guidelines for Ethical Conduct in Aboriginal and Torres Strait Islander Health Research, and Guidelines for Ethical Research in Australian Indigenous Studies (GERAIS)*

  Note*: If you are planning to undertake health and/or wellbeing research involving Aboriginal people in New South Wales, then you must also submit your proposal to the Aboriginal Health and Medical Research Council (AH&MRC) Ethics Committee for review prior to commencing your research.*
- People in other countries (Chapter 4.8)*
- Other cultural and ethnic groups

Researchers are obliged to ensure that they protect the interests of these groups if they are in any way involved in a project, and are therefore advised to investigate thoroughly how these special groups may or may not be involved in, or represented in, the project and to consider if there might be an adverse effect on members of these groups in they are involved in or represented in the project.

If participation of any of the above listed groups is a focus of your research, your ethics application is unlikely to qualify for review through the Expedited Review process. Participant groups marked with an asterisk (*) may qualify for Expedited Review in some cases, this will depend on the assessed level of risk associated with your research.

4.1 Participants

Please provide detail on the group and source of potential participant(s).

The group will be selected from SME's in the construction industry. The research is about issues for the firm rather than the individuals in the firm.

4.2 Are there any pre-existing or dual relationships between any of the nominated investigators and the participants?

☐ Yes ☐ No

If indicated YES,

- Outline the nature of the pre-existing or dual relationship
- Identify the investigator-participants that may be affected by the pre-existing or dual relationship

Note: Pre-existing relationships may include teachers and students; course leaders and students, employer and employees, etc.

4.3 Expected age (s) of participant(s)

Please check one or more of the following:

☐ Children (under 14)

☐ Young People (14-18)

☐ Adults (>18)

For Research in Australia: All investigators working with Children and Young People must provide evidence of either a Blue Card or Blue Card Positive Exemption notice with this application.

☐ Copy of Blue Card
OR
☐ Copy of Blue Card Positive Exemption notice

Researchers are encouraged to contact Blue Card directly (free call: 1800 113 611) for an assessment of their individual situation.

4.4 Expected Number of Participant(s)

If the research has several stages and/ or groups of participants please provide the total number of participants expected as well as the number and participant group involved in each stage

The exact numbers of participants is undetermined at the moment. It could be in the range of 10-50 firms from each of the regions identified. With the assumed 10-50 from each regions the number of participants will be in the order of 200-1000, with 1000 responses the maximum allowable from the survey tool.

4.5 How will potential participant(s) in your research be recruited?

Please outline:

- How participants will be invited to participate in the research project (e.g. personal approach, email, through an organisation, advertisement, mail out)
- How participant contact details (for invitation purposes) will be obtained
- Who will be involved in the invitation and recruitment of participants (For example, will approval or permission from a person representing an organisation grant permission for the investigators to access potential participants under their authority?)

Note: Ensure written evidence of permissions granted are submitted with this application

- How participants will be invited to participate in the research project (e.g. personal approach, email, through an organisation, advertisement, mail out)

Participants (firms) will be invited by email.

- How participant contact details (for invitation purposes) will be obtained

Contact details will be obtained by web search of SME in the construction industry. Obtained from sources published to the public.

- Who will be involved in the invitation and recruitment of participants (For example, will approval or permission from a person representing an organisation grant permission for the investigators to access potential participants under their authority?)

Christopher Wright, primary researcher, will be solely involved in the invitation and recruitment of

participants.

4.6 Who will be involved in the recruitment of the participant(s)?

Christopher J. B. Wright

4.7 List all of the geographical location(s) where the data will be collected

Northland Region
Auckland Region
Waikato Region
Bay of Plenty Region
Gisborne Region
Hawke's Bay Region
Manawatu-Wanganui Region
Taranaki Region
Wellington Region
Tasman Region
Nelson Region
Marlborough Region
West Coast Region
Canterbury Region
Otargo Region
Southland Region

Australian Capital Territory, New South Wales
Victoria
Queensland
South Australia, Northern Territory
Western Australia
Tasmania

4.8 Does this research involve USQ staff, students or data?

☐ Yes ☐ No

If indicated YES,

- Please list the relevant courses, schools or faculties you propose to recruit from
- Please specify whether you have obtained written permission to recruit USQ students and provide documentary evidence of the approval granted.

Note: Approval to recruit USQ staff and students must be obtained from the appropriate delegate of the University.

Scope of recruitment	Appropriate Delegate

Students with a course/courses within one discipline	Head of School
Students within one Faculty area	Executive Dean
Students across the University and/or across University campuses	Deputy Vice-Chancellor (Students & Communities)
Staff (any)	Senior Deputy Vice-Chancellor

4.9 Does this research involve recruitment through an organisation other than USQ?

☐ Yes ☐ No

If indicated YES,

- Please list the organisations
- Please specify whether you have obtained written permission from the organisation to recruit the participants and provide documentary evidence of the approval granted

5. RISKS AND BENEFITS

5.1 Please indicate any potential risk/s to a participant, researcher, or others connected with the proposed project.

Risk is a potential form of harm, discomfort or inconvenience, and involves both the likelihood that a harm (or discomfort or inconvenience) will occur, and the severity of the harm, including its consequences.

Please refer to Chapter 2.1 Risk and benefit of the *National Statement on Ethical Conduct in Human Research, 2007*.

Researchers are encouraged to reflect on what they will be "doing" to a participant at each stage of the research project, as well as what they will be "leaving" with a participant. Ethical conduct of research is about more than just "taking" the information that you wish to use for your research project.

☐ **Physical risk**
This relates to injury, significant pain, infection, disease, death and other deleterious impacts on the physical wellbeing of individuals – most typically participants, but includes the researchers and others. This is the category of risk most people think of when asked about risks in research, but is not the only category of risk and obviously is unlikely to be a relevant consideration for many research designs.

☐ **Psychological risk**
A psychological risk refers to harms that include anguish, significant emotional upset, anxiety or stress. In some cases (e.g. with a high level of suicide ideation or clinical depression) this can include devaluing personal worth.

☐ **Social risk**
Research can have deleterious impacts on personal relations (e.g. within a familial unit) or peer relations (e.g. the standing of an individual within their peer or work group). These risks can frequently be an issue for research in broad social sciences, where research can often relate to, and impact upon, personal relationships.
Pre-existing or dual relationships between the investigator/s and participant/s are also encompassed within this potential risk.

☐ **Time imposition**
A time imposition risk is one where a participant would need to commit a reasonable amount of time to participate in

the research. Whether participation would be a time imposition will be dependent on the expected duration of participation, together with the context in which the participation occurs (e.g. the expectation that a busy mother of young children would participate in a 4-hour focus group would be considered a time imposition, whereas completion of a 10 minute anonymous survey would be unlikely to cause an imposition).

☐ **Economic risk**
Economic risks are those relating to loss of income, loss of job or career prospects, loss of benefits or entitlements, diminished market share or brand reputation, or other factors that might have deleterious financial implications.

☐ **Legal risk**
Some research can raise legal risks, such as civil or criminal proceedings, fines or some other form of regulatory response. While research can justifiably be intended to expose illegal or inappropriate behaviour, such research typically requires a higher level of ethical review.

☐ **Other risks** (Please provide details)

5.2 Please indicate your assessment of the overall level of risk to a participant

☐ Extreme Risk
☐ High Risk
☐ Some Risk
☐ Low Risk
☐ No foreseeable risk associated with this project

Note: if you have indicated a potential risk in Section 5.1., then you must indicate at least 'low risk' in this section

5.3 Identify the initial risks that you considered were important to address in your research design

5.4 Explain the strategies used to negate or minimise those initial risks occurring

5.5 Identify any remaining risks that are still present in your research design, despite your attempts to minimise risks

5.6 Describe your strategies to manage the harms if the remaining risks occur

5.7 Explain the degree to which the anticipated benefits of the research justify any remaining risks and/or the inconvenience of participating in the research

6. Informed Consent Process

Please refer to Chapter 2.2 General requirements for consent and Chapter 2.3 Qualifying or waiving conditions for consent of the *National Statement on Ethical Conduct in Human Research, 2007*.

6.1 How will consent from a participant be obtained?

For each of the research techniques you have identified, please indicate how consent will be obtained. Please choose as many as required (e.g. for interviews and focus groups, consent may be obtained in writing, however, for completion of an anonymous survey, consent may be tacit). Add more rows if required.

Research Technique	Method informed consent will be obtained
Anonymous Survey	Consent by completion of survey

6.2 Is it anticipated that all participants will have the capacity or authority to consent to their participation in the research?

☐ Yes ☐ No

If No,

- explain why not (e.g. children and young people, people highly dependent on medical care, people with a cognitive impairment, an intellectual disability or a mental illness, etc.)
- explain how proxy or substitute consent will be obtained from the person with legal authority to consent on behalf of the participant.

6.3 Does the research specifically target the following groups of participants?

☐ Minors (under 18 years)

☐ Aboriginal and Torres Strait Islander peoples

☐ People from non-English speaking backgrounds

☐ People with an intellectual impairment or a mental illness

☐ Prisoners

☐ People who may be involved in illegal activities

☐ People in dependent relationships with the researcher, institution or funding body (i.e. researcher's clinical clients or students, employees of the institution, recipients of service provided by the funding body)

☐ Any other vulnerable group of participants

If Yes, please provide details of:

- The group of participants
- How the research participants' rights will be protected

- How you will be sensitive to cultural backgrounds (if applicable)

Participants will be contacted via email. The email will contain the link to the survey and a USQ consent form attached or as the main body of text for the email. Would like an edited version where the act of filling the form out is considered giving consent.

6.4 How does the consent process ensure that informed consent is freely obtained from a participant?

Note: Please detail how participants will provide consent to participate in the project

Participants are informed that they are not obliged to take part in the research if they do not wish to. The information will be collected through electronic survey, which requires their manual input. To fill the form in it will be stated as an act of giving consent to the use of the information.

6.5 How does the project address a participant's freedom to discontinue participation?

There will be no identifiable information from each participant, upon completing the survey it isn't expected possible to identify his or her information and remove it.

6.6 Will there be any adverse effects on a participant if they withdraw their consent?

☐ Yes ☐ No

If Yes,

- explain what adverse effects are anticipated

6.7 Will a participant be able to withdraw data concerning themselves if they withdraw their consent to participate?

☐ Yes ☐ No

If No,

- explain under what circumstances an individual participant's data would not be withdrawn
- ensure information pertaining to both a participant's ability to withdraw from the project, and withdraw data about themselves is clearly set out in the Participant Information Sheet

The information will be non-identifiable and therefore once they have filled the form it will be collected with all the other unmarked data.

6.8 Does the project involve withholding relevant information from participants or deceiving them about some aspects of the research?

☐ Yes ☐ No

If indicated YES please justify

6.9 Will participants be offered reimbursements, payments or incentives to participate in the research?

☐ Yes ☐ No

If indicated YES,

- outline the amount/ benefit
- explain the justification for this
- ensure that information about whether a reimbursement, payment or incentive will be offered to a participant is clearly outlined in the Participant Information Sheet

7. Debrief and Feedback

7.1 Does your project involve the use of deception?

☐ Yes ☐ No

If Yes,

- Outline the process of how a participant will be debriefed at the conclusion of the project
- Include the name and contact details of agencies to which participants may be referred if they become distressed by the procedures
- Ensure the referral contact details are clearly outlined in the Participant Information Sheet

7.2 Will participant(s) be provided with an opportunity to ask questions of the researcher after participating in the project?

☐ Yes ☐ No

If Yes,

- Outline the method a participant may undertake to engage with the investigator

7.3 Will a summary of results be made available to participant(s)?

☐ Yes ☐ No

If Yes,

- Explain the process for providing the information
- Explain how participant confidentiality will be maintained in the presentation of results

Note: It would not be considered appropriate to offer participants a copy of a completed thesis. A summary of results should be no more than two pages in length and be written in 'everyday' language (i.e. no discipline-specific jargon, inclusion of definitions of terms used as they relate to this research project, and no acronyms)

8. Data collection, storage, disposal, reporting and future use

Identifiability of data

Consider the identifiability of your data when you are collecting it from participants, reporting results in the public domain and storing it at the completion of your project. Data may be in the following form(s):

- **Individually identifiable** – data from which the identity of a specific individual can reasonably be ascertained (e.g. when researchers are collecting information from a participant in a face-to-face interview; audio and video recordings).
- **Re-identifiable** – data from which identifiers have been removed and replaced by a code, but it remains possible to re-identify a specific individual (eg if researchers are labelling questionnaires with codes and have a key that matches participant names to the codes).
- **Non-identifiable** – data that has never been labelled with individual identifiers or from which the identifiers have been permanently removed (eg if researchers are conducting an anonymous online survey).

More than one response is possible as you may be collecting multiple types of data in different forms. If so, please explain. In describing the identifiability of your data, it is important to not only consider individuals, but also organisations, institutions, businesses etc.

8.1 Collection of data

The information collected by the research team from participants will be in the following form(s):

☐ Identifiable
☐ Re-identifiable
☐ Non-identifiable

8.2 Reporting and dissemination of data

The information about participants that will be reported, published, and/or disseminated in the public domain will be in the following form(s):

☐ Identifiable
☐ Re-identifiable
☐ Non-identifiable

8.3 Storage of data

The information about participants stored at the end of the project will be in the following form(s):

☐ Identifiable

☐ Re-identifiable

☐ Non-identifiable

8.4 Provide details of how and where you will store the data, both during, and after the completion of the research project

Note: Normally, requirements are to store all paper and hard copy files in locked cabinets, and all electronic files on password protected computers. Copies of data should be kept at the University of the Southern Queensland, but can also be stored elsewhere provided the data is secure.

The data will be stored primarily on the primary researchers Survey Monkey account. The data will be exported periodically and stored on a password-protected laptop.

8.5 Do you intend to use the data collected in this project in future research projects, or make it available for use by other researchers?

☐ Yes ☐ No

Note: Describe how the data may be used in the future (i.e. for what other purpose). If future use of the data is intended, you must ensure participants are fully informed of this in the Participant Information Sheet and Consent Form.

If Yes,

- Outline how you will inform participants in this research project of how their data will be used in the future.
- Ensure this information is clearly outlined in the Participant Information Sheet and Consent Form.

8.6 Will the data collected be retained for the requisite 5 years (or 15 years for clinical research)?

☐ Yes ☐ No

Note: Note that normally this is at least five years after completion of the project or any publication derived from it. This is in accordance with section 601.2/C124 and 601.2/C125 of the Queensland State Archives University Sector Retention and Disposal Schedule. See this schedule at the following website
http://www.archives.qld.gov.au/Recordkeeping/GRKDownloads/Documents/Universities.pdf

If No,

- please justify

8.7 Will a recording (audio, video, photograph or other) of participants be made?

☐ Yes ☐ No

*Note: Audio and video recordings form part of original data collected, and must be retained for the minimum retention period. Therefore, recordings **must not** be destroyed or wiped after they have been transcribed.*

If Yes,

- what purpose will this recording be used for?

9. Privacy

9.1 Does this project involve obtaining identifiable information (e.g. data) from a third party without prior consent from the participant(s) or their legal guardian(s)?

☐ Yes ☐ No

If Yes,

- Outline the details of the information
- Include the details of the third party

9.2 Will the research involve access to identifiable personal information (e.g. contact lists) held by another agency/body subject to the Privacy Act 1988 (Cth) or Public Health Act 2005 (QLD)?

☐ Yes ☐ No

If Yes,

- outline the measures to obtain prior consent from the identified individuals
- outline procedures to address the regulatory privacy considerations
- If an exemption under S95/S95A of the Privacy Act is to be sought, please contact the Manager, Research Integrity and Ethics.

10. CHECKLIST

Anonymous survey	☐ Survey ☐ Participant Information Sheet (PIS)
Identified survey	☐ Survey ☐ Participant Information Sheet (PIS) ☐ Consent Form
Interview/ focus groups	☐ Sample Questions ☐ Participant Information Sheet (PIS) ☐ Consent Form
Other method (where applicable)	☐ Instrument ☐ Participant Information Sheet (PIS) ☐ Consent Form
Advertisements/letters of invitation (where applicable)	☐ Yes ☐ N/A
Evidence of permission from external organisation to conduct research and/or recruit participants (e.g. School or Hospital)	☐ Yes ☐ Currently being sought ☐ N/A
Evidence of permission to recruit USQ Staff/Students	☐ Yes ☐ Currently being sought ☐ N/A
Copy of Blue Card or Blue Card Positive Exemption notice for all investigators working with children and young people.	☐ Yes
Other, please describe	

SIGNATURES PAGE

Project Title	Evaluation of issues for small and medium-sized enterprises in the use of advanced and green engineering materials.

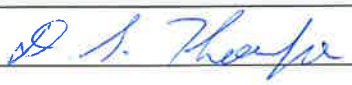
Declaration

I/we the undersigned confirm that the information contained in this application is accurate; conduct will not commence until ethical certification has been granted; and all members of the research team will conduct this project in accordance with the principles contained in the National Statement on Ethical Conduct in Human Research (2007), and will comply with any other conditions laid down by the University of Southern Queensland Human Research Ethics Committee.

Chief Investigator

Name (please print)	**Signature**	**Date**
Christopher Wright		27/06/2014

Supervisor (if applicable)

Name (please print)	**Signature**	**Date**
Dr David Thorpe		27/06/2014

Other Investigator/s

Name (please print)	**Signature**	**Date**