EXPLOITATION OF SOLID WASTES IN CONSTRUCTION – CHALLENGES AHEAD

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ABSTRACT

This paper reports the findings of a long term intensive research programme focused on the exploitation of solid wastes in construction. The objective of the programme is to develop an environmental-friendly and economical process for the exploitation of solid wastes including biomass, industrial ashes and packaging wastes, particularly rice husk, paper sludge and expanded polystyrene in concrete. An engineered shear wall system with the combination of recycled expanded polystyrene and lightweight concrete provides an environment-friendly and economical solution to construction on soft soil, towards providing affordable quality-assured fast-track method and to enhance the competitive edge of the construction industry. Obstacles to commercialsation is briefly discussed.

INTRODUCTION

Nature is a grand master of materials. These materials include inorganic minerals, crystals, clays, seashells, pearls, wood, silk, horn, bone and teeth. The natural process of material fabrication has inspired the human race to learn and explore, in order to go beyond nature's materials. This paper reports the experimental findings of an intensive research programme focused on the exploitation of solid wastes in construction. The objective of the programme is to develop an environmental-friendly and economical process for the exploitation of solid wastes including biomass, industrial ashes and packaging wastes, particularly rice husk, paper sludge and expanded polystyrene. The engineering properties of the biomass composites such as density, strength, dimensional stability and acoustic thermal insulation properties are determined. Paper sludge and rice husk are the solid wastes highlighted in this paper. Some of the disposal problems and methods include landfill and incineration are covered. Due to growing environmental concerns and the need to conserve energy and resources, alternatives have been developed to dispose these industrial wastes. The alternatives include energy production and the development of value-added products for acoustic thermal insulation.

Researchers who have made significant contribution to knowledge include Huang *et al* [1] who reviewed the assessment of chloride diffusion in high strength concrete using the accelerated ionic migration test. To improve the quality of clinker, Singh *et al.* [2] studied the addition of 3% boiler-fired rice husk ash to the black meal of a vertical shaft kiln. Amer *et al.* [3] studied blended cements made from rice husk ash fired at 450 °C and portland cement. Water demand was increased with the increase of rice husk ash content. Lin and Hwang [4] describe the hydration mechanism of rice husk ash with calcium hydroxide which starts by the release of the water absorbed in the porous silica structure of the ash. This enables the quick reaction of Si with Ca to form growing CSH gel. Pore structure is influenced by the burning conditions. Sugita *et al.* [5] designed a semi-industrial prototype furnace to produce a highly reactive and homogeneous rice husk ash. By controlling the burning temperature and grinding, the concrete strength, resistance to acid attack, chloride penetration and carbonation have been improved.

The pozzolanic properties of palm oil fuel ash (POFA), a waste material obtained on burning of palm oil husk and shell, was studied by Hussin *et al.* [6]. Compressive strength test with Portland cement substitution levels between 10-60% indicate the possibility of replacing 40% ash without affecting concrete strength. A maximum strength gain at the 30% level was achieved. Awal *et al.* [7] utilized POFA to reduce the expansion of mortar bars containing tuff as a reactive aggregate. According to the results, the palm oil fuel ash has a good potential in suppressing alkali-silica reaction expansions. El-Hosiny *et al* [8] used Nitrogen adsorption to measure the surface properties portland cement/rice husk ash pastes. The rice husk ash was obtained at three firing temperatures of 450, 700 and 1000 °C. Higher surface areas were obtained for pastes made from rice husks fired at 450 and 700 °C. The surface area and pore volume results were related to the pore structure of the silica produced in the rice husk ash. A controlled incineration method at temperature between 450 to 550 °C is being experimented to produce highly reactive amorphous rice husk ash with a high pozzolan activity and a low unburnt carbon content.

SOLID WASTES

Rice Husk

Rice is a basic food in Asian countries such as Malaysia, Thailand, Indonesia, India and Japan. It is abundantly available in most part of the world. Substantial amounts are also cultivated in various countries in America and Europe. The present world rice production of about 400 million tons per year will probably increase in the future, owing to the great increase in population, paticularly in Asian countries. When rice grains are husked, the husks make up about 14 to 35%, depending on the variety of rice. Since the husks have a low bulk weight of about 100 kg/m^3, they take up 560 to 1400 million m^3. Rice husk is an abundant by-product of agriculture industry in countries with large paddy crop cultivation, such as Malaysia, China, Thailand, India and Bangladesh. It constitutes one-fifth by weight of paddy harvested. A significant amount of waste is generated every year from the rice milling process. It is estimate that over 100 million tons of rice husk is generated annually with 90% accounted for by developing countries. Although rice husk has its traditional uses, it is mostly under-utilised and causing disposal problem in most countries. It is estimated that 54 million tons of rice husk is produced in China every year. Exploitation is crucial to avoid the waste of energy and environmental pollution. According to a recent study, Malaysia generates about 3.41 million cubic meter of rice husk annually with an average density of 100 kg/m^3 .

Microstructure

The microstructure of paper sludge was examined using the SEM. Figure 1 shows the Scanning Electron Microscope (SEM) micrograph of the paper sludge. It shows the pores and the surface texture of paper sludge. The perforated surface would probably increase the sound absorption coefficient of the paper sludge composite. When the sound wave propagates through the porous absorption material, part of the energy will dissipate by frictional and viscous loss within the pore. The sound wave will also cause vibration to the molecules of the material and the sound energy will be converted to heat energy.

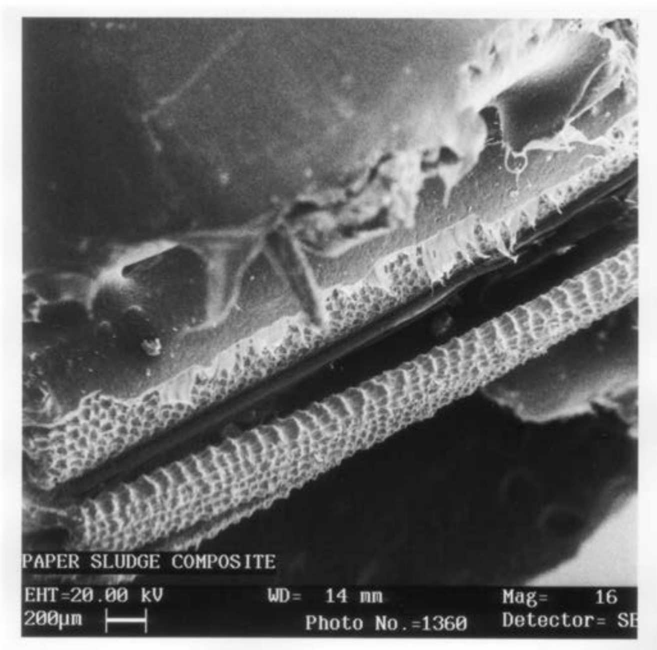

Figure 1 SEM Micrograph of Paper Sludge

One of the SEM micrograph for rice husk (Figure 2) clearly shows the shape of the rice husk. The curved shape of rice husk increases the volume of air void in paper sludge composite thus increases its porosity. This will enhance the sound absorption properties of paper sludge composite containing rice husk.

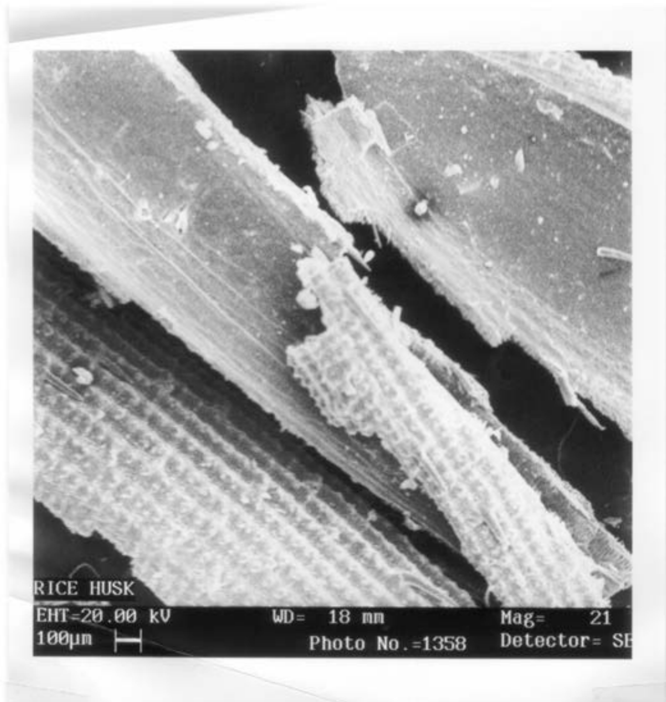

Figure 2 SEM Micrograph of Rice Husk

Paper Sludge

Paper sludge is one of the solid wastes produced by paper industry. Paper sludge containes fragments of paper fibre. These fibres are not suitable for use in recycled paper. Disposal options include landfill and energy production. Usually in the paper production, only 65% of the paper pulp will be turn into paper, the other 35% will be the waste material in the form of paper sludge. Paper sludge contains a high percentage of very fine kaolin clay and fillers, which is used to create a smooth finish on fine paper. Besides kaolin, there are also other contaminants in the paper sludge, such as de-inking compounds, surfactants, residuals from inks and dyes, compounds from laser printing, photocopying and also coagulant that has been used to coagulate the paper sludge during the disperser process. Heavy metals is one of the contaminants exist in paper sludge. Some of these metals are toxic to plants, animals and also human being. When the paper sludge are dumped in the dumpsite, there are possibilities for leachate from the sludge to get into groundwater, stock ponds, or drinking wells. Besides, when the paper sludge is dumped in the dumpsite, it will undergo anaerobic decomposition and this will cause odour problem. The paper sludge used in this project is obtained from the Kimberly-Clarke paper mill located in Kluang, Johor. This paper mill produces 30 metric tonnes of paper sludge per day and the cost for transporting the paper sludge to the dumpsite is approximately RM 10,000 per month. Table 2 summarises the chemical composition of paper sludge obtained from Kimberly-Clarke paper mill.

Table 2 Chemical composition of paper sludge

pH	7.94
Aresenic (As)	<0.05 ppm
Barium (Ba)	1.2 ppm
Boron (B)	<0.2 ppm
Cadmium (Cd)	0.003 ppm
Chromium (Cr)	<0.001 ppm
Copper (Cu)	<0.01 ppm
Lead (Pb)	<0.05 ppm
Mercury (Hg)	<0.001 ppm
Nickel (Ni)	<0.01 ppm
Selenium (Se)	<0.1 ppm
Silver (Ag)	<0.01 ppm
Tin (Sn)	<0.1 ppm
Zinc (Zn)	0.33 ppm
Chloride (Cl)	0.028 %
Oil & Grease	2470 ppm
Cyanide	<0.05

The microstructure of the paper sludge composite was examined using the SEM. The micrographs show that there are pores inside the composite. This indicates that the paper sludge composite is a porous material. The porous structure of the composite will enhanced the sound absorption properties of the composite. When the sound wave propagates through the porous absorption material, part of the energy will dissipate by frictional and viscous loss within the pore. Therefore, it is believed that the porous structure creates the sound absorption properties of paper sludge composite.

Figure 3 SEM micrograph I of paper sludge composite

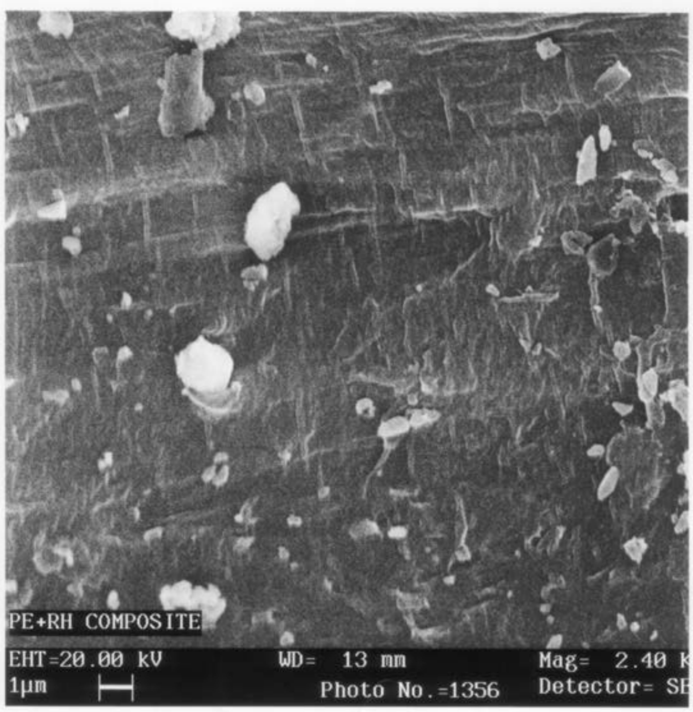

Figure 4 SEM micrograph II of paper sludge composite

RESEARCH SHOWCASE

Micronised Silica

Ten years of intensified research into the synthesis of micronised silica is beginning to create the impact. Cementitious composites and concrete products derived primarily from the innovative exploitation of solid wastes from controlled incineration of biomass has attracted much research interest and award of research grants. Summary of research showcase is available online via a research achievement portal www.1.edu.my. The research achievement milestone and images of the rotary furnace and bulk handling system developed for the study are shown in Appendix A.

Challenges Ahead

Much attention is focussed recently on the commercialisation of research products. Despite the fact that researchers are given 50 % tax exemption on income such as royalty received from the commercialsation of their findings for 5 years from the date of such payment, the success rate of commercialisation has been modest. Most researchers need support services from patent agents to draft patent specification and the involvement of successful businessmen in the preparation of winning business plan. There is also a need for researchers to be aware of the mindset of businessmen in order to enhance their negotiation skill.

A method of soft soil stabilisation with foamed concrete containing micronised silica or a lightweight, inert, finely divided, readily available naturally-occurring material such as volcanic ash, or an industrial or agricultural waste, powdered waste plastics material, rice husk and other locally available biomass are being experimented. The composition is injected at prescribed locations with innovative precast lightweight hollow-core concrete pile to effect replacement of portions of the soft soil and solidifies in situ, providing cost-effective geotechnical solution as the surrounding soft ground becomes compacted. It is envisaged that such blended cement products are competitive and have potential to expedite the physical development of the university. However, the development of blended cement for waterproofing applications has also encountered obstacled due the high cost of the opposed jet mill.

Innovative foundation system with the utilisation of used tyres are being adopted in some housing projects. The engineered shear wall system which is expected to revolutionise the construction process is in the final stage of intellectual property protection and negotiation for commercialsation by an industrial partner. Several research products with potential for commercialsation and selected drawings in the patent document are shown in Appendix B.

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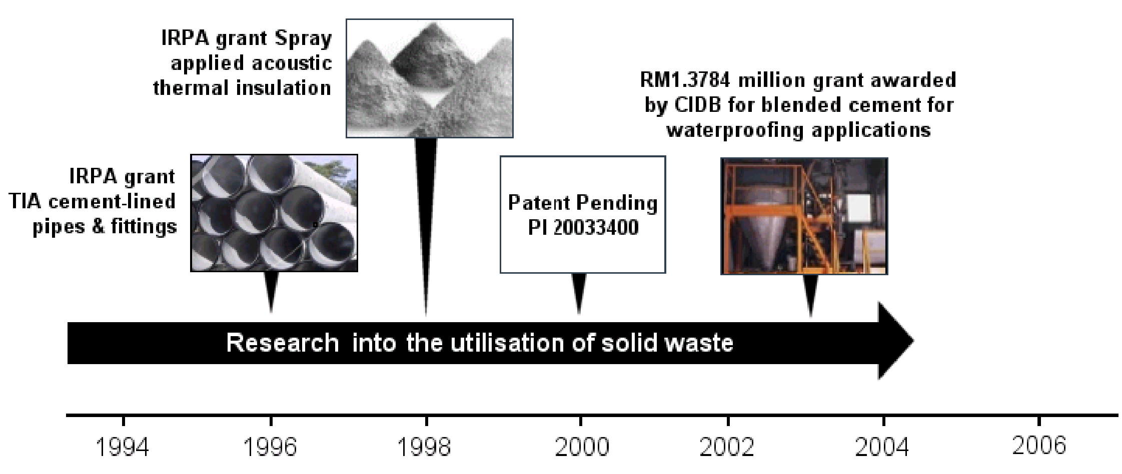
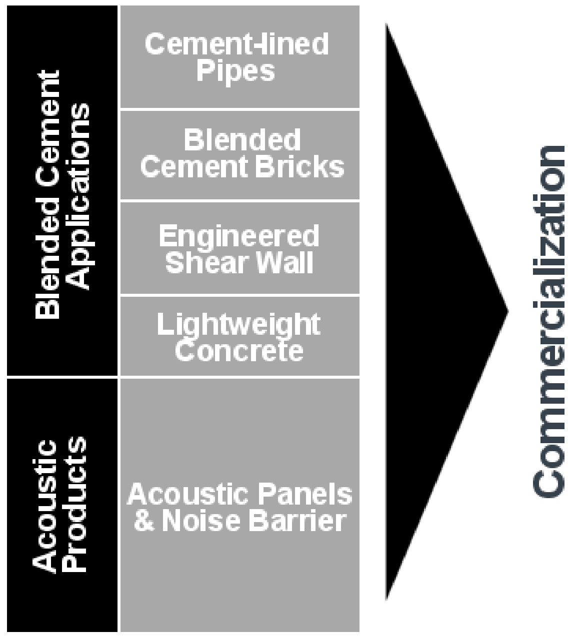
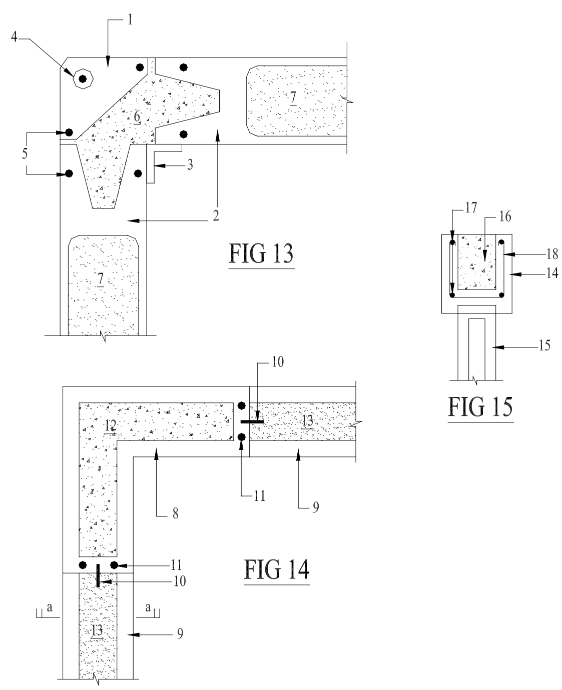
Appendix A



Rotary furnace for the synthesis of white silica

Bulk handling system





Patent-pending industrialized building system (PI 20044277)