



**GLOBAL CONSTRUCTION  
ULTIMATE CONCRETE OPPORTUNITIES**

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## **EXPLOITATION OF SOLID WASTES IN FOAMED CONCRETE – CHALLENGES AHEAD**

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**ABSTRACT.** This paper reviews the contribution of some researchers on blended cement and reports recent findings of a research programme focused on the exploitation of solid wastes in foamed concrete. Solid wastes studied include rice husk and its derivatives, paper sludge and recycled expanded polystyrene (EPS). The objective is to develop an environmental-friendly and economical foamed concrete for construction. A novel process for the synthesis of micronised silica for use in foamed concrete is revealed in order to provide a unique solution to construction on soft soil. Concerted collaborative effort by researchers and the readymix concrete industry is expected to enhance the competitive edge of the construction industry.

**Keywords:** Solid wastes, foamed concrete, blended cement, micronised silica, soft soil

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## INTRODUCTION

Ecologically sustainable construction is a major challenge in this millennium. The natural resources needed for concrete construction are expected to diminish with time. The time has come for researchers to focus their effort on resource generation and the synthesis of alternative materials. 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.

## FOAMED CONCRETE RESEARCH

Kearsley, E.P. and Wainwright [9-12] reported various factors affecting the engineering performance of foamed concrete. Fly ash content of up to 67% has been experimented with encouraging findings. Foamed concrete of controlled density between 1400 kg/m<sup>3</sup> and 1500 kg/m<sup>3</sup> has been found to achieve compressive strength exceeding 8 N/mm<sup>2</sup> with drying shrinkage less than 0.09% with water absorption less than 10%.

## SOLID WASTES

### Rice Husk

Rice husk constitutes one-fifth by weight of paddy harvested. A significant amount of rice husk is generated every year from the rice milling process. It is estimated that over 100 million tons of rice husk is generated annually with 90% accounted for by developing countries. According to a recent study, Malaysia generates about 3.41 million cubic meter of rice husk annually. The average density of rice husk is  $100 \text{ kg/m}^3$  [13]. Due to growing environmental concerns and the need to conserve energy and resources, alternatives have been developed to dispose these solid wastes. The alternatives include energy production and the development of value-added products for acoustic thermal insulation and the creation of concrete composite canoe for recreation and sports [14].

### Expanded Polystyrene

Ganesh Babu [15] studied the use of expanded polystyrene (EPS) beads as lightweight aggregate both in concrete and mortar, containing a fly ash replacement of 50% in the cementitious material. The concretes were designed to cover a wide range of densities ( $550\text{--}2200 \text{ kg/m}^3$ ), through EPS replacements ranging from 95% to 0%. The results were compared with similar concrete composites, essentially having OPC as the binder. The study indicates that the EPS mixes produced with fly ash show lower absorption values and have a better chemical resistance. The chloride permeability of these concretes was 50–65% lower compared to that of normal concretes having similar water cement ratios. The corrosion rates of these concretes were also lower compared to the normal concretes.

### Paper Sludge

Paper sludge is one of the solid wastes produced by paper industry which contains 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 turned 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. Heavy metals are some of the contaminants that exist in paper sludge. When the paper sludge are disposed into the dumpsite, there are possibilities for leachate to get into groundwater. Anaerobic decomposition will cause odour problem. The paper mill located in Kluang, Johor produces 30 metric tonnes of paper sludge per day and the cost of disposal is approximately RM 10,000 per month. Table 1 summarises the heavy metal content of paper sludge obtained from the laboratory of the paper mill.

Table 1 Heavy metal content of paper sludge

| HEAVY METAL   | CONCENTRATION (PPM) |
|---------------|---------------------|
| Arsenic (As)  | <0.05               |
| Barium (Ba)   | 1.2                 |
| Boron (B)     | <0.2                |
| Cadmium (Cd)  | 0.003               |
| Chromium (Cr) | <0.001              |
| Copper (Cu)   | <0.01               |
| Lead (Pb)     | <0.05               |
| Mercury (Hg)  | <0.001              |
| Nickel (Ni)   | <0.01               |
| Selenium (Se) | <0.1                |
| Silver (Ag)   | <0.01               |
| Tin (Sn)      | <0.1                |
| Zinc (Zn)     | 0.33                |

### PROPERTIES OF FOAMED CONCRETE

Specification for controlled density foamed concrete products have been prepared for the readymix concrete industry in Malaysia based on typical properties of foamed concrete (Table 2) made with LCM foaming agent. The drying shrinkage of such foamed concrete is less than 0.09 % for dry density more than 1500 kg/m<sup>3</sup>. The average coefficient of water permeability determined in accordance with ISO/DIS 7031 is in the order of 10<sup>-10</sup> m/s for foamed concrete of dry density between 1500 kg/m<sup>3</sup> and 1600 kg/m<sup>3</sup>. This test was conducted with Germann Water permeability Test Rig on two surfaces of two foamed concrete cubes to obtain the average. The draft standard is available online via a research portal [www.i.edu.my](http://www.i.edu.my). Foamed concrete composites derived from the innovative exploitation of solid wastes has been identified for use in the experimental production of concrete canoe.

Table 2 Typical properties of LCM foamed concrete

| MIX PROPORTIONS |                   |                       |                             | DRY DENSITY       | COMP. STRENGTH    |        |
|-----------------|-------------------|-----------------------|-----------------------------|-------------------|-------------------|--------|
| Cement<br>(kg)  | Fine sand<br>(kg) | Water/binder<br>ratio | Foam/binder<br>ratio (l/kg) | kg/m <sup>3</sup> | N/mm <sup>2</sup> |        |
|                 |                   |                       |                             |                   | 7-day             | 28-day |
| 1               | 2                 | 0.45                  | 0.65                        | 1500              | 5-6               | 7-8    |
| 1               | 2                 | 0.50                  | 0.70                        | 1600              | 7-8               | 8-10   |

### SPECIAL APPLICATIONS OF FOAMED CONCRETE

The first major application of LCM foamed concrete in Malaysia is at the SMART tunnel project in Kuala Lumpur. The foamed concrete specified was of density 1800 kg/m<sup>3</sup> which achieved compressive strength of 3 N/mm<sup>2</sup> at the age of 28 days. Foamed concrete block of size 17m x 17m x 6m was cast in three stages in order to allow a maximum height of 2m per cast. The completed foamed concrete block serves to protect the diaphragm wall when the tunneling machine is coming out into the junction box. The completed foamed concrete block is shown in Figure 1.

Other lightweight, inert, finely divided materials such as powdered waste plastics, rice husk and other locally available biomass are also being experimented. The composition is proposed to be injected at prescribed locations with innovative precast lightweight hollow-core concrete pile to effect replacement of portions of the soft soil. The system is expected to provide cost-effective geotechnical solution as the surrounding soft ground becomes compacted while foamed concrete solidifies in situ. Foundation system with the utilisation of used tyres are being experimented in some housing projects in Malaysia. Successful deployment of the system is expected to provide a fast-track method for affordable quality-assured housing. The system is applicable for the homeless people who urgently need a decent shelter. Technical specification has been prepared for an industrialized building system complying with modular coordination.

### SYNTHESIS OF BIOMASS SILICA

It is generally accepted that 1 kg of carbon dioxide is released into the atmosphere while producing 1 kg of Portland cement. It is envisaged that the development of blended cement foamed concrete could contribute to sustainability. The generation of renewable energy from controlled incineration of biomass such as rice husk has been initiated in Kedah, Malaysia since 1997. The rice husk fired cogeneration plant has a rated capacity of 450 kW. A 10 MW biomass power project is now in progress in the neighbouring state of Perlis, Malaysia. The synthesis of biomass silica is experimented with a rotary furnace. The controlled incineration at a constant temperature of 500°C produces white amorphous silica of consistent quality. The synthesis of micronised silica process is planned to be integrated to one of the existing cogeneration plants.

## OPPOSED JET MICRONISING PROCESS

The use of opposed jet mill produced micronised silica of particle sizes 5 $\mu$ m and 10 $\mu$ m. The micronising process enables particles to be accelerated to supersonic velocity by the carrier air inside a specially designed nozzle. Opposite particle streams from the nozzle collide in the tiny micronising chamber for comminution to take place. The high amount of kinetic energy released inside the chamber enhances the effectiveness of the micronising process. For compressed air flow rate of around 2 Nm<sup>3</sup>/min, a capacity of around 50 kg/h can be achieved for micronised silica of particle size 10 $\mu$ m. Micronising, classification and drying can be carried out in a single process. The synthesis of micronised white amorphous silica and its potential applications in cementitious products is shown in Appendix A. Experimental application of foamed concrete containing micronised silica as one of the pre-commercialisation activities is shown in Appendix B.

## CONCLUSION

Innovative exploitation of solid wastes in foamed concrete is expected to revolutionise the construction process. A method of soft soil stabilisation with foamed concrete containing micronised silica is proposed for a postgraduate programme. The programme could lead the establishment of research centres focused on renewable energy, advanced materials for construction and manufacturing.

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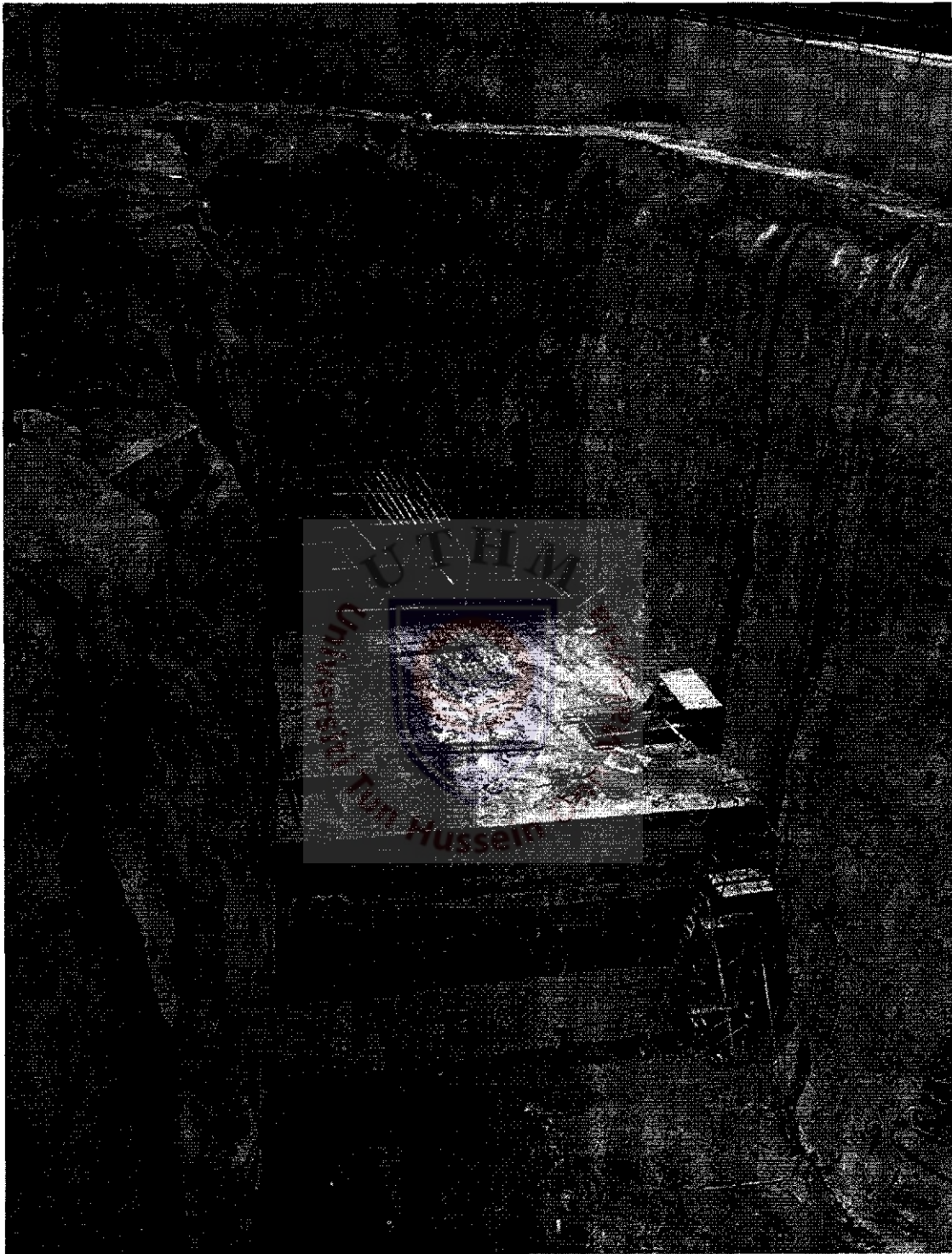


Figure 1 Foamed concrete application at the SMART tunnel in Kuala Lumpur



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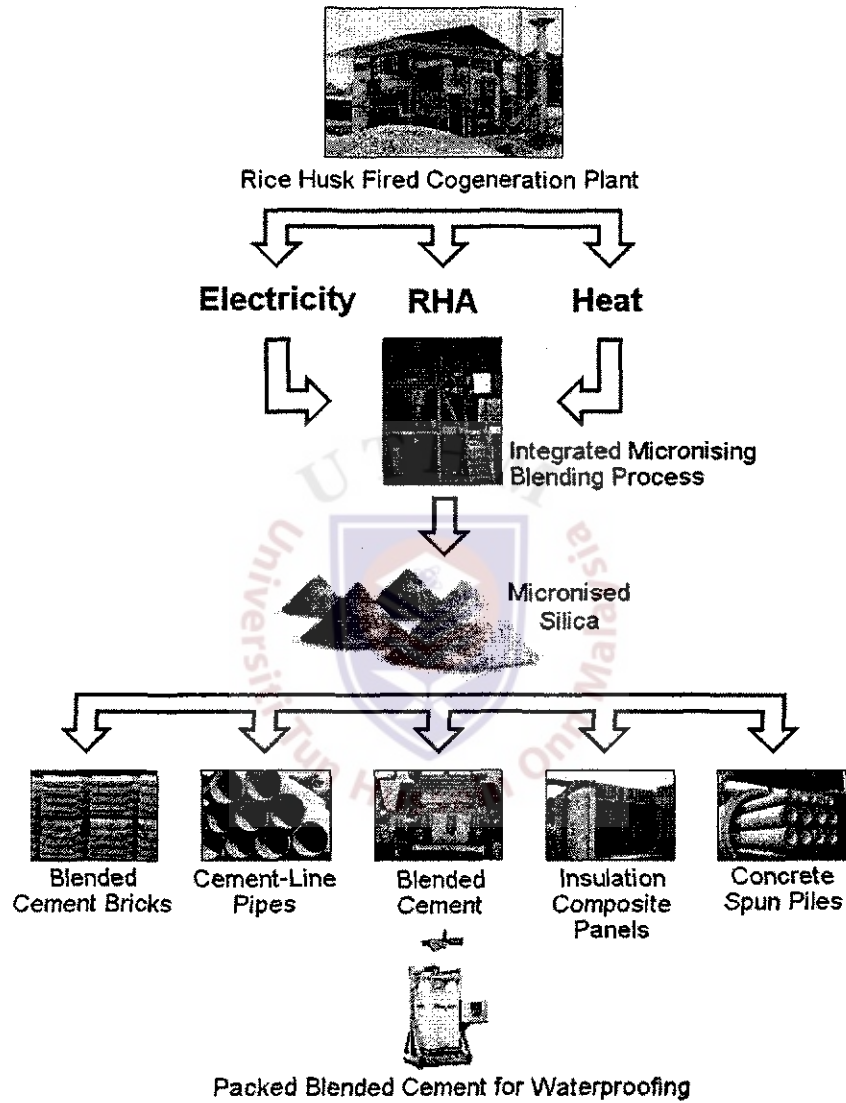
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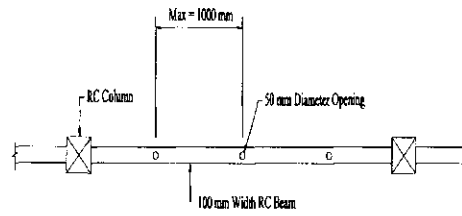
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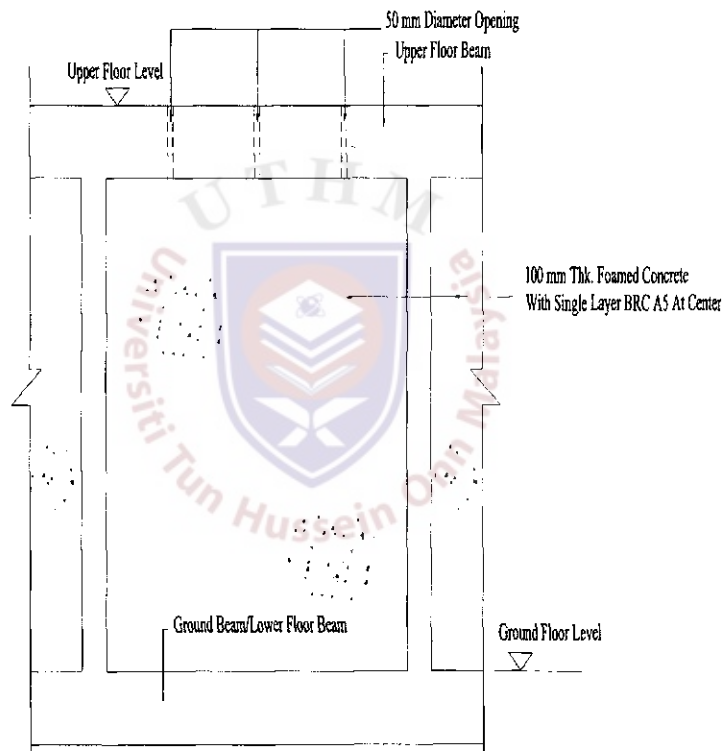
## POTENTIAL APPLICATIONS OF MICRONISED SILICA



## Appendix B



UPPER FLOOR PLAN



ELEVATION