BCA-NUS R&D Project

Development of High Strength Lightweight Concrete With and Without Lightweight Aggregate

Objective:

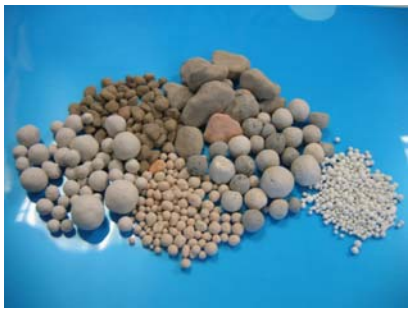
- This project aims to **enhance buildability** in the building and construction industry by carrying out a systematic and extensive R&D to develop **cost-effective** high strength lightweight concrete (HSLWC) with and without aggregate (LWA) **for various matching applications** such as with energy-saving features to improve or maintain good indoor thermal environment in buildings, fire-proof, sound-proof and floating structures etc.

- One of the key deliverables of this project is to develop HSLWC for non-structural application for large panel external walls, partition walls, volumetric precast components and closed cell bath units with weight below 1000kg/m3 while satisfying other performance requirements.

- The study also includes the assessment of HSLWC for structural applications.

Main Achievements to-date:

- Techniques for production of **various types of cost-effective HSLWC** with density ranging from **below 1000 to 2000 kg/m3** and compressive strength ranging **from 10 to 90 MPa** have been successfully developed **without** using **lightweight fine aggregate** and **expensive lightweight coarse aggregate** (such as Liapor from Germany).



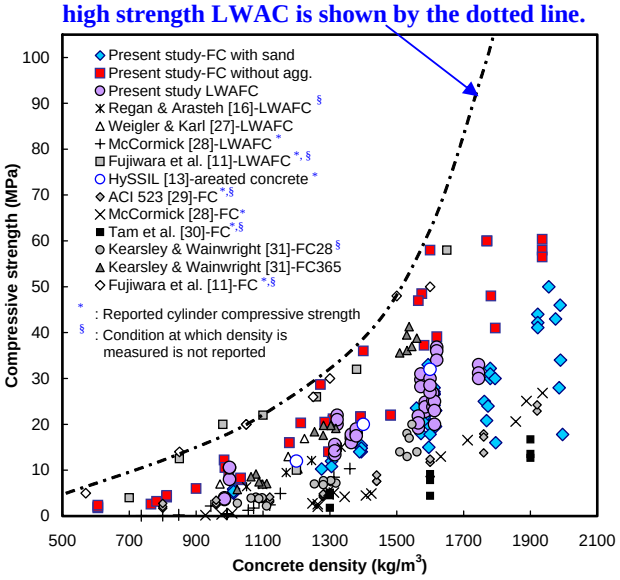
Different types of LWA

LWA Concrete Core

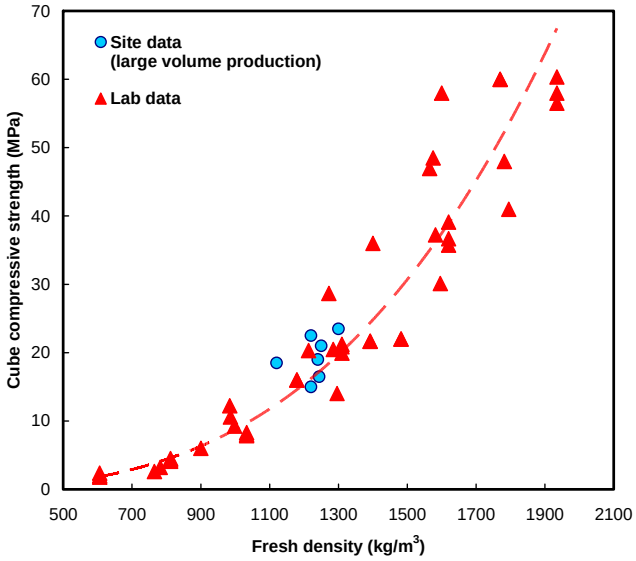
Various Types of HSLWC with and without LWA

- **Foamed concrete** has also been produced with density and strength to **match the current state-of-the-art of the development of lightweight aggregate concrete (LWAC) including high strength LWAC, up to grade 60 MPa.**

The current state-of-the-art of the development of LWAC including high strength LWAC is shown by the dotted line.



Comparison of Lightweight Foamed Concretes produced in this project with Aerated Concretes of others and the current state-of-the-art of LWAC



Foamed concrete produced at laboratory and site

- **With** such a **high strength lightweight foamed concrete**, **combination of foamed concrete with LWA will offer the possibility of a material giving high reduction in weight and significant thermal insulation, yet having sufficient strength for many applications**. In other words, **more choice of types of LWC is available based on cost and application for compressive strength up to 60 MPa.**

- Following the successful development of the HSLWC, low-cost lightweight wall panels were produced and they were found to satisfy the performance criteria of BS 5234:Part2:1992. A **pilot test was carried out** in which the low-cost lightweight wall panels were produced and erected on site in June 2005 **at the Centre for the Arts at National University of Singapore (NUS)**. The performance of these installed walls is being monitored. To date, the performance is good.

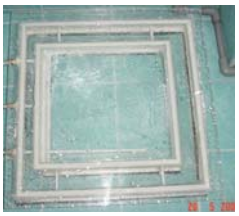
Pilot test using low-cost lightweight wall panels, produced in lab and erected on site in June 2005 at the Centre for the Arts at NUS.

- In a further development, the incorporation of hollow cores into walls to further reduce its weight was revisited and an **optimization methodology has been derived to yield the best design for producing light and strong hollow core walls by extrusion**. US provisional patent has been filed for the optimization methodology by NUS.

Precast lightweight concrete wall panel produced by extrusion method with optimized cross section geometry

- An **innovative cost effective technique to minimize/control cracking at joints of precast wall panels, has also been invented** and US provisional patent has been filed by NUS. This invention also doubles up to prevent water leakage at the joints of external precast wall panels.

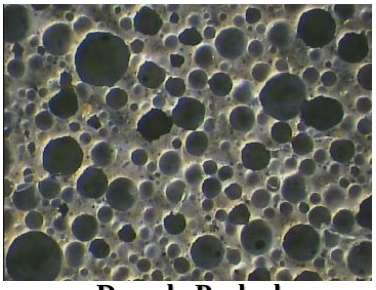
- To address the concern of water ingress into HSLWC and encourage its use in external wall and wet areas, a **technique to speedily and effectively waterproof the concrete in-situ has been invented.** US provisional patent has been filed by NUS for this technique.



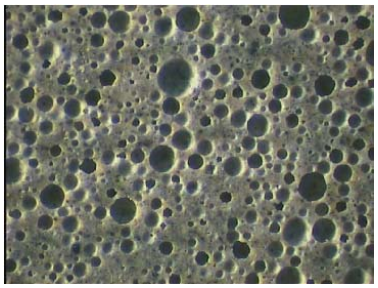
- The **combination of all the above techniques collectively offer a solution for cost effective use of HSLWC for non-structural application in wet and outdoor conditions**, such as external walls and closed cell bath units, with weight below 1000kg/m^3 while satisfying other performance requirements.

- A **portable adiabatic temperature rise (ATR) chamber has been invented** to accurately track the concrete temperature rise under adiabatic condition, due to the heat liberated from the hydration reactions. Knowledge of this heat generation can be used to advantage leading to a speedy and cost-effective mass production of precast wall panels. An International Patent Application (PCT) has been submitted for the invention.

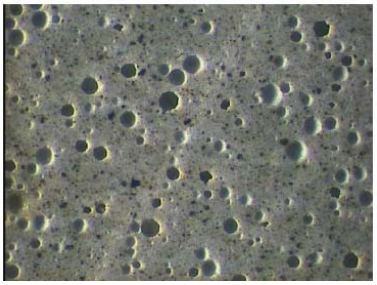
Some Microscopic pictures of Air-void system in Lightweight high strength foamed concretes with different density of packing of isolated air bubbles



Densely Packed

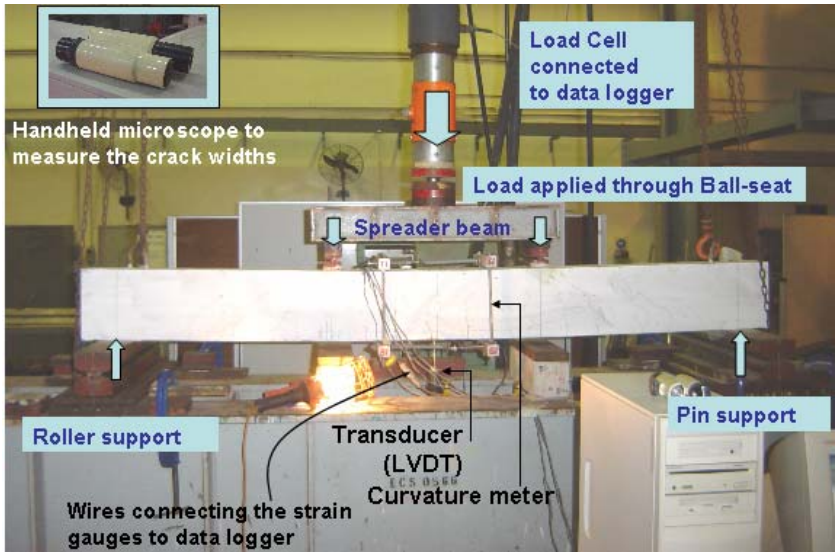


Moderately Packed



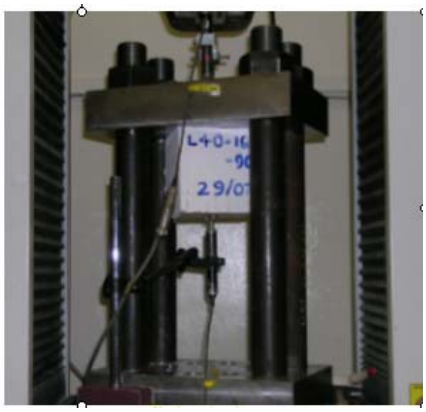
Loosely Packed

Some of the various tests on properties and behaviours of HSLWC to provide technical information and guidelines for various applications…….



Testing of HSLWC beam under flexure

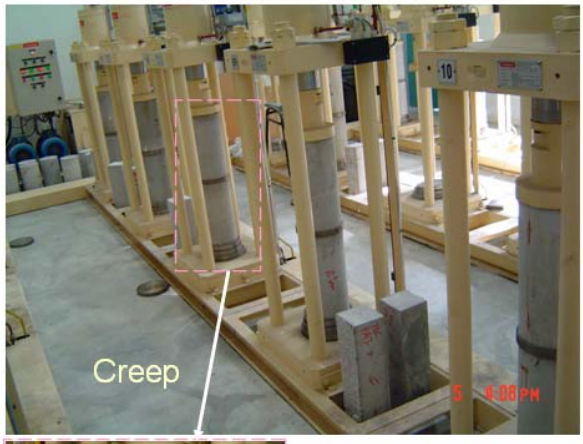
Study on bond strength & Bond stress vs slip behavior of various HSLWCs



Study on bond strength & Bond stress vs slip behavior of various HSLWCs

Study on modulus of elasticity and stress-strain behaviour

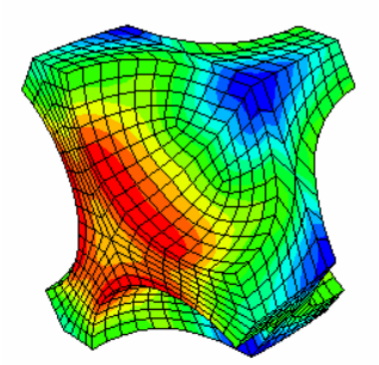
Study on Shrinkage and Creep of various types of HSLWC with and without LWA



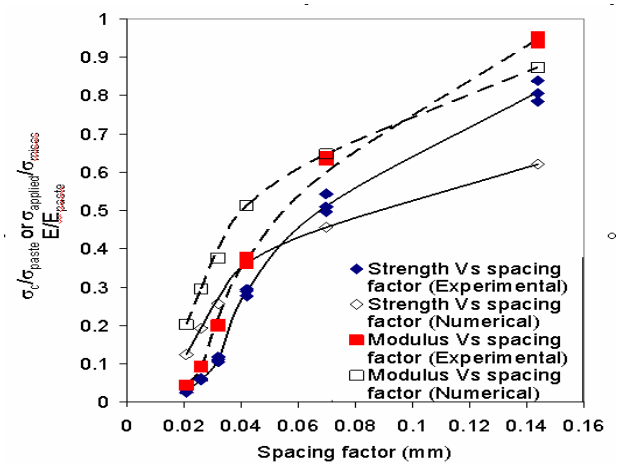
ASTM C 512

Hydraulically controlled creep rigs.

Numerical analysis on effect of air-void system on mechanical properties

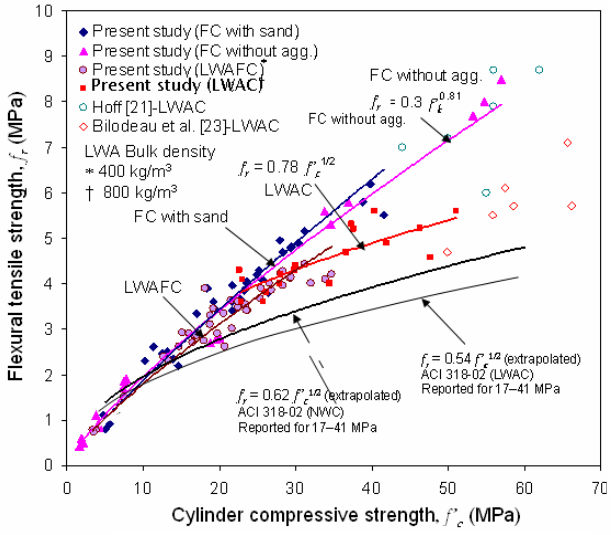


Stress contour of model meshed with 20-node brick element under compression loading

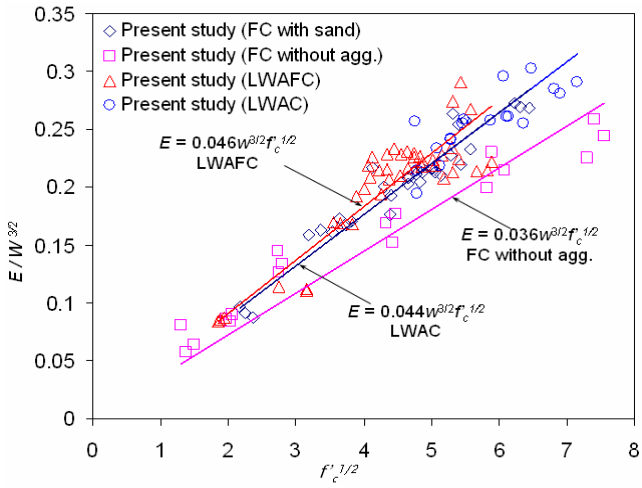


Comparison of experimental and Numerical analysis

For details, please refer to "Air-void system of foamed concrete and Its effect on mechanical properties", ACI Materials Journal, V, 103, No. 1, January-February 2006, 45-52.



Comparison of flexural tensile strength of various types of HSLWC



Comparison of modulus of elasticity of various types of HSLWC

For details, please refer to "Recent developments in lightweight high strength concrete with and without aggregates", The Third International Conference on Construction Materials: Performance, Innovations and Structural Implications, University of British Columbia, Vancouver. Canada, 22-24 August 2005. (INVITED PAPER)

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