

The Future of Green Concrete Revolution



The Art of Lightweight Technology





Care & Passion

Industrial Wastes and Climate Change have been a topic of utmost importance that affecting all aspects of life from Geopolitics to Economies to Migration.

World Leaders have been scrambling for the best solution to combat global warming and decarbonisation to achieve sustainable environments for our Just One Earth.

Gramata's R&D is set up for a purpose which dares to share solution for waste materials. Gramata's R&D has spanned the last seven years, including on how to recycle industrial wastes such as glass, red mud, marine clay, ceramic, coal bottom and fly ash, demolition hardcore, etc, of which some contain heavy metal and toxicity.

Gramata continually does research and development to transform waste materials into a neutral state and safe use as **Structural and Non-Structural Lightweight Green Aggregates (LiGrA)**. This **Noble Green Material Innovation** is a **revolutionary** and great impact for construction and other industries to reduce cost of foundation, increase column span, boost productivity, enhance heat insulation besides saving on logistic and transportation costs indirectly while saving fossil energy and achieving a sustainable environment.

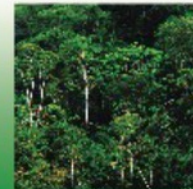
Reduction on natural resources, **Recycling** waste materials and **Reusing** such new sustainable green material are everyone's and every company's responsibility to the earth for a circular economy. These three-pronged creative innovation, waste management and reducing man-made environment impacts are the solution to every country achieving Zero waste and Green country sustainable development goals to make our Just One Earth a better living ecosystem for future Generations.



Boediman WIDJAJA, MBA
Founder & CEO JOE Green Group

"Inventing and Developing Novel Lightweight Green Aggregates from Waste Materials to Support Global Climate Challenge to Build a Sustainable Future"

go green  go global



NOW IS THE RIGHT TIME

According to World Bank:

2.24 billion tonnes of solid waste in 2020

According to Journal of Science, NATURE:

30 billion tonnes of Concrete is used each year.

How to recycle waste in Concrete?

The answer is 



zero waste

LiGrA
Lightweight Green Aggregates

SOCIAL AND ECONOMIC IMPACT OF CARBON EMISSION



The cost of adapting coastal areas to rising sea levels

Relocation of whole towns



Loss of the capacity to work due to heat

Shrinking productivity of harvests



More wars to gain access to limited resources

Prices of basic foodstuffs and consumer goods will rise



Extreme meteorological phenomena will cause widespread poverty



Fresh water will be in short supply in some areas

Diseases will spread due to higher temperatures



Coal Bottom Ash



Marine Clay



Demolition Waste



Bauxite Waste



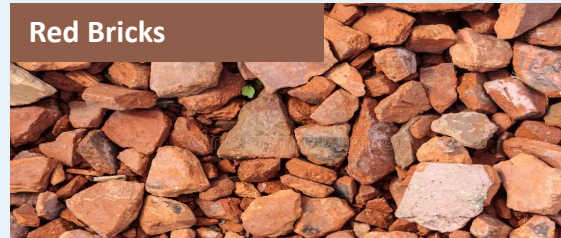
Ceramic & Porcelain



Glass Waste



Red Bricks

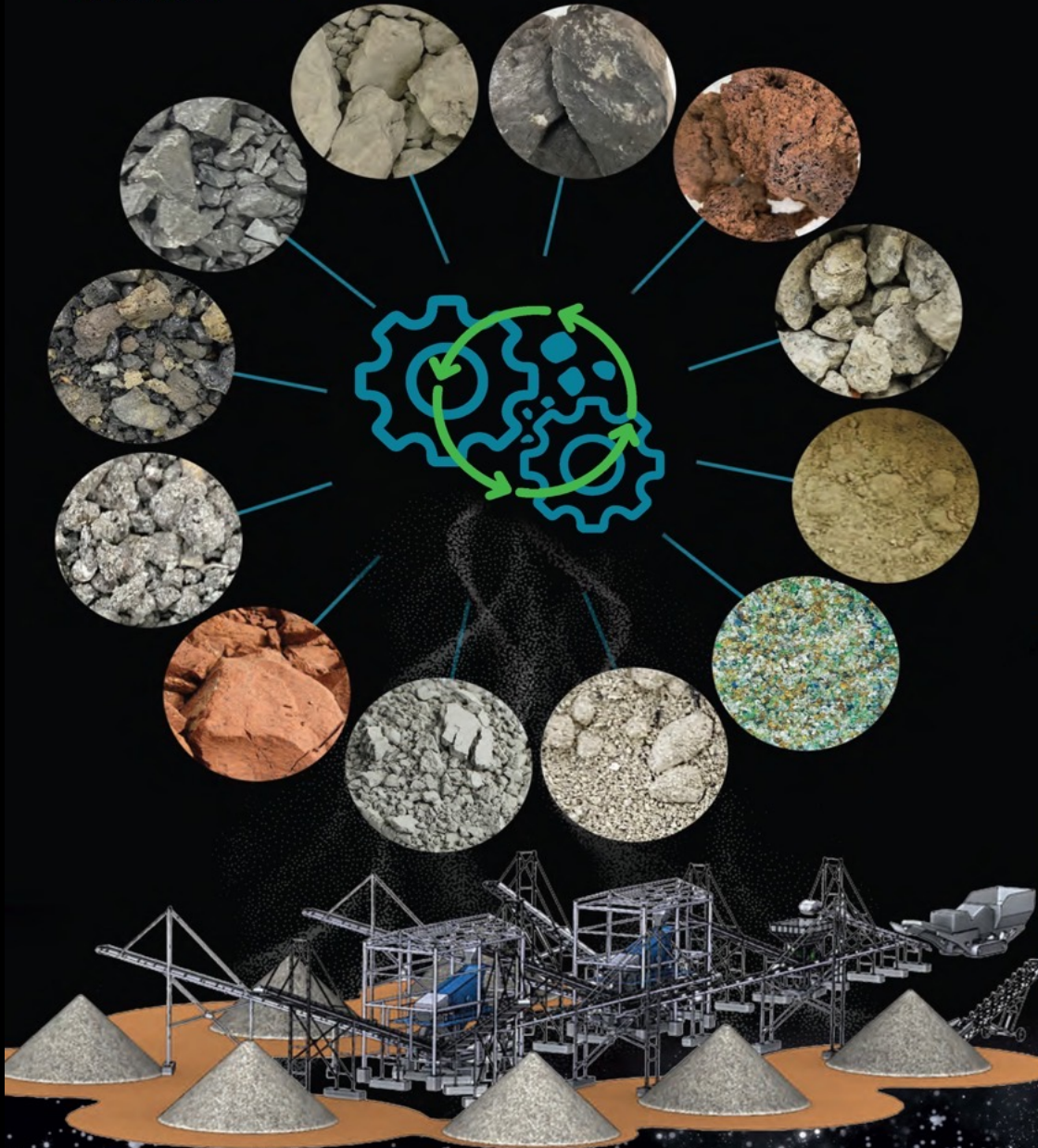


Roof Tiles



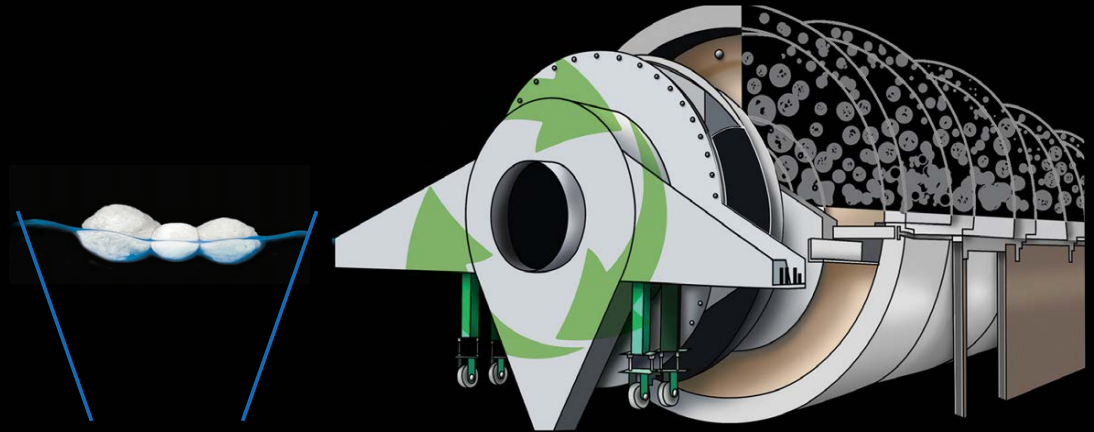
Industrial & Consumer Wastes

- ✓ Transforming inorganic waste materials into new structural and non-structural Lightweight Green Aggregates (LiGrA)
- ✓ Waste Management Solution and recycling into new materials
- ✓ State of the art technology to encapsulate heavy metal and toxicity for green building and safe use of mankind



The Engineering of Lightweight Green Aggregates

We acquired state of the art technology from overseas experts and higher learning institutions to identify, calibrate and formulate lightweight green aggregates from various types of inorganic wastes. The equipment has also been tailor-made for these specific purposes.



Inhouse R&D

- Lightweight aggregate using various waste materials
- Lightweight concrete mix design and performance
- Water reducing agent – for cement and quarry fines
- Super absorbent - natural and synthetic
- 3 in 1 Coating – skim, paint base coat and waterproofing
- Waterproofing Coating
- Wood plastic composite
- Wood LWA composite



THE STRAITS TIMES | SATURDAY, SEPTEMBER 10, 2022



Joe Green's Lightweight Green Aggregates (LiGrA) building materials (above) are made from recycled waste. PHOTO: JOE GREEN

Smarter recycling, greener concrete

Joe Green

Concrete is the most widely used commodity in the world and supports the growth of cities through housing and infrastructure.

But it is bad for the built environment. According to German news agency Deutsche Welle, the manufacturing of more than four billion tonnes of cement is responsible for about 8 per cent of global carbon dioxide emissions – more than double the numbers notched up by global flying or shipping.

But what if there were greener ways to make concrete? That was the mission of Mr Boediman Widjaja, chairman and founder of Joe Green, a global group based in Singapore which manufactures innovative building materials for the precast wall business, the built environment and industrial applications.

One of its top-selling ranges is the Lightweight Green Aggregates (LiGrA) line of building materials such as panels and precast concrete. It is made from recycling waste materials such as ceramics, ash, sludge and glass – which, according to the latest report by Singapore's National Environment Agency, form only between 8 and 13 per cent of all waste recycled.

Research and development for

the manufacture of LiGrA started in 2015, with Joe Green staff collaborating with industrial and academic experts from countries including Japan, China, Russia and in Europe. The final product was ready in 2020. Joe Green now produces about 60,000 cubic metres per annum of LiGrA in the form of lightweight concrete aggregates.

The company displayed lightweight wall panels and structural and non-structural LiGrA products at BEX Asia.

Mr Widjaja, 60, graduated with a master's degree in business administration in 1989 from the Florida Institute of Technology in the United States, and has more than 20 years of experience in distribution and trading in South-east Asia, Europe and the US.

"The building materials available in the market today are manufactured from precious natural minerals such as clay, gravel, sand and shale, and imported from overseas. In producing LiGrA from waste, we not only solve the waste disposal problem, but also reduce the exploitation of natural minerals such as granite and sand," he says, adding that Singapore is one of the biggest importers of such natural resources to cater to the demands of the built environment.

Wednesday, December 07, 2022



Our economy is currently based on a linear production and consumption model in which resource wastefulness is inherent.

A major portion of goods post-consumption ends up in landfills or are incinerated which leads to significant economic losses. Also, this leads to over exploitation of the environment thereby posing a threat to the planetary boundaries.

The solution lies in moving to a circular economy. It will lead to a reduction in waste generation and also reuse the generated waste. Thus, reducing the environmental pressure through the reduction in the rate of extraction of raw materials. This also offers benefits in terms of value retention in otherwise waste or under-utilized materials.

JOE Green had foreseen the need for sustainable and circular economy under the 3R Green Concept since its inception 2006 into Precast Hollow core Wall Panel Business. Reduce, Reuse, Recycle.

Our products with hollow core profiles had help reduces: Raw material content by more than 30%, coupled with usage of blasted furnace slag further reduced more than 20% reliance of OPC usage, 50% content of mineral end tail waste from granite quarry – manufactured sand in replacement to concrete sand extracted from natural resources.

Recovery of other industrial waste & transforming to New Lightweight Green Aggregate- LiGrA.

These contributes to lighten up building dead loads, lower carbon footprint. Savings in foundation design, Cost & time with higher productivity and performances.

Since 2015, with more focus on Green Effort and continue its vision to be a Green Builder and Zero Waste Manufacturer. Our journey begins with R&D into carbon neutralizing projects, searching for ultimate solution to manufacture light-weight green aggregate from waste and create a sustainable circular economic built environment.

With successful R&D results, JOE Green commences its venture into setting up an innovative plant to recycle waste into new materials as Light weight Green Aggregate – LiGrA for various industries applications.

Having its new Manufacturing Plant commissioning in Q3 2022 under operation of Gramata Fordea, JOE Green's Green Effort would lead the group of companies into the New Era of achieving its ESG policies and Sustainable Development Goals.



JOE GREEN MARKETING PTE LTD

THE ART OF LIGHTWEIGHT TECHNOLOGY

JOE Green is especially honoured and privileged to have the opportunity to be named once again as one of the top 50 SMEs in the 2022 - E50 Awards. We are grateful and blessed to be able to receive such a prestigious award, we are humbled.



We hope to take this opportunity and spotlight to be able to create a positive difference for the building, construction, and material for a greener and brighter future. In addition, we wish to have this prestige award, we could attract more customers and stakeholders to join our Green projects to save our Just One Earth.

businessstimes.com.sg/singapore/smes/joe-green-makes-concrete-go-green?session-refresh=1

THE BUSINESS TIMES

ENTERPRISE 50

Published Thu, Mar 02, 2023

Joey Kang, Ng Yan Bin, Phua Wei Lin

Joe Green makes concrete go green

WHAT do the upcoming public flats in Tengah estate have in common with Changi Airport's Jewel? The answer may not be immediately visible, but it is central to both developments: their eco-friendly precast concrete walls, supplied by Joe Green Marketing.

The company is a registered Housing and Development Board supplier, and its precast panels are used in over a thousand residential, industrial and commercial buildings in Singapore. Besides being physically lightweight, Joe Green's hollow-core concrete panels are light in terms of environmental impact, as they are made from recycled materials.



Joe Green Marketing's founder and managing director Boediman Widjaja (right) and marketing director Charlina Lim at the Enterprise 50 Awards in 2021.
PHOTO: JOE GREEN MARKETING

THE BUSINESS TIMES

Wednesday, May 03, 2023

Moving light, but with strength: Joe Green sees potential in hi-tech recycled building materials

With new Ligra product, founder Boediman Widjaja seeks to set an eco-friendly example for the industrial waste and construction sector.

BY CHLOE LIM

BUILDING materials manufacturer Joe Green is committed to a zero-waste manufacturing process. Its concrete panels are made of recycled materials, and waste or residual material from the manufacturing process is also reused.

The result of this process is a panel that is both sustainable and lightweight, allowing Joe Green's end customers to build green buildings at lower costs both financial and environmental.

But Joe Green, which was founded in 2006 by Boediman Widjaja, is now facing competition from other building materials companies that are also keen to offer lightweight products. One example is autoclaved aerated concrete walls, which contain air pockets to make them lighter.

So, what will continue to set Joe Green apart? Widjaja, who is both chairman and managing director, is looking to the company's lightweight green aggregate (Ligra) product – the fruit of several years of research and development.

Enter Ligra

Joe Green's Ligra development dates as far back as 2015, as the company considered ways to stay ahead of the competition. "We knew that we had to further improve our own product to truly stand out in the market in the long run, because just being lightweight (at some point) was not enough," said Desmond Ng, technical director at Joe Green.

More than just lightweight and environmentally friendly, Ligra boasts strength and durability. These two factors tend to be compromised in lightweight materials, said Widjaja.

"Lightweight products in the market these days tend to end up very porous, which could compromise the final solid nature of the panel eventually," he said.

Water could end up seeping into wall panels more easily, and create a more drying texture in the long run.

Widjaja said Joe Green's Ligra panels prioritise density and firmness without compromising on the lightweight element.

In its development, Joe Green faced the challenge of sourcing raw materials. "To produce lightweight aggregates, one would need to import them, said Ng.

"We needed to find the best and nearest source (of such material) and ensure that these supply chains were stable."

This turned out to be difficult. "Most neighbouring countries, such as Malaysia and Indonesia, are not (consistently) working on lightweight aggregates," Ng said.

The company could have been sourced for these materials in further markets, such as China, India or Thailand. "But the high costs of imports did not make sense for us," he added.

In addition, many of these lightweight aggregates did not

meet Joe Green's standards, as they did not come from natural sources. So, in 2017, Joe Green started its own inventory of aggregates instead.

These materials have been or are being used in various projects: residential ones such as the up-and-coming Tengah estate, healthcare buildings from National University Hospital to Sengkang General Hospital, and local universities such as the National University of Singapore (NUS), Nanyang Technological University and Yale-NUS College.

"As Ligra continues to be lightweight, transport of the material continues to be cheaper, which saves on overall costs as well," Ng said.

"With buildings made from Ligra, the dead load of the entire building will be 30 per cent lighter, which means now reinforcements can be lighter as well."

Construction processes are also sped up, and hence more efficient, he added. "Furthermore, in that process, a lower dead load due to less concrete (mass) used brings down the carbon footprint as well."

Joe Green has begun mass producing Ligra at its factory in Johor, as the company prepares to promote Ligra with market partners this year. Said Widjaja: "Within this year, we are expecting to see a good response to the product."

A key R&D focus

The "continuous investment" in

research and development (R&D) that has made Joe Green's Ligra product possible has been a core component of the company's activities, said Ng.

"While Ligra has been a main focus in our R&D work, we also spend time and effort improving the systems and operations behind our products," he said. This may take the form of improving existing precasting structures and making lighter 3D-printed products.

"It's always good to sell the standard panel; but in the past, we've received feedback that we were not serving enough customisation needs," Ng said. "So, from 2015, we've been working on more custom options of our panels, to offer various sizes and material types."

With Ligra, wall panels can be made solid or hollow, for example, in the event that wires need to be inserted within the wall. Ng said customised offerings have minimised risks in the construction process and reduced wastage by 5 per cent.

With potential enhanced margins from Ligra, the team at Joe Green is hopeful that more resources can be allocated for R&D.

A 'revolution' for the concrete industry

Ng is looking forward to continuing Joe Green's development of Ligra.

"There will be different models," he said. "Ligra is made from waste glass. We hope to treat bottom ash to make Ligra in the future."



JOE GREEN'S Lightweight Green Aggregates (Ligra) (below) building materials are made from recycled waste. The company has started mass-producing Ligra at its factory in Johor (above), as it prepares to promote the product with market partners this year. PHOTOS: JOE GREEN



It may take some time for Joe Green's product to win over customers, though. "Added costs must be justifiable," Ng said. "But we are sure that market recognition will come quickly for us."

A recent report by French multinational Schneider Electric and the Singapore Green Building Council said 61 per cent of business leaders cited cost and return on investment as their biggest concerns when it comes to green building adoption.

At the same time, an overwhelming 95 per cent of respondents agreed that 80 per cent of Singapore's buildings should be "green" by 2030.

The report surveyed more than 500 business leaders across 340 multinational corporations and

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Desmond Ng, technical director JOE Green

Benefits of lightweight green concrete and aggregates

LIGHTWEIGHT GREEN CONCRETE

- Saving in construction cost and time
- Saving in handling and transportation cost
- Saving in foundation cost
- More durable structures
- Higher earthquake resistance
- Longer building service life
- Bigger space savings between columns
- Lintel & stiffener joint cost savings
- Lower crane capacity
- Energy savings benefits
- Sustainable environments built

LIGHTWEIGHT GREEN AGGREGATES

- Extra lightweight and strong
- 100% biodegradable and recyclable
- Environmentally friendly
- Lower carbon footprint
- Economic and competitive
- No hazards to health
- Non combustible
- High resistance to fire
- Good thermal insulation
- High acoustic insulation
- Low water absorption

Recycled lightweight concrete advantages over normal weight concrete

- Internal and external curing
- Strong interface between aggregate and cement
- Modulus compatibility of aggregate and cement

- Continuous strength gain
- Lifelong durability
- Uniform stress distribution

SOURCE: JOE GREEN
GRAPHIC: BT VISUAL

and Malaysia, the company has a plant in Jakarta, Indonesia.

It plans to target every major city in Indonesia.

"Considering Indonesia's sizeable population of over 250 million people, we hope to better tap the market by building a plant in each of Indonesia's major cities, in a bid to move beyond Singapore's market, which is comparatively much smaller," said Widjaja.

He is also entertaining the possibility of going global, having had recent conversations with potential partners in China and Dubai.

"However, it's not easy to get good commercial terms on these fronts (as yet); so this continues to be a work in progress," he added.

"I daresay that Ligra is set to revolutionise the concrete industry," Widjaja said.

"As we move light but strong with this new technology, we are on track to setting an example of strength for the industrial waste and construction sector while emphasising environmental responsibilities."

chloe.lim@sph.com.sg

This is the first of a 5-part Green Business series, in collaboration with UOB, exploring sustainability trends across businesses and industries.

Brought to you by:



Thursday, May 11, 2023

In the commercial field, sustainable development is not only a key factor affecting the long-term survival and development of enterprises, but also a responsibility of enterprises to society. The "Sustainable Operations for the Future" series interviews companies in various fields that develop sustainable materials or adopt sustainable business practices to learn how they overcome challenges and seize opportunities for sustainable development, benefiting from them now and in the future, and benefiting society.

Developing environmentally friendly technology lightweight aggregates to create zero-pollution green buildings.

“

In the first six years, we suffered huge losses continuously. My family and friends even asked me to give up, but I did not retreat at all.

”

■ Lu Lishan

An entrepreneur's firm belief to lead a local zero-waste manufacturer company against all odds in its journey towards sustainable development and greening of areas and the global construction industry.

In 2006, Director Mr. Boediman Widjaja (61 years old) registered JOE Green in Singapore and set up a factory. At that time, the local construction industry began to switch to using prefabricated cement wall panels. The Construction Bureau also encouraged construction companies to reduce or replace traditional labor and time-consuming, highly polluting red bricks that require kiln firing.

With few competitors, he saw a business opportunity and set up a local factory to produce pre-fabricated cement wall panels. At present, the company is one of the largest suppliers of pre-fabricated cement wall panels in the local area. The hollow cement wall panels developed by it are used in regional and local construction projects.

It has completed more than 1,000 industrial and commercial projects, private residences, government HDB flats and subway construction projects locally, including Jewel Changi, as well as many hospitals such as the National Cancer Center of Singapore and Sengkang General Hospital. In 2013, it entered the construction of government HDB flats.

However, Mr. Widjaja's efforts are not limited to this. He used high-tech recycling waste to produce green prefabricated cement wall panels. Later, he successfully developed and produced the raw material of these cement wall panels - green lightweight aggregate (LiGrA, Lightweight Green Aggregates), to provide alternative raw materials for the wider construction industry. However, there are many obstacles along the way.

First of all, Mr. Widjaja, who was born in Indonesia, was a successful computer agent in Indonesia and the local area in the first half of his life. He changed his career in middle age and entered the field of greening engineering in the construction industry. After that, he started learning from scratch.

The company initially rented a factory building in the Tuas area. Unexpectedly, in 2007, Indonesia announced an embargo on the raw material to produce cement wall panels: sand and stone. This made Mr. Widjaja determined to speed up the research and development of recycling waste as raw materials for production.

He recalled: "In the first six years, we suffered huge losses continuously. My family and friends even asked me to give up, but I did not retreat at all. In order to save costs, we moved the factory to Malaysia in 2011."

The plant is located in Senai, Johor, with an investment of SGD 9 million to build a 3.5 hectare plant, and additional crushing equipment to crush and process industrial waste such as tiles and wall panels.

Produce green raw materials with lightweight technology

This year, they successfully developed Recycled Concrete Aggregates, becoming one of the zero-waste manufacturers, and used it to produce prefabricated hollow cement wall panels. As a result, they became the first company to be awarded the four ticks by the Singapore Green Building Council. One of several high scorers.

The company's name, JOE (Just One Earth), lives up to the green mission: We only have one Earth. Mr. Widjaja said: "We must protect the earth and slow down the impact and depletion on the environment, especially in the construction industry."

The construction industry has one of the highest carbon footprints, accounting for 40 percent of global carbon emissions and one-third from the production of building materials such as steel, cement and glass. Concrete used in construction also requires other raw materials, such as sand or granite, which need to be transported long distances during the mining process, deepening the carbon footprint.

Cement is the most widely used substance on earth, but the cement industry is responsible for about 8% of global warming and carbon dioxide emissions - far more than the global aviation industry's carbon emissions.

When JOE Green designs and produces prefabricated hollow cement wall panels, it reduces the required raw materials by about 40%, and uses more than 30% of renewable cement aggregates produced from industrial waste.

Next, JOE Green is developing towards renewable lightweight technology. They imported lightweight aggregates from abroad to produce renewable lightweight wallboards. In 2015, they developed their own scientific research and used industrial waste glass to produce green lightweight aggregates.

With funding provided by UOB, JOE Green has been able to deploy resources to develop research and development programs aimed at achieving sustainable business growth. UOB is still continuing to cooperate with the company to meet its business development needs.

In 2017, the company purchased a land near the factory in Malaysia to prepare for the production of the second factory. Unexpectedly, the epidemic interrupted all progress, and the plant was not completed until 2022 to start production.

As of the first quarter of this year, green lightweight aggregates have been used by various industries, such as ready-mixed concrete industry, cement prefabricated parts industry, chemical industry, etc. Product testing, providing them with green lightweight aggregate as a raw material for the production of green products.

These green lightweight aggregates will be further made into lightweight prefabricated parts (wall panels), which are lighter in weight, durable, heat-resistant and earthquake-resistant, so buildings can have a longer life, save air-conditioning power consumption and building safety, condensation.

The company can also make larger and lighter prefabricated components according to the needs of individual projects, which greatly reduces transportation fuel consumption, reduces crane capacity during installation, and speeds up construction due to larger components, greatly reducing carbon footprints.

Small particles, big vision

JOE Green is currently developing steadily locally, in Malaysia and Indonesia, and currently has a factory in the capital Jakarta.

The company is also developing towards regionalization and internationalization. Many countries such as China, Vietnam, India, the Middle East and African countries have expressed interest, and the company will find suitable cooperation solutions, including technology transfer or other strategic cooperation.

Mr. Widjaja emphasized: "Especially those countries that generate a large amount of industrial waste can set up LiGrA plants; these industrial wastes include coal bottom ash (slag), bauxite waste (red mud), glass or bottles, ceramic tiles and marine clay."

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Locally, my country currently only recycles about 15% of glass waste, and there is still 85% of waste to be converted into useful renewable products, so there is huge room for development.



Mr. Boediman Widjaja, Founder and Director of JOE Green: Doing business should not only be for profit, but to measure the present and future needs. (Special photography by Tan Shuhui)

Under the green building blueprint promoted by the government, JOE Green continues to strengthen cooperation and participation with local material recycling facilities and government departments such as the National Environment Agency, as well as environmental, social and governance (Environmental, Social, Governance).

Now they hope to successfully obtain a business license from the Environmental Bureau to carry out glass waste recycling projects and use the company's technology to carry out glass waste recycling.

In his eyes, protecting the environment is the responsibility of this generation. "Doing business can no longer be just for profit, but to measure the needs of the present and the future. We must leave a greener and sustainable environment for the next generation."

"We only have one Earth after all."



本系列由大华银行呈献



Worldwide, Buildings Account for 40% of Global Energy Consumption and 33% of Greenhouse Gas Emission



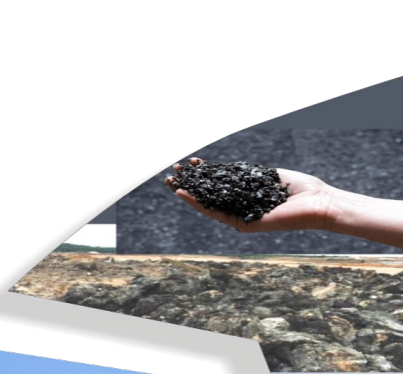
JOE Green has a Plan to Decarbonise the Industry, With a focus of Sustainability



Lightweight Green Aggregate (LiGrA) is Made from Recycled Waste, Help to reduce CO2 Emissions, Resource use and Construction costs.



JOE Green is Continuously Developing other products, with the aim of Reducing Emissions, Manpower, Resource use and Energy Inefficiency.



Bottled Glass

Waste Glass crushing

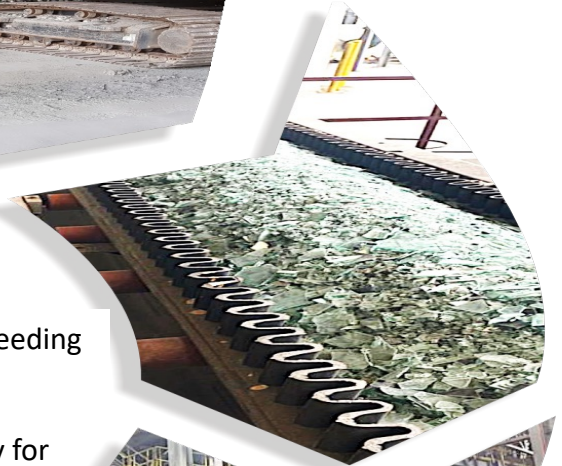
Recyclable Industrial
Wastes



Demolition Waste

 **Net-Zero**
Reduce Carbon Footprint/Emission

Waste Glass Feeding



Factory Technology for
Aggregates Production

Building



Precast
Component/Ready Mix



Various Lightweight Green
Aggregates (LiGrA)



Sustainability Solution with LiGrA:

Bauxite waste (Red Mud) & Coal Bottom Ash

Raw material

Lightweight Green Aggregates (LiGrA)



Dispose for Landfilled



Lightweight Green Concrete

Chemosphere 307 (2022) 135895



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Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere



Recycling municipal solid waste incineration fly ash in super-lightweight aggregates by sintering with clay and using SiC as bloating agent

Siyu Han, Yingchun Song, Tongya Mengdan Liu, Jinglin Li, Jianguo

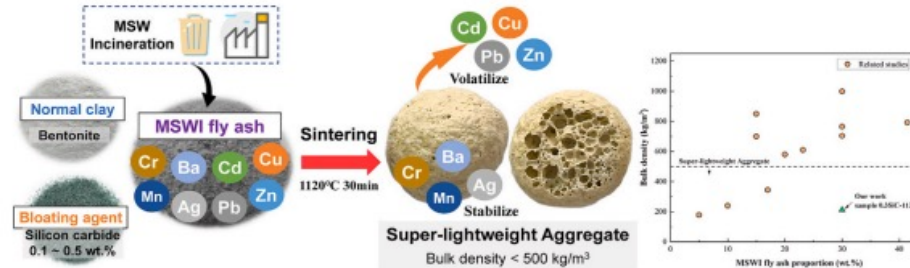
School of Environment, Tsinghua University, Beijing 100084



● Risk of heavy metal leaching toxicity has been mitigated after sintering.

HIGHLIGHTS

- SiC was applied as bloating agent to produce LWA with MSWI fly ash.
- Super-lightweight aggregate could be produced by adding 0.1–0.5 wt% SiC.
- Effects of SiC addition and sintering conditions were studied in detail.
- Risk of heavy metal leaching toxicity has been mitigated after sintering.
- Formation of complex diopside-based phase during sintering was revealed.



Effectiveness of Sintering to Encapsulate Toxicity

Coal Bottom Ash Waste

Client's Name : JOE GREEN PTE LTD
Sample Ref. : COAL POWER PLANT BOTTOM ASH

Client's Name : JOE GREEN PTE LTD
Sample Ref. : CONCRETE MORTAR WITH 100% COAL POWER PLANT BOTTOM ASH

Client's Name : JOE GREEN PTE LTD
Sample Ref. : BOTTOM ASH - LIGHT WEIGHT AGGREGATE

Test Items	Result ⁽¹⁾	Unit	Test Method	Maximum Allowable Concentration (mg/L) ⁽³⁾	Met Criteria
Arsenic (As)	< 0.1	mg/L	EPA 1311:1992 / EPA 6020B:2014	5	Yes
Barium (Ba)	0.4	mg/L		100	Yes
Cadmium (Cd)	< 0.1	mg/L		1	Yes
Chromium (Cr)	< 0.1	mg/L		5	Yes
Copper (Cu)	< 0.1	mg/L		100	Yes
Iron (Fe)	< 0.1	mg/L		100	Yes
Lead (Pb)	< 0.1	mg/L		5	Yes
Manganese (Mn)	0.1	mg/L		50	Yes
Nickel (Ni)	< 0.1	mg/L		5	Yes
Selenium (Se)	< 0.1	mg/L		1	Yes
Silver (Ag)	< 0.1	mg/L		5	Yes
Zinc (Zn)	0.1	mg/L		100	Yes
Mercury (Hg)	< 0.01	mg/L		0.2	Yes
Phenol Compounds (as Phenol)	< 0.01	mg/L	EPA 1311:1992 / HACH 8047	0.2	Yes
Total Cyanide (as CN ⁻)	< 0.01	mg/L	EPA 1311:1992 / HACH 8027	10	Yes
Fluoride (as F ⁻)	< 0.1	mg/L	EPA 1311:1992 / APHA 4500-F C	150	Yes

Remarks:

- (1) < refers to 'less than'.
- (2) Leaching Test - NEA Recommended acceptance criteria for suitability of industrial wastes for landfill disposal.
- (3) The above results were tested as per sample submitted by client.
- (4) Conformity statement reported with no decision rule applied. Uncertainty of measurement available on request.

Test Items	Result ⁽¹⁾	Unit	Test Method	Maximum Allowable Concentration (mg/L) ⁽²⁾	Met Criteria
Arsenic (As)	< 0.1	mg/L	EPA 1311:1992 / EPA 6020B:2014	5	Yes
Barium (Ba)	0.7	mg/L		100	Yes
Cadmium (Cd)	< 0.1	mg/L		1	Yes
Chromium (Cr)	0.1	mg/L		5	Yes
Copper (Cu)	< 0.1	mg/L		100	Yes
Iron (Fe)	< 0.1	mg/L		100	Yes
Lead (Pb)	< 0.1	mg/L		5	Yes
Manganese (Mn)	< 0.1	mg/L		50	Yes
Nickel (Ni)	< 0.1	mg/L		5	Yes
Selenium (Se)	< 0.1	mg/L		1	Yes
Silver (Ag)	< 0.1	mg/L		5	Yes
Zinc (Zn)	0.1	mg/L		100	Yes
Mercury (Hg)	< 0.01	mg/L		0.2	Yes
Phenol Compounds (as Phenol)	< 0.01	mg/L	EPA 1311:1992 / HACH 8047	0.2	Yes
Total Cyanide (as CN ⁻)	0.020	mg/L	EPA 1311:1992 / HACH 8027	10	Yes
Fluoride (as F ⁻)	0.5	mg/L	EPA 1311:1992 / APHA 4500-F C	150	Yes

Remarks:

- (1) < refers to 'less than'.
- (2) Leaching Test - NEA Recommended acceptance criteria for suitability of industrial wastes for landfill disposal.
- (3) The above results were tested as per sample submitted by client.
- (4) Conformity statement reported with no decision rule applied. Uncertainty of measurement available on request.

Test Items	Result ⁽¹⁾	Unit	Test Method	Maximum Allowable Concentration (mg/L) ⁽²⁾	Met Criteria
Arsenic (As)	< 0.1	mg/L	EPA 1311:1992 / EPA 6020B:2014	5	Yes
Barium (Ba)	< 0.1	mg/L		100	Yes
Cadmium (Cd)	< 0.1	mg/L		1	Yes
Chromium (Cr)	< 0.1	mg/L		5	Yes
Copper (Cu)	< 0.1	mg/L		100	Yes
Iron (Fe)	< 0.1	mg/L		100	Yes
Lead (Pb)	< 0.1	mg/L		5	Yes
Manganese (Mn)	< 0.1	mg/L		50	Yes
Nickel (Ni)	< 0.1	mg/L		5	Yes
Selenium (Se)	< 0.1	mg/L		1	Yes
Silver (Ag)	< 0.1	mg/L		5	Yes
Zinc (Zn)	< 0.1	mg/L		100	Yes
Mercury (Hg)	< 0.01	mg/L		0.2	Yes
Phenol Compounds (as Phenol)	< 0.01	mg/L	EPA 1311:1992 / HACH 8047	0.2	Yes
Total Cyanide (as CN ⁻)	< 0.01	mg/L	EPA 1311:1992 / HACH 8027	10	Yes
Fluoride (as F ⁻)	0.1	mg/L	EPA 1311:1992 / APHA 4500-F C	150	Yes

Remarks:

- (1) < refers to 'less than'.
- (2) Leaching Test - NEA Recommended acceptance criteria for suitability of industrial wastes for landfill disposal.
- (3) The above results were tested as per sample submitted by client.
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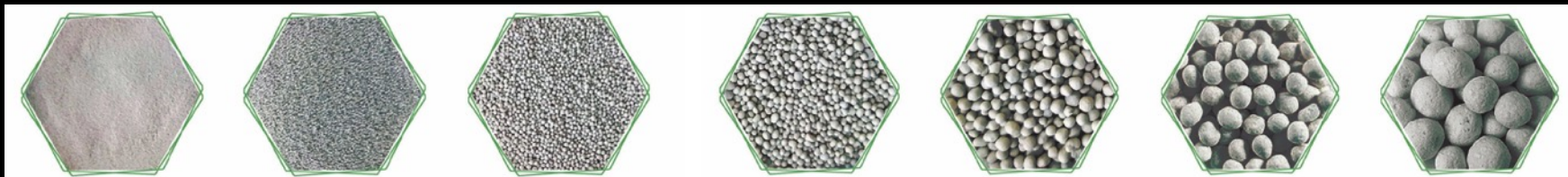
ANNUAL PRODUCTION
60.000 M³



Superior Material
Properties & Performance



Efficient and High Quality
Production Facility



Zero Waste
Manufacturing

Properties	Mikron 0.1	Mikron 0.25	Mikron 0.50	Mikron 1
Grain size [mm] ⁽¹⁾	0.1 – 0.25	0.25 – 0.5	0.5 – 1	1 – 2
Bulk Density in [kg/m³] ⁽²⁾ (± 50)	420	360	290	250
Effective particle density [kg/m³] ⁽³⁾ (± 50)	1050	790	550	450
Bulk crushing resistance [N/mm²] ⁽⁴⁾ (± 10%)	4.7	3.3	3.1	2.6
Softening point [°C]	860/1250			
Melting point [°C]	1250 – 1500			
Thermal Conductivity [W/ (m.k)] ⁽⁵⁾	< 0.07			
Water absorption % by mass (± 20%)	30			
Colour	Light creamy white			
pH value	7 – 12			
Grain form	Sphere			

Note: More than 90% of the Lightweight Aggregates (LWA) falls within the specified size.

1) Technical data given after testing basic grain sizes according to EN 13055 – 1:2016/AC: 2016

2) Manufacturing tolerance

3) According to EN 1097 – 6: 2013

4) According to EN 13055 – 1: 2016

5) According to EN 12939: 2002

The properties shown on this data sheet represent typical average results generated using standard test method, conducted under controlled conditions and cannot be considered to be guaranteed specifications. Properties are subject to normal manufacturing statistical standard deviation ranges and the company reserves the right to modify the properties and specifications at any time without prior notice.

Properties	LD	HD (Low)	HD (High)	Fahrenheit
Grain size [mm] ⁽¹⁾	3-8			
Bulk Density in [kg/m ³] ⁽²⁾ (± 50)	200	600	800	150
Effective particle density [kg/m ³] ⁽³⁾ (± 50)	320	1000	1250	270
Bulk crushing resistance [N/mm ²] ⁽⁴⁾ (± 10%)	1.8	12.5	21	0.6
Softening point [°C]	860			
Melting point [°C]	1250 – 1500			
Thermal Conductivity [W/ (m.k)] ⁽⁵⁾ (± 10%)	0.07	0.12	0.18	0.06
Water absorption % by mass ⁽⁶⁾	< 30	< 8	< 5	< 40
Colour	Off white			
pH value	7 – 12			
Grain form	Sphere			

Note: More than 90% of the Lightweight Aggregates (LWA) falls within the specified size.

1) Technical data given after testing basic grain sizes according to EN 13055 – 1:2016/AC: 2016

2) Manufacturing tolerance

3) According to EN 1097 – 6: 2013

4) According to EN 13055 – 1: 2016

5) According to EN 12939: 2002

6) According to EN 1097 – 6: 2013

The properties shown on this data sheet represent typical average results generated using standard test method, conducted under controlled conditions, and cannot be considered to be guaranteed specifications. Properties are subject to normal manufacturing statistical standard deviation ranges and the company reserves the right to modify the properties and specifications at any time without prior notice.

APPLICATIONS



PPVC & PBU Precast



Lightweight Building Materials



Lightweight Ready-Mix, Concrete & Industrialised Building System (IBS)



Hydroponic Media



Thermal Insulation
(Roofs, Floors, Fire Doors)



Floating Concrete & Structure



Insulation of Pipeline in Oilfield



Lightweight Fillers for Ceramic and Polymeric Products



Filtration Media



Heat Resistant Plaster & Dry Mortar



Geotechnical Applications (Retaining Wall, Soil Stability & Foundation)



Wastewater Treatment



Automotive Body Composite



Decorative Materials

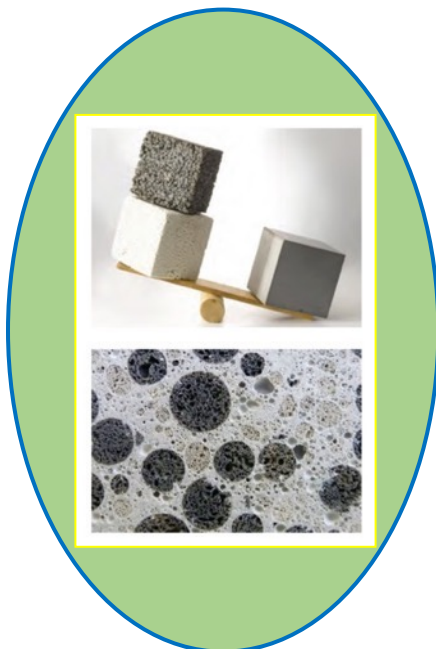
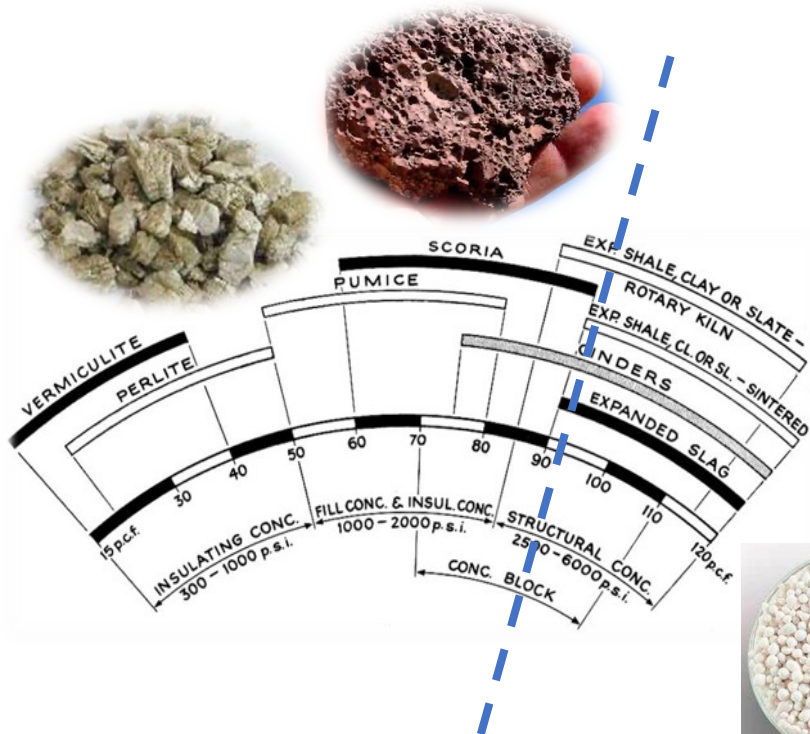


Heat Resistant Paints & Wallpapers

What is Lightweight Aggregate?

Lightweight aggregate (LWA) are granules or pellets of lightweight materials that have many applications. They can either be mined from natural sources or manufactured using minerals or waste materials.

Natural Lightweight Aggregate



What is Lightweight Concrete?

Lightweight Concrete is produced by replacing the **heavy aggregates** with **lightweight aggregates**

1 m³ of Normal Weight Concrete

Cement	Fine Aggregate (Sand)
	Coarse Aggregate (Granite)
Water	

Density = 2400 Kg/m³

1 m³ of Lightweight Concrete

Cement	Fine Aggregate (LWA)
	Coarse Aggregate (LWA)
Water	

Density > 800 to 2000 Kg/m³

→ structural application

Density < 800 Kg/m³

→ non-structural application



Structural LiGrA
Densely packed finer pores

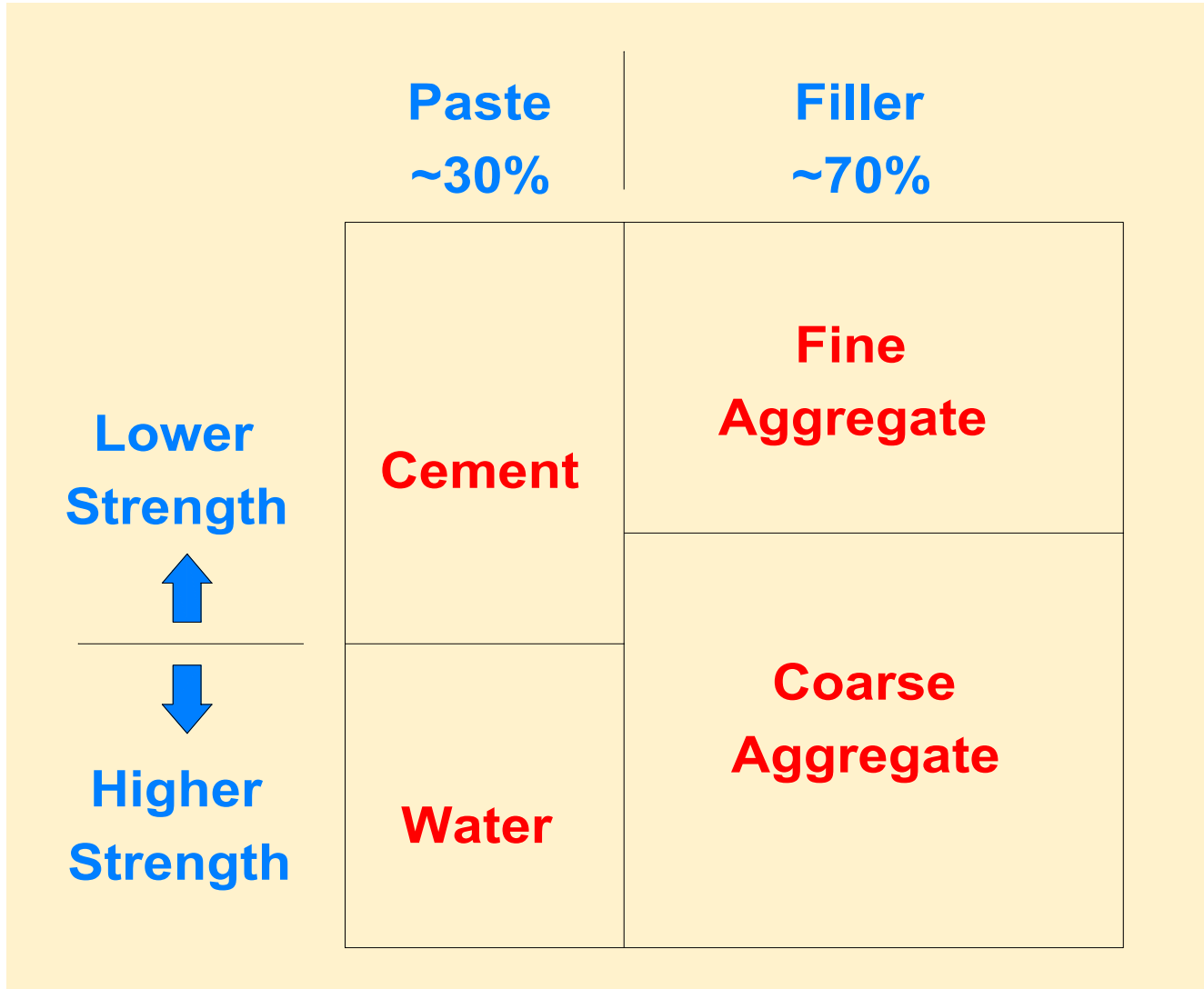


Non-Structural LiGrA
Loosely packed coarser pores

THE HISTORY OF CONCRETE - Milestones

- 1844 ○ Portland Cement
- 1849 ○ Reinforced Concrete
- 1917 ○ Lightweight Aggregate Concrete
- 1929 ○ Pre-stressed Concrete
- 1960 ○ Fibre Reinforced Concrete
- 1980 ○ Polycarboxylate Ether

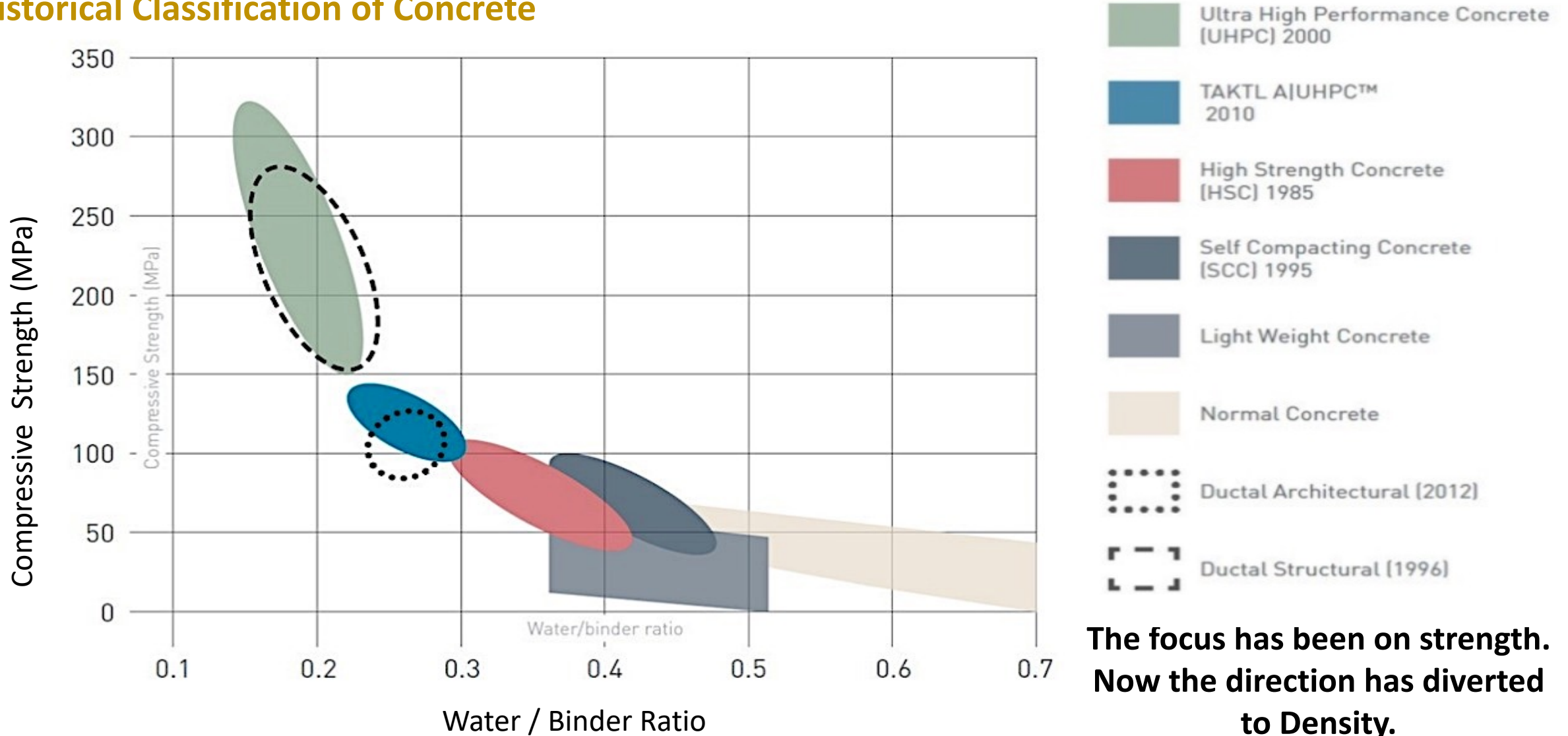
Effect if Polycarboxylate Ether in Concrete



The reduction of water in concrete increases strength but reduces workability.

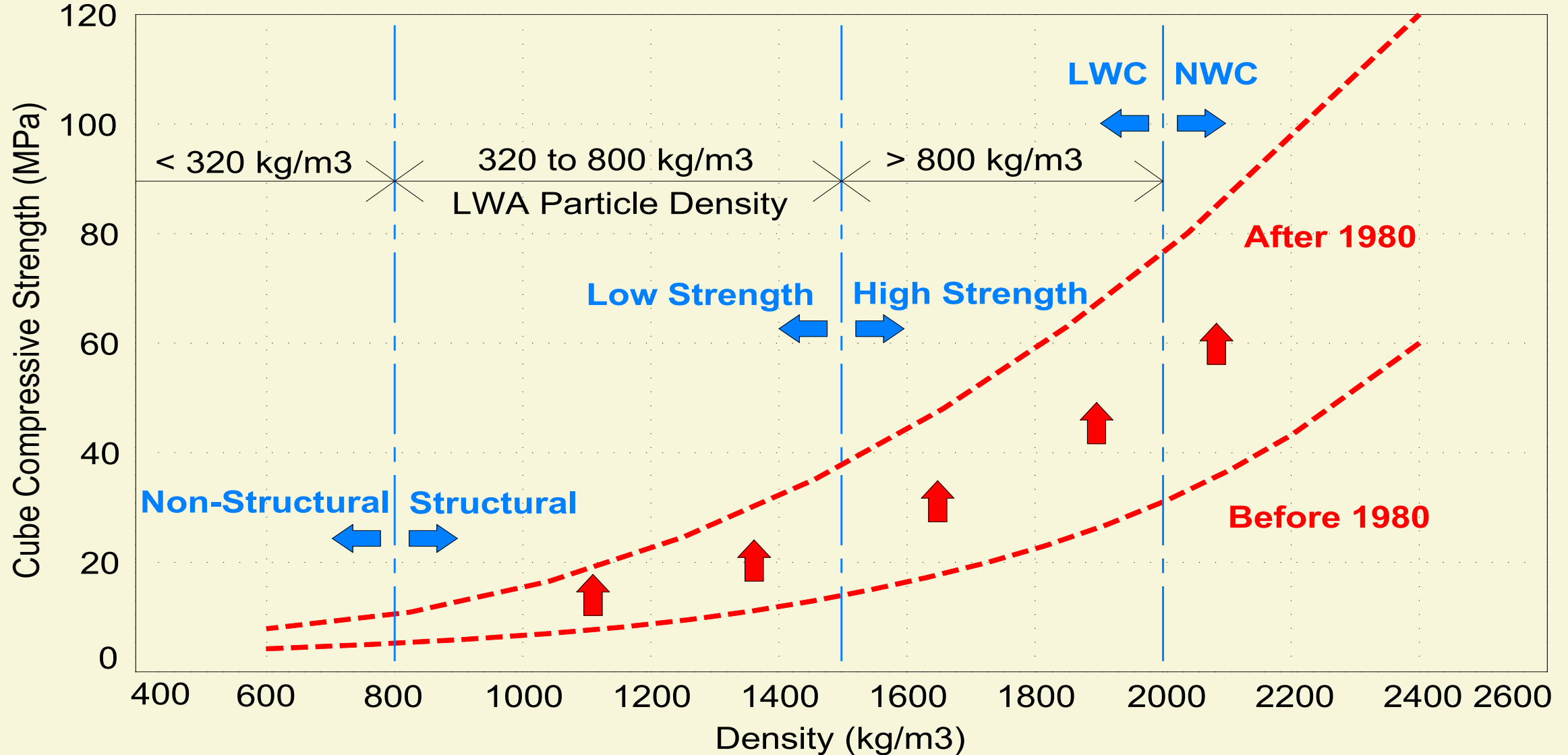
Polycarboxylate Ether helps to reduce water in concrete without reducing workability.

Historical Classification of Concrete



**The focus has been on strength.
Now the direction has diverted
to Density.**

LWC strength increases after 1980



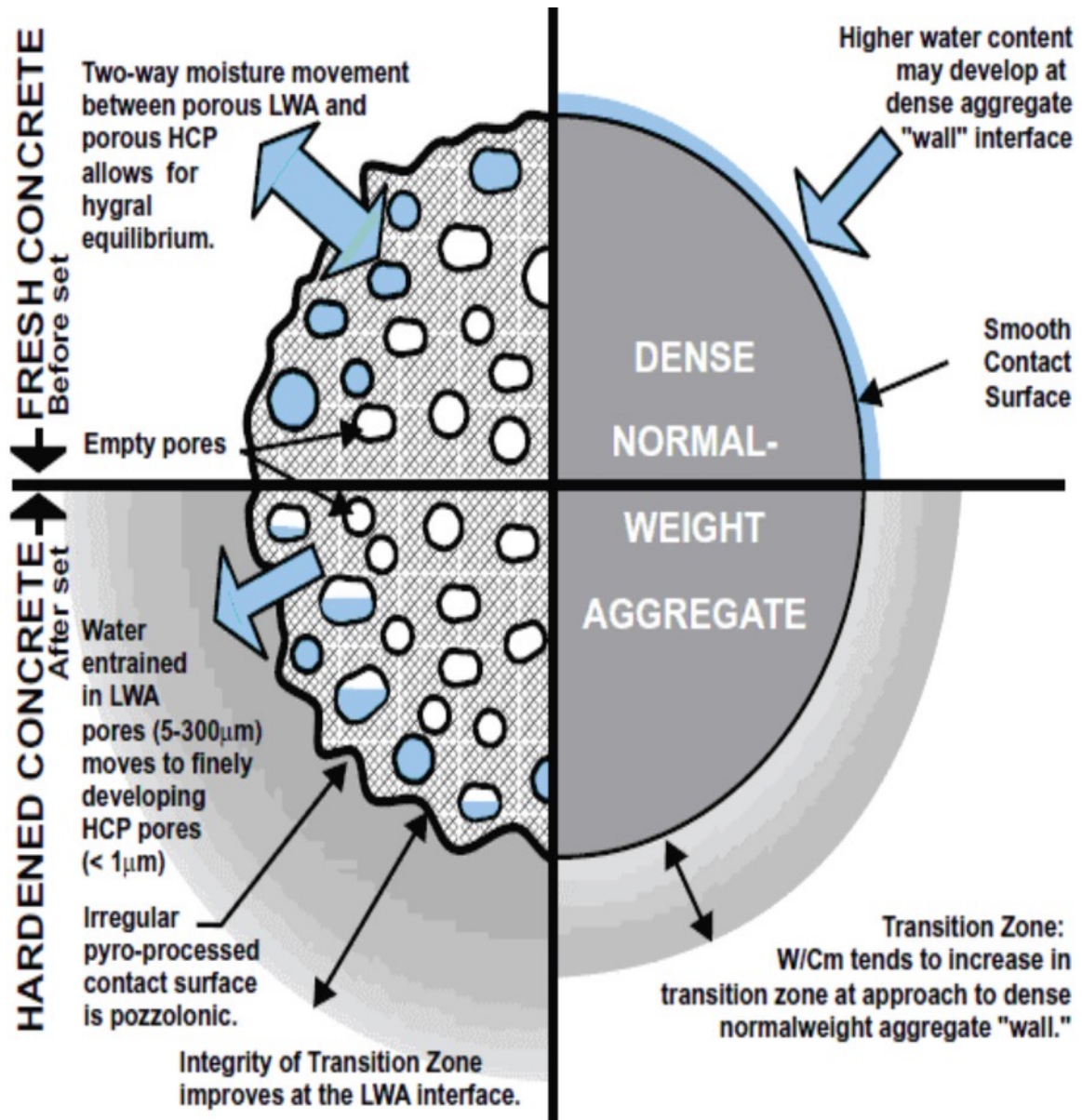


Lightweight aggregates are most commonly used in lightweight aggregate concrete. In comparison with normal weight concrete, lightweight aggregate concrete has been shown scientifically to exhibit **exceptional durability and higher performance** attributed to three factors:

1. Prolonged Internal Curing
2. Strong aggregate-cement paste interface
3. Modulus compatibility of aggregate and cement paste

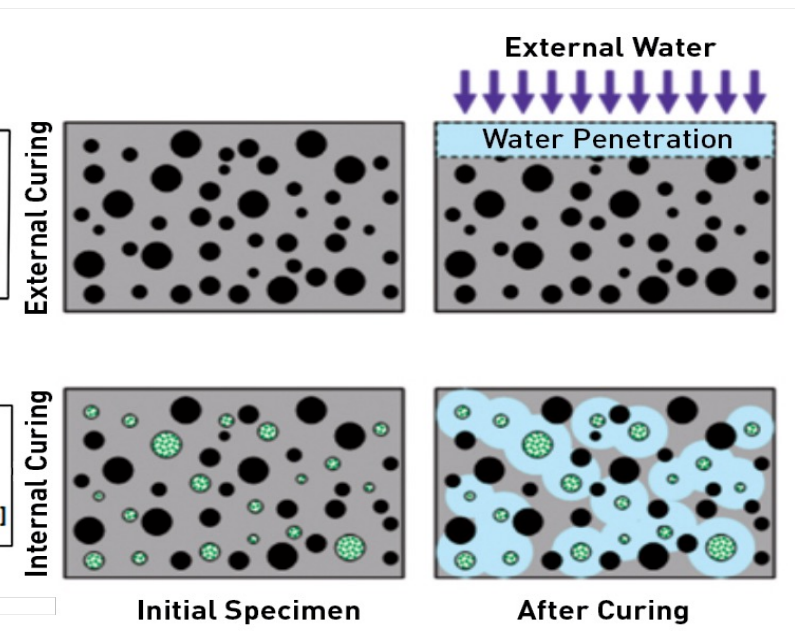
Launched in **1919**, the USS SELMA was built with lightweight aggregate concrete of compressive strength **26.7 MPa**. In **1980**, when scientists conduct core test on the ship, the strength was found have increased to **55.2 MPa**. This phenomenon is unheard of for normal weight concrete.

Internal Curing and Strong Interface

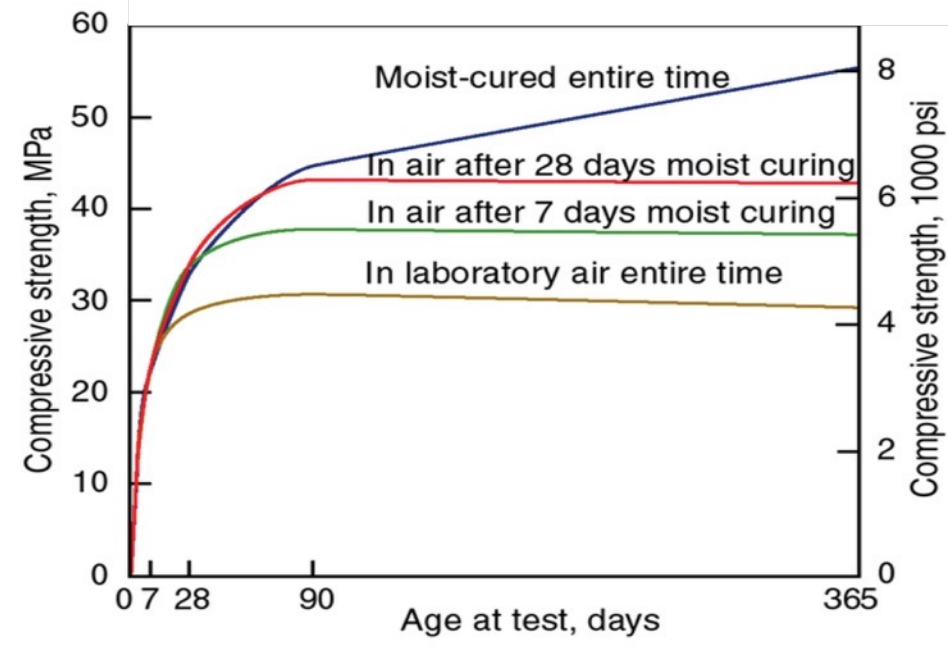


NWA
Interface between Hydrating Cement Paste (HCP) and the non-absorbing dense normalweight aggregate "wall"

LWA
Interface between two porous materials [LWA pores and Hydrating Cementitious Paste (HCP)]




● Normal Aggregate ● Water Filled Inclusion ● Cured Zone



Lightweight Concrete Structures



 **The Wellington Stadium**
New Zealand's First Use of High Strength Lightweight Precast Concrete

Leonard G. McSaveney
Golden Bay Cement, Division of Fletcher Concrete & Infrastructure, Ltd., Auckland, New Zealand

STRUCTURAL ENGINEER
Holmes Consulting Group

LIGHTWEIGHT PRODUCER
TXI Pacific Custom Materials, Inc., CA

CONTRACTOR
Fletcher Construction Ltd.

PRECAST SUPPLIER
Stresscrete

OWNER
The Wellington Stadium Development Trust



Exterior of 40,000-seat Wellington Stadium nearing completion



BRITISH STANDARD

Lightweight aggregates —

Part 1: Lightweight aggregates for
concrete, mortar and grout

BS EN
13055-1:2002
*Incorporating
Corrigendum No. 1*

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Annex ZA (informative) Clauses of this European Standard addressing essential requirements or other provisions of EU Directives	28

FACTORS	CURRENT STATUS	NEAR FUTURE
Supply	Europe USA Japan	Waste >> LWA Regional Supplier Increase
Familiarity	BS EN – 2004 / SS EN – 2008 (Eurocode 2)	
Cost	High shipping cost Use of mined minerals	Regional Supplier – lower transportation cost Use of waste – reduce cost

BS EN 1992 - Reduction Factor for Lightweight Concrete

CONCRETE MECHANICAL PROPERTIES	DENSITY CLASS	
	1.6	1.8
Compressive Strength	1	1
Tensile Strength	0.85	0.9
Shear Strength	0.71	0.75
Secant Modulus	0.56	0.71
Creep Coefficient	0.56	0.71

Why is Lightweight Concrete not commonly use?

Table 11.1: Density classes and corresponding design densities of LWAC according to EN 206-1

Density class	1,0	1,2	1,4	1,6	1,8	2,0	
Density (kg/m ³)	801-1000	1001-1200	1201-1400	1401-1600	1601-1800	1801-2000	
Density (kg/m ³)	Plain concrete	1050	1250	1450	1650	1850	2050
Density (kg/m ³)	Reinforced concrete	1150	1350	1550	1750	1950	2150

RC Self Weight Reduction

1. Class 1.6 = 30%
2. Class 1.8 = 22%

English version

Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings

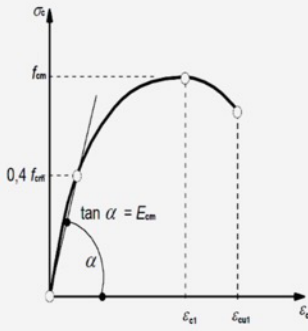
BS EN 1992-1-1:2004
EN 1992-1-1:2004 (E)

SECTION 11 LIGHTWEIGHT AGGREGATE CONCRETE STRUCTURES

11.1 General

(1)P This section provides additional requirements for lightweight aggregate concrete (LWAC). Reference is made to the other Sections (1 to 10 and 12) of this document and the Annexes.

Correction Factors for Concrete Strength

	Normal Weight Concrete	Lightweight Concrete	Remark
Comp Strength	$f_{cd} = \alpha_{cc} f_{ck} / \gamma_c$	$f_{lcd} = \alpha_{lcc} f_{lck} / \gamma_c$	$\alpha_{cc} = \alpha_{lcc} = 0.85$ and $\gamma_c = 1.5$ for both
Tensile Strength	Value given in Eurocode 2, Table 3.1	NWC value multiplied by $\eta_1 = 0.40 + 0.60 \rho / 2000$	$\eta_1 = 0.85$ & 0.89 for Class 1.6 & 1.8, respectively
Shear Strength	$v = 0.6 [1 - f_{ck} / 250]$	$v = 0.5 \eta_1 [1 - f_{ck} / 250]$	Shear Capacity Reduction = 0.71 and 0.75 for Class 1.6 & 1.8, respectively
Secant Modulus	Value given in Eurocode 2, Table 3.1	NWC value multiplied by $\eta_E = (\rho / 2200)^2$	$\eta_E = 0.56$ & 0.71 for Class 1.6 & 1.8, respectively
Creep	Value given in Eurocode 2, Table 3.2	NWC value multiplied by Factor = $\eta_2 (\rho / 2200)^2$ where $\eta_2 = 1.3$ for $f_{lck} \leq LC16/18$ $\eta_2 = 1.0$ for $f_{lck} \geq LC20/22$	Considered in water retaining structure where crack control is particularly important.
Shrinkage	Value given in Eurocode 2, Table 3.2	NWC value multiplied by η_3 where $\eta_3 = 1.5$ for $f_{lck} \leq LC16/18$ $\eta_3 = 1.2$ for $f_{lck} \geq LC20/22$	Considered in water retaining structure where crack control is particularly important.
Non-linear Behaviour		ϵ_{c1} and ϵ_{cu1} should be replaced with ϵ_{lc1} and ϵ_{lcu1} given in Table 11.3.1 in Eurocode 2	No impact when using first order elastic analysis
Concrete Protection	Exposure class given in Table 4.1 and concrete cover given in Table 4.2 in Eurocode 2	No change for exposure class. Concrete cover given in Table 4.2 increased by 5mm	Using LWC does not reduce environmental protection.

Reduction in Carbon Emission

	CONCRETE WITH		
	LiGrA	LWA	NWA
Higher Durability	EC	EC	X
Lighter Raw Material & Concrete	EC	EC	X
Lighter Precast Component	EC	EC	X
Larger Precast Component	EC	EC	X
Longer Span Structures	X	X	X
Lighter Building Weight	EC	EC	X
Better Earthquake Resistance	X	X	X
Higher Thermal Resistance	OC	OC	X
Replace Natural Resources	EC	X	X
Recycle Waste	EC	X	X

EC Reduction in Embodied Carbon Emission
 OC. Reduction in Operational Carbon Emission



The Bank of America, Charlotte, N.C. built in 1991

Lightweight concrete post-tensioned beams with floor system was selected to minimize the dead weight and to achieve the required 3-hour fire rating.

Mix Design	1	2	3
Cement (kg/m ³)	326	385	445
Fly Ash (kg/m ³)	83	83	83
LWA (kg/m ³)	534	534	534
Sand (kg/m ³)	813	763	714
WRA (l/m ³)	0.78	0.90	1.01
HRWRA (l/m ³)	1.56	2.31	2.27
Fresh Concrete Properties			
Initial Slump (mm)	63	51	57
Slump after HRWRA (mm)	130	191	171
Air Content	2.5	2.5	2.3
Fresh Conc Density (kg/m ³)	1887	1890	1890
Compressive Strength			
4 days	29.6	35.2	39.4
7 days	33.6	39.9	44.4
28 days	43.2	47.0	51.4

The Stolma Bridge, Norway

By adjusting the density of the 301 m mid-span by lightweight concrete, it was possible to move the pillars to more shallow waters and reduce the cost for foundation.



Properties of LWAC		
Mix Design		
Cement CEM-1 52.5	420	kg/m ³
Silica Fume	35	kg/m ³
Natural Sand (dry)	700	kg/m ³
LECA 800 4-12mm	600	kg/m ³
Water	208	kg/m ³
Stabiliser Melstab	12	kg/m ³
Retarder	1	kg/m ³
Leca 800 Dry Bulk Density	825	kg/m ³
Leca 800 Dry Particle Density	1450	kg/m ³
Mean Cube Strength	70.4	MPa
Characteristic Cube Strength	64.1	MPa
Demoulded Density	1931	kg/m ³
Density 28d Cubes	1940	kg/m ³

The Nordhordland Floating and Cable Stayed Bridge in Norway completed in 1993

High strength LWAC were used in the pontoons and main span of the bridge.

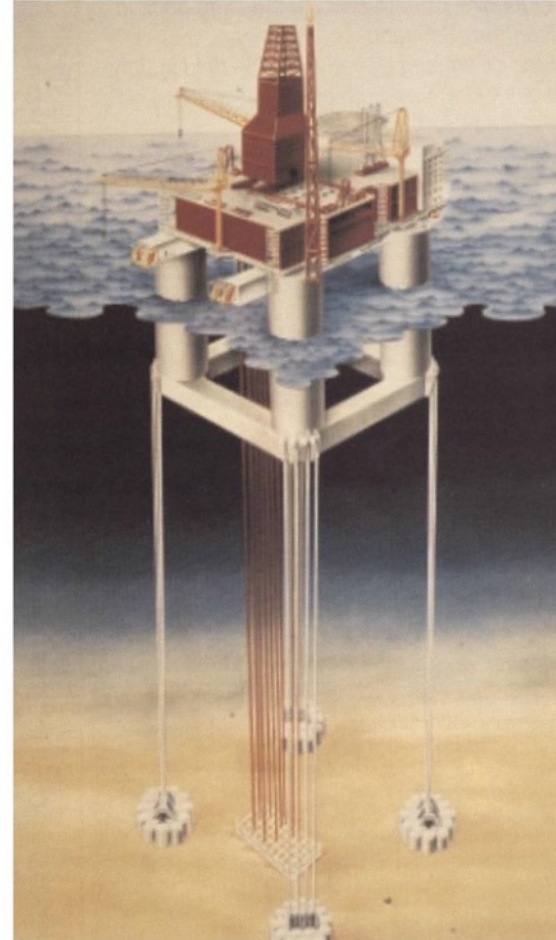


Mix Design for LWAC	LC55 in Pontoon	LC55 in Bridge	
Portland Cement	410	430	kg/m ³
Silica Fumes	33	35	kg/m ³
Sand 0-5 mm	675	630	kg/m ³
Liapor 8, 4-8 mm	270		kg/m ³
Liapor 8, 8-16 mm	325		kg/m ³
LECA 750, 4-8mm		295	kg/m ³
LECA 750, 8-12mm		275	kg/m ³
Water	200	195	kg/m ³
WRA/HRWRA	10 to 12	7	kg/m ³
Demolding Density	1918	1881	kg/m ³
Ave Cube Strength	70.4	69.9	Mpa
Standard Deviation	4.31	2.38	MPa
Bulk Density	800	750	kg/m ³
Particle Density	1440	1300	kg/m ³

The high buoyancy required for the tension leg platform was provided the use of high strength lightweight concrete.

Mix Design of LWAC		
Cement	420	kg/m ³
Silica Fume	20	kg/m ³
Sand	720	kg/m ³
Liapor 8, 4-8 mm (dry weight)	307	kg/m ³
Liapor 8, 8-16 mm (dry weight)	254	kg/m ³
Superplasticizer	6 to 9	kg/m ³
Air-entraining admixture	1 to 3	kg/m ³
Fresh Density	1885	kg/m ³
7 Day Strength	70	Mpa
7 Day Standard Deviation	3.0	
28 Day Strength	79	MPa
28 Day Standard Deviation	3.5	

Heidrun tension leg platform completed in July 1995



Application of Lightweight Concrete



Issues of HDPE Floating Solar Platform

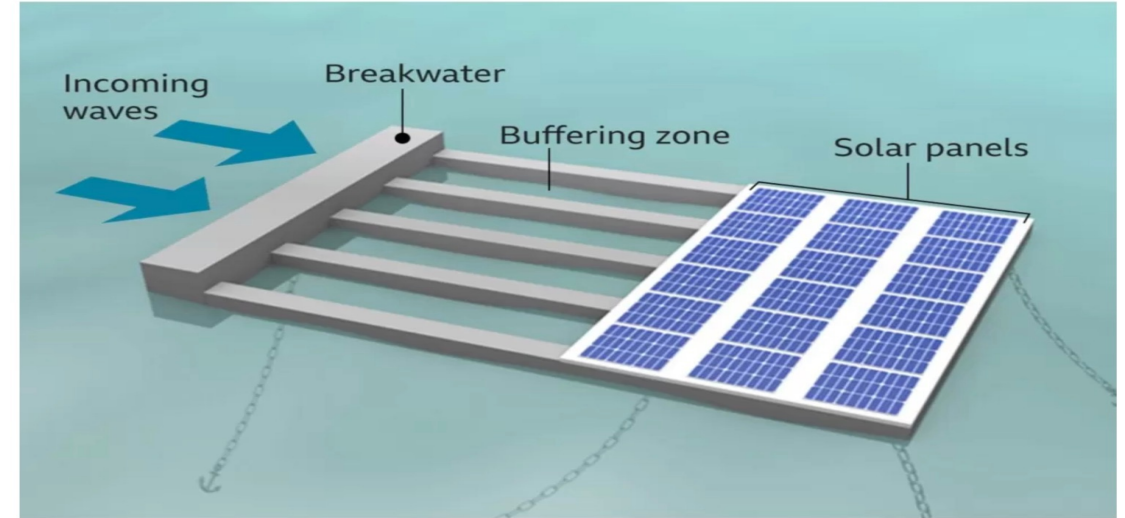


After the outermost row had ripped off the wind-facing edge did not have any ballast anymore to counter uplift from wind. The modules and floaters began to curl-up with the result of an electrical fire.

Image: Solar Power Plant Business / Nikkei Business Publications

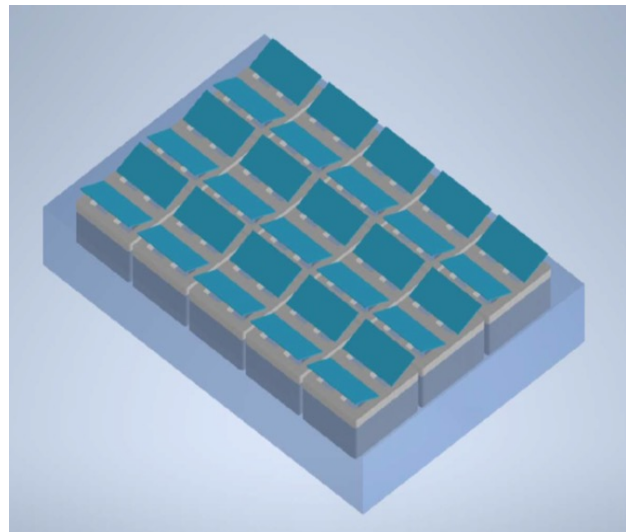


The Solar2Wave system



Source: Cranfield University

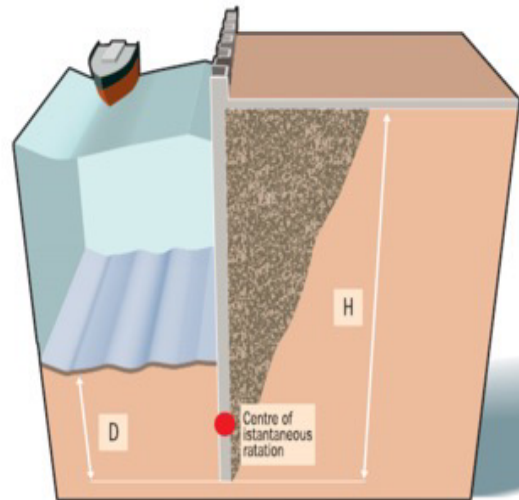
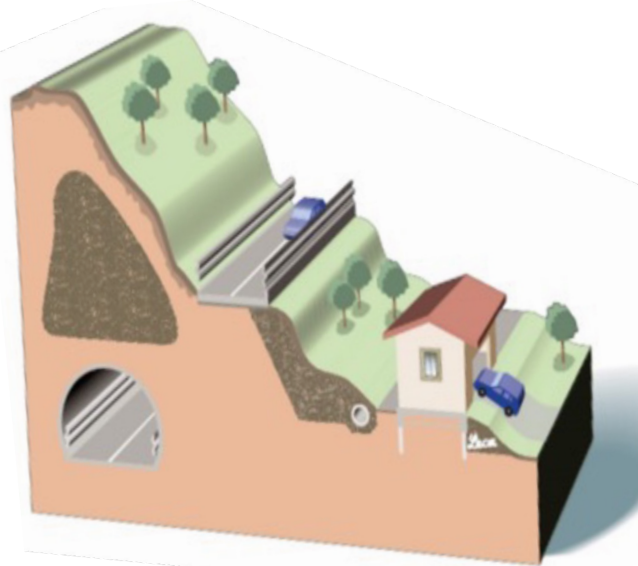
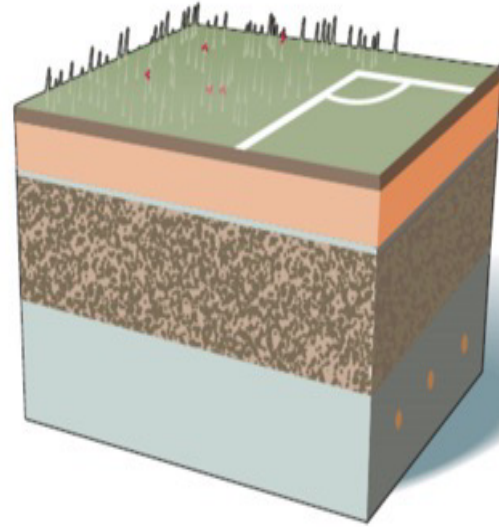
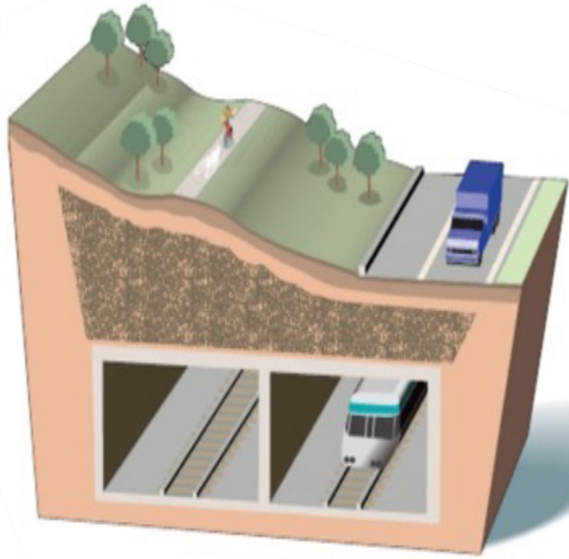
BBC



Performance	HDPE	LiGrA
Load Capacity	✗	✓
Stability	✗	✓
Contaminant to Water	✗	✓
Combustability	✗	✓
Durability	✗	✓

Other Applications of Lightweight Green Aggregates

Geotechnical Applications



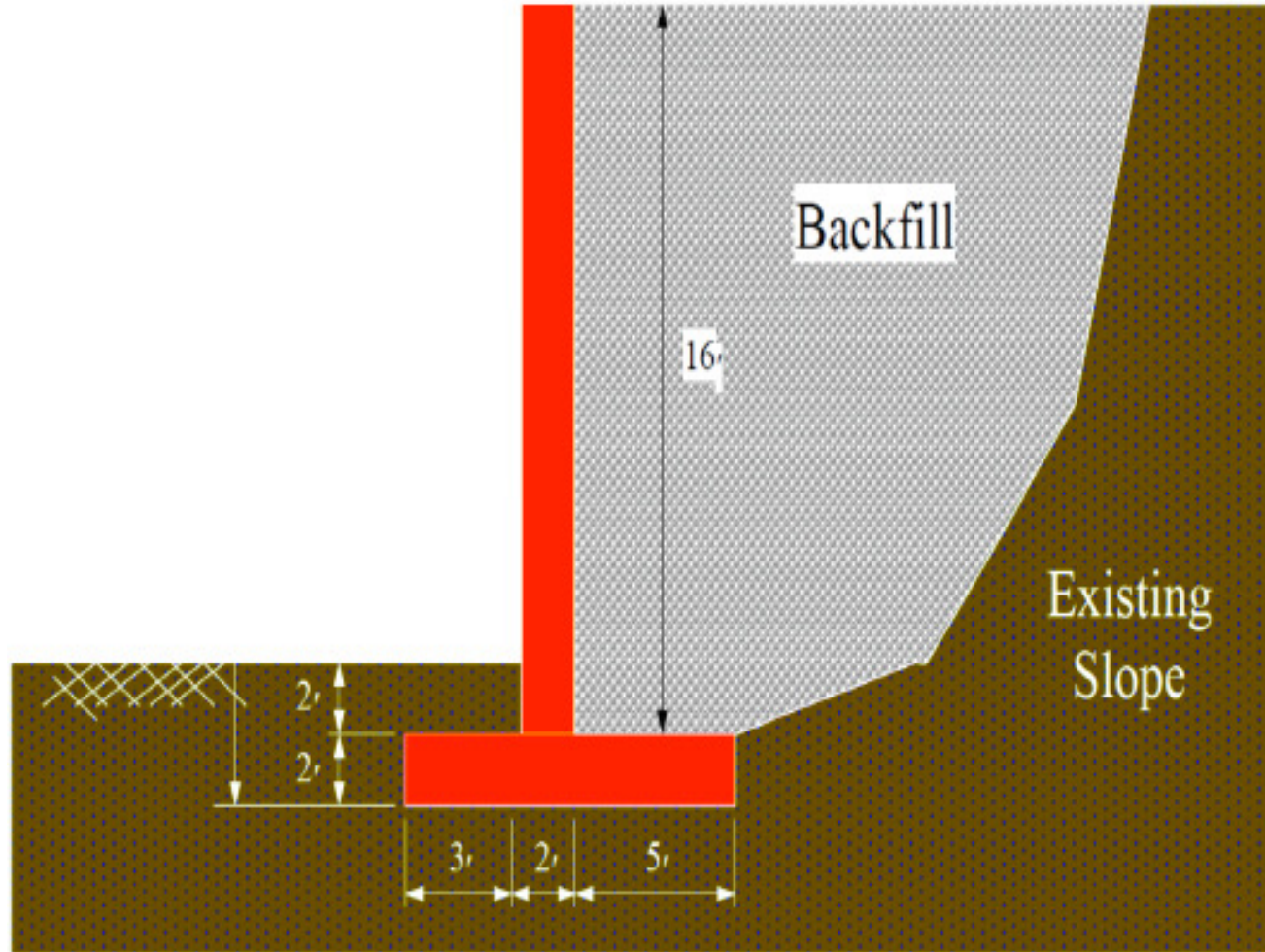
Roof Insulations



Sewage Treatment Plant



RETAINING WALL APPLICATION



Compare effect of using LW backfill on wall design

Height of Wall	5m
----------------	----

	Normal Soil	LWA
Unit Weight	1900 kg/m ³	950 kg/m ³
Angle of Friction	30 deg	42 deg

Factor of Safety	Normal Soil	LWA
Overturning	2.8	6.2
Sliding	1.6	6.2
Bearing Capacity	2.6	6.3

COMPARISON OF NWC AND LWC

	NWC	LWC
Mechanical Properties	★	
Thermal Resistance		★
Weight (lighter)		★
Durability		★
Carbon Footprint		★
Concrete Price	★	
Saving to Project Cost		★
Sustainability		★

Benefits of LWC vs NWC



Lower building weight → Lesser foundation

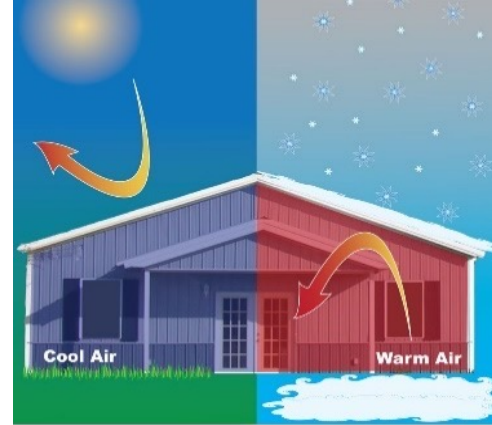


Lighter & Larger Precast Component. Longer Span → Construction cost & time saving

Benefits of LWC vs NWC



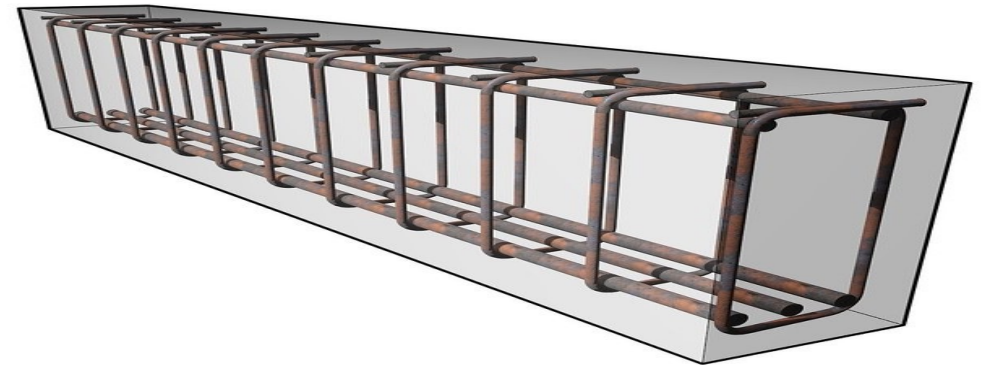
Higher Durability → **Longer life Span**
Lighter Building → **Better earthquake resistance**



Higher Thermal Resistance & Lower Specific Heat Capacity → **Lower aircon consumption & lesser condensation problem**



Lightweight → **Saving in transportation cost**



Lower concrete weight → **Lesser Reinforcement**

Additional Benefits of LiGrA vs NWC

- *Increase Sustainability*
- *Reduce Carbon Emission*
- *Solve Waste Disposal Problem*
- *Reduce Exploitation of Natural Minerals*
- *Saving in Cost*



Reduce Mining activities

Recycle Waste – Increase Sustainability



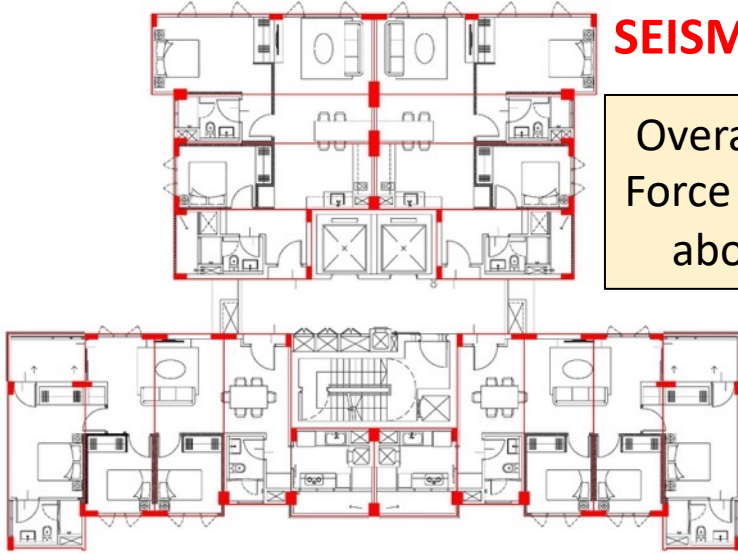
BENEFITS in Comparison with NWC	Reduction in Carbon Emission	Saving in Cost
Recycle Waste	★	★
Reduce Exploitation of Virgin Materials	★	★
Higher Durability	★	★
Lighter Raw Material and Concrete	★	★
Lighter Precast Components	★	★
Larger Precast Components	★	★
Lesser Foundation	★	★
Longer Span	★	★
Lesser Reinforcement	★	★
Higher Earthquake Resistance	★	★
Higher Thermal Resistance	★	★
Lower Specific Heat Capacity	★	★
Reduce Condensation	★	★

SEISMIC LOADING

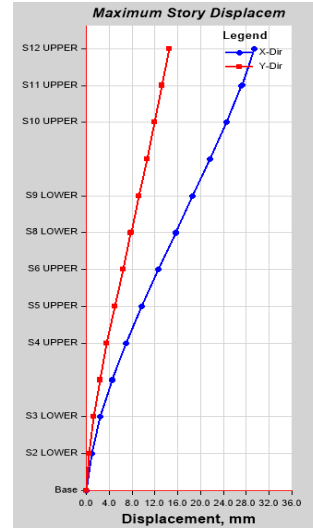
Normal Weight Concrete

Light Weight Concrete

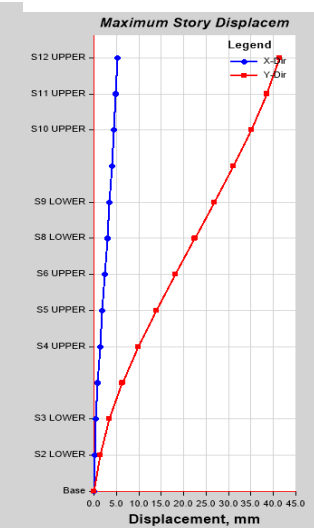
Overall Seismic Force Reduction about 10%.



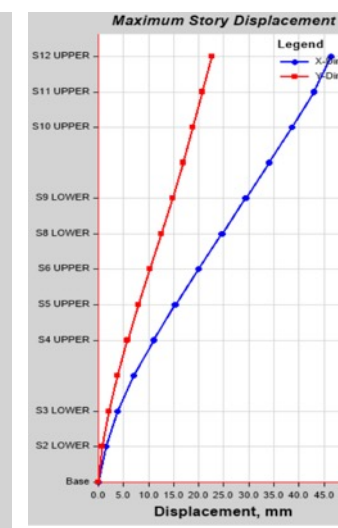
TYPICAL MODULE LAYOUT



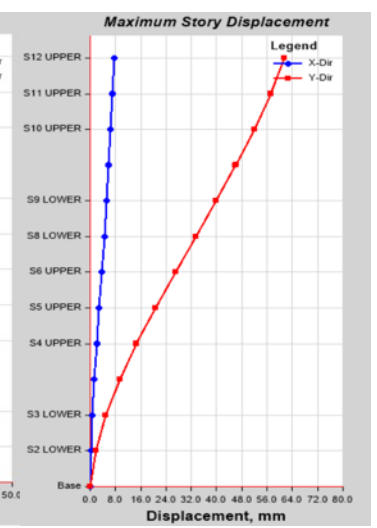
30mm



40mm



46mm



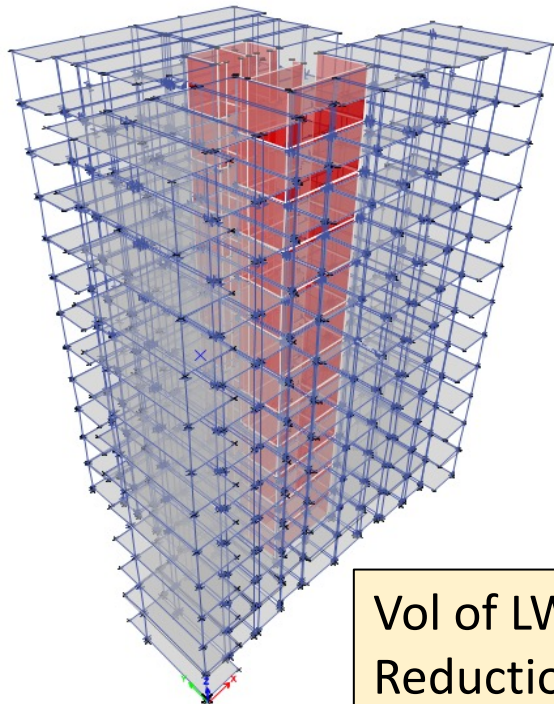
60mm

Allowance limit, 189mm (H/200).

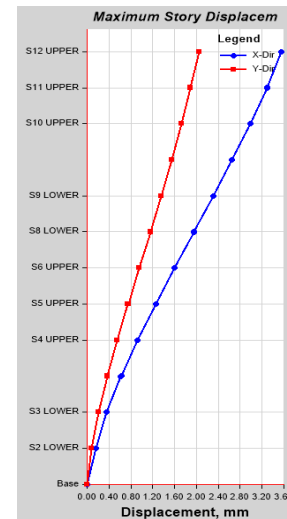
WIND LOADING

CASE STUDY

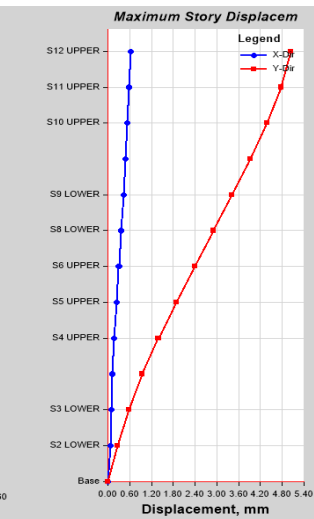
Density Class 1.6
Comp Str = 40 MPa



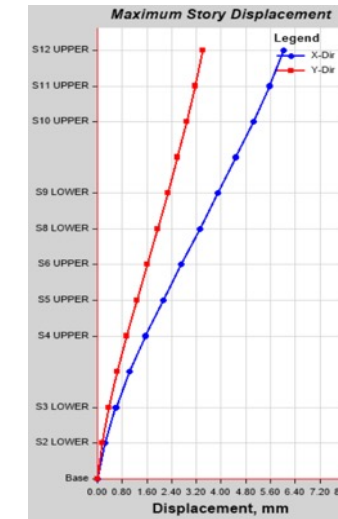
Vol of LWC = 1107m³
Reduction in Load = 830 ton



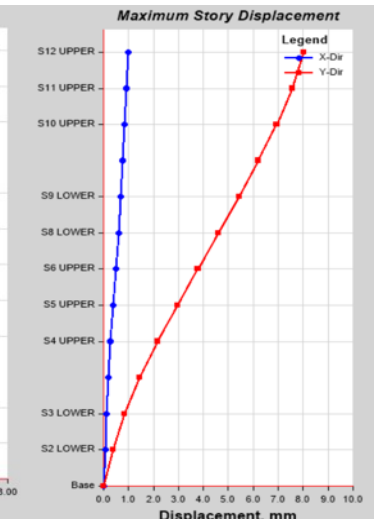
4mm



5mm



6mm



8mm

Allowance limit, 76mm (H/500).

Cost Savings in Using Lightweight Concrete

	Volume m ³	Cost SGD	
		NWA	LWA
CEMENT	0.145		
WATER	0.155		
SAND	0.3		
AGGREGATE	0.4	31.8	216

Estimated Construction Cost SGD
 = 8,000 Sqft x 12 storey x SGD 350
 = 33,600,000

Additional Cost SGD
 = 1107 x (216 – 31.8)
 = 203,909 (0.6% of construction cost)

These Benefits

1. Foundation cost due to reduction of dead load of 830 ton
2. Transportation cost due to lighter precast components
3. Maintenance cost due to higher durability
4. Energy cost due to high thermal insulation
5. Bigger spaces, lesser columns
6. Lighter deadload, lesser reinforcement steels
7. Reductions in Embodied and Operational Carbon Emission

Versus

Cost of LiGrA



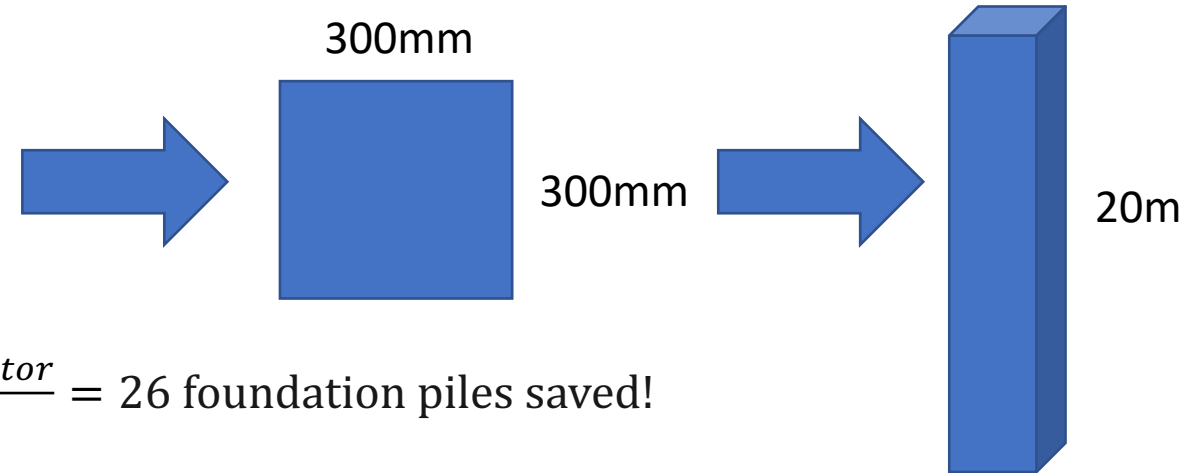
SGD 203,909

Cost Savings in Using Lightweight Concrete

1. Foundation cost due to dead load reduction

Assuming Foundation used was 300 by 300mm square pile:

- Allowable Pile capacity of 90 tones per meter
- Factor of Safety (FOS) applied is 2
- Pile to be driven into 20m depth



Number of piles saved: $\frac{\text{Reduction of applied load} \times \text{Dead Load factor}}{\left(\frac{\text{Allowable pile capacity}}{\text{FOS}}\right)} = 26$ foundation piles saved!

Parameters/ Properties	Cost SGD/unit	Total Cost Savings SGD
Supply and installation of driven piles	61.80	32,136.00
Pile cutting cost and supply of capping plate	53.00	1,378.00
Installation of mild steel pile shoe	45.00	1,170.00
Total Foundation savings		34,684.00

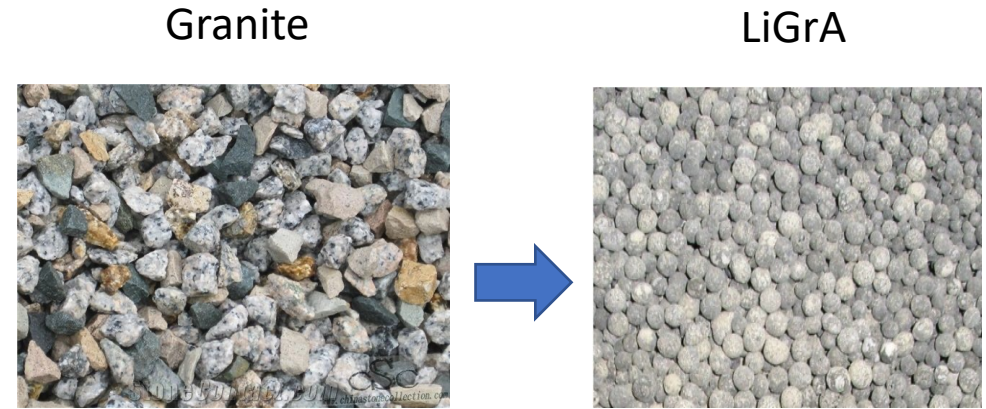
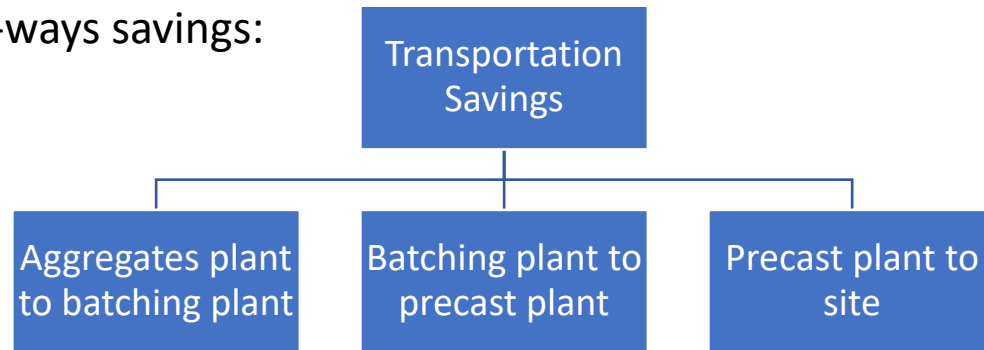
Costing calculation is based from HDB Standard Schedule of Rates for Building Works, Civil Engineering works and electrical

2. Transportation Savings due to lighter material and precast components

Assumptions:

- Transportation cost of about SGD 271.73
- Lorry capacity of 25 tones

3-ways savings:



Reduction of about $\frac{1}{8}$ to $\frac{1}{10}$ in weight

Reduction load of 830 tones aggregates, number of lorry required:

$$\text{No. of lorry required} = \frac{\text{Reduction in load (aggregates)}}{\text{Lorry capacity (tones)}} = 34 \text{ lorries saved!}$$

Parameters/Properties	Cost SGD/unit
Transportation Cost	271.73/trip
No. of lorry required	34
Transportation Savings	27,716.46

Beside financial savings, it will also reduced the operational carbon emission induced by lorries.

3. Lighter Deadload, lesser reinforcement steels

Assumptions:

- Standard percentage of reinforcement in concrete of around 3%
- Assuming 6m span T-beam as case study for relevant comparison

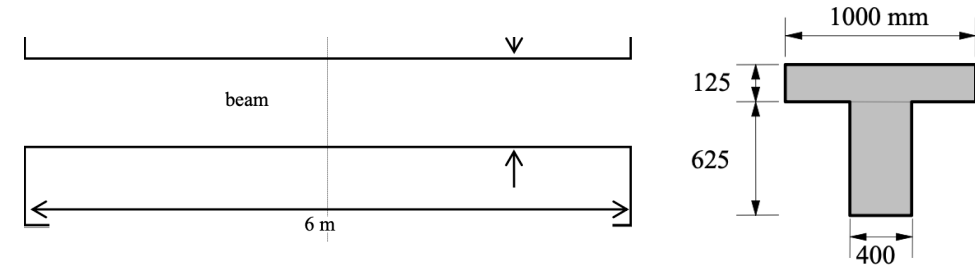
Working load:

NWC		LWC	
Dead Load	Live Load	Dead Load	Live Load
40 kN	30 kN	27.83 kN	30 kN

Costing for 6m span beam:

Total mass of reinforcement steel	Mass Kg	Cost/Kg	Cost SGD/Kg
NWC	200.46	2.60	397.77
LWC	179.36	2.60	286.97
Reduction in cost SGD			38.40

#Assuming the reduction of stirrups design around 30% of Total reinforcement bars



Using 12mm diameter reinforcement steels to design:

Reinforcement size	Position	NWC	LWC
N12	Top	10	9
	Bottom	18	16
Y12		10	9

Using LWA, the percentage of reinforcement steel is reduced by approximately 10.53%. This percentage can be utilized to calculate the cost savings for the case study.

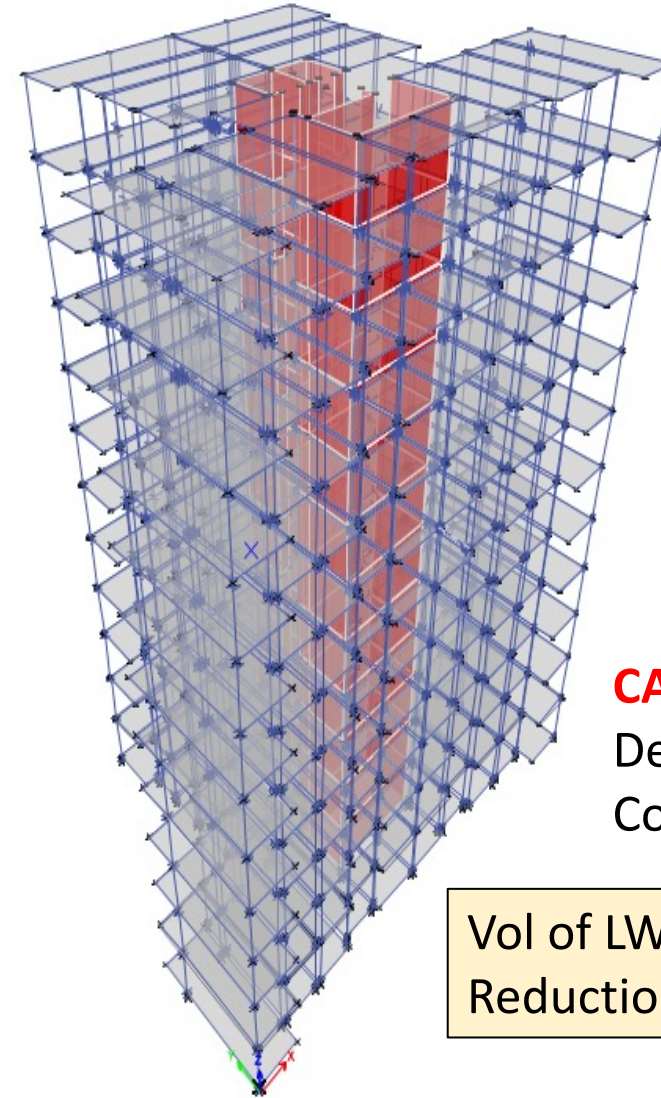
Cost Savings in Using Lightweight Concrete

Assumptions:

- Thumb rule steel quantity for Reinforced Concrete = 3%
- Density of steel taken as 7,850 kg/m³

Parameters	Mass (Tones)	Cost SGD 2.60 / kg
NWC	260.70	677,820
LWC	233.26	606,470
Savings	27.44	71,349

By using LiGrA, amount of SGD 71,349 can be saved based on this case study. The self-weight of the structure reduces building dead load. With lesser dead load, lesser steel reinforcement is required for Reinforced Concrete.



CASE STUDY

Density Class 1.6
Comp Str = 40 MPa

Vol of LWC = 1107m³
Reduction in Load = 830 ton

4. Energy Cost due to high thermal insulation

Assumptions:

- Energy savings for room Air Conditioner is measured with Energy Efficient Ratio (EER)
- Electricity tariff for households is SGD 0.30 per kWh – Energy Market Authority (2022)
- AC unit "Daikin MKS65TVMG" channels 4 Indoor Unit (IDU) for 4 rooms flats (HDB)
- Floor area of case study is 8000 Sq Ft or 743.22 Sqm

Parameters	NWC	LWC
Concrete Density (Kg/m ³)	2350	1600
Material Conductivity, k (W/m/K)	1.16	0.54

Reduction of 53.45% from normal weight concrete (NWC)

For AC unit with $21,200 \frac{Btu}{hr}$ = Cools down 4 room flats of HDB (85-93 Sqm)

Parameters	4-room flats (Reference)	Case Study PPVC
Floor area (Sqm)	93	743.22
Energy usage by Air-Conditioning Unit (Btu/hr)	21,200	169,422

This number represents the capacity of an AC. Knowing the capacity, how we find the Power W absorbed by the AC?

5. Energy Cost for high thermal insulation

Assuming an Energy Efficient Ratio (EER) of 10:

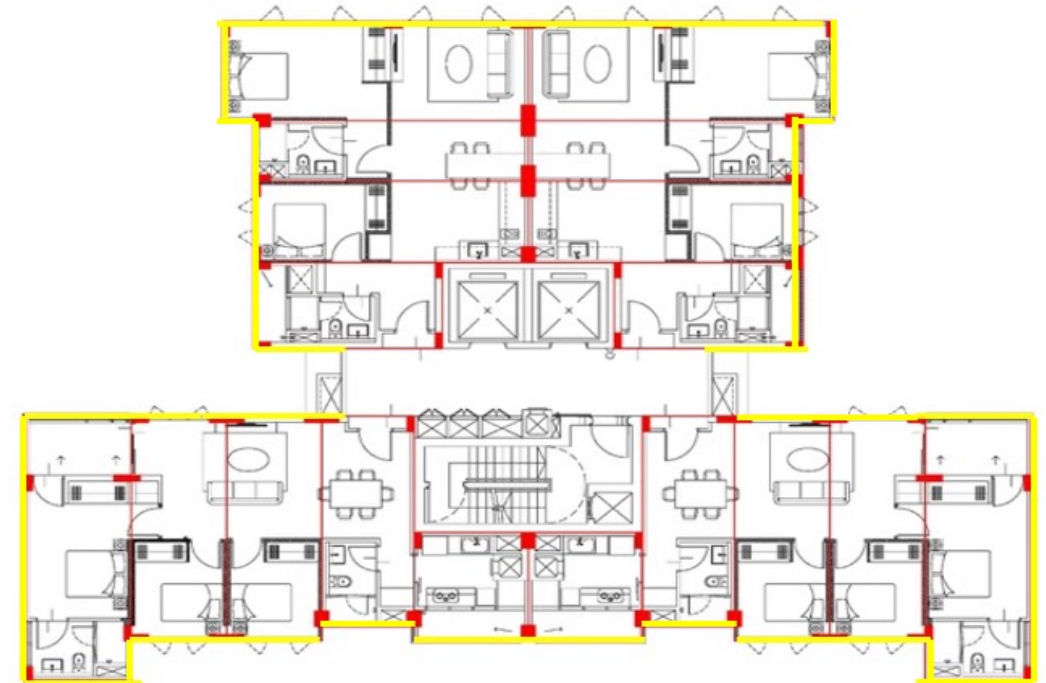
$$EER = \frac{\text{Output cooling energy (BTu)}}{\text{Input electrical energy (Whr)}}$$

$$\text{Input electrical energy} = 16942.2 \text{ W}$$

Input Electrical Energy for LWC (Watt)

$$(100-53.45)\% \times 16942.2 \text{ Btu/hr} = 7886.60 \text{ W}$$

Parameters/Properties	NWC	LWC
Power Consumption W	16,942.2	7886.60
Energy Consumed kWh/Day	406.61	189.28
1kWh Cost SGD	0.30	0.30
Energy Cost/Yr SGD	43,914.18	20,442.06
Energy Cost Savings SGD/Year	23,472.11	
Energy Cost Savings 30 year	234,721.10	



TYPICAL MODULE LAYOUT

Usage of LiGrA, the energy consumption by AC unit can be reduced. The savings based on this case study sums up to SGD 234,721.1 for 10 years. This finding is supported with LiGrA properties having high thermal insulation.

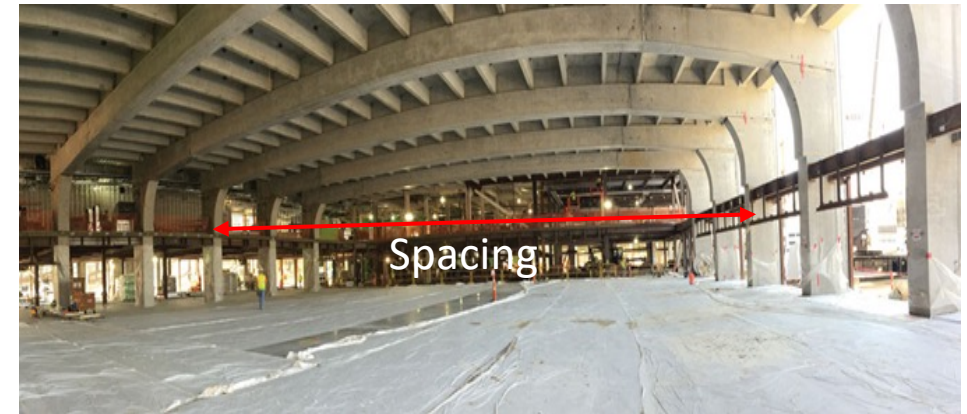
6. Bigger spaces, lesser columns

Based on savings from Reinforcement Steel, using LWA:

- Building self weight will decrease
- Lesser columns needed to structurally transferred the loading from the beam
- Lesser quantity of column



Normal Weight Aggregates

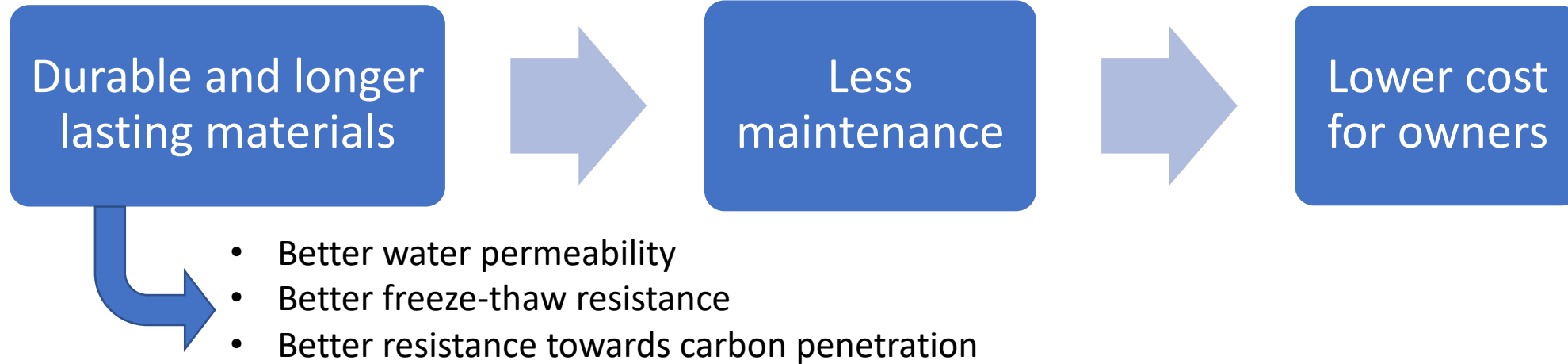


Light Weight Aggregates

Comparison	NWC	LWC
Spacing between columns	↓	↑
Design Efficiency	✗	✓
Cost optimized	✗	✓

7. Maintenance Cost due to higher durability

How does usage of LiGrA helps on reducing the cost of maintenance and repair?



Method of Damage	Solution	Cost SGD
Water penetration	External wall leakage repair (PU Grouting)	400-800 (Exc. GST)/m2 of crack
Freeze-thaw damage	Concrete sealer	1.25 to 1.75/ Sqft
Fungus on the wall due to condensation	Mold remediation	3500/Service

By utilizing LiGrA, we could reduce the rate of maintenance, which consequently lower the cost of maintaining the structure.

Cost Savings in Using Lightweight Concrete

Total Savings against Total Additional Cost

Savings	Savings LWC	Factor of Reduction	Savings Cost SGD
Construction	Foundation Cost	Pile Usage	34,684.00
	Transportation Cost	Lorries	27,716.46
	Reinforcement Cost	Steel Reinforcements	71,349.47
Operational	Energy Cost	AC Unit Electricity	234,721.10
	Total Cost Savings (SGD)		368,471.03



Against Total Additional Cost of **SGD 203,909.40**

Total cost savings:

- Excluding expenses from maintenance cost
 - Reducing embodied and operational carbon emissions
- are **more than** the additional cost to be spent if LiGrA is used.

Reduction in Carbon Emission using LiGrA

Embodied Carbon - The ICE Database	kg CO2e / kg
LiGrA	0.278
Granite Agg	0.00438
LECA	0.393

Additional CO2e due to use of LiGrA = 123.1 ton CO2e
 Additional CO2e due to use of LECA = 168.9 ton CO2e

Reduction in Embodied Carbon Emission	ton CO2e
Waste Glass Diversion from Incineration	436.6
Saving in Transportation	9.7
Lesser Reinforcement	145.3
Lesser Foundation	28.0
Total	619.6

Reduction in Operational Carbon Emission	ton CO2e
Aircon Energy Saving (annually)	38.6
Longer Life Span	
Lesser Maintenance	
Total	38.6
In 30 years, reduction = 1,158 ton CO2e	

Sources: (1) ICE DB V3.0 (Embodied Carbon of Materials), (2) NEA 5th Biennial Report 2022, (3) IPCC Transport tool Version 2.6, (4) IGES List of Grid Emission Factors 2021, (5) Korea LCI Database



Save Our Just One Earth





The Art of Lightweight Technology

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Thank You

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