Sustainable Green Concrete

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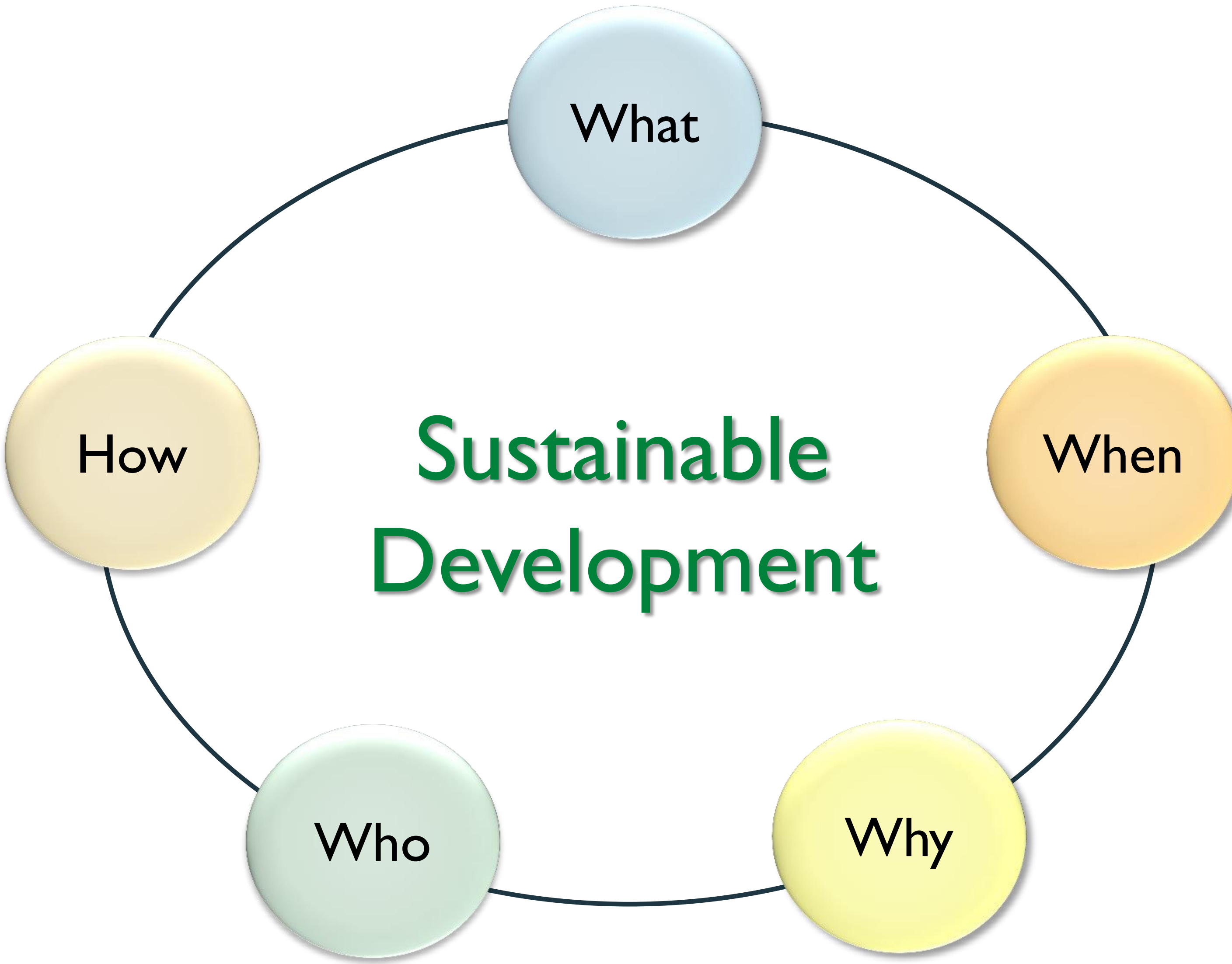
What
How
Sustainable Development
When
Who
Why

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What is Sustainable Development?

Sustainable development has been defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

For sustainable development to be achieved, it is crucial to harmonize three core elements: Economic growth, Social inclusion and Environmental protection.

www.un.org/sustainabledevelopment, United Nations

Do we have worldwide goals?

Yes!

Sustainable Development Goals (SDGs)

- 17 SDGs adopted by world leaders in September 2015
- They call for action by all countries
- The SDGs are not legally binding
- However, governments are expected to take ownership and establish frameworks to monitor the progress

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When to achieve the Goals?

This year the Global Goals for Sustainable Development come into effect to achieve three extraordinary things by 2030 – end poverty, combat climate change and fight injustice and inequality.

For the goals to be reached, everyone needs to do their part: governments, the private sector, civil society and people like you and me

When to start?

Act now!

Why do we need Sustainable Development?

To create a better World!

Why does Concrete matter?

- Most commonly used construction materials
- Consumptions (in m^3) 2^{nd} to water

Who should participate in Sustainable Development?

- Government
- Architects / Structural Engineers / Consultants
- Concrete Producers / Material Suppliers
- Contractors
- Occupants / Users
- Students
- Etc…

ALL OF US – Collaborative Effort!

How to produce Sustainable Green Concrete?

Building / Structural Design	Mix Design	Operations
Transportation	Management Systems	On-site Treatment

Part 1

Building / Structural Design

Considerations

- Design Life
- Life Cycle Assessment
- Cradle to Grave Environmental Impact (materials input, production process, transportation, application, demolition, recyclability, disposal)

Part 2

Mix Design

Major Components of Concrete

- Cementitious Materials ⇦ Most Concerned!
- Aggregates
- Water
- Admixtures

Simplified Cement Production Process

Raw Materials (limestone, silica bearing materials, iron ore, etc.)

Kiln (sintering temperature of ~1450°C)

Clinker

Grinding → Gypsum

Cement

Embodied Energy

- The sum of energy required to produce the goods or services, considered as if that energy was incorporated, or "embodied" in the product itself

Embodied Carbon

- A measure of the carbon emitted into the atmosphere in order to produce the goods or services

Secondary Cementitious Material (SCM)

- ✓ Pulverized Fuel Ash (PFA)
- ✓ Condensed Silica Fume (CSF)
- ✓ Ground Granulated Blast-furnace Slag (GGBS)

Pulverized Fuel Ash (PFA)

- A by-product from Coal Burning Power Plant
- Ash aloft during Combustion
- Extracted by Electrostatic precipitation
- Used in Concrete Production after Classification

HKE – Lamma Power Station

CLP – Castle Peak Power Station

Coal

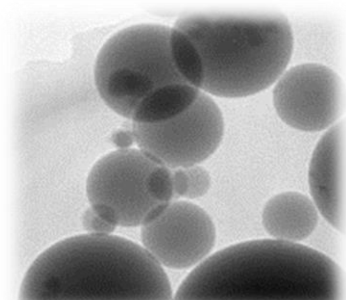
PFA

Condensed Silica Fume (CSF)

- A by-product of Silicon Metal and Ferrosilicon Alloy production
- Produced in an Electric Arc Furnace
- High Temperature produces SiO_2 Vapors
- Condensed in Low Temperature to Tiny Particles

Silicon production plant

Electric arc furnace



Silica fume particles

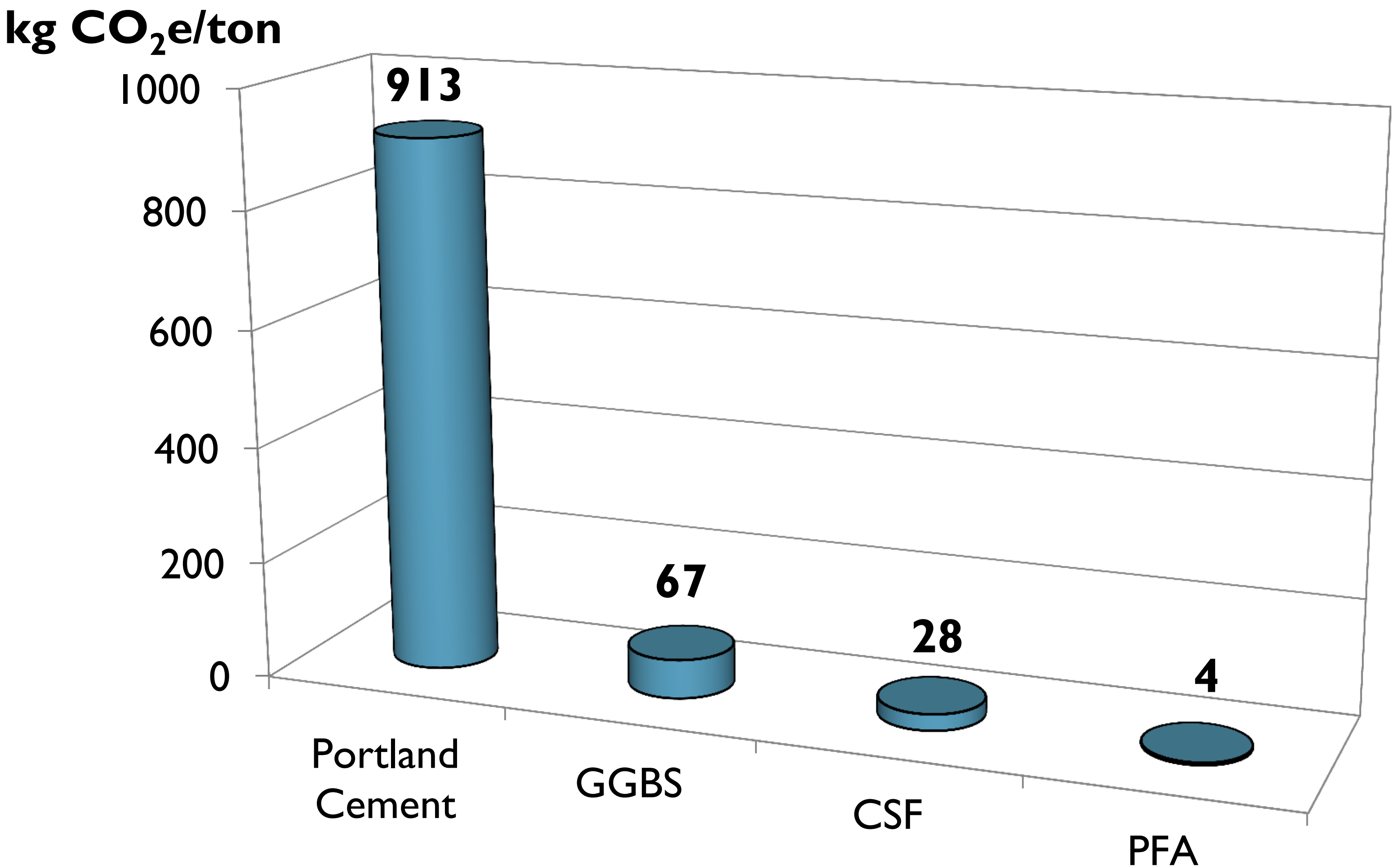
Ground Granulated Blast-furnace Slag (GGBS)

- A by-product of Iron & Steel Making
- Originated from Molten Iron Slag from a Blast Furnace
- Quenching in Water of Steam
- Grind into Fine Powers

Blast furnace

Iron/Steel mill

Embodied CO2e of Cement and SCMs



Mineral Products Association (UK) – Fact Sheet 18

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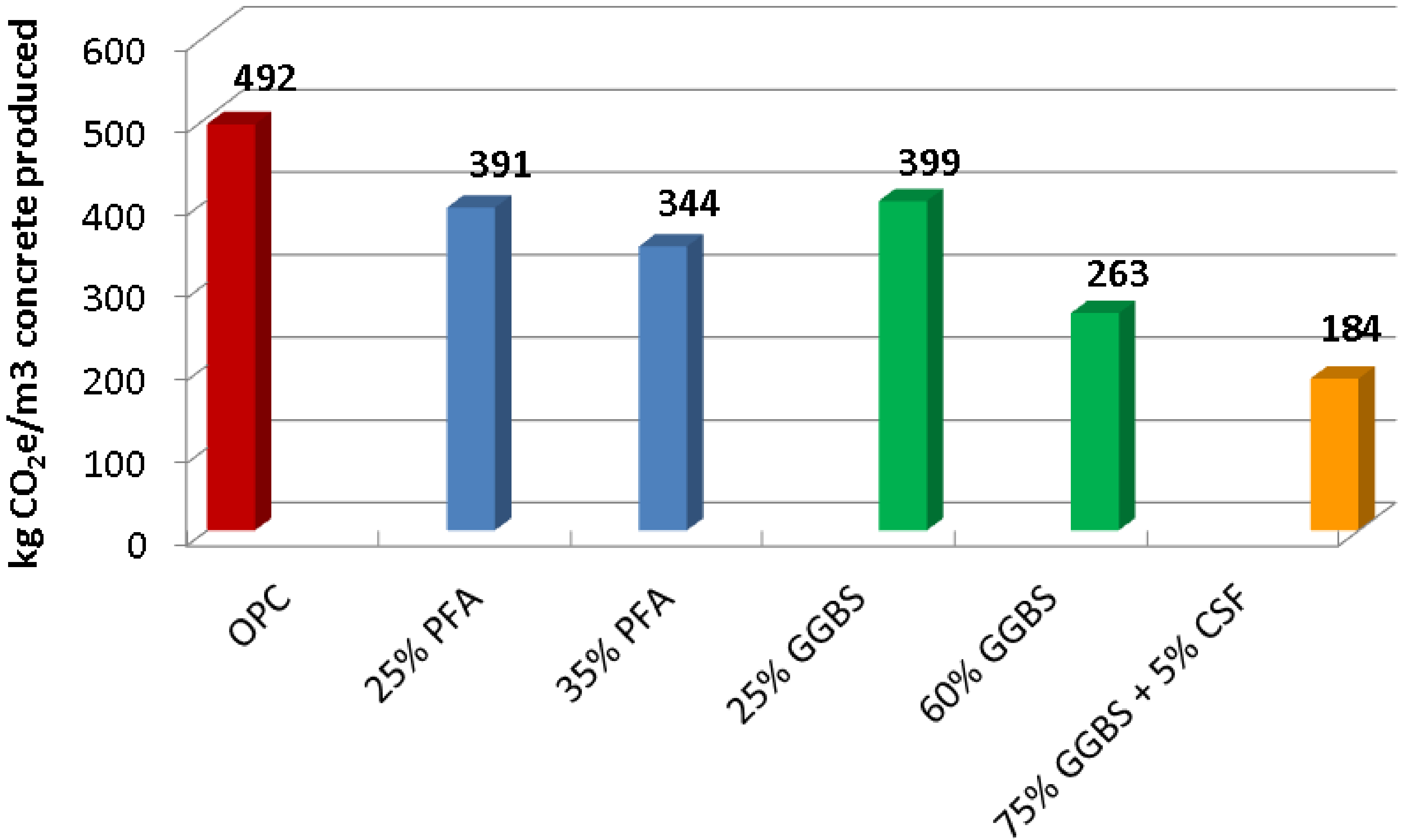
Evaluate Embodied Carbon of Concrete Mixes

- Different combinations of SCMs are selected
- Total cementitious content : 450kg/m^3
- Same water / cement ratio and aggregate / cement ratio
- Same sources of cement and aggregates

Evaluate Embodied Carbon of Concrete Mixes

- Selected Combinations
  - OPC Mix
  - PFA 25%
  - PFA 35%
  - GGBS 25%
  - GGBS 60%
  - GGBS 75% + 5% CSF

Embodied Carbon of Concrete Mixes

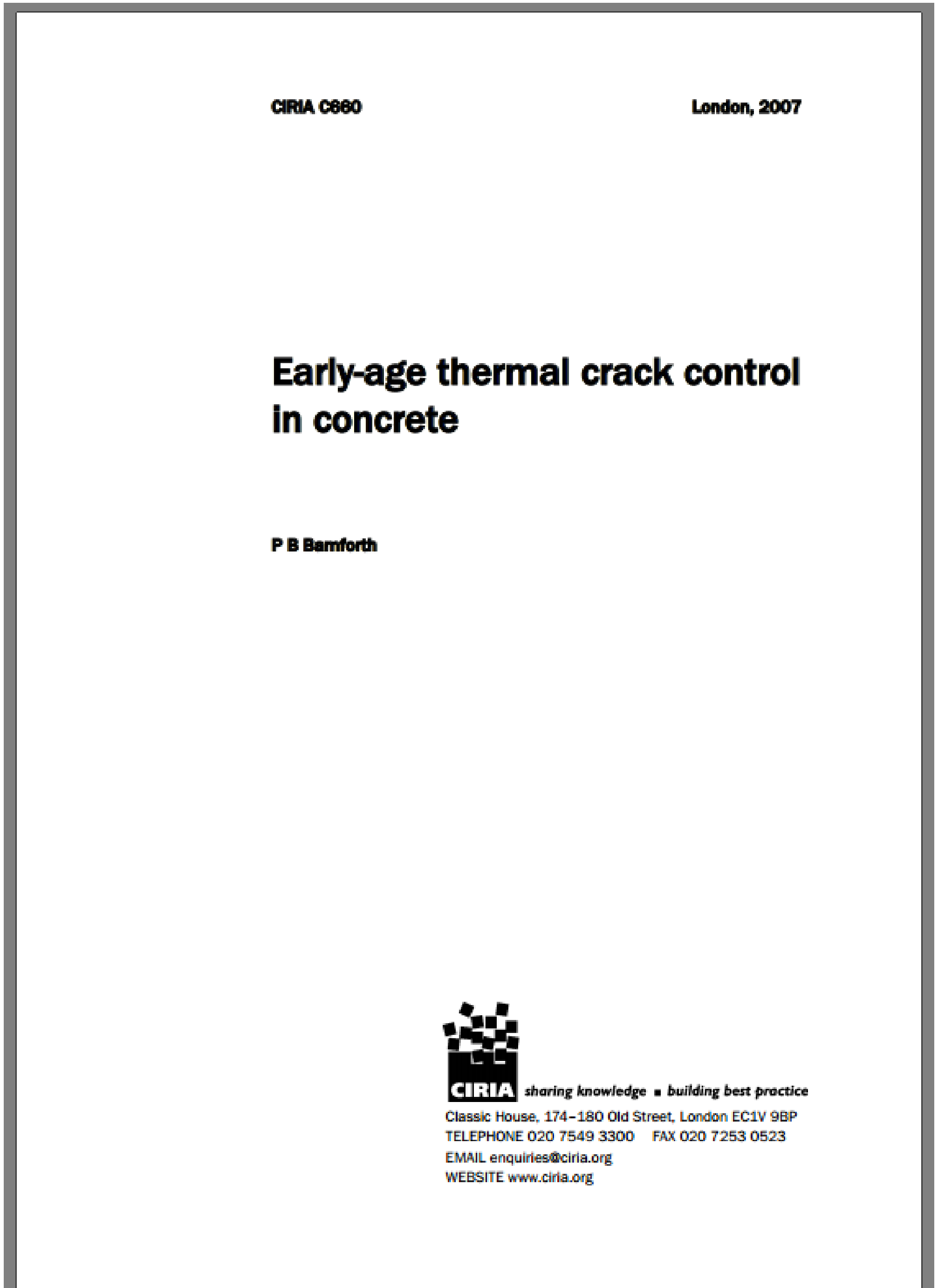


Use of Secondary Cementitious Materials (SCM) in Local Specifications

Type of SCM	ASD GS 2012	HKHA Specification Library 2014	COP of Structural Use of Concrete 2013	CEDD GS 2006	MTRC M&W 2014
PFA	25-35%	35% for foundation 25% for others	25-35% for ordinary concrete	25-35% for ordinary concrete; 25-40% for marine concrete	25-35%
GGBS	≤ 40%	Only allow 35% for precast concrete façade (pilot project only)	35-75% for ordinary concrete	35-75% for ordinary concrete; 60-75% for marine concrete	36-75%
CSF	≤ 10%	-	≤6% for High Strength Concrete	5-10% for marine concrete	5-10%

Estimation of Peak Temperature in a Concrete Structure

- By Calculation: Construction Industry Research and Information Association (CIRCA) Report C660
- Temperature Rise Evaluation Test (TRET)
- Trial Column / Trial Panel



CIRIA C660 London, 2007

Early-age thermal crack control in concrete

P B Bamforth

CIRIA sharing knowledge ▪ building best practice

Classic House, 174–180 Old Street, London EC1V 9BP

TELEPHONE 020 7549 3300 FAX 020 7253 0523

EMAIL enquiries@ciria.org

WEBSITE www.ciria.org

CIRIA C660

A comprehensive report describing the thermal behavior of concrete structures and early-age thermal crack control

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CIRIA C660

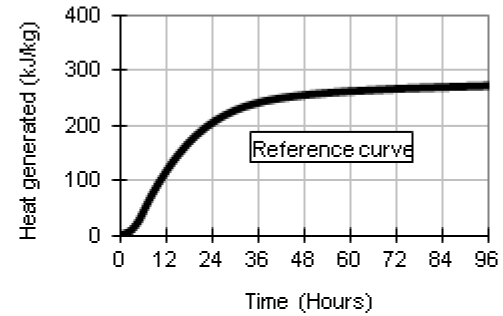
B	C	D	E	F	G	H	I

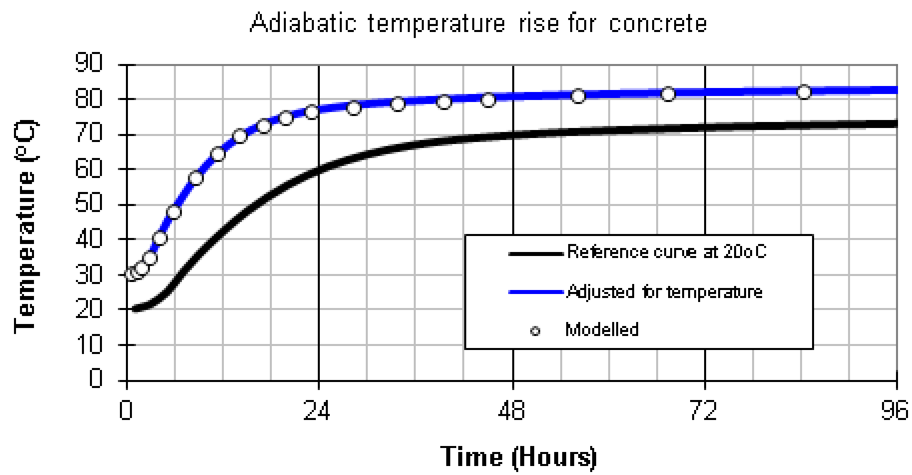
Adiabatic temperature rise

Cells for input data

Binder content	460	(kg/m^3)
Binder type	fly ash	
Addition	35	(%)
Density	2351	(kg/m^3)
Specific heat	1	kJ/kg°C

Temperature drop T_1 48 °C





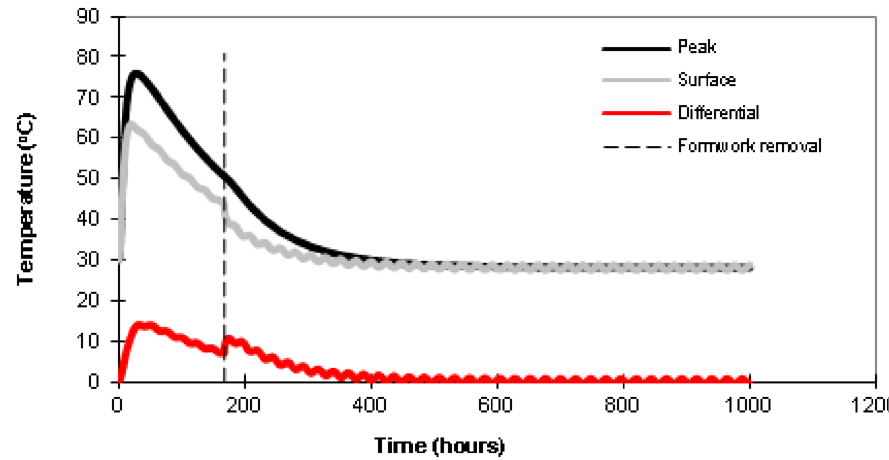
CIRA C660

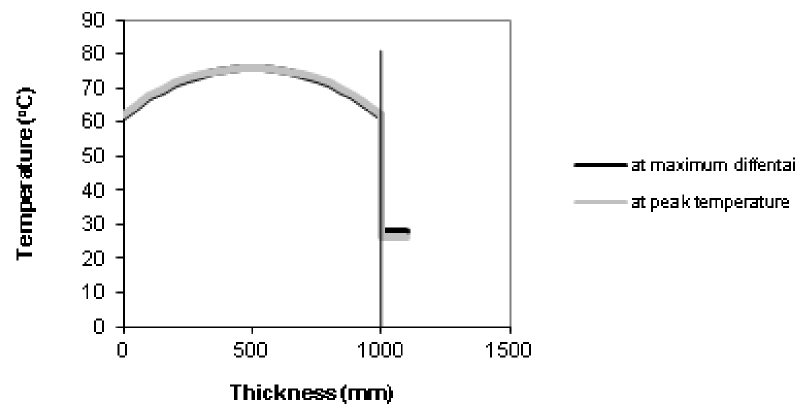
B	C	D	E	F	G	H	I	J	K	L	M

TEMPERATURE RISE AND DIFFERENTIALS

Cells for input data

Element details			
Pour thickness		1000	mm
Formwork type		37mm plywood	
Wind speed		0	m/s
Surface conductance		2.4	W/m²K
Formwork removal		168	hours
Concrete properties			
Thermal conductivity		1.4	W/m°C
Temperature			
Placing temperature		30	°C
Ambient temperature	Minimum	26	°C
	MEAN	28	°C
	Maximum	30	°C
Placing time (24 hour clock)		1	hours
Temperature OUTPUT			
Maximum temperature		76	°C
	at time	28	hours
Maximum differential		14	°C
	at time	32	hours
Temperature drop	T_1	48	°C



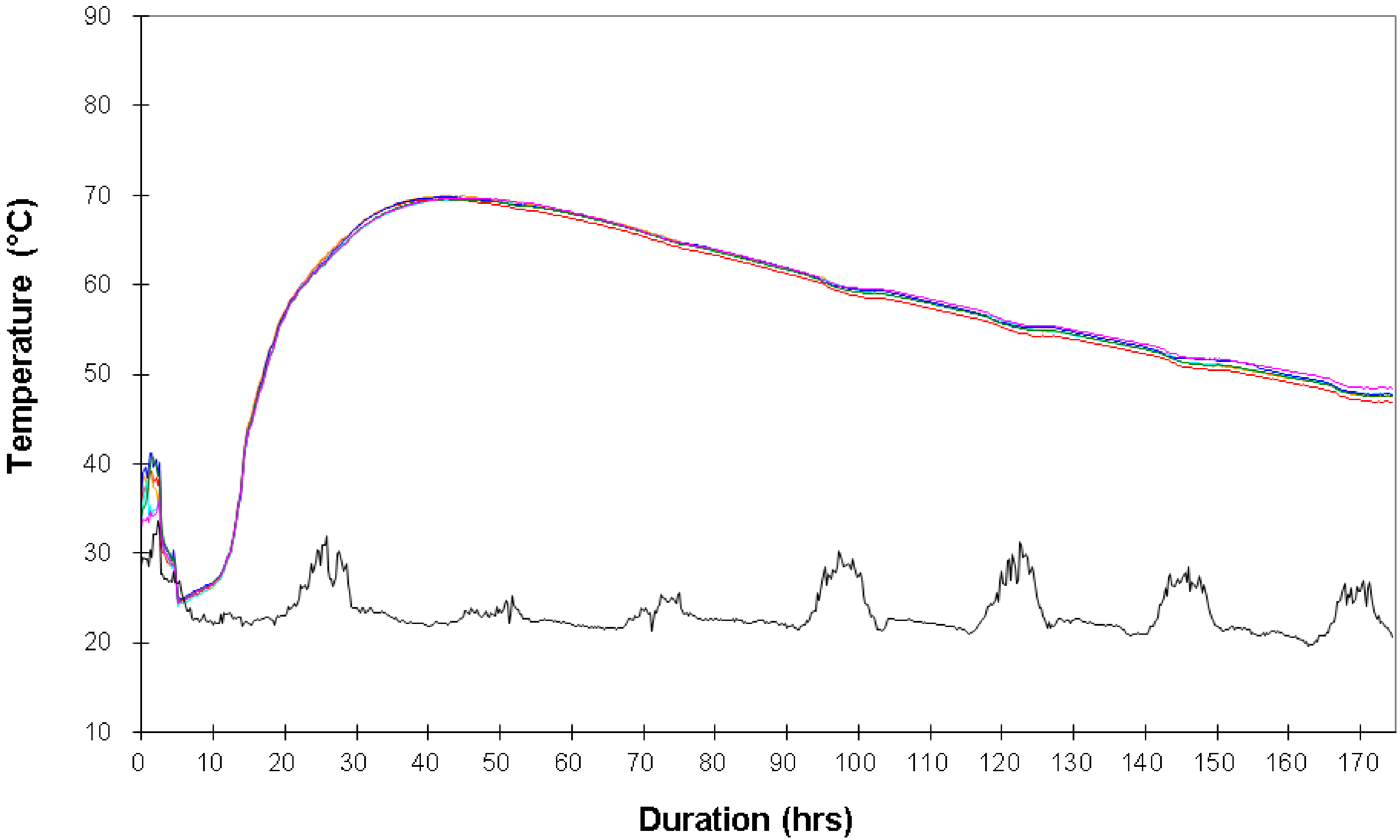


Temperature Rise Evaluation Test (TRET)

Data Logger

TRET Box

TRET Results



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Trial Column

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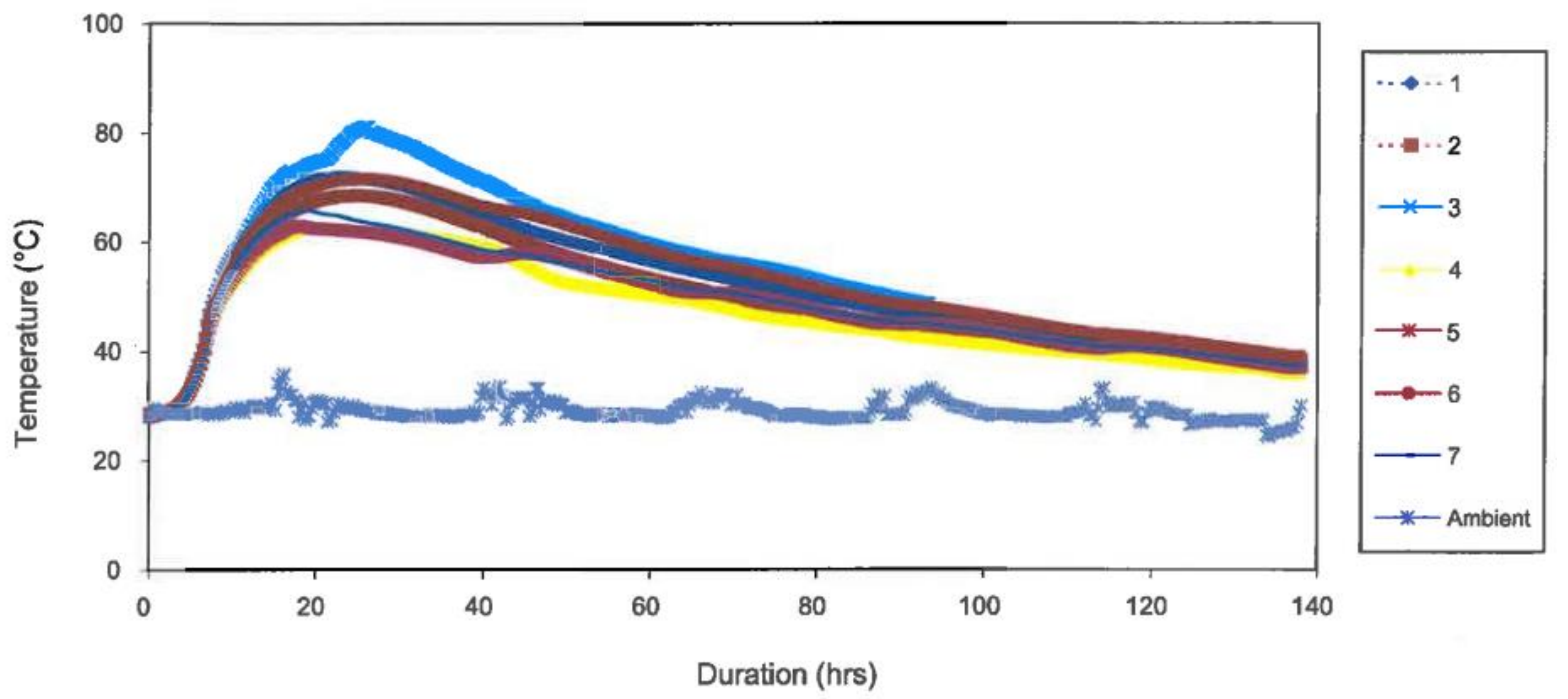
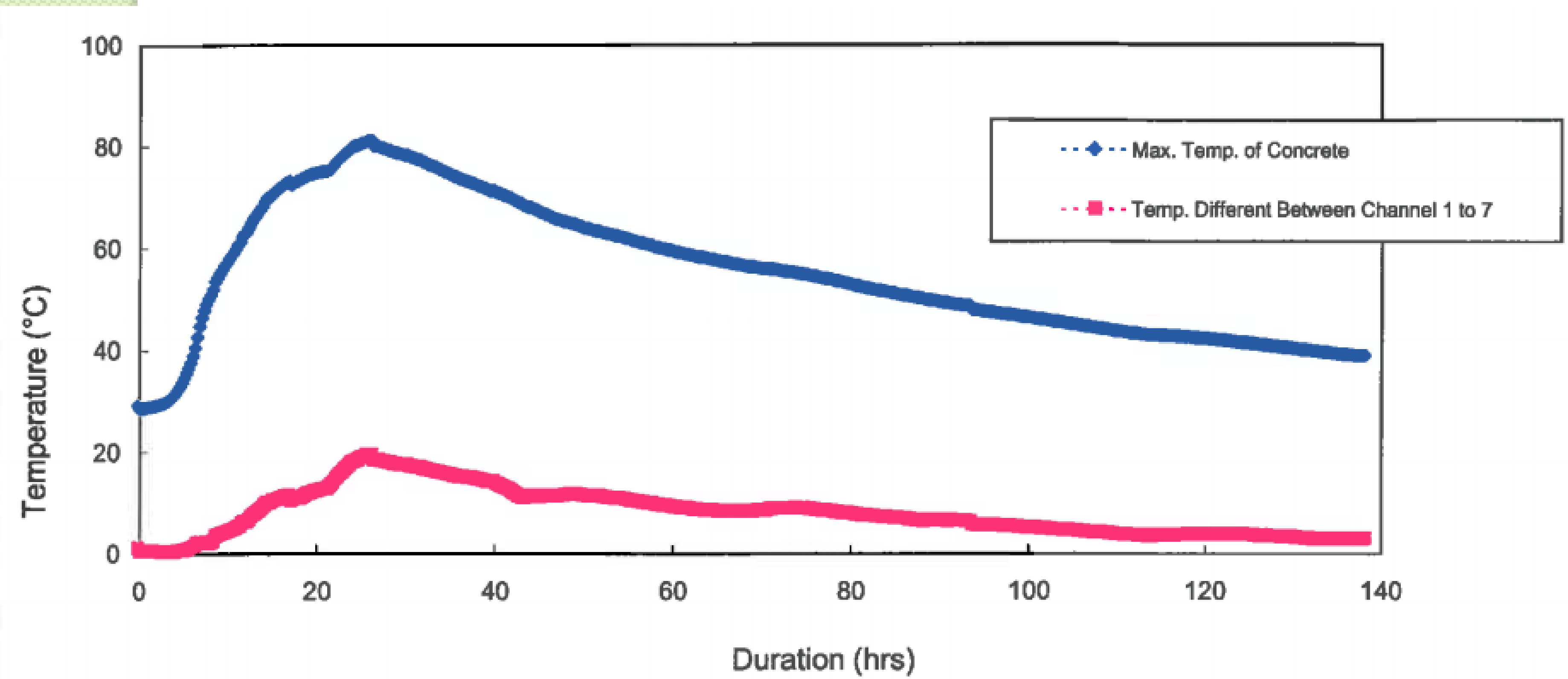
Temperature Monitoring of Trial Column

Channel Temperatures



Temperature Monitoring of Trial Column

Max. Temperature & Temperature Difference



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Part 3

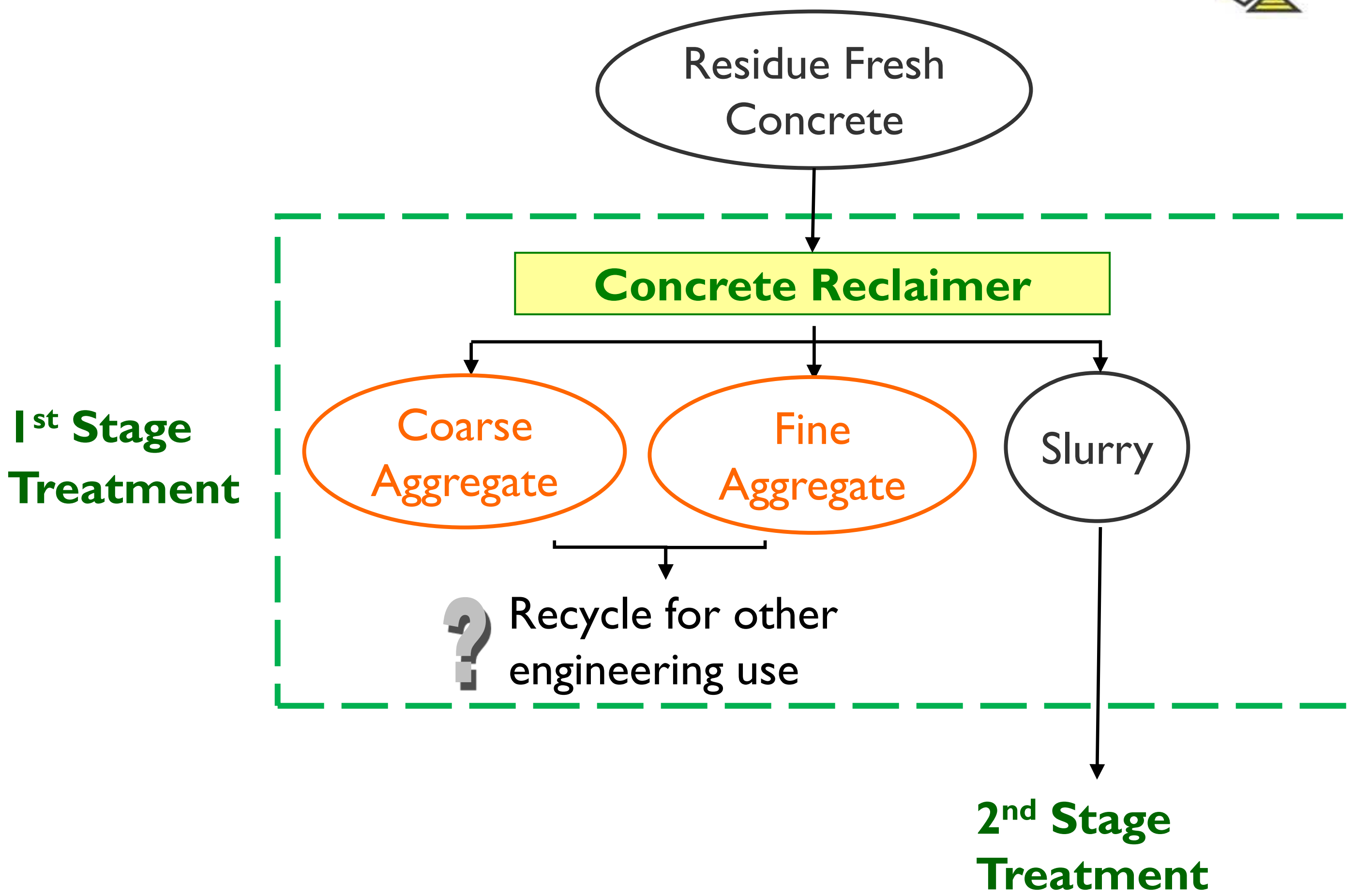
Operations

Considerations

- Reduction in Trial Mix Requirements
- Quality Control Measures to reduce wastage of non-compliance concrete
- Better Energy Management for Production Operations

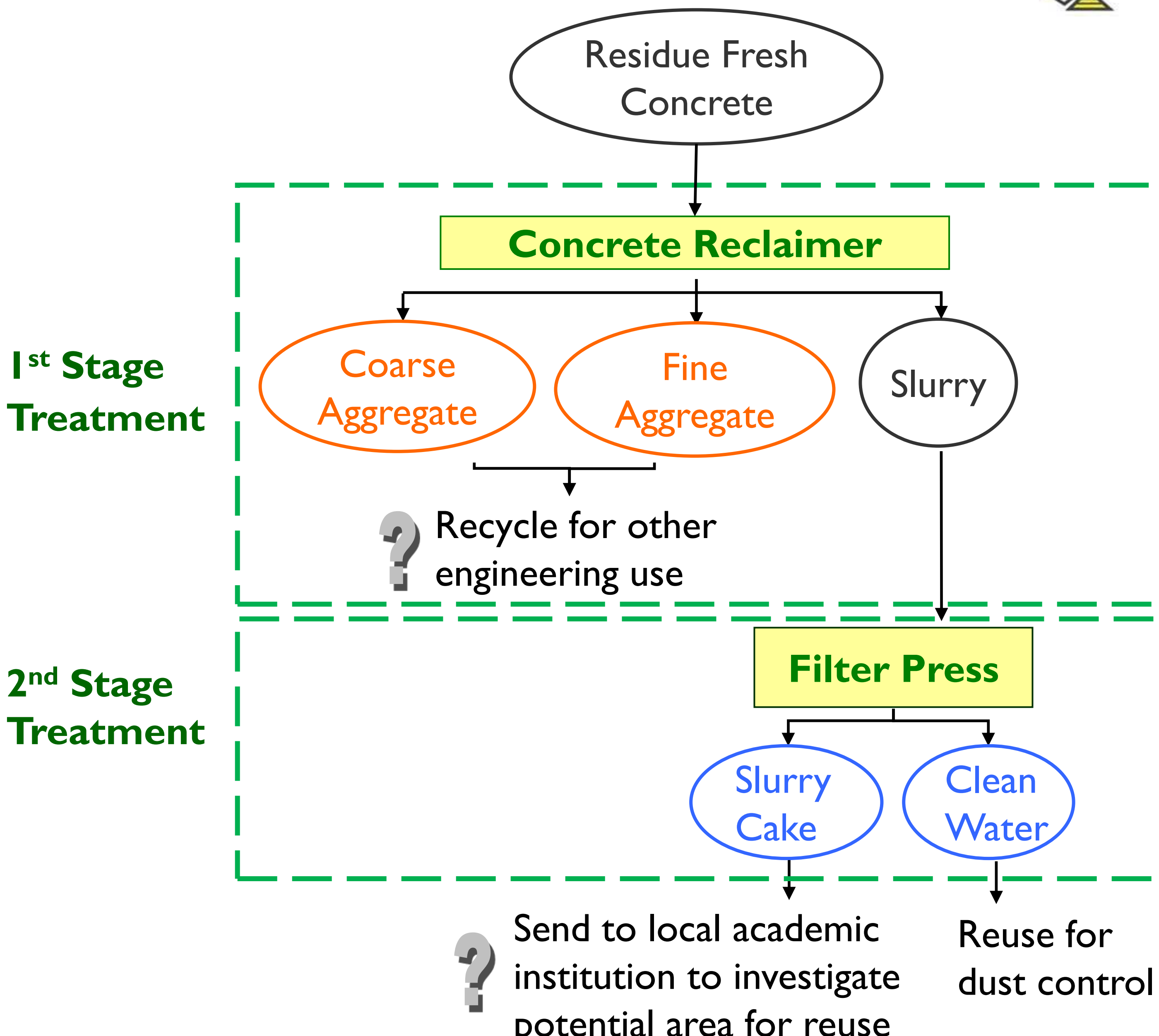
Residue Concrete Treatment

- Dumped to Landfill
- Reduce Over-ordered
- Reuse if Possible, e.g. blinding, concrete blocks as barriers etc.
- Recycle → Is it Possible after Treatment?



Volume reduce by ~70%!

Concrete Reclaimer


Residue Fresh Concrete
Concrete Reclaimer
1st Stage Treatment
Coarse Aggregate
Fine Aggregate
Slurry
Recycle for other engineering use
Filter Press
2nd Stage Treatment
Slurry Cake
Clean Water
Send to local academic institution to investigate potential area for reuse
Reuse for dust control

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Filter Press

Other Considerations

- Space at Batching Plants
- Accommodating Facilities, e.g. water storage tanks, civil works
- Speed & Capacity
- Blocking of Filters by Fibres

Part 4

Transportation

The Concrete Truck Mixers

- Emissions from heavy vehicles are considered as a source of pollutants

How to go Greener?

- Concrete produces try to optimize the delivery distance to minimize emissions
- Maximize the delivery efficiency (≥ $8m^3$ capacity)

⇨ Plant locations too remote?

What is Euro 6?

- Euro 6 (2014) is the latest engine emission legislations being driven by the European Commission.
- 4 harmful substances within the exhaust stream:

  Carbon monoxide (CO), Hydrocarbons (HC),

  Oxides of Nitrogen (NOx) and Particulate Matter (PM)

  (Target of reduction)
- Comparing with Euro 5 (2008), HC is reduced by 72%, NOx by 80% and PM by 50%.

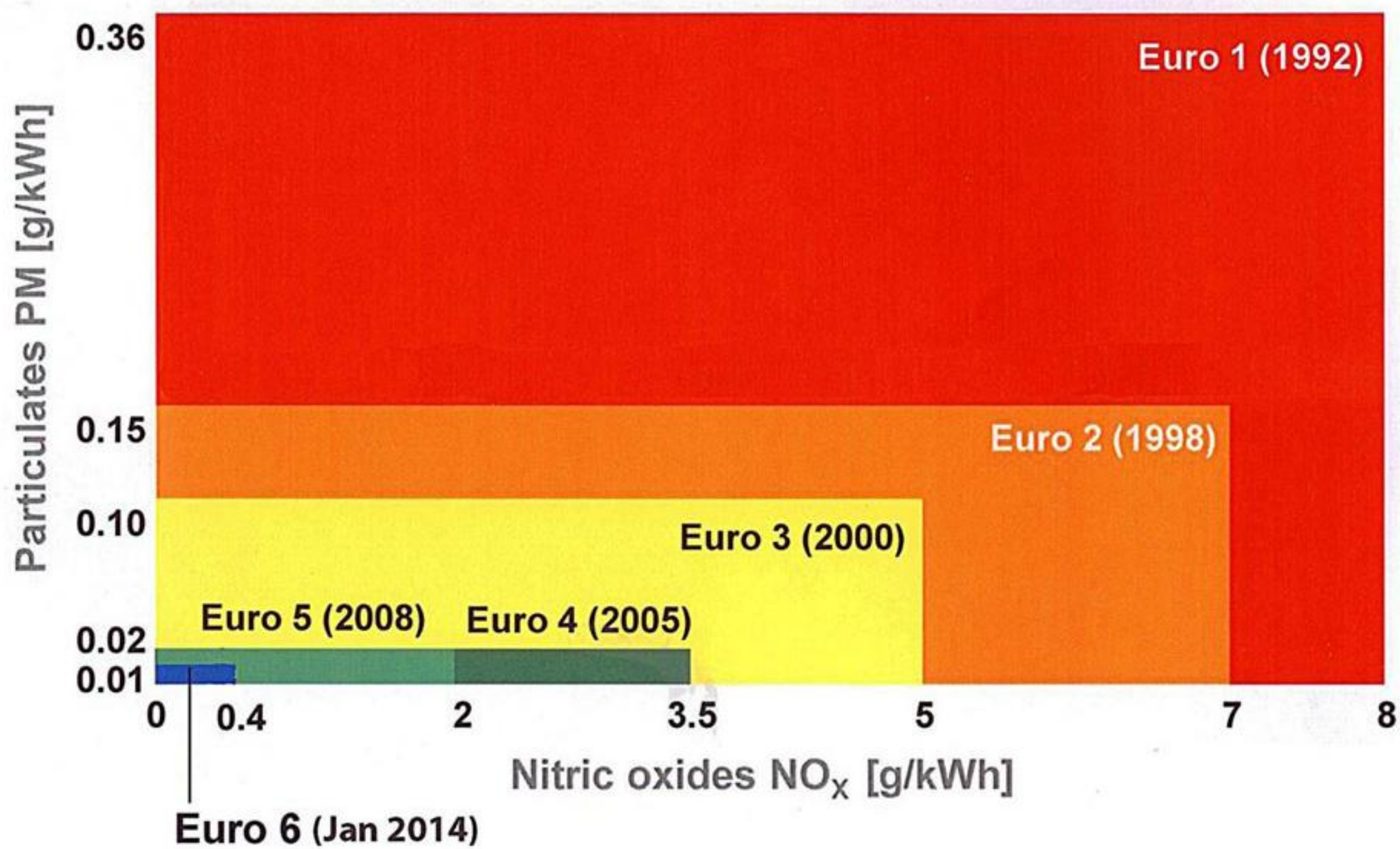
Progress in EU Standard

The standards are defined by engine energy output, g/kWh

1. Carbon monoxide (CO)
2. Hydrocarbons (HC)
3. Oxides of Nitrogen (NOx)
4. Particulate matter (PM)

Emission level	Date	CO	HC	NOx	PM
Euro I	1992	4.5	1.1	8.0	0.36
Euro II	1998	4.0	1.1	7.0	0.15
Euro III	2000	2.1	0.66	5.0	0.10
Euro IV	2005	1.5	0.46	3.5	0.02
Euro V	2008	1.5	0.46	2.0	0.02
Euro VI	2014	1.5	0.13	0.4	0.01

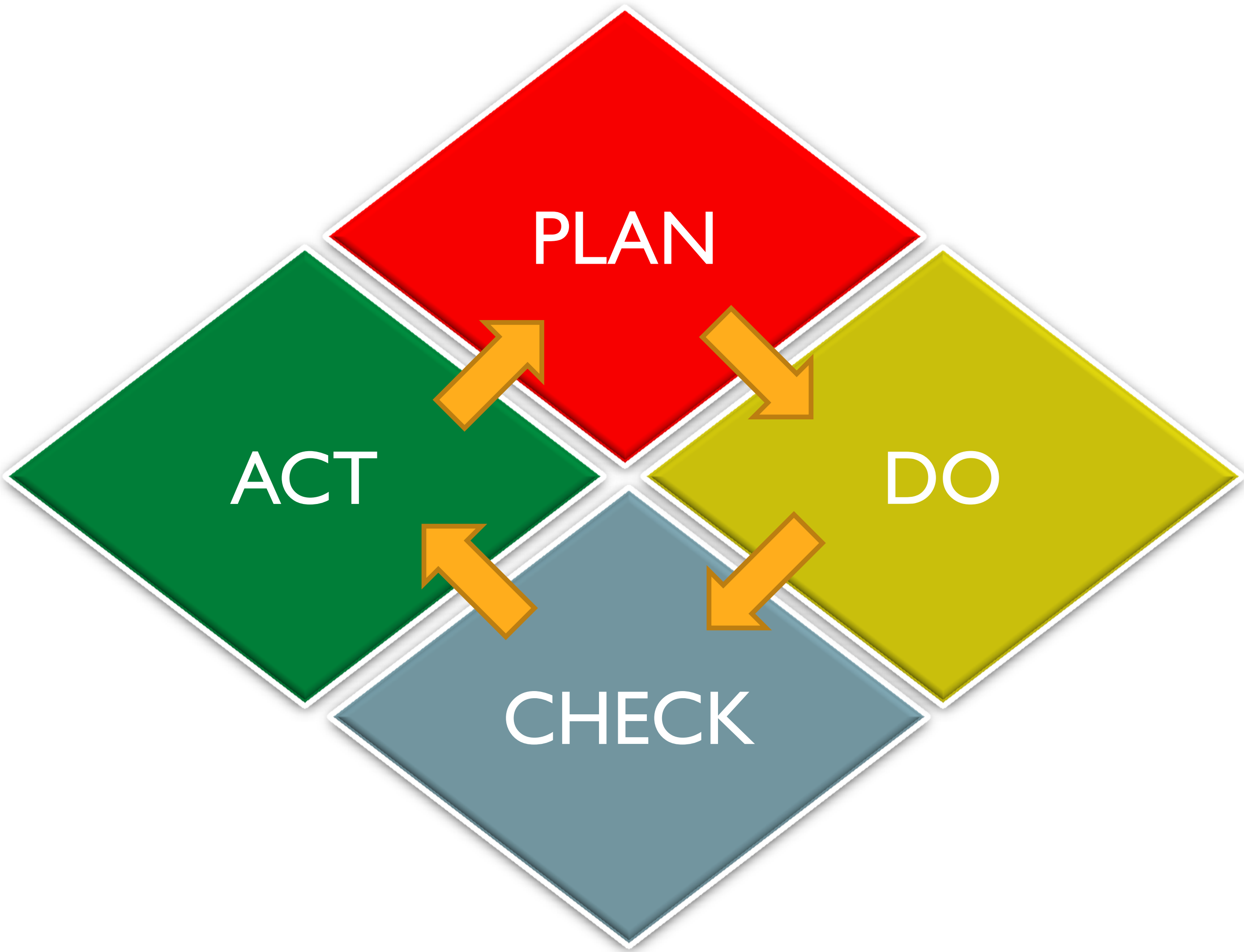
Progress in EU Standard



Part 5

Management Systems

The Plan-Do-Check-Act Cycle



Common Management Systems

- ISO 9001 – Quality Management System
- ISO 14001 – Environmental Management
- OHSAS 18001 – Occupational Health and Safety Management
- ISO 50001 – Energy Management

Carbon Footprint

- ISO 14064 – International Standard for GHG Emissions Inventories and Verification
- PAS 2050 – Product Carbon Footprint Standards

Process of Carbon Footprint

Initial Study & Scoping Exercise

↓

Baseline Analysis & Benchmarking

↓

Determine the Carbon Reduction Targets

↓

Data capturing & Analysis

↓

Carbon Reduction Initiatives

↓

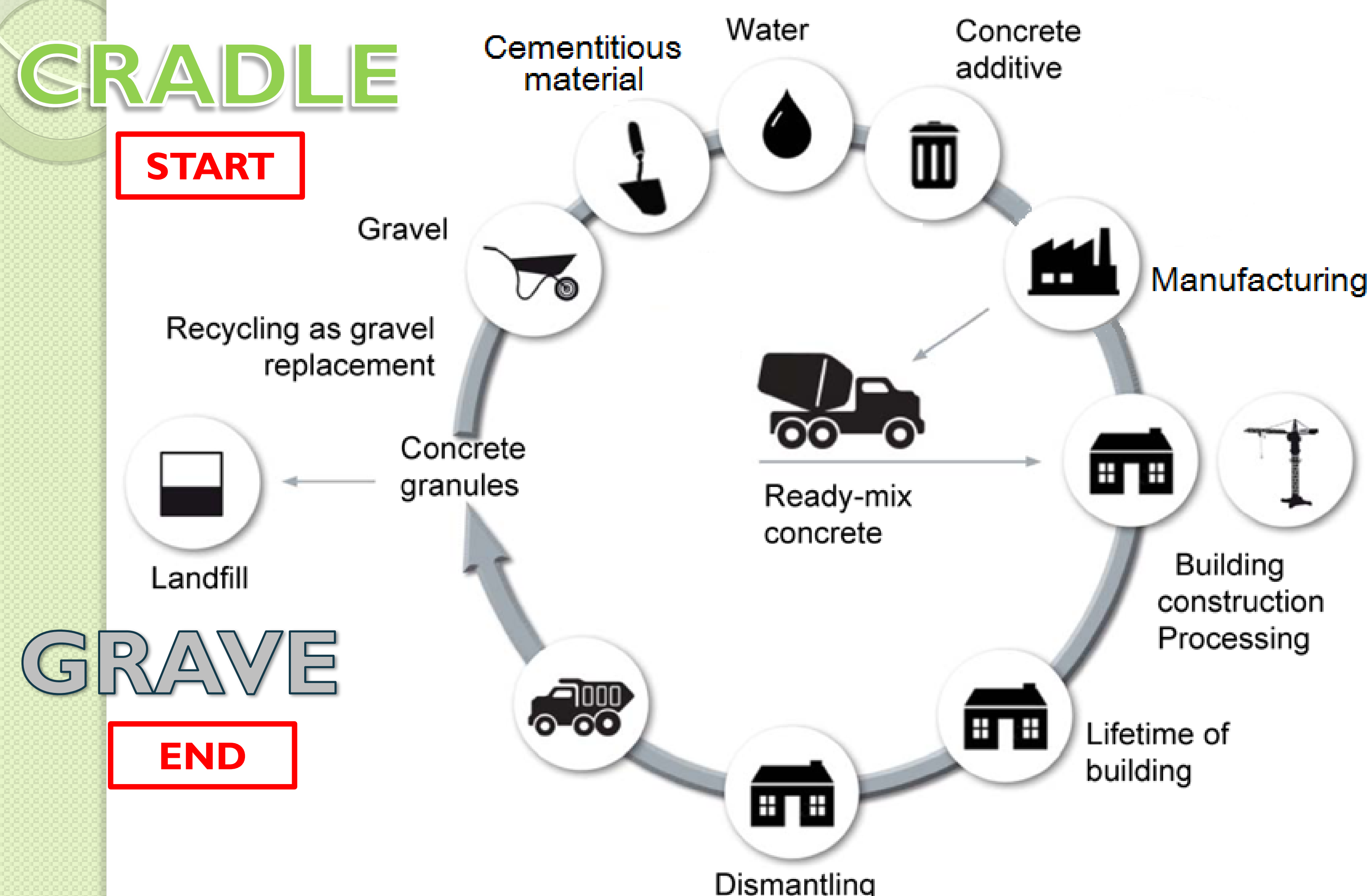
Compare with Baseline Readings

Different Ways of Defining Embodied Carbon

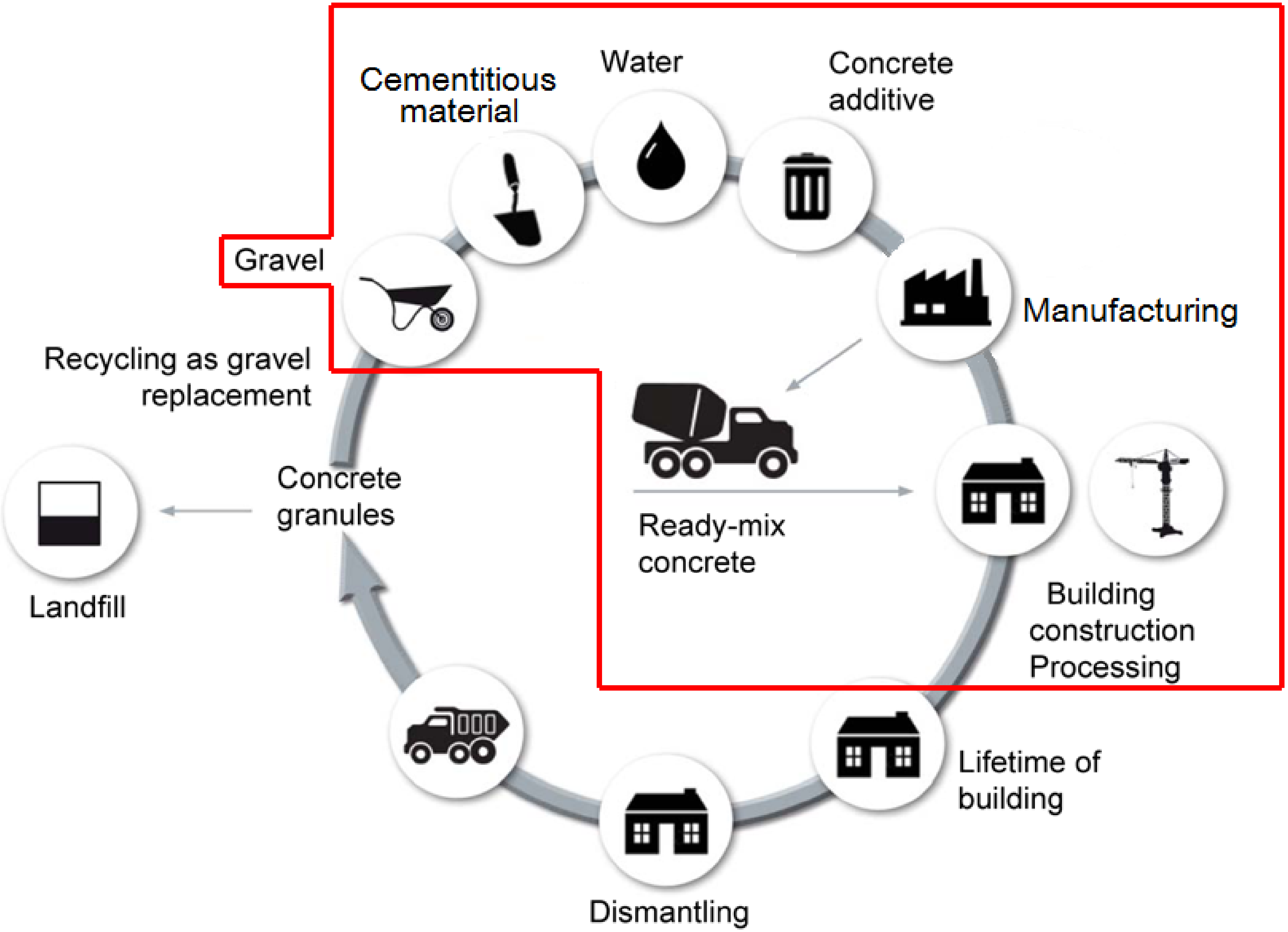
The Most Common Options:

1. Cradle-to-Grave
2. Cradle-to-Site
3. Cradle-to-Gate

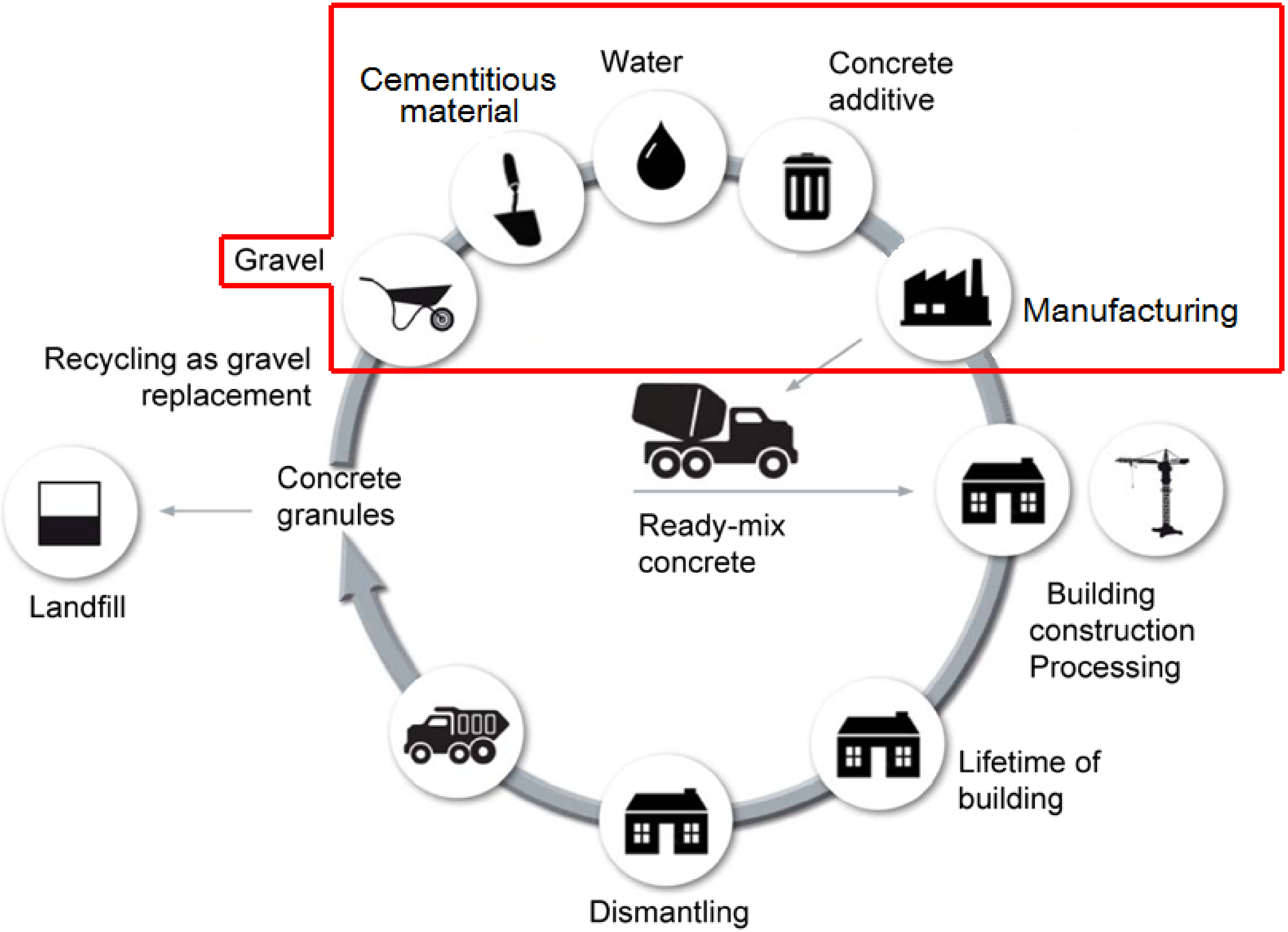
Concrete Life Cycle



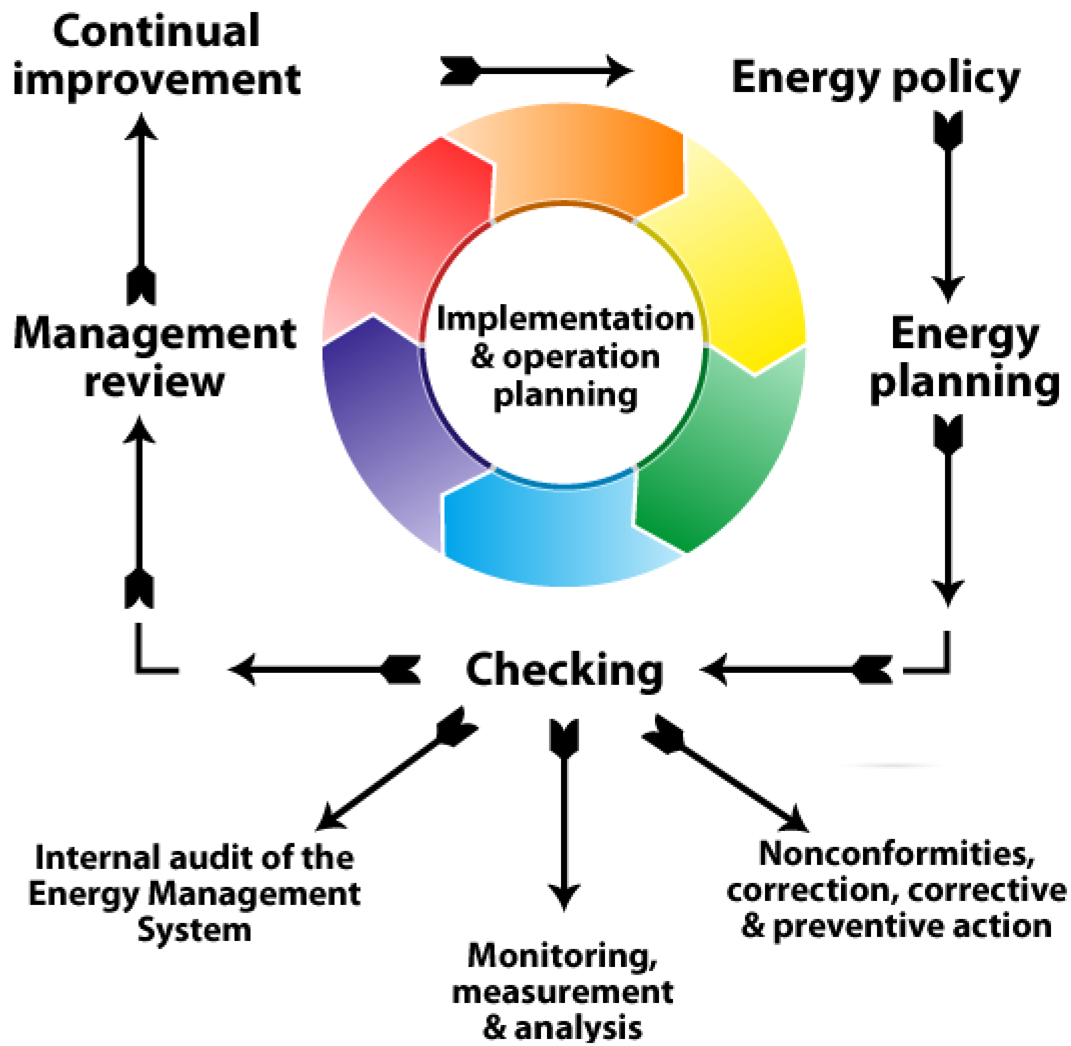
Grade-to-Site



Grade-to-Gate



ISO 50001
Energy Management System



Source: www.certification-requirements.com

Part 6

On-site Treatment

Permeability and Durability

- Durability increases with decreased Permeability
- Reduce Permeability by optimizing the mix design including lowering the w/c ratio and use of SCM
- However, Crack is the Enemy!
- Common types of Cracks:
  - Plastic Shrinkage Cracks
  - Cracks due to Thermal Movements
  - Structural Cracks due to Early Loadings
  - Restraint Cracks
  - Settlement Cracks

Cracks and Sustainability

- Cracks can lead to problems such as leakage, spalling, etc.
- Shortening of Design Life of concrete structures
- Abandon / Demolish of affected structures due to structural integrity consideration

Good design, good selection of materials, on-site workmanship etc. can well enhance the durability of concrete structures

Cracks in In-situ Concrete Structures

Cracks in In-situ Concrete Structures

Cracks in In-situ Concrete Structures

How to avoid?

- Mix Design can Help. However, there is Limitation!
- The Contractor also plays an Important Role, especially under Extreme Weather Conditions

Again – Collaborative Effort!

Finishing of Concrete Surface

Curing of Concrete On-site

Curing of Concrete On-site

Thermal Insulation

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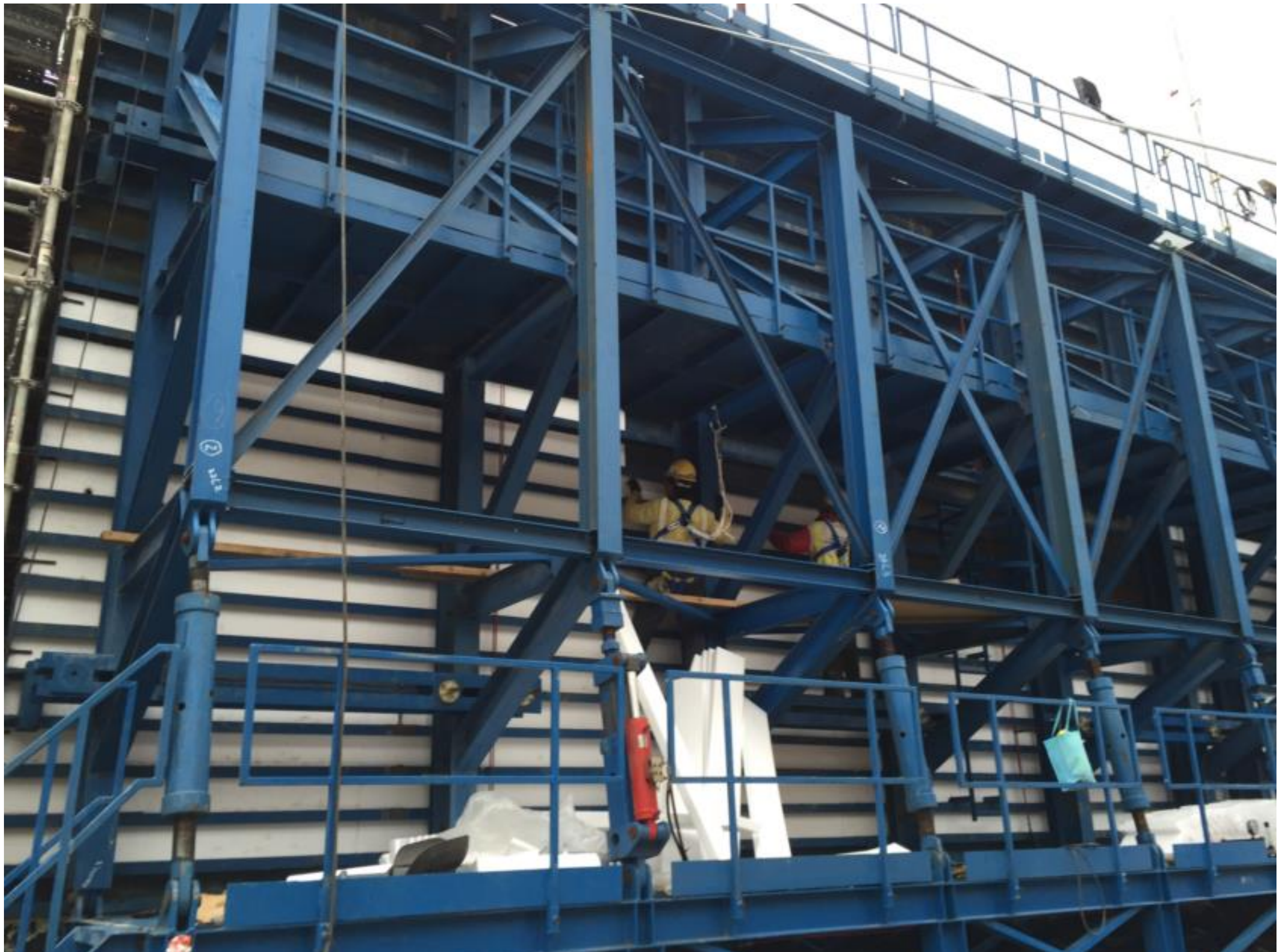
Thermal Insulation



Challenges

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Challenges

- Government's/Architect's/Engineer's Approval
- Specification Restrictions
- Concrete Plant Modification including the Addition of Silos
- Change in Construction Methodology
- Influence on Working Cycle
- Acceptance of Innovation, etc.

How to Overcome?

Again – Collaborative Effort!

Concluding Remarks

- All of us play a role in Sustainable Development
- We are on the journey to produce Sustainable Green Concrete – Keep moving forward!
- A Collaborative Effort is the key to overcome challenges!

~Thank You~