Chapter

Bioconc-Based Green Concrete Quality Treatment for Mass Concrete's Low Heat Concrete

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Abstract

Thermal cracking in concrete members having large sections, namely *mass concrete*, continues to be a concern for designers and specifiers of concrete. These issues are common to both large structural components in buildings and in civil engineering infrastructure projects. The common issues is based on the large scale of concreting dimension; mean large cement content cause more thermal hydration of concrete extremely. There is often a conflict for concrete specifier or concrete structural designer, between requirement to form high strength concrete for structural durability and structural bearing load capacity, which needs higher binder content versus higher heat of hydration characteristic of concretes. The potential problem that may be occurred is concrete thermal crack. The reaction of cement with water is exothermic, therefore it produces heat. The more Portland cement in the mix, the greater is the heat produced. To control the thermal crack means to control the concrete hydration thermal. The research started by laboratory scale trial mix Fc'25 Low Heat Concrete Bioconc-based concrete Job Mix, from cement content reduction 20, 25, 30, and 40%. The attached result shows optimum jobmix is Fc'25 Low Heat Concrete Bioconc-based concrete Job Mix on 40% cement as binder content reduction, was chosen as Low Heat Concrete Mix Mock Up. Later on, based on the optimum concrete jobmix Fc'25 R = 40%, cement content reduction 40%, above mentioned trial mixed, the research developed to project scale on mock up for sampling mass concrete dimension 1000 × 1000 × 2500 mm^3 compared with similar two mock-up of mass concrete thermal hydration control, i.e., Fc'25 + FA.20% + Ice Block (Pre-cooling with crushed ice block Mass Concrete Fc'25 with fly ash 20%) and Fc'25 + FA.40% (Low Heat Concrete Fc'25 with Fly Ash 40%). The attached Graph Thermal Monitoring Low Heat Concrete shows that the peak temperature occurred 63.5°C in 29.5 h after pouring and maximum thermal differential between LHC layers is 19.5°C. Another two Low Heat Concrete Method Statement, i.e.: Pre-cooling and Low Heat Concrete with Fly Ash 40%, Mock Up Graph Thermal Monitoring also attached for comparison study. The observation and analysis proof that, "Low Heat Concrete Hydration Thermal Reduction with Bioconc" is work simplifier and economically, for mass pouring. The most essential thing is that, the basic concept of Bioconc's Low Heat Concrete on reducing the mass concrete cement-binder content means reducing CO_2 emission in every concrete production, without any hazard impact to the environment. Its mean Bioconc based Low Heat Concrete contribute to develop the green technology and eco-friendly technology on the concrete industry as sustainable green technology.

Keywords: mass concrete, concrete hydration thermal control, low heat concrete, pre-cooling, post cooling, Bioconc, green technology, eco-friendly

1. Introduction

The concrete is most common construction material which is use on every construction project. Mostly concrete construction material, especially related to high-rise building structural elements, in large dimension forms mass concrete. Mass concrete is any volume of concrete with dimension large enough to require that measures be taken to cope with the generation of heat from hydration of cement and attendant volume change to minimize cracking. The design of mass concrete structure is generally based on durability, economy, and concrete hydration thermal control, and strength often being secondary concern [1].

Therefore this journal is written the research on how to control the hydration thermal control with Bioconc, in concentration of discussion to observe the engineering feasibility and economical feasibility.

1.1 Reference's discussion

There are several existing method to control the potential concrete thermal cracks on mass concrete, with the following concrete hydration thermal method statements:

1. Pre-cooling Method with Ice, refer https://www.scribd.com/document/109689638/Mass-Concrete-Method-Statement comparison reference [2].

2. Pre-cooling Method with Liquid Nitrogen, https://www.concreteconstruction.net/how-to/materials/precooling-mass-concrete_o [3].

3. Post-cooling Method, https://www.forconstructionpros.com/concrete/equipment-products/article/11598829/how-to-plan-and-manage-curing-for-mass-concrete-pours [4].

4. Low Heat Concrete with Fly Ash 40% Concrete Mix, to reduce the binder as source of hydration heat on acceptable peak temperature and thermal differential not exceed than 20°C, as comparison reference [5].

The first three method statements are costly, since they have to provide ice blocks, liquid nitrogen, and post cooling installation system. The last method statement Low Heat Concrete with Fly Ash 40% is most economically method but facing the environmental and human health issues, based on the following references:

1. https://www.psr.org/wp-content/uploads/2018/05/coal-ash-hazardous-to-human-health.pdf [6].

2. ojs.unsw.adfa.edu.au/index.php/juer/article/download/465/300 [7].

This chapter discuss the concrete *hydration thermal control* with the economical and *eco-friendly* Method Statement, based on the basic performance of concrete bio-admixture, Bioconc, which is produce micofiller, reduce the binder content up to 40% as described on sub clause 1.2.

The concrete hydration thermal sources is from the cement as binder, since Bioconc may reduce up to 40% binder content, the concrete hydration thermal can be controlled and worked as *Low Heat Concrete*. The paper limited discuss about the application of the Bioconc, for laboratory scale trial mix, *Low Heat Concrete* mock up modeling test and comparison with another 2 (two) Low Heat Concrete above mentioned [2, 5].

1.2 Research's object

The Object of Research is how to control concrete thermal hydration on mass concrete with bio-admixtures Bioconc, compared with existing common method statement in control mass concrete thermal hydration, of precooling as described previously on reference [2, 5].

Bioconc is a biotechnology product that is a liquid which is made of organic, natural materials, denatured proteins, biopolymer surfactant and organominerals which already fermented by beneficial microbes. Bioconc is an environmentally friendly product, non-toxic, safety use and not harmful to humans and other living things, related to object treated, concrete [8]. Bioconc performed by several microbe, which is one of them produce mycelia, functioned as microfiller for concrete mix, as shown on SEM (Scanned Electronic Microscopy) **Figure 1**

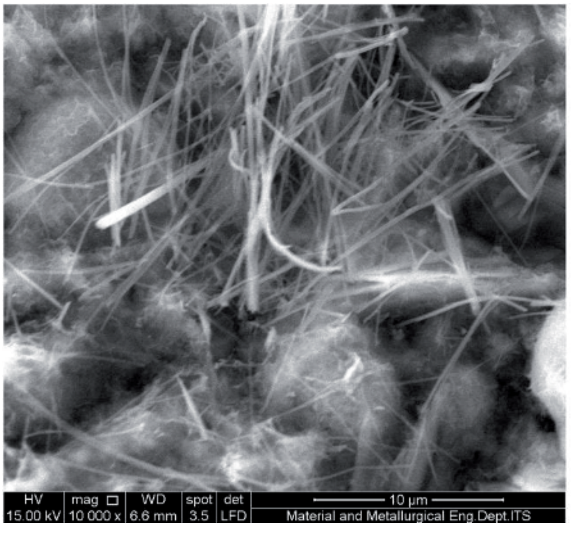

Figure 1.
SEM Bioconc treated concrete.

Figure 2.
SEM regular concrete.

and compared with normal concrete mix shown on **Figure 2**. The Physical of this Bioconc mycelia as the following [8]:

a. Diameter 5 μm s.d. 10 μm

b. Length 5–30 μm

c. Growing Speed 10^7–125^9 within 1 day (Refer to **Figure 3**).

d. Alive survival under concrete heat setting 1 hour in 60°C (Refer to **Figure 4**), then "dormant"

1.3 The aim of research

The Research's Aim is directed to observe the following objects, in controlling the potential thermal crack caused by the differential thermal between mass concrete core hydration thermal rising and mass concrete surface cooling as captured on **Figures 5** and **6**. The objects of the research's aim are:

1. The engineering effectiveness of concrete bio-admixture, Bioconc on control the concrete thermal hydration, compared with another mass concrete hydration thermal control as reference [2, 5].

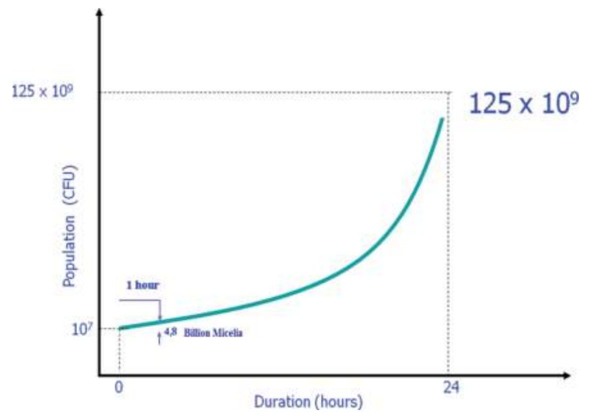

Figure 3.
Growing speed 10^7–125^9 within 1 day.

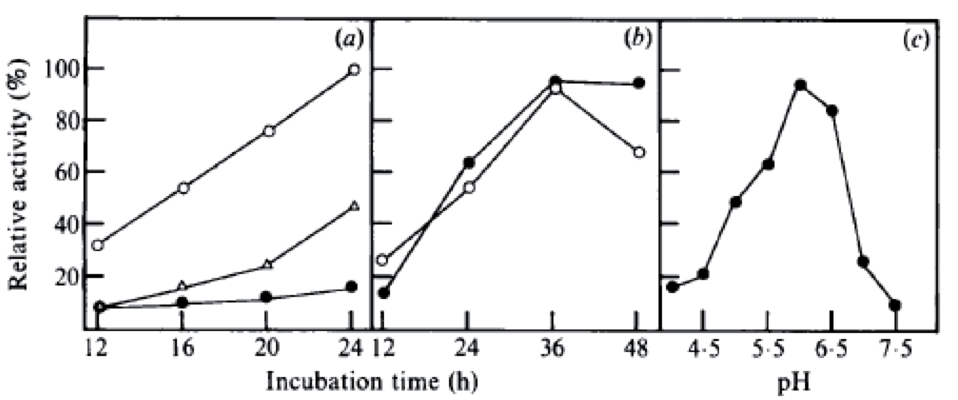

Figure 4.
(a) Incubation time of microbe which is life in Bioconc 24°C, 28°C, 34°C. (b) Mycelium age from microbe which is life in Bioconc 18°C and 24°C. (c) Mycelium age from microbe which is life in Bioconc on various pH.

2. The effectiveness of concrete bio-admixture, Bioconc on increase the mass concrete quality, compared with another mass concrete hydration thermal control as reference [2, 5].

3. The economical effectiveness of the application of concrete bio-admixture, Bioconc on control the concrete thermal hydration on Low Heat Mass Concrete compared with another mass concrete hydration thermal control as reference [2, 5] (**Figure 7**).

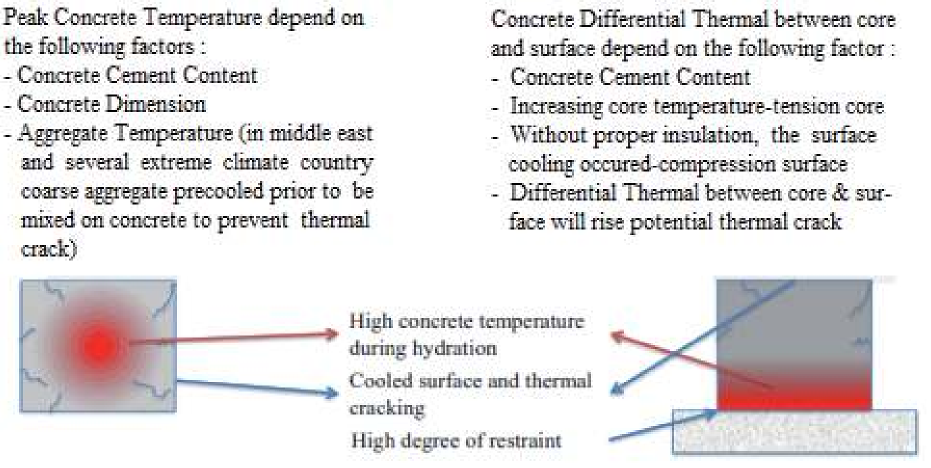

Figure 5.
Potential thermal crack of mass concrete caused by differential thermal core and surface.

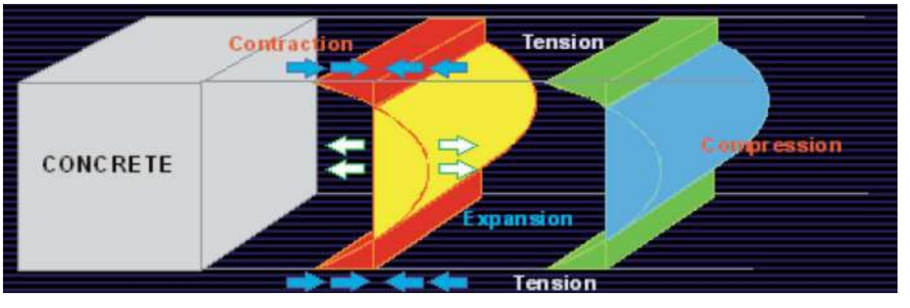

Figure 6.
Mass concrete core hydration thermal rise up expansion vs. surface tension potential crack.

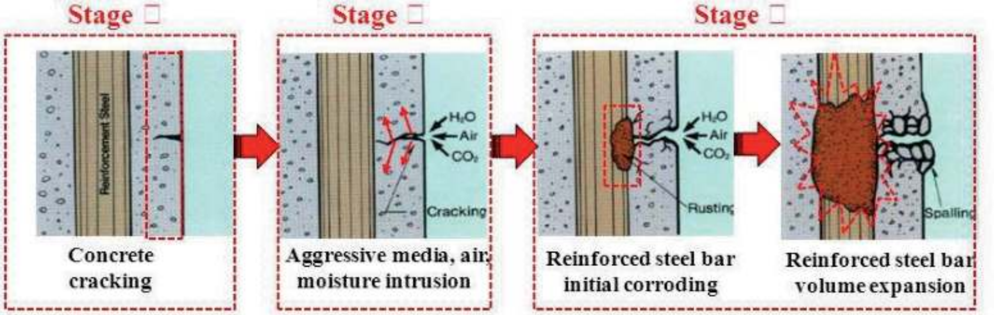

Figure 7.
Mass concrete potential crack defect and potential rebar corroding.

1.4 Scope of discussion

The discussion scope is directed on the following object:

1. Laboratory scale trial mix, directed to observe the optimum Bioconc's Low Heat Concrete Jobmix.

2. The mass concrete modeling or mock up scale of Bioconc based, Low Heat Concrete 1000 × 1000 × 2500 mm^3 dimension, observation to discover the peak temperature on the observed peak time.

3. Simply economical calculation of the Bioconc-based Low Heat Concrete application.

Those scopes of discussion are compared with another mass concrete hydration thermal control reference [2, 5].

2. Method statement

The bio-admixture Bioconc treatment concrete job mix modification from original job mix (non-fly ash job mix) is describe on the following **Table 1**:

Material mix	NFA mix	Bioconc Jobmix modification
Cement	A	A. (1 – R%)
Water	B	B. (1 – R%)
Coarse Ag-1	C	C+(A + B).R%.{C/[C + D + E]}
Coarse Ag-2	D	D+(A + B).R%.{D/[C + D + E]}
Fine Aggregate	E	E +(A + B).R%.{E/[C + D + E]}
Bioconc (cc)		−600 cc [9]
Total weight	A + B + C + D + E	A + B + C + D + E+600 cc

Table 1.
NFA job mix and Bioconc Jobmix modification.

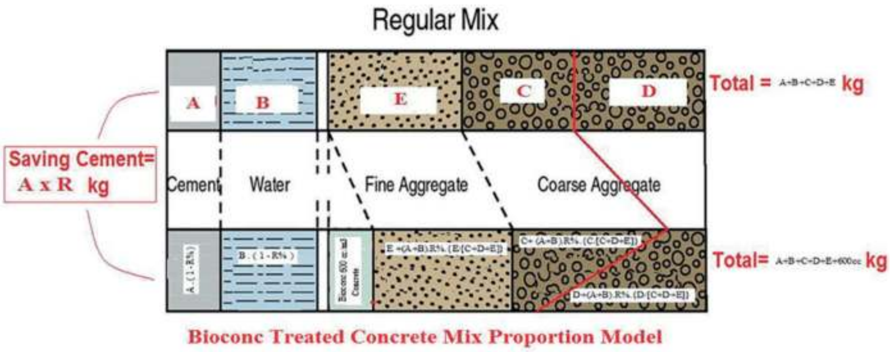

Figure 8.
Concrete job mix between original mix (NFA mix) vs. modified Bioconc-treated concrete mix.

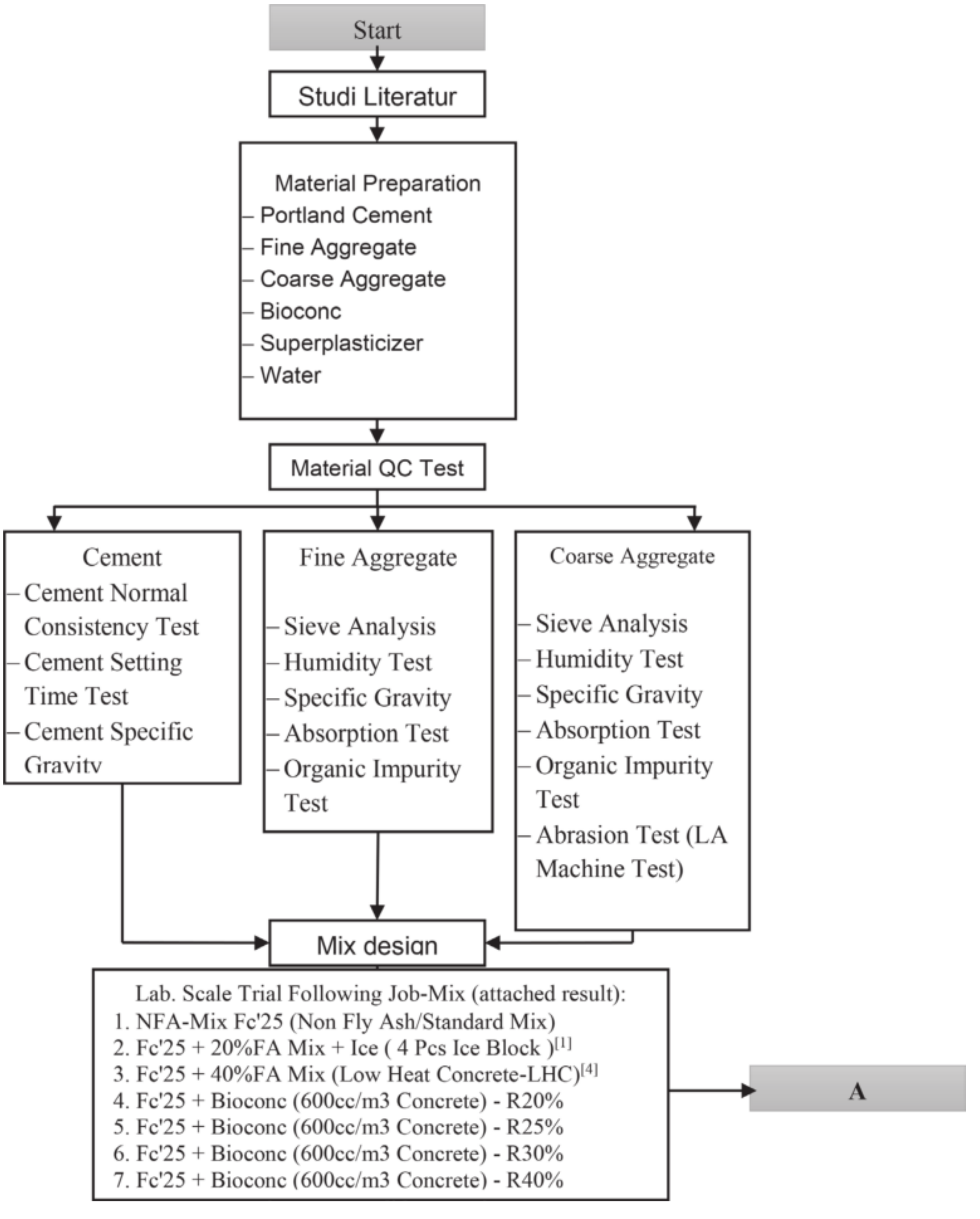

Figure 9.
Flow chart of lab scale trial mix.

Observed cement content (binder content) reduction = R %.

Concrete Job Mix - Grade (G) = Fc'25 (in this research, but not limited to).

Concrete Volume - standard jobmix reference = 1 m^3.

Optimum Bioconc dosage in 1 m^3 of Concrete = 600 cc [9].

The Modified Concrete Job Mix, based on the original concrete mix (non-fly ash concrete mix), can be described on the following **Figure 8**.

The sequence OF the research execute as the following method statement, refer to the previous research on reference [9–11], describe on the following flow chart (**Figures 9–11**).

Sequence of Bioconc mock-up and thermocouple monitoring compared to another 2 method concrete hydration thermal control is provided in **Figures 12–18**.

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Low Heat Concrete Fc'25 Trial Mix

Bioconc Treatment Low Heat Concrete Fc'25 Trial Mix Observation In Order to Find Out Optimum Low Heat Concrete Job Mix and Comparison with another 2 (two) Low Heat Concrete Method

Age (days)	Concrete Strength (Mpa) Compared another 2 LHC-Method		Standard Fc'25 (Mpa)	Trial Mix Low Heat Concrete Fc'25-with Bioconc as Microfiller Cement on Various Concrete Mix Cement Content Reduction Strength (Mpa)				Mock-Up LHC-Bioconc FAS=0,45 Fc'25_R=40% (Mpa)	Notes
	Low Heat Concrete Fc'25 - FA=40%	Ice Concrete Fc'25 (4 Ice-Block/m3)		R = 20%	R = 25%	R = 30%	R = 40%		
0	0	0	0	0	0	0	0	0	
3	20.0	12.8	11.5	31.14	27.17	24.73	12.46	12.46	
7	24.5	18.3	17.5	35.61	31.33	31.33	21.89	25.48	
14	30.6	24.7	20.5	40.80	36.80	33.40	25.48	29.44	
28	35.3	29.0	25	43.1	40.7	39.3	26.82	30.164	

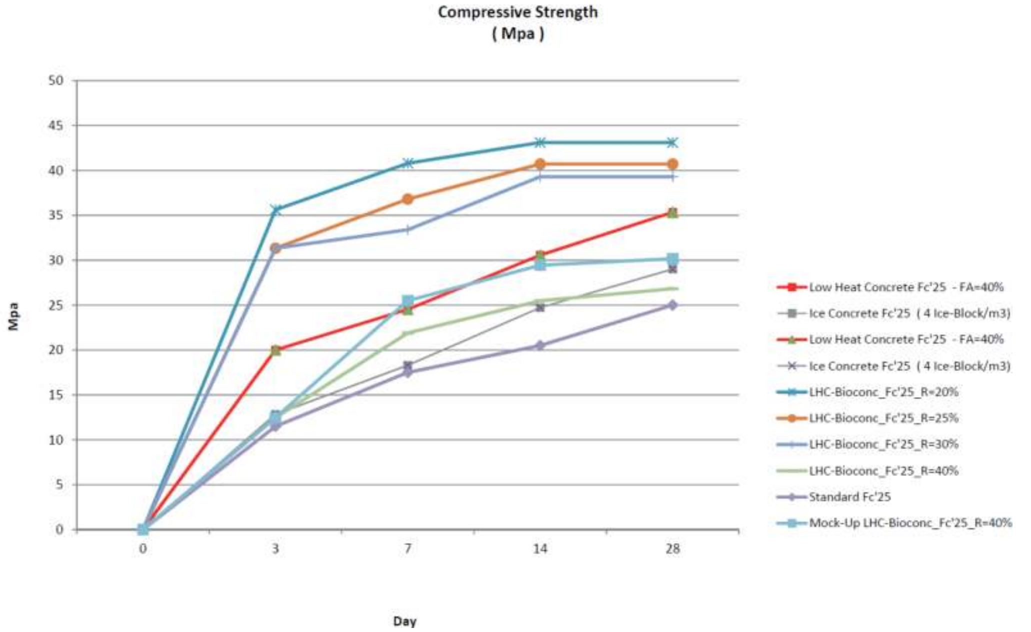


Figure 10.
Strength test of Cylindrical Samples lab Trial and Site Mock-up Mass Concrete.

3. Concrete hydration thermal control research data result

Based on the above mentioned sequences method of research, the following output data found.

3.1 Bioconc low heat concrete Fc'25, with cement binder content reduction R = 40% research data result

The Mock Up Bioconc Treatment Low Heat Concrete with cement binder content reduction R = 40% to control concrete hydration thermal, on mass concrete modeling 1000 × 1000 × 2500 mm^3, Graph thermocouple monitoring output data, figured on the following graph (**Figure 19**).

3.2 Fc'25 + concrete Fly-ash 20% + 4 pcs ice block/m^3 concrete research data result

The Mock Up of Fc'25 + FA20% + 4pcs Ice Block to control concrete hydration heat, on mass concrete modeling 1000 × 1000 × 2500 mm^3, Graph thermocouple monitoring output data, figured on the following graph (**Figure 20**).

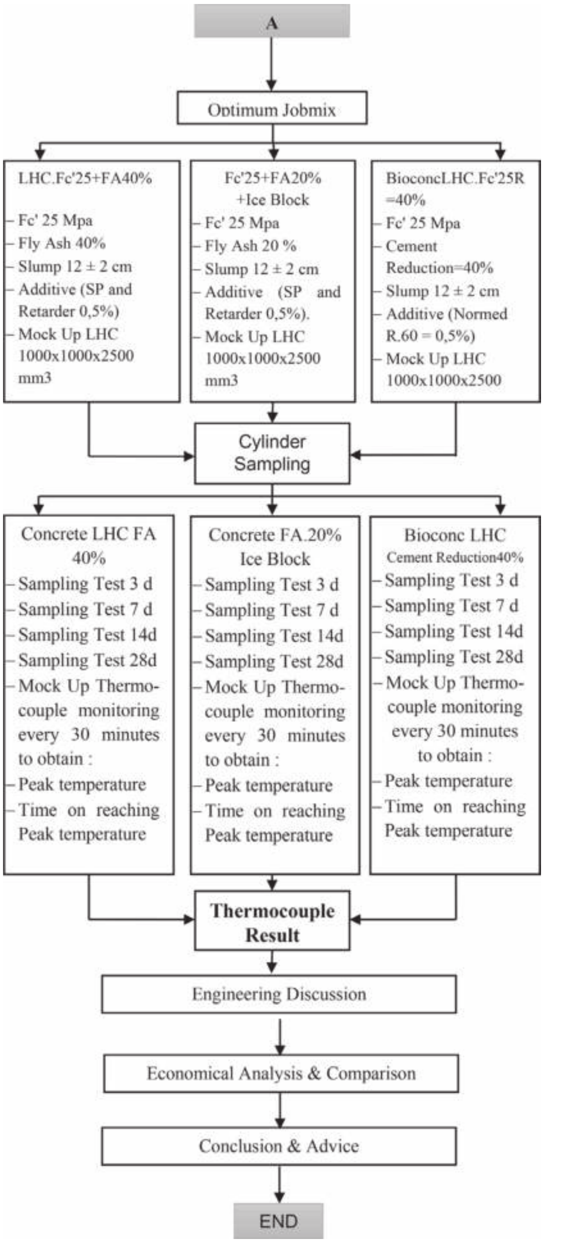


Figure 11.
Mass concrete mock up 1000 × 1000 × 2500 mm^3 and thermocouple monitoring.

Figure 12.
Bioconc LHC mixing plant.

Figure 13.
Slump test.

Figure 14.
Bioconc LHC concreting.

Figure 15.
Bioconc product packing.

Figure 16.
Fc'25 + FA40% LHC & Fc'25 + ice.

3.3 Fc'25 + concrete Fly-ash 40% low heat concrete research data result

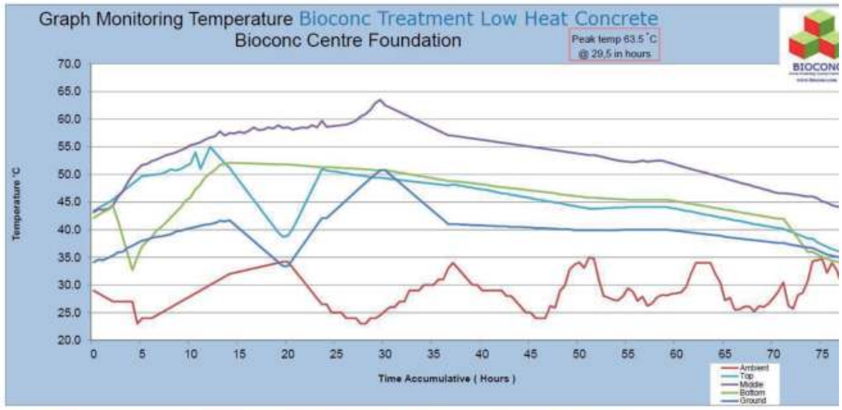
The Mock Up of Fc'25 + FA40% Low Heat Concrete to control concrete hydration heat, on mass concrete modeling 1000 × 1000 × 2500 mm^3, Graph thermocouple monitoring output data, figured on the following graph (**Figure 21**).

4. Engineering discussion

Mainly concern of mass concrete Quality Control is on the Hydration Thermal Control, as the above mentioned research data result (item 3.1, 3.2 and 3.3) can be summarized as following **Table 2**:

Figure 17.
Bioconc LHC mock up.

Figure 18.
Bioconc LHC mock up thermocouple monitoring.



LOW HEAT CONCRETE - BIOCONC BASED PERFOMANCE AS MICROFILLER ON R=40%							
Temp °C	Ambient	TOP	MIDDLE	BOTTOM	TOP-MIDDLE	MID-BOTM	Bottom-Ground
Min	23.0	36.0	43.1	32.7	-1.1	0.1	-4.4
Max	35.0	55.0	63.5	52.1	19.7	17.1	18.4
Average	28.34	45.58	53.80	46.01	8.22	7.79	5.99

Initial	at Plant	at Site
Slump	16,5 cm	12 cm
Temp	32.5°C	33°C

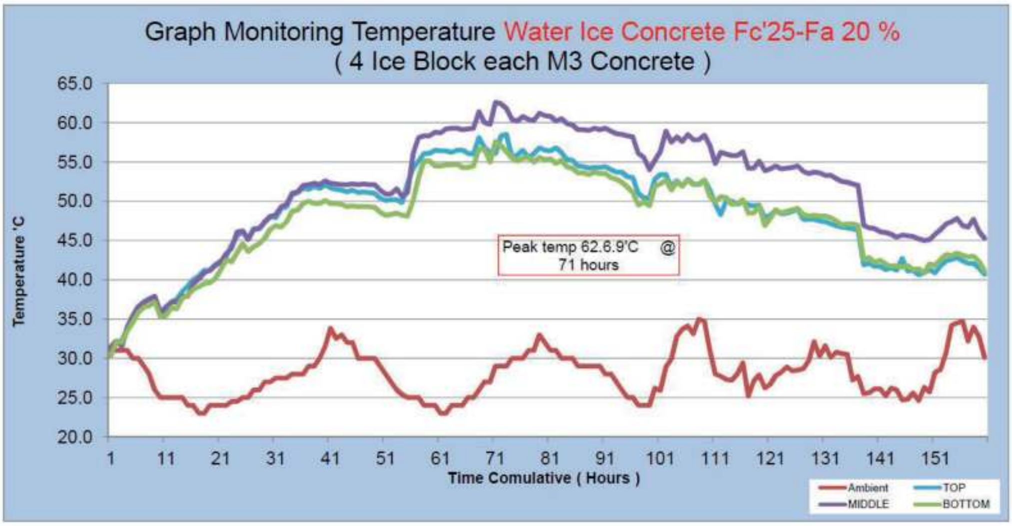
Figure 19.
Thermocouple Bioconc-LHC monitoring, Summary data & mock up sketch.

Based on **Table 2**, Bioconc Treatment Low Heat Concrete the faster method to reach the peak time on 29.5 hours from concrete pouring. On construction process, its mean cost advantage, since faster the peak temperature of mass concrete occurred, faster the next step of construction can be execute, also cheaper overhead cost in maintaining the mass concrete, such as rent of mass concrete tends, curing, etc.

Secondly concern of mass concrete Quality Control is on the concrete strength is the concrete cylindrical samples strength test as describe on **Figure 6**, shown that various Concrete Strength Tests are match to the specified.

5. Economic feasibility analysis

Based on the each jobmix material proportion, Low Heat Concrete LHC-Fc'25 + FA40%, Fc'25 + FA20% + Ice block and Bioconc Treatment Low Heat



NORMAL CONCRETE + ICE						
Temp °C	Ambient	TOP	MIDDLE	BOTTOM	TOP-MIDDLE	MIDDLE-BOTTOM
Min	23.0	31.3	31.4	30.3	-1.3	-0.5
Max	35.0	58.5	62.6	57.6	7.9	7.1
Average	27.46	48.39	51.55	47.63	3.16	3.92

Initial	at Plant	at Site
Slump	12 cm	11 cm
Temp	22°C	25°C

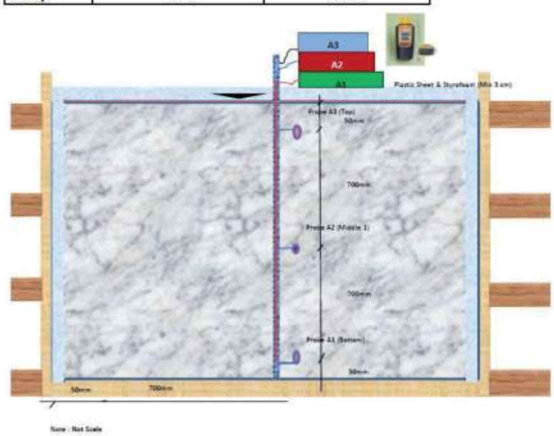


Figure 20.
Thermocouple Fc'25 concrete+20%FA + ice, monitoring, Summary Data & Mock up Sketch.

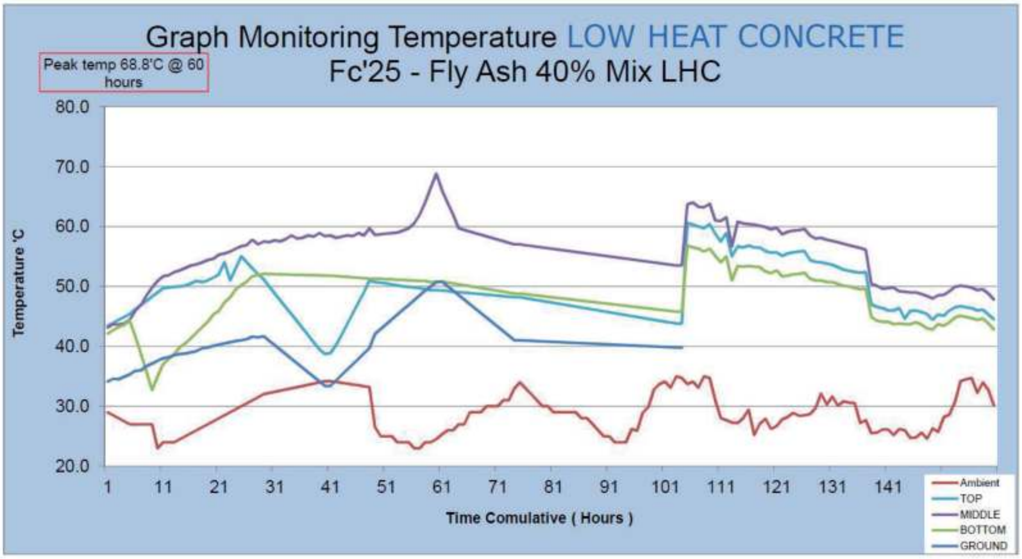
Concrete with cement binder content reduction R = 40%, can be analyzed the initial each cost of production as the following **Table 3**:

Based on **Table 3**, Fc'25-LHC + FA40% is the cheapest one, but considering the risk of environmental hazard and human health [6, 7] the Bioconc Treatment Low Heat Concrete as the mass concrete's hydration thermal control is the wise option to avoid any environmental hazard and human health.

6. Conclusion

1. Considering the eco-friendly, engineering and economical aspect, the Bioconc Treatment Low Heat Concrete satisfy all related condition.

2. Considering the time required to reach peak temperature, the Bioconc Treatment Low Heat Concrete fastest method to control mass concrete's hydration thermal in 29.5 h after pouring. This facs impact to reduce indirect cost of production of the mass concrete, and speed up to execute the next stage of the construction.



LOW HEAT CONCRETE						
Temp °C	Ambient	TOP	MIDDLE	BOTTOM	TOP-MIDDLE	MIDDLE-BOTTOM
Min	0.0	0.0	35.7	35.9	-1.1	-1.4
Max	0.0	0.0	68.8	61.5	4.5	8.9
Average	0.00	0.00	56.05	51.15	1.97	4.90

Initial	at Plant	at Site
Slump	12,5 cm	12 cm
Temp	30°C	32°C

Figure 21.
Thermocouple Fc'25 + FA40%-LHC graph monitoring, Summary Data & Mock-up Sketch.

Material mix	Bioconc LHC	FA20% + Ice	LHC-FA40%
Peak thermal (°C)	63.5	62.6	68.8
Peak time (h)	29.5	71	60
Dif. thermal (°C)	19.7	7.9	8.9

Table 2.
Thermocouple monitoring summary.

No.	Material Composition					Cost of LHC FA 40%	Cost of LHC FA 20% + Ice Block	Cost Of LHC Bioconc	Remark
	Material	LHC FA 40	LHC FA 20 + Ice Block	Bioconc LHC+R=40%	Rate @ Rp.	Rp.	Rp.	Rp.	
1	Cement	236.0	315.0	236.0	1,000	236,000	315,000	236,000	
2	Water	158.0	158.0	158.0	100	15,800	15,800	15,800	
3	Fly Ash	158.0	79.0	-	100	15,800	7,900	-	
4	Coarse Agg	1,160.0	1,160.0	1,160.0	250	290,000	290,000	290,000	
5	Fine Agg	760.0	760.0	760.0	175	133,000	133,000	133,000	
6	Ice Block	-	4.0	-	35,000	0	140,000	0	
7	Ice Block Sto-rage System		1.0 Lump-sump		52,500		52,500		
8	Bioconc	-	-	0.6	80,000	-	-	48,000	
	Total Initial Cost of Production					690,600	954,200	722,800	

Table 3.
Initial cost of production analysis and comparison.

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