Low heat concrete hydration thermal reduction with bioconc

IOP Conf. Series: Materials Science and Engineering **615** (2019) 012110 doi:10.1088/1757-899X/615/1/012110

Low heat concrete hydration thermal reduction with bioconc

M Basoeki[1*], Koespiadi[2] and J J Ekaputri[3]**

[1]Bioconc Foundation Centre, Sidoarjo, Indonesia
[2]Universitas Narotama, Surabaya, Indonesia
[3]Civil Engineering Department, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia

[*]maknobasoeki@gmail.com, [*]maknobasoeki@bioconc.co.id, [**]januarti@ce.its.ac.id

Abstract. This paper presents the experimental study on the control of the heat of hydration of mass concrete using the concrete bio-admixture, bioconc. The basic issue of mass concrete is thermal cracking, because of the heat of hydration of the cement content in mass concrete. This paper reports on the research results of using the concrete bio admixture, bioconc as a micro filler. To control the heat of hydration of mass concrete the cement content was reduced significantly up to 40 percent. The product is called bioconc low heat concrete. In order to control the researched object, it was compared with: pre-coolingmasscon and fly ash based low heat masscon. There were three parameters to be compared for asessing the product: hydration heat control effectiveness, cost of raw materials and the environmental impact. In this research, the concrete was made with fc' 25 and the size of the mass concrete mock-up was 1000x1000x2500 mm^3. Research result written in series of following data: the peak temperature, duration to reach peak temperature, thermal gap between core-edge off masscon and masscon raw material cost. The peak temperature at bioconc low heat concrete was 63.5 ^{o}C within 29.5 hours after pouring. It has thermal different at 19.5 ^{o}C. The cost of material was US$ 54.6 per cubic meter.

1. Introduction
This research was refer to the previous research of bioconc [1-4], with specific object of reducing cement content related to reducing masscon hydration heat. In general, concrete construction uses mass concrete (masscon), concrete which has large dimensions approximately exceeding more than 3 feet or 1000 mm [5]. Thermal crack is the main issue of masscon that needs to be solved. Masscon thermal cracks occur due to the following sequence: large dimension of mass concrete, need of high cement content to meet the target strength, hydration heat occure at the early hours after casting [4, 6-10]. If the hydration reaction in mass concrete exothermically increases the the hydration heat, and the heat in the core tends to be slowly released, compared to the edge towards the surface, it produces thermal stresses which causes thermal cracks in the concrete. The thermal different between core and the surface can exceed 20 ^{o}C [6]. Concrete thermal crack behaviour was caused by concrete's brittle behaviour, based on concrete tensile strength only about 8% of its compressive strength and the deformability is poor. Concrete thermal crack occurs under uncontrolled as hydration heat increases in masscon.

This paper provides experimental study in industrial scale based on the bioconc low heat concrete method, which was compared with two methods commonly used for masscon: the precooling method of mass concrete and fly ash based low heat mass concrete [11]. The object of masscon research was mock up shape 1000x1000 x2500 mm^3, which was casting of thermal isolated formwork, and installment of 4 unit of thermal probe to control thermocouple on each layers.

Based on the large dimension, more cement content produces more CO_2, so increases the environmental pollution [12]. Bioconc, as a micro filler, may reduce the cement content but also decreases the concrete workability. The laboratory research is to determine the optimum mix to control the mass concrete hydration heat, with various degrees of cement content reduction for a fixed water cement ratio [4, 13-21]. Fly ash, as a concrete filler, may reduce the cement content, so confronting the environmental issues [22, 23], but it has to be cost competitive in concrete hydration heat control [11].

A precooling system may control mass concrete hydration heat but needs a lot of preparation, such as ice block storage, ice block crushing, and a tight schedule control to prevent ice block melt [11]. This research was to determine the optimum cement content with the laboratory scale trial mix [4, 13-21] to find out the optimum bioconc amount based on low heat concrete. The following published research was referred to regarding the above mentioned problems for solving mass concrete hydration heat control:

- Concrete strength increase, based on the basic concept of a biochemical technology approach to increase the mechanical properties of cement-based material is called bio-mineralisation and is one of the functions of bioconc in increasing the concrete strength [1-3].
- Several publications on microbially based concrete admixtures to improve the mechanical properties of the treated concrete [24-34].
- Research to observe the optimum dosage of bioconc in concrete treatment such that the relation between bioconc treatment in concrete, on various dosage vs concrete strength, was observed [13].

This research was directed to observe the following aims:

- Controlling the potential of thermal cracking caused by the thermal differential between the mass concrete core and the mass concrete surface, with reducing the cement content. It was was observed in a laboratory scale trial mixing mass concrete with various cement contents reduction to find out the optimum cement content reduction.
- The engineering effectiveness of the concrete bio-admixture, bioconc, on controlling the concrete heat of hydration, compared with the usual controls on the mass concrete system, precooling and fly ash based low heat concrete [11].
- Determining the economical effectiveness of the application of the concrete bio admixture, bioconc on the control of the concrete thermal hydration, which is compared to common mass concrete system, precooling and fly ash based low heat concrete [11].

2. Materials and methods

2.1. Concrete raw material

The material in this study consisted of fresh concrete and the concrete bio-admixture bioconc, produced in Sidoarjo-East Java-Indonesia. The concrete was designed for fc'25 with a designed compressive strength of 25 MPa. Fine aggregate was from deposits from Lumajang-East Java- Indonesia. Coarse aggregate was from deposits from Mojokerto-East Java- Indonesia. Portland Cement from OPC, Ordinary Portland Cement made by PT Semen Gresik-Indonesia. Fly ash was from Paiton.

The bio-admixture material used was bioconc, made in Sidoarjo-East Java-Indonesia. Bioconc performed with the perfomance of several microbes. One of them is produced micro filler which is inserted in the micro gap of the concrete, reducing the cement content and increase the concrete strength [1-4, 35]. The comparison between bioconc treated concrete and regular concrete is shown in figure 1 and figure 2.

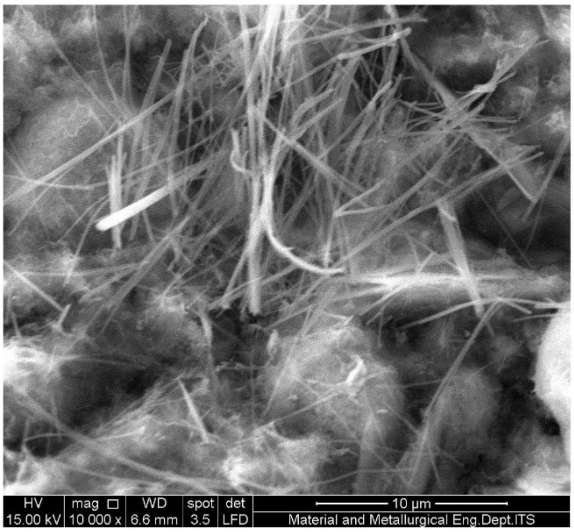


Figure 1. SEM of bioconc treated concrete.

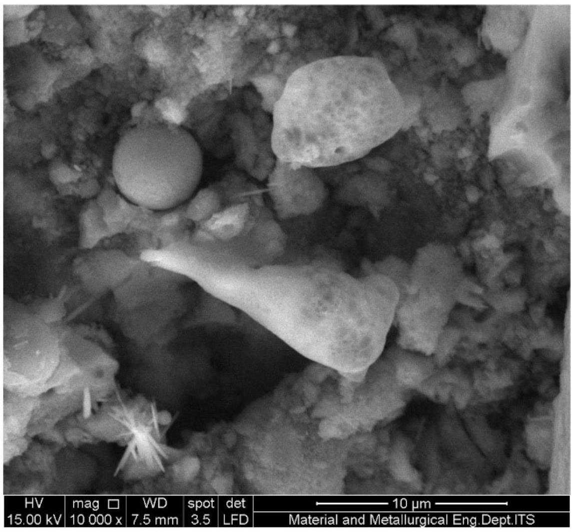


Figure 2. SEM of normal concrete.

2.2. Concrete mix

The concrete mix grade fc'25, with various treatments with bioconc, are listed in table 1.

Table 1. Job Mix fc'25 with various treatments (*control another masscon hydration heat system [11]).

Concrete Grade	Cement (kg)	Water (liter)	Fly Ash (kg)	Sand (kg)	Coarse Ag. 3/4"	Coarse Ag. 1"-1,5"	IceBlock (pcs)	SP (liter)	Bioconc (cc)
Fc'25 FA 40% *)	236	95	158	760	350	810.0	-	1.50	-
Fc'25FA20%+Ice*	315	104	79	820	240	930.0	4	1.30	-
Fc'25 (NFA Mix)	394	158	-	820	240	930.0	-	1.05	-
Fc'25 Bioconc R20	317	126	-	804	370	856.7	-	0.99	600
Fc'25 Bioconc R25	297	119	-	815	375	868.4	-	1.07	600
Fc'25 Bioconc R30	277	111	-	826	380	880.1	-	1.14	600
Fc'25 Bioconc R40	236	110	-	1020	370	850.0	-	2.40	600

2.2.1. Laboratory Observation. The laboratory observation was carried out to obtain the optimum jobmix of the bioconc. Based concrete treatment were conducted according to the flow chart in figure 4a, with the following steps :

- Concrete material mechanical properties tested based on the SNI Code [14-17]
- Concrete slump test referring to the SNI Code [18]
- Concrete cylindrical samples manufacturing and curing referring to the SNI Code [21]
- Concrete specific gravity determination referring to the SNI Code [3419
- Concrete compression strength test referring to the SNI Code [21]
- Concrete jobmix design and laboratory scale trial of the mix referring to the SNI Code [13], concrete grade fc'25 with the various treatments, such as fc'25 bioconc-R20%, fc'25 bioconc-R25%, fc'25 bioconc-R30% and fc'25 bioconc-R40%. Each trial mix, as tabulated in table 1 was tested in the following sequence:
  - o Slump test of the concrete samples.
  - o Cylindrical samples 150 mm diameter, 300 mm height, in a 4 x 3 unit for the series of concrete ageing tests over 3, 7, 14, and 28 days, with 3 pcs sampled for each period.
  - o Testing the cylindrical concrete samples for compression strength.

- Compiling and analysing the data.

- Bioconc Concrete Job Mix Modification as table 2 and figure 3
  Observed cement 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. [4]

Table 2. NFA job mix and bioconc jobmix modification.

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 [4]
Total Weight	A+B+C+D+E	A+B+C+D+E+600cc

Non fly ash concrete mix (original concrete mix)

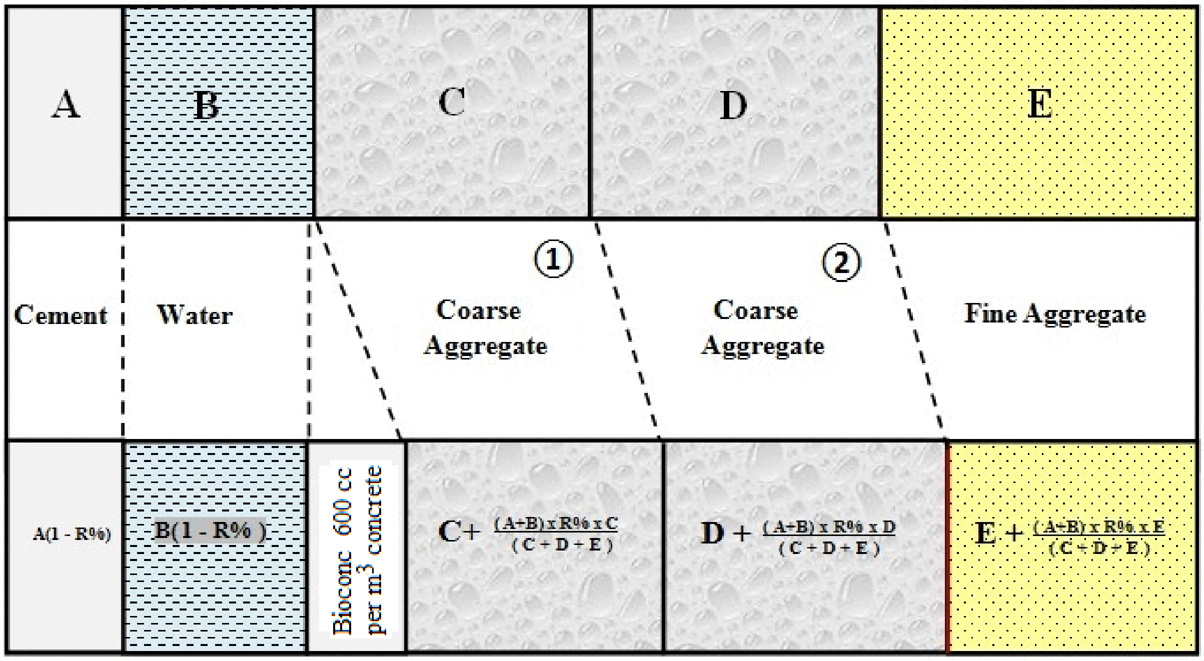
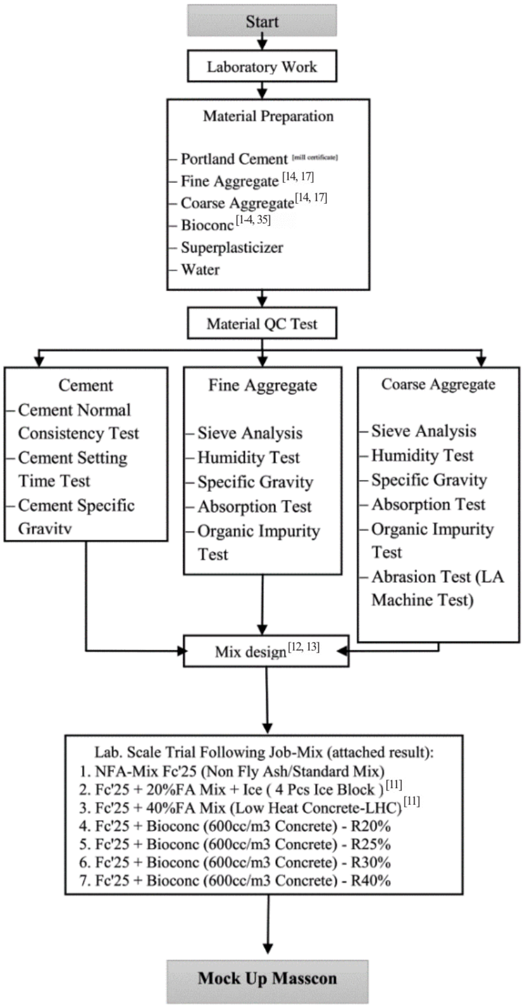


Figure 3. Modified bioconc treated concrete mix.



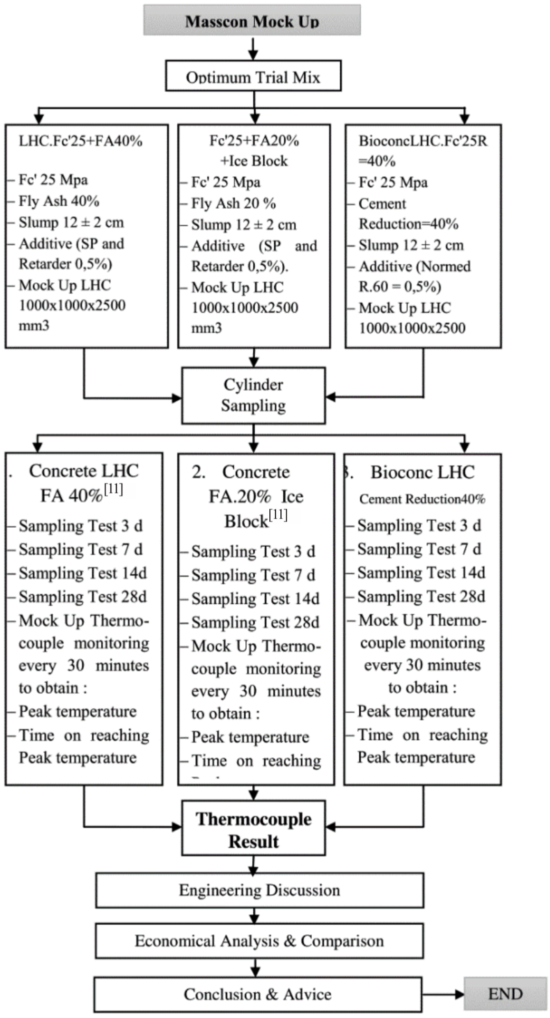


Figure 4a. Flow chart of lab. scale trial mix **Figure 4b.** Mock-up scale thermocouple monitoring

2.3. Mass product scale mock-up of the bioconc's mass concrete observations.

The mass product scale mock-up of the bioconc's mass concrete observation was done referring to the observed optimum jobmix (2.2. and 3.1) with the following steps:

a. Set up mock-up of the mass concrete formwork LxWxH = 1000x1000x2500 mm^3 as figure 5
b. Set up the 4 (four) units of the thermocouple probe as sketched in figure 6
c. The mock-up process of the bioconc based treatment of the mass concrete fc’25 R 40%, were conducted according to the flow chart on figure 4b, and were carried out according to the following sequence :

- Slump test of the concrete samples.
- Making cylindrical samples 150 mm diameter, 300 mm height, with 7 x 3 units for the series of concrete ageing tests over 3, 7, 14, 28, 56, 84, and 112 days, with 3 pcs sampled per each period.
- Testing the compression strength of the cylindrical concrete samples.
- Pouring the mock-up of bioconc treated mass concrete fc’25 R40% on the formwork.
- Monitoring the thermocouple data at 30-minute intervals started from the end of the mock-up mass concrete pouring.
- Data compilation and analysis.

Figure 5. Mock-up form with the size of 1000 x 1000 x 2500 mm^3.

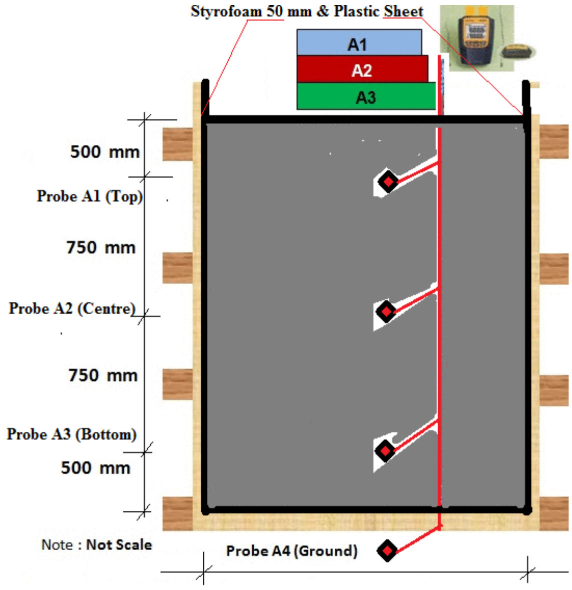


Figure 6. Thermocouple probe position in formwork.

3. Results and discussion

3.1. Laboratory scale trial mix result

The compression test results of the laboratory scale trial mix are shown in table 3. The results showed that the optimum bioconc low heat concrete's job mix was fc'25 R40, which means a cement content reduction of up to 40% from the binder content.

Table 3. Job Mix fc'25 on various treatment (*control specimen [11]).

Each 3 pcs Cylindrical concrete samples compression test average (MPa)								
Concrete Grade	3days	7days	14 days	28 days	56 days	84 days	112 days	Remark
Fc'25 FA 40% *)	20.0	24.5	30.60	35.3	-	-	-	-
Fc'25FA20%+ice*	12.8	18.3	24.70	29.0	-	-	-	-
Fc'25 (NFA Mix)	11.5	17.5	20.50	25.0	-	-	-	-
Fc'25 Bioconc R20	31.1 35.61		40.80	43.1	-	-	-	-
Fc'25 Bioconc R25	27.2 31.33		36.80	40.7	-	-	-	-
Fc'25 Bioconc R30	24.3 31.33		33.40	39.3	-	-	-	-
Fc'25 Bioconc R40	12.46 21.89		25.48	26.82	-	-	-	-

3.2. Mass concrete mock-up results

The cylindrical sample's age compression test results of the *bioconc low heat concrete* mock-up, up to 112 days, are shown in table 4. The compression test results for both the laboratory test and mock-up results are shown in figure 7.

Table 4. Bioconc's mock-up mass concrete (*bioconc low heat concrete*) fc'25 bioconc R 40%.

Each 3 pcs Cylindrical concrete samples compression test average (MPa)								
Concrete Grade	3days	7days	14 days	28 days	56 days	84 days	112 days	Remark
fc'25 Bioconc R40	12.5	25.48	29.44	30.16	34.68	37.50	43.60	-

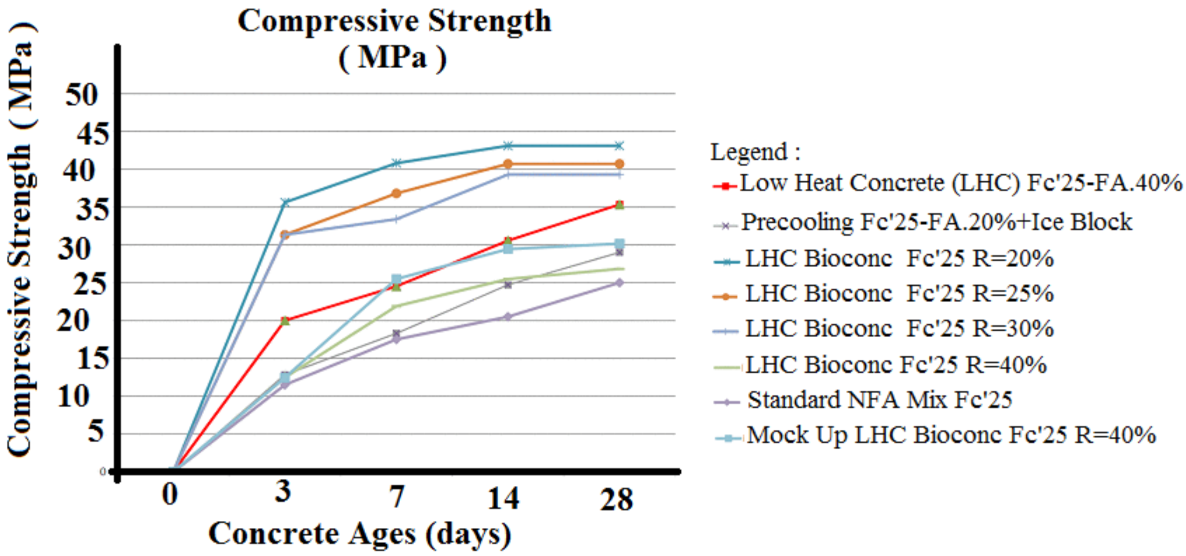


Figure 7. Chart of both lab. scale trial mix & mass concrete mock-up compressive strength.

3.3. Concrete hydration heat control monitoring results

In order to observe the results of the mock-up mass concrete, the thermocouples were checked every 30 minutes to find out the maximum temperature, of the core or peak temperature, during the time to reach the peak temperature, and to determine the thermal differential between the core of the mass concrete and the edge of the concrete. The results are charted in figure 8 which is controlled by the bioconc low heat concrete, figure 9 which is controlled by the pre cooling mass concrete system fc'25-FA.20% + ice block, and in figure 10 which is controlled by fly ash based low heat concrete fc'25-FA.40%. Bioconc low heat mass concrete fc'25-Bioconc R40, R40 means cement binder content reduction 40%, modeling size 1000x1000x2500 mm^3 Graph thermocouple monitoring output data, figured on the following graphic on figure 8 and summary of the thermocouple monitoring in table 5a and table 5b.

Table 5a. Thermocouple monitoring fc'25 bioconc R. 40%.

Temp °C	Ambient	Top	Middle	Bottom	Top-Mid	Mid-Btm	Bottom-Ground
Min	23	36.0	43.1	32.7	-1.1	0.1	-4.4
Max	35	55.0	63.5	52.1	18.70	17.10	18.4
Average	28.34	45.58	53.8	46.01	8.22	7.79	5.99

Table 5b. Slump loose and fresh concrete temperature monitoring.

Initial	At batching plant	At mock-up site / project site
Slump	16.5 cm	12 cm
Temperature	32.5 °C	33 °C

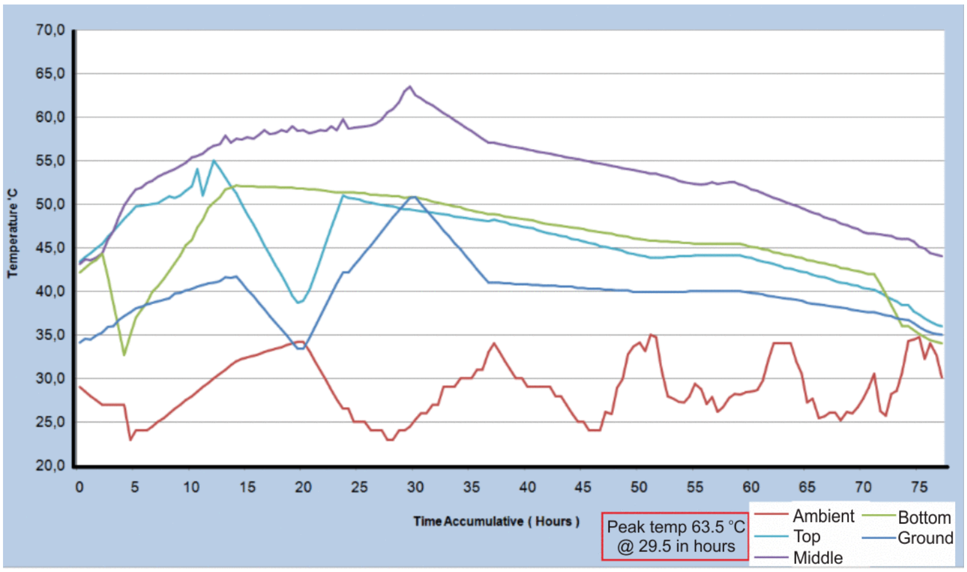


Figure 8. Thermocouple graph monitoring temperature of bioconc low heat concrete fc'25 - Bioconc R 40%.

3.4. Precooling masscon fc'25+concrete fa20%+4 pcs ice block/m^3 data result [11]

Graph thermocouple monitoring output data of the mock-up of fc'25+FA20%+ precooling with 4 pcs ice block to control concrete hydration heat, on mass concrete modeling with the size of 1000x1000x2500 mm^3, figured on the following graphic on figure 9 and thermocouple monitoring summary in table 6a and table 6b.

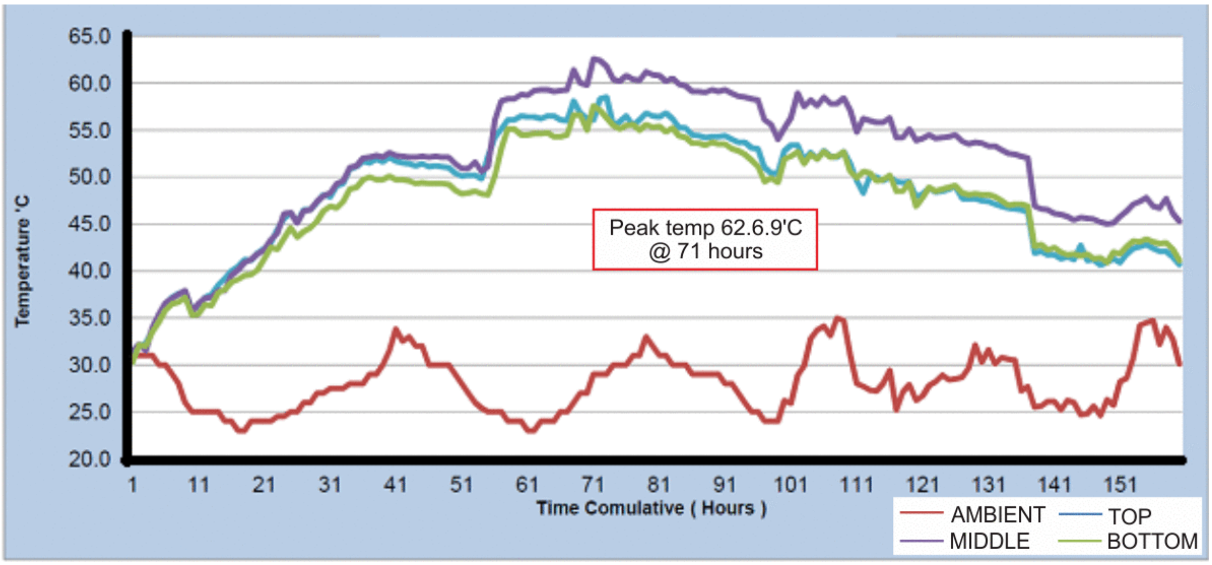


Figure 9. Thermocouple monitoring of precooling masscon mock-up fc'25 +20%FA+ice block.

Table 6a. Summary of tthermocouple monitoring of masscon mock-up fc'25 +20%FA+ice block.

Temp °C	Ambient	Top	Middle	Bottom	Top-Mid	Mid-Btm	Bottom- Ground
Min	23	31.3	31.4	30.3	-1.3	0.1	-0.5
Max	35	58.5	62.6	57.6	7.90	17.10	7.1
Average	27.46	48.39	51.55	47.63	3.16	7.79	3.92

Table 6b. Slump loose and fresh concrete temperature monitoring.

Initial	At batching plant	At mock-up site / project site
Slump	12 cm	11 cm
Temperature	22 °C	25 °C

3.5. Fly ash based low heat mass concrete mock-up fc'25-fa.40% data result [11]

Graph of the thermocouple monitoring output data of the mock-up of fc'25+FA40% fly ash based low heat concrete to control the concrete hydration heat, on mass concrete modeling size 1000x1000x2500 mm^3, is shown in figure 10 and summarized in table 7a and table 7b.

Table 7a. Summary of the thermocouple of fly ash based low heat concrete fc'25+FA.40%.

Temp °C	Ambient	Top	Middle	Bottom	Top-Mid	Mid-Bottom	Bottom-Ground
Min	22.5	38.5	35.7	35.9	-1.1	0.1	-1.4
Max	36	60.5	68.8	61.5	7.90	4.5	8.9
Average	29.25	49.5	56.05	51.15	3.16	1.97	4.90

Table 7b. Slump loose and fresh concrete temperature monitoring.

Initial	At batching plant	At mock-up site / project site
Slump	12.5 cm	12 cm
Temperature	30 °C	32 °C

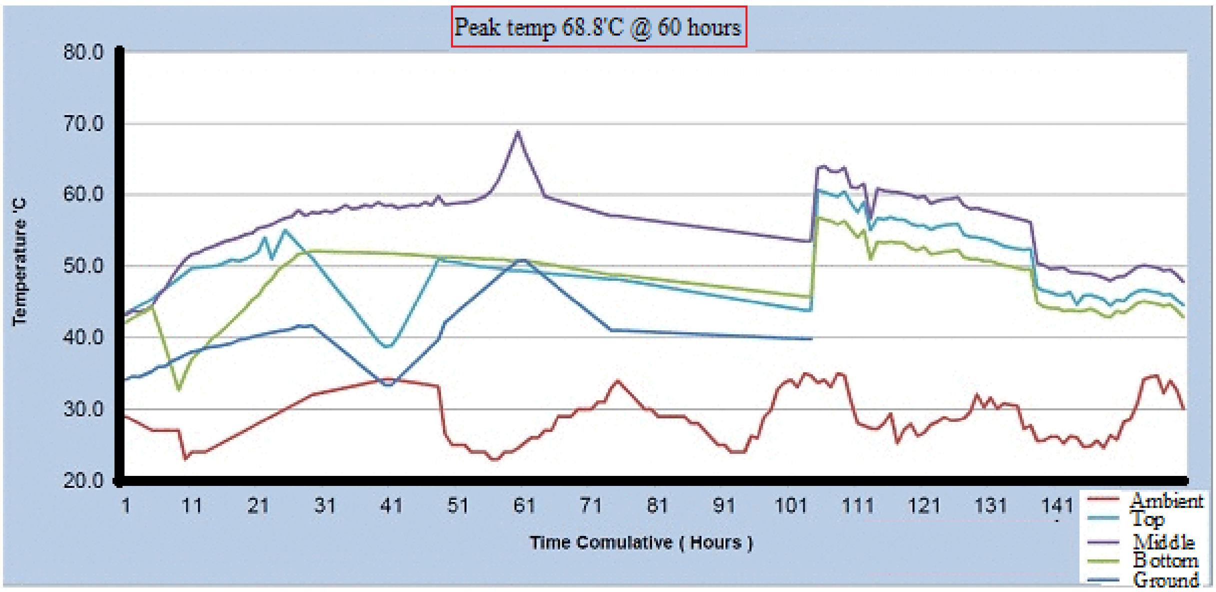


Figure 10. Thermocouple monitoring of low heat mass concrete fc'25+FA40%.

4. Discussion

4.1. Engineering discussion

The summary of the three system of mass concrete is provided in table 8:

Table 8. Thermocouple monitoring summary.

Masscon	Bioconc LHC	FA20%+Ice	LHC-FA40%
Peak Temp	63.5 □C	62.6 □C	68.8 □C
Peak Time	29.5 hours	71 hours	60 hours
Dif.Thermal	19.7 □C	7.9 □C	8.9 □C

In table 8, bioconc treatment low heat concrete was the faster method to reach the peak time, after 29.5 hours from the concrete pouring. In the construction industry this means a cost advantage, since the faster the peak temperature of mass concrete can be achieved, the faster the next step of construction can be executed. This would make it cheaper by reducing the overhead costs in maintaining the mass concrete, such as the rent of mass concrete construction facilities, curing, etc.

4.2. Economic discussion

Based on each jobmix material proportion, fly ash based low heat concrete-Fc'25+FA40%, fc'25+FA20%+ice block and bioconc low heat concrete with reduced cement/binder content reduction R 40%, can be analysed with the initial cost of each mass concrete production as described in table 9.

Table 9. Initial cost of production analysis per m^3 mass concrete comparison.

No.	Material	Masscon	System	Model	(kg)	Cost **LHC.Fc'25. FA40** (US$)	Cost **Fc'25.FA20 +Ice** (US$)	Cost **Bioconc.Fc'25. R40** (US$)
		Fc'25.FA.40	FA.20+Ice	Fc'25.Bio Con.R40	Rate (US$)			
1	Cement	236	315	236	0.07	16.56	22.11	16.56
2	Water	158	158	158	0.01	1.11	1.11	1.11
3	Fly Ash	158	79	-	0.002	0.28	0.14	-
4	Coarse Ag	1160	1160	1160	0.02	20.35	20.35	20.35
5	Fine Agg	760	760	760	0.01	9.33	9.33	9.33
6	Ice Block	-	5	-	2.46	-	12.28	-
7	Ice Process	-	1	-	3.51	-	3.51	-
8	SP (Litre)	1.5	1.3	1.4	2.46	3.56	3.19	3.44
9	Bioconc	-	-	0,6	6.32	-	-	3.79
Total material cost of mass concrete production = US$						51.30	72.00	54.60

5. Conclusion

- Bioconc low heat concrete reduces the cement content by up to 40% to control the heat of hydration
- Research data result from thermocouple monitoring shown that bioconc low heat concrete's peak temperature 63.5◦C within 29.5 hours after pouring, thermal differential between core and edge of masscon 19.5 ◦C and material cost of production US$ 54.6/m^3
- Research data result from thermocouple monitoring shown that precooling mass concrete's peak temperature 62.6 ◦C within 71 hours after pouring, thermal differential between core and edge of masscon 7.9 ◦C and material cost of production US$ 72/m^3
- Research data result from thermocouple monitoring shown that 40% fly ash based low heat mass concrete's peak temperature 68.8◦C within 60 hours after pouring, thermal differential between core and edge of masscon 8.9 ◦C and material cost of production US$ 51.3/m^3

- Considering the time required to reach peak temperature, 29.5 hours after pouring, means a reduced cost of production of the mass concrete, and a shorter time before the execution of the next construction step
- Fly ash based low heat concrete fc'25-LHC+FA40% is the cheapest option but considering the risk to the environment and human health [22, 23, 36], the bioconc low heat concrete, as the mass concrete's hydration thermal control method, is the wiser option to avoid any environmental hazards and harm to human health

Acknowledgments
The authors wish to acknowledge the support of The Material and Metallurgical Laboratory & Concrete Laboratory Institut Teknologi Sepuluh Nopember Surabaya and PT SCG Readymix Indonesia - Surabaya Branch, who supported this research.

References
[1] Kiki D W, Januarti J E, Triwulan and Davin H E S 2018 Effect of microbial agents to the properties of fly ash-based paste *MATEC Web of Conf.* vol 195
[2] Azwar A, Januarti J E and Triwulan C F 2016 Microbe admixtures advantage for high-quality concrete with silica fume addition *ITS Engineering J.* **5**
[3] James H T, Januarti J E and Triwulan C F 2016 The influence of silica fume addition as binder substitution on high grade concrete compression strength with black liquor addition and microbacteria (Surabaya: Undergraduae Thesis of Civil Engineering Department Institut Teknologi Sepuluh Nopember Surabaya)
[4] Tony H B, Makno B and Sofyan A P 2017 Optimum concrete compression strength using bio enzyme *EACEF 2017 The 6th International Conference of Euro Asia Civil Engineering Forum; Seoul-Korea*
[5] ACI Committee 207 2006 *Guide to Mass Concrete* American Concrete Institute-ACI 207.1R-05
[6] Zhu B 2014 *Thermal Stresses and Temperature Control of Mass Concrete* (China: Institute of Water Resources and Hydropower Research and Chinese Academy of Engineering Tsingua University
[7] Najah E 2007 *The effect of heat of hydration of mass concrete for cast in place piles* San Joe State University Scholar Works
[8] Jinxin L 2012 *Predicting early-age thermal behaviour of mass concrete for bridge foundation* Graduate Theses and Disertation (USA: Iowa State University)
[9] Abdol R C, Larry C M, Lucy A and Sophia T 2003 *Determination of the maximum placement and curing temperatures in mass concrete to avoid durability problems and DEF* (Florida: Department of Transportation, University of Florida)
[10] Barbara K, Maciej B, Maciej P and Aneta ĩ 2007 Analysis of cracking risk in early age mass concrete with different aggregate types *Int. Conf. on Analytical Models and New Concepts in Concrete and Masonry Structures AMCM*
[11] SCG Readymix Indonesia 2017 *Mock Up Trial Low Heat Concrete&Mass Concrete fc'25+Ice Block* (Surabaya : Avenue88 Project)
[12] Bagio and Tony H 2002 *Concrete mix design method DoE British Standard with microsoft excel* (Lecturing subject Narotama University-Surabaya)
[13] SK SNI 03-2834-1992 1992 *Procedure of Normal Concrete Mix Design* Indonesian SNI Code 1992
[14] SK SNI 03-1968-1990 1990 *Coarse Aggregate and Fine Aggregate Sieve Analysis Testing Method* Indonesian SNI Code 1990
[15] SK SNI 03-1969-1990 1990 *Specific Gravity and Coarse Aggregate Water Absorption Measuring Method* Indonesian SNI Code 1990
[16] SK SNI 03-1970-1990 1990 *SpecificGravity and Fine Aggregate Water Absorption Measuring Method* Indonesian SNI Code 1990

[17] SK SNI 03-1971-1990 1990 *Coarse Aggregate Water Content Measuring* Indonesian SNI 1990
[18] SK SNI 03-1972-1990 1990 *Concrete Slump Measuring Method* Indonesian SNI Code 1990
[19] SK SNI 03-1973-1990 *Concrete Specific Gravity Measuring Method* Indonesian SNI 1990
[20] SK SNI 03-1974-1990 *Concrete Compression Test Method* Indonesian SNI Code 1990
[21] SK SNI 03-2493-1991 *Concrete Samples Making and Curing Method* Indonesian SNI 1991
[22] Rawaz K, Jose D S, Jorge de B 2018 *Toxicity and environmental and economic perfomance of fly ash and recycled concrete aggregates use in concrete* (Portugal: Universidade de Lisboa)
[23] Juliana K 2010 *The Hazard of Fly Ash Final Thesis Report* (Canberra : University of New South Wales Australia Defence Force Academy, School of Engineering and Information Technology, ACT2600)
[24] Anuja U C, Latkar M V and Chakrabarti T 2017 Microbially assisted cementation-a bio-tech nically approach to improve mechanical properties of cement *J. Construction and Building Materials* **135** 472-476
[25] Tugba O O, Hang N N, Sarah L C, Debora F R 2016 CO2 sequestration by ureolytic microbial consortia through microbially-induced calcite precipitation *J. Science of the Total Environment* **572** 671-680
[26] Mostafa S, Ali K S and Aydin B 2016 Bioconcrete: the next generation of self-healing concrete *J. Applied Microbiology and Biotechnology* **100**(6) (DOI 10.1007/s00253-016-7316-z)
[27] Dominique J T, Mark O C and Vernon R P 2014 The Transport of Sporosarcina pasteurii *J. Applied Geochemistry* **42** 38-44
[28] Yoosathaporn S, Tiangburanatham P, Bovonsombut S, Chaipanich A and Pathom-aree W 2016 A cost effective cultivation medium for biocalcification of Bacillus pasteurii KCTC 3558 and its effect on cement cubes properties *J. Microbial Research* **186-187** 132-138
[29] Periasamy A, Chang-Ho K, Yu-Jin S and Jae-Seong S 2015 Formation of calcium carbonate minerals by bacteria & its multiple applications *Springer Plus* **5** 250
[30] Yusuf C E, Filipe B D S, Nico B, Willy V and Nele D B 2015 Screening of bacteria and concrete compatible protection materials *J. Construction and Building Material* **88** 196-203
[31] Kagan E, Suyin Y, Daisuke S, Iwao S and Arata K 2015 Effect of bentonite and yeast extract as nutrient on decrease in hydraulic conductivity of porous media due to $CaCO^3$ precipitation induced by Sporosarcina pasteurii *J. of Bioscience & Bioengineering* **120** 411-418
[32] Navneet C and Rafat S 2013 Permeation properties of concrete made with fly ash & silica fume: Influence of ureolytic bacteria *J. Construction and Building Materials* **49** 161-174
[33] Ramin A, Muhd Z A M, Mohd W H, Mohanadoss P, Ali K, Jahangir M and Han S L 2016 The Optimum concentration of Bacillus megaterium for strengthenning structural concrete *J. Construction and Building Materials* **118** 180-193
[34] Soo G K 2010 *Effect of heat generation from cement hydration on mass concrete placement* Graduate Theses and desertation (USA: Iowa State University)
[35] Basoeki and Makno 2000 *Microbe enzyme concrete admixture perfomance on compression strength increasement and CO2 emision reduction* (Panel Discussion : Bogor-Indonesia)
[36] Ignjatovic Z S, Dragas J, Somlai and Kovacs T 2016 Radiological and material characterisation of high volume fly ash *J. of Environmental Radioactivity* **168** 38-45