Advances in Social Science, Education and Humanities Research, volume 429
International Conference on Agriculture, Social Sciences, Education, Technology and Health (ICASSETH 2019)

Heat Hydration of Recycled Concrete:

Experimental Study

Suharwanto Suharwanto*
Civil Engineering Faculty Dept.
Wiralodra University
Indramayu, Indonesia
*suharwanto.ft@unwir.ac.id

***Abstract*—The experimental study has been done to get data of heat hydration. It important to know the temperature in the concrete during hydration reaction and forming a gel condition of silica reaction with water. Eighteen concrete specimens of cubes have been tested for many dimensions, those are cube 25cm, 50cm, 75cm for length all of side. They made from a fine and coarse aggregate of natural and recycled aggregate from burning building waste and ready-mix residual as a base concrete material. Base on the experimental study, the peak of heat hydration occurs at 10 to 21 hours. Then it will decrease that caused by hydration reaction will be complete and form to gel condition. The heat hydration in the concrete is not affected by site or room temperature, because it is caused by the hydration reaction process between silica and water until gel condition. The peak of heat hydration will increase along with higher concrete strength because it requires more cement that is reactor with water. It can affect to surface cracking for the mass concrete because it causes increasing adiabatic to fresh concrete in the early age. And it also affects a volumetric expansion in the core, so the surface of concrete gets excessive tensile stress beyond of capacity.**

Keywords: burning building waste, heat hydration, natural aggregate, recycle concrete, recycled concrete aggregate, ready-mix residual, surface crack

I. INTRODUCTION

Concrete is a composite material from cement, water, sand, and coarse aggregate [1,2]. Sometimes it adds with admixture chemical in powder or liquid type. There are silica fume or fly ash for powder type, and Superplasticizer, accelerator, retarder, or other material to modify fresh and hard concrete characteristic. The concrete has often used for a building, bridge, dam, a rigid pavement of the road, and other civil work and those are intensive to construct, so concrete demand is increasing. It causes a natural aggregate requirement, such as sand and stone, to make a concrete material.

In the other case, a building is often modifying or renovation and will be demolished to change a new structure. And a burning building will also be dismantled that has caused by the safety issue. The other material of solid waste is residual of ready mix, that often occurs, and it has discharged to any location. All of the solid waste of concrete that discharge on the ground surface become infertile, and the solid waste material has only used for backfilling. Those are not useful and has no economic value. So, in this research, those materials will be used for recycled concrete aggregate that it predicts to substitute natural aggregate in the concrete [3]. It is called XXXRecycled Concrete [4].

Recycled concrete may be a different characteristic, so it shall be investigated to get more data. The data have used for design and placement or structural function. A kind of concrete characteristic is concrete strength and heat hydration [5-21]. Concrete strength is an indicator of concrete quality, and heat hydration is an indicator of period time hydration reaction and setting time. The heat of hydration is a reaction process of cement and water to form a silica calcium hydrate to gel condition. Those reactions are to create a Tricalcium Silicate Hydrate, Calcium Trisulfoaluminat Hydrate, Calcium Monosulfoaluminate Hydrate, Tetracalcium Aluminate Hydrate, and Calcium Aluminoferrite Hydrate [2]. The heat hydration is essential for concrete to know the time and temperate. Time of reaction has increased, but the reaction speed will decrease because of the composition of the main compound completely reaction. And the temperature will increase due to the reaction speed of hydration and exothermic process. The heat will increase without external temperature influence [8,10-12,17,18,22].

In the massif concrete, the heat of hydration will be affected by increasing adiabatic for fresh concrete in the early age. It also causes a volumetric expansion in the core, so the surface of concrete gets excessive tensile stress beyond of capacity. This resulting affected crack on the surface [10,12].

This paper will explain the experimental study of compressive strength and heat hydration process of concrete. The concrete is three types, and those are normal concrete, recycled concrete that is made by burning building waste and ready-mix residual. The experimental will be to know the behavior of heat hydration of all type of concrete that already mentioned above.

II. EXPERIMENTAL PROGRAM

A. Concrete Base Material Test

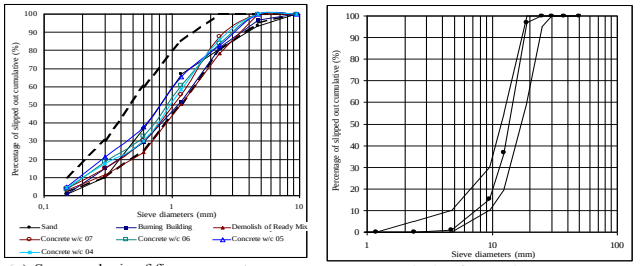
The experimental program of recycled concrete has been started from fine and coarse aggregate, that those are a base concrete mix material. The fine aggregate uses sand and crushing recycled concrete aggregate that shall meet to

specification. The coarse aggregate also uses natural and recycled concrete coarse aggregate that shall also attend to specification. The specification of fine and coarse aggregate is ASTM C-136-06 [1,10]. The save analysis result can be seen in Figure 1 and 2.

The recycled coarse aggregate has been arranged to a proper gradation to meet the ASTM C-136-06 specification [1,10]. So, the recycle coarse aggregate diameter must be manually setting that it can be seen in Figure 2. Base on the arrangement of recycle coarse aggregate gradation, the recycle coarse aggregate has met to the ASTM C-136-06 [1,10]. So, recycle coarse aggregate can replace the natural in the concrete, but it has to study more detail to know the characteristic of concrete that makes from the recycled coarse aggregate.

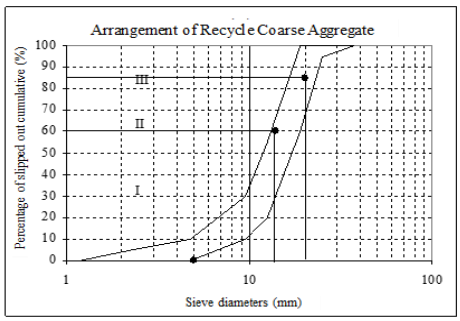
The arrangement of recycle coarse aggregate are:

- percentage of particle retention on sieve size 5.0 mm is 60%;
- percentage of particle retention on sieve size 10.0 mm is 25%;
- percentage of particle retention on sieve size 14.5 mm is 15%.

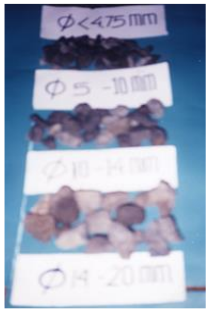


(a) Save analysis of fine aggregate (b) Save analysis of natural coarse aggregate

Fig. 1. Save analysis of all type fine aggregate and natural coarse aggregate.



(a) Save analysis of recycled aggregate



(a) Grain separation

Fig. 2. Save analysis arrangement of recycled coarse aggregate.

B. *Preparation of Specimens*

The dimension of specimen is three type, those are cube 25 cm x 25 cm x 25 cm, 50 cm x 50 cm x 50 cm, 75 cm x 75 cm x 75 cm. It aims to know the variation of the database on dimension. The variation of specimens also uses for several compositions of fine and coarse recycled aggregate; there are 0% and 50% recycled fine and coarse aggregate. The source of fine and coarse recycled aggregate also different type, there are burning building waste and ready-mix residual. The strength of the concrete also uses difference, that is 25 and 50 MPa.

The name of several specimens as above mention are:

- AAHK-0-0-25 for variation of 0% of fine and coarse recycled aggregate or normal concrete and the strength is 25 MPa
- AAHK-0-0-50 for variation of 0% of fine and coarse recycled aggregate or normal concrete and the strength is 50 MPa
- DKHK-50-50-25 for variation of 50% of fine and coarse recycled aggregate from burning building waste material and the strength is 25 MPa.
- DKHK-50-50-50 for variation of 50% of fine and coarse recycled aggregate from burning building waste material and the strength is 50 MPa
- DRHK-50-50- 25 for variation of 50% of fine and coarse recycled aggregate from ready mix residual material, and the strength is 25 MPa.
- DRHK-50-50-50, for variation of 50% of fine and coarse recycled aggregate from ready mix residual material, and the strength is 50 MPa.

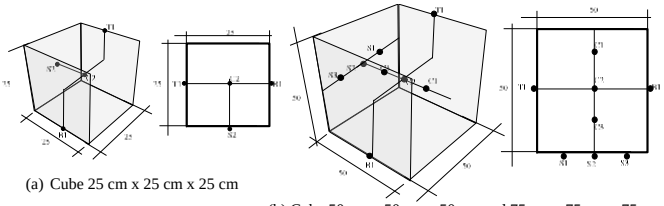
Monitoring all of the experimental periods is seven days, but the interval recording during this period is a different time. The interval recording for 0 to 2 days is every 45 minutes, 2 to 3 days is every 2 hours, and 3 to 7 days is every 12 hours. The experimental study aims to know the heat development in the concrete.

C. *Measuring Devices*

The measurement devices of this experimental is a thermocouple, that places in the difference in the concrete mass. There are in the core and three sides of the specimen. Base on the above mention of three dimensions, of example, the thermocouple number is the difference, there are:

- Cube 25 cm x 25 cm x 25 cm is only four places, as shown in Figure 3.a.
- Cube 50 cm x 50 cm x 50 cm and 75 cm x 75 cm x 75 cm are 8 places as shown in the Figure 3.b.

The location of measurement devices can be seen in Figure 3. The point of it is several various; those are C1, C2, and C3 in the core. The point of S1, S2, and S3 in the side, T1 in topside and B1 in the bottom side. The outside or room temperature also recoded to compare with the side of point measurement devices. The specimen is wrapped or insulted by aluminum foil, that aims to cover the heat and difference temperature with outside.



(a) Cube 25 cm x 25 cm x 25 cm

(b) Cube 50 cm x 50 cm x 50 cm and 75 cm x 75 cm x 75 cm

Fig. 3. Position of thermal devices point.

III. Test Results and Discussion

A. *Compressive Strength of Concrete*

The concrete specimen has been tested by crushing test to obtain the strength of concrete. The concrete strength result can be seen in Table 1.

Base on the concrete strength result, the recycled concrete is lower than normal concrete. The recycled concrete aggregate causes that it contains mortar from the old concrete when crushing. So, the strength of the aggregate is also lower than the natural aggregate. The recycled concrete that has made from ready mix residual is higher than burning building waste. The material of recycled aggregate causes it is weaker than the other recycled aggregate.

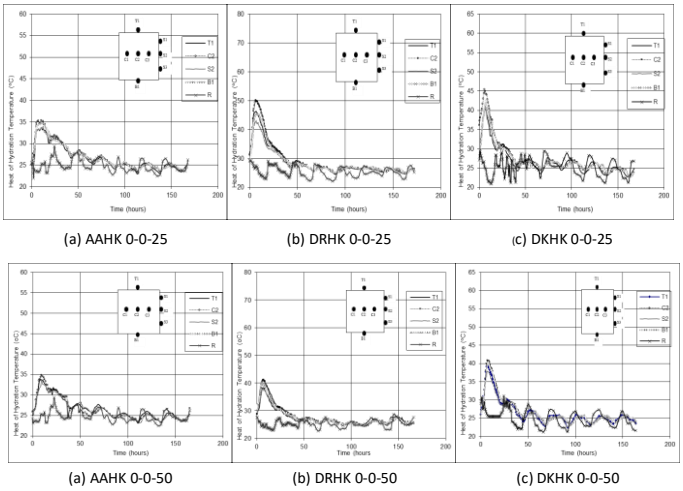
TABLE. 1. Concrete Strength Test Result

No.	Name of Sample	Concrete Strength	
		25 MPa	*50 MPa*
1	AAHK-0-0	30,09	51,78
2	DKHK-50-50	28,68	43,06
3	DRHK-50-50	29,26	46,45

B. *Temperature - Time Curves*

Figure 4 to 6 show the measured temperature-time curves for all sample. The point of heat monitoring as an above explanation, there is at the center, side, top, and bottom. In this figure, the temperature has recorded, and a history of increasing temperature is 10 to 21 hours, then decreasing temperature is until seven days the age of fresh concrete monitoring. Base on the historical curve, the temperature in the concrete is not affected by outside or room temperature. The peak temperature is about 17 to 21 hours after concrete pouring for cube 75 cm x 75 cm x 75 cm, 10 to 15 hours for cube 50 cm x 50 cm x 50 cm and 5 to 8 hours for cube 25 cm x 25 cm x 25 cm.

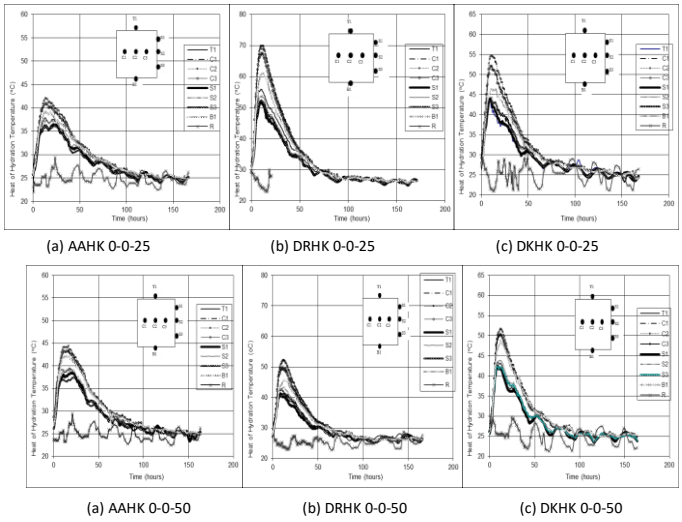
The temperature will decrease with increasing time, that caused by hydration reaction will be complete and form to gel condition. The peak temperature is the peak hydration reaction for all of the compound. It increases with increasing concrete strength. It also causes the difference in cement content that the higher strength of concrete needs more cement. So, it affected the hydration reaction. For more cement content, the compound to be reacted is also increasing.



(a) AAHK 0-0-25 (b) DRHK 0-0-25 (c) DKHK 0-0-25

(a) AAHK 0-0-50 (b) DRHK 0-0-50 (c) DKHK 0-0-50

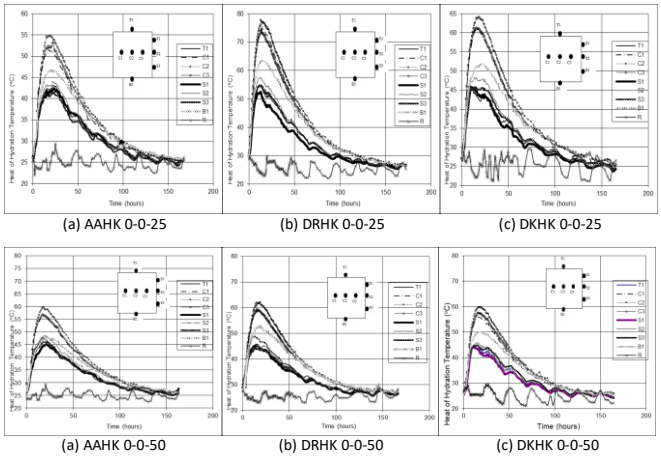
Fig. 4. Heat hydration of cube 25 cm x 25 cm x 25 cm specimen (25 & 50 MPa).



(a) AAHK 0-0-25 (b) DRHK 0-0-25 (c) DKHK 0-0-25

(a) AAHK 0-0-50 (b) DRHK 0-0-50 (c) DKHK 0-0-50

Fig. 5. Heat hydration of cube 50 cm x 50 cm x 50 cm specimen (25 & 50 MPa).



(a) AAHK 0-0-25 (b) DRHK 0-0-25 (c) DKHK 0-0-25

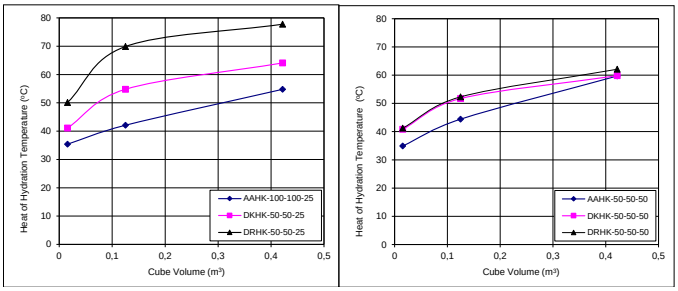
(a) AAHK 0-0-50 (b) DRHK 0-0-50 (c) DKHK 0-0-50

Fig. 6. Heat hydration of cube 75 cm x 75 cm x 75 cm specimen (25 & 50 MPa).

C. Temperature – Cube Dimension Curves

Figure 7 illustrates the increasing peak temperature for all variation specimen. In this case, the curve is only drawing a center of heat monitoring. For the other data of heat hydration location is similar to the center point. The peak temperature will differ for difference specimen dimension; it decreases for the smaller size. It is caused by core deepness and a long time for heat transfer to a surface. So, the size of mass concrete shall anticipate volumetric expansion caused by temperature, and it also will be crack on the surface. In the other case, the temperature also increases with increasing concrete strength. It caused by some cement content that relates to the concrete strength. The increasing concrete strength will require cement, that cement is a binder of aggregate in the concrete. So, concrete strength will be higher that will need more cement. Cement content in the concrete effects to heat hydration, because the silica compound in the concrete will react with water, and it will hap heat. For more concrete mass dimension, the concrete shall be cover or insulate with aluminum foil or other material that can protect the heat. It aims to reduce heat differences in the core and on the surface because the length difference of temperature can rapidly crack on the surface.

The next research needs to prevent crack grown to expect concrete damaged by an intrusive, aggressive chemical in the concrete throughout the crack.



(a). Concrete Strength 25 MPa (b). Concrete Strength 50 MPa

Fig. 7. Peak temperature of heat hydration for cube and strength variation.

IV. Conclusions

Based on the experimental study, conclusions can take:

- The heat hydration in the concrete is not affected by site or room temperature.
- The average of the peak of heat hydration occurs at 10 to 21 hours, then it will decrease that caused by hydration reaction will be complete and form to gel condition.
- The period of peak temperature will increase along with the bigger size of the sample.
- The peak of heat hydration will increase along with higher concrete strength because the higher concrete strength requires more cement that is reactor with water.
- The heat hydration can affect surface cracking to the mass concrete because it causes increasing adiabatic to fresh concrete in the early age. And It also affects a volumetric expansion in the core, so the surface of concrete gets excessive tensile stress beyond of capacity.

References

[1] ASTM C136-06/C136M-14. Sieve Analysis of Fine and Coarse Aggregates, 2006.

[2] A.M. Neville, Properties of Concrete. Longman, Fifth Edition, 2011.

[3] A. Katz, “Properties of concrete made with recycled aggregate from partially hydrated old concrete,” Cement and Concrete Research, vol. 33, pp. 703-711, 2002.

[4] N.D. Oikonomou, “Recycled concrete aggregates,” Cement & Concrete Composites, vol. 27, pp. 315–318, 2018.

[5] A. Alhozaimy, G. Fares, O.A. Alawad, and A. AlNegheimish, A., “Heat of Hydration of Concrete Containing Powdered Scoria Rock as a Natural Pozzolanic Material”, Construction and Building Materials, vol. 81, pp. 113-119, 2015.

[6] C.D. Ati, “Heat Evolution of High-Volume Fly Ash Concrete”, Cement and Concrete Research, vol. 32, no. 5, pp. 751-756. 2002.

[7] H. Beushausen, M. Alexander, and Y. Ballim, “EarlyAge Properties, Strength Development and Heat of Hydration of Concrete Containing Various South African Slags at Different Replacement Ratios”, Construction and Building Materials, vol. 29, pp. 533-540, 2012.

[8] B. Wu and D. Wu, “Test study on hydration temperature of compound concrete made of demolished concrete lumps and fresh concrete,” Procedia engineering, vol. 210, pp. 120-125, 2017.

[9] D.W. Ko and H.B. Choi, “Hydration Analysis of Fine Particle and Old Mortar Attached on the Surface of Recycled Aggregate,” Journal of the Korea Institute of Building Construction, vol. 12, no. 5, 2012.

[10] N. Elias, “The effects of Heat of Hydration of Mass Concrete for Cast-in-Place Concrete Piles,” Unpublished.

[11] J. Topič and Z. Prošek, “Hydration Heat Evolution of the Cement Paste with Recycled Concrete: Influence of Grain Size Distribution of Recycled Concrete Powder,” Key Engineering Materials, vol. 731, pp. 37-42, 2017.

[12] S.G. Kim, “Effect of Heat Generation from Cement Hydration on Mass Concrete Placement,” Unpublished.

[13] M. Xinwei, H. Zhaoxiang, and L. Xueying, “Reactivity of dehydrated cement paste from waste concrete subjected to heat treatment,” In Second international conference on sustainable construction materials and technologies, 2010.

[14] Z. Shui, D. Xuan, H. Wan, and B. Cao, “Rehydration reactivity of recycled mortar from concrete waste experienced to thermal treatment,” Construction and Building Materials, vol. 22, no. 8, pp. 1723–1729, 2008.

[15] S. Mehmood and F. Butt, “Effect of Steel Fibers on Heat of Hydration and Mechanical Properties of Concrete Containing Fly Ash,” Mehran University Research Journal of Engineering & Technology, vol. 38, no. 1, pp. 83-94, 2019.

[16] E. Rastrup, “Heat of hydration in concrete,” Magazine of Concrete Research, vol. 6, no. 17, pp. 79-92, 1954.

[17] K.A. Riding, J.L. Poole, A.K. Schindler, M.C. Juenger, and K.J. Folliard, “Evaluation of Temperature Prediction Methods for Mass Concrete Members,” Materials Journal, vol. 103, no. 5, pp. 357-365, 2006.

[18] T.S. Seo, S.S. Kim and C.K. Lim, “Experimental Study on Hydration Heat Control of Mass Concrete by Vertical Pipe Cooling Method,” Journal of Asian Architecture and Building Engineering, vol. 14, no. 3, pp. 657-662, 2018.

[19] K.H. Yang, G.D. Moon, and Y.S. Jeon, “Implementing Ternary Supplementary Cementing Binder for Reduction of the Heat of Hydration of Concrete,” Journal of Cleaner Production, vol. 112, pp. 845-852, 2016.

[20] Y. Rui, S. Rongguang, S. Zhonghe, X. Dongxing, and Z. Rui, "Influence of thermal treatment on the performance of rehydration of dehydrated cement paste," Cement, vol. 12, pp. 5-7, 2007.

[21] Y. Runzhang and T. Dalu, "Research on the surface properties of hydrated calcium silicate," Journal of the Chinese Ceramic Society, vol. 16, no. 6, pp. 489-49, 1988.

[22] M.H. Lee, B.S. Khil, and H.D. Yun, "Influence of cement type on heat of hydration and temperature rise of the mass concrete," Indian Journal of Engineering and Materials Sciences, vol. 21, no. 5, pp. 536-542, 2010.