Heat Hydration of Recycled Concrete: Experimental Study

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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 Trisulfoaluminate 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
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%.

The recycled coarse aggregate or normal concrete and the strength is 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 recorded to compare with the side of point measurement devices. The specimen is wrapped or insulated by aluminum foil, that aims to cover the heat and difference temperature with outside.
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.

| No. | Name of Sample | Concrete Strength |
|-----|----------------|-------------------|
| 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.
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.

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.

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