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Recycled Coarse Aggregates (RCA) as natural coarse aggregates replacement in concrete design; the better alternative

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ABSTRACT
This paper introduces the potential use of recycled coarse aggregates (RCA) as natural coarse aggregates replacement in concrete design. RCA is obtained from the demolition and waste of old building. RCA is suggested to be used as substitution for natural coarse aggregates in new concrete mixture in order to reduce the consumption of natural resources. In the pass research towards RCA suggested that by replacing natural coarse aggregates by RCA can be more environmental friendly and reducing the consumption of natural resources. This paper will be pointed on the further study on the various relative range of RCA replacement in concrete design. In this study, the percentage of replacement is undertaken by specimens 0% (control specimens), 15%, 30%, 60% and 80% by weight. Compressive strength test, flexural strength test, density test, ultrasonic pulse velocity test will be carried according to British Standards.

Introduction

Environmental Aspect

Nowadays, every country in our earth is looking into one of the most popular topic which is “the sustainability development for a better future”. The sustainable construction concept was introduced due to the growing concern about the future of our planet. This is due to construction industry is a massive consumer of natural resources and on the other hand a huge waste producer (Cachim, 2009). On the other hand, the cost of raw materials is increased while the natural resources are keeps on reduction. Thus, waste materials become a potential alternative in the construction industry. This waste material, when properly processed, it will be effective as natural construction materials and readily meet the design specifications standard. (Mannan, Ganapathy, 2004).

There are some kinds of study about concrete design to obtain the solutions in this construction industry. By implementing industrial waste such as recycled coarse aggregate (RCA) in concrete design may be contribute some recycling method on these industry wastes. In addition, we can decrease the usage of primary resources on casting concrete (Mehta, 2001). In Germany alone, there are 77millon tons of demolition waste per annum that produced in that country. Approximately 13 million tons estimated values of concretes are demolished in France every year and as well as Japan for a total quantity of concrete debris is in value of 10-15 million tons each year.

On the other hand, Hong Kong generates about 20 million tons demolition debris per year and facing serious problem for its disposal solution. Then, United State of America alone is utilizing approximately 2.7 billion tons of aggregate annually out of which 30 to 40% are used in road works and balance in structural concrete work (Singh, 2005). The massive quantities of demolished concrete waste are available at most of the construction sites due to the purpose of redevelopment of the cities. This situation leads to a serious problem of waste concrete disposal in urban areas. But in a conservative way, this can easily be recycled as aggregate and used in new fresh concrete. Research & Development activities have been carried on all over the world to prove its environment sustainability, economic viability, cost effectiveness and feasibility on this construction industry (Oikonomou, 2005).

Recycled Coarse Aggregates

RCA is those aggregates resulting from the processing of inorganic material previously used in concrete building. RCA is obtained from crushing of demolished concrete from the crushing plant. Most of the waste product from building and demolition wastes can be used to produce recycled coarse aggregates. Nowadays building and demolition wastes can easily obtain due to there are country that rebuild and develop their cities for the purpose of revolution in a new mankind era (Marta & Pilar, 2009)

RCA often contain a large amount of attached cements paste and mortar. The old mortar may contain up to 20-30% from the volume.

This is mainly depends on the properties of the original concrete and the concrete crush production process. The main difference between RCA and natural coarse aggregates is mainly accounts on the attached mortar and cement paste on the recycled coarse aggregates (Li, 2004).

Previous Study on Recycled Coarse Aggregates

Tensile Strength of Recycled Coarse Aggregates

According to figure below, the tensile behavior of concrete is shown with different RCA contents according to direct tensile test which evaluated and tested by Liu et al. (2005), Xiao and Lan (2006). This figure shows that, as the RCA content in concrete design increases, the tensile strength will decreases.

The tensile strengths can only be reached at 69% and 88% of the control concrete for the concrete that contain 100% of RCA content. According to the research, they also found that if the percentage of RCA contents when is not exceed 20%, the

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influence of RCA on a concrete design can be neglected (Li, 2008).

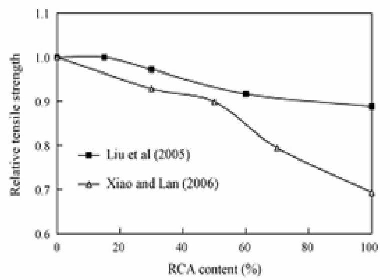

Figure 3.1: Influence of RCA content on the concrete uniaxial tensile strength (Li, 2008)

Compressive Strength of Recycled Coarse Aggregates

On the other hand, the compressive strength of the concrete will decrease as the RCA increase in the mixture. Figure 3.2 below show the decrease of compressive strength when RCA increased in a concrete design (Li, 2008).

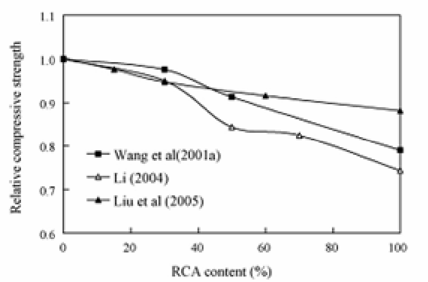

Figure 3.2: Influence of RCA content on the concrete compressive strength (Li, 2008)

Density of Recycled Coarse Aggregates

The density of dry surface recycled aggregate concrete (RAC) is in the range of 2340 kg/m³ with coarse aggregates size (4-8mm) and 2490 kg/m³ with coarse aggregate size (16-32mm) (Hansen & Narud, 1983).

According to another researcher, he pointed out the density of waste concrete is 2510 kg/m³ with coarse aggregates size (15-30mm) when the outer surface is dried (Turanh, 1993).

While for ordinary concretes, these values are between 2500 kg/m3 with coarse aggregates size (4-8mm) and 2610 kg/m3 with coarse aggregates size between (16-32mm) (Hansen & Narud, 1983).

Research Developments

Compressive Strength Test

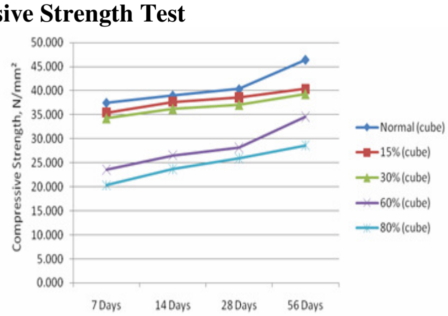

Figure 4.1: Influence of RCA content on the concrete compressive strength

According to figure 4.1 above, for the most basic understanding, the compressive strength of the concrete is directly proportional to the curing time. The longer the age of the concrete, the higher compressive strength of the concrete will be achieved.

Among all the specimens, the normal concrete achieved the highest strength. Then, followed by 15%, 30%, 60% and 80% modified concretes. This is due to RCA contain attached mortar that attached to the RCA and the strength of attached mortars is very weak. Thus, this will affect the entire compressive strength of the RCA replacement concrete.

The relationship between compressive strength and the percentage of RCA content in concrete is in inversely proportional in direction. The higher the RCA contents in a concrete, the lower compressive strength that can be achieved by the concrete.

Flexural Strength Test

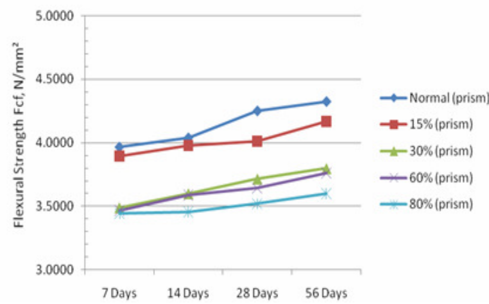

Figure 4.2: Graph of flexural strength test

The results in figure 4.2 show that the flexural strength at all specimens increases with the increasing age at curing. The normal specimen shows an increase from 3.967 N/mm2 at about 7 days to 4.322 N/mm2 at the age at 56 days. The modified 15% concrete shows the highest flexural strength compare to others modified specimens at 3.896 N/mm2 at the 7 days age to 4.167 N/mm2 at the age of 56 days.

The flexural strength of the concrete is decreasing while the percentage of RCA replacement in the concrete increase. Normal concrete achieved highest flexural strength reading which is and the flexural strength of the concrete decrease in percentage of RCA replacement. On the other hand, 80% RCA replacement concrete achieved the lowest flexural strength. The relationship between flexural strength and RCA content is inversely proportional. The higher quantity of RCA replacement in concrete design, the lower flexural strength will be achieved.

Density Test

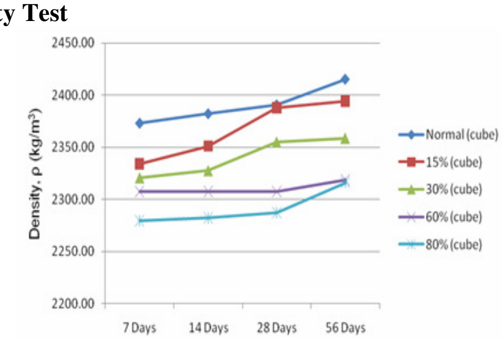

Figure 4.3: Density of cube specimens

The relationship between density and the age of concrete gives a directly proportional result. The results in figure 4.3 show that the density at all the specimens increases with the increasing age of curing. The increased in density of concrete when the age of concrete increased is due to the internal harden of concrete increased in time. The particle inside the concrete is hydrated in time while the void of the concrete will decrease. The concrete will become more and more compacted and the strength of the concrete will be increase in time as well.

On the other hand, the density of the concrete achieved decreased when the percentage of RCA replacement in concrete increased. The highest density along the entire 7 days to 56 days curing age achieved which is normal concrete and followed by 15% modified concrete, 30% modified concrete, 60% modified concrete and the lowest 80% modified concrete. The relationship between density and percentages of RCA replacement in concrete design gives an inversely proportional result.

In conclusion, we can conclude that the density of the concrete will affect the strength of concrete. While the higher the concrete density achieved, the higher the strength of the concrete harden.

Ultrasonic Pulse Velocity Test

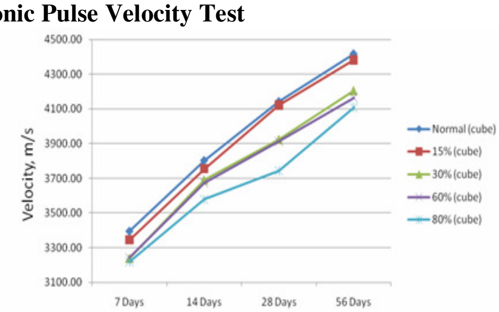

Figure 4.4: Graph of ultrasonic pulse velocity test

According to figure 4.4 above, we can notice that the velocity of the ultrasonic pulse velocity test is in the range of 3100 m/s to 4500 m/s. The readings between the specimens are inversely proportional to the velocity achieved. The higher the RCA replacement in the concrete design, the lower velocity would be achieved. This is due to the RCA attached mortars that contain voids that affected the velocity of the test.

When looking into the relationship between the velocity of the ultrasonic pulse velocity test towards the age of the concrete, we can clearly see that the velocity in directly proportional to the age of the concrete. The higher the age of the concrete, the velocity achieved will be higher. This is due to the internal particles of the concrete takes time to bind within each others. The hydration of the concrete takes time to achieve fully hydrated. The longer the time of hydrating process, the concrete will achieve stronger strength. When the binder between the particles of the concrete is fully harden and there is lesser void in the concrete, the velocity from the ultrasonic pulse velocity test will be achieve higher reading. The higher the velocity of the concrete reading, the stronger strength will be achieved by the concrete.

According to table 4.1, we can know the rating for our concrete specimens. During the age of 56 days, all the concrete specimens achieved velocity on the range of 4100 m/s to 4400 m/s. The lowest reading 4108.33 m/s achieved which is modified 80% concrete and the highest reading 4418.33 m/s achieved by normal concrete. As a result, we can conclude that the general conditions on the specimens are good in rating.

As a results, ultrasonic pulse velocity test can be use to understand the characteristic of the internal particles of concrete for predicting the quality of the concrete, by understanding the relationship between velocity achieved toward the characteristic of internal particles of concrete.

Conclusion

The characteristic of RCA in concrete mixing design is determined and understand in this paper. The percentage of RCA replacement in concrete design will affect the physical property and concrete characteristic of the concrete. The main concern is the strength of the concrete, the percentage of RCA replacement in concrete is inversely proportional to the strength of the concrete. The higher the percentage of RCA replacement in concrete design, the lower the strength achieved.

As a conclusion, the knowledge on characteristic of the RAC is very important, for our future construction development. If RAC successfully implemented in a concrete design accordingly; it can fulfill our future environmental green and sustainable development concept which is towards the conservation of our natural resources.

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Table 4.1: Suggested pulse velocity ratings for concrete Source: Malhotra 1976

Pulse Velocity		
ft per sec	m/ s	General condition
Above 15000	4575	Excellent
12000 to 15000	3660-4575	Good
10000 to 12000	3050-3660	Questionable
7000 to 10000	2135-3050	Poor
Below 7000	2135	Very poor