Technology and Innovation for Sustainable Development Conference (TISD2008)
Faculty of Engineering, Khon Kaen University, Thailand
28-29 January 2008

Water Permeability of Recycled Aggregate Concrete

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Abstract

Durability is one of indicator to produce a good concrete. Meanwhile, water permeability is in durability aspect. This paper presented the study on water permeability of Recycled Aggregate Concrete. This experiment was conducted by using Recycled Aggregate as various percentage replacements (0%, 25%, 50%, 75% and 100%) of coarse aggregate in concrete mixes. Water-cement ratio of concrete mixes was 0.4, 0.5 and 0.6. It was found from this study that Recycled Aggregate Concrete obtained higher water permeability compared to Natural Aggregate Concrete.

Keywords: water permeability, recycled aggregate, water-cement ratio, recycled aggregate concrete

1. Introduction

Environment nowadays faces many challenges and as part of society, it is our responsibility to protect the environment. Mehta (1999) stated environmental protection, conservation of natural aggregate, shortage of disposal sites, increasing cost for waste treatment are the prime factors that influence interest in using concrete waste as recycled aggregate.

Recycled Aggregate (RA) is an aggregate which produced from used material. RA can be used as recycled coarse aggregate or recycled fine aggregate. The application of recycled aggregate has started since end of World War II (Olorunsogo and Padayachee, 2002). A large amount of demolition concrete waste produced because of World War II had attracted the application of RA. They revealed that during the post of World War II in United States, the demolished concrete pavement was crushed and used as recycled aggregate in unstabilised base course for road construction.

In South Africa, Netherland, United Kingdom (UK), Germany, France, Russia, Canada and Japan (Olorunsogo and Padayachee, 2002), RA is not a new material and commonly applied in construction industry. RA has attracted many interests to apply because of some reasons. For example in United Kingdom, the increasing cost of landfill and scarcity in reducing supply of natural aggregate that comes from increasing demand of aggregate for construction has influenced RA application. Meanwhile in Netherland, the government itself has support RA application by introducing the legislation to support the use of RA. The policy regarding to selling price of RA which is lower than Natural Aggregate (NA) became a favourable policy. This policy was also supported by increasing cost of landfill (Collins, 2003).

In Malaysia there is a very few information of RA application in Malaysian construction industry. Ridzuan et al. (2001) claimed this phenomenon occur because of the lack of knowledge about the behaviour of material under local climatic conditions. Another reason is, until today there is no depletion of natural aggregate in Malaysia so the problem is not emerged yet. On the other hand, according to Diah and Majid (1998), based on environmental problem nowadays, NA supply will be reduced in future and it is no reason that why RA cannot become as an important material for construction industry.

Concrete that used RA as coarse or fine aggregate is familiarly known as Recycled Aggregate Concrete (RAC). In this concrete, partially or fully NA is replaced with RA. RA has attracted many researchers to study and improve its quality when producing RAC. The continuous research for improving quality of RAC can be seen when Hansen (1992) have reviewed the research work on RAC and published the Third State of the Art Report 1945-1989.

2. Experimental Work

2.1 Materials

The materials used in this experiment were:

1. Ordinary Portland Cement (OPC)
2. Sand
3. Natural aggregate with maximum size 20mm (NA)
4. Superplastizer

The recycled coarse aggregates were produced by crushing the waste concrete cube outer UTHM concrete laboratory that had compressive strength between 20 and 25MPa. These waste cubes were broken into smaller pieces and crushed using a jaw crusher. Then the RA produced is sieved with maximum size 20mm. Table 1 showed the physical properties of NA and RA.

Table 1. Physical Properties of NA and RA

Tests	Natural Aggregate (NA)	Recycled Aggregate (RA)
Specific Gravity (SSD)	2.48	2.39
Specific Gravity (Oven Dried)	2.46	2.31
Specific Gravity (Apparent)	2.51	2.5
Aggregate Impact Value (%)	17.6	36.3
Aggregate Crushing Value (%)	17.25	35.86
Water Absorption (%)	0.83	3.34

2.2 Concrete Mixes

Two groups of concrete mixes, NAC and RAC were produced using natural sand as fine aggregate. The concrete mixes were designed according to DOE Standard. The target strength of concrete at 28 days is 25 MPa. The slump target is between 60 mm and 180 mm for NAC and RAC mixes. Skim Quick Set (SQS) from SCI is used as superplastcizer. Coarse natural aggregate in concrete mixes were partially or fully replaced by RA at 25%, 50%, 75% and 100% for producing RAC. Meanwhile for NAC, fully crushed granite was used as coarse aggregate. For each concrete mix, 100mm cubes were prepared using standard steel moulds. 3 cubes were used for compressive test and ISO/DIS 7031 tests meanwhile 3 cubes were used for modified DIN 1048. After removing from its mould, the cubes were cured in water until testing.

2.3 Testing of Fresh Concrete

Workability of fresh concrete was measured by using slump tests. This test was conducted accordance to BS 1881: Part 102: 1983.

2.4 Testing of Hardened Concrete

There are two basic tests which conducted for three different water cement ratios. There are compressive test and water permeability test. Table 2 shows details of the tests conducted

Table 2. Details of tests conducted

Test	Specification	Type of Specimen	Number of Specimens
Compressive Test	BS 1881 : Part 116	Cube 100mm x 100mm x100mm	3
Water Permeability	ISO/DIS 7031	Cube 100mm x 100mm x100mm	3
Water Permeability	Modified DIN 1048	Cube 100mm x 100mm x100mm	3

3. Results and Discussion

3.1 Workability

Figure 1 shows the slump value for various percentage replacement of RA. It shows that when RA content is increased, its slump value is decreased. It was expected because RA had a high capacity in water absorption. NAC obtained higher in slump value compared to RAC. This figure also shows that lower w/c ratio of concrete mixes will lead to lower in workability. Concrete with w/c ratio of 0.4 had lowest slump compared to concrete with w/c ratio of 0.5 and w/c ratio of 0.6.

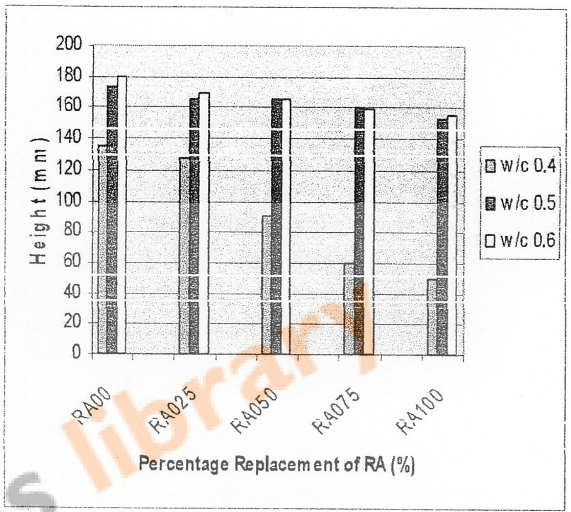

Figure 1. Slump Value for Various Percentage Replacement of RA

3.2 Compressive Strength

Compressive strength for hardened concrete was determined by using compression machine. Figure 2 shows the result for compressive strength at 28-d for various percentage replacement of RA. For w/c ratio of 0.4, its compressive strength decrease to 21.91%, 23.67%, 43.29% and 32.69% when RA replacement ratio in concrete mixes is increased to 25%, 50%, 75% and 100% compared to 0% replacement at 28 days. Meanwhile for w/c ratio of 0.5, its compressive strength decreased to 13.25%, 16.89%, 27.15% and 21.85% when RA replacement in aggregate content is increased to 25%, 50%, 75% and 100% compared to 0% replacement.

Further, for w/c of 0.6, its compressive strength decrease to 11.85%, 17.06%, 31.28% and 22.27% for RA replacement in aggregate content is increased to 25%, 50%, 75% and 100% compared to 0% replacement. From this figures, it also showed that RAC had a lower compressive strength compared to NAC. Olorunsogo(1999) identified that probably smoother texture and rounder shape of RA is lead to this matter. Crusher type also played an important role in creating shape of RA (Ridzuan et.al., 2001).

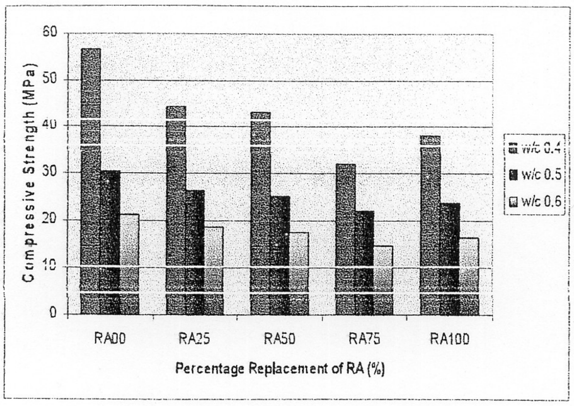

Figure 2.Compressive Strength for 28-d for Various Percentage Replacement of RA

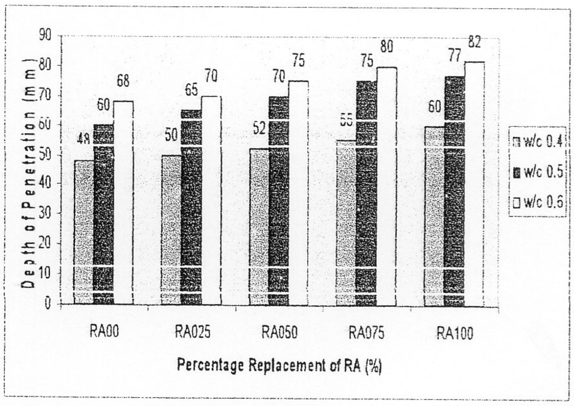

Figure 4. Depth of Water Penetration for 28-d for Various Percentage Replacement of RA

3.3 Water Permeability

Water permeability for hardened concrete was measured by using GWT Apparatus and Water Impermeability Apparatus Three-Model. GWT Test was performed accordance to ISO/DIS 7031. Meanwhile Water Impermeability Apparatus Three-Model was performed accordance to Modified DIN 1048. Figure 3 shows coefficient of water permeability that obtained from GWT test. This figure shows that as replacement of RA is increased, its coefficient of permeability is also increased.

Meanwhile figure 4 shows the penetration of water in concrete cubes that obtained by Water Impermeability Apparatus Three-Model. This figures showed that when RA percentage in concrete mixes is increased, its depth of penetration is decreased at 28 days. These results were expected because RA had high water absorption capacity compared to NA (Hansen, 1992). Additionally, from all these figures, it was found that concrete mixes with w/c ratio of 0.4 had a lowest coefficient in water permeability and lowest in depth of water penetration compared to w/c ratio of 0.5 and w/c ratio of 0.6.

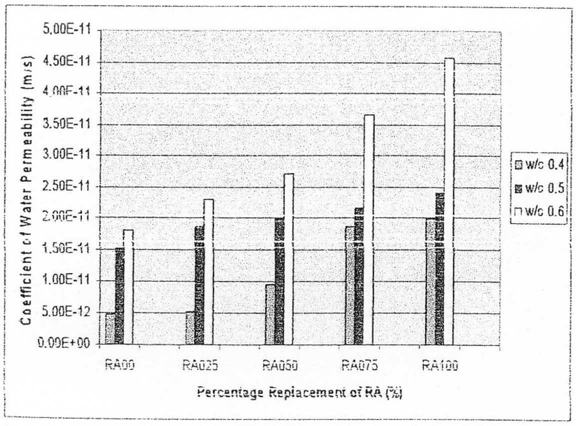

Figure 3. Coefficient of Water Permeability for 28-d for Various Percentage Replacement of RA

4. Conclusions

The following conclusions can be made from this study.

1. Slump value for RAC is lower compared to NAC. A concrete mixture with w/c ratio of 0.4 is the lowest compared to the mixes of 0.5 and 0.6 w/c ratio mixes.
2. Compressive strength at 28 days for RAC is lowered compared to NAC. A concrete mixture with w/c ratio of 0.4 is the highest in compressive strength compared to the mixes of 0.5 and 0.6 w/c ratio mixes.
3. Water permeability for RAC is higher compared to NAC. A concrete mixture with w/c ratio of 0.4 is the lowest in water permeability, compared to the result 0.5 and 0.6 w/c ratio mixes.

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