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The Use of Recycled Aggregate in a Development of Reinforced Concrete Container as a Retaining Wall: Preliminary Study

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Abstract. Construction waste has been increasing due to fast development of construction industries. These wastes usually end up on landfill or to be left nearby construction site. This paper focuses on the potential use of recycled waste aggregate in a development of reinforced concrete rectangular container, RACC, as a solid waste storage. The filled container is intended to be used as a retaining structure at riverbanks to control erosion. The experimental programme include cube and cylindrical specimens tested to determine characteristic properties of recycle aggregate concrete (Pc, Pt, E). The characteristic properties obtained were used in designing the RACC to function as storage container and also as a retaining wall as referred to BS 8110 and BS 8007. Results showed that recycle aggregate concrete has relatively high compressive strength, tensile strength and modulus of elasticity. RACC size of 1.0 m x 1.0 m x 1.0 m with 150 mm thickness is found to be suitable and safe to be used both as container and retaining wall. This is proven by the maximum deflection and crack widths achieved which are lower than the allowable limit values.

Introduction

In Malaysia, the growing pace of development and construction activity has spurred the demand for fast, cost-effective and quality residential buildings [1]. The conventional construction method is to use traditional material which is conventional concrete strengthened by steel reinforcement. However, the use of conventional concrete has several disadvantages in term of its large self-weight, usage of natural resource (aggregate) and higher cost of steel reinforcement.

Past researchers have found recycled aggregate concrete has higher compressive strength. It is claimed that recycled aggregate has more angular shape and rough surface texture compared to natural aggregate. The angular shape and rough texture of recycle aggregate leads to better bond and higher strength of concrete. To increase the compressive strength, recycle aggregate should be oven dried condition that will create the interfacial bond between cement paste and aggregate particles [2]. In this study, recycled waste aggregate will be used in a reinforced concrete to develop a rectangular reinforced concrete container used as storage and retaining wall.

The term retaining wall has traditionally been applied to free standing walls whose purpose is to resist the thrust of a bank of earth or other materials. It provides soil stability at a change ground elevation [3]. The pressure exerted by the soil on these structures is known as earth pressure and must be determined before a satisfactory design can be made [4].

A satisfactory retaining wall must be structurally capable of withstanding the earth pressure applied to it. The foundation of the wall must also be capable of supporting both the weight of the wall and the force resulting from the earth pressure acting upon it.

Experimental Program

The tests was carried out on 18 cubes and 6 cylinders for compressive strength test to find the compressive strength, split cylindrical test to find the tensile strength and compressive strength on cylindrical specimens to find the modulus elasticity of conventional concrete and recycled aggregate concrete. All the cube specimens were of size 150 x 150 x 150 mm. The compressive strength test carried out according to BS 1881: Part 116 [6]. For split cylindrical test, a cylinder specimen with 150mm diameter and 300mm height was placed with its axis in a horizontal plane. It was subjected to a uniform load along the length of the specimen. The procedure for measuring the static modulus of elasticity in compression is described in BS1881: Part 121.The testing procedure for determining the Modulus of Elasticity was referred to BS 1881-121: 1983.

The mixing of the concrete was done according to the DOE method for the targeted compressive strength of 25 MPa at 28 days. Three mixes were cast using the recycle aggregate and natural aggregate with different sizes of 10 mm, 14 mm and 20 mm. The 100 % of recycled aggregate was used in the mix as a coarse aggregate. Based on the mix design by DOE method, the target slump is between 60-180 mm [5].

Design of RACC

Ultimate Limit State and Serviceability Limit State. The design process was carried out according to BS 8007:1987, Design code of practice for concrete structures retaining aqueous liquids structure.

Dimension of RACC. Size and dimension of RACC was chosen to provide strength, stability, durability and to avoid cracking. In this research, size of wall is 1.0m x1.0 m x 1.0 m.

Wall Thickness. A minimum concrete thickness of 200 mm will be required to prevent cracking for structures subjected to liquid pressures.

Structural Stability. RACC must be able to resist horizontal forces subjected by liquid pressures.

Cracking. For reinforced concrete, the maximum design surface crack widths for direct tension and flexure or restrained temperature and moisture effects for RACC is 0.2 mm.

Deflections. For RACC the recommendations for span/effective depth ratios given in BS 8110-1:1985 apply to horizontal members carrying uniformly distributed loads. Limits for deflections will normally be those for non-liquid-retaining structures.

Results and Discussion

Compressive Strength. Figure 1 shows the comparison between compressive strength of conventional concrete and recycled aggregate concrete at 7, 14 and 28 days. The values shown good agreement for both types of concrete. It is proven that concrete mixture using recycled aggregate to replace the natural aggregate could achieve similar or slightly higher compressive strength.

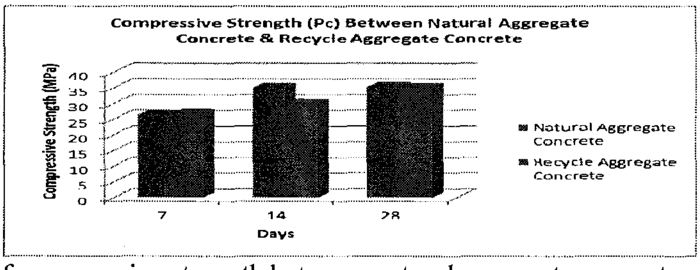


Figure 1: Bar chart of compressive strength between natural aggregate concrete and recycle aggregate concrete

Tensile Strength. Figure 2 shows the concrete tensile strength obtained for the conventional concrete is 2.83 MPa whilst for the recycled aggregate concrete is 3.14 MPa. This result shows recycle aggregate concrete is able to achieve higher tensile strength compared to the natural aggregate concrete.

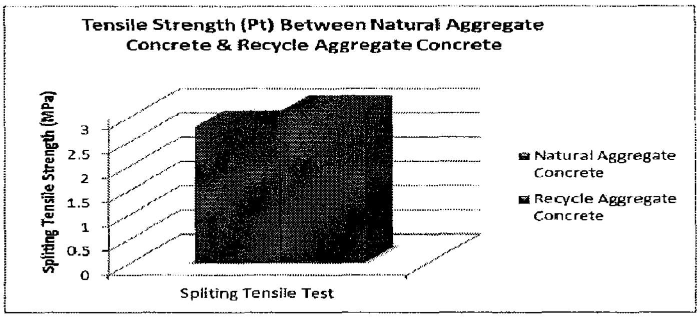


Figure 2: Bar chart of tensile strength between natural aggregate concrete and recycle aggregate concrete

Modulus of Elasticity. Figure 3 shows the values obtained from the experiment for Modulus of Elasticity, (MOE) for conventional concrete and recycled aggregate concrete. From the result, MOE obtained for the conventional concrete is slightly higher than the value obtained for the recycled aggregate concrete. This implies that the difference of modulus of elasticity between natural aggregate concrete and recycle aggregate concrete is not significant.

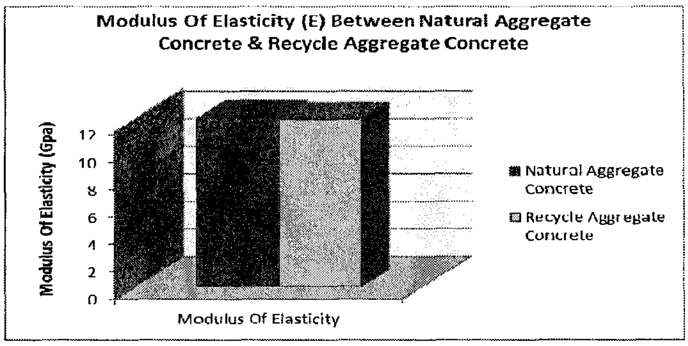


Figure 3: Bar chart of modulus of elasticity between natural aggregate concrete and recycle aggregate concrete

Design Summary. The design of RACC was separated in three parts; namely, the design of wall, base slab and cover slab. In the wall design, the load was taken from the water, soil pressure and pressure from the solid waste filled in RACC. From the design calculation, the values of the parameters listed below were obtained:

Ultimate Moment Design Wall = 4.26 KNm
Ultimate Moment Design Slab Base = 2.07 KNm
Ultimate Moment Design Slab Cover = 2.54 KNm
Area of steel provide for all panel = 314 mm^2 / m @ 250 mm^2/m
Deflection Checking = (L/d) actual = 10.53 < (L/d) allowable = 40
Crack Width Checking = 0.002 mm < 0.2 mm

Number of reinforcement used is 314 mm^2/m @ 250 mm^2/m for all member of RACC. After determination of reinforcement, checking of deflection and cracking were carried out. The calculated value of deflection is (L/d) actual = 10:53 <(L/d) = 40 and crack width a is 0.002 mm which is lower than the 0.2 mm crack limit.

Deformation by FEM Simulation. The deformation for empty container compared to filled container was suprisingly different. Figures in Table 1 show the container changed shape when the load was applied. The deformation for the empty container was focused on the surface exposed with the lateral load as the displacement value for z-axis was higher then y-axis. This is considered as critical displacement and should be considered for design purposes. For the filled container, there was displacement outward due to the load transferred trough the fill material. This situation was governed by the vertical displacement at the edge especially the edge exposed to both loads.

The RACC container is stacked in between containers with its rear wall surface is leaning to the earth surface. For the wall moving into the soil, the passive dynamic pressure will oppose the impulsive force acting on the wall, while for the wall moving away from the soil, the active pressure will add to the impulsive force [6]. This caused the front wall to experience a deformation shape and not the rear wall. The vertical and lateral displacement of the container is generally influenced by the stiffness of the backfill soil. Table 2 gives the maximum displacement values in z and y axis for both empty and filled container.

Table 1 : Deformation for both empty and filled container

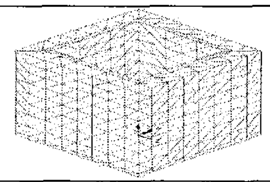
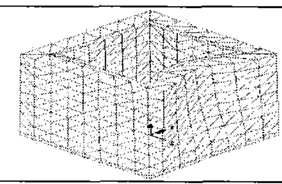
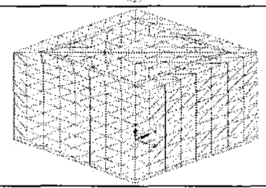
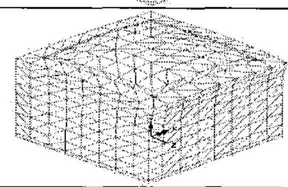
Deformation	Before	After
Empty Container		
Filled Container		

Table 2 : Displacement of filled and empty RACC

	Empty	Filled
Maximum z-axis displacement (mm)	1.28	0.1
Maximum y-axis displacement (mm)	0.8	0.6

Conclusions

1. Recycle aggregate concrete (RAC) has almost similar compressive strength and higher tensile strength compared to natural aggregate concrete. Modulus of Elasticity (MOE) of both RAC and normal concrete is also in good agreement.
2. The value of actual deflection is = 10:53 mm which did not exceed the limit value of 40 mm. The crack width is 0.002 mm, lower than the limit value of 0.2 mm.
3. From FE simulation, the filled container is found to experience much smaller deformation when compared to its empty condition.

Therefore, it can be concluded that recycle aggregate can be used as replacement of aggregate in concrete mixing for reinforcement concrete structure. Recycle aggregate concrete has good compressive strength, tensile strength and modulus of elasticity. From the design calculation, it shows that RACC can be used as a retaining wall structure

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References

[1] Zakaria, F. (1997). " Engineering Properties and Behaviour of Fiber Reinforced Slag Cement Mortar". FKA, UTM, Malaysia. PhD Thesis.

[2] Poon, C. S., Shui, Z. H., Lam, L., Kou, S. C. (2004). "Influence of Moisture States of Natural and Recycled Aggregates On The Slump and Compressive Strength of Concrete". *Journal of Cement and Concrete Research*, Vol. 34, pp 31-36.

[3] Mu'azu M.A. (2009). Evaluation of causes of retaining wall failure. Romania. Issue 14. January – June. http://lejpt.academicdirect.org/14/. Pp. 11-18.

[4] Clough G. W. and Duncan J.M. (1991). *"Earth Pressures"*. Foundation Engineering Handbook, Pp. 223-235, SpringerLink.

[5] Ismail Abdul Rahman, Hasrudin Hamdam and Ahmad Mujahid Ahmad Zaidi (2009) "Assessment Of Recycled Aggregate Concrete" *Journal of Modern Applied Science*, ISSN 1913-1844 (Print) ISSN 1913-1852 (Online).Vol. 3 No. 10.

[6] Okabe, S. (1991) "General Theory of Earth Pressures". *Journal of the Japan Society of Civil Engineering*, Vol.12 (1), pp.223-235.

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