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AN ENVIRONMENTAL-STRUCTURAL UTILIZATION OF GLASS WASTE: AN ASSESSMENT OF GLASS TENSILE TO INITIAL PREDICTION OFGLARC-BEAM FLEXURAL STRENGTH

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ABSTRACT

Even there are any compressive strength reductions of compared to its natural, the utilization of RAC (recycled aggregate concrete) has a good result to convert CDW (construction demolition waste) become beneficial things. Due to the significant RAC lack strength and the lavish of unrecyledglass craps, and has been proposed. A more environmental friendly hybrid concrete of RAC and its reinforcement using glass pieces, cullet or waste – have higher strength than RAC itself - called GLARC (Glass Reinforced Concrete) has been proposed. A tensile testing data are needed in the assessment of the mechanical properties over the actual measurement of the flexural behavior of GLARC system. A direct tensile testing was carried out in coupon spesimen forms using H011N tensile/compression equipment. Almost all of the specimens show a brittle failure. Several of them still suffers a local punching even a grip tool was applied. Tensile strength average of glass is 21.12 MPa much better than concrete tensile strength that was relatively low, around 10-15% of its compressive strength or 3 to $5\sqrt{f_c}$’, thus give value around 2-5 MPa. It can be concluded that glass cullet and pieces was be able used to reinforce both NAC (natural aggregate concrete), concrete with natural aggregate and RAC, recycled concrete aggregate in order to reduce and manage unrecycled glass waste. Finally, it can be predicted initially that flexural strength of GLARC-beam structures that contain glass strips reinforcement will be increased and hence a new GLARC-beam structures has been proposed.The tensile results then used to evaluate the initial bending response and predict the flexural strength capacity in the GLARC-beamlater.

Keywords: hybrid concrete, GLARC structural system, glass waste.

1.INTRODUCTION

Recently, RAC (recycled aggregate concrete) have been widely utilized as an alternative building material. Its aggregate originated from demolished building that usually called RA recycled aggregate (Foster, 1986; Corinaldesi, 2011; Limbachiya *et al,* 2012). Likeother wastes, glass derived from industry, glass shops or households. Glass waste abounds in very large quantity and become a successor scrap that will complicate for environment due to usual recycling method does not cover all of the waste.

In the scale of town to metropolis city, glass waste raise rapidly.Beside glass public consumptions, a subsidiary contribution from industry and glass shop release thousand tons every day in pieces and cullets. Construction demolition waste also responsible for huge volume of glass waste, although its cost is expensive enough as building material but as waste, they have very low cost.

In various valid references, only very limited glass wastes were recycled, others are embedded in the grounds or left lands open. Waste glass material actually is environmentally friendly when processed into sand or powder glass aggregate because theoretically mechanics, waste glass has certain characteristic to be developed as aggregate. There for glass waste can be added to partial sand as addition or even total replacementof sand. Sand glass contents SiO_2 larger than 60%, and other ingredients are Al_2O_3, Fe_2O_3 and CaO. Theoritically these can increase concrete compressive strength (Polley, *et al*., 1998; Meyer and Xi, 1999; Dhir, *et al*., 2001; Park, *et al*., 2004; Park and Lee, 2004). Powdered glass can be cementitious or cement substitution and can be expected to increase concrete compressive strength, due tothe fulfillment of pores because of their very small grain in concrete (Polley, *et al*., 1998; Shao, *etal*., 2000). Contrary, the use of glass waste as coarse aggregate suffer a such phenomenon called ASR (alkali-silica reaction) that can cause serious concrete degradation or cracks by an expansive pressure that could concrete spalling occurs and another structural problems, then reduce compressive strength significantly until finally its collapse.

Several researchers such as Kou (2006) and Meyer (2009) have discussed experimental study about RAC; they intended that RAC compressive strength have significant reduction compared to NAC (natural aggregate concrete). Refer to many literatures, hence, in this paper a more environmental friendly hybrid concrete of RAC and its reinforcement using glass pieces, cullet or waste – have higher strength than RAC itself - called GLARC (Glass Reinforced Concrete) has been proposed.

Glass waste used as a hybrid reinforcement in RAC will support the idea utilization of waste glass into something have both economic and strengthvalue. The beams and columns of GLARC (Glass Reinforced Concrete) can be expected to become such building

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materials that overcome environmental problems. Besides, the economical of the hybrid RAC-glass waste feasibility can improve the value added of glass waste advantage that has not been taken well.

2. GLASS STRUCTURES

Glass is a non crystalline amorphous material as depict in Figure-1 generally is considered that there is no structural stuff in glass, but actually not as it. Various primal forms is likely toequalize at meso scale level, such as chains conceiving three and seven silica atoms with intercessor of oxygen atoms in between them.

The common glasses are silicate composed based on silica, SiO_2 that containtetrahedra where every oxygen-endis linked with the adjacent tetrahedron. Each tetrahedral unit is also combined into chains can metamorf into distinct kind of ceramics.

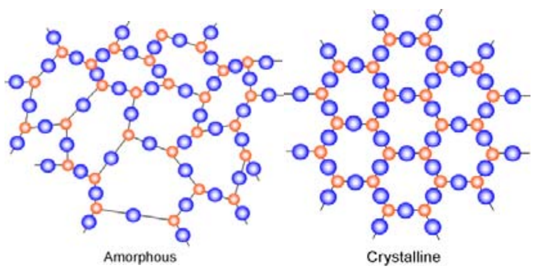

Figure-1. Two diffenrent kind of atomic structures: amorphous and crystalline.
Source: unsw.edu.au

Two main type of glasses are soda-lime glass, usually in panel-form application, using configuration of $70SiO_2.10CaO.15Na_2O$, as described in Figure-2 and borosilicate glass, frequently in chemical glassware application, using following configuration $80SiO_2.15B_2O_3.5Na_2O$.

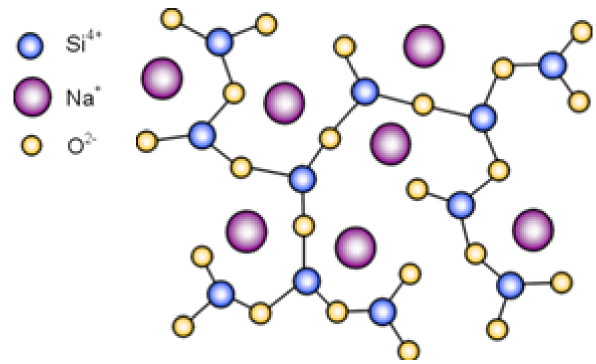

Figure-2. The structure of soda-lime glass.
Source: unsw.edu.au

Several main covalent bonds link these chains into a 3D structure are dispersed by Na+ ions and OH- groups of the soda additives that will lower melting point by splitting 3D networks. Therefore, even if there are some noticeable elements, there is no patternrehearsal ofthis structure and therefore no crystallinityoccurs.

Aside from soda lime type, glasses may have distinc structures as stated by Rouxel (2006). The drawback of a crystalcubicavoidsdeformation and hencediscards any potential plasticity. But in the case of broken, the adjacent covalentbondscould not simply reform. A bond failure can occurs if chemical bond strength is exceeded by raised stress concentration around a notch, hole or any defect location. In this condition fracture failure will control, otherwise it dislocate elastically. Differential stresses due to adjacent pores then induce breaking if the tensile strength is exceeded (Weeks and Zarzycki, 1991).

3. TENSILE TEST SPECIMEN AND INSTRUMENTS

The specimens used in tensile test is formed into dog-bone couponof glass waste in the longitudinal form using ASTM D-638 M.

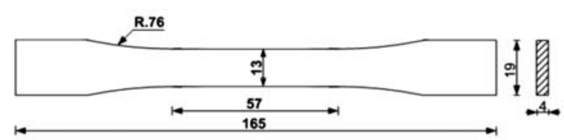

Figure-3. Dimension glass piece for tensile specimen following ASTM D-638 M geometry.

Tension loading given was longitudinal and parallel to its axial axis and assumed to be homogen in every stressed coupon area. In order to get accurate results, the coupon specimen should be handled by a transformation rod to ensure the failure occurs in the middle section of the coupon. Otherwise, the unexpected failure result will occurs such as crush penetration, shear or even torsion failure types. The tensile glass specimens, universal testing machine and is extra linked grip tool are described in Figure-4.

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Figure-4. a) Glass tensile specimens b) Matest UTM H011N c) extra linked grip tool to ensure expecting failure.

In this testing field, the equipment used is H011N tensile/compression machine, cyber-plus evolution control unitfrom MATEST with piston's stroke of 100 mm while its precision of ± 1% read value figured in Figure-4 c). Force was applied to the tensile specimen through a pair of extra linked grip tool to ensure strong clamp to both specimen ends. Force controlled tensile tests using 0.001 N/sec loading rate. Inert strength testing is generally accomplished by testing the specimen to failure in a tensile testing machine, which requires only a load cell and not a strain-gauge extensometer, as stress alone is what concerns us here, not displacement (Pepi, 2014). So MATEST equipment that captured curve between forces versus time of the specimen was adequate to investigate glass tensile strength.

4. RESULTS

Almost all of the specimens showa brittle failure. Several of them still suffers a local punching even a grip tool was applied. Tensile strength average of glass is 21.12 MPa and some of tensile results were shown in Figure-5 below.

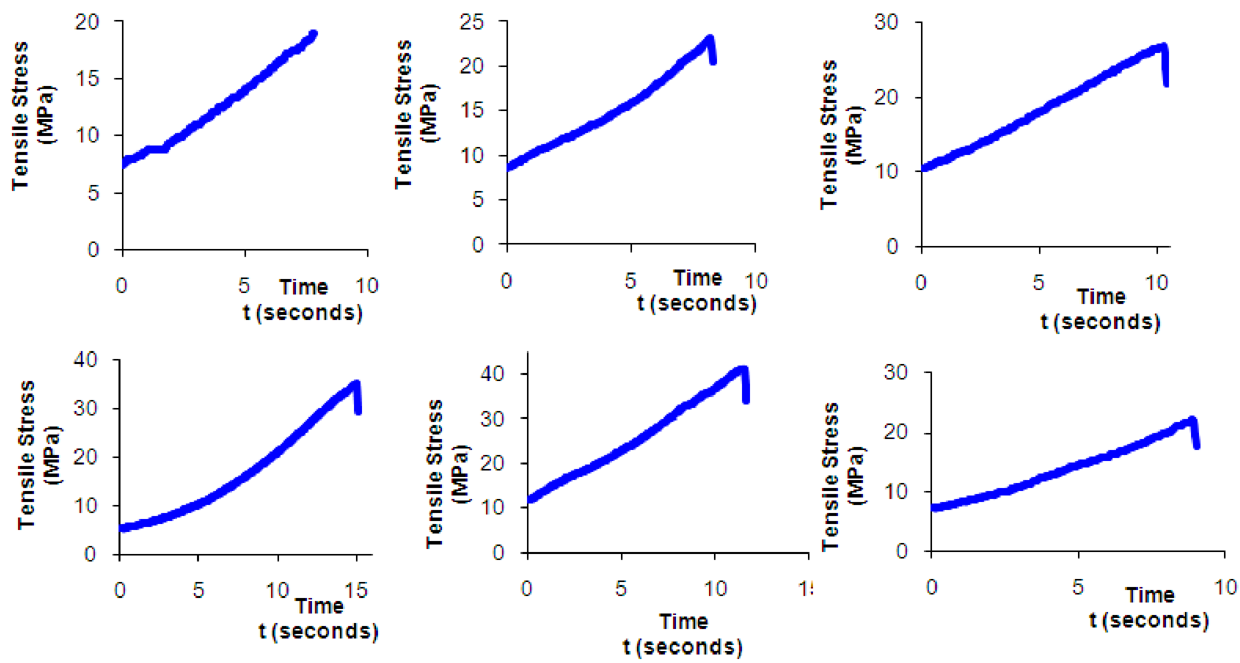

Figure-5. Tensile strength of some glass specimens.

The tensile strength of glass piece was 21.12 MPa much better than concrete tensile strength that was relatively low, around 10-15% of its compressive strength or 3 to $5\sqrt{f_c'}$, thus give value around 2-5 MPa.

The tensile results then used to initially predict the flexural strength capacity in the GLARC-beam that consist several kind of glass piece reinforcement that is vertical glass piece strips, horizontal glass piece strips, randomize glass piece, and uniform glass piece reinforcement as depict in Figure-6.

Figure-6. Preparation and experimental setting of flexural testing of GLARC-beam structures.

5. CONCLUSIONS

From the experimental results, it can be concluded that glass cullet and pieces was be able usedto reinforce both NAC, concrete with natural aggregate and RAC, recycled concrete aggregate in order to reduce and manage unrecycled glass waste. Also it can be summaried that glass as reinforcement have better tensile strength than concrete, thus any addition glass on reinforcement of concrete will avoid premature cracking. Finally, it can be predicted initially that flexural strength of GLARC-beam structures that contain glass strips reinforcement will be increased and hence a new GLARC-beam structures has been proposed.

REFERENCES

Corinaldesi V. 2011. Structural concrete prepared with coarse recycled concrete aggregate: from investigation to design, advances in Civil Engineering, advances in Civil Engineering, Vol. 2011, Article ID 283984, p. 6.

Dhir R. K., T. D. Dyer, dan M. C. Tang. 2001. Expansion due to Alka¬li-Silica Reaction (ASR) of Glass Cullet Used in Concrete. Proceedings of the International Symposium: Reuse of Waste Materials, London, UK. pp. 751-761.

Foster S.W. 1986. Recycled Concrete As Aggregate. Concrete International, America.

Kou S. 2006. Reusing Recycled Aggregates in Structural Concrete. Doctoral dissertation, The Hong Kong Polytechnic University.

Limbachiya M., Meddah M.S., dan Ouchagour Y. 2012. Use of recycled concrete aggregate in fly-ash concrete. Constr. Build. Mater. 27(1): 439-449

Meyer C., dan Y. Xi. 1999. Use of Recycled Glass and Fly Ash for Precast Concrete. Journal of Materials in Civil Engineering, ASCE. 11(2): 89-90.

Meyer C. 2009. The Greening of the Concrete Industry. Cement and Concrete Composites, Vol. 31(18), 2009, pp. 601-605.

Park S. B., B. C. Lee dan J. H. Kim. 2004. Studies on Mechanical Properties of Concrete Containing Waste Glass Aggregate. Cement and Concrete Research. 34(12): 2181-2189.

Park S. B., dan B. Lee. 2004. Studies on Expansion Properties in Mortar Containing with Waste Glass and Fibers. Cement and Concrete Research. 34(7): 1145-1152.

Polley C., S. M.Cramer dan R. V. Cruz. 1998. Potential for Using Waste Glass in Portland Cement Concrete. Journal of Materials in Civil Engi¬neering, ASCE. 10(4): 210-219.

Pepi J.W. 2014. Strength Properties of Glass and Ceramics. Spie Press.

Shao, Y., T. Lefort., S. Moras dan D. Rodriguez. 2000. Studies on Concrete Containing Ground Waste Glass. Cement and Concrete Research. 30(1): 91-100.

Weeks R.A. and Zarzycki J. 1991. Glasses and Amorphous Materials.
www.materials.unsw.edu.au/tutorials/ Atomic Structure.