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Optimising the use of recycled concrete aggregate and waste glass in concrete

Student: Yichen Fang, Bernice Ka Wai Kwok **Supervisor: Dr Fangying Wang**

Introduction

This is a study on the substitution of artificial aggregates obtained from industrial waste in the production of concrete, and aims to reduce the reliance on natural aggregate (NA), hence, to prompt the development of a more eco-friendly concrete mix to ensure a more sustainable future in the construction industry.

The substitution of natural coarse aggregates (NCA) with recycled concrete aggregate (RCA) and natural fine aggregate (NFA) with waste glass cullet (WGC) in concrete is investigated in this study, and aimed to identify and evaluate the limits of RCA and WGC replacement in concrete, based on their engineering performance.

Aim and Objectives

The aim of this project is to produce high-engineering-performance concrete mixture with the optimised use of recycled concrete aggregate (RCA) and waste glass cullet (WGC) that are created from construction and demolition. The mixed-use of both recycled materials in concrete is fairly new to Civil Engineering, thus further studies are needed.

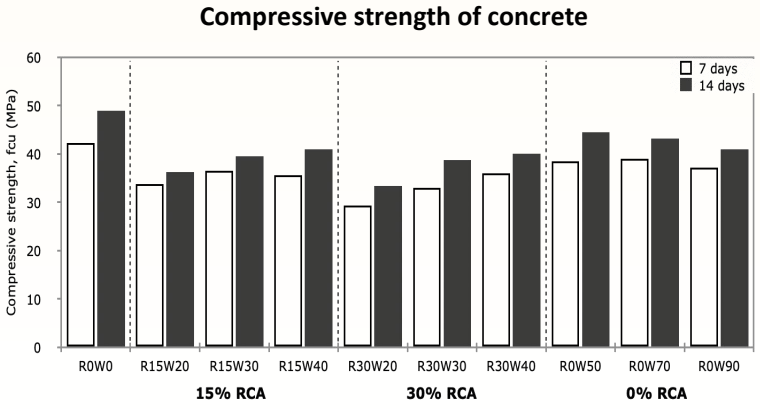
- Objective 1: To identify the primary physical and mechanical characteristics of natural aggregates (NCA and NFA) and recycled aggregates (RCA and WGC)
- Objective 2: To develop pre-treatment methods to improve RCA strength and adhesion properties to WGC
- Objective 3: To determine and evaluate the engineering performance of concrete mixture with RCA and WGC at the age of 7 days and 14 days

Testing

Concrete cubes of 150 x 150 x 150 mm size were cast to test at the age of 7 days and 14 days. The mixes were designed with a target slump of 30 to 60 mm and a compressive strength of 43 N/mm2 at the age of 7 days.

Concrete specimens were made with a combination of partially substituting NCA with RCA (15% and 30%) by weight, and the variation of NFA substitution with WGC (20%, 30% and 40%) by weight, as well as three other mixtures made of high proportion of NFA substitution with WGC (50%, 70% and 90%) by weight, without any RCA replacement.

Compressive strength of concrete



Characteristics of Materials

Results show that RCA exhibits higher water absorption, more porous, lower in density and less stiff than NCA. In contrast, WGC has water absorption of almost 0%, slightly higher specific gravity value and bulk density than NFA, and has similar physical properties and hardness as NFA.

Physical characteristics of the aggregates used in the experimentation

Properties	Coarse aggregate		Fine aggregate	
	NCA	RCA	NFA	WGC
Size (mm)	4 - 10	10 - 20	0.5 - 4	0.4 - 1
Bulk Density (Mg/m3)	2.65	2.62	2.68	- - -
Specific Gravity	2.58	2.27	2.59	2.60
Porosity (%)	3.01	13.20	3.58	- - -
Water Absorption (%)	1.17	5.97	1.40	0.10

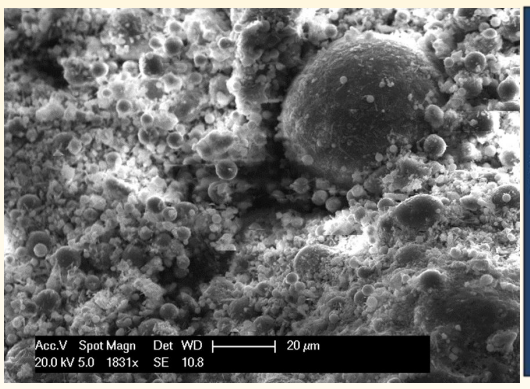
Pre-treatment Methods

Adoption of three different types of slurries; (1) Fly ash and Silica fume (FA&SF), (2) Fly ash and Cement (FA&C), (3) Nanosilica fume (NSF), and (4) Polyvinyl alcohol (PVA) as a partial replacement of fly ash and cement slurry were used. Scanning electron microscopy (SEM) coupled with Energy-Dispersive X-ray (EDX) spectroscopy will be used to identify the Microstructural features and elemental compositions of these recycled materials.

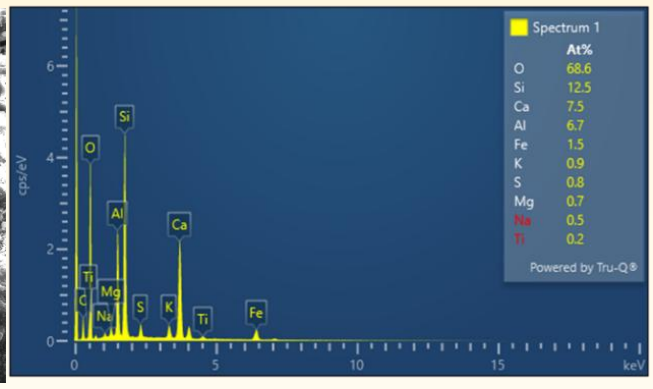
The results show that the four surface treatment methods reduce the water absorption and porosity, as well as enhance the microstructure and improve the surface homogeneity of RCA.Considering the combined economics and effectiveness, the NSF method was adopted.This results have been published in CEW2023.

Particle density, water absorption and porosity of RCA before and after surface treatment

Surface treatment	Density, OD (g/cm3)	Density, SSD (g/cm3)	Apparent density (g/cm3)	Water absorption (%)	Porosity (%)
RCA	2.5911	2.5145	2.4954	1.3607	3.6739
10% PVA (oven-dry)	2.6370	2.5590	2.5395	0.7400	1.9233
10% PVA (air-dry)	2.6424	2.5643	2.5448	0.6900	1.8829
40% FA&SF	2.6409	2.6000	2.6093	1.0600	2.7446
40% FA&C	2.6908	2.6964	2.7803	0.7900	2.0793
3% NSF	2.6509	2.7071	2.7917	0.8300	2.3987



(a) SEM image



(b) EDS spectrum of FA&C slurry-treated RCA

Results and Discussion

RCA negatively impacted all aspects of engineering performance due to its characteristics. WGC exhibited a positive effect on workability, porosity and hardened density due to its smooth surface texture and impermeable nature until the replacement level of WGC was more than 50%. Excessive WGC (>50% by weight), the dilution effect caused by excessive unreactive silica reduces the hardened density and compressive strength of the concrete.

The inhomogeneous mixture, caused by the angular shape of RCA and WGC, was responsible for the overall strength reduction. Despite this, WGC improved the compressive strengths of specimens made with 15% and 30% of RCA replacement.

Acknowledgement:

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More details of the work can be found in a conference paper: Wang H, Fang, Yichen, Wang, Fangying, Airey, Gordon. Property enhancement of recycled concrete aggregates through surface treatment. Proceedings of the 7th Chinese-European Workshop on Functional Pavement (CEW2023), 2023.