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Axial compression behavior of reinforced geopolymer concrete columns with demolished concrete lumps

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Abstract

This paper presents results of an experimental study on the axial compression behavior of reinforced geopolymer concrete columns with demolished concrete lumps (DCLs). A total of 22 reinforced concrete short columns were tested under axial compression. The test variables include the type of fresh concrete (ordinary Portland cement concrete (CC) and geopolymer concrete (GC)), strength level of fresh concrete (FC) and demolished concrete, and replacement ratio of FC by DCLs. The test results were used to evaluate the effect of strength difference between fresh and demolished concrete, and replacement ratio of FC by DCLs on bearing capacity and deformation ductility of geopolymer concrete columns with DCLs. Data from these tests showed that the axial compression behaviors of short columns made of geopolymer concrete and ordinary concrete with DCLs were similar. The ultimate bearing capacity and stiffness of recycled concrete columns with DCLs decrease with an increase in replacement ratio. Nevertheless, the maximum reduction in bearing capacity of geopolymer recycled concrete columns is only 10%, when the replacement ratio of FC by DCLs is 24%. The strength difference between fresh concrete and DCLs has a significant influence on mechanical properties of recycled concrete columns, especially for geopolymer recycled concrete columns. Compared to ordinary recycled concrete columns with DCLs, geopolymer recycled concrete columns with DCLS exhibit a slight lower bearing capacity, but a higher ductility.

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Keywords: Geopolymer concrete; Demolished concrete lumps;Axial loading;Short columns

1. Introduction

Recycling and reusing demolished concrete has been a research focus in recent years, and which is motivated by the deteriorating environment and depleting natural resource. One of the popular approaches of recycling demolished concrete is so-called recycled aggregates concrete (RAC). The physical and mechanical properties, as well as application guidelines of RAC, together with the performance and suitability of structural members manufactured with RAC, have been documented by many researchers and organizations [1-3]. However, the technology of crushing and sieving concrete debris to produce high-quality recycled aggregates is often costly and time-consuming, making it less energy-saving or less economical in actual practice.

To deal with this concern, a new eco-friendly method of using recycling demolition concrete lumps has been proposed [4]. In this proposal, the fresh concrete (FC) serves as the "binder", and mixed with demolished concrete lumps (DCLs) directly.

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Compared to the traditional recycled aggregates, DCLs have larger sizes ranged from 50 to 300 mm. Therefore, the recycling process is greatly simplified, as crushing to smaller pieces and sieving are lessened. In addition, the amount of cement in recycled concrete with DCLs is saved. It is reported by Wu et al [5, 6] that the mechanical properties of recycled concrete with DCLs were closed to that of common RAC, when the replacement ratio of FC by DCLs (the ratio of DCL mass to the total mass of concrete) is below 40 percent. And the bearing capacity and ductility of structural members manufactured by this kind of recycling concrete is also comparable with that of traditional RAC members [7, 8].

In the above recycled concrete with DCLs, ordinary Portland cement concrete is often used as the fresh concrete. However, Portland cement concrete is regarded as a main cause of global warming, due to a great amount of CO_2 emission during cement production. Geopolymer concrete is considered to have a great potential in the production of "green" concrete with a lower carbon footprint [9, 10]. It has comparable mechanical and durability with Portland cement concrete [11, 12]. Therefore, geopolymer concrete is also seen in the use for recycled concrete [13, 14].

In the current study, geopolymer concrete was used as fresh concrete and mixed with DCLs to form recycled concrete. Axial compression tests were carried out on 22 reinforced concrete short columns. The test variables includes the type of fresh concrete, replacement ratios and strength level of fresh concrete and demolished concrete. Visual observations and data of load, deformation and concrete strain of tested columns were recorded. These observations and data were utilized to compare the compressive behavior of cement recycled concrete and geopolymer recycled concrete columns with DCLs.

2. Experimental program

2.1 Materials

2.1.1 Fresh Concrete

Three types of concrete, including two types of geopolymer concrete with different strength levels (denoted as GC1 and GC2), and ordinary Portland cement concrete (CC), were used as the fresh concrete. Geopolymer concretes (GC1 and GC2) were derived by mixing potassium silicate solution, metakaolin-fly ash blend precursor, coarse and fine aggregates. The multi-compound alkaline activators used in geopolymer concrete mixes consisted of tap water, potassium hydroxide (KOH) and sodium silicate (Na_2SiO_3) solution with a concentration of 40% by mass. The alkaline activator solution was premixed and left to rest for 24 h at ambient temperature prior to use. The cement used in ordinary concrete (CC) was Grade 32.5 Portland cement. In order to increase the workability of CC, polycarboxylate super plasticizer was added.

The same aggregates were used in the three types of concrete. Coarse aggregate was basalt gravel with a maximum particle size of 20 mm. Fine aggregate was local nature river sand. The mix proportions of three types of concretes were listed in Table 1. The compressive strength of CC, GC1 and GC2 at 28-day age is 66.6 MPa, 59.9 MPa and 66.8 MPa respectively.

Table 1. Mix proportions of fresh concrete.

Concrete type	CC	GC1	GC2
Water/kg	145	61	61
Coarse aggregate/kg	1076	1113	1199
Sand/kg	702	600	514
Cement/kg	468	--	--
Super plasticizer/kg	9.36	--	--
Metakaolin/kg	--	179	179
Fly ash/kg	--	179	179
KOH/kg	--	58	58
Sodium silicate solution/kg	--	210	210
Liquid/binder ratio(w/b)*	0.31	0.4	0.4

*Including the water coming from the crystal water of $Na_2SiO_3.nH_2O$.

2.1.2 Demolished concrete lumps

Demolished concrete lumps, with a characteristic size ranged from 70 to 100 mm, were prepared as the substitute of partial fresh concrete in concrete columns. They were produced through crushing and striking demolished concrete to near-spherical lumps, as shown in Fig. 1. These lumps were sourced from two types of old concrete, with cubic compressive strength of 46 MPa and 31 MPa. They were grouped under two groups, and designated as D1 and D2 respectively.