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Reactivity of Dehydrated Cement Paste from Waste Concrete Subjected to Heat Treatment

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ABSTRACT

Construction and demolition (C&D) debris contributes a large amount of solid waste generation in China, in which concrete and cement motor are the main contents. To reuse the aggregate and cement paste C&D waste, the concrete rubbles were burned at 750°C, by which the aggregates were separated from the cement paste. The recycled aggregates were reused in fresh concrete and cement mortar, and the pulverized dehydrated cement paste can have reactivity again. By blending Portland cement and pulverized dehydrated cement paste, a new kind of cementing material is obtained. The strength of this cementing material can meet the requirement of lower strength cement. In this way, construction and demolition waste concrete and cement mortar could be recycled and reused for the manufacture of new construction products; less natural resources and fuels are consumed and less green house gases are emitted.

INTRODUCTION

Sustainable development is development that meets the needs of the present without compromising the ability of future generation to meet their own needs [World Commission on Environment and Development, 1987]. Now, the rises of global-scale resource requirement, energy crisis and global warming have been recognized as the most important issues. Extensive extraction of natural resources for building construction jeopardizes the principle of sustainability and has received increasing objections from environmentalists [Tam, 2009]. The comprehensive building development and redevelopment plans in different countries have aggravated construction problems pertaining to building demolition [Blengini, 2009]. To optimize the use of natural resources and particularly concrete demolition waste, there is a need to develop long-term action plans on the use of materials [Torring, 2000]. The main waste minimization strategies are reuse, recycle and reduction, which are the so called “3Rs”.

Cement, sand and gravel or crashed stone are the raw materials for the composition of concrete. It is commonly believed that natural sand and gravel or crushed stone are abundant in the natural world. But the mining of stone has an adverse impact on the environment, and the process of crushing stone consumes a large amount of electric power. Cement industry is regarded as one of the most energy consuming industry. It is reported the cement production is approximately ten times as energy intensive as our economy in general. In some Third World countries, cement production accounts for as much as two-thirds of total energy use, according to the World watch Institute [Malvern Instruments Ltd, 2009]. If the construction and demolition (C&D) waste concrete and cement mortar could be recycled and reused for the manufacture of new construction products, the cement and concrete industries can make substantial contributions to sustainable developments by reducing the emission of greenhouse gases. Recycling, being one of the strategies in waste minimization has three advantages: It reduces the demand upon new resources; it cuts down transport and production energy costs; it uses waste which would otherwise be transferred to landfill sites.

The crashed C&D waste concrete is being widely used as coarse aggregate [Sakai, 2007; Mulder and Feenstra, 2007; Ann et al, 2008]. Fine recycled concrete aggregates were also used as partial or global replacements of natural fine aggregates structural concrete [Evangelista and Brito, 2007]. Considering the fact that the quality of the parent concrete varies to a considerable extent, this diversity affects the quality of the recycled aggregate concrete [Padmini et al, 2009]. This paper discusses the latest approach in waste concrete management, where the original aggregate and cement paste are separated and reused separately.

HEAT TREATMENT OF CONCRETE RUBBLE

It is suggested that dehydrated hydration products have the potential to hydrate again [Yuan and Tan, 1988]. In order to reuse the aggregates and cement paste, a thermal process was laid out for the treatment of concrete rubble. Firstly, the waste concrete is crushed to concrete rubble whose size is bellow 60mm. For reinforced concrete, the reinforcement steel should be taken out.

Based on the experience of other researchers [Sakai, 2007; Mulder and Feenstra, 2007], the heating must be performed at a temperature at least 700°C. To make sure that the cement paste and aggregate could be separated, and the hydration products could be dehydrated furthest, the concrete rubble must be treated at a proper temperature. A thermogravimetric analysis (TGA) was carried out to determine the calcination temperature.

The thermogravimetric (TG) curve and differential thermogravimetric (DTG) curve are shown in Fig.1.

The TG curve indicates that the mass of cement paste decreases steadily from room temperature to 1000°C. The DTG curve shows that there are four mass losing peaks. The two peaks below 114°C indicates that the free water and absorbed water were lost. Calcium hydroxide ($Ca(OH)_2$) dehydrated from 472°C to 500°C, and the other obvious dehydration process from 682°C to 775°C is that the C-S-H gels were decomposed into water and the likely cementitious materials. The highest dehydration rate is at 740°C. After that, the weight loss is not obvious. So, the concrete rubble is treated at 750°C for 1 hour in this experiment. Higher temperature may affect the structure of the coarse aggregate, and more power is consumed.

The burnt concrete rubble was cooled sharply by electric fan. By a manual crushing and sieving, clean aggregates and dehydrated cement paste could be separated. Inevitably, some fine aggregate was blended into the cement paste powder. The dehydrated cement paste is expected to be used as a part of Portland cement.

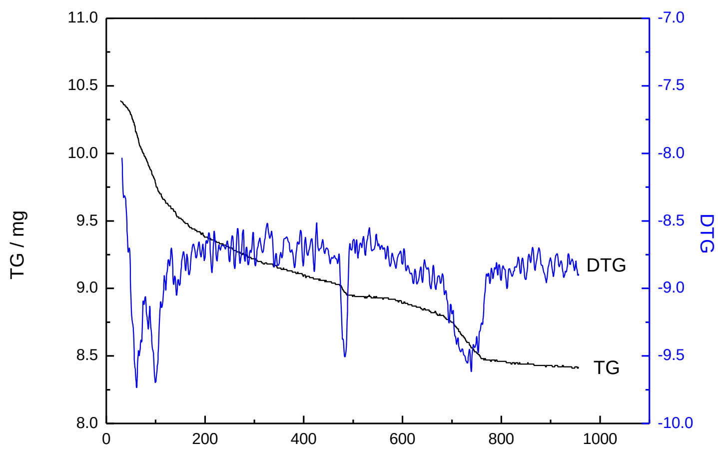

Fig.1 Curves of thermogravimetric analysis of cement paste

The properties of the dehydrated cement paste are investigated in this paper, but those of aggregates are to be presented elsewhere.

RESULT AND DISCUSSION

The physical properties of the pulverized dehydrated cement paste

The physical properties that are concerned in this paper are density, fineness, water requirement and times of setting. After the burnt concrete was crunched, the cement paste was separated with the aggregates by sieving, the screen size of which is 0.15mm. This dehydrated cement paste powder was ground in a vibromill. The specific surface area of the resulting powder is 390m2/kg that is slightly finer than ordinary Portland cement. The density of this powder is 2670kg/m3, which is lower than Portland cement.

The water requirement of this pulverized dehydrated cement paste powder is much higher than Portland cement, which could be as high as 60%. This result is accordance with Yu's experience [Yu et al, 2007]. Though the water requirement could be less when the thermal treatment temperature is lower, the cement could not be separated with the aggregates, and the cement paste could not be dehydrated and less reactive. What lead to the high water requirement may be that the particles of the dehydrated cement paste are porous, and more water is absorbed in the pores. Fig. 2 shows the shapes and structures of the cement paste particles before and after being burnt.

Fig.2 (a) shows the cement paste particles before being burnt. The particles have natural edge just like the crushed stone; those after being burnt are porous, which is a bit similar with the cinder.

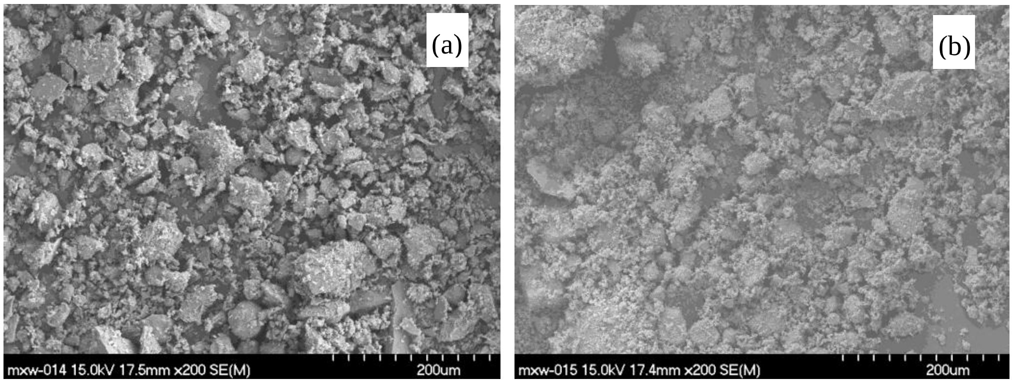

Fig.2 Particle shape and structure of cement paste before and after burnt

According as the results of this experiment, the times of setting of the dehydrated cement paste powder are shorter than cement products. The time of initial setting is 23─25min, and the time of final setting is 60─65min. This reactive power needs a proper retarding admixture when it is used industrially.

Strength of dehydrated cement paste

To confirm the reactivity of the dehydrated cement paste, strength experiments were carried out. In the strength experiments, Portland cement (P.I 52.5R), pulverized dehydrated cement paste and the mixtures of them were used. For the three mixed binder, Portland cement was substituted with dehydrated cement paste by 40%, 50% and 60% respectively. The mixture proportions are shown in table 1.

Table 1 mixture proportions of the cement mortar

Mixture ID	P.I cement /g	Dehydrated cement paste/g	Water cement ratio (W/C)	Standard sand /g
P-100	450	−	0.5	1350
P-60	270	180	0.5	1350
P-50	225	225	0.5	1350
P-40	180	270	0.5	1350
P-0	−	450	0.5	1350

The water to cement ratio of all these mixture is 0.5. The experiment follows the standard test method of hydraulic cement mortars (GB/T 17671-1999). Flow tests indicated that the higher is the dehydrated cement paste content, the thicker is the cement mortar. The strengths of Portland cement, pulverized dehydrated cement paste and the mixtures of them are shown in fig.3.

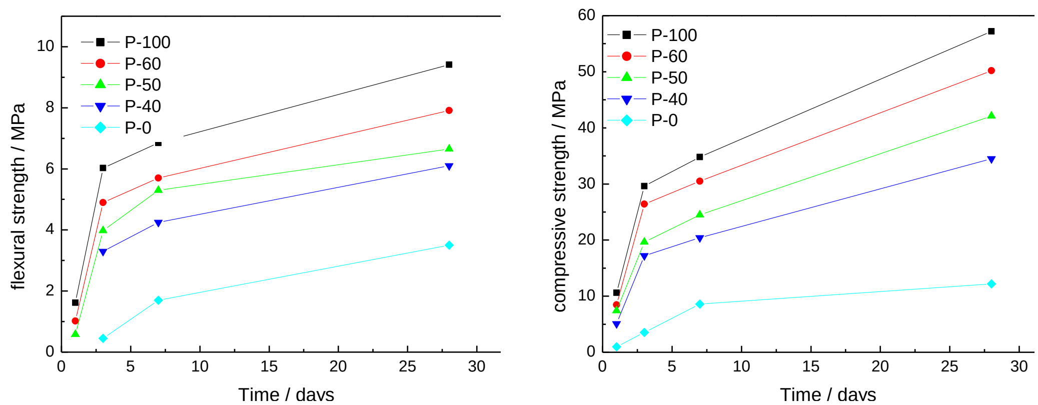

Fig3 Strengths of Portland cement, pulverized dehydrated cement paste and the mixtures

For the pulverized dehydrated cement paste without any Portland cement, the flexural strength is 3.5MPa, and the compressive strength is 12.3MPa at the age of 28 days. This implies that the pulverized dehydrated cement paste is reactive and cementitious. Other researchers also find the preheated hydrated cement paste has rehydration reactivity [Shui et al, 2008).

By the addition of some retarding admixture, this pulverized dehydrated cement paste powder is expected to be used directly in plastering engineering.

When Portland cement is substituted with pulverized dehydrated cement paste by 40%, 50% and 60%, the strengths of the mortar dropped to some extents. As the substitution rate is 60%, the flexural and compressive strengths can reach 65% and 60% of that of pure Portland cement respectively, which can meet the requirement of 32.5# blended cement. The other properties of this blended cementing material are to be studied continually.

CONCLUSION

The following conclusions can be drawn from the experiments provided in the paper

- Construction and demolition waste concrete and cement mortar can be decomposed through thermal treatment. Being treated at 750°C, the aggregates and cement paste are separated from each other, and the cement paste is dehydrated.
- The dehydrated cement paste is reactive itself. the flexural strength is 3.5MPa, and the compressive strength is 12.3MPa at the age of 28 days.
- The combination of the pulverized dehydrated cement paste, clinkers and gypsum can hopefully yield a new cement product.

- The waste concrete and cement motor could be recycled, which is advantageous for a sustainable development of construction industry. The natural resources and fuels could be saved and less greenhouse gases are emitted.

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