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Research Article

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An experimental of strength properties of concrete admixed with copper slag

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ABSTRACT

This paper gives an introduction of the current situation of comprehensive utilization of copper slag from different aspects in domestic and overseas, and puts forward the problems existed in the comprehensive utilization of copper slag. It has been found that copper slag have micro pozzolanic effect in the study. Workability of copper slag concrete is poor, but mixing the appropriate amount of micro-aggregates can improve their workability significantly. The mechanism of copper slag powder in composite cementitious materials is filling effect, activity effect and acceleration effect. The filling effect of copper slag can make matrix denser and the accelerating effect can accelerate the early hydration. Test and analysis are made on the influence of copper slag on strength and brittleness of concrete. Brittleness of concrete can decreased by adding copper slag, and mechanism is analyzed.

Key words: concrete, copper slag, compressive strength, flexural strength

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INTRODUCTION

Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially. The sustainable development for construction involves the use of nonconventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment.

The admixtures in making of concrete are mainly fly ash. The using of fly ash not only saves the cement, but also effectively reduces the rise of the heat of hydration temperature of concrete. The mixing amount of fly ash is even to reach to 50% to 70% in RCC dam which emerges in 1970s. Fly ash is the most widely, the largest amount of concrete admixtures at present. It can not only ensure the performances of the strength of late period of concrete, but can offer a good solution to the problem of concrete temperature control in construction. So the fly ash plays a decisive role in concrete.

The shortage of fly ash is gradually come into being, while the rapid development of water conservancy, transportation, industry and civil engineering of domestic and foreign in recent decades,. Such problem has also emerged in China, especially in the southwest of it. Fly ash out of stock is also emerged frequently in other regions of China. The shortage of fly ash is evident in the water conservancy project of China in particular, because most of the hydropower project is basically in the remote areas, and more large cubic metre of concrete is needed in hydropower project than other projects. The usage of concrete is usually millions of cubes, and some even more than 10 million cubes. Fly ash is in great demand in this project. At the same time, the long-distance transport of fly ash will greatly enhance the unit cost of concrete. Therefore, it is imperative to find an easy access, high quality and cheap new admixture.

It has been estimated that the production of one tonne of blister copper generates 2.2 tonnes of slag. Metal industry slag, mine stone and mining waste are generally suitable for recycling or reuse and the use of these inorganic wastes

as alternative materials in building, road and geotechnical applications have been reported [1-6]. There are 1.5 million tons or more copper slag which is produced by China per year, and more than 2500 tons have totaled at present [7], yet the environmental pollution caused by by-products of the copper industry -- water quenching copper slag (GCS) also affects the development of mine regions. How to use of copper slag effectively and cleanly and to promote China's green environmental protection construction is a major issue worthy of further study.

MAIN PROBLEMS OF THE CURRENT RESEARCH

Copper slag is a massive metallurgist waste and it is recognized as an industrial passive. It is obtained from the transformation of cooper concentrates, to metallic copper (anode) in smelters. Slag is then deposited in tailings that occupy large soil surface designated for this purpose. A great portion of these residuals is poured with no suitable recycling[8]. Physical and mechanical characteristics of slag will depend directly on the cooling speed that is submitted to. Copper slag is, in general, air-cooled, favoring partial crystallization of the held oxide, resulting in a mixture of crystalline and vitreous components. Its chemical composition is rich in iron oxide, silicon and aluminum. On the other hand, regarding the mineralogical composition, it is frequent the presence of fayalite and magnetite, among other components[9].

According to Gorai et al[9], it is estimated that for each ton of metallic copper produced, 2.2 tons of copper slag are generated and 24.6 mill tons of slag are generated worldwide annually. In Chile, during 2002, the existing seven copper smelters produced 2,360,000 metric tons of copper slag[10].

The use of copper slag in the preparation of anti-ray heavy concrete was made by the Eighth Metallurgical Construction Research Institute of China in the late 1970s [11]. Li Shuguang mixed copper slag with concrete instead of part of the construction sand [12]; Li Feng's research showed that: copper slag have the same physical and mechanical properties and durability with the ordinary concrete [13]; Du Hongyong and others have produced high-performance road portland cement by using of copper slag, and the concrete with characteristics of a high flexural strength, the lower content of f-Cao, small drying shrinkage and good wear-resisting performance [14]; Huang Shaowen and other's experiments showed that copper slag as iron raw material to calcination of cement clinker and to form mineral has a good adaptability, and copper slag also has a certain degree of mineralization and copper slag with the raw material has a better burnability [15];Tang Ming has prepared of ultra high strength, high wear resistance of cement mortar by winnowing ultrafine fly ash, copper slag aggregate and high-performance concrete admixture [16].

EXPERIMENTAL PROGRAM AND TESTRESULTS

During the period of conducting doctoral research the author was involved in the subject of copper-nickel blast furnace slag powder in concrete structural materials. Studies found that: copper slag has the effect of micro volcanic ash; the workability of copper slag concrete is poor, but by mixing with appropriate amount of micro-aggregates its workability will be improved significantly. The largest particle size of copper-nickel blast furnace slag powder is greater than 50μm (but its number is very less), some part of the particle size is of between 10μm to 50μm, the majority of particle size is less than 10μm.If it is mixed superplasticizer with concrete, the particle size distribution can be optimized, the powder particles are fully dispersed and paste gap can be filled. Figure 1 is the ESEM photos of slurry mixed with fly ash and slurry mixed with copper slag before the initial setting. Copper-nickel blast furnace slag can react with Ca $(OH)_2$.The reaction can produce hydration product which is similar with cement hydration. The reaction of Copper-nickel blast furnace slag and Ca $(OH)_2$ is earlier and faster than the corresponding reaction of fly ash.

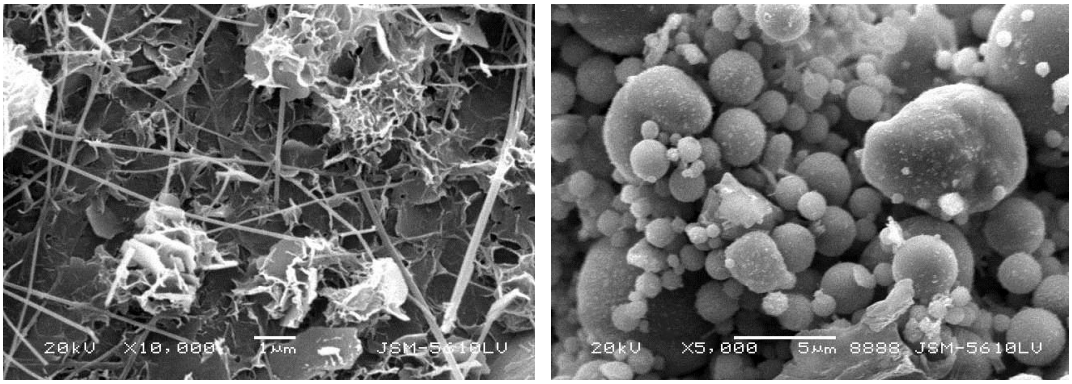

Figure 1 ESEM photo of slurry body doped with copper slag (left) and slurry body mixed with coal ash (right) before the initial setting

Obviously, there is larger and more fly ash cement paste gap, but if the copper slag is doped, the gap, and the large gap in particular, most of them can be filled, and a dense network structure is formed. MIP (mercury penetration) and BSE (back scatter) test also confirmed that the copper slag has a good filling effect and can improve the pore structure of concrete.

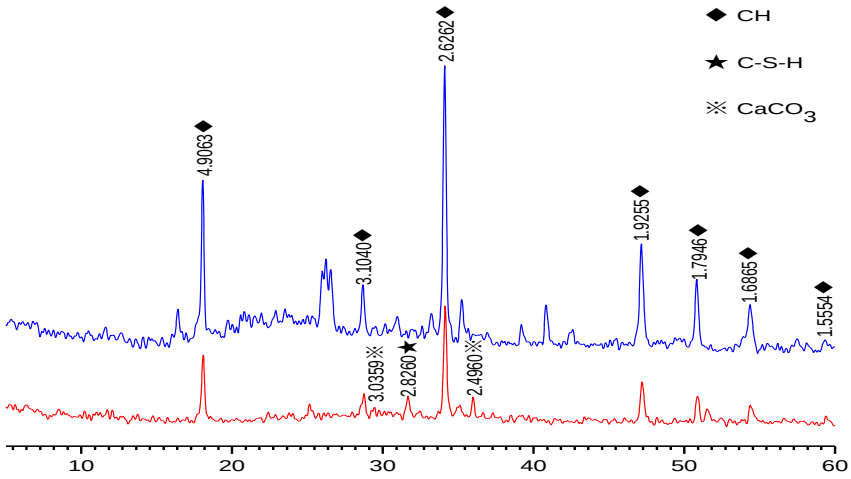

Figure 2 The XRD patterns of copper slag and fly ash hydration 28d
(from bottom to up, respectively, is the copper slag and fly ash)

Thus, the mechanism of copper slag powder in composite cementitious materials is filling effect, activity effect and acceleration effect. The filling effect of copper slag can make matrix denser than before; the acceleration effect can accelerate early hydration of cement (28d before).

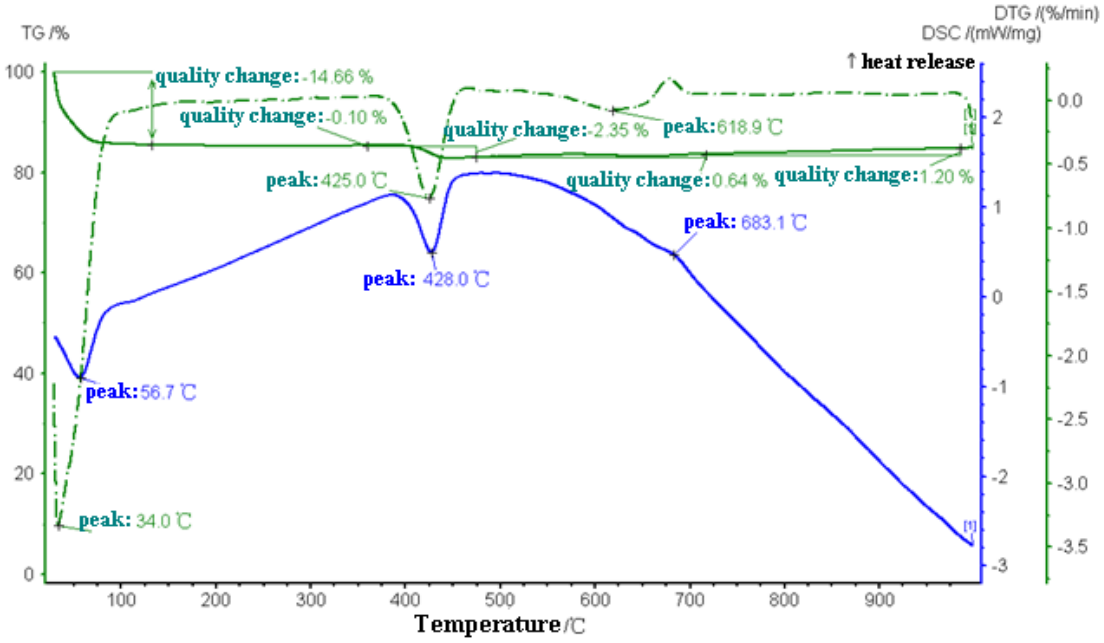

Figure 3 TG, DTG and DSC map of blast furnace of copper-nickel slag hydration of 28d

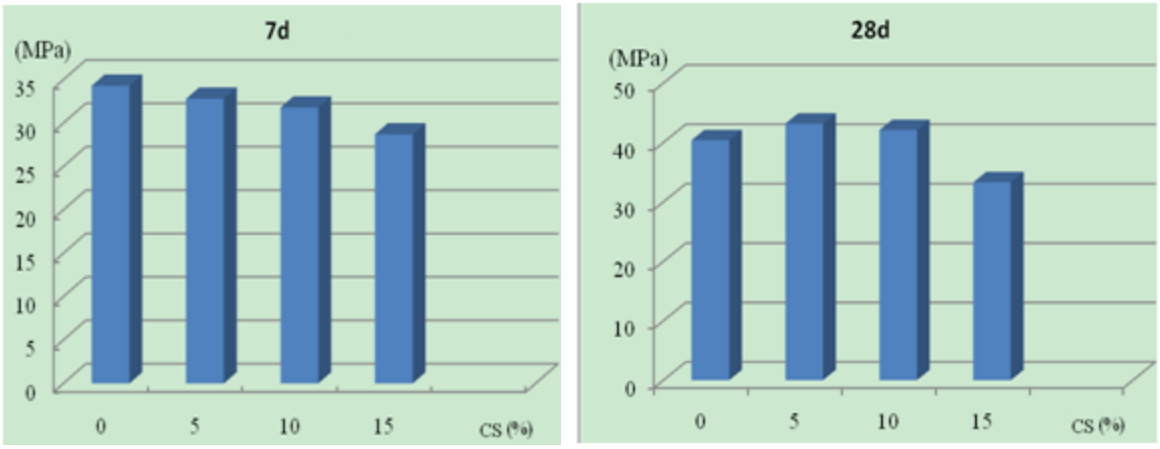

Figure 4 Compressive strength of copper slag concrete

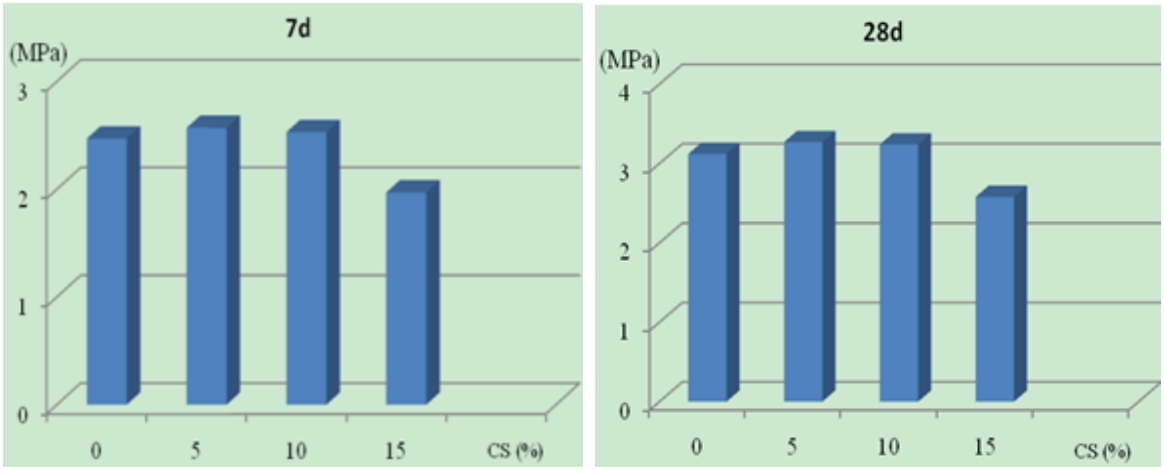

Figure 5 Tensile strength of copper slag concrete

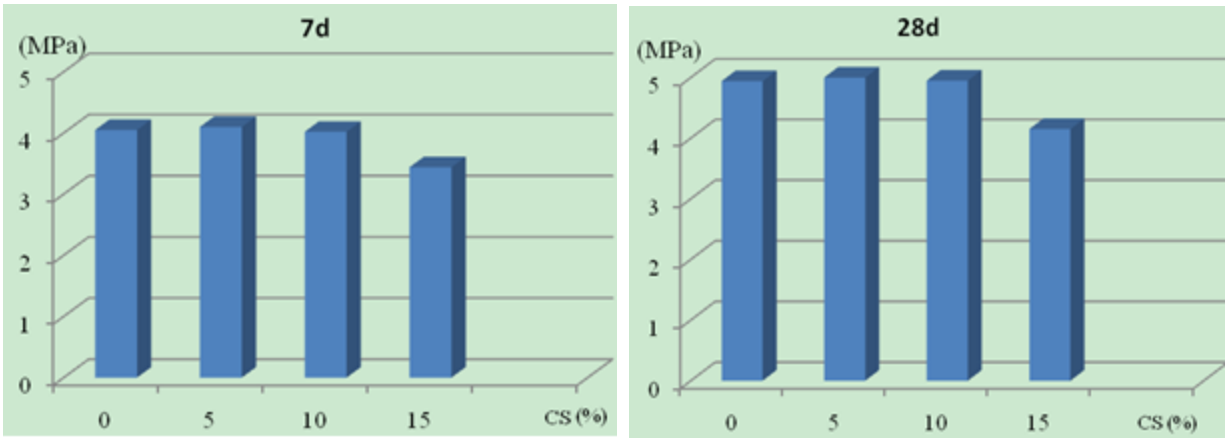

Figure 6 Flexural strength of copper slag concrete

Test and analysis are made on the influence of copper slag on strength and brittleness of concrete. Brittleness of concrete can decreased by adding copper slag, and mechanism is analyzed. Testing result shows that along with the increase of copper slag admixture, the concrete strength decreased from these figures4-6, but the drop range is small. As the strength increases, the brittleness of concrete increases. When copper slag content is 5%, brittleness increased slightly compared with the original concrete, but with the increase of copper slag content, the brittleness coefficient decreased. When copper slag content is 10%, brittleness coefficient of copper slag concrete and the original concrete is equivalent. When copper slag content is 15%, brittleness coefficient is smaller than the original concrete, and the brittleness of concrete becomes small.

CONCLUSION

The research on copper slag in concrete is mainly as substitutes in producing cement raw materials and fine aggregate in concrete at present, while few studies are on the material instead of cement as finely ground active admixture, and the researches still remain on the macroscopic properties of workability and strength of hardened concrete in the fresh concrete (mortar). There are still few researches on mechanism of Copper slag as an admixture in concrete. There is not carried out the study of the mechanism of the hydration characteristics of the system of the microscopic structure and cementitious materials and the hydration process of copper slag in cementitious materials system. At the same time the in-depth study to long-term service performance of Copper slag to concrete is also not carry out, and the theory and methods are not put forward to improve the structure and properties of copper slag concrete.

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