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Review

Utilization and efficiency of ground granulated blast furnace slag on concrete properties – A review

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HIGHLIGHTS

- Utilization and the efficiency of GGBFS on the properties of mortar/concrete was discussed and reviewed.
- Production process and reaction mechanism of GGBFS were presented.
- Fresh, hardened, permeability and durability properties of GGBFS included mortar/concrete were discussed.

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ABSTRACT

Ground granulated blast furnace slag (GGBFS) is a byproduct from the blast-furnaces of iron and it is a very beneficial in the mortar and concrete production. The present paper reviews the literature related to the utilization and the efficiency of GGBFS on the properties of mortar/concrete. Firstly, general information about GGBFS production, reaction mechanism and heat of hydration are presented. Then, workability, setting time, bleeding, rheological properties, slump loss, segregation resistance and early age cracking potential and finishability are addressed among the fresh concrete properties. Strength and rate of strength gain, modulus of elasticity, creep, shrinkage, influence of curing on performance of GGBFS, permeability, resistance to freeze/thaw cycles, carbonation resistance, deicing salt scaling, alkali–silica reaction and sulfate attack are among reviewed hardened concrete properties.

Contents

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1. Introduction

Blast furnace slag is a byproduct acquired in the production of pig iron in the blast furnace and is involving essentially of silicates and alumino-silicates of calcium and of other bases, which is developed in an igneous condition consecutively with iron in a blast furnace [1]. When the molten slag is rapidly cooled with water in a pond, or cooled with powerful water jets, it turns into a fine, granular, almost fully noncrystalline, glassy form known as granulated slag, having latent hydraulic properties [2]. Such granulated slag, when finely ground has been found to exhibit excellent cementitious properties either used with Portland cement or alkali activated [3]. This paper is a review of published studies on the utilization and efficiency of GGBFS on the properties of mortar and concrete. Firstly, a general overview to the production process and reaction mechanism of GGBFS is presented. The next section gives a summary on the fresh properties of GGBFS included mortar and concretes. Fresh properties are discussed in term of workability, setting time, bleeding, early age cracking and finishability, rheological properties, slump loss, segregation resistance and early age cracking potential depend on the used GGBFS contents. Then, effect of GGBFS usage on mechanical, permeability and durability related properties such as compressive strength, tensile strength, elastic modulus, creep, shrinkage and abrasion resistance, water, chloride ion, gas permeability, freezing–thawing, carbonation resistance, alkali aggregate reaction, sulfate attack, resistance to deicing chemicals of mortars and concretes were discussed depend on the used GGBFS content. Overall, this review paper focuses on awareness of GGBFS utility in terms of potential environmental impacts and technical benefits for sustainable construction.

2. GGBFS

2.1. Production process of GGBFS

Blast furnace slag is produced in a blast furnace concurrently with Fe. Fig. 1 schematically represents obtaining the blast furnace slag from the iron ore. Iron oxides are reduced to igneous Fe in the furnace by adding a flux such as limestone or dolomite and a fuel and with a reducing agent such as coke [4]. The igneous slag indwells on the pig iron and its temperature is close to that of the igneous iron, which is between 1400 and 1600 °C. The slag rises to the surface and is tapped off from be timely. If the igneous slag is cooled fastly a glassy Ca–Al–Mg silicate forms. There are two common practices to fast cool of igneous slag. In the first practices high-pressure water (about 0.6 MPa) jets is used to granulate igneous slag directly at the furnace as it departs the nozzle. In this practice, 3 m^3 of water is used for a ton of slag and after treatment about 30% of water is exist in the obtained slag. As a second practices, palletization, which was developed in Canada in the 1970s, is used. In this practice, the igneous slag is cooled firstly with water then flung into the air by a rotary drum (300 rpm). The water consumption is about 1 m^3/t of slag and the residual water content in the slag is only approximately 10% [5]. After the granulated blast furnace slag is obtained, it must be dehydrated, dried, and ground before using as a binder material. Magnets are often used before and after grinding to remove remaining iron. For increased cementitious activity at early ages, the slag is normally ground finer than Portland cement. As is well known that reaction rate increases with improving the fineness of pozzolans like as Portland cement [6].

2.2. Chemical composition and hydration mechanism

The composition of blast-furnace slag is changed depend on the ores, fluxing stone and impurities in the coke feed into the blast furnace. Normally, silica, calcium, aluminum, magnesium, and oxygen are more than 95% in the composition of the blast-furnace slag. Typical chemical compositions of GGBFS produced in different countries are tabulated in Table 1. For the better hydraulic activity of slag, its chemical composition is very important. As chemically, slags can be classified into their basicity index. CaO/SiO_2 ratio given by Nkinamubanzi et al. [7] is the simplest basicity indices and it was mentioned that calcium over siliceous oxide ratio must be greater than 1. Hydraulic activity is depends on the basicity of the slag, the more basic the slag, the greater its hydraulic activity

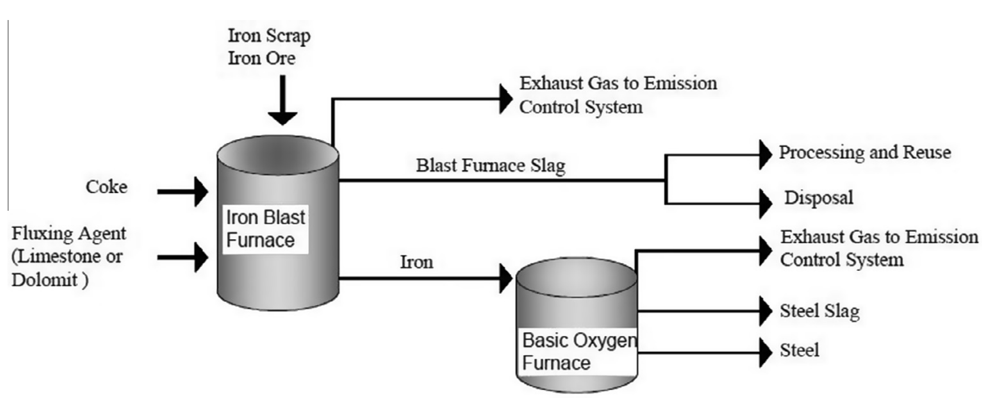

Fig. 1. Production process of slag [4].