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The Properties of Normal Concrete with Ground Manganese Slag as Binder Replacement

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ABSTRACT

Manganese slag is a by-product from the production of ferrosilicon and manganese alloys. It has been found to possess pozzolanic properties and is therefore suitable for use in concrete mixtures. This paper investigates the properties of normal concrete with ground manganese slag as a binder replacement in terms of workability, compressive strength, flexural strength, and leaching characteristics. In this study, it is found that using ground manganese slag as a binder replacement increases the slump of fresh concrete. It is also found that using ground manganese slag as a binder replacement reduces both the development of compressive and flexural strengths. However, at a 10% binder replacement rate, the deterioration is considered minimal. The results of leaching characteristics from 'The Tank Test' show that using ground manganese slag as a binder replacement increases the alkalinity of the solution surrounding the concrete, indicating that the metal ions in the ground manganese have diffused and dissolved in the solution.

1. Introduction

Concrete is utilized in construction in two times the amount of all other building materials combined and will undoubtedly continue to be used in building construction for a very long time [1]. Cement, water, and aggregate (sand and gravel or crushed stone) make up the three main ingredients of the commonly used building material known as concrete. This robust and versatile material may be used to build structures like buildings, roads, bridges, and other kinds of infrastructure. Concrete is a popular building material because of its durability, affordability, and strength.

The cement, which binds the elements of concrete together, is currently accountable for 8% of the world's emissions of carbon dioxide (CO_2) gas [2], the primary greenhouse gas causing climate change. Even though it appears clear that since its invention in the 19th century in its current form, concrete has been and will continue to be a fundamental material for the construction industry. After fossil fuels and land use change, cement production has dramatically expanded globally in recent

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years, making it the third-largest source of anthropogenic carbon dioxide emissions. With a production growth of 2.5% annually, it is anticipated to increase to 3.7-4.4 billion tons by 2050 [3]. The cement production in 2022 has been recorded as 4.1 billion tons by Garside [4].

In Sarawak, Malaysia, due to the development of the Samalaju Industrial Park, a number of metal smelting plants have been established recently and has been in full production since almost 5 years ago [5-7]. Manganese slag has been the by-products from these industries and they are categorised as scheduled wastes by the Department of Environment (DOE), Malaysia. As a result, storage of these wastes have become an issue with substantial amount of waste pilling up on the premises of the factories. According to Chen *et al.,* [8], manganese slag comprises of harmful heavy metals and will produce excessive sulphate and ammonia nitrogen that can potentially pollute the surrounding environment and harm the aquatic ecosystem and agriculture system. Therefore, a proper disposal method of the industrial waste residue is vital to ensure the safety of the environment in this region. One of the strategies to ensure the sustainability of the environment is to implement manganese slag as a binder replacement in concrete. To the best knowledge of the authors, the research work in this respect is still onging and therefore motivated the investigation reported herein. Thus, a literature review is reported in the impending discussion followed by the report on experimental work on using ground manganese slag as binder replacement in normal concrete. To the authors' best knowledge, ongoing research in this domain has served as the drive for the current investigation. Consequently, the forthcoming disussion includes a comprehensive literature review, followed by an exposition of experimental works focused on the utilization of ground manganese slag as a substitute binder in conventional concrete.

Generally, there are two types of manganese slag, namely ferromanganese slag and silicomanganese slag; that can be produced from the metal smelting process [9] as shown in Figure 1. The differentiation between these two types of manganese slag is through their manganese oxide (MnO) and silica (SiO_2) content [10]. The comparison of MnO, SiO_2, Calcium Oxide (CaO), magnesium oxide (MgO), Aluminum Oxide or Alumina (Al_2O_3) and Iron (III) Oxide (Fe_2O_3) content in ordinary Portland cement, ferromanganese slag and silicomanganese slag [11-13] is shown in Table 1.

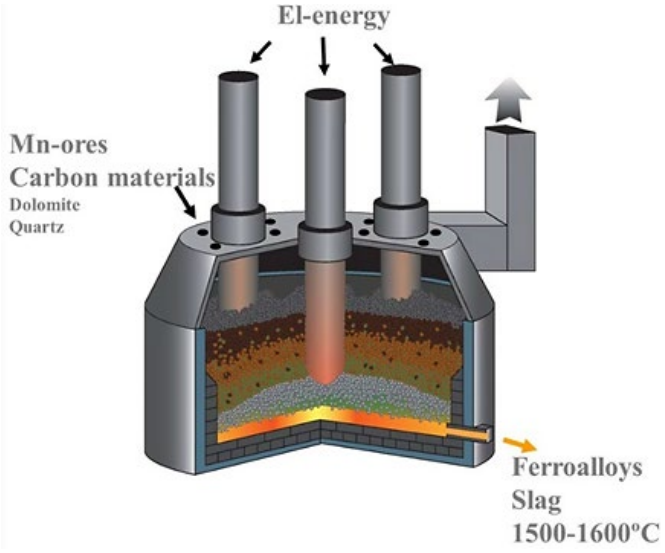

Fig. 1. Typical production of manganese slag in closed furnace (Tangstad *et al.,* [9])