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# The implementation of scale and steel chips waste as a replacement for raw sand in concrete manufacturing

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ABSTRACT

This research study was motivated by the ecological concerns over the disposal of scale and steel chips waste and scarcity of natural sources of raw sand in many countries. This paper reports the findings of an investigation undertaken on concretes made using scale and steel chips waste from the iron and steel industries as a substitute for sand. The percentage of natural sand replaced with scale and steel chips waste varied from 25% to 100% in terms of weight of sand. The concrete was classified according to the concentration of scale and steel chips waste – ScC-25, ScC-50, ScC-75, ScC-100, SchC-25, SchC-50, SchC-75, and SchC-100. The aim of this study is to investigate the compressive strength properties of mixed concrete shields and to compare the thickness of mixed concrete shields with the thickness of ordinary concrete shields (OC-0) to protect against X-ray radiation.

For comparison between the thicknesses of mixed concretes and ordinary concrete, we first determined the thickness of OC-0 corresponding to the thickness of concretes with a scale and steel chips waste admixture using lead equivalent (LE). The experimental results were at once rewarding and promising. The results obtained demonstrate a tendency for the thicknesses of mixed concretes to decrease as the mixing ratio of scale and steel chips waste aggregate increases. The data shows that concrete mixed with steel chips waste have better strength than ordinary concrete, while in the case of concrete mixed with scale waste, an addition of over 25% brought about a reduction in compressive strength.



## 1. Introduction

Due to global urbanization, rapid industrialization and economic development, waste generation has increased, and the increasing amount of waste generated is usually not properly managed. Despite the fact that most of these contain toxic chemicals which are harmful to air, water, and land, as well as to the human population, industries have traditionally managed their waste products by discharging them into the environment without prior treatment. This practice has resulted in an increase in pollution and has had a markedly negative environmental impact (Casares et al., 2005).

The problems derived from waste have a unique and complicated character; they may not be merely treated as troublesome ballast, but still carry both the value of subjective human labor as well as the energy used for their production. This waste constitutes a potential source of secondary materials. The use of industrial waste in the construction industry as aggregate is one of the essential processes which reduce the amount of waste and pollution. Additionally, recycling reduces the cost of transportation and the reliance on the analysis of the use of waste as a substitute in the production held by LCA.

The wider usage of radiation techniques in various fields such as health care facilities conducting radiation therapy, nuclear research facilities, as well as nuclear engineering and space technology, creates the necessity to protect people against both electromagnetic and neutron radiation. For a long time, lead was used for x-ray protection. The utilization of lead in x-ray protection would surely be a good choice in terms of protection against radiation, but for the fact that it is heavy and expensive. On the other hand, lead has many important disadvantages which limit its areas of application and usage, such as extremely high toxicity for both people and the environment, its heaviness, and low mechanic and chemical stability and inflexibility (La et al., 2016).

Developing alternative radiation shielding materials is a priority

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for protecting people who work in close contact with radiation. Concrete has long been the main material used in the construction of buildings, and is one of the most important materials used for radiation shielding in facilities containing radioactive sources and radiation-generating equipment. It is a relatively inexpensive material, which may be easily handled and cast into complex shapes. It contains a mixture of light and heavy elements and therefore possesses suitable nuclear properties for the attenuation of photons and neutrons (Okunade, 2002; Noor Azman et al., 2012; Gencel et al., 2010).

Aggregate is the main constituent of concrete, occupying more than 70% of the concrete matrix. In many countries, there is a scarcity of natural aggregate which is suitable for construction, whereas in other countries the consumption of aggregate has increased in recent years, due to the development of the construction industry. In order to reduce the depletion of natural aggregate due to construction, artificially manufactured aggregate and some industrial waste materials can be used as alternatives (Gorai et al., 2003; Shi et al., 2008). Scale and steel chips are a form of industrial waste produced in the iron and steel industry, which were previously considered as waste and disposed as landfill accordingly. This waste, however, has the potential to be used as coarse aggregate in concrete.

Although studies that have reported on the effect of waste materials and by-product as aggregates on the properties of concrete do exist, there has been little research concerning the incorporation of scale and steel chips as fine aggregates in concrete technology. This research was thus undertaken to evaluate the potential use of scale and steel chips as sand replacement in concrete production. The objectives of this study are to investigate the effect of the use of scale and steel chips as a replacement for raw sand in various percentages (25–100%), on concrete properties such as compressive strength and x-ray radiation attenuation, and to compare the thickness of mixed concrete shields with the thickness of ordinary concrete shields to protect against X-ray radiation. Scale and steel chips are taken into consideration specifically because of their particle sizes suitable for use as sand replacement in concrete, and their high density (4.72 g/cm3 for scale and 7.30 g/cm3 for steel chips) allows them to be used as heavy aggregates.

## 2. Literature review

Study of absorption of X-rays radiations in shielding materials has been an important subject in the field of radiation physics. In order to design the protective shielding in facilities containing radioactive sources and radiation generating equipment, the knowledge of the attenuation of X-rays in shielding materials is essential. In general, various materials such as lead, high density concrete, tungsten, copper, bismuth, and steel have been used for the radiation shielding in different applications.

A number of experimental and theoretical works have been performed on radiation shielding, which has large different application areas with different materials. Costa et al. (2015) in their work X-ray transmission data and spectra through ordinary concrete, concrete with addition of hematite and concrete with addition of steel grit were measured. They concluded that concrete with steel grit was found to be the best for shielding among the samples. Noor Azman et al. (2012) studied the effect of implanted ions such as tungsten (W), gold (Au) and lead (Pb) on the X-ray attenuation. Results show that the threshold of implanted ions above which X-ray mass attenuation coefficient, of the ion-implanted epoxy composite is distinguishably higher than the mass attenuation coefficient of the pure epoxy sample is different for W, Au and Pb. (Okunade, 2002) compared lead attenuation and lead hardening equivalence of materials used in respect of diagnostic X-ray shielding. Results show that, by guided choice of thickness, lead and steel can be made to provide closely similar attenuation and hardening, producing nearly the same values of lead attenuation equivalent and lead hardening equivalent. There are significant differences in the values of exposure from beams transmitted by lead hardening equivalent and equivalent thicknesses of plate glass and gypsum wallboard, with lead recording higher exposure values. From the results presented, specification of lead hardening equivalent in the case of plate glass and gypsum wallboard can result in significant under shielding, lead hardening equivalent producing lower reduction in exposure than corresponding thicknesses of these materials. Amritphale et al. (2007) utilized red mud for making X-ray radiation-shielding materials. They concluded that, the shielding thickness of the red mud based shielding materials, in comparison to concrete, is significantly very less for the various energies of X-ray photons, i.e. 100, 150, 200 and 250 kV and therefore red mud based shielding materials can provide effective shielding at very less thickness itself.

Kim et al. (2012) has developed an economic, easily workable and environmentally-friendly radiation shielding sheet using barium compounds. The authors found that, the shielding ability of the tungsten and silicon combination with BaSO4 was the same as that of a 0.3 mm lead equivalent.

Different types of natural and artificial aggregates are used to enhance compressive strength of concrete, as each country has to gain its own experience depending on the available cheap and effective local materials. Yellishetty et al. (2008) examined reuse of iron ore mineral waste in civil engineering. The results confirmed that the mean values of uniaxial compressive strength of concrete cubes after 28 days of curing was found to be of the order of 21.93 and 19.91 MPa with mine aggregate and granite aggregate, respectively.

Li and Zhao (2003) presented a laboratory study on the influence of combination of fly ash and ground granulated blast-furnace slag on the properties of high-strength concrete. The results indicated that their application can improve both short- and long-term properties of concrete.

Furthermore, Demirboga and Gül (2006) researched the use of blast furnace slag aggregate (BFSA) to produce high-strength concretes. Their results showed that the compressive strength of BFSA concretes was approximately 60–80% higher than that of traditional concretes.

Al-Jabri et al. (2009) studied the use of copper slag as a replacement for sand in high strength concrete with almost constant workability. They reported an increase in the concrete strength due to the increased content of copper slag as replacement of fine aggregate.

The experimental work by Qasrawi et al. (2009) on the use of low CaO unprocessed steel slag in concrete as fine aggregate indicated that when optimum values are used, the 28-day the compressive strength is improved by 1.1–1.3 times depending on the replacement ratio and the grade of concrete. The best results are obtained for replacement ratios of 15–30% for compressive strength.

Ismail and Al-Hashmi presented an extensive data on effects of replacements of sand with waste iron on the properties of concrete (2008). The compressive strengths and flexural strengths were higher than the plain concrete mixes.

Recently, numerous studies have focused on the use of different waste as a sand replacement for concrete. Singh and Siddique (2016) have evaluated the utilization of coal bottom ash as a substitute for sand at six different substitution rates (20%, 30%, 40%, 50%, 75 and 100%) and concluded that after 90 days of curing, the compressive strength was almost comparable to that of the control