Optimization of Recycling the Granulated Slag as Partial Substitute of Cement to Produce Sustainable Concretes

Mohammed T. Hayajneh
Industrial Engineering Department, Jordan University of Science and Technology,
P.O. Box 3030, Irbid, 22110, Jordan
Email: hayajneh@just.edu.jo

Ahmad Ezzat
Industrial Engineering Department, Jordan University of Science and Technology,
P.O. Box 3030, Irbid, 22110, Jordan
ezzat@yahoo.com

Abstract
The production of cement results in emission of many greenhouse gases in atmosphere, which are responsible for global warming. Hence, this study motivated of using the waste material having cementing properties, which can be added to the concrete as partial replacement of cement, without reducing its strength, which will result in reduction of cement manufacturing thus decreasing in emission in greenhouse gases. The granulated slag (GS) is a waste product from the steel industry, which may be used as partial replacement of cement in concrete. This is an experimental research of strength of concrete prepared with Portland cement, partially substituted by GS in different quantities varying from 0% to 50%. It is noted from the study that the strength of concrete is inversely proportional to the percentage of replacement of cement with GS. It is concluded that the 10% replacement of cement is possible without reducing the strength with 42 days curing.

Keywords
Optimization, Sustainable Concretes, Green Systems, Recycling, Slag.

1. Introduction
The production of cement is an energy intensive process, resulting in emission of greenhouse gases which adversely impact on the environment. At the same the cost of production of cement is increasing at alarming rate and natural resources giving the raw material for its manufacturing. The use of waste material having cementitious properties as a replacement of cement in cement concrete has become the thrust area for construction material experts and researchers. The main focus now days is on search of waste material or bye product from manufacturing processes, which can be used as partial replacement of cement in concrete, without reducing the desired strength. The granulated slag (GS) is a waste product from the steel industry, which may be used as partial replacement of cement in concrete due to its natural cementing properties.

In the country like Jordan, where the development of the infrastructures projects such road and building projects are either being constructed or in completion of their planning and design stage, such uses of waste material in cement concrete will not only reduce the emission of greenhouse gases but also will be the sustainable way of management of waste.

The Fly ash, granulated slag, and silica fume are some of the materials which can be recycled in concrete as partial replacement of cement. A number of researches are going on to explore the effect of use of these materials as cement replacements and the results are promising. These materials include fly ash, silica fume and ground-granulated blast furnace slag used separately or in combination. The strength and other characteristic of concrete depend on the properties of its constituents, proportion of mix, method of compaction and other controls during curing. For concretes, a mixture of mineral and chemical admixtures is always important to confirm achievement of the necessary strength. Recycling of industrial solid waste has been crucial in the search for sustainable development, enabling the preservation of non-renewable natural resources, through the replacement of these alternative materials with appropriate properties to use. Recycling allows potential benefits to society; including energy savings, reducing the volume of wastes, less pollution, job creation, reduced costs of environmental control industries, increased durability. In this context it has to recycling slag as raw material in construction, able to present an excellent technical and economic, to which must be added its environmental importance, if properly used.

Currently, much of the dross is deposited next to factories where they form piles of waste land. The uncertain fate of this material causes various environmental and economic problems, among which are increases in production costs, large physical space for waste dumps environmental pollution; reducing the quality of life around industries, land next to industries becoming unfit for cultivation and the room where pollutants such as particulate emissions are a serious threat to plant and animal life. However, the environmental impact can be minimized, adding economic value to the slag if they are applied in civil construction on different forms, such as ballast on railways, fill material, added to base and sub-base pavement or coating asphalt, aggregate for concrete and raw materials in cement production.

The noblest fate of these recyclable materials depends on the existence of appropriate characteristics for the proposed use. These recyclable byproducts (such as slag) and aggregate for concrete and the sub-bed of roads is a less noble use, which does not use the potential of these pyroclastic materials properties (pozzolánicas) and cementing. Thus, replacing part of the cement (in the manufacture of cement or concrete production), it is a nobler application, which is attractive from the economic point of view; since the price of the additional cement is lower than the cement. In addition, this type of employment allows excellent economic and energy benefits, such as reduced environmental impact in the production of cement, decreasing the formation of gases, especially CO_2, harmful to the atmosphere, energy saving and preservation of natural resources, everything that qualifies as a sustainable practice. The possibility of the use of slag as material cementing depends primarily on its chemical composition (acidic or basic slag), its reactive characteristics (depending on the type of cooling) and environmental characteristics (classification the waste as hazardous and not inert or inert). Experiences with blast furnace slag has shown that greater proportion glassy (amorphous structure) is instrumental in the reactivity of these residues once incorporated into the cement, as appropriate chemical composition. The granulation through (quenching), electric arc furnace slag (slag refining oxidizing and reducing) acquire glassy structure (amorphous), stabilizing expansive properties and can be used as an addition to cement, plus allow significant recovery of the metal phase. Also the same for oxygen steelmaking slag cooled sharply as stabilization, and the possibility of adding cement. The molten slag (cupola) is suitable for use as mild aggregate cement based materials. He also notes that the slag has been used as a substitute aggregate in structural concrete.

Granulated slag (GS) has amorphous structure, essentially consisting of oxides of silicon and calcium. Thus, this work aims to study the performance of concrete with the use of foundry granulated slag as cement replacement part, through the evaluation of their mechanical properties for this concrete test bodies with different combinations of substitution tenors granulated slag cement casting (percentage of slag=10%, 30% and 50%) by volume and water/binder (w/c) (0.40, 0.55, 0.70), to be compared to the reference concrete (0% percentage of slag, no GS). For each age concrete (7, 28 and 42 days) compression strength and Flexure strength tests were conducted.

2. Literature Review

Many investigators have studied the replacement of cement with Granulated slag (GS) in concrete and found the good results. Sun et al. (2007 concluded that the recycling of slag will certainly become significant measure for the environment protection and therefore will be of large significance. Dubey et. al. (2012) observed that the curing period required for GS concrete is more as compared to standard concrete. Khan and Usman (2004) concluded that workability of GS concrete is more and thus water cement ratio may be reduced resulting in increase in compressive strength. Shariq et. al. (2008) found that the replacement of Ordinary Portland Cement (OPC) in concrete with GS gives the optimum strength at 40% but after curing of 56 days. Naidu et al. (2012) studied on geopolymer concrete with addition of GS and found the increase in strength of concrete. Barnett et al. (2005) concluded from their research that the early strength development of mixtures containing GS is highly dependent on temperature under standard curing conditions and the GS mortar gain strength more slowly than mortars with Ordinary Portland Cement.

3. Materials and Methods

3.1 Variables Analyzed

In this paper, the controllable factors (independent variables) were chosen, i.e. process parameters potentially significant effects on the response variables were (1) Replacement granulated slag cement casting (GS), by volume, which were investigated four levels, three replacements (10%, 30% and 50%) and reference (0%), (2) three levels of water/binder (w/c) were investigated (0.40, 0.55 and 0.70) and three levels of age (degree of hydration) of concrete were studied (7, 28 and 42 days). The response variables (dependent variables) measures were the compressive strength and the flexure strength.

3.2 Materials Used

Cement

In order to evaluate the influence of replacing part of granulated slag on the strength of concrete, without the interference of other additions, it was decided to use pure cement commercially and economically found (Figure 1). cement used has specific mass equal to 3.11g/cm^3 and average grain size equal to 16.67 microns.

Granulated Slag

The granulated slag (Figure 2) is waste generated in the process of melting scrap cast iron in furnace. Features resulting from the quenching amorphous structure (granulation) it undergoes during emptying with a water flow channel. The sample of GS was the result of different loads the furnace and held on different days, to ensure greater representation. This material during the collection is presented on the form of small particles close to those of gravel dimensions. To acquire appropriate as a substitute for part of the cement characteristics, this was held (ground) in cylindrical rings mill, to an average grain size of 26.4 microns which classifies pyroclastic materials properties. Granulated slag casting has specific mass equal to 2.83g /cm^3.

Aggregates

The concretes were made using tiny aggregates (sand) and unwrapped (gravel) in the region (Figure 3). The specific mass of gravel is of 2.63g /cm^3.

		
Figure 1: Portland cement.	Figure 2. Granulated slag.	Figure 3.Coarse aggregate.

3.3 Concrete Casting

Concrete is a combination of cement, sand, aggregate, water, and possibly an admixture. Proportions of each ingredient are adjusted to create a well-balanced mix. Concrete sets in as few as 10 hours and lasts to harden and cure as long as moisture and unhydrated cement are present.

3.4 Procedure

Before mixing concrete, the mixer has been "buttered" with a mixture of cement, sand, and water. Starting the mixer. Adding about half the fine aggregate. Then, carefully adding all the cement with the mixer running. Mixing until all the cement is blended in. Adding the rest of the coarse and fine aggregate. Adding enough water from the final quarter of the water to produce a workable mix. Mixing for three minutes, followed by a three-minute rest, followed by a two-minute final mixing. Filling molds and stirring (Figure 4). Finishing the casting by surfacing (Figure 5). Storing specimens in water (Figure 6). Specimens are ready for tests.

Figure 4. Filling moulds and stirring.

Figure 5. Finishing the casting by surfacing.

Figure 6. Storing specimens in water.

3.5 Test Methods

All the specimens are kept in water tank for curing. All the cube specimens are tested for compressive strength in compression testing machine (Figures 7 and 8) while all beam specimens are tested for Flexure strength by using Flexure test machine as shown in Figures 9 and 10.

Figure 7. compression test

Figure 8. fracture shape in compression test

Figure 9. Flexure test.

Figure 10. Fracture shape at flexure test.

4. Results and Discussion

This study was performed to study the influence of granulated slag on the characteristics strength of concrete. In this investigation 108 cubes were made to study the effect of replacement percentages (0%, 10%, 30%, and 50%), water/binder (0.4, 0.5 and 0.7) and age (7, 28 and 42 days) on the compressive strength of the concrete with three replicates (4 replacement percentages× 3water/binder×3 age× 3replicates=108). 108 cubes were made to study the effect of replacement percentages (0%, 10%, 30%, and 50%), water/binder (0.4, 0.5 and 0.7) and age (7, 28 and 42 days) on the flexure strength of the concrete with three replicates (4 replacement percentages× 3water/binder×3 age× 3replicates=108).

The variation of compressive strength and flexural strength of concrete mix with different percentage of slag as partial replacement of cement is shown in Figures 11 and 12 at the age of 7, 28, 42 days for different water/binder ratio. It may be observed from the plots that the properties of can be maintained with GS as partial replacement of cement up to 10%. The replacement of OPC by GS up to 10 % shows the marginal reduction of 8% in compressive and flexural strength for 42 days curing.

5. Conclusions

The following conclusions are drawn from the study:

1. The increase in % of GS results in decrease in strength of concrete.
2. The replacement of OPC by GS up to 10 % shows the marginal reduction of 8% in compressive and flexural strength for 42 days curing.
3. The partial replacement of OPC in concrete by GS, not only offers the economy in the building but it also aids environmental friendly disposal of the waste slag which is generated in enormous quantities from the casting industry.

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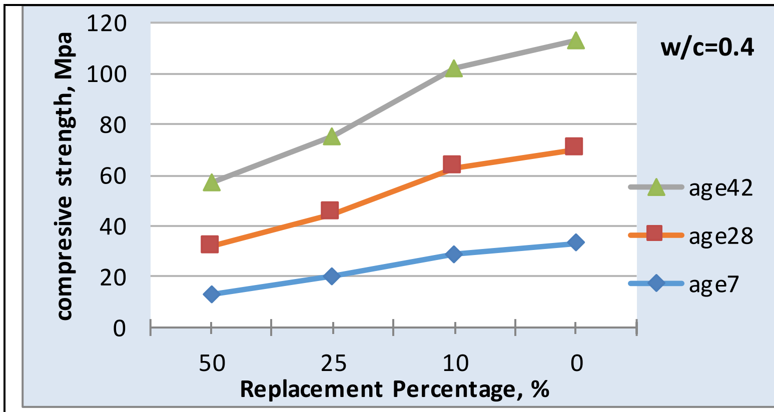
Biography

Dr. Mohammed Taiseer Hayajneh is a Professor at the Industrial Engineering Department, Jordan University of Science and Technology. He received the BSc, and MSc, degrees in Mechanical engineering from Yarmouk University, Irbid, Jordan; and Jordan University of Science and Technology, Irbid, Jordan, respectively. He earned his PhD in mechanical engineering/Manufacturing and design from Concordia University, Montreal, Canada in 1998. His research interests include Manufacturing Technology; material, Fuzzy Logic and Clustering in Manufacturing Systems, Fuzzy Control, Quality Control of the Machined Surfaces, Analytical Modelling and Testing, Design of Experiments, Statistical Analysis, Metal Matrix Composite and Energy Saving in Manufacturing.

Ahmad Ezzat is undergraduate student in the Industrial Engineering Department, Jordan University of Science and Technology.



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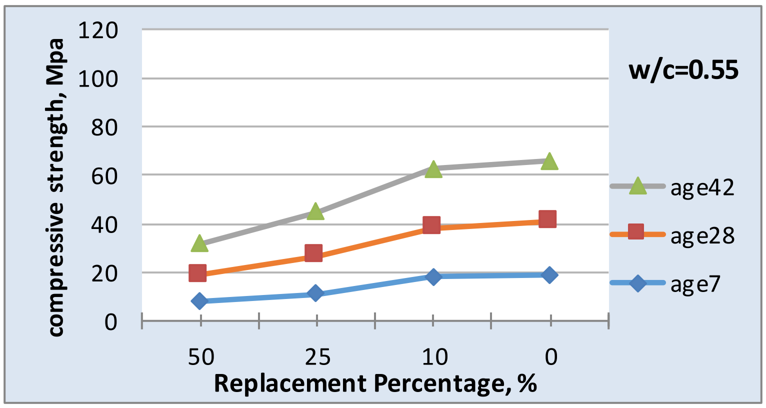

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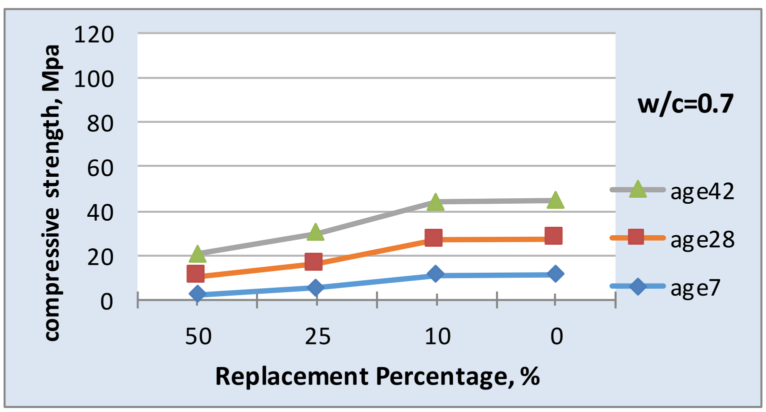

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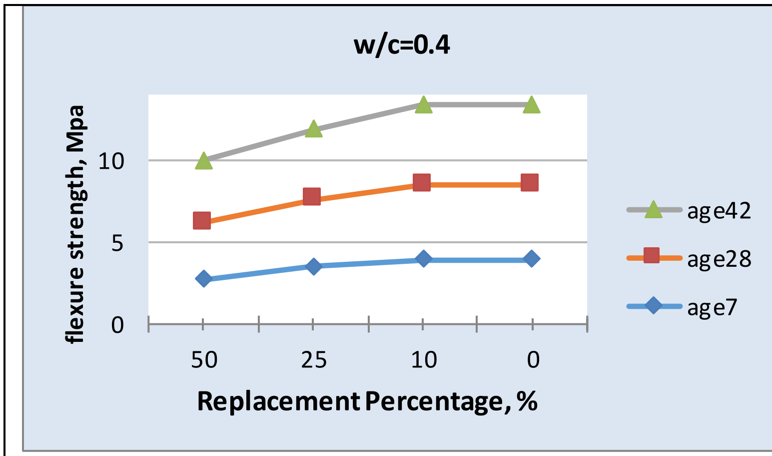
Figure 11. Compressive strength test results.



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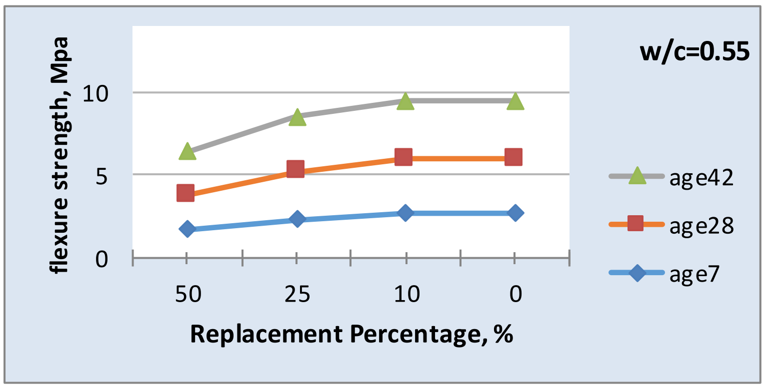

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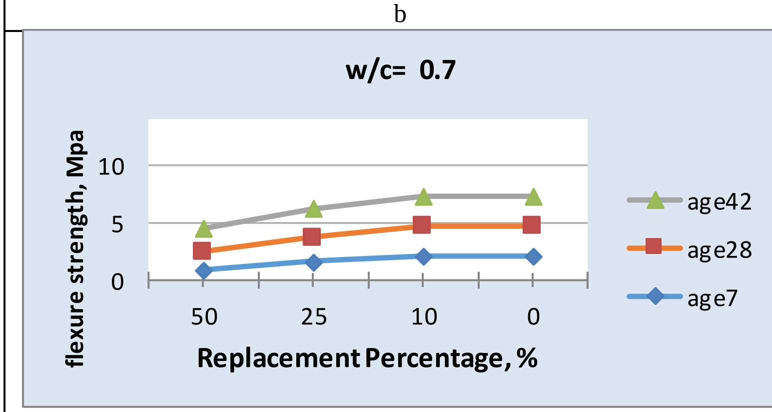

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Figure 12. Flexural strength test results.