Recycling Of Ferrochromium Industrial Wastes in Albania as Coarse Aggregate, in Road Base Construction and in Concrete.

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ABSTRACT

This study investigates the possibility of recycling the ferrochromium industrial wastes in the Mat region of Albania by introducing it as a substitute for conventional coarse aggregate, in road base construction and in concrete. The chemical composition and aggregate abrasion resistance tests were carried out for ferrochromium slag (FCS). Moreover the compressive strength of concrete with FCS as coarse aggregate was investigated. The results were compared with those carried out with natural river aggregates (NRA) and crushed river aggregate (CRA). Based on the results the abrasion resistance of FCS was (25% mass loss in the Los Angeles abrasion test) the highest compared to those of the conventional specimens. The compressive strength of concrete produced with FCS was 24% higher than that of CRA specimen. The data acquired from the tests showed that FCS could be conveniently used as coarse aggregate in road base construction and higher compressive strength concretes.

INTRODUCTION

Heavy industry was a priority during the communist regime in Albania. Among all the producing and exporting industries, Mining and metallurgy were some of the leading ones. Bulqiza chromite mining district has been the main axis of the chromite mining industry in Albania since mining works started in the 1940's. [1]

Annual chromite production in Albania peaked at about 1.2 million tones chromite ore during the 1980's, when Albania was the third biggest producer in the world (about 10% of the global production) after South Africa and the Soviet Union [2], a great quantity of wich was enriched in the Ferrochromium Enrichment Plant near the town of Burrel. In Figure 1. Chromite Production in Albania between 1981 – 2007 is shown.

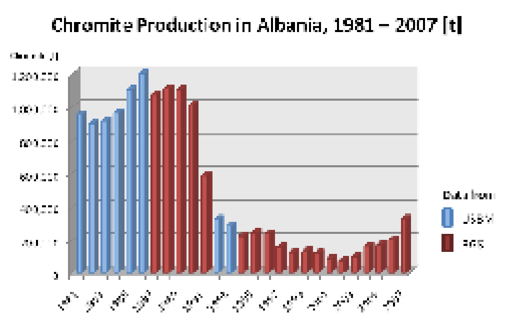

Figure 1. Chromite Production in Albania, 1981 – 2007. Sources:USBM – US

At the moment millions of tones of industrial wastes in the form of slag are deposited near the plant in the town of Burrel. The land filled with the waste materials has become a significant source of pollution of air, water and soil, and further adversely affects the human health, animal health and the growth of plant and vegetation. [3] Research showes that some kinds of slags containing chromium at an amount of 8–12%, like stainless steel slag, can release Cr into water and it may be harmful to the environment. [4]

In this study the possibility of protecting the environment in the region from this waste material, and at the same time make use of it has been investigated. Previous studies evaluating the use of industrial by-products as aggregate in concrete have been reported. [5]. Using the industrial waste products for concrete making will make possible to produce sustainable concrete and greener environment. [6]. It is considered to be a good option to produce concrete with non-conventional aggregates for environmental reasons. [7] Lately the growth in industrial production and the increase in consumption have led to fast decline in natural resources. This high rate of production has generated a considerable amount of waste materials which have adverse impact on the environment [8]. Earlier researches show that industrial and other wastes were used in concrete-making in order to enhance the properties of concrete and to reduce cost. [9]. Beside concrete-making industrial wastes are used in road construction. The base course of a road is a layer that needs to be able to provide stable foundation for the surface layers. It is produced from compacted aggregate, asphalt, or concrete. Hundred percent crushed slag aggregate has been tested and proven as a superior base coarse material over time, offering many advantages related to other materials. Slag bases are long wearing and require less maintenance, and are totally stable under possible moisture conditions. [10]. Previous researches show that slag aggregate bases have better drainage rate than any other types of conventional aggregates of similar size grading [11].
Depth of base is reduced with slag aggregate because of its high strength. It is also well suited for use as a structural fill material for the construction of highway embankments or the filling of other large areas. [12]. The ferrochromium slag can be a good material that showes volume stability, high volume mass, good abrasion resistance to wear and crushability which makes the reinforced slag concrete suitable for wearing courses of concrete pavements or consrete roads [13]. This study investigates the possibility of recycling the ferrochromium industrial wastes in Albania by introducing it as a substitute for conventional coarse aggregate, in road base construction and in concrete. For this purpose the chemical composition and aggregate abrasion resistance tests were carried out for ferrochromium slag (FCS). Moreover the compressive strength of concrete with FCS as coarse aggregate was investigated. The results were compared with those carried out with natural river aggregates(NRA) and crushed river aggregate(CRA).

MATERIALS AND METHODS

Materials

Cement

Portland Composite cement, (type CEM II /B-S strength class 42.5N according to EN 197) in the Fushe Kruja Cement Factory was used in this study.

Aggregates

Crushed ferrochromium slag (FCS), limestone as natural river aggregate (NRA) and as crushed river aggregate (CRA) with a maximum nominal size of 31.5 mm were used as coarse aggregates, while crushed river sand (CRS) with a maximum size of 4 mm was used as fine aggregate. Two control specimens were made with limestone as coarse aggregate separately, one as (NRA) and the other with (CRA). For all the specimens (CRS) was used as fine aggregate.. The properties of aggregates are in conformity with (AASHTO T-85-88; 1998)

Ferrochromium Slag(FCS)

The Ferrochromium slag is an industrial waste remaining from the enrichment of chrome mineral in the Ferrochromium Enrichment Plant, Burrel, Albania. After the extraction of the FeCr metals by melting the mineral in high temperature furnaces and slowly cooling of the molten slag in air, a stable crystalline dense rock is produced.[14]. In Figure 2, ferrochromium slag sample is shown.

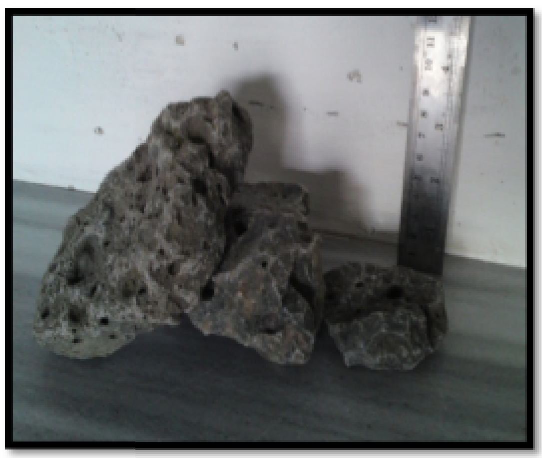

Figure 2. Ferrochromium Slag Sample

Methods

Preparation of the Specimen mixtures

Three different types of concrete specimen were prepared. The first specimen type was prepared with crushed ferrochromium slag (FCS) as coarse aggregate and crushed river sand (CRS) as fine aggregate. The second specimen type was prepared with crushed river aggregate (CRA) as coarse aggregate and crushed river sand (CRS) as fine aggregate. The third concrete specimen type was prepared with natural river aggregate (NRA) as coarse aggregate and crushed river sand (CRS) as fine aggregate. The formulations of the concrete mixtures are given in Table 1. For all the mixtures, the coarse and fine aggregates were weighed in a dry condition. The coarse aggregate was then immersed in water for 24 h. The excess water was decanted, and the water retained by the aggregates was determined by the weight difference. A predetermined amount of water was added to the fine aggregate that was then allowed to stand for 24 h. A water to-cement ratio of 0.6 was used for all the specimens.

Table 1. The formulations of the concrete mixtures

Specimen Type	Water (kg/m3)	Cement (kg/m3)	Fine aggregate (kg/m3)	Coarse aggregate (kg/m3)
FCS	193	316	728	1230
CRA	193	316	728	1110
NRA	193	316	728	1100

Casting of the specimens

The specimens were casted into cubic moulds of 150 x 150x 150mm and tested for 7 and 28 days compressive strength. All the cubes were cast in two layers. Each layer was consolidated by rodding 25 times. After casting, all the specimens were covered with plastic sheets. The specimens were then kept in the casting room for 24 h. They were then demoulded and transferred to the curing tank at 22±2 ◦C and 100% relative humidity until their testing dates. (EN 12350-1, EN 12390-1, EN 12390-2)

Experimental Program

Chemical composition of FCS

The mineral character of aggregate affects the possibillity of using it as a construction material and also strength, durability, elasticity of concrete when used as a concrete aggregate. In Figure 3 the chemical composition of the ferrochromium slag analyzed in the Adana Cement Factory, in Turkey is shown.

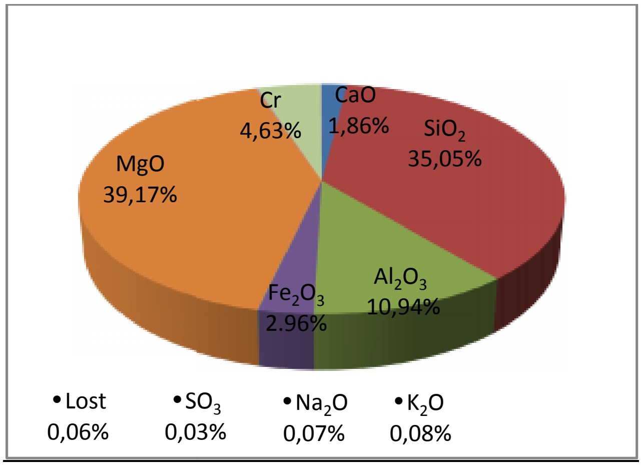

Figure 3. The chemical composition of the ferrochromium slag

Specific gravity and Water absorption of FCS

The specific gravity is defined as the ratio of the density of a material to the water density, whereas water absorption determines the water amount that an aggregate can absorb. Specific gravity of crushed FCS was 2.97 whereas the water absorption varied 0.6%. No limit for specific gravity has been specified in the published literature (AASHTO T-85-88; 1998). The water absorption was found well with in 2% specified limits The physical properties of aggregates are given in Table 2.

Table 2. The physical properties of aggregates

Aggregate Type	Specific gravity (gr/cm^3)	Water absorption (%)
(FCS) coarse aggregate	**2.97**	**0.6**
(CRA) coarse aggregate	**2.68**	**0.9**
(NRA)coarse aggregate	**2.67**	**1.1**
(CRS) fine aggregate	**2.62**	**1.6**

Los Angeles Abrasion test of FCS

In order to work out the toughness and durability of crushed aggregate, Los Angeles abrasion test is recommended in the published literature. The Los Angeles value is a very important indicator for concrete aggregate, but it is particularly important for aggregate when used as road base or sub-base material, which repeatedly undergoes to the dynamic traffic load. The Los Angeles abrasion value of FCS was 24.3%. (AASHTO T-96) The maximum allowed values of aggregates for sub-base, base course and ordinary Portland cement and asphalt concrete are 50%, 40% and 35%, respectively. In Figure 4 FCS specimen for Los Angeles abrasion test is shown.

Figure 4. FCS specimen for Los Angeles abrasion test

Compressive strength test

For each mixture, the compressive strength was determined after 7 and 28 (three samples were tested at each age for each type of mixture) These tests were carried out according to the relevant (EN 12390-3, EN 12390-4) standards. The test results are shown in Figure 5.

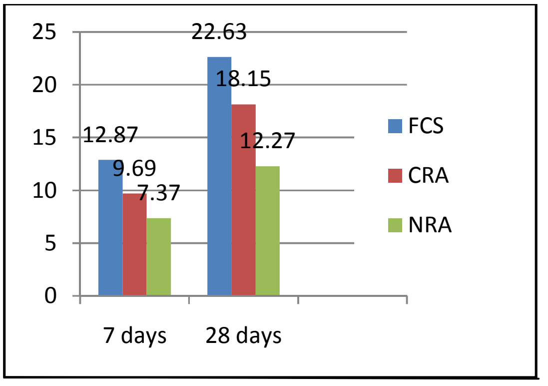

Figure 5. 7 and 28 Days Compressive Strength, MPa

RESULTS AND DISCUSSION

According to the test results in Table 2, the ferrochromium slag aggregate has a specific gravity 2.97 g/cm^3 higher than that of the crushed river aggregate which had a specific gravity of 2.68 g/cm^3 and of the natural river aggregate which had a specific gravity of 2.67 g/cm^3. The results show that the ferrochromium slag is a relatively dense material compared to the conventional coarse aggregate. The very low rate of absorption 0.6% also confirms it.

These two properties show that the aggregate has also a low permeability, which is a very important property for concrete aggregate and also for road base and sub-base aggregates. The low rate of abrasion, in the Los Angeles abrasion test with 24.3% mass loss indicates a good abrasion resistance. Therefore it is a very good alternative material for road base.

The compressive strength test results for the concrete are given in Figure 5. The results showed that the use of FCS resulted in a significant increase in the compressive strength of the concrete, as the 7 day compresive stength of FCS specimen was 32.8% higher related to the CRA specimen, whereas 28 day compressive strength of FCS specimen was 24.7% higher related to that of CRA specimen.

The chemical composition of the FCS shows a high percentage of SiO_2 , the presence of which gives to the slag the properties of a hydraulic binder. (that is why blast furnace slag is currently used in the making of cement). Although the concrete specimen with FCS showed a much higher compresive strength than the other specimen the presence of a high percentage of MgO, might effect the long term performance of concrete produced with FCS. So other tests related to its durabillity of concrete with FCS should be inspected.

CONCLUSION

In this study the possibility of protecting the environment in the region of Burrel, Albania from ferrochromium slag industrial wastes, and at the same time make use of it has been investigated. The use of these wastes as coarse aggregate in concrete making and in road construction leads to cleaner environment and better performance construction materials. Based on the results the abrasion resistance of FCS was (24.3% mass loss in the Los Angeles abrasion test) the highest compared to those of the conventional specimens. The results showed that the use of FCS resulted in a significant increase in the compressive strength of the concrete, as the 7 day compresive stength of FCS specimen was 32.8% higher related to the CRA specimen, whereas 28 day compressive strength of FCS specimen was 24.7% higher related to that of CRA specimen. The data acquired from the tests showed that FCS could be conveniently used as coarse aggregate in road base construction and higher compressive strength concretes.

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