

Determination of Concrete Compressive Strength of Aggregate Serpentine Concrete for Radioactive Transport Cask

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Abstract - Compressive strength is an essential parameter considered in making concrete. This research focus determined the compressive strength of aggregate serpentine concrete of different sizes. The obtained local Serpentine rock was crushed into four different granule sizes of 5 mm, 10 mm, 15 mm and 20 mm respectively and casting of the concrete samples, sample weight measurements and concrete sample crushing using a load testing machine for determination of the concrete compressive strength was carried out. The results of the measured density of the fabricated samples showed that the density achieved for the concrete samples with 5 mm, 10 mm, 15 mm, and 20 mm were all above the world average value of 2350 kg/m³ which revealed that the compaction of the fabricated concrete samples was optimum. The results of the corresponding compressive strengths of the concrete samples showed that the concrete with aggregate size of 10 mm met the requirement for adequate strength of an ordinary concrete which is 15 MPa followed by 15 mm aggregate size. This showed that the concrete cask design with 10 mm aggregates size from the point of view of physical strength, will withstand an external stress of magnitude up to 15 million Pascals (15 MPa) which could be attributed to the fact that better aggregate compaction was achieved at a size of 10 mm as demonstrated from the value of the density of the concrete sample. While those concrete samples fabricated with other aggregate sizes will withstand an external stress of magnitude as high as 10 million Pascals (10 MPa) in proportion to their respective compaction in the concrete matrix. Hence, from the entire results of this research work, Serpentine concrete of aggregate sizes 10-15 mm was recommended for the optimum design of a radioactive source transport cask.

Keywords: Compressive, Strength, Concrete, serpentine and Radioactive.

I. INTRODUCTION

Nuclear energy produces far fewer CO₂ emissions over the course of its lifetime than fossil fuel-based energy generation, it has become one of the most widely used and efficient methods of producing power globally. Nuclear energy does, however, result in the production of radioactive material, which eventually degrades into radioactive waste that contains radioactive isotopes with half-lives of between a hundred and a million years. For the nuclear industry to remain viable, materials that efficiently decrease exposure to dangerous indirect ionizing radiation like gamma rays and neutrons are crucial. Therefore, modified heavy glass systems doped with heavy metals and rare earth element oxides are among a few examples of the radiation shielding materials that have been created and reported in literature [1, 2, 3] polymeric composites [4] modified alloys [5], and modified radiation shielding concretes that utilize heavy natural minerals, synthetic aggregates, and/or certain micro and nano additives [6, 7, 8]

Despite this, radiation shielding concrete is still the most used type of shielding material because it is suitable for both small and large rigid shielding components and installations and has excellent strength, durability, malleability, and adaptability [9] Prior to undertaking any actual research, it is common practice to analyze and/or use numerical modeling to evaluate a material's effectiveness to protect radiation [2, 7]. The material's radiation shielding parameters, such as the mass attenuation coefficient (μ), linear attenuation coefficient (μ), half value layer (HVL), tenth value layer (TVL), mean free path (MFP), effective atomic number (Z_{eff}), exposure build-up factors (EBF), fast neutrons macroscopic effective removal cross-section (R), thermal neutron macroscopic absorption cross-section (CR), and compressive strength are first examined to assess their capabilities in attenuation.

The physical qualities of concrete are improved by utilizing marble powder as a partial substitute for cement or sand, according to [10]. According to [11] used marble powder and diatomite as a partial cement substitute. The

findings show that mechanical qualities of concrete may be improved by using either 5% marble powder alone or 5% marble powder combined with 10% diatomite [12]. Additionally, it was discovered that adding up to 10% marble powder improves the mixture's workability while preserving its compressive strength [13]. Recent research revealed that the workability of concrete decreased as marble powder fine aggregate content increased in the mixture, while the concrete's compressive strength increased due to the presence of CaCO_3 and SiO_2 [13]. Moreover, the cement with optimal concrete strength was obtained using 10 % waste marble as a replacement for cement [14, 15] This study examines the compressive strength of serpentine concrete which is proposed to be used as aggregate in making radiation shielding concrete.

II. MATERIALS AND METHOD

2.1 Fabrication of concrete blocks with different aggregate sizes

To achieve this, samples of Serpentine rock was obtained from Jibiya Local Government of Katsina State, Nigeria. The same was transported to a quarry site at Zaria, Kaduna State for grinding into fine aggregates of sizes 5 mm, 10 mm, 15 mm and 20 mm respectively which were accurately obtained with the aid of sieves. 200 kg of sharp river sand was collected at river Kubanni in Zaria and a sieve was also used to obtain sand of sizes ranging between 4-5 mm. 100L of treated water was collected at Zaria Water Treatment Plant located at Congo-Zaria. With the aid of a hand trowel and shovel, a concrete mixture was produced using the standard mixes ratio of 1:2:4 for cement-sand-aggregate and 2:5 for cement-water mixture. Using 20 constructed 15 cm by 25 cm metallic molds, concrete mixed with each aggregate size was loaded into 5 molds of different depths to produce concrete blocks of different thicknesses (9cm, 8cm, 7cm, 6cm and 5cm respectively). Vibrating table was used to ensure uniform distribution of the aggregates in the concrete matrix. Hence a set of 4 concrete blocks (5 in each set with thicknesses numbered 1-5) were fabricated and labelled A, B, C, and D Figure 1.



Figure 1: Fabricated Serpentine Concrete Samples

The compressive strength of the concrete samples was determined at the concrete laboratory at the department of Civil Engineering, Ahmadu Bello University Zaria. The concrete block samples were transported to the concrete laboratory after the radiation dose measurements for density measurements and compressive strength testing using a Load Testing Machine (Pro-Ikon cube press). Figure 2 and 3 presents schematic diagrams of weight and compressive strength measurement set-ups.

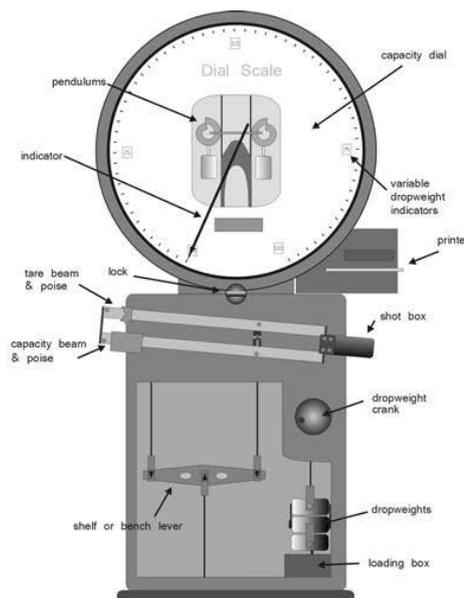


Figure 2: Schematic Diagram of a Typical Weight Balance with a Dial Scale

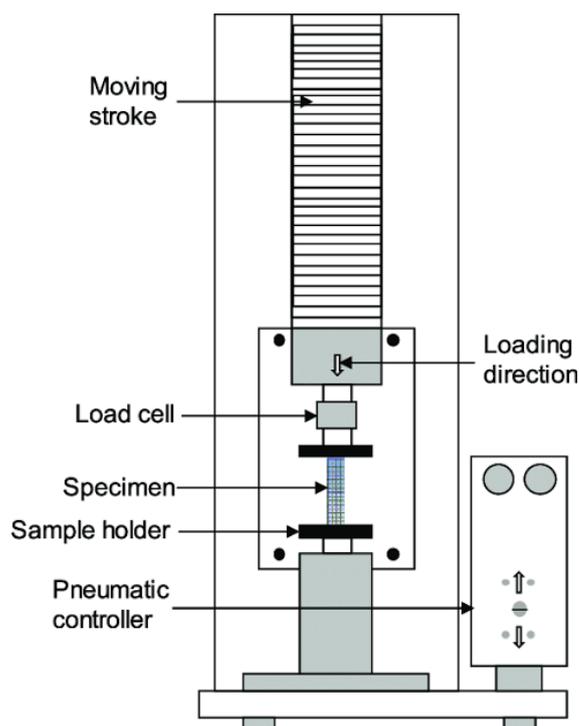


Figure 3: Schematic Diagram of a Load Testing Machine [16]

III. RESULTS AND DISCUSSIONS

3.1 Determination of Concrete Density and Compressive Strength Test

From the dimensions of the concrete samples, the area and volume of each concrete sample was calculated. Using the measured weight of each sample, the corresponding densities were determined and the average density of each concrete sample A, B, C, and D was computed. The results are presented in Table 1. Similarly, from the measurements taken on the Load Testing Machine, and the computed surface area of the concrete samples, the compressive strength of each concrete sample was computed and the average was determined for each concrete sample A, B, C, and D. These results are also presented in Table 1.

Table 1: Concrete Density and Compressive Strength

Sample ID	Average Density (Kg/m ³)	Compressive Strength (MPa)	Ordinary Concrete Strength (MPa)
A	3129.24 ± 540.39	10.45 ± 1.33	15.0
B	3326.19 ± 504.66	15.63 ± 2.65	
C	3152.44 ± 563.32	11.95 ± 2.83	
D	3176.23 ± 806.26	13.17 ± 4.73	

From Table 1, the density of concrete sample B with aggregate size of 10 mm was found to be higher than other samples which also accounted for its higher compressive strength of 15.63 MPa. Generally, the density of all the concrete samples were found to be higher than the world's average density for ordinary concrete which is 2350 Kg/m³[17] which demonstrates a high-water retention capacity of Serpentine aggregates in concrete. The compressive strength of the concrete with aggregate size 10 mm met the requirement for adequate strength of an ordinary concrete which also implies that a transportation cask design with this aggregate will withstand an external stress of magnitude of 15 million Pascals (15 MN/m²). Generally, the concrete cask design with any of the aggregates size from the point of view of physical strength, will withstand an external stress of magnitude up to 10 million Pascals (or 10 MN/m²).

IV. CONCLUSION

The density of the fabricated samples and their corresponding compressive strengths were also determined and the results showed that the density achieved for the concrete samples with 5 mm, 10 mm, 15 mm, and 20 mm were all above the world average value of 2350 kg/m³ which revealed that the compaction of the fabricated concrete samples was optimum. The results of the corresponding compressive strengths of the concrete samples showed that the concrete with aggregate size of 10 mm met the requirement for adequate strength of an ordinary concrete which is 15

MPa. This showed that the concrete cask design with 10 mm aggregates size from the point of view of physical strength, will withstand an external stress of magnitude up to 15 million Pascals while those fabricated with other aggregate sizes will withstand an external stress of magnitude up to 10 million Pascals.

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