

Evaluation of Different Concrete Mixtures Used in Radioactive Material Transportation

The safe transport of radioactive materials is a critical component of nuclear safety, aimed at protecting people and the environment from potential radiation exposure during handling and transit. One of the key safety measures involves the use of concrete as a shielding and containment material. The transport and packaging of radioactive materials, whether from the government or private industry, must adhere to rigorous regulations. These regulations help prevent radiation exposure to the public, transport employees, the surrounding environment and the package must safeguard its contents and provide adequate shielding under typical transportation conditions. In addition, packaging must undergo the specific tests without any release of its contents. These tests including drop test, water spray test and penetration tests, to verify its ability to withstand accidents.

Nuclear and radioactive materials are packed in three different types.

Package Type A: These are standard industrial packages designed for low-activity sources and lower-level radioactive materials

Package Type B: Constructed for high-level waste transport, including spent fuel, integrating dense radiation shielding and reinforced containment to mitigate accident risks.

Package Type C: This is the most robust type, designed to withstand extreme accident scenarios, particularly for transporting high-activity materials by air.

Concrete is widely used in the design of transport containers—known as packages Type B—due to its excellent shielding properties, structural strength, thermal resistance, and cost-effectiveness. These containers are engineered to withstand extreme conditions, including impacts, fire, and water immersion, without releasing radioactive contents. The dense composition of concrete helps attenuate gamma radiation and, when combined with steel liners and lead shielding, ensures robust protection. The CONSTOR registered design was developed as an alternative multipurpose cask concept for transport spent nuclear fuel. This steel cask sandwich concept with heavy concrete as an additional shielding material fulfills the same safety criteria as the CASTOR registered cask design.

This paper aims to investigate the radiation shielding properties, physical and mechanical properties of concrete which using in fabrication of COSTOR for transportation of radioactive materials especially spent nuclear fuel. The study program consists of two main parts, the experimental part which conducted to investigate the effect of different nanomaterials on the radiation, physical and mechanical properties of normal weight concrete and heavy weight concrete containing barite aggregate. The theoretical part using the Monte Carlo transport code MCNP5 and XCOM to simulate the linear attenuation coefficient of the two types of concrete containing nano particles. Five nano materials were used (nano titanium (NT), nano hematite (NH), nano silica (NS), nano metakaolin (NMK) and nano ceramic (NC). Nanomaterials were added with 0, 0.5, 0.75, 1, and 2% as a replacement of cement weight. to experimentally investigate the gamma radiation, physical and mechanical characteristics of concrete. Moreover, the scanning electron microscopy technique (SEM) and X ray diffraction analysis (XRD) were used to prove the improvement in the microstructure of concrete as a result of using nano particles and their hybridization.

The experimental results showed that the single addition of each of nano particles and their combination improved the attenuation coefficient, physical properties, and mechanical properties of normal and heavy weight concrete. The results of the hybrid nano addition showed that the synergistic phenomenon occurred in some cases. Furthermore, the scanning electron microscopy technique (SEM) was used to prove the enhancement in the microstructure of concrete as a result of the addition of NS, NH, NT, NMK, Nc and their combination. In addition, the results of the simulation of the linear attenuation coefficient using the Monte Carlo simulation were in good agreement with the experimental and XCOM program results.

Country or International Organization

Instructions

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