Radiation Physics and Chemistry 117 (2015) 88–92

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

A research on the radiation shielding effects of clay, silica fume and cement samples

Suat Akbulut [a], Arvin Sehhatigdiri [b], Hayrettin Eroglu [c,*], Semet Çelik [d]

[a] Yıldız Technical University, Civil Faculty, Civil Engineering Department, İstanbul, Turkey
[b] Ataturk University, Graduate School of Natural and Applied Sciences, Department of Nanoscience and Nanoengineering, 25240, Erzurum, Turkey
[c] Ataturk University, Faculty of Engineering, Department of Biomedical Engineering, 25240, Erzurum, Turkey
[d] Ataturk University, Faculty of Engineering, Department of Civil Engineering, 25240, Erzurum, Turkey

HIGHLIGHTS

- The strength and radiation shielding properties of clay and some soils were examined.
- All tests were performed on compacted soil in optimum water content.
- Clay–white cement mixtures have the highest unconfined compression strength.
- Clay–white cement mixtures have the highest linear attenuation coefficient.
- Clay–white cement mixture can be used as building materials in radioactivity places.

ARTICLE INFO

Article history:
Received 23 August 2014
Received in revised form
29 July 2015
Accepted 4 August 2015
Available online 5 August 2015

Keywords:
Clay
Silica fume
Cement
Radiation Shielding

ABSTRACT

Nowadays, as the application areas of nuclear technology increases, protection from radiation has become even more important. Especially, the importance of radiation-shielding is important for the environment and employees which are in close proximity. Clays can be used as additives for shielding the radioactive materials. In this study, the shielding properties of micronize clay–white cement, clay–silica fume, gypsum, gypsum–silica fume, cement, white cement, cement–silica fume, white cement–gypsum, white cement–silica fume, red mud–silica fume, silica fume and red mud at different energy levels were examined. Additionally, compaction and unconfined compression tests were carried out on the samples. The results of clays and other samples were compared with each other. As a result, it was found that clays, especially clay–white cement mixture were superior than other samples in radioactive shielding.

1. Introduction

Radiation is defined as the emission and transmission of atomic energy by electromagnetic waves or particles in vacuum. It can also be defined as a type of energy ranging from long radio waves to cosmic rays. The usage areas of radiation, mainly used to be medical and industrial fields, nowadays has significantly widened to cover various environments and fields (Berk, 2002).

Radiation's presence was first perceived with Wilhelm Roentgen's discovery of X-rays and with the proof of the existence of radioactivity in 1902 by the Curie couple, it has begun to be used in many research areas including medical science, agriculture and industry, and it has been used for nearly 100 years at an increasing rate. Although the information regarding its existence is considerably new, the usage area of radiation has increasingly become widespread. In addition to its benefits, radiation has significant hazards to living organisms. X, α, β and γ rays which are known as ionized radiation can become important threats for living organisms if required precautions are not taken. These rays may cause biological, chemical and physical changes in living organisms. All these changes may be temporary or permanent depending on the type, duration and density of exposure to ionized radiation (Öztürk, 2010; Görpe and Cantez, 1992).

In nature, there are no living cells immune to radiation and there hardly exists a radiation-free place. Each person living on earth is exposed to radiation originating from cosmic rays, radioactive sources or artifical sources of daily life. 78% of the public doze is caused by the natural sources, 20.7% by medical irradiators and the rest is caused by occupational irradiators and artificial sources (Berk, 2002). It should be noted that these numbers may

* Corresponding author. Fax: +90 442 231 2766.
E-mail address: heroglu@atauni.edu.tr (H. Eroglu).

http://dx.doi.org/10.1016/j.radphyschem.2015.08.003
0969-806X/

show little variations and are expected to be location-dependent.

There are three main elements of radiation protection. These are necessity, optimization and personal dose limitations. The purpose of radiation protection is to prevent deterministic effects and to keep the probability of harmful effects at an acceptable level by limiting the exposed dose to below certain threshold values. In practice, important protection measures such as duration, distance and shielding can be taken for radiation-protection (Berk, 2002; Murray and Holbert, 2015).

The dose of radiation received is directly proportional to duration of the exposure, and inversely proportional to the square of the distance from the source. Additionally, the most important and effective way of preventing the radiation hazard is shielding. Placing a barrier between the radiation source and the employee provides a reduction in radiation intensity. In this process, radiation attenuation property of the substances is utilized so that the working duration around the source can be extended. Shielding can be in various shapes and thicknesses depending on the radiation type and energy. α rays can be stopped by a paper or body skin, whereas β rays require 2.5 cm thickness and γ rays require large amounts of lead or concrete (Berk, 2002; Kowalsky and Perry, 1987).

Shielding is especially important in places where radiation is used and the vicinity of radioactive area is covered with lead or concrete bricks in order to protect the working environment from the harmful effects of radiation. However, this type of shielding has high costs and is very cumbersome.

In recent years, numerous studies have been made in the building materials, especially by using nanotechnology in cement-based materials. Nano building materials, which have self-cleaning, dirt-repellent, flame-retardant, sound insulating and light control film properties bring a different perspective to conventional building materials (Pacheco-Torgal and Jalali, 2011; Hanus and Harris, 2013; Chen and Poon, 2009). Clay minerals are very tiny crystalline substances evolved primarily from chemical weathering of rock-forming materials (Holtz and Kovacs, 1981). In recent years, the researchers have been interested in surfactants and polymers to modify clays for improving their engineering properties. Some researchers have indicated that the geotechnical properties of organoclays show significant change when compared to natural clay (Akbulut et al., 2010, 2012). In these studies it was obtained that the specific gravities, unconfined compression strengths, cohesions and maximum dry densities of cationic and anionic organoclays were decreased (Akbulut et al., 2010, 2012). Additionally, optimum moisture content and swelling pressure values were decreased in cationic surfactant modified clays. However, optimum moisture content and swelling pressure values of anionic surfactant clays are increased. Indicated that, clays modified with zwitterion, nonionic and anionic surfactants gave the lowest contact angles compared to those for natural clay; however, the clays modified with cationic surfactants gave the highest contact angles. Similarly, the electrokinetic properties (zeta potential, electrical conductivity, pH and cation exchange capacity) of surfactant modified clays were changed when compared with natural clay (Akbulut et al., 2010, 2012).

Many researchers have used various oxides on the nanoscale (such as nano-SiO_2, nano-TiO, nano FeO_2) to improve the chemical and physical properties of the concrete. The use of these small grains helps to improve the shielding properties of concrete (Pacheco-Torgal and Jalali, 2011; Hanus and Harris, 2013; Chen and Poon, 2009).

In this study, the effect of nanoscale clays and clay reinforced mixtures on shielding is investigated. The studies show that clay materials improve the shielding effect and decrease the radiation permeability. Hence, it can be considered as an alternative solution in shielding problems.

2. Materials and method

2.1. Materials

In this study, mechanical features and radioactivity shielding performances of micronize clay, natural red clay, natural yellow clay, gypsum, cement, white cement, silica fume, red mud, and some mixtures of these materials are investigated.

Radioactivity sources at different energy levels including ^{99m}Tc (Technetium-99m), ^{241}Am (Americium-241), ^{109}Cd (Cadmium-109), ^{131}I (Iodine-131) are used for the calculation of radiation permeability of the materials prepared for radiation shielding. The energy levels of these sources are given in Table 1.

2.2. Sample preparation

Red clay, yellow clay, micronize clay, gypsum, cement, white cement, silica fume and red mud samples and some mixtures of these samples were prepared for testing. These mixtures and their ratios are given in Table 2.

Each mixture shown in Table 1. were compacted by using modified proctor test (MPT). As a result of MPT, optimum water content and maximum dry unit weight were obtained. The maximum dry unit weight is obtained when compaction is performed at optimum water content.Unconfined compression tests and measurement of radiation permeability were performed onsamples compacted in the optimum water content.

The samples obtained from compaction were placed into the mold by using shielding mold. The samplesbecame ready for the tests after leaving the mold in the oven for 24 h.

2.3. Compaction test

The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soiltype will become most dense and achieve its maximum dry density. The term Proctor is in honor of R.R. Proctor, who in 1933 showed that the dry density of a soil for a given compactive effort depends on the amount of water the soil contains during soil compaction (Day, 2001). His original test is the most commonly referred to as the standard Proctor compaction test; later on, his test was updated to create the modified Proctor compaction test.

In this study, modified proctor test were implemented on samples according to ASTM D 1557. This test method is a compaction method used to determine the relationship between water content and dry unit weight of soils compacted in 101.6 mm diameter mold with a 44.5 N rammer dropped from a height of 457 mm. As a result of the test, optimum water content and maximum dry unit weight values of the samples were determined.

2.4. Unconfined compression test

Unconfined compression tests were carried out according to ASTM D 2166. Compacted specimens, which were prepared with optimum water content and maximum dry unit weight, were used in this study. Undisturbed samples were collected from compacted soil in proctor mold. Samples having a diameter (D) of 38 mm and a height (H) of 76 mm were prepared for unconfined compressive tests. In the test procedure, for the determination of unconfined compressive strength of soil samples, cylindrical soil sample were first subjected to load in axial direction only and then unconfined compressive strength of soil samples were determined.

2.5. Measurement of radiation permeability

Measurements of radiation permeability were performed on