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# Effect of Gamma Ray Energies and Addition of Nano- SiO2 to Cement on mechanical properties and Mass Attenuation Coefficient.

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***Abstract:*** *In nuclear and radiation facilities, the major construction inputs are steel and concrete, which comprise over 95% of the material inputs and the main purpose of the shields is to protect operating personnel from possible injury by nuclear radiation, and in some cases, to reduce radiation exposure. Gamma-ray absorption coefficient in some shielding materials, such as concrete, is measured experimentally in the present study using point isotropic ɤ-ray sources.It is concluded that the addition of SiO2 nanoparticles improves the mechanical and nuclear properties of concrete. The increase of SiO2 nanoparticles content up to 1.5 % increases the total γ-ray attenuation coefficient μ for all energies. There are deviations between theoretical and experimental values of both linear and mass attenuation coefficient. These results may be useful when these samples are to be used in radiation shielding, application.*

## I. Introduction

Concrete has been used in the construction of nuclear facilities because of two primary properties, its structural strength and its ability to shield radiation. Concrete structures have been known to last for hundreds of years, but they are also known to deteriorate in very short periods of time when exposed todeterious physical and chemical environmental conditions[1].The use of concrete in nuclear facilities for containment and shielding of radiation and radioactive materials has made its performance crucial for the safe operation of the facility. Spent nuclear fuel (SNF) is stored in concrete structures, casks, and vaults for planned storage up to 40 years [2].Nano particles have been attracted increasing attention in recent years and their different typeshas been used in concrete mixtures in order to improve both the mechanical properties andpore structure of the concrete. The effect of these particles, mostly SiO2 nanoparticles, hasbeen studied by many researchers. Tao [3] investigated the water permeability andmicrostructure of concrete containing nano-SiO2 and reported that presence of nano-SiO2 canimprove the resistance to water penetration in concrete specimens. Besides, an ESEM test in their study showed that the microstructure of the concrete containing nano-SiO2 was morecompact and these particles improved the pore structure of the concrete[4]. Several studiesdemonstrated the more pozzolanic activity of nano-SiO2 than that of silica fume and noticedits positive effects on the mechanical properties of hardened cement [5,6]. More researchersassert that the amount of crystallization in hydrated cement increases as a result of an increasein the amount of nanomaterial [7].In the present paper, samples of cement without and with different percentages by weight (0.5%, 1%, 1.5%, 2% and 2.5%) of nano- silcon oxide were prepared, it has been undertaken to evaluate the former samples as γ-ray shields and mechanical properties. Experimental values of mass attenuation coefficients have been compared with theoretically calculated values of these samples using XCOM program [8].

## II. Experiments

### 2.1 Materials and Sample Preparation

The cement sample without Nano- silicon oxide,the cement mixed with different percentages by weight(0.5%, 1%, 1.5%, 2% and 2.5%) of nano- silcon oxide. To study the nuclear attenuation properties and mechanical properties, cubic samples (7 × 7× 7 cm) were prepared. The chemical analyses of Portland cement given in Table 1,in addition there is a chemical analyses of Nano- silicon oxide (Table 2).

### 2.2. Compressive strength test

*The compressive strength test was conducted by crushing three cubical concrete specimens of 150 mm at 28 days in accordance with ASTM (1996-2013b). The average of the three tests at each period was reported.*

**Table 1** Chemical Analysis of Portland Cement.

| Serial Number | Chemical Composition | Weight (%) |
|---|---|---|
| 1 | **SiO2** | **23.69** |
| 2 | **Al2O3** | **5.63** |
| 3 | **Fe2O3** | **3.28** |
| 4 | **CaO** | **63.68** |
| 5 | **MgO** | **1.38** |
| 6 | **SO3** | **0.19** |
| 7 | **K2O** | **1.18** |

**Table. 2** Chemical Composition of Nano- SiO2

| Serial Number | Oxide Composition | Percent (%) |
|---|---|---|
| 1 | **CaO** | **0.5** |
| 2 | **SiO2** | **93.3** |
| 3 | **Al2O3** | **3.2** |
| 4 | **Fe2O3** | **1.7** |
| 5 | **MgO** | **0.3** |
| 6 | **SO3** | **0.1** |
| 7 | **K2O** | **0.1** |
| 8 | **N2O** | **0.1** |

### *2.4.* Measurement of Gamma Ray Intensities:

The attenuation coefficient[μ] of samples under investigation has been determined by the usual attenuation equation:

$I= I_o e^{-\mu x}$ ........................................................................................*1*

Where**I** is the gamma ray intensity after the shield material, $I_o$is the gamma ray intensity before the shield material,μ is the attenuation coefficient factor and x is the shield material thickness[9]

Gamma ray intensities behind concrete samples with different percentages of nano-SiO2 have been measured. Measurements have been carried out using a collimated beam of the point isotropic ɤ-ray sources **137Cs**, with one line of energy 0.662 MeV, **60Co** with two lines E1=1.17 MeV and E2=1.33 MeVand**22Na** with two lines, E1=0.511MeV and E2=1.274 MeV,.

## III. Results and discussion

Fig. 1 shows the relation between the amount of nano-SiO2 added to cement and the compressive strengths values , from the figure we can noted that the compressive strengths increases with increasing SiO2 content from 0.5 to 1.5 wt. % , the reason of this increasing that, When a small amount of the nanoparticles is uniformly dispersed in the cement paste, the nanoparticles act as a nucleus to tightly bind with cement hydrate and further promote cement hydration due to their high activity, which is favorable for the strength of cement. Besides, the nanoparticles among the hydrate products will prevent crystals from growing which are not favorable for the strength of cement. The nanoparticles fill the cement pores, thus increasing its strength. Nano-SiO2 can contribute to the hydration process to generate more C-S-H through reaction withCa(OH)2 [10]. Also from the figure.1, the increasing of the amount of Nano-SiO2 more 1.5%, the compressive strength decreases, this behavior is attributed to agglomeration of SiO2 particles which exert more voids in concrete and decreases of $C_3S$ content[10].

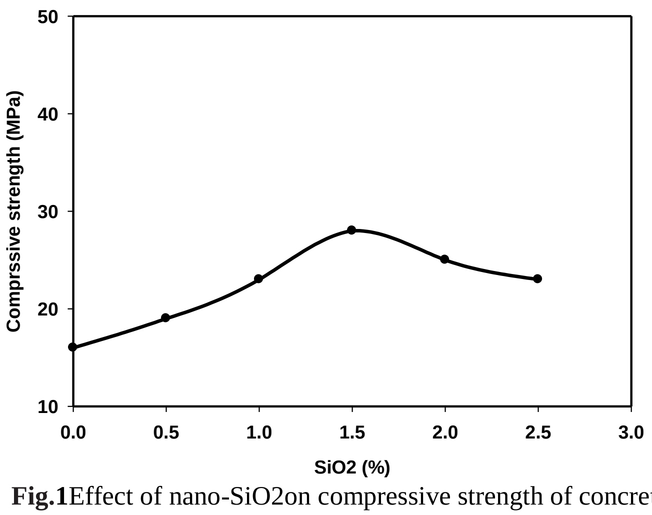


**Fig.1**Effect of nano-SiO2on compressive strength of concrete

Fig. 2 shows the relation between the density and nano- silcon oxide content percentage by weight. The results show that the density increases with increasing the nano- silcon oxide up to 1.5 %, because the nanoparticles fill the cement pores, thus increasing the density of concrete, but for 2 and 2.5 % samples the density of concrete decreases. When nano- silcon oxide content increases by more than 1.5 %, the inference of nano- silcon oxide with each other increases so that the internal voids in the mixture of concrete increases leading to a decrease in the total density [11].

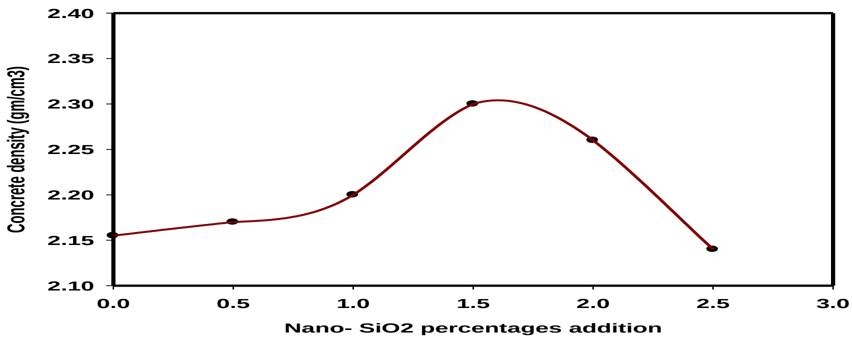


Fig. 2 Effect of nano- SiO2 percentages addition by weight to cement on densituy.

The linear attenuation coefficient is the simplest absorption coefficient to measureexperimentally, but it is not usually tabulated because of its dependence on the density of the absorbing material. Gamma rays interact primarily with atomic electrons; therefore, the attenuation coefficient must be proportional to the electron density P, which is proportional to the bulk density of the absorbing material. However, for a given material the ratio of the electron density to the bulk density is a constant, Z/A, independent of bulk density.
The ratio Z/A is nearly constant for all except the heaviest elements and hydrogen[12].

**P= Zp/A ………………………………………………2**

Where P = electron density p = mass density
A = atomic mass. Z = atomic number
Fig. 3 shows the relation between the nano- silcon oxide and total linear attenuation coefficient μ at different γ-ray energies in MeV. Fig 3. Show the total linear attenuation coefficient increases with increasing the nano-silcon oxide content up to 1.5 % by weight where the concrete density increased, but at 2.5 % by weight the total γ-ray linear attenuation coefficient decreased due to decreasing density. It is also noted from the figure that the total γ-ray linear attenuation coefficients decreases with increasing γ-ray energies.[11]The ratio of the linear attenuation coefficient to the density (μι/ρ) is called the massattenuation coefficient **μ** and has the dimensions of area per unit mass (cm2/g). Theunits of this coefficient hint that one may think of it as the effective cross-sectionalarea of electrons per unit mass of absorber. The mass attenuation coefficient can bewritten in terms of a reaction cross section, σ (cm2):
**μ= No σ / A…………………………………………....3**

Where No is Avogadro's number (6.02 x 1023) and A is the atomic weight of theabsorber. The cross section is the probability of a gamma ray interacting with a singleatom[12]. Fig. 4 shows the variation of γ-ray mass attenuation(μ/ρ) with the γ-ray energies in Mev., for different samples of cement without and with nano-silcon oxide percentages by weight. It is shown that the mass attenuation coefficient (μ/ρ) decrease increasing γ-ray energies in Mev., the higher values of mass attenuation coefficient (μ/ρ) were found at cement sample with 1.5 % nano- silcon oxide, while the lowest values were found for cement sample without nano- silcon oxide, i.e., the mass attenuation coefficient (μ/ρ) increase with increasing the nano- silcon oxide percetagesup to 1.5 % .

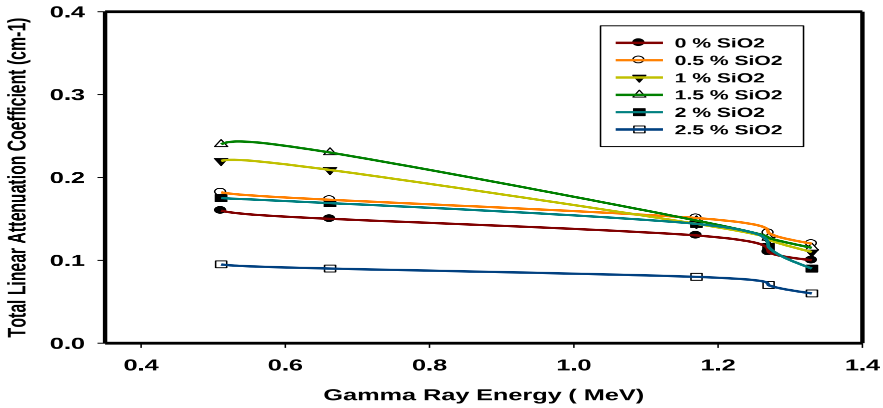


**Fig. 3 Ëffect of gamma ray energy on concretetotal linear attenuation coefficiente at different nano-SiO2 content .**

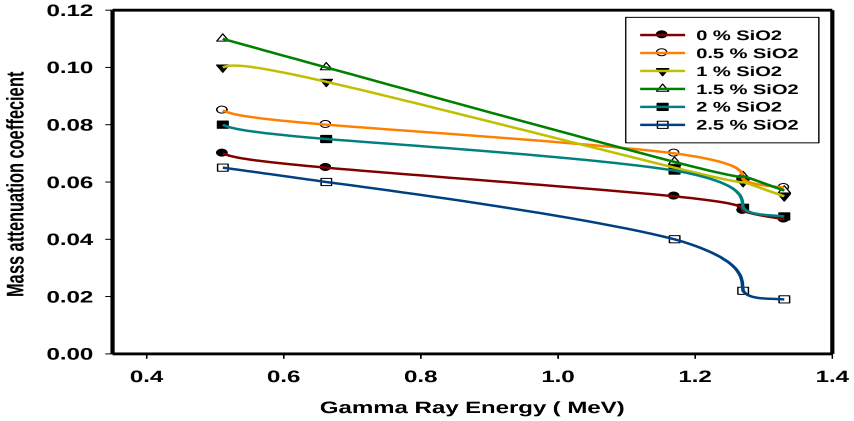


**Fig. 4 Effect of nano- SiO2 Percentages by weight addition to cement on mass attenuation coeffecient at different gamma ray energies in Mev**

Figs. 5 and 6 represent the effect of cement samples without and with nano- silcon oxide at different γ-ray energies in Mev. (0.511, 0.662, 1.17, 1.275 and 1.33 Mev), where the linear attenuation coefficient and mass attenuation coefficient , respectively, increase with increasing the nano- silcon oxide percentages . The highest values of linear attenuation coefficient and mass attenuation coefficients ($\mu/\rho$) found at the lowest energy 0.511 Mev but the lowest values were found at the highest energy 1.33 Mev.A gamma ray may interact with a bound atomic, electron in such a way that itloses all of its energy and ceases to exist as a gamma ray .Some of the gamma-ray energy is used to overcome the electron binding energy, and most of the remainder is transferred to the freed electron as kinetic energy. A very small amount of recoil energy remains with the atom to conserve momentum, this is called photoelectric absorption. Photoelectric absorption is important for gamma-ray detection because the gamma ray gives up all its energy, and the resulting pulse falls in the full-energy peak. The probability of photoelectric absorption depends on the gamma-ray energy, the electron binding energy, and the atomic number of the atom. In most detectors, the photoelectron is stopped quickly in the active volume of the detector, which emits a small output pulse whose amplitude is proportional to the energy deposited by the photoelectron.[13]

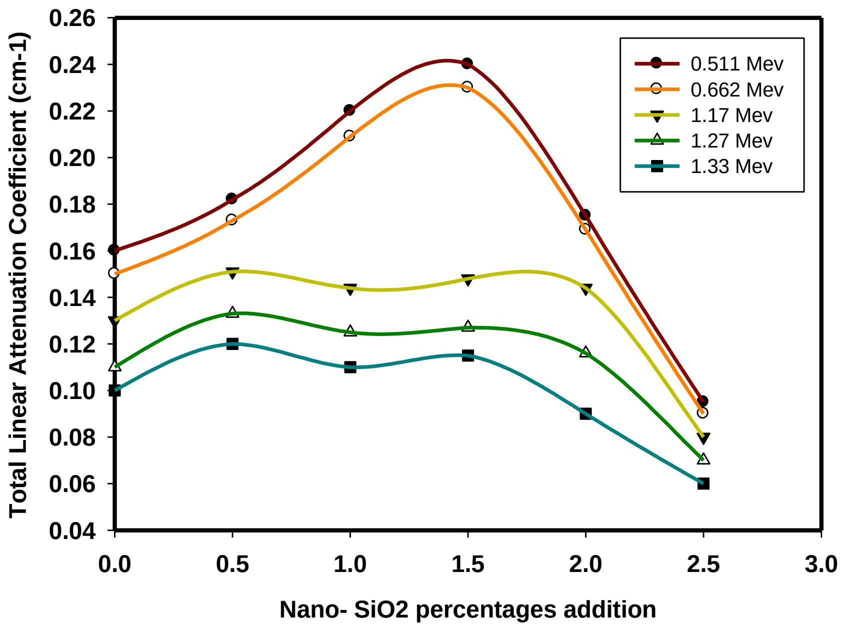


**Fig. 5 Effect of nano- SiO2 Percentages by weight addition to cement on total linear attenuation coeffecient at different gamma ray energies in Mev**

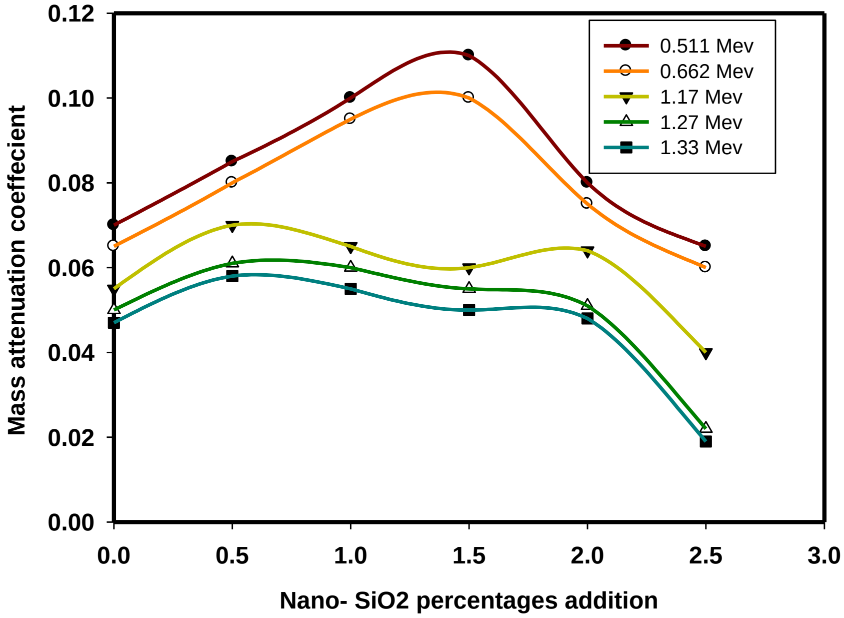


**Fig. 6 Effect of nano- SiO2 Percentages by weight addition to cement on mass attenuation coeffecient at different gamma ray energies in Mev**

Fig. 7 show the dependence of mass attenuation coefficient (μ/ρ) theoretically using XCOM program, the results indicate that all samples of nano- silcon oxide have the same values of mass attenuation coefficient at different gamma ray energy , the results show that increase in gamma ray energy leads to a decrease in mass attenuation coefficient (μ/ρ).Fig. 8 displays the dependence of mass attenuation coefficient (μ/ρ) theoretically using XCOM program and experimentally on the nano- silcon oxide by weight addition to cement(2%), at γ-ray energies 0.511, 0.662,1.17,1.27 Mev and 1.33 Mev. It was found that there are deviation between theoretical values of mass attenuation coefficient (μ/ρ) and experimental values of mass attenuation coefficient where the theoretical values higher than experimental values. This is due to the presence of air voids in cement samples without and with percentages ofnano- silcon oxide by weight [14].

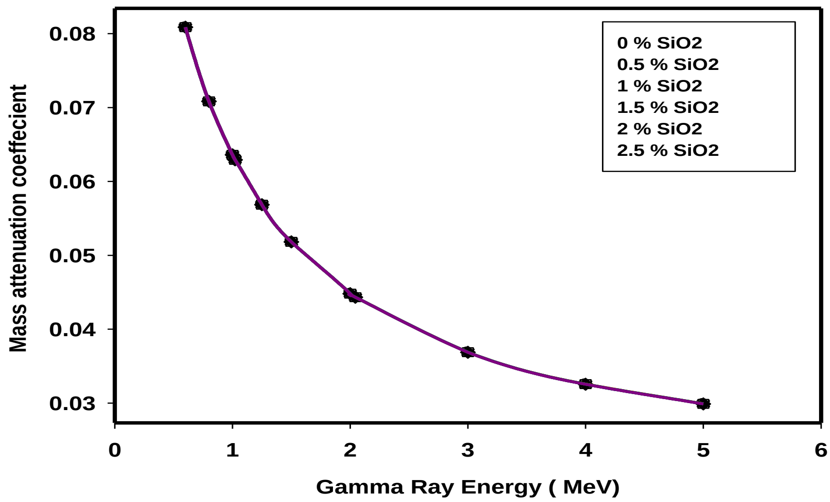


**Fig. 7 Effect of gamma ray energy( X-COM Program) on concrete mass attenuation coefficiente at different nano-SiO2 content .**

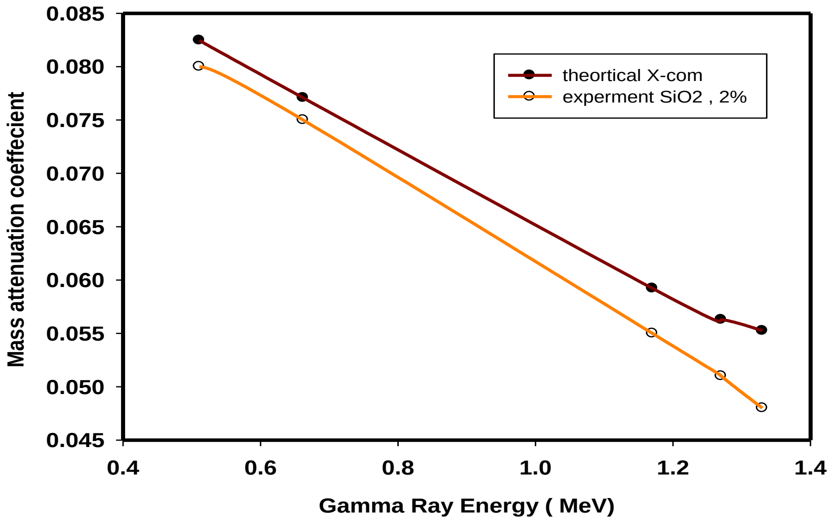


**Fig.8 Effect of gamma ray energy( X-COM Program theortical and experment result) on concrete mass attenuation coefficiente at 2% nano-SiO2 content .**

## IV. Conclusion

Nano- silicon oxide in the concrete mixture improves the pore structure of the concrete. This is mainly because of performance of nano-SiO2as nano fillers and not the formation of more hydrated products. It is concluded that the addition of SiO2 nanoparticles improves the mechanical and nuclear properties of concrete. The increase of SiO2 nanoparticles content up to 1.5 % increases the total γ-ray attenuation coefficient μfor all energies. Thereare deviations between theoretical and experimental values of both linear and mass attenuation coefficient. These results may be useful when these samples are to be used in radiation shielding application.

## Reference

[1] Ye Q. Research on the comparison of pozzolanic activity between Nano-Sio2 and silica fume. Concrete Journal, No. 1,3(2001) 19-22.

[2] Chen RS, Ye Q. Research on the comparison of properties of hardend cement paste between Nano-Sio2 and silica fume added concrete, Concrete Journal, No. 1, 1(2002) 7-10.

[3] Tao J. Preliminary study on the water permeability and microstructure of concrete incorporating Nano-Sio2. Cement and Concrete Research, No. 10,35(2012) 1943-7.

[4] I. I. Bashter, et al., "A comparative study of the attenuation of reactor thermal neutrons in different types of concrete", Ann. Nucl. Energy, vol. 23, no.14 (1996), pp. 1189– 1195.

[5] I. I. Bashter, "Effect of silica fume addition to concrete mixes on Radiation Attenuation Properties", Arab Journal of Nuclear Science and Applications, vol. 34, (2001), pp. 179 -189.

[6] J. Sommers, “Gamma Radiation Damage of Structural Concrete Immersed in Water,” Health Physics,Vol. 16, pp. 503508.

[7] A. Saetta, R. Vitaliani, “Experimental Investigation and Numerical Modeling of Carbonation Process in Reinforced Concrete Structures. Part 1 Theoretical Formulation,” Cement and Concrete Research,Vol. 34, 2004, pp. 571579.

[8] S.P. Shirmardi, Comparison of photon attenuation coefficients of various barite concrete and lead by MCNP code, XCOM and experimentaldata, Annals of Nuclear Energy 55 (2013) 288-291.

[9] C.M. Lee, Cracking effect on gamma ray shielding performance in concrete, Nuclear Engineering 49 (2007) 303-312.

[10] Gopinath, S., Mouli, P. C., Murthy, A. R., Iyer, N. R. and Maheswaran, S., Effect of nano silica on mechanical properties and durability of normal strength concrete. *Arch. Civ. Eng.*, 2012, **4**, 433–444.

[11] A.A. El-Ghany and etc, Effect of Gamma Ray Energies and Addition of Iron Slag by weight to Portland Cements on Mass Attenuation Coefficient , Journal of Materials Science and Engineering A 3 (12) (2013) 838-842

[12] Y. Ichikawa, G. England, “Prediction of Moisture Migration and Pore Pressure Build-Up in Concrete at High Temperatures,” Nuclear Engineering and DesignVol. 228, No. 1-3, March 2004, pp. 245259.

[13] YU-Cheng Kam, et al., "Strength and fracture toughness of heavy concrete with various iron aggregate inclusions", Nuclear Engineering and Design, 228 (2004), pp. 119-127.

[14] Shekari, A. H. and Razzaghi, M. S., Influence of nano particles on durability and mechanical properties of high performance concrete. *Procedia Eng.*, 2011, **14**, pp. 3036–3041.