Asian J. Adv. Basic Sci.: **2015, *4(1)*,** 68-72
ISSN (Print): 2454 – 7492
ISSN (Online): 2347 – 4114
www.ajabs.org

An Intensive Study of Gamma Ray Interactions with Flyash Concretes

Kanwaldeep Singh[1*] and Gurmel Singh[1]

[1] *Department of Physics, Punjabi University Patiala 147002 INDIA*
[*] *Correspondance: E-mail: kanwal345@gmail.com*

(Received 08 Nov, 2015; Accepted 17 Nov, 2015; Published 19 Nov, 2015)

ABSTRACT: Six concrete mixtures were casted with 0%, 20%, 30%, 40%, 50% and 60% of flyash replacing the cement content and having constant water to cement ratio. The different radiation parameters were computed theoretically in the energy region of 10 keV to 100 GeV. The mechanical properties show improvement with specimen age and results of radiation parameters show no significant effect of flyash substitution on mass attenuation coefficient while there is some variation in results of some parameters.

Keywords: Concrete; Flyash; Radiation attenuation and Interaction parameters.

INTRODUCTION: With the increasing applications of radioactive isotopes in several fields of science and technology, there arises the need of using them with extreme care, only after having proper shielding. Efficiency and cost of the material are the two factors that are primarily taken care of, for selecting any material for field applications. Concrete is the most widely used material for shielding gamma radiations satisfying the guidelines. It is used in abundance, particularly due to its good radiation shielding and mechanical properties (Mehta, 2006). To make cost effective concrete, research has been carried out to use minimum amount of cement and aggregates and utilise by-products in as much quantity as possible. Ground blast furnace slag, silica fume, foundry sand, cement kiln dust and flyash are the major materials that have been tested as an alternative of cement. Among the various admixtures, flyash is most suitable due to its pozzolanic nature. Flyash not only plays the role of filler but also has the properties of a binder. It is particularly suitable for mass concrete applications where the cement requirement is large.

The properties of fresh and hardened concrete have been studied in detail by various workers. Different workers (Kovler and Roussel, 2011; Almusallam, 2001; García et al., 2008; Lydon, 1987) addressed a number of practical issues including workability, slump loss, setting time, bleeding, and segregation among the various properties of fresh concrete. Also several workers (Kaszynska, 2002; Li and Yao, 2001; Gardner et al., 2005; Zhutovsky and Kovler, 2012; Ortiz et al., 2005; Bocca and Antonaci, 2005; Sahmaran et al., 2009) studied the various hardened concrete properties; primarily the compressive strength and other mechanical and physical properties of hardened concrete, such as tensile strength, elastic properties, shrinkage, creep, cracking resistance, electrical, thermal, transport and other properties were studied. Also the effect of addition of flyash in preparing concrete on the quality, workability and durability was studied. Durability of concrete having certain amount of flyash in place of cement was superior to concrete without flyash (Bouzoubaa et al., 2001; Boga and Topcu, 2012; Malhotra, 1990), the effect of flyash incorporation on the water demand was reported (Jiang and Malhotra, 2000; Poon et al., 2000), the compressive strength of flyash concrete showed continuous improvement with their age (Bouzoubaa and Lachemi, 2001; Siddique, 2004; Atis, C.D., 2005) and the early shrinkage behaviour of flyash concrete were studied (Kayali et al., 1999; Gesoglu et al., 2004). Their study results clearly states that the use of flyash in concrete is suitable, but with proper care of the requirements of working conditions.

The interaction of gamma radiation with matter has been studied in the past by several workers in concretes with the help of different interaction parameters such as mass attenuation coefficient (Bashter, 1997; Singh et al., 2004; Akkurt et al., 2004; Kharita et al., 2010; Damla et al., 2010), effective atomic number (Bhandal and Singh, 1993; Yilmaz et al., 2011; Kumar and Reddy, 1997), electron density (Manohara et al., 2008), buildup factor (Singh et al., 2010; Brar et al., 1994; Singh et al., 2008; Chilton, 1965), etc. Flyash was studied as a radiation shielding material for gamma rays and Singh et al. (2003) reported that it if compacted to high degree, it can be used for shielding.

In this study, concrete specimens were casted with flyash substituting different percentages of cement. The radiation interaction parameters namely, linear and mass attenuation coefficient, effective atomic number and electron density were calculated for the prepared specimens.

MATERIAL AND METHODS:

Materials: Ordinary Portland cement (43 grade) was used. Flyash used in the study was obtained from thermal power plant, Bathinda. Flyash used was of Class F type. Fine aggregate (natural sand) used in this study was having 4.75 mm maximum size. Coarse aggregate (gravel) used in this study was of 12.5 mm nominal size. Potable water was used as mixing water for preparation of specimens.

Methods: Six concrete specimens were prepared. One mixture was made without using flyash and other mixtures were made with flyash as a replacement for cement by weight. Cement was replaced with 20, 30, 40, 50 and 60% of flyash by weight. The mixture proportion (kg/m^3) of prepared concrete specimens is shown in Table 1. The concrete samples were prepared with same water to cementitious ratio. W/c = 0.40 was taken for preparing samples. This ratio was taken as constant; so as to only investigate the effect of flyash addition to the ordinary concrete. The prepared samples were named as OC1, OC2, OC3, OC4, OC5 and OC6, in which 0%, 20%, 30%, 40%, 50% and 60% of flyash have replaced the cement content.

The test specimens were prepared according to specifications of IS: 516-1959. Concrete cubes of 50 mm in size were casted for testing radiation interaction parameters. They were kept in casting room for 24 hours at a temperature about 25°C and were demolded after 24 hours.

Table 1: Mixture proportions (kg/m^3) of concrete specimens.

Sample	Cement	Flyash %	Flyash Weight	Water	w/(c+fa)	Fine aggregate	Coarse aggregate
OC1	456	0	0	182	0.40	615	1026
OC2	351	20	87	175	0.40	591	985
OC3	300	30	128	171	0.40	577	963
OC4	254	40	168	168	0.40	569	949
OC5	208	50	208	166	0.40	561	936
OC6	165	60	247	164	0.40	556	927

The mass attenuation coefficients of all six concretes have been calculated with the help of winXCOM, a computer program initially developed by Berger and Hubbell and later modified to window version by Gerward et al. (2004). From the results obtained, other interactions parameters were evaluated. Also the narrow beam γ-ray transmission geometry was used for the attenuation measurements of prepared concrete specimens using ^{137}Cs at 0.662 MeV as described by Singh et al. (2015).

Theory: When a beam of monochromatic radiations passes through matter, the intensity of the beam is reduced to some extent. The decrease in intensity of radiation from I_o to I is given by Lambert-Beer law:

$$I = I_o e^{-(\mu/\rho)\rho x},$$

Where; ρ is density of target sample, x is the thickness of target sample and μ/ρ (cm^2/gm) is mass attenuation coefficient, denoted by μ_ρ. For a compound or mixture, it is given by

$$\mu/\rho = \sum w_i (\mu/\rho)_i$$

Where; w_i and $(\mu/\rho)_i$ are the weight fraction and mass attenuation coefficient, respectively, of the constituent element i. The linear attenuation coefficient, μ (cm^{-1}) was calculated by multiplying μ_ρ by the density of samples.

The effective atomic number, Z_{eff} is a parameter that characterizes the atomic number of composite material for different gamma ray interaction processes at different energies. The prepared concrete specimens cannot be marked by single atomic number. It can be obtained by the relation

$$Z_{eff} = \frac{\sigma_{t,a}}{\sigma_{t,el}}$$

Where; $\sigma_{t,a}$ is average atomic cross-section and $\sigma_{t,el}$ is average electronic cross-section.

Electron density, N_e is defined as the number of electrons per unit mass. It can be calculated with the help of expression

$$N_e = \frac{\frac{\mu}{\rho}}{\sigma_e} = \left(\frac{Z_{eff}}{M}\right) N_A \sum_i n_i,$$

Where; $M = \sum_i n_i A_i \rightarrow$ Molar mass,

$N_A \rightarrow$ Avogadro's constant,

$n_i \rightarrow$ Number of formula units of ith element.

RESULTS AND DISCUSSION:

Attenuation coefficient: The mass attenuation coefficients of concrete samples were calculated by XCOM. Figure 1 shows the variation of total mass attenuation coefficient, μ_ρ with energy for the chosen concretes in the wide energy range of 10 keV to 100 GeV. Also the experimental data of mass attenuation coefficient for six concrete specimens at 0.662 MeV has been marked in the figure. It is observed that μ_ρ decreases sharply in the low energy region, then it becomes almost constant in the medium energy region and it increases in the high energy region. Figure 1 shows that total mass attenuation coefficients decreased drastically with increasing photon energy in energy region 1 keV to 100 keV, it decreased slightly with increasing photon energy in energy region of 100 keV to 10 MeV and it increased slowly and further becomes constant with increasing photon energy in energy region of 10 MeV to 100 GeV. This behaviour of μ_ρ confirms the Z-dependence of different interaction processes in different energy regions and hence the variation of corresponding mass attenuation coefficients with energy. The results of mass attenuation coefficients confirmed that there is no effect on these radiation parameters with change in flyash content from 0% to 60% in place of cement.

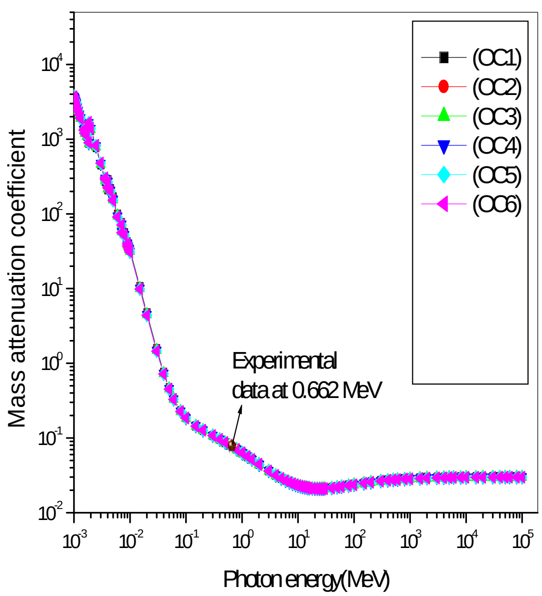

Figure 1: Mass attenuation coefficient with photon energy.

Effective atomic number: Figure 2 shows that Z_{eff} has large magnitude at lower set of energies, then it decreases with increase in photon energy and obtained minimum value for the prepared flyash concrete specimens. Above this value of energy corresponding to minima, Z_{eff} remains almost constant. Figure 2 also clearly shows that the behavior and magnitude of effective atomic number of different flyash concrete specimens having flyash content from 0% to 60% is nearly same.

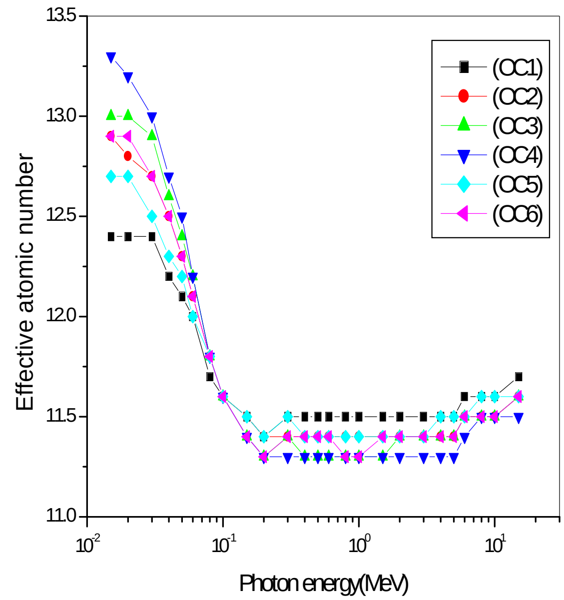

Figure 2: Effective atomic number with photon energy.

The sharp decrease in Z_{eff} in the low energy region is due to the dominance of photoelectric absorption process over other interaction processes. The Z-dependence of interaction cross-section is of the order of 4-5, which is responsible for descent of this interaction parameter. Z_{eff} remains almost constant in the energy region of 0.15 MeV to 6.0 MeV. This constancy can be attributed to the fact that in this energy region the dominant process being the incoherent scattering process, for which interaction cross-section depends linearly on Z. For energies greater than 6.0 MeV, an increase in the Z_{eff} value is noted down and it is due to the dominance of the pair production process.

Electron density: The variation of N_e with energy is given in Figure 3. The electron density, N_e is nearly constant with for six concrete specimens in the range of 2.9 - 3.5 × 10^{23} electrons per unit gram of material. Figure 3 shows that some variation in N_e is there in the low energy region and after that N_e is almost constant. Also a decrease in N_e has been observed in the low energy region. Also N_e remains constant in the energy region of 0.1 MeV to 4.0 MeV. For photon energy greater than 4.0 MeV, an increase in it has been noted.

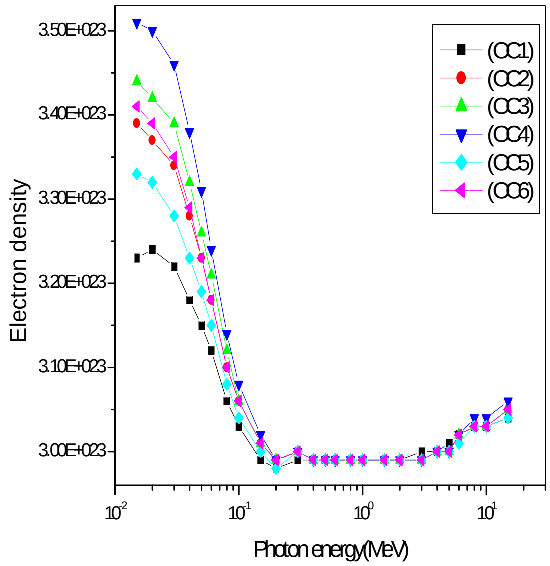

Figure 3: Electron density with photon energy.

All the results of interaction parameters are shown in Table 2.

Table 2: Results of radiation parameters.

Sample	μ_ρ (cm^2/g)	ρ (g/cc)	μ (cm^{-1})	$Z_{eff.}$	N_e (no./g)$\times 10^{23}$
OC1	0.0769	2.28	0.175	11.44	2.986
OC2	0.0769	2.19	0.168	11.36	2.986
OC3	0.0769	2.14	0.164	11.30	2.977
OC4	0.0769	2.11	0.162	11.23	2.977
OC5	0.0769	2.08	0.159	11.37	2.976
OC6	0.0769	2.06	0.158	11.30	2.977

CONCLUSION: From the undertaken study, it is clear that there is no change in mass attenuation coefficient of all the test specimens with flyash content. Electron density of concrete specimens is constant. There is only slight variation in results of linear attenuation coefficient and effective atomic number. The change in linear attenuation coefficient with flyash replacement confirmed its dependence on the density of mixtures.

REFERENCES:

1. Mehta, P. K., Monteiro, P. J. M., (2006) Concrete: Microstructure, Properties and Materials, third ed. The Mcgraw Hill Companies.
2. Kovler, K., Roussel, N., (2011) Properties of fresh and hardened concrete, *Cem. Concr. Res.*, 41, 775-792.
3. Almusallam, A. A. (2001) Effect of environmental conditions on the properties of fresh and hardened concrete, *Cem. Concr. Compos.*, 23, 353-361.
4. Garcia, A., Castro-Fresno, D., Polanco, J. A., (2008) Evolution of penetration resistance in fresh concrete, *Cem. Concr. Res.*, 38, 649-659.
5. Lydon, F. D., (1987) Observations on the density and quality of concrete, *Int. J. Cem. Compos. Lightweight Concr.*, 9, 205-216.
6. Kaszynska, M., (2002) Early age properties of high-strength/high-performance concrete, *Cem. Concr. Compos.*, 24, 253-261.
7. Li, J., Yao, Y., (2001) A study on creep and drying shrinkage of high performance concrete, *Cem. Concr. Res.*, 31, 1203-1206.
8. Gardner, D. R., Lark, R. J., Barr, B., (2005) Effect of conditioning temperature on the strength and permeability of normal- and high-strength concrete, *Cem. Concr. Res.*, 35, 1400-1406.
9. Zhutovsky, S., Kovler, K., (2012) Effect of internal curing on durability-related properties of high performance concrete, *Cem. Concr. Res.*, 42, 20-26.
10. Ortiz, J., Aguado, A., Agullo, L., Garcia, T., (2005) Influence of environmental temperatures on the concrete compressive strength: Simulation of hot and cold weather conditions, *Cem. Concr. Res.*, 35, 1970-1979.
11. Bocca, P. G., Antonaci, P., (2005) Experimental study for the evaluation of creep in concrete through thermal measurements, *Cem. Concr. Res.*, 35, 1776-1783.
12. Sahmaran, M., Yaman, I. O., Tokyay, M., (2009) Transport and mechanical properties of self consolidating concrete with high volume fly ash, *Cem. Concr. Compos.*, 31, 99-106.
13. Bouzoubaa, N., Zhang, M. H., Malhotra, V. M., (2001) Mechanical properties and durability of concrete made with high-volume flyash blended cements using a coarse flyash, *Cem. Concr. Res.*, 31, 1393-1402.
14. Boga, A. R., Topcu, I. B., (2012) Influence of fly ash on corrosion resistance and chloride ion permeability of concrete, *Constr. Build. Mater.*, 31, 258-264.
15. Malhotra, V. M., (1990) Durability of concrete incorporating high-volume of low-calcium

(ASTM Class F) fly ash, *Cem. Concr. Compos.*, 12, 271-277.

16. Jiang, L. H., Malhotra, V. M., (2000) Reduction in water demand of non air-entrained concrete incorporating large volumes of flyash, *Cem. Concr. Res.*, 30, 1785-1789.

17. Poon, C. S., Lam, L., Wong, Y. L., (2000) A study on high strength concrete prepared with large volumes of low calcium flyash, *Cem. Concr. Res.*, 30, 447-455.

18. Bouzoubaa, N., Lachemi, M., (2001) Self-compacting concrete incorporating high volumes of flyash Preliminary results, *Cem. Concr. Res.*, 31, 413-420.

19. Siddique, R., (2004) Performance characteristics of high-volume class F flyash concrete, *Cem. Concr. Res.*, 34, 487-493.

20. Atis, C. D., (2005) Strength properties of high-volume flyash roller compacted and workable concrete and influence of curing condition, *Cem. Concr. Res.*, 35, 1112-1121.

21. Kayali, O., Haque, M. N., Zhu, B., (1999) Drying shrinkage of fibre-reinforced lightweight aggregate concrete containing fly ash, *Cem. Concr. Res.*, 29, 1835-1840.

22. Gesoglu, M., Ozturan, T., Guneyisi, E., (2004) Shrinkage cracking of lightweight concrete made with cold-bonded fly ash aggregates, *Cem. Concr. Res.*, 34, 1121-1130.

23. Bashter, I. I., (1997) Calculation of radiation attenuation coefficients for shielding concretes, *Ann. Nucl. Energy,* 24, 1389-1401.

24. Singh, C., Singh, T., Kumar, A., Mudahar, G. S., (2004) Energy and chemical composition dependence of mass attenuation coefficients of building materials, *Ann. Nucl. Energy,* 31, 1199-1205.

25. Akkurt, I., Kilincarslan, S., Basyigit, C., (2004) The photon attenuation coefficients of barite, marble and limra, *Ann. Nucl. Energy,* 31, 577-582.

26. Kharita, M. H., Yousef, S., AlNassar, M., (2010) The effect of the initial water to cement ratio on shielding properties of ordinary concrete, *Prog. Nucl. Energy,* 52, 491-493.

27. Damla, N., Cevik, U., Kobya, A. I., Celik, A., Celik, N., Grieken, R. V., (2010) Radiation dose estimation and mass attenuation coefficients of cement samples used in Turkey, *J. Hazard. Mater.,* 176, 644-649.

28. Bhandal, G. S., Singh, K., (1993) Photon attenuation coefficient and effective atomic number study of cements, *Appl. Radiat. Isotop.,* 44, 1231-1243.

29. Yilmaz, E., Baltas, H., Kiris, E., Ustabas, I., Cevik, U., El-Khayatt, A. M., (2011) Gamma ray and neutron shielding properties of some concrete materials, *Ann. Nucl. Energy,* 38, 2204-2212.

30. Kumar, T. K., Reddy, K. V., (1997) Effective atomic numbers for materials of dosimetric interest, *Radiat. Phys. Chem.*, 50, 545-553.

31. Manohara, S. R., Hanagodimath, S. M., Thind, K. S., Gerward L., (2008) On the effective atomic number and electron density: A comprehensive set of formulas for all types of materials and energies above 1 keV. Nucl, *Instru. Meth. Phys. Res.*, (B) 266, 3906-3912.

32. Singh, S., Ghuman, S. S., Singh, C., Thind, K. S., Mudahar, G. S., (2010) Buildup of gamma photons in flyash concrete: A study, *Ann. Nucl. Energy,* 37, 681-684.

33. Brar, G. S., Singh, K., Singh, M., Mudahar, G. S., (1994) Energy absorption buildup factor studies in water, air and concrete up to 100 mfp using G-P fitting formula, *Radiat. Phys. Chem,*. 43, 623-627.

34. Singh, S., Kumar, A., Singh, C., Thind, K. S., Mudahar, G. S., (2008) Effect of finite sample dimensions and total scatter acceptance angle on the gamma ray buildup factor, *Ann. Nucl. Energy,* 35, 2414-2416.

35. Chilton, A. B., (1967) Buildup factors for point isotropic gamma ray sources in infinite medium of ordinary concrete, *Nucl. Engin. Des.*, 6, 205-212.

36. Singh, K., Singh, C., Sidhu, G. S., Singh, J., Singh, P. S., Mudahar, G. S., (2003) Flyash: A radiation shielding material, *Ind. J. Phys.,* 77A, 41-45.

37. IS: 8112-1989, Specifications for 43-Grade Portland cement, Bureau of Indian Standards, New Delhi, India.

38. IS: 383-1970, Specifications for coarse and fine aggregates from natural sources for concrete, Bureau of Indian Standards, New Delhi, India.

39. IS: 516-1959, Indian standard code of practice-methods of test for strength of concrete, Bureau of Indian Standards, New Delhi, India.

40. Gerward, L., Guilbert, N., Jensen, K. B., Levring, H., (2004) WinXCom- a program for calculating X-ray attenuation coefficients. Radiat, *Phys. Chem.*, 71, 653-654.

41. Singh, K., Singh, S., Dhaliwal, A. S., Singh, G., (2015) Gamma radiation shielding analysis of lead-flyash concretes, *Appl. Radiat. Isotopes*, 95, 174-179.