Asian Journal of Multidisciplinary Studies

ISSN: 2321-8819 (Online)
2348-7186 (Print)
Impact Factor: 0.92
Volume 3, Issue 11, Nov. 2015

Computation of buildup factor for studying piling up of photons in flyash concretes

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Abstract: Six concrete mixtures were prepared with 0%, 20%, 30%, 40%, 50% and 60% of flyash replacing the cement content and having constant water to cement ratio. In the lower energy region and with low Z interaction medium, photons pile up resulting in peak around 100 keV; predominantly less than this value. Buildup factor can describe it effectively and it was computed in the energy range of 0.015 MeV to 15 MeV. Mechanical strength results of the specimens assert improvement with age and results of buildup factor show no significant effect of flyash substitution of cement on it.

Keywords: Photon piling; Buildup factor; Flyash concrete.

INTRODUCTION

With the advancement of technique, there is a constant need of looking for new materials/composites that can be used as radiation shielding material. Also there is a demand of using existing resources, waste industry materials in optimum quantity so that it can benefit two important aspects: first, it is environment friendly and secondly, it is cost effective. Flyash is the finely divided residue resulting from the combustion of powdered coal, which is transported from the firebox through the boiler by flue gases (ACI Committee 116) and it is a by-product of coal-fired electric generating plants. Its pozzolanic nature makes it a good choice among other industrial by-product for complementing cement content in concretes. Its effectiveness in using it as a complement of cement in concretes for radiation shielding can be checked by studying buildup factor of different concretes.

In the past, buildup factor data for various elements has been generated and compared with ANSI/ANS 6.4.3. standard reference data. The objectives of the present investigations were to generate buildup factor data for different flyash concretes. The interaction of gamma radiation with matter has been studied in the past by several workers in concretes with the help of buildup factor. Buildup factor values of bismuth borosilicate glasses were compared with steel-magnetite concretes to explore its usage in shielding applications [(1)]. The variation of buildup factor data for concretes in different energy regions has been studied [(2)]. The energy absorption buildup factors for water, air and concrete were calculated up to 100 mfp using G-P fitting formula [(3)]. The variation of gamma ray buildup factor with absorber thickness and total scatter acceptance angle in high volume flyash concrete and water was studied [(4)]. Buildup factor have been calculated for some boron compounds in the energy region 15-100 keV and a better shielding material among the selected samples was identified [(5)]. Buildup factor was computed using G-P fitting method to estimate about the absorbed amount of energy for bone [(6)], human teeth [(7-8)] and human tissues [(9)] in the energy range 0.015-15 MeV and up to 40 mfp.

In this study, concrete specimens were prepared with flyash substituting different percentages of cement, namely 0%, 20%, 30%, 40%, 50% and 60% and the gamma ray buildup factors were computed using the Geometric Progression formula in the energy range 0.015-15 MeVand up to penetration depth of 40 mean free path (mfp) and the results have been interpreted in simple terms so that utility of flyash as cement substitute can be checked out from all possible views.

MATERIAL AND METHODS

Materials

Ordinary Portland cement (43 grade) was used. The physical properties of cement are as specified by Indian Specifications IS: 8112-1989 [(10)]. Flyash used in the study was obtained from thermal power plant, Bathinda. Flyash used was of Class F type (CaO < 10%). 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.

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 concrete samples were prepared with same water to cementitious ratio. W/C = 0.40 was taken for preparing samples. 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 [11].

Methods

The G–P fitting parameters were obtained by the method of interpolation from the equivalent atomic number (Z_{eq}). Then the gamma ray exposure buildup factor for the chosen flyash concretes has been calculated in the energy range 0.015–15.0 MeV and for a penetration depth up to 40 mfp using Geometrical Progression formula.

To study the contribution of secondary radiations due to multiple scattering, a correction factor called buildup factor (B) is determined. It is the ratio of total detector response to that of the uncollided photons. It is calculated from the equivalent atomic number as given by:

$$Z_{eq}=\frac{Z_1\left(logR_2\text{-}logR\right)\text{-}Z_2\left(logR\text{-}logR_1\right)}{logR_2\text{-}logR_1}$$

where Z_1 and Z_2 are the atomic numbers of elements corresponding to the ratios R_1 and R_2 respectively such that $R_1<R<R_2$, where $R=\mu_{comp}/\mu_{total}$. The G-P fitting parameters are thus obtained by interpolation of Z_{eq} in particular energy range and penetration depth. These parameters then generate buildup factor values by the following relation:

$$B(E,x)=1+\frac{(b-1)(K^x-1)}{K-1} \qquad \text{for } K\neq 1$$

$$B(E,x)=1+(b-1)x \qquad \text{for } K=1$$

RESULTS AND DISCUSSION

The G-P fitting parameters were computed for six concrete specimens in the energy region of 0.015-15 MeV. From these parameters, buildup factor was calculated up to a penetration depth of 40 mean free paths. The variation of buildup factor with energy is shown in Fig. 1. In this graph, buildup factor has been plotted against photon energy at 5 mfp for six concrete specimens. The nature of graphs is similar to the Fig.1 for buildup factor plotted against photon energy at 10 mfp, 15 mfp, 20 mfp, 30 mfp and 40 mfp for six concrete specimens. At energies lower than or equal to the energy value at which photoelectric cross-section matches the Compton cross-section, the photoelectric effect is the most dominant resulting in low value of buildup factor. For energies greater than 1.5 MeV, buildup factor value starts decreasing due to increasing dominance of pair production over Compton effect. Within energies 0.1 to 0.8 MeV, the buildup factor is maximum due to multiple scattering in the intermediate region. With change in flyash content, there is no significant effect on buildup factor.

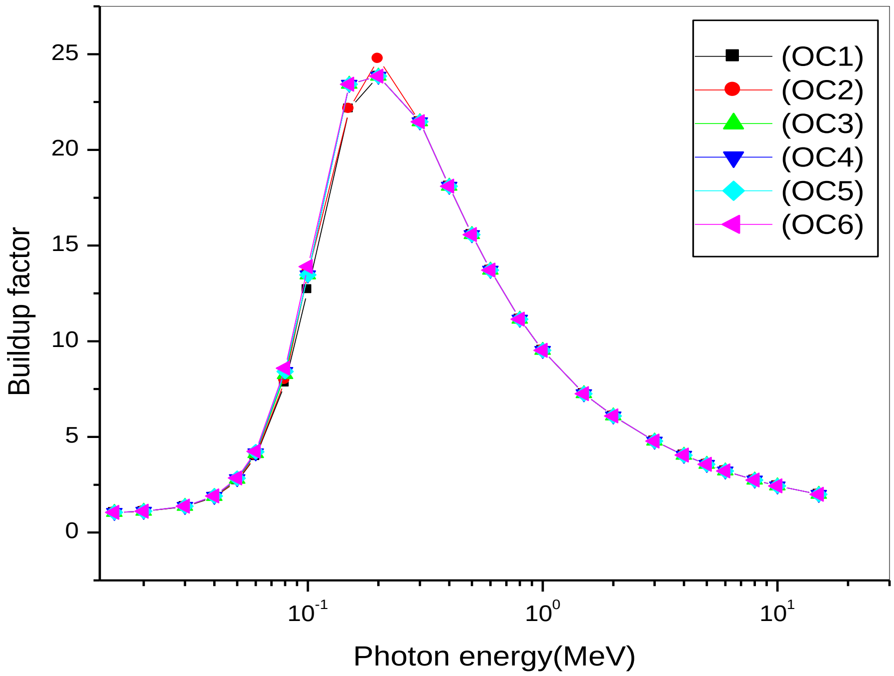

Figure 1. Buildup factor with photon energy for penetration depth 5 mfp.

As reported earlier [12], flyash substitution of cement in concretes leads to improvement in strength of concrete, it may be compressive or flexural or modulus of elasticity. All of these gain with age of sample.

So it can be said that 'buildup factor', a corrective parameter for photon interaction study, leads to the statement that flyash substitution have no peculiar/significant effect on the piling up of photons in the lower energy region.

CONCLUSIONS

With an increase in penetration depth, buildup factor increases. Due to Compton scattering in the medium energy region, increase in buildup factor is more pronounced as the photons are not completely removed from the incident beam. Buildup factor results indicated that there is no significant effect of flyash substitution on its magnitude for different concrete specimens.

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