The Variation of Gamma Attenuation with Strength of Concrete

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Abstract

The aim of this research is to study the gamma attenuation in different concrete samples which have different values of strength. This research also attempts to compare the attenuation coefficients obtained by using thin samples and the attenuation coefficients which are graphically determined by the varying of gamma counts with the increasing thickness of concrete. Therefore, concrete samples which have different values of strength were prepared to compare their gamma-attenuation properties.

Key words : concrete, gamma attenuation, NaI (Tl) detector

Introduction

Concrete is by far the most widely used material for reactor shielding due to its cheapness and satisfactory mechanical properties. It is usually a mixture of hydrogen and other light nuclei and nuclei of fairly high atomic number. It is, therefore, efficient both in absorbing gamma rays and in slowing down fast neutrons by elastic and inelastic scattering.

A thick layer of concrete surrounds nuclear reactors which play two roles in supporting the reactor and its related equipments and protecting the surrounding from high level radiations emitted from the reactor.

The mechanical tests for the concrete samples are compressive and tensile strengths. The compressive strength of ordinary concrete is influenced by many factors such as water/cement ratio, mix properties, type and size of aggregate and curing conditions in addition to the shape and size of the test specimens.

MATERIALS AND METHOD

1. Sample Preparation

The samples used in this research are made in Soil Test Laboratory, Public works, Mandalay. Concrete samples with dimension [8cmx8cmx2cm] and with five samples of values of strength are made by using cement, sand, chipping and water. To achieve their mechanical strengths each five samples are placed in water for 7 days, 14 days and 28 days respectively. Therefore three groups of samples, each includes five different values of strength are obtained. They are:

(1) Group 1 (7 days strength of 10, 15, 20, 25 and 30 MPa),
(2) Group 2 (14 days strength of 10, 15, 20, 25 and 30 MPa) and
(3) Group 3 (28 days strength of 10, 15, 20, 25 and 30 MPa).

The compositions of concrete samples used in this research are shown in Table (1).

2. Experimental Set-up

The experimental arrangements include 2"x2" NaI (Tl) scintillation detector (Model No. 2M2/2), the photomultiplier tube base (digiBASE) with USB connection and MAESTRO-32 gamma detection software installed in a computer. As a gamma source, ^{137}Cs (30.07 years half-life and activity 1 μCi) is also used. The detection system of the present work is set up as shown in Figure (1).

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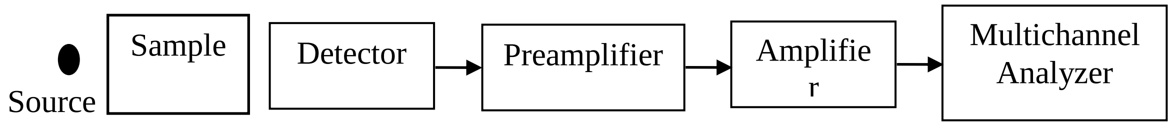

Figure (1) Experimental set-up of radiation detection system

3. Experimental Procedure

All measurements for this research were done in Nuclear Physics Laboratory, Department of Nuclear Physics in Yadanabon University.

In this research work, the voltage is adjusted to 950 V at the preset time of 180 sec by the MAESTRO-32 software. The background counts were measured for three times and average counting rate is taken. Then, the ^{137}Cs gamma source is placed from the detector window. After measuring the gamma counts in the absence of sample, the different strength of the samples were placed between source and detector. The measured spectra are analyzed by the MAESTRO-32 software.

Table (1) The composition of concrete samples

Strength (MPa)	Cement (kg/m^3)	Sand (Fine aggregate) (kg/m^3)	Chipping (Coarse aggregate) (kg/m^3)	Water (kg/m^3)	Water/ Cement
10	286	571	1268	203	0.709
15	314	571	1268	203	0.646
20	343	571	1268	203	0.592
25	374	571	1268	186	0.497
30	400	571	1268	183	0.458

Results of the Measurements

The net counts obtained from the attenuation of photon after passing through the given samples are shown in Table (2). The attenuation coefficient 7 days, 14 days and 28-days strength of concrete samples are shown in Table (3).

Discussions

To get the required mechanical properties of the concrete, the dimensions of the investigated samples are made (15cmx15cmx15cm) for mechanical test. The thin samples (8cmx8cmx2cm) were also prepared for nuclear tests.

It was found that the photons counts decrease after the 2cm thickness of concrete samples had been placed before the detector. Then, the photons counts more evidently decreases after the 4cm and 6cm thickness of samples has been placed before the detector. The similar effect can be found in the 14days and 28 days strength of samples and the attenuation in these samples is greater than that in the former samples. The attenuation coefficient of the 28 days strength of samples is greater than that in the 7 days strength of concrete samples. Curing time is also an important factor in determining concrete strength. Therefore, it can be said that the strength of concrete samples which are more longer period of curing process can have the greater strengths and may be improve the nuclear attenuation properties of concrete. In this research work, the investigated samples are made the present dimension (15cmx15cmx15cm) and (8cmx8cmx2cm) enough to carry out mechanical and nuclear tests.

Water plays a critical role, particularly the amount used. The strength of concrete increases when less water is used to make concrete. Concrete is actually mixed with more water than is needed for the hydration reactions. The water not consumed in the hydration reaction will remain in the microstructure pore space. These pores make the concrete weaker. Therefore, gamma ray can pass through easily in lower strength of concrete. Figure (2) shows schematic drawings to demonstrate the relationship between the water/cement ratio and porosity.
The attenuation coefficients of the samples under investigation have been determined by the two ways. Firstly, it was determined by the usual equation: $n = n_0 e^{-\mu t}$, where n_0 and n are the photon counts before and after the sample, μ is the coefficient of attenuation and t is the thickness of the thin sample (2 cm). Secondly, it was graphically determined by the use of variation of gamma counts with the thickness of each sample as in figure (4) to (8). The values of the attenuation coefficients of the investigated samples are shown in Table (3) and (4).

Table (2) The variation of gamma counts in different concrete samples
The initial counts =34200.

strengths of concrete	thickness of samples	net counts		
		(after 7 days)	(after 14 days)	(after 28 days)
10 M Pa	2 cm	14501	13327	10178
	4 cm	4486	4207	2501
	6 cm	1879	1468	1300
15 M Pa	2 cm	13666	13299	8915
	4 cm	4409	4178	1817
	6 cm	1572	1382	1297
20 M Pa	2 cm	13597	13229	8607
	4 cm	4301	3904	1716
	6 cm	1549	1371	1276
25 M Pa	2 cm	13502	12908	8493
	4 cm	4288	3854	1636
	6 cm	1532	1346	1120
30 M Pa	2 cm	13401	12118	8441
	4 cm	4259	3739	1149
	6 cm	1476	1334	1034

Table (3) The attenuation coefficients of concrete samples

strengths of concrete	attenuation coefficients obtain by using thin sample			attenuation coefficient determined by graphical method		
	(after 7 days)	(after 14 days)	(after 28 days)	(after 7 days)	(after 14 days)	(after 28 days)
10 M Pa	0.43	0.47	0.61	0.49	0.53	0.56
15 M Pa	0.46	0.47	0.67	0.51	0.53	0.57
20 M Pa	0.46	0.47	0.69	0.52	0.54	0.57
25 M Pa	0.46	0.49	0.70	0.52	0.54	0.59
30 M Pa	0.47	0.52	0.70	0.52	0.54	0.62

Table (4) The formulated strength and the actual strength of concrete samples

The formulated strength by the composition	The actual strength		
	(after 7 days)	(after 14days)	(after 28 days)
10 MPa	18 MPa	25 MPa	32 MPa
15 MPa	19 MPa	26 MPa	35 MPa
20 MPa	21 MPa	28 MPa	37 MPa
25 MPa	22 MPa	30 MPa	39 MPa
30 MPa	24 MPa	31 MPa	40 MPa

Conclusion

It can be concluded that more longer period of curing process can improve not only the mechanical properties but also the nuclear attenuation properties of concrete. It is common to use a 28-day test to determine the relative strength of concrete.

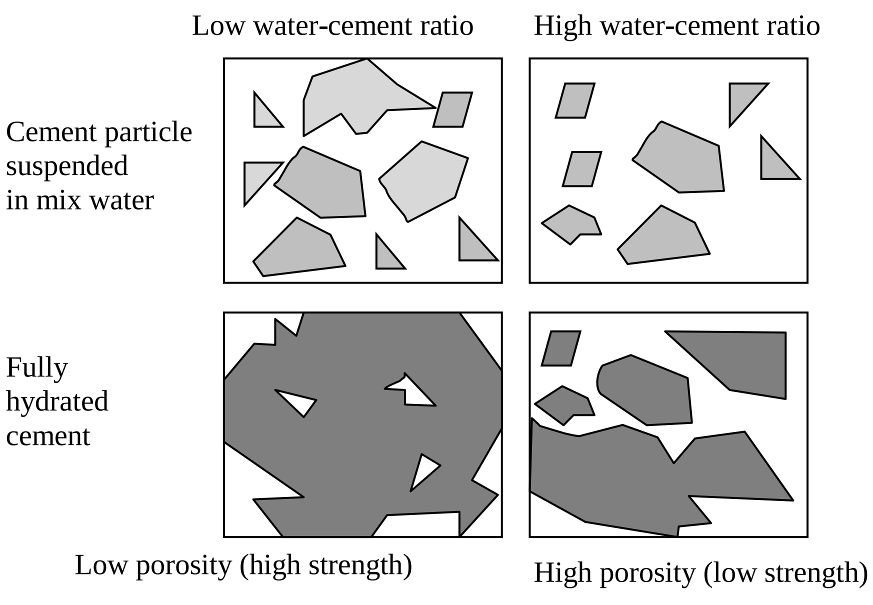

Figure (2) Schematic drawings to demonstrate the relationship between the water/cement ratio and porosity

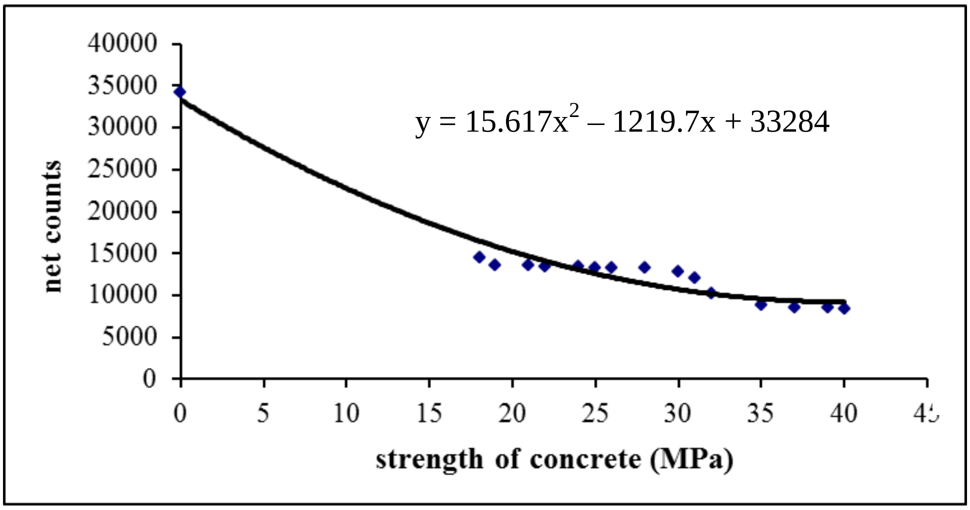

Figure (3) The variation of gamma counts with the actual strength of concrete samples

Table (5) The variation of gamma counts with actual strength of concrete samples

The actual strength	The net counts obtained from thin samples
18 MPa	14501
19 MPa	13666
21 MPa	13597
22 MPa	13502
24 MPa	13401
25 MPa	13327
26 MPa	13299
28 MPa	13229
30 MPa	12908
31 MPa	12118
32 MPa	10178
35 MPa	8915
37 MPa	8607
39 MPa	8493
40 MPa	8441

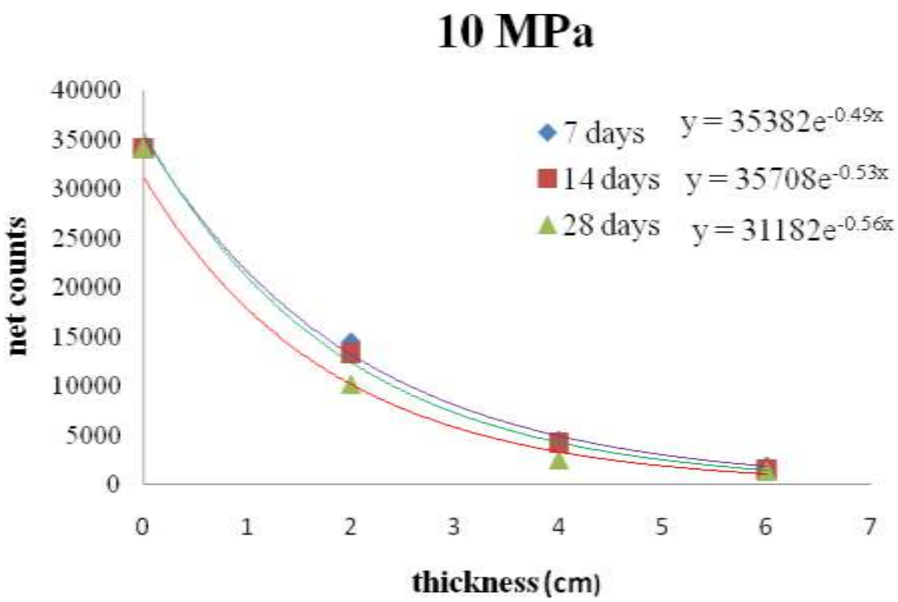

Figure (4) The variation of gamma counts with the thickness of 10 MPa concrete sample

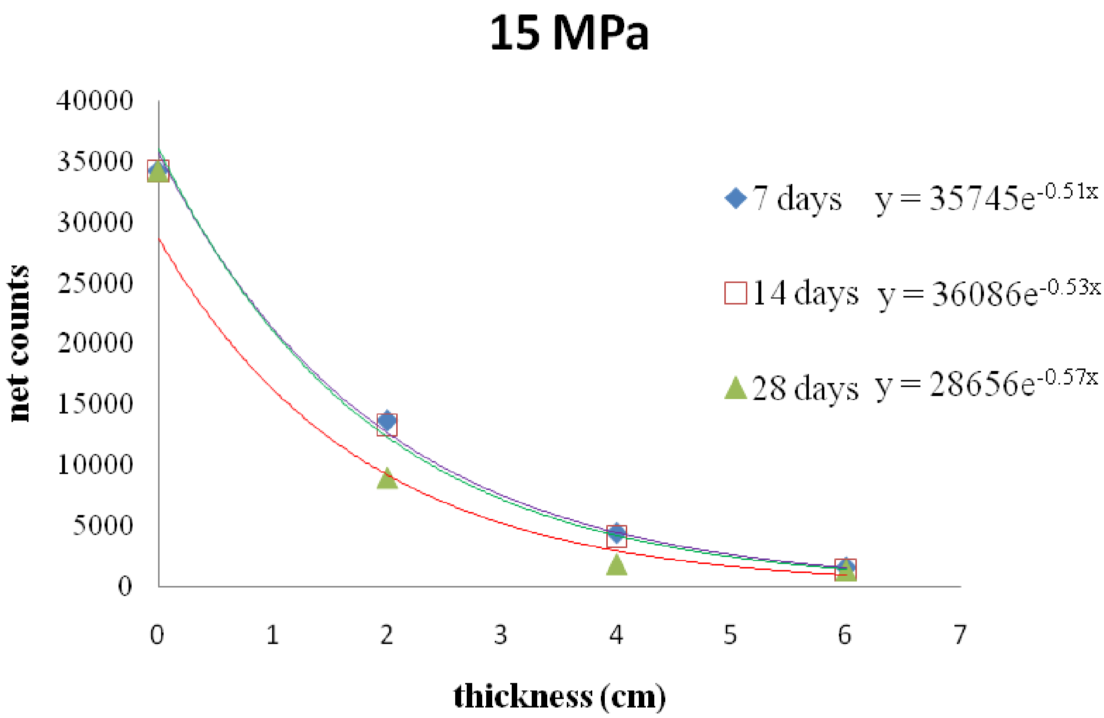

Figure (5) The variation of gamma counts with the thickness of 15 MPa concrete sample

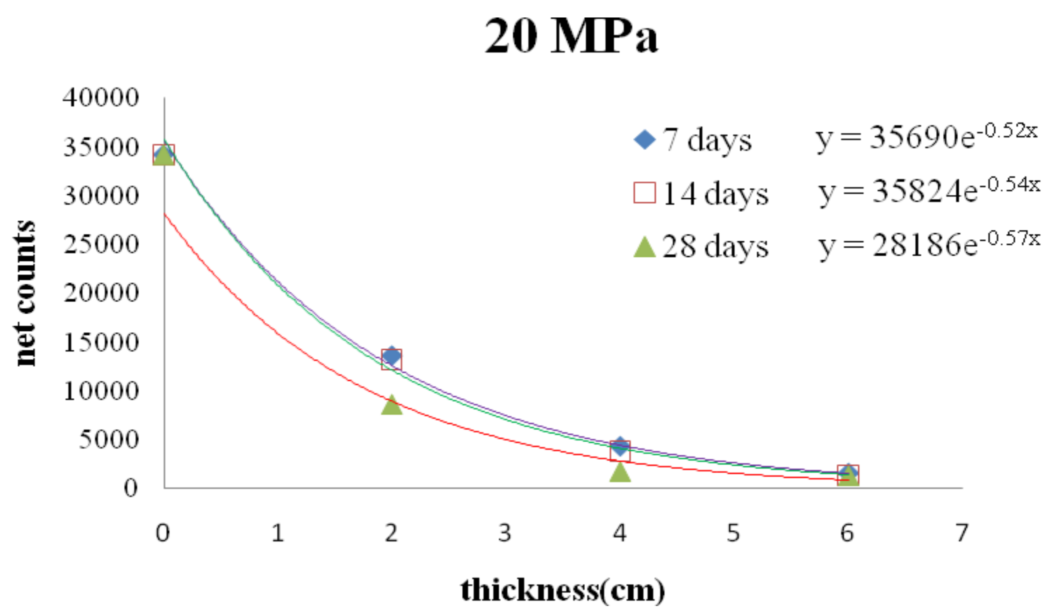

Figure (6) The variation of gamma counts with the thickness of 20 MPa concrete sample

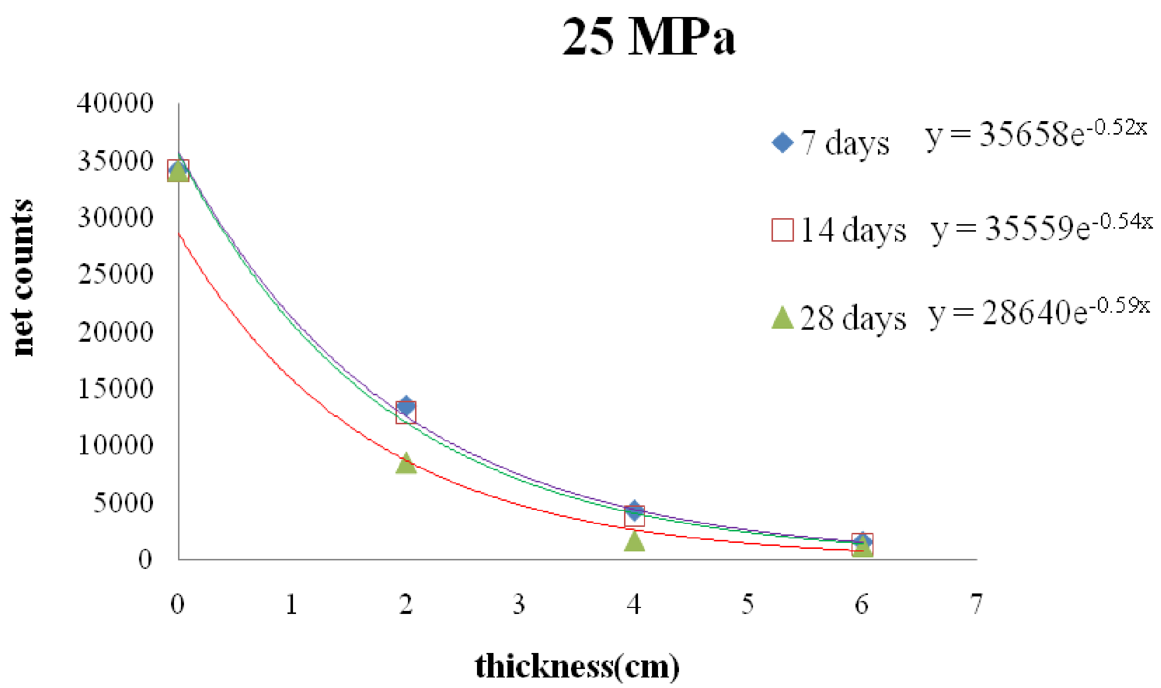

Figure (7) The variation of gamma counts with the thickness of 25 MPa concrete sample

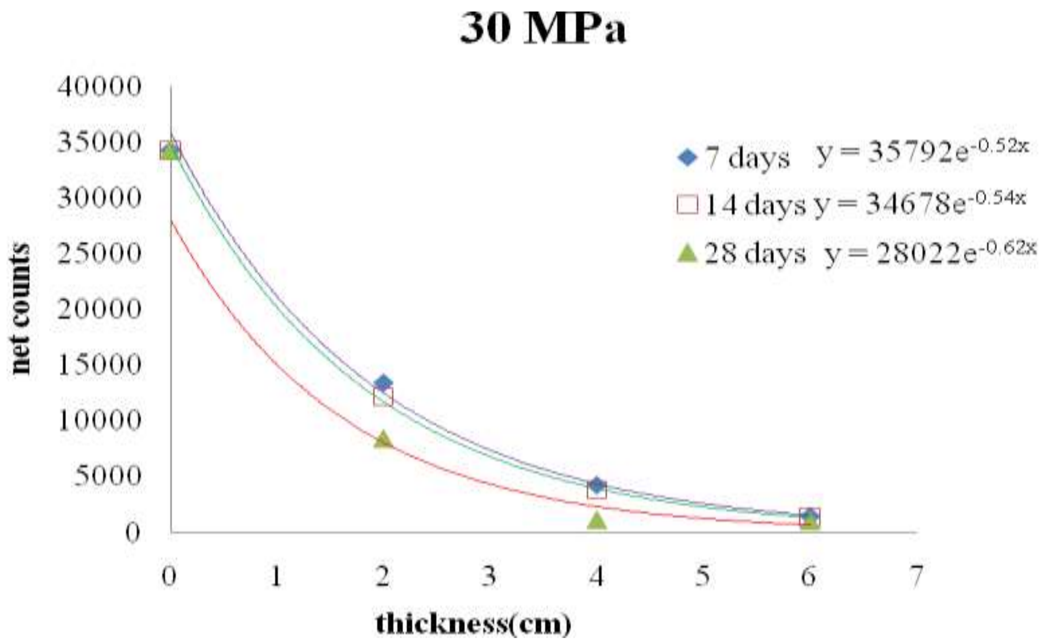

Figure (8) The variation of gamma counts with the thickness of 30 MPa concrete sample

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