A Study on the Application of gamma transmission Techniques on the quality control of sandcrete block

Abstract: This study considered the setup of gamma transmission facility to develop a methodology for determining the amount of cement in sandcrete block twelve block sample was moulded in varying sand/cement ratio. The 12 samples each were measured both on volume, masses and density each of the sample went through a destructive test to determine the compressive strength via strength test machine. Also each of the sample went through a non destructive gamma ray transmission (GRT) test where gamma count was taken both before and after crushing. The linear & mass attenuation co-efficient U & U (cm^2/g) was determined by (1) the incident gamma ray intensity. The attenuation gamma ray intensity and (3) the background intensity we realized that the cement weight concentration against the mass attenuation co-efficient has a linear corelation of 0.97, while the compressive strength of the same samples against cement concentration also give a linear correlation of 0.96 except for lower cement values of 7.35 and 9.37wt% which deviates from the straight line. Its deduced that there is a remarkable relationship between mass attenuation coefficient, compressive strength and cement concentration thus mass attenuation coefficient against compressive strength has a linear correlation of 0.985. conclusively it was noted that gamma transmission technique is non-destructive, fast and cost effective not costly compared to the conventional method.

Keywords: cement, mass attenuation coefficient, linear attenuation coefficient, compressive strength, Linear correlation, gamma transmission, sandcrete block, sand, cement, water.

Introduction:

The basic material for construction of buildings in Nigeria are sandcrete blocks whose composite materials are made up of sand, cement and water in appropriate proportion (Barry,1969). It's a material widely used in Nigeria and other countries as walling unit.

The frequent collapse of building leading to loss of lives and properties across the world, and in Nigeria in particular (fadairo & Fakere, 2012; oyekan, 2008) has raised a demand that material used for construction of building must meet the minimum requirement (Ukpata, 2006).

It was researched that more than 80% of the sandcrete block produced in Nigeria is well below the minimum strength range of 2.5 – 3.45N.mm**2** provided by Nigeria industrial standard (Nig 87, 2000). The use of substandard materials, poor workmanship, abscense or poor quality control of the production process are contributing factors to the prevalence of substandard sandcrete blocks for construction of building in Nigeria (olaniyi 2000, usiwo 2000). Consequently, these sand crete frequently fail to meet load bearing specifications. It's therefore common to observe development of micro cracks on building walls after construction (Anosike & Oyebande, 2012; Banden and Tuili, 2004) also Nwokoye (1999) argued that structural failure is directly related to constituent materials failure. Its therefore pertinent to put in place quality control processes that will ensure that the block used for construction works in Nigeria contain appropriate amount of cement and that the sand used is of required quality.

In order to achieve this purpose there is need to develop analytical procedure aimed at determining the amount of cement contained in sandcrete block. This will allow the appropriate authorities to determine whether the sandcrete block produced in the country meets the necessary requirement in terms of concentration of cement in the block. Low energy gamma ray transmission technique offers a possibility of determining the amount of cement in a sandcrete block, since it has been used in the past to determine the ash content of coal (folks et al, 1977 Boyce et al, 1977 and omeye, 2006).

The photon attenuation coefficient is an important parameter for characterizing the penetration & diffusion of gamma rays in composite materials such as alloys, organic & inorganic compounds, soils and biological materials (Singh and mudahar, 1992; okunade et al; 2011).

The effects of different parameters on the attenuation coefficient of soils have been discussed in several studies by using the gamma transmission method. The gamma ray attenuation technique used in determination of water content in soil. Some radioactive sources emitting gamma radiation were used in the measurement of soils. For example ^{60}CO (Gardner and Calissendorff, 1967 and Appoloni and Rios, 1994).

In the present work, γ-ray transmission techniques was used for determination of cement content in a sancrete block on a laboratory scale using single energy γ-rays. This is done by calibrating the system with simulated sandcrete standards prepared by combining natural sand with known concentrations of cement in various proportions. The setup used consist of Am-241 radiosotope sources, NaI (TI) detector and precast sandcrete sample in cylindrical form. A single channel analyzer with relatively higher sensitivity and with windows set at appropriate energy was utilized for determining transmitted γ-counts from the sample.

MATERIALS AND METHODS

The materials used for production process of sandcrete blocks in varying quantities are important factors that determine the quality of sancrete blocks. The materials used and method of manufacture employed in this research are presented below.

- **Materials of the sandcrete blocks**

The sancrete block constitute sand, cement and water

- **Sampling and sample preparation of sandcrete block**

Sharp sand was collected from a sancrete block producer and taken to the centre for energy research and training (CERT) where the work was carried out. The Sharp sand was dried to constant weight at 60°C for 2hrs in an oven and subsequently homogenized using a grinding machine. This allow adequate control in the qualification of amount of water that will be used in forming the sandcrete block.

The mould used in forming the sandcrete block was constructed using PVC pipe of 7cm diameter and 8cm height. Sandcrete block consisting of varying amount of sharp sand & cement were produce. In Table 1 using the PVC mould. In this way twelve sandcrete blocks were constructed and used for the experiment.

Table 1: Amount of constituent material in Sandcrete moulds

Sample	Sample composition (m^3)			Total	Sample composition (kg)			Weight Percent		
	Cement	Sand	Water		Cement	Sand	Water	Cement	Sand	Water
SI	0.000030	0.000270	0.000030	0.000330	0.0396	0.4725	0.02690	7.35	87.65	5.00
S2	0.000038	0.000262	0.000030	0.000330	0.0502	0.4582	0.02710	9.37	85.57	5.06
S3	0.000045	0.000255	0.000030	0.000330	0.0594	0.4463	0.02714	11.15	83.76	5.09
S4	0.000050	0.000250	0.000030	0.000330	0.0660	0.4375	0.02720	12.44	82.44	5.13
S5	0.000055	0.000245	0.000030	0.000330	0.0726	0.4288	0.02726	13.73	81.11	5.16
S6	0.000065	0.000235	0.000030	0.000330	0.0858	0.4113	0.02737	16.36	78.42	5.22
S7	0.000072	0.000228	0.000030	0.000330	0.0950	0.3990	0.02745	18.22	76.51	5.26
S8	0.000080	0.000220	0.000030	0.000330	0.0106	0.3850	0.02754	20.38	74.30	5.32
S9	0.000090	0.000210	0.000030	0.000330	0.0119	0.3675	0.02765	23.12	71.51	5.38
S10	0.000100	0.000200	0.000030	0.000330	0.0132	0.3500	0.02776	25.89	68.66	5.45
S11	0.000110	0.000190	0.000030	0.000330	0.0145	0.3325	0.02787	28.72	65.77	5.51
S12	0.000120	0.000180	0.000030	0.000330	0.0158	0.3150	0.02798	31.59	62.83	5.58

- **Measurement of compressive strength**

Twelve sandcrete blocks having varying concentration of cement & sand in each mixture were used for the measurement. Since cement act as a stabilizer and binder. It is thus assured that the quantity of cement in the mixture determines the compressive strength of various blocks. The compressive strength of the sample were obtained by performing compressive strength test on different samples. The masses of the blocks were initially measured before testing. The sandcrete is centered on the compressive test machine and loaded to complete crushing. The crushing load is then recorded and divided by the cross-sectional area to obtain the compressive strength.

$$\text{Compressive strength} = \frac{\text{crushing load}}{\text{Cross sectional area of the crushing surface}} \quad (1)$$

Table 2 shows the data obtained from the compressive strength machine using the formula above

Table 2: Data for determination of Compressive strength of Sandcrete blocks

Sample	Cement Concentration (wt%)	Fixed diameter of crushing surface	Load bearing failure (KN)	Compressive strength (N/m^2)
SI	7.35	6.8	18	4.96
S2	9.37	6.8	30	8.26
S3	11.15	6.8	53	14.6
S4	12.44	6.8	56	15.43
S5	13.73	6.8	58	15.98
S6	16.36	6.8	64	17.63
S7	18.22	6.8	76	20.94
S8	20.38	6.8	82	22.59
S9	23.12	6.8	88	24.24
S10	25.89	6.8	100	27.55
S11	28.72	6.8	109	30.03
S12	31.59	6.8	115	31.68

- ❖ **Measurement of mass attenuation Coefficient**

Derivation of Linear Attenuation coefficient

Gamma-rays interact with electrons in the atoms of various elements in a materials by photoelectric effect, Compton-scattering and pair production. These three processes can be expressed as a cross section or attenuation (absorption) coefficient, which depends on the thickness or surface weight of the target material with which the gamma ray interacts.

In general, the attenuation of gamma ray in a medium is expressed by

$$dI = -\mu I dx \quad (2)$$

μ = proportionality constant called linear Coefficient
- = intensity is reduced by the absorber
x= thickness of the material
Integrating equation (2) shows intensity that has not suffered interaction which follow the beer lambert law. The attenuation of gamma-rays in a medium such as sandcrete block is expressed by equation (3)

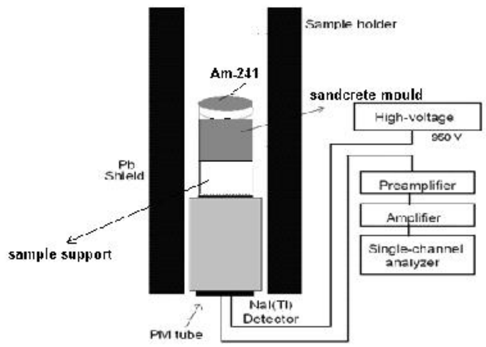
$$I = I_o \exp(-\mu x) \qquad (3)$$

I_o = Initial intensity of gamma rays
I = Intensity of gamma rays after attenuation through a media of length
x; μ is the linear attenuation coefficient of the material
μ is a macroscopic cross-section for gamma ray interaction cross-section and it has units cm^{-1} which can be described as

$$\mu = \left(\frac{\mu}{\rho}\right) \rho = \mu_m \rho \qquad (4)$$

$$I = I_o \exp(-\mu_m \rho x) \qquad (5)$$

Thus the radiation intensity will decrease in an exponential fashion with the thickness of the absorber such that the rate of decreased is controlled by the linear attenuation coefficient



❖ **Measurement of Mass Attenuation Coefficient**

Fig 1

Experimental arrangement for gamma transmission techniques

❖ **Measurement Procedure**

The Sets of measurement were taken in order to determine the mass attenuation coefficient of the sandcrete blocks. These are incident gamma ray intensity, the attenuated gamma ray intensity and the background.
The sample/source holder was marked to indicate the position where the sample and source will be placed in order to obtain a reproducible geometry. For all the measurements the distance between the source/sample was maintained at 5cm. the intensities of incident and transmitted photons when the detector was biased to 950v were determined.
Sandcrete blocks containing varying concentration of cement were placed in turn in the marked position and replicated measurements of un attenuated & attenuated gamma ray intensity were measure at the present time. Table 3 show the intensity data consisting of background, source and sample intensity data determine for each sandcrete sample.
Using the measured values of unattenuated intensity I_o and attenuated photon intensity I, the mass attenuation Coefficient $(\mu/\rho)_c$ of all the precast sandcrete blocks containing known amount of cement were determined using the equation

$$\mu_m = (\mu/\rho)_c = \frac{\ln(I_o/I)}{\rho t} \qquad (6)$$

Where ρt is the mass thickness of the absorber in g/ cm^2.

Table 3 Intensity data for sandcrete samples

SandcreteMould	Mean background count (I_{BG})	Mean Source Count (I_o)	Mean sample count (I_s)	Ln(Net Intensity ratio)	Density thickness (kg/m^2)
SI	38	1115	281.25	1.487845	140.0754
S2	26	1133	268.4	1.541779	139.1373
S3	19	1210	256.85	1.65614	138.4410
S4	33	1124	231.3	1.6496	137.8979
S5	38	1157	240	1.695883	137.3678
S6	32	1139	230.75	1.693025	136.2661
S7	30	1135	234.45	1.687277	135.5047
S8	34	1162	233.7	1.748066	134.6343
S9	28	1238	232.95	1.817334	133.5455
S10	36	1248	219.75	1.850414	132.4568
S11	38	1291	203.95	1.961325	131.3681
S12	26	1276	199.25	2.027584	130.2793

❖ **Result & Discussion / Analysis & Discussion**

The bulk mass coefficients of twelve sandcrete mixture containing known concentration of cement which act as a binder were determined using 241Am radioisotope source having y-rays energy of 51.5kev. the mass attenuation co-efficient determined from the gamma ray transmission data and the density thickness of the sandcrete samples. Also along with the compressive strength values of the twelve samples are displayed in

Table 4: variation of mass attenuation coefficient with compressive strength

Sandcrete Mould	Cement Concentration (wt %)	Bulk Mass Atten. Coefficient (m^2/kg)	Compressive strength (N/m^2)
SI	7.35	0.0106217	4.96
S2	9.37	0.0110810	8.26
S3	11.15	0.0119628	14.6
S4	12.44	0.0119625	15.43
S5	13.73	0.0123456	15.98
S6	16.36	0.0124244	17.63
S7	18.22	0.0124518	20.94
S8	20.38	0.0129838	22.59
S9	23.12	0.0136083	24.24
S10	25.89	0.0139699	27.55
S11	28.72	0.0149300	30.03
S12	31.59	0.0155634	31.68

The graphic presentation of the variation of mass attenuation coefficient with cement concentration in each sandcrete moulds are presented in fig 2.0

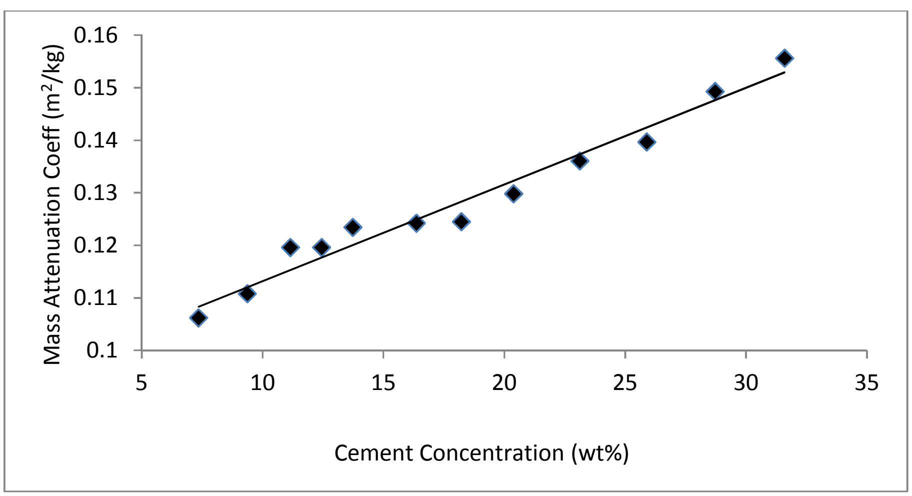


Fig 2: variation of mass attenuation coefficient with cement conc. In Sandcrete mould

its clearly observed that the mass attenuation coefficient varies linearly with cement concentration with correlation coefficient 0.97.

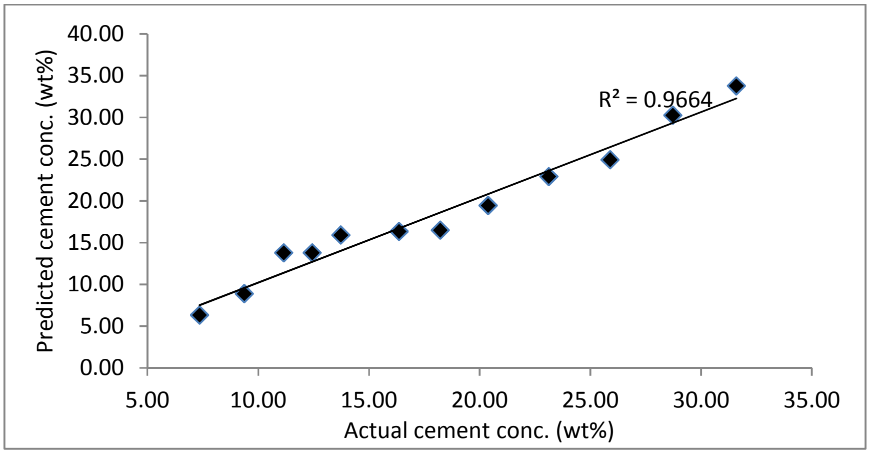


Fig 3: predicted versus actual cement conc. Of sandcrete moulds using gamma transmission setup.

also compares the predicted weight percent concentration of cement with actual weight percent values. This comparision yields a correlation coefficient of 0.97. thus indicating that the experimental setup and procedure can be used as a quality control facility for sandcrete cement block production.

In a related manner, variation of compressive strength with cement concentration is also depicted in Fig 4.

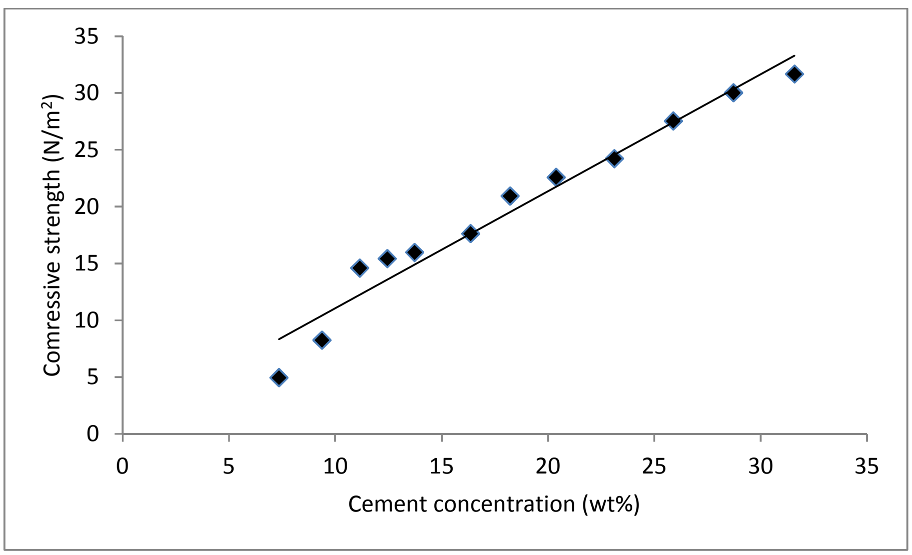


Fig 4: variation plot of compressive strength against the cement conc.

It's also observed that compressive strength of sandcrete mould also vary linearly with cement concentration except for the lower cement concentration values of 7.35 and 9.36 wt% which deviates from the straight line graph. Inspite of this deviation the correlation coefficient of 0.96 was still obtained.

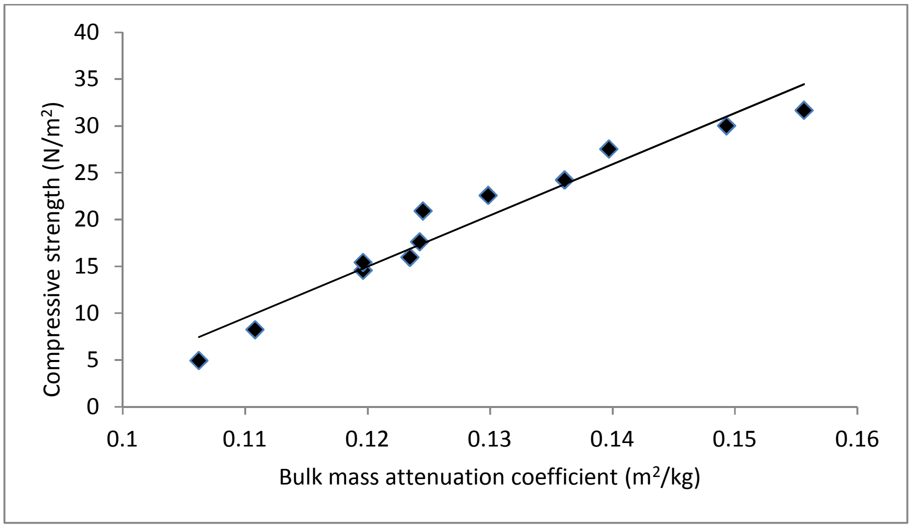


Fig 5: compressive strength versus mass attenuation coefficient of sandcrete moulds

The behavior of mass attenuation coefficient and compressive strength with cement concentration is remarkable and serves as an indication that a strong correlation exist between mass attenuation coefficient and compressive strength of sandcrete moulds. To buttress this deduction, a graph showing the variation of mass attenuation coefficient with compressive strength of sandcrete mould with reference to table 4 was plotted.

As expected the graph indicates a high correction between the mass attenuation coefficient and compressive strength of sandcrete moulds with correlation coefficient of 0.95. this clearly incates that the mass attenuation coefficient provides a very good approximates measure of compressive strength and vice-versa.

It can readily be observed that both the mass attenuation coefficient & compressive strength vary with cement concentration. It is thus expected that compressive strength and mass attenuation coefficient should posses linear relationship. Fig 5 shows the plot of compressive strength versus mass attenuation coefficient with one of the data points removed to obtains correlation coefficient of 0.985. this readily depicts a linear change in compressive strength with mass attenuation coefficient.

The variation is easily fitted by the equation

$$Y = 547.29x - 50.701 \quad (7)$$

With y representing compressive strength while the x – value represent the bulk mass attenuation coefficient. It should be noted that the method used for measuring compressive strength is destructive whereas the gamma ray transmission experiment used to determined mass attenuation coefficient is non destructive.

Conclusion

Gamma-ray transmission technique has been used to determine the mass attenuation coefficient in sandcrete moulds containing different concentrations of cement. The mass attenuation coefficient was found to exhibit positive and high correlation coefficient of 0.95 with the compressive strengths of the same set of samples. Consequently a strong correlation was established between mass attenuation coefficient and compressive strength of sandcrete moulds and thus measurement of mass attenuation coefficient can be used to carry out rapid determination of load bearing failure in structures.

In addition, gamma ray transmission technique has been used to develop analytical method for the determination of cement concentration in sandcrete block. This was done by using sandcrete moulds of known concentration of cement which were subsequently subjected to gamma transmission measurement so that bulk mass attenuation coefficient of each mould can be determined. The result obtained showed that all samples demonstrate a linear change in attenuation with increase in weight percent concentration of cement. The predicted weight percent concentration of cement using the calibration equation shows excellent correlation with actual concentration of cement in the samples. Consequently, the experimental set up and procedure developed in this work can be used as a quality control facility for sandcrete cement block production.

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