JOURNAL OF MECHANICS OF CONTINUA AND MATHEMATICAL SCIENCES
www.journalimcms.org

ISSN (Online) : 2454 -7190 Vol.-15, No.-11, November (2020) pp 160-168 ISSN (Print) 0973-8975

RADIATION SHIELDING EFFECT OF BASALT CONCRETE; AN EXPERIMENTAL APPROACH

Engr. Furqan Wali[1] Manzoor Khan[2], Jahanzeb Khan[3], Maaz Ahmad[4], S. Ali Raza[5]

Department of Civil Engineering Iqra National University, Peshawar Hayatabad Phase 2, Khyber Pakhtunkhwa, Pakistan

[1]Furqanwali@inu.edu.pk, [2]manzoorhussainmarwat@gmail.com

Corresponding Author: **Furqan Wali**

https://doi.org/10.26782/jmcms.2020.11.00014

(Received: October 13, 2020; Accepted: November 22, 2020)

Abstract

This paper presents an assessment of gamma radiation performance, specifically in terms of attenuation energy, of concrete containing coarse aggregate having different physical and chemical properties. Basalt being heavier and somehow having high specific gravity is likely to have a good performance against gamma radiation. Through this paper, the author has made a comparison between the concrete having different coarse aggregates, normal aggregate phase and basaltic aggregate phase by evaluating the attenuation energies of both the phases at the Institute of Radiotherapy and Nuclear Medicine (IRNUM) Peshawar.

Also, the water to cement ratio (W/C) for both the phases was distinguished i.e. 3.5 and 5.7 to make the results more promising and enabling to make the comparison effective. The test was likely to be conducted on Molds having 10 cm by 10 cm cross-section of each W/C ratio with varying thickness of about 2cm and will lead up to 10cm. The detecting device used was a phoenix teletherapy machine operating with a former type ionization chamber having an energy of 1.25 MeV. The source of radiation was Cobalt 60. The results indicated that basalt despite having strong physical properties is insufficient to be used for Gamma shielding. The two materials vary very little, so it is negligible to be used for a specific reason.

Keywords: Basalt rock, Cobalt 60, W/C, Phoenix Teletherapy machine (PTW)

I. Introduction

Concrete is a composite material composed of coarse aggregate bonded together with a fluid cement that hardens over time. Its versatility, durability, sustainability, and economy have made it the world's most widely used construction material [V]. Generally, for the protection of harmful rays use different types of admixture issued for better performance. Also, the most effective way to protect against the most dangerous forms of extraction (neutron and gamma-lights) is very heavy concrete. The density of heavy concrete is dependent on the aggregate's specific gravity and the properties of the other concrete components. According to TS EN 206-1, concrete with specific gravities greater than 2600 kg/m3 is referred to as low weight concrete and aggregates with specific gravities greater than 3000 kg / m3 are referred to as heavyweight aggregates [II]. Depending on the radiation form and resources, radiation shields are normally made using materials such as lead, graphite, steel, polyethylene, concrete, etc. Concrete is considered the most suitable material of all materials that can be used profitably in the manufacture of shields that have not only sufficient attenuation properties but also the mechanical strength necessary [VII]. The strength of concrete mainly depends on aggregate. Crushed stone is a form of coarse aggregate which is in high demand for the production of concrete.75% strength of concrete depends on a coarse aggregate [V] [VIII].

For the production of high dense concrete, we use Basalt stone as a coarse aggregate. Basalt is a general term used for several volcanic rocks that are dark grey in color. With a particular gravity ranging from 2.7 to 3.3, basalts' stone is relatively heavy [IV]. We used high-density coarse aggregate (Basalt stone) in concrete preparation and after, we will analyze that concretes prepared with high-density coarse aggregate are useful radiation absorbents or not. Basalt rocks are completely applied to the concrete mixture to achieve high strength and good workability [III]. The main objective of this research is "To investigate the suitability of basalt as a coarse aggregate for high-performance against radiations and heavy density concrete production" and providing sufficient information about the product and make it vibrant for further research [IX] [X].

I.i. Problem statement and Motivation

The protection of gamma radiations has attracted significant attention over the past several decades and is still a research hotspot until now. The Protection of gamma radiations of concrete is always the main dilemma behind any nuclear structure design. Concrete structures may face radiation protection challenges to overcome these challenges different researchers use different techniques to protect gamma radiations some researchers use barite due to its high specific gravity i.e 3.6 approximately to protect the radiation while some played with The initial water to cement ratio of ordinary concrete. Some researchers added Carbon powder to shielding concrete made of Hematite aggregates to investigate its effects on shielding properties. all of them gives good radiation in the field of protection but all of the above processes were quite complicated and costly there should be some local and cheap technique in order to protect radiations.

I. ii. Objectives of the Research Work

This study focused on the development of dense concrete that will have an efficient capacity against radiations. The primary objectives of this research study are listed below:

a. To study, experimentally, the effect of basalt in concrete on the protection of radiation
b. The relation between protection capacity and water to cement ratio
c. Uses of dense concrete
d. Introducing local material basalt to industries
e. Footprint for further research on radiation protection

I. iii. Scope of Research

The scope of this research includes studying the effects of basalt in the protection of radiations in concrete the effect of water to cement ratios of concrete in radiation protection

II. Methodology

The materials used in this project are, fine aggregate Margalla crush (coarse aggregate) and cement obtained from Kohat cement Company. We used high-density coarse aggregate in concrete preparation. The aggregates namely Basalt Stone and Margalla hill stone were selected and investigated for their properties by ASTM. Basalt rocks are available in Kohistan, Ranikot, Dargai complex Peshawar, Mohmand district and Hazara.

We used two specimens, basalt coarse aggregate and Margalla coarse aggregate. We have to make concrete cubes with X-Section of (10 x 10) cm with varying thickness from 2 to 10 cm at an interval of 2 as shown in Table 1

No. of molds having water-cement ratio 0.35

Table 1

Thickness (Cm)	2	4	6	8	10
No. of molds for Basalt Concrete	1	1	1	1	1
No. of molds for normal Concrete	1	1	1	1	1
Total No. of molds	2	2	2	2	2

Similarly, for other ratios i.e. 0.57

We have to make 20 molds, of which 10 molds for the basalt coarse aggregate concrete and 10 molds for the Margalla coarse aggregate concrete.

II. i. Chemical Analysis

Chemically, basalt contains 45% to 52% SiO_2 which is an indication that they are basic. They are also high CaO and Al_2O_3 values reflecting the more plagioclase content and a significant amount of FeO and Mgo representing the presence of the major ferromagnesian mineral components such as pyroxene and olivine (minor amount of magnetite, limonite, biotite and chlorite, when present, also contribute). We are doing a chemical analysis test on basalt stone in PCSIR, Peshawar. After the analysis of stone, it contains the parameters that are given in Table 2

Table 2

Parameter	Results
Silica as SiO_2	48.00
Aluminum as Al_2O_3	12.00
Iron as Fe_2O_3	10.00
Calcium as CaO	18.00
Magnesium as MgO	12.00
Loss on Ignition (LOI)	00.50
Total	100.50

II. ii. Lab Activities

In Lab activities, we have performed a different experiment on materials that are used in our project. The experiment is done according to the ACI standard that is given in Table 3.

Table 3

F.M of fine aggregate	2.4
Maximum aggregate size down	¾ inch down
Dry rodded unit weight of normal coarse aggregate	101.91 lb/ft^3
Specific gravity of fine aggregate	2.47
Water absorption capacity of fine aggregate	1.11%
Water absorption of normal coarse aggregate	1.37%
Specific gravity of normal coarse aggregate	2.65
Specific gravity of basalt coarse aggregate	3.2
Water absorption of basalt coarse aggregate	0.23%
Dry rodded unit weight of basalt coarse aggregate	112.12 lb/ft^3

II. iii. Mix Design

We use two ratios of mix design, one for Margalla coarse aggregate and the other for basalt coarse aggregate. The design strength for both coarse aggregate is 3000 psi. The coarse aggregate ratio is 1:2.309:3.286 for Normal and the coarse aggregate proportion is 1:1.98:3.61 for basalt. The design strength for both coarse aggregate is 3000 psi. We used two w / c ratios, 0.57 and 0.35, respectively.

III. Result and Discussion

Penetrating electromagnetic radiation arising from the radioactive decay of atomic nuclei is gamma rays. As a **x**-ray passes through matter, it consists of photons in the highest observed photon energy spectrum; the probability of absorption is proportional to the layer thickness, the material density, and the cross-section of the absorption of the material. With high-intensity radiation sources, when the walls serving for radiation shielding simultaneously perform the function of structural elements of the building housing the source, e.g., with ion or electron accelerator and nuclear reactors, the thickness of the walls is defined primarily by the required radiation shielding and not by statistical aspects, since from the construction view thinner wall would usually do as well. It is preferable to test the serviceability of such walls concerning radiation shielding and for such tests, inspection with gamma rays in general use. However, with increasing wall thicknesses, higher energies and intensities of the radiation will be required. In this very research, we pursued the attenuation power of the two different concrete specimens with distinct properties and with varying thicknesses and subsequently compare the aftermath of both concrete specimens. In realistic conditions, the gamma (X-rays) photons reaching the detector (the human organism to be protected) by multiple scattering on the shield must also be taken into account. The theoretical discussion of this project is beyond the scope of the present paper hence we are only confined to the shielding effects of concrete samples against Gamma rays. The result is given in the following tables.

Table 4

Material	thickness (Cm)	Radiations mcr/30sec with tray	Radiations mgr/30sec without tray	W/C Ratio
Basalt	2	275.5	295.6008584	0.57
Basalt	4	213.7	229.2918455	0.57
Basalt	6	146.6	156.9593148	0.57
Basalt	8	115.7	123.875803	0.57
Basalt	10	82	87.79443255	0.57
Material	**thickness (Cm)**	**Radiations mcr/30sec with tray**	**Radiations mgr/30sec without tray**	**W/C Ratio**
Normal	2	288.4	309.4420601	0.57
Normal	4	224.7	241.0944206	0.57
Normal	6	153.9	164.7751606	0.57
Normal	8	125.5	134.3683084	0.57
Normal	10	98	104.9250535	0.57

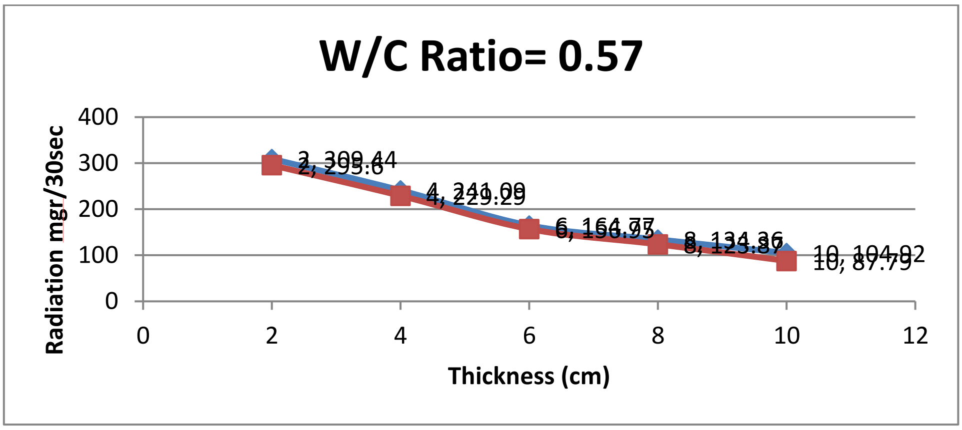
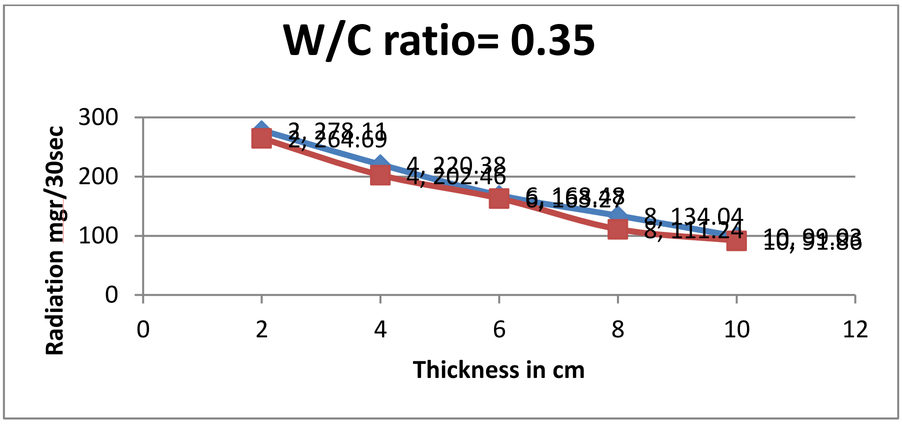


Table 5

Material	thickness (Cm)	Radiations mcr/30sec with tray	Radiations mcr/30sec without tray	W/C Ratio
Basalt	2	246.7	264.6995708	0.35
Basalt	4	188.7	202.4678112	0.35
Basalt	6	152.5	163.2762313	0.35
Basalt	8	103.9	111.24197	0.35
Basalt	10	85.8	91.86295503	0.35
Material	thickness (Cm)	Radiations mcr/30sec with tray	Radiations mcr/30sec without tray	W/C Ratio
Normal	2	259.2	278.111588	0.35
Normal	4	205.4	220.3862661	0.35
Normal	6	155.5	166.4882227	0.35
Normal	8	125.2	134.0471092	0.35
Normal	10	92.5	99.03640257	0.35



IV. Conclusion

To conclude the standard test procedure for the determination of attenuation energy from the sample, it is observed that the attenuation is greatly affected by variation in water to cement ratio (W/C). Therefore, it is recommended to maintain a healthy W/C ratio to obtain good shielding property. If a batch is not properly mixed, the result will not represent the actual protection of basaltic concrete. It can be also concluded from the test and results that basalt despite having strong physical properties is insufficient to be used for Gamma shielding. As the results of both materials differ by a very little margin so it is insignificant to be used for a specific purpose. Other materials are having such properties and have been used in concrete for the very purpose i.e. Barite, Magnetite etc. having a specific gravity greater than 3.5 shows optimum results It can be concluding that the attenuation property doesn't depend upon density only. Attenuation energy might also depend on **Effective atomic number** (Sum of electron donated by all ligands and those represent central metal ion) **Coefficient of attenuation** (Is a volume of material characterized by how easily it can penetrate by a beam of energy source greater the coefficient greater will be attenuation and vice versa) **Source of energy** (Cobalt 60, potassium-40, Radon, Cosmic rays)

V. Recommendations

The following are the various recommendations on the basis of our research work.

- As discussed above that the attenuation energy is greatly affected by the W/C ratio so it is recommended to maintain a healthy W/C ratio for getting good shielding property
- Mix design should be done properly by eliminating all major and minor errors.
- One should not consider that attenuation depends upon density only i.e. density is not only governing factor radiation protection
- Attenuation depends on the radiation type.
- For gamma and x radiation, the main factor is electron density (which is as closely related to mass density as to make no difference for practical purposes).

- This is because gamma and x-rays interact with electrons, so the more electrons per unit volume, the better. For most materials in the main gamma energy range encountered for important isotopes such as Cs-137 and Co-60, Compton scattering is the dominant interaction process.
- The second area of importance is the atomic number, Z. This is important as high Z increases the probability of photoelectric effect and pair production. So dense high Z materials make effective gamma shields. Lead and depleted uranium are good examples.
- For neutrons, which do not feel the electrostatic forces, electrons are unimportant. Besides, the speed of neutrons has a big effect on the probability of absorption, so an effective neutron shield uses the material to slow neutrons down (a *moderator)* and a capture medium.
- Water is a good neutron shield as it moderates well and has a reasonable probability of neutron capture. An ideal material would be a boronated polymer, as the polymer is a good moderator and boron has a big probability of capturing a slow neutron.

Conflict of Interest:

Authors declared : No conflict of interest regarding this article

References

I. Asad-ur-Rehman Khan, Tatheer Zahra, : Elasto-damage Modeling of Concrete Subjected to Proportionate and Non-proportionate Multiaxial State of Stress, J. Mech. Cont. & Math. Sci., Vol.-14, No.-2, March-April (2019) pp 7-26.

II. Abdo, W. Kansouh and R. Megahid, "Investigation of Radiation Attenuation Properties for Baryte Concrete", *Japanese Journal of Applied Physics*, vol. 41, no. 1, 12, pp. 7512-7517, 2002. Available: 10.1143/jjap.41.7512 [Accessed 8 October 2020].

III. A. El-Sayed Abdo, M. Ali and M. Ismail, "Influence of magnetite and boron carbide on radiation attenuation of cement–fiber/composite", *Annals of Nuclear Energy*, vol. 30, no. 4, pp. 391-403, 2003. Available: 10.1016/s0306-4549(02)00074-9.

IV. M. Kharita, S. Yousef and M. AlNassar, "The effect of carbon powder addition on the properties of hematite radiation shielding concrete", *Progress in Nuclear Energy*, vol. 51, no. 2, pp. 388-392, 2009. Available: 10.1016/j.pnucene.2008.10.002 [Accessed 8 October 2020].

V. C. Lee, Y. Lee and K. Lee, "Cracking effect on gamma-ray shielding performance in concrete structure", *Progress in Nuclear Energy*, vol. 49, no. 4, pp. 303-312, 2007. Available: 10.1016/j.pnucene.2007.01.006 [Accessed 8 October 2020].

VI. A. Ouda, "Development of high-performance heavy density concrete using different aggregates for gamma-ray shielding", *Progress in Nuclear Energy*, vol. 79, pp. 48-55, 2015. Available: 10.1016/j.pnucene.2014.11.009 [Accessed 8 October 2020].

VII. Pignatelli, A. Kumar, R. Alizadeh, Y. Le Pape, M. Bauchy and G. Sant, "A dissolution-precipitation mechanism is at the origin of concrete creep in moist environments", *The Journal of Chemical Physics*, vol. 145, no. 5, p. 054701, 2016. Available: 10.1063/1.4955429 [Accessed 8 October 2020].

VIII. Pignatelli, A. Kumar, R. Alizadeh, Y. Le Pape, M. Bauchy and G. Sant, "A dissolution-precipitation mechanism is at the origin of concrete creep in moist environments", *The Journal of Chemical Physics*, vol. 145, no. 5, p. 054701, 2016. Available: 10.1063/1.4955429 [Accessed 8 October 2020].

IX. .Rudnov, V. Belyakov and R. Galiakhmetov, "New Concrete for Protection from Radiation in the Urals Based on Natural Fillers", *Solid State Phenomena*, vol. 284, pp. 1042-1046, 2018. Available: 10.4028/www.scientific.net/ssp.284.1042 [Accessed 8 October 2020].

X. Rudnov V., V. Belyakov and R. Galiakhmetov, "New Concrete for Protection from Radiation in the Urals Based on Natural Fillers", *Solid State Phenomena*, vol. 284, pp. 1042-1046, 2018. Available: 10.4028/www.scientific.net/ssp.284.1042 [Accessed 8 October 2020].

XI. khan Imtiaz, Intikhab Ahmad, Fawad Ahmed, Muhammad Zeeshan Ahad, : Mechanical behavior of concrete having springs at different zones, J. Mech. Cont.& Math. Sci., Vol.-14, No.-3, May-June (2019) pp 385-392