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Feasibility Study of Using Recycled Coarse Aggregate as a Radiation Shielding Material

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Abstract— Radiation shielding is considered as a highly sensitive issue in the department of medical physics. Proper utilization of material in radiation shielding can be effective in terms of economy, durability and safety measure. Concrete is nowadays extensively used as a material for radiation shielding. The coarse aggregate of concrete plays an important role in concrete density where the density is related to the radiation attenuation. In this research, the feasible study has conducted of using the recycled coarse aggregate in radiation shielding. The focus of this paper is to introduce a possible better alternative of fresh aggregate to make the concrete shielding. Two types of recycled aggregates were taken; recycled stone aggregate (RCA) and recycled brick aggregate (RBA). Aggregate material properties were found out at the beginning of the research. As the Brachytherapy unit used in the research, the Cobalt-60 (Co-60) was selected as a source of photon energy. Then the HVL and TVL were measured based on the attenuation of radiation. The study shows that the use of recycled concrete in the radiation shielding is optimistic.

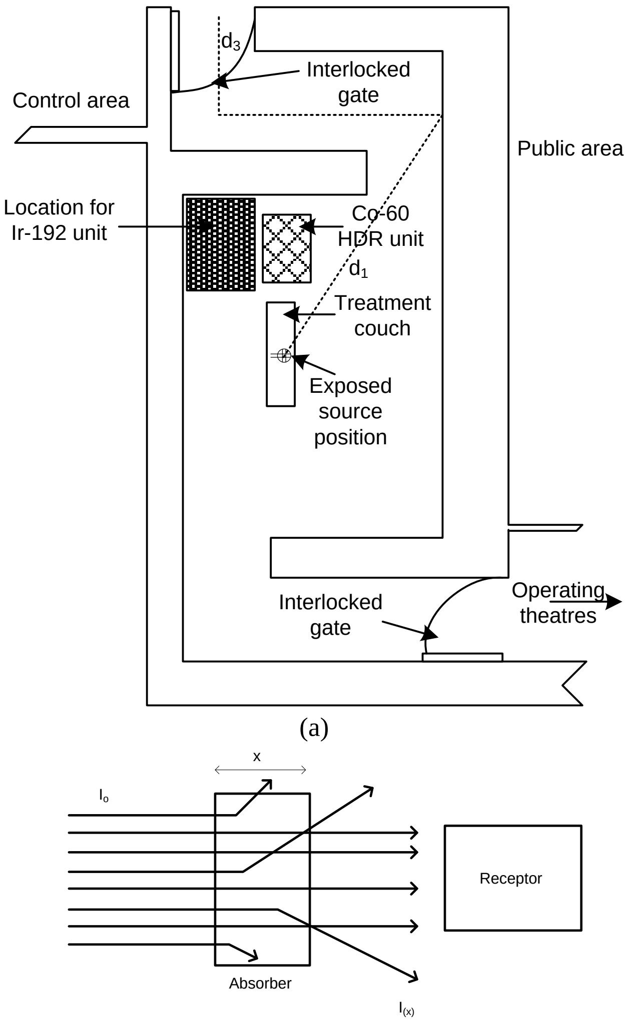
Index Terms— Recycled coarse aggregate, attenuation coefficient, radiation shielding, Co-60.

I. INTRODUCTION

As an expected increase in the construction of brachytherapy facilities, radiation related facilities should be carried out in specially designed shielded treatment rooms. Brachytherapy sources should be kept behind shielding except when in or being inserted into the patient. Even when the sources are in the patient, shielding barriers should be used to provide some protection for the staff and visitors. That's why this shielding demands more safety measure.

Concrete is nowadays extensively used as a material for radiation shielding. Introducing the recycled concrete in radiation shielding as a shielding material is a great advancement of material science in the field of medical physics. Nowadays concrete is vastly used as a radiation shielding material because of its low cost and commonly availability. Now the focus of this research is to bring the recycled concrete (concrete that made of recycled coarse aggregate) as a better replacement of fresh concrete. Sometime the engineers are so concerned about the usage of recycled concrete. This paper shows the possible of application of recycled concrete in radiation protection sector shown in Fig. 1(a) [5] and Fig. 1(b). In the research work recycled stone aggregate (RSA) and recycled brick aggregate (RBA) were. This recycled concrete is collected from the construction sites after demolishing the building.

The collected recycled concrete is crushed into small chips which are then used as a coarse aggregate in making the concrete taken which are shown in Fig. 2. Finding out the possible application of the concrete using recycled coarse aggregate based on the parametric studies is the main concern of this research.



(a)

(b)

Fig. 1: (a) Model of brachytherapy shielding room & (b) Process of energy attenuation

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(a)

(b)

Fig. 2. (a) Recycled brick aggregate & (b) Recycled stone aggregate

II. MATERIAL PROPERTIES

A. Recycled aggregate

1) Density

The density of the coarse aggregate and the radiation attenuation coefficient are directly related. The recycled coarse aggregates were tested in the laboratory to find out the density (ρ) of the aggregate. The average density of the coarse aggregates is given in Table 1 [1].

Table 1. Density of different types of coarse aggregate

Material	Density (Kg/m^3)
Recycled stone aggregate	1328
Fresh stone aggregate	1527
Recycled brick aggregate	1263
Fresh brick aggregate	1079

2) Gradation of coarse aggregate

Gradation of coarse aggregate plays a very important role in density of concrete. The word "grading" refers to the combination of various sizes of aggregates in a certain proportion to make well graded coarse aggregate. Aggregate gradation affects the strength, durability, economy, water-cement ration. For mix design of concrete, three different sizes of aggregate were taken for all the types of coarse aggregate. Aggregates in 1″ passing and ¾″ retained, ¾″ passing and ½″ retained, ½″ passing and #4 retained were taken. The smooth well graded curve are drown for recycled stone aggregate and recycled brick aggregate shown in Fig. 3 and Fig. 4. From that gradation curve it is seen that 1″ passing and ¾″ retained size aggregate required 10 %, ¾″ passing and ½″ retained size aggregate required 32 % and ½″ passing and # 4 retained size aggregate required 58 %.Then we mixed those proportion according to that gradation curve to get the desired aggregate.

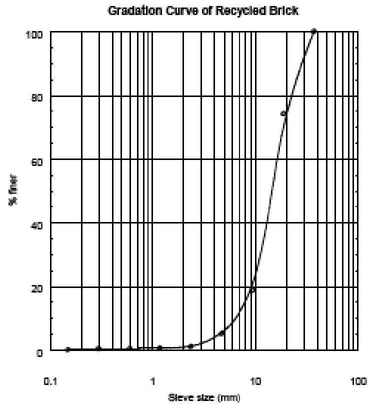

Fig. 3 Gradation curve of recycled brick

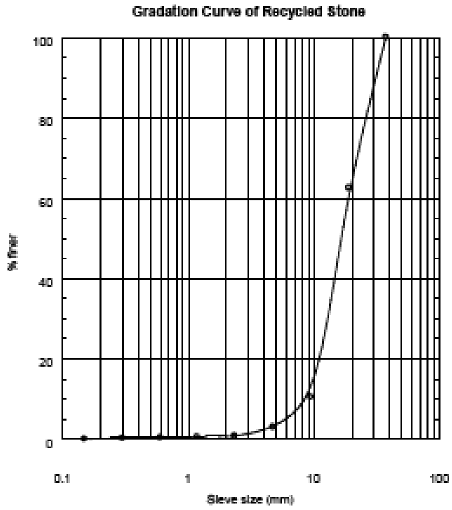

Fig. 4 Gradation curve of recycled stone

B. Cobalt-60

In this work, calculation was done for high dose rate (HDR) Cobalt-60. HDR Co-60 source is manufactured by BEBIG (Germany) for the Multi-Source HDR after loader. The designed source active length 3.5 mm and total external diameter of 1.0 mm shown in Fig. 5 [6].

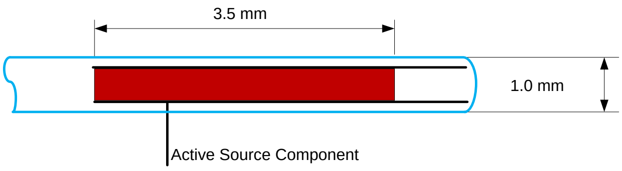

Fig. 5. Design Source for HDR Co-60, The HDR The curietron multisource HDR (BEBIG, Germany)

Cobalt isotope emits radiation in two or three discreet wavelengths. Cobalt-60 emits 1.33 and 1.17 MeV Gamma rays.

III. THEORETICAL ANALYSIS

A. Attenuation Coefficient

The linear attenuation coefficient (μ) is determined from the mass attenuation coefficients (μ/ρ). The mass attenuation coefficient is calculated using XCOM code [2, 4].

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B. Half-Value and Tenth-Value Layers

The attenuation of photons by various absorbing materials under ideal narrow beam conditions satisfies given the relationship [3].

$$I(x) = I_0 e^{-\mu x} \tag{1}$$

where, I_0 is the initial photon intensity (fluence or flux), $I(x)$ is the photon intensity after passing through an absorber, x is the thickness in narrow-beam geometry, and μ is the total attenuation coefficient (cm^{-1}),

It is important to express the exponential attenuation of photons in terms of a half-thickness or half-value layer (HVL). The HVL is the thickness of absorber required to decrease the intensity of a beam of photons to one-half its initial value which can be expressed as [3],

$$\frac{I(x)}{I_0} = 0.5 = e^{-\mu x_{1/2}} \tag{2}$$

where, $x_{1/2}$ is the half-value thickness. Now,

$$x_{1/2} = HVL = \frac{\ln(2)}{\mu} \tag{3}$$

In a same way, the tenth-value layer (TVL) is the thicknesses of attenuating material that decrease the photon beam intensities to 10% of the original value (100%) and that can be expressed as [3],

$$TVL = \frac{\ln(10)}{\mu} = \frac{2.303}{\mu} \tag{4}$$

IV. RESULT

As it was mentioned before that the attenuation coefficient will be determined from mass attenuation coefficient. From the XCOM calculation, the resulted graph of mass attenuation graph is shown in Fig. 6.

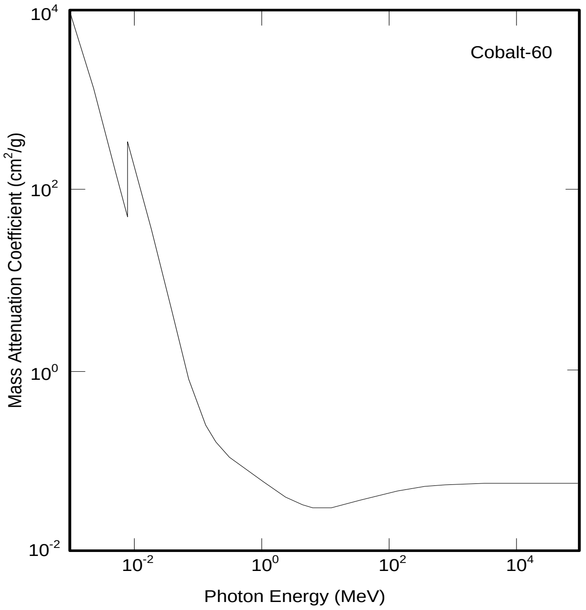

Fig. 6. Graph of mass attenuation coefficient (μ/ρ) vs photon energy

The calculated attenuation coefficients (μ) for different types of coarse aggregates are shown in Fig. 7 and Fig. 8.

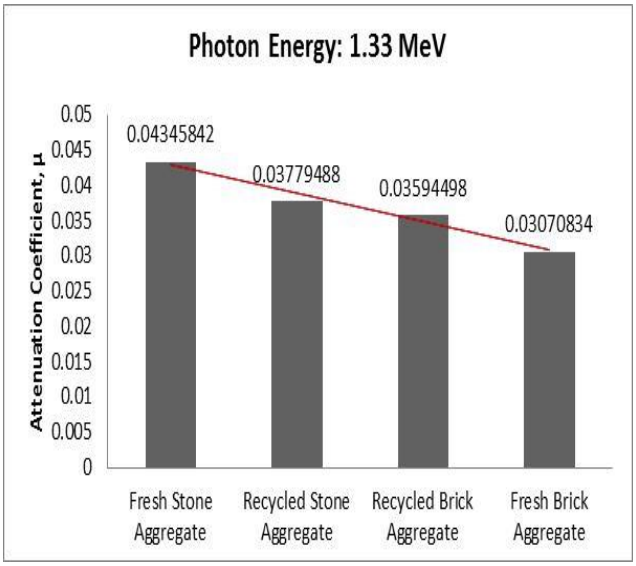

Fig. 7. Attenuation coefficient (μ) for different aggregates at 1.33 MeV photon energy

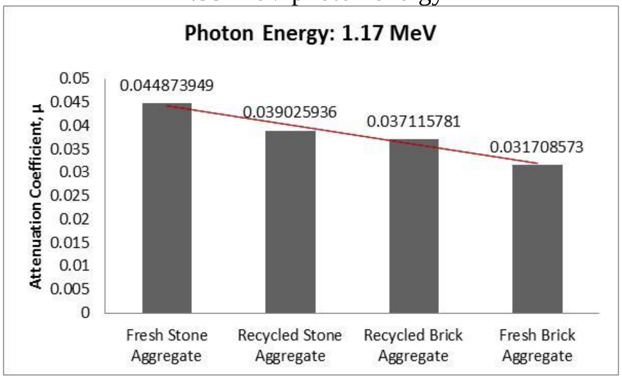

Fig. 8. Attenuation coefficient (μ) for different aggregates at 1.17 MeV photon energy

Half value layer plays an important role on radiation shielding. The thickness of variation as per the density is clearly given in the Fig. 9 and Fig. 10.

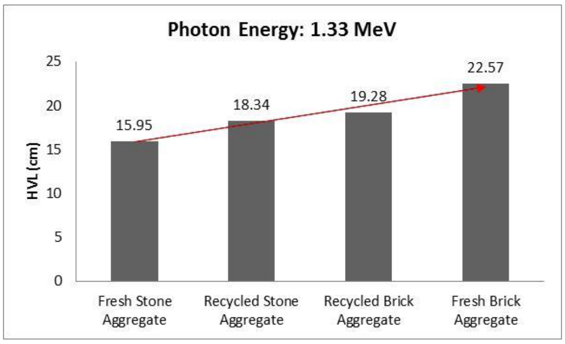

Fig. 9. HVL value for different aggregates at 1.33 MeV photon energy

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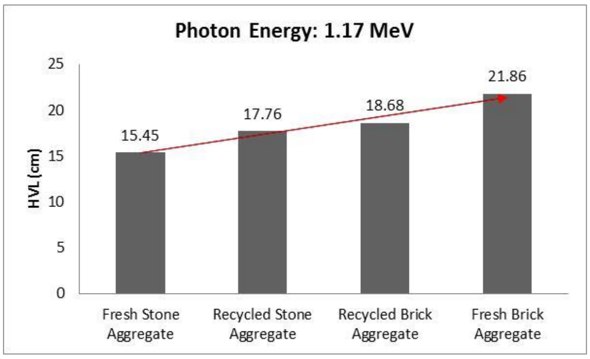

Fig. 10. HVL value for different aggregates at 1.17 MeV photon energy

Tenth value layer is also calculated for finding its thickness after using recycled and fresh aggregates. The comparative bar chart is given in Fig. 11 and Fig. 12.

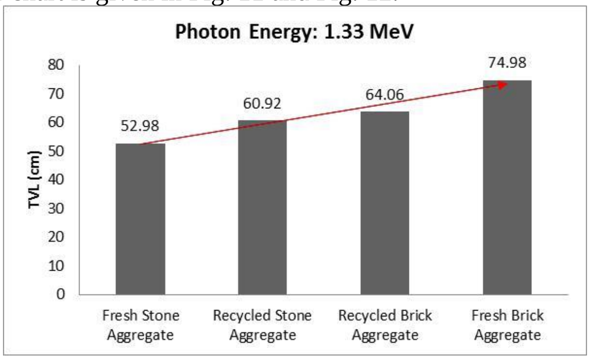

Fig. 11. TVL value for different aggregates at 1.33 MeV photon energy

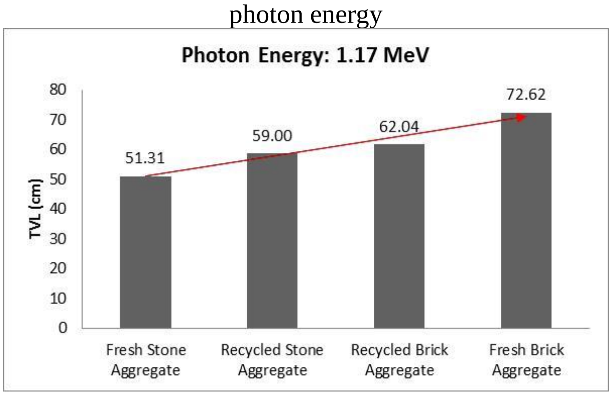

Fig. 12. TVL value for different aggregates at 1.17 MeV photon energy

V. CONCLUSION

As Co-60 emits two photon energies and these are 1.33 and 1.17 MeV. From this research study, the following conclusions can be determined for the both photon energies,

1. Radiation attenuation coefficient (μ) depends on the density of the coarse aggregates. Attenuation coefficient decreases with the decrement of the coarse aggregate which is clearly shown in Fig. 7 and Fig. 8.
2. In case of HVL and TVL, Fig. 9 to Fig. 12 describes the thickness increases due to the decrease of density of the coarse aggregate.
3. The most vital finding is about recycled stone aggregate and recycled brick aggregate. Form each figure it is clearly expressed that the fresh stone aggregate shows the best attenuation characteristics, but on the other hand the RSA and RBA show a very close attenuation performance which is higher than fresh brick aggregate. Therefore it can be concluded that it is better to use the RSA and RBA instead of using fresh brick aggregate as a radiation shielding material.
4. After studying every point of view, it can be said that there is a large scope to use the recycled coarse aggregate as a radiation shielding material.

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