

# Radiation shielding properties of ferro-boron concrete

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**Abstract.** The problem of shielding against gamma and neutron radiation in nuclear facility have always attracted a great deal of attention. Typically, the best-known materials for shielding both gamma-ray and neutrons are concrete. However, due to low neutron absorption cross section in ordinary concrete, it can only weakly absorb thermal neutrons. In order to increase the neutron capture cross section, additional compound was mixed into the original concrete. In this paper, we have used ferro-boron compound to enhance the radiation shielding properties of concrete. Ferro-boron is an alloy, which is formed by combining iron with boron compound content between 10% to 17%. In this work, Monte Carlo simulation codes of MCNPX was used to simulate the radiation shielding properties of ferro-boron concrete. According to the simulation results, it is clearly shows that adding ferro-boron compound into concrete mixture can significantly enhance the radiation shielding properties of the concrete.

## 1. Introduction

Protection of biological entities from the harmful effects of radiation exposure is fundamental requirement in the application of nuclear technology [1]. Nowadays, many fields use nuclear technology in their application such as agriculture, cancer treatment centre, nuclear research reactors, nuclear power plant, industry inspections and research facilities has set people and environment around the facilities in serious exposure from ionizing radiation. Hence, an adequate protection is needed to ensure people and environment around the nuclear facilities is safe from any harmful effects of ionizing radiation. Radiation exposure can be avoided by methods involving time, distance and shielding [2]. Shielding is the most important method as compared to the others [3]. Typically, concrete is widely used as radiation shielding in many nuclear facilities [4].

Concrete is mainly made up from cement, aggregates and water. The properties of the materials used in the concrete give significant affect to the radiation shielding capability of the concrete [5]. In this study, we have used ferro-boron compound as aggregates for the concrete. Ferro-boron is an alloy which is formed by combining iron with boron compound between 10% to 17% [6]. Boron has large absorption cross section (700 -760 b) and <sup>10</sup>B which 19.9% of nature boron, has huge thermal neutron absorption cross-sections (3840 b) [2]. Thus, it is important to include boron compounds in concrete mixture to enhance its capability as a biological shielding material.

Several studies have been carried out on the radiation shielding properties using different materials. D. Venakata [7] has compared neutron attenuation properties of ferro-boron slabs with other high



density materials including ferro-tungsten, boron carbide and mild steel plates. S.Özavci [3] and S. J. Stankovic [5] have measured and simulated linear attenuation coefficients for concrete containing different type of materials.

In this paper, we have calculated the minimum shielding thickness wall of concretes containing ferro-boron against the thermal neutrons (0.025 eV) and gamma radiation (1173 keV and 1332 keV) by using Monte Carlo simulation codes of MCNPX.

## 2. Methodology

In this work, Monte Carlo simulation code of MCNPX version 2.6 was used to simulate the transmitted thermal neutron and gamma-ray from ferro-boron concrete with different density. The elemental compositions and densities of the materials used in this work shown in table 1. Table 2 shows five different samples that have been simulated in this study.

For simulations, input files have been prepared. In this input files, irradiation geometry, material definition, physical settings and tally options have been represented in sequential order. A cube of 100 cm dimensions was used in this code as a shielding concrete. A beam of thermal neutron (0.025 eV) and gamma-rays (1173 keV and 1332 keV) were directed toward the shielding concrete. Cubical ferro-boron are added to the concretes. The code was run for 100 million particles history. F2 and F4 tally have been used to simulate the average surface flux and average flux in the cell for every 10 cm shielding thickness. Simulation results have been read from MCNPX output files.

**Table 1.** The elemental compositions and density of the materials [6][8].

Material	Element	Fraction (%)	Density (g/cm <sup>3</sup> )
Standard Concrete	C	23.00	2.34
	O	40.00	
	Si	12.00	
	Ca	12.00	
	H	10.00	
	Mg	2.00	
Ferro-Boron	C	0.50	4.00
	Fe	79.40	
	B	17.00	
	Al	1.00	
	Si	2.00	
	P	0.05	
	S	0.05	

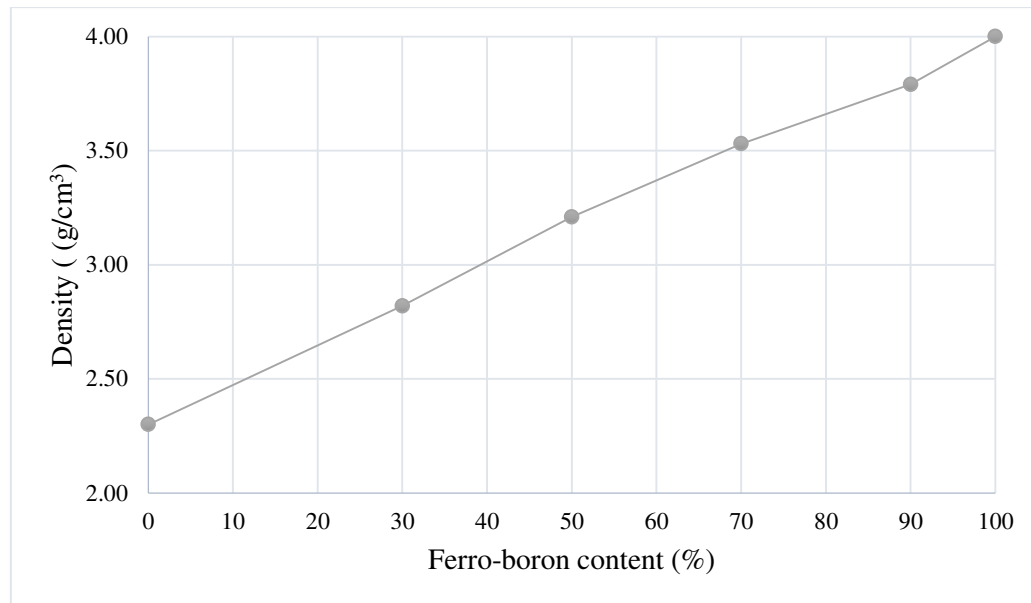
**Table 2.** Ferro-boron contents and density of simulated samples.

Samples	Ferro-Boron Content (%)	Density (g/cm <sup>3</sup> )
Standard Concrete	0	2.30
Concrete + FeB 1	30	2.82
Concrete + FeB 2	50	3.21
Concrete + FeB 3	70	3.53
Concrete + FeB 4	90	3.79
Ferro-Boron	100	4.00

### 3. Results and discussion

Radiation shielding properties of concretes containing ferro-boron compounds were investigated using Monte Carlo method. MCNPX code was used to calculate the minimum shielding thickness of concrete containing the additional material which is ferro-boron.

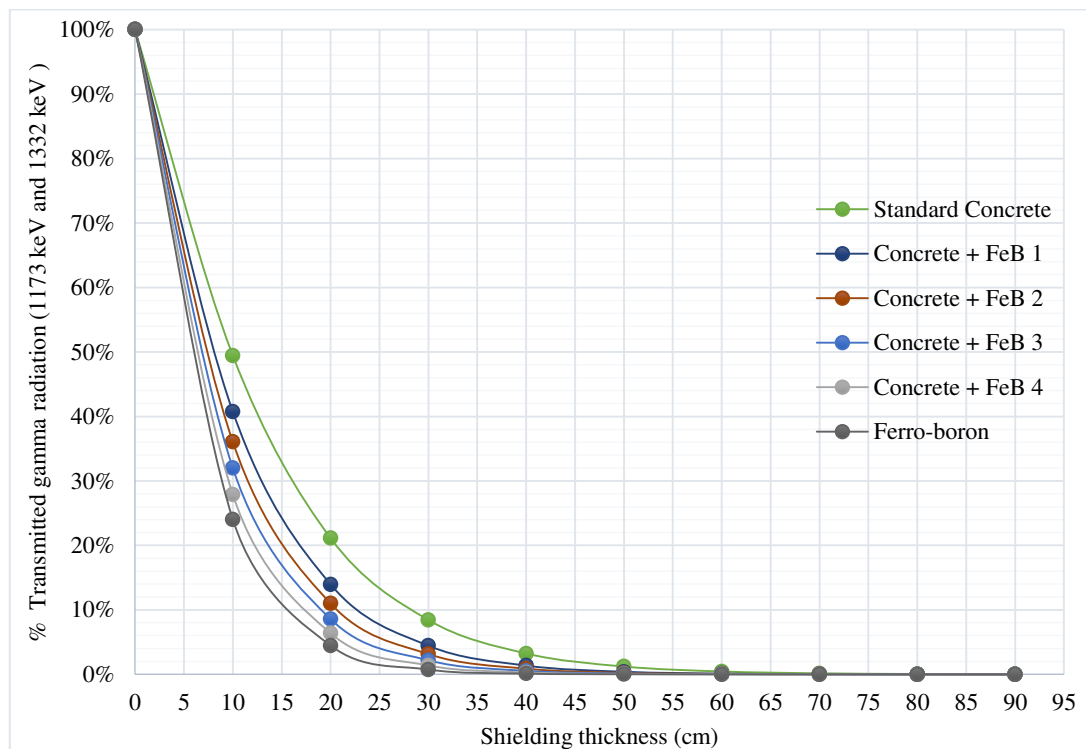
The concentration of ferro-boron in concrete is changed from 0 % to 100 %. The density of standard concrete is smaller than ferro-boron and concrete density can be increase depending on the additional materials. The densities versus ferro-boron content in concrete were plotted in figure 1. From figure 1, the densities of the concrete significantly increase as the ferro-boron content increases.



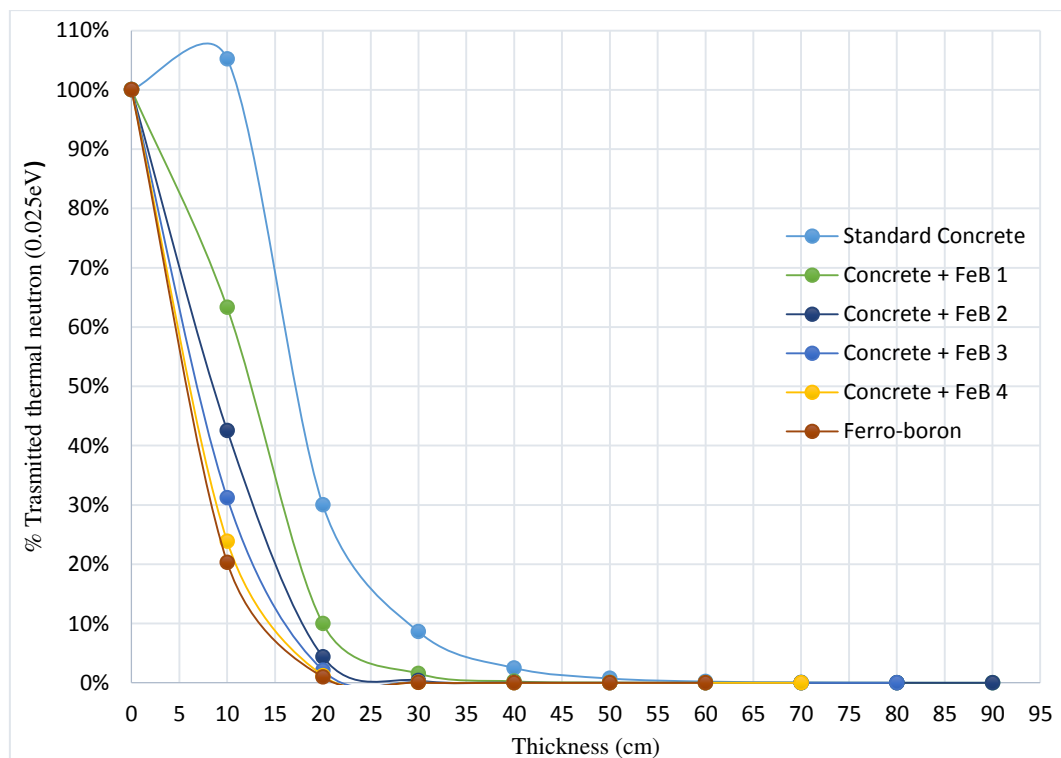
**Figure 1.** The densities of concrete samples with different ferro-boron content.

Simulated gamma and thermal neutron transmission versus shielding thickness were given in figure 2 and figure 3 respectively. From previous investigations, it is known that high density concrete increased its radiation shielding capability and decreased the shielding thickness depending on the properties of additional materials [9]. From figure 2 and figure 3, it is seen that concrete containing ferro-boron capable to block almost all the gamma radiation and thermal neutrons at thickness of 40 cm and 30 cm respectively, while standard concrete needs shielding thickness around 60 cm for shielding gamma and thermal neutron radiation.

Standard concrete curve from figure 3 shows higher transmitted thermal neutron at 2<sup>nd</sup> layer of MCNPX model flux tallied, this is due to multiple scattering within the tallied area. From figure 2 and figure 3, it also seen that concrete containing ferro-boron has better shielding properties for thermal neutron as compared to gamma radiation. This is due to ferro-boron that contain boron compound which has high neutron absorption cross section. Hence, it shows that ferro-boron is capable of enhancing shielding properties of concrete.



**Figure 2.** Transmitted gamma radiation versus shielding thickness.



**Figure 3.** Transmitted thermal neutron versus shielding thickness.

#### 4. Conclusion

In this study, the shielding thickness of concrete containing ferro-boron at different ratios was determined using Monte Carlo simulation code of MCNPX. According to the simulation results, it can be considered that ferro-boron is a good shielding material for enhancing shielding properties of concrete.

It is known that boron is a great thermal neutron absorber material while iron is a crucial shielding material to moderate fast neutrons below 1MeV. Therefore, we should consider adding ferro-boron into concrete mixture as a promising shielding material for neutron application facilities.

#### 5. References

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