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Effect of Serpentine Aggregates on the Shielding, Mechanical, and Durability Properties of Heavyweight Concrete

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ARTICLE

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ABSTRACT

Concrete is a material that can easily absorb nuclear radiation, and in this process, the density of concrete is an essential factor in absorbing the rays. Therefore, due to performance limitations and thickness, heavyweight concrete is used. In this study, serpentine coarse aggregates (SCAg) and serpentine fine aggregates (SFAg) were used as a substitute for sand and gravel in heavyweight concrete containing lead slag to protect against gamma rays. Determination of mechanical properties (compressive strength, tensile strength, and ultrasonic pulse velocity), physical properties (water absorption and electrical resistivity), and shielding properties (shielding against gamma rays) were among the main objectives. The results indicated the positive effect of SFAg and SCAg on the shielding properties of concretes against gamma rays. The replacement of SFAg and SCAg with natural aggregates increased the density of the samples, which resulted in an increase in 3.8 to 42.9% in the linear attenuation coefficient against gamma rays. SFAg has a significant effect on gamma-ray attenuation, especially when these materials are made of high-density minerals, due to their property of reducing the pores in concrete.

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1. INTRODUCTION

Concrete is a primary consumable materials in civil engineering structures due to its technical advantages and better performance in terms of environmental and energy issues [1, 2]. On the other hand, today, with an increasing progress in science and technology, an increase in the use of radioactive radiation in various fields is observed. Despite radioactivity's many applications and benefits, protection against this harmful radiation to cells and living tissues is essential and unavoidable [3-5]. Heavyweight concrete has higher specific gravity than concretes made with conventional aggregates and is usually made using heavy aggregates and is specifically used as a shield against radiation. Today, a long period of time has passed since the production of heavyweight concrete. At first, heavyweight concrete was used to increase the safety of special buildings against earthquake. Heavyweight concrete has been used as a nuclear shield with the development of atomic energy and mainly to prevent the emission of deadly rays such as neutrons and gamma that can penetrate objects [6-9]. It is very important to repel or absorb radiation from radiation because it can be harmful to the environment. Concrete absorbs these rays, and in this process, concrete density is an essential factor in absorbing the rays. Therefore, heavyweight concrete is used due to performance limitations and thickness [10, 11]. Many studies have been done in the field of radiation-resistant concretes. Tekin et al. [13] examined the shielding attributes of hematite-serpentine concrete comprising tungsten (WO_3) and photocatalytic nanoparticles (Bi_2O_3). The results showed that adding nanoparticles to heavyweight concrete improved protective properties, with potential applications in civil engineering constructions and potential use as building materials for

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nuclear facilities [13]. Çullu and Bakirhan [14] investigated lead-zinc mine waste rock and heavyweight concrete in the energy range of 662–1460 keV. The results showed that concrete strength affects radiation absorption [14]. Baalamurugan et al. [15] studied the utilization of steel slag from smelting furnaces in concrete as aggregates for protection against gamma rays. The results showed that using 50% slag is effective in gamma protection [15]. Zayed et al. [16] investigated the effect of heavy aggregates of hematite, barite, and serpentine on the shielding attributes of heavyweight concrete. Barite and hematite aggregates of 25 and 50% of the aggregate were used. Serpentine aggregates of 50% by weight were also used. The behavior of the samples was investigated using gamma ray, compressive strength, and fracture tensile tests. Unlike barite, hematite increases the porosity of concrete. Barite and hematite reduce the mechanical strength of concrete. The use of 50% barite showed the highest radiation resistance. It was found that in addition to barite and hematite, serpentine aggregates increase bulk density and decrease mechanical strength. In addition, unlike barite, hematite increases water absorption [16]. Masoud et al. [17] investigated barite and hematite's effects on concrete's shielding. For this purpose, a gamma radiation test was performed on the samples. The combination of barite and hematite has a negative effect on the physical properties of serpentine concretes and improves compaction. On the other hand, this combination improved the damping properties of serpentine base concretes. This improvement was more effective in the use of barite than hematite [17]. Mymrin et al. [18] investigated the use of waste materials from serpentine aggregates and recycled shards of glass to produce ceramics. XRD, XRF, flexural strength and water absorption tests were performed. The flexural strength of ceramics ranged from 2.85 to 56.97 MPa. The water absorption of the samples was 0.28 to 17.61. At the end, it was concluded that the use of serpentine waste and recycled glass fragments, in addition to being useful in the production of building materials can also be environmentally beneficial [18].

Constructing shielding structures against harmful radiation using concrete made with ordinary aggregates costs much more than making concrete with heavyweight aggregates. Structural elements with normal thickness cannot have a proper response against the radiation of the surrounding environment. Structural elements with normal thickness cannot have a proper response against the radiation of the surrounding environment. The design of structural elements with larger thicknesses, along with the addition of lead sheets, multiplies the project's cost. Also, the project's construction time is another important point in reducing construction costs. In the present study, the combination of serpentine aggregates and lead slag was used to construct heavyweight concretes so that all the above-mentioned cases could be solved. With this concrete, an environment-friendly structure can be provided with the possibility of designing structural and non-structural elements for further use.

The aggregates that can improve the density of concrete can play a role in affecting its shielding properties against radiation. Limited research has been conducted on heavyweight concrete containing serpentine aggregates. Access to waste from serpentine aggregates is easy in Iran, and studies have shown that they can be used in heavyweight concrete. In the present study, the use of serpentine aggregates in heavyweight concrete was investigated with the aim of protection against gamma rays. The purpose of making this concrete is to prevent gamma radiation, and its use is intended for structures related to nuclear facilities or wherever possible radioactive radiation. A combination of serpentine coarse aggregates (SCAg) and serpentine fine aggregates (SFAg) were used as a substitute for natural fine and coarse aggregates (sand and gravel).

2. EXPERIMENTAL PROCEDURES

The present study was conducted in a laboratory manner. The materials used include cement, natural aggregates, serpentine aggregates, water, and superplasticizer. The aggregates were graded according to ASTM C127 [19] and ASTM C128 [20] (Figure 1). Heavyweight aggregates (serpentine aggregates) were obtained from Zakaria mine in Mashhad city in Iran. A stone crusher crushed heavyweight aggregates. XRF analysis of serpentine aggregates is presented in Table 1. The physical and chemical characteristics of cement are shown in Table 1. The water used to make concrete meets the standards recommended by ASTMD-1129 [21]. The lead slag was prepared from the waste battery recycling center .The density of lead slag is equal to 4.08 g/cm^3. The chemical analysis of lead slag is presented in Table 1. The fresh properties were evaluated by slump test according to ASTM C143-78 [22].

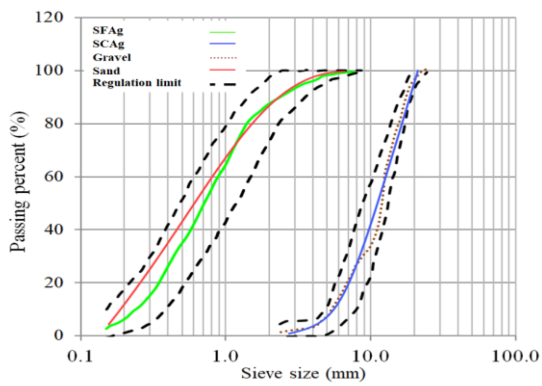

Figure 1. The size of the aggregates used in the investigated heavyweight concrete

TABLE 1. The chemical attributes of the materials used in the investigated heavyweight concrete

Components (wt. %)	Cement	Serpentine aggregate	Lead slag
Al_2O_3	4.95	0.79	2.1
CaO	62.95	0.27	5.1
SiO_2	21.27	41.98	11.8
Fe_2O_3	4.03	7.02	12.9
MgO	1.55	38.55	0
SO_3	2.26	0.03	0.05
K_2O	0.65	0.03	0.18
Na_2O	0.49	0	0.42
Mn_2O_3	-	0.05	-
TiO_2	-	0.04	-
P_2O_5	-	0.03	-
Cl	-	0.02	-
Cr_2O_3	-	0.32	-
NiO	-	0.38	-
CO_3O_4	-	0.04	-
PbO	-	-	48.8
LOI	-	10.45	18.65
Specific gravity	3.15	2.79	4.08

The mechanical attributes of concrete samples were investigated by performing compressive strength, tensile strength, and ultrasonic pulse velocity (UPV) tests (Figure 2). The compressive strength test was performed according to ASTM C39 [23]. This test is one of the most important factors of quality control of concrete and it expresses the tolerance value of the sample in terms of compressive strength. Cube molds with dimensions of 150×150×150 mm were used to make the samples. After concreting, the molds were kept in open air for 24 hours. After this period, the molds were opened and the samples were placed in the water environment and tested. Splitting tensile strength test was performed according to ASTM C496 [24] in order to investigate the tensile strength of the samples. In this experiment, standard cylinders of 150×300 mm were used. The ultrasonic pulse velocity (UPV) was performed according to ASTM C597 [25].

The Durability of concretes was also checked by conducting water absorption [26], and electrical resistivity [27] tests (Figure 3).

A device for measuring the electrical resistivity with a variable frequency of 10 to 10,000 Hz was used. Copper plates were used to attach the two heads of specimen to the device. In order to prevent the copper plates from attaching to the floor and the worktable, 150×150 mm plastic molds were used, and the copper plates were

(a) (c) (b)

Figure 2. The mechanical attributes tests (a) Compressive strength (b) Splitting tensile strength (c) UPV

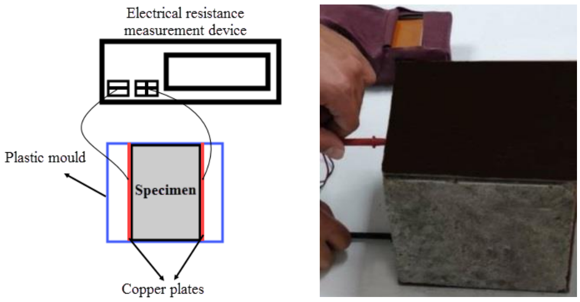

Figure 3. Electrical resistivity test

positioned 100 mm apart. Each of the wires of the device was connected to one of the copper plates, the frequency of the device was set at 10 Hz, and the electrical resistivity number was recorded [1, 27]. Estimation of corrosion probability of buried rebars in concrete based on electrical resistivity is presented in Table 2.

The shielding attributes were investigated using gamma-ray attenuation test (Figure 4). Concrete samples with dimensions of 10 cm were exposed to gamma rays for 10 minutes. In this experiment, radiation source, cs137 was used. A cylindrical lead collimator with an external diameter of 12.5 cm and an inner cavity in the form of an incomplete cone with a diameter of the lower base of 3 cm and a diameter of the upper base of 2 cm, and a height of 2 cm was used around the fountain. The concrete sample was placed at a distance of 4 cm from the spring.

TABLE 2. Estimation of corrosion probability of buried rebars in concrete based on electrical resistivity [28, 29]

Electrical resistivity (kΩ-cm)	Estimation of corrosion probability
Less than 50	Very high
Between 50 and 100	High
Between 100 and 200	Low
More than 200	Very low

Figure 4. Gamma-Ray Attenuation

3. MIXED DESIGN

Table 3 summarized the mixed design. Serpentine aggregates were placed in water for 24 hours before mixing to saturate. Then, their surface was dried with a cloth, and hot air flow to become saturated with the saturated surface dry (SSD). This action was done due to the water absorption of serpentine aggregates. The pores of the grains do not absorb the mixing water required for water and cement hydration activities, and the concrete does not suffer from dehydration and drying. The amount of river sand water absorption was considered 1.5% by weight. In the mixing stage, aggregates and cement were mixed in a mixer for several minutes. Then the mixing water, which was already mixed with the superplasticizer, was gradually added to the dry materials and mixed for 7 to 10 minutes. The concrete was taken out of the mixer, and after the slump test, they were poured into the desired molds.

4. RESULTS AND DISCUSSION

4. 1. Workability

Figure 5 demonstrates slump of heavyweight concrete samples. The slump recommended range according to ACI 211.1-91 [30] for reinforced foundation walls, footings, plain footings, caissons, substructure walls, pavements, slabs, and mass concrete are in the range of 20 to 80 mm. In addition, the slump recommended range for beams, reinforced walls, and building columns are between 20 to 100 mm. The slump of all specimens is in the range of 59 to 74 mm.

Addition of 25% of SCAg and SFAg increased the slump to a negligible amount. However, adding more than 25% of SCAg and SFAg reduced the slump of heavyweight concrete samples. This decrease in slump can be attributed to the water absorption of serpentine aggregates and their rough surface, which has caused the workability of concrete to decrease.

TABLE 3. Mixture design

Mix code	Cement (kg/m^3)	SFAg[a]	SCAg[b]	W/C	Sand	Geavel	LS	SP[d]
F0C0	400	0	0	0.4	430	275	1350	3
F0C25	400	0	68.75	0.4	430	230	1350	3
F0C50	400	0	137.5	0.4	430	185	1350	3
F0C100	400	0	275	0.4	430	90	1350	3
F25C0	400	107.5	0	0.4	360	275	1350	3
F25C25	400	107.5	68.75	0.4	360	230	1350	3
F25C50	400	107.5	137.5	0.4	360	185	1350	3
F25C100	400	107.5	275	0.4	360	95	1350	3
F50C0	400	215	0	0.4	300	275	1350	3
F50C25	400	215	68.75	0.4	300	220	1350	3
F50C50	400	215	137.5	0.4	300	180	1350	3
F50C100	400	215	275	0.4	300	85	1350	3
F100C0	400	430	0	0.4	160	275	1350	3
F100C25	400	430	68.75	0.4	120	275	1350	3
F100C50	400	430	137.5	0.4	70	275	1350	3
F100C100	400	684.87	402.064	0.4	0	0	1350	3

SFA: Serpentine fine aggregates (SFAg)
SCA: Serpentine coarse aggregates (SCAg)
SP: Superplasticizer
W: Water
C: Cement
LS: Lead slag

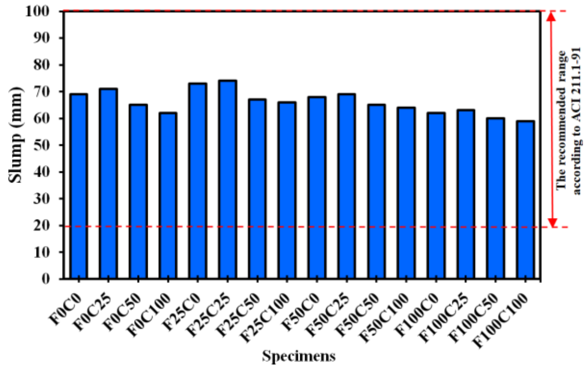

Figure 5. Slump results

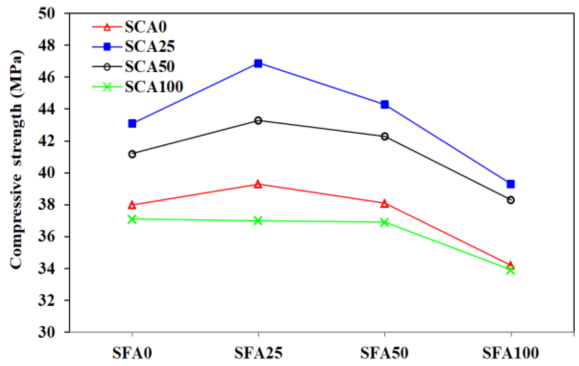

Figure 7. Compressive strength

4. 2. Density The concrete density depends on mixed design (material ratio, granularity distribution), compaction, porosity, humidity and curing method [31]. In Figure 6, the density of heavyweight concrete samples is presented. By increasing the replacement percentage of SCAg with normal aggregates, the density increases. The density of concrete containing 100% SFAg and 100% SCAg is about 15% higher than the control sample. According to EN 206-1 [32] heavyweight concrete has a density of higher than 2600 kg/m^3. The exact amount of this number depends on the weight and type of aggregates, the method of compaction and the aggregates discharge. All the manufactured samples have a density of more than 2600 kg/m^3. The use of 25, 50 and 100% SFAg has increased the density of samples by 1, 3 and 6%. In addition, the density of the samples containing 25, 50 and 100% SCAg increased by 1, 2 and 3%, respectively. The combined use of SFAg and SCAg increased the density of the samples by 1-15%.

4. 3. Compressive Strength The obtained compressive strengths are the average values of three samples (Figure 7). The compressive strength of samples contained 25% SFAg and 25% SCAg has increased by 23.4%. In fact, the lowest compressive strength

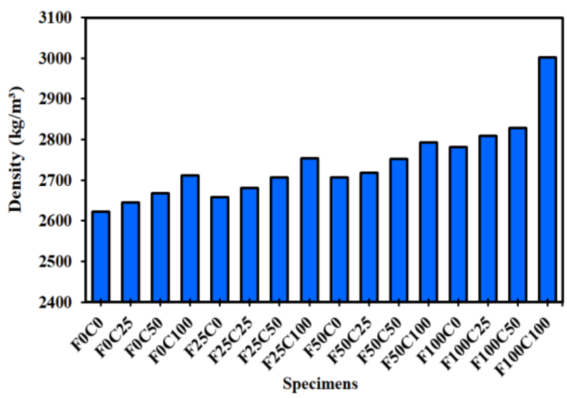

Figure 6. Density test results

corresponds to the sample in which 100% SFAg and 100% SCAg are used. With an increase in serpentine aggregates to more than 25%, the compressive strength of concrete has decreased. According to the observations made, maybe the reason for this decrease in compressive strength is weak hydration of cement paste and insufficient adhesion of cement paste with serpentine aggregates in concrete. The images of samples containing 100% SFAg and 100% SCAg are shown in Figure 8. As can be seen, after breaking the sample, the aggregates were not broken and the crack occurred between the boundaries of the aggregates. Due to the lack of cement around them, the aggregates did not show their performance and showed lower compressive strength.

According to the chemical analysis, about 42% of the chemical structure of serpentine consists of silica. By increasing the amount of serpentine aggregates to more than 25%, the amount of silica in the concrete mixture increases and is more than the released calcium hydroxide. This issue leads to excessive washing of silica and the formation of a weak zone, and a decrease in compressive strength.

4. 4. Splitting Tensile Strength Figure 9 shows the tensile strength of the samples. Each of the presented values is an average of the tensile strength of two 30 x 15 cm cylindrical samples. Similar to the compressive strength results, 25% substitution of SFAg and SCAg has


Figure 8. Failure of the F100C100 sample

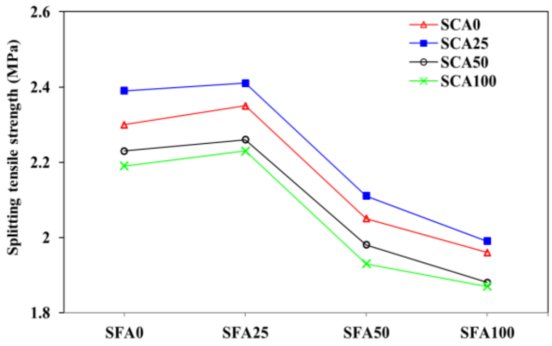

Figure 9. Splitting tensile strength

led to a slight increase in the tensile strength of the samples. The tensile strength of F25C0 and F25C25 samples has increased by 2.2% and 4.8%, respectively. In addition, the tensile strength of the F0C25 sample has increased up to 3.9%. In the other samples, addition of serpentine aggregates has reduced the splitting tensile strength. Among the factors that led to a decrease in the strength of heavy concrete samples containing serpentine aggregates, we can mention holes, concrete porosity and lack of hydration of cement, which were observed during the failure of cylindrical concrete samples.

4. 5. UPV Figure 10 shows the UPV in different designs. It can be seen that by replacing 25% of SFAg with natural fine aggregates, the UPV increased by 1.5%. In addition, the UPV of F25C0 and F25C25 samples increased by 1.26 and 2%, respectively. The UPV of other samples has decreased, but they are not significantly different from the control sample and have decreased by about 2% compared to the control sample.

Whitehurst [33] has made a proposal for the classification of concrete in terms of quality, and according to that, concrete is divided into 5 categories: excellent, good, questionable, poor and very poor. The UPV of the manufactured samples is in the range of 3500 to 4500 m/s. As long as the UPV values are in "good" and "excellent" categories; it means that the concrete in question does not have cracks or large holes that affect the integrity of the sample structure. Almost all the samples are in the range of good category.

4. 6. Water Absorption In Figure 11, the Water absorption percentages of the samples are compared with each other. According to CEB [26], concrete quality is divided into three categories. All samples are in the medium range. The water absorptions of F0C0, F0C25, F0C50 and F0C100 samples were 3.81, 3.95, 4.20 and 4.29%, respectively. Also, the water absorption of F25C0, F25C25, F25C50 and F25C100 samples were 3.61, 3.81, 4 and 4.02% respectively. The water absorptions of F50C0, F50C25, F50C50 and F50C100 samples were 4.1, 4.2 and 4.3% respectively. The water absorptions of F100C0, F100C25, F100C50 and F100C100 samples were 4.6, 4.7, 4.7 and 4.8%, respectively. The lowest water absorption was obtained in the samples in which 25% of SFAg was used. Also, SCAg increased the water absorption.

Adding SFAg up to 25% reduces water absorption. SFAg interrupt the flow channels inside the cement paste matrix and affect the micro cracks in the transition zone between the coarse aggregates and the cement paste, leading to a decrease in water absorption. The use of SCAg increased water absorption in all cases. By increasing the percentage of SCAg in the concrete mix due to an increase in slump and over time with the evaporation of the water in the concrete, holes are created in it, which increases the water absorption in the samples. The highest water absorption is related to the sample with 100% SCAg and 100% SCAg, and the lowest value is related to the concrete sample containing 25% SFAg. SFAg reduces water absorption due to an increase in cement adhesion to the aggregate and the filling of the pores of the aggregate.

4. 7. Electrical Resistivity The electrical resistivity is mainly affected by two basic factors of concrete pore structure and can be a suitable index to appraise the resistance of concrete against chloride

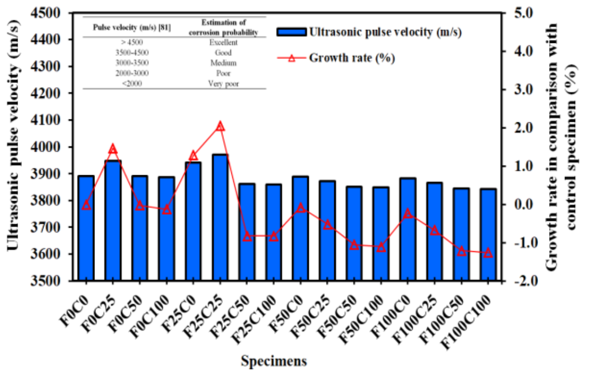

Figure 10. UPV

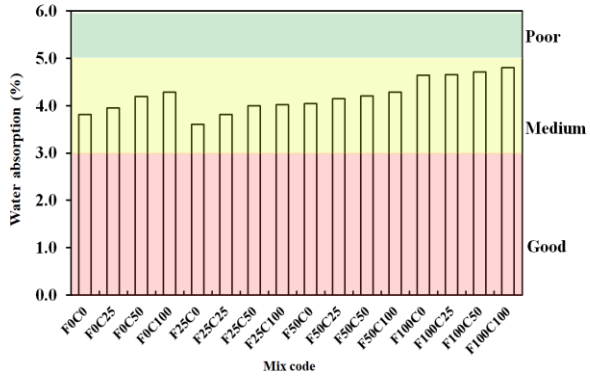

Figure 11. Water absorption

penetration. The samples electrical resistivity are presented in Figure 12. By increasing the amount of SFAs up to 25%, the electrical resistivity samples increased; The electrical resistivity of F25C0, F25C25, and F25C50 mixtures compared to the control sample increased by 11.5, 10.3, and 2.6%, respectively.

RILEM RECOMENDAION TC154-EMC [27] divided concrete samples into 4 categories based on electrical resistance and corrosion probability (Table 2). Based on this, all samples have a low probability of corrosion. An increase in electrical resistivity of samples containing 25% SFAs is due to pozzolanic reactions and reduction of pore liquid conductivity of concretes. The use of 25% SFAs increases electrical resistance and reduces corrosion as a result of increasing the durability. This effect can be justified due to the effect of SFAs on the adhesion of SFAs, which causes the creation of denser and fuller concrete, and as the density increases in concrete, the porosity decreases, which means increasing the durability of concrete.

4. 8. Shielding Properties The linear attenuation coefficient values of the samples in different states are presented in Figure 13. As it is known, the use of SFAg and SCAg has led to an increase in the linear attenuation coefficient. A higher linear attenuation coefficient means that the concrete is in a more ideal condition and shows a reduction in the output flux of gamma rays, which means more protection against radiation. In the samples where natural coarse aggregates were used, by addition of 25, 50 and 100% SFAg increased the linear attenuation coefficient by 3.8, 4.8 and 7.2%, respectively. In the samples containing 25% of SCAg, by addition of 0, 25, 50 and 100% of SFAg increased the linear attenuation coefficient by 24.9, 25.3, 26.3 and 28.7%, respectively. In the samples containing 50% of SCAg, by addition of 0, 25, 50 and 100% of SFAg increased the linear attenuation coefficient by 35.3, 35.6, 36.6 and 39.1%, respectively. In the samples containing 100% SCAg, by addition of 0, 25, 50 and 100% SFAg increased the linear attenuation coefficient by 39.1, 39.5, 40.5 and 42.9%, respectively. The replacement of SCAg, as seen before,

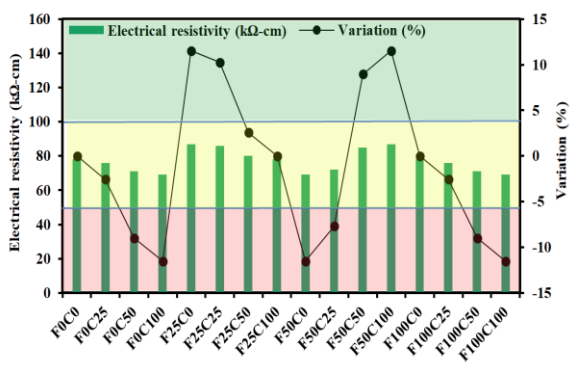

Figure 12. Electrical resistivity

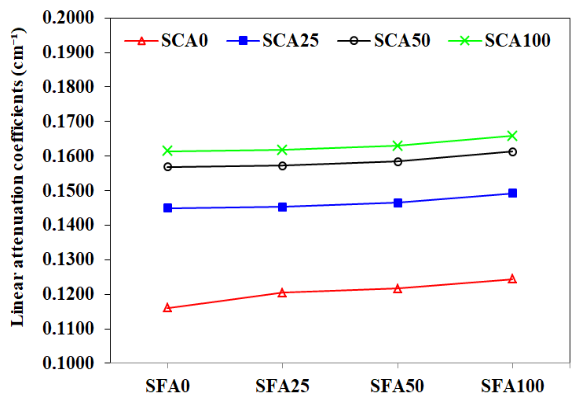

Figure 13. Linear attenuation coefficients

has increased the density of the obtained sample, which results in an increase in 3.8 to 42.9 percent of the linear attenuation coefficient against gamma rays. Just as the need for density of heavy concrete used as protection against radiation was mentioned earlier, the results obtained for concrete samples that were made from serpentine aggregates also confirm this. SFAg have a significant effect on gamma ray attenuation, especially when these materials are made from high-density minerals, due to their property of reducing the pores in concrete.

The two factors of reducing the pores and replacing low density materials with heavier materials are responsible for this improvement in the protective properties of concrete. In general, outcomes of the gamma ray test demonstrate, the great impact of pores on the shielding attributes of concrete; because, when these pores are empty, the radiation passes through it without any interaction or disturbance. It can also be concluded from the above that the effect of filling the pores to increase the radiation attenuation coefficient is greater than the presence of heavy elements. Based on the results, 25% SFAg and 25% SCAg can be considered as the optimal amount to improve the protective features against gamma rays. Because the mentioned values, in addition to improve the protective characteristics of heavy concrete, also lead to the improvement of the mechanical characteristics of concrete.

4. CONCLUSIONS

Workability, mechanical and shielding properties of heavy concrete containing serpentine aggregates were evaluated. For this purpose, SFAg was used as a partial replacement for sand (0, 25, 50 and 100%) and SCAg was used as a partial substitute for gravel (0, 25, 50 and 100%). Workability of heavy concrete samples was evaluated using slump test. The mechanical properties of the samples were investigated. The shielding properties of heavy concrete samples were evaluated through gamma ray testing.

- Addition of 25% of SFAg and SCAg increased the slump values of the samples to a negligible amount. But adding more than 25% of SFAg and SCAg reduced the slump of heavy concrete samples. This decrease in slump can be attributed to the water absorption of SFAg and SCAg and their rough surface, which has caused the workability of concrete to decrease.
- The use of 25, 50 and 100% serpentine sand increased the density of the samples by 1, 3 and 6%, respectively. Also, the density of the samples contained 1, 2 and 3% SCAg increased by 8, 12 and 14%, respectively. In addtion, the combined use of SCAg and SFAg has improved the density of the samples by 1-15%.
- The lowest water absorption was obtained in the samples in which 25% of serpentine grains were used. Also, the use of serpentine aggregates in all samples has increased the water absorption.
- The use of large SCAg increased water absorption in all cases. By increasing the percentage of SCAg in the concrete mix due to an increase in slump and with respect to time with the evaporation of the water in the concrete, holes are created in the samples, which increases the water absorption in the samples. The highest water absorption is related to the sample with 100% SCAg and 100% SFAg, and the lowest value is related to the concrete sample containing 25% SFAg. SFAg reduces water absorption due to an increase in cement adhesion to the aggregate and the filling of the pores of the aggregate.
- The use of 25% of SFAs increased the electrical resistivity and reduced corrosion as a result of increasing the durability. This effect can be justified due to the effect of SFAs on the adhesion of slag paste, which caused the creation of denser and fuller concrete, and as the density increased in the concrete, the porosity decreased, which means the durability of concrete increased.
- Serpentine aggregates increased the density of the obtained sample, which results in an increase of 3.8 to 42.9% in the linear attenuation coefficient against gamma rays. SFAg have a significant effect on gamma ray attenuation, especially when these materials are made from high-density minerals, due to their property of reducing the pores in concrete.
- The two factors of reducing pores and replacing low density materials with heavier materials are the reasons for improving the protective properties of concrete. In general, gamma ray test shows the great impact of pores on the protective properties of concrete; because, when these pores are empty, the radiation passes through it without any interaction or disturbance.

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Persian Abstract

چکیده

بتن ماده‌ای است که به راحتی می‌تواند تشعشعات هسته‌ای را جذب کند و در این فرآیند، چگالی بتن عاملی ضروری در جذب پرتوها است. بنابراین به دلیل محدودیت عملکرد و ضخامت، از بتن سنگین استفاده می شود. در این مطالعه، سنگدانه های درشت سرپانتین و سنگدانه های ریز سرپانتین به عنوان جایگزینی برای شن و ماسه در بتن سنگین وزن حاوی سرباره سرب برای محافظت در برابر اشعه گاما استفاده شدند. تعیین خواص مکانیکی (مقاومت فشاری، مقاومت کششی و سرعت پالس اولتراسونیک)، خواص فیزیکی (جذب آب و مقاومت الکتریکی) و خواص محافظ (محافظت در برابر پرتوهای گاما) از جمله اهداف اصلی بودند. نتایج حاکی از تأثیر مثبت ریزدانه‌ها و درشت دانه‌های سرپانتینی بر خواص محافظ بتن در برابر اشعه گاما بود. جایگزینی ریزدانه‌ها و درشت دانه‌های سرپانتینی با سنگدانه های طبیعی باعث افزایش چگالی نمونه ها شد که منجر به افزایش ۳.۸ تا ٤۲.۹ درصدی ضریب تضعیف خطی در برابر پرتوهای گاما شد. ریزدانه‌های سرپانتینی به دلیل خاصیت کاهش منافذ در بتن، اثر قابل توجهی بر تضعیف اشعه گاما دارد، به ویژه زمانی که این مواد از مواد معدنی با چگالی بالا ساخته شده باشند.