ZERO CEMENT GEOPOLYMER CONCRETE AS AN ANTI-RADIATION MATERIAL WITH IRON SLAG AS A COARSE AGGREGATE

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ABSTRACT

This research aims to analyze the use of iron slag as a substitute for coarse aggregate in geopolymer concrete as an anti-radiation material. In this program, 45 cylindrical 15 × 30 cm test objects were used. Treatment of the specimens was carried out by immersing them in a pool for 7 days, 14 days, and 28 days. Variations in iron slag in this study were taken at 0%, 20%, 25%, 30% and 35%. The radiation test is carried out by exposing the test object to X-rays, which is carried out in the Radiotherapy room at the Dharmais Cancer Hospital, Jakarta The results of radiation tests with a dose of 100 kV, geopolymer concrete with 35% iron slag was able to absorb 17.63% higher radiation than normal test objects without slag. Apart from that, the addition of iron slag with a content of 35% was able to reduce the reduction in compressive strength of concrete exposed to radiation. It was recorded that with 35% slag, there was a reduction in compressive strength of 5.09% after radiation. Based on its specific gravity, geopolymer concrete with 35% iron slag produces a specific gravity of up to 3,162.34 kg/m^3, or an increase of 31.76% from the specific gravity of normal concrete.

Keywords: geopolymer concrete, iron slag, coarse aggregate, radiation, compressive strength.

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INTRODUCTION

Urban infrastructure development is by SDGs (Sustainable Development Programs) number 11, leading to the realization of inclusive, safe, resilient, and sustainable cities and settlements. United Nations Habitat defines a sustainable city as a city that carries out development in the social, economic, and physical fields over a long period. Sustainable urban development has a continuous supply of natural resources by taking into account carrying capacity, carrying capacity, and sustainability. In urban infrastructure development, construction materials such as reinforced concrete, steel, wood, and so on are needed.

One effort to achieve the goal of SDGs 11 (Sustainable Cities and Human Settlements) is to replace materials that can damage natural resources by using waste. The cement industry is included in the list of the top ten industries contributing to air pollution in Indonesia (Wawan Hermawan, 2003). Cement is a powder mixed with water which can bind the material into a solid unit. According to the Chairman of the Indonesian Cement Association (AS), cement production in Indonesia reaches 42 million tons per year, cement demand is estimated at 31 million tons/year, and 7 million tons are for export. Cement is made from clinker which is the main component that produces the largest CO_2 in cement manufacture. Therefore, cement contributes as much as 7% of global CO_2 emissions. PT. Semen Indonesia Merdeka (Tbk) can produce 52.6 tons per year. Based on this, innovation is needed in making concrete materials, one of which is replacing cement material with fly ash so that cement production and air pollution can be minimized. Innovation in the development of concrete construction is carried out through the development of geopolymer concrete which is environmentally friendly and energy efficient [1]. Fly ash-based geopolymer concrete has advantages over conventional concrete. Geopolymer concrete does not require large energy consumption like conventional concrete, reduces the effects of global warming because it does not emit carbon dioxide, and is resistant to aggressive environmental attacks [2].

Coarse aggregate according to SNI-03-2847-2002 [3] coarse aggregate is gravel resulting from the natural disintegration of rock or crushed stone obtained from the stone crushing industry and has a grain size of between 5 mm to 40 mm. Fine aggregate according to SNI-03-2847-2002, fine aggregate is natural sand as a result of the natural disintegration of rock or sand produced by the stone crushing industry and has the largest grain size of 5.0 mm. Cement, coarse aggregate, and fine aggregate are processed products from natural resources which, if continuously exploited in large quantities, will over time become depleted or reduced.

SDGs 3 on health aims to ensure healthy lives and promote well-being for all people of all ages. Quoted from the Indonesian Ministry of Health's website, it is stated that cancer data in Indonesia in 2018 reached 18.1 million cases with a death rate reaching 9.6 million deaths. One method of treating cancer is by using X-rays. This method uses X-rays which will be shot at points where there are cancer cells in the human body. Radiation from X-rays can penetrate certain objects and have harmful effects on living things, radiation can also cause burns to the skin. Therefore, radiotherapy room facilities are needed that can protect against these dangers. One of the construction materials that can be used in building radiotherapy room facilities is concrete. According to Raj,

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et al. (2006), concrete has advantages, namely that it is resistant to fire, can protect embedded steel reinforcement, and can also be used as protection from radioactive waste [4]. Several other researchers have also developed studies of concrete as an anti-radiation construction material [5-11] The construction of a radiotherapy room structure is still relatively rare because it requires quite a lot of money and special conditions must be met for the safety and security of users.

Construction work is expected to also implement the SDGs concept, by using used or waste materials to be recycled and used in building construction. Iron slag is classified as B-3 hazardous waste, the amount of which is increasing as iron production increases. Based on USGS (United States Geological Data Survey) data, iron slag production in 2020 reached 13.4 million. According to Lewis *et al.* (2003), the components contained in iron slag which are the same as cement are very suitable when added to the concrete mixture, with the advantages of reducing the heat of hydration and lowering the temperature, increasing the ratio between flexibility and compressive strength of concrete [12]. Using iron slag as an additional material in geopolymer concrete can help reduce industrial waste, making it more environmentally friendly. Iron slag contains heavy metals such as iron and manganese, which have high atomic numbers. Materials with high atom numbers are more effective in absorbing radiation, so they can increase the anti-radiation properties of geopolymer concrete. This research aims to examine the potential of geopolymer concrete using iron slag as an anti-radiation structural material, especially in terms of utilizing iron slag waste as a substitute for natural coarse aggregate.

MATERIALS AND METHODS

The research object used in this activity is geopolymer concrete made from fly ash with iron slag as a partial substitution of natural coarse aggregate. The physical properties of the aggregate used in this research, are presented in Table-1.

Table-1. Physical properties of aggregate.

Physical Properties	Coarse Agg.	Fine Agg.	Iron Slag
Bulk Specific Gravity	2.55	2.53	2.89
Unit weight	1.46	2.81	1.46
Sludge level	0.89	3.22	0.84
Absorption	2.81	2.86	2.81
Abrasion	20.67	-	21.76
Fineness Modulus	7.75	3.11	7.76

The percentage of iron slag is from 0%, 20%, 25%, 30%, and 35% of the weight of coarse aggregate. In this research, 5 types of concrete mixture were used, which were planned according to the Indonesian standard SNI 03-2834-2000 [13]. Table-2 shows the 5 different concrete mixtures. BGSB 20 is a mixture of 20% coarse aggregate in the form of iron slag, BGSB 25 for a steel slag percentage of 25%, BGSB30 for a 30% iron slag percentage, and BGSB 35 for a 35% iron slag percentage.

Table-2. Material composition per 1m^3 concrete mixture.

Code	fly ash	NA_2SIO_3	NaOH	Coarse Aggregate	Iron Slag	Fine Aggregate	Water
	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
BGSB 0	408	545	218	1201	0	647	14.3
BGSB 20	408	545	218	960,8	240,2	647	14.3
BGSB 25	408	545	218	900,75	300,25	647	14.3
BGSB 30	408	545	218	840,7	360,3	647	14.3
BGSB 35	408	545	218	780,65	420,35	647	14.3

Radiation Test Method

X-ray testing is carried out in the Radiotherapy room at Dharmais Cancer Hospital using X-ray. The doses used to shoot X-rays are 100 kV (kilo Volt) and 75 kV (kilo Volt). The position of the tube is facing downwards towards the examination table which already has a phantom slab which is assumed to be the patient. The position of the test object is on the table at a distance of 1.5 meters from the phantom slab and 1 meter from the wall of the Radiotherapy room. The meter survey tool is placed at a distance of 30 cm from the test object which is located behind the test object and must not be moved. The test objects were shot with X-rays with a first dose of 100 Kv and a second dose of 75 kV, shot at 15 test objects with iron slag percentages of 0%, 20%, 25%, 30%, and 35% with an age of 28 days. During radiation, the door to the Radiotherapy room must be closed and researchers and Radiotherapy room staff are in the operator's room. Figure-1 shows the lighting technique that can be seen on the monitor in the operator's room.

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Figure-1. Radiation room.

The specimens used in this research are a concrete cylindrical test object with a diameter of 150 mm and 300 mm in height. Concrete compressive strength testing is carried out based on the ASTM C39/C39M-2 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens [14]. Figure-2 shows the research flow diagram.

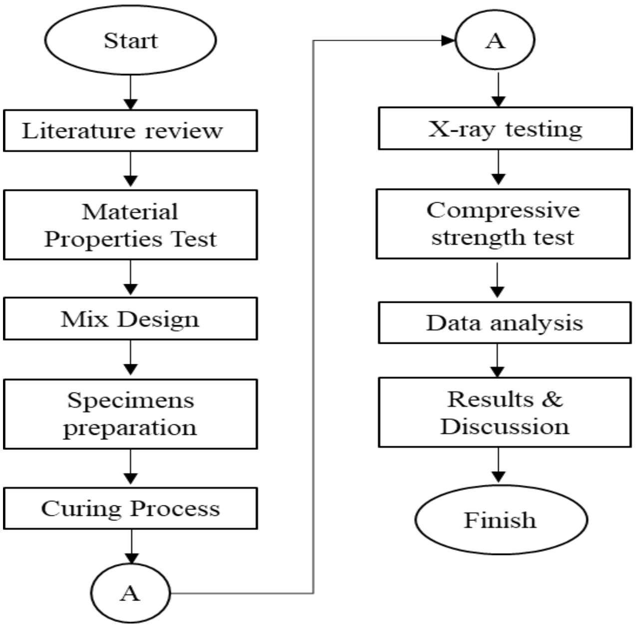

Figure-2. Research flow diagram.

RESULTS AND DISCUSSIONS

Radiation Test

These results were obtained from the test object used in a cylindrical shape with a diameter of 150 mm and a height of up to 300 mm. Researchers tested a total of 15 specimens aged 28 days with different iron slag compositions. The radiation exposure test is as follows. The radiation process is carried out by taking a shooting range of 1.5 m, a background dose of 0.009, and by taking a calibration factor of 1.01.

Table-3. Results of 100 kV exposure radiation.

Test Code	Meter Survey Reading	The Calculation Results	Absorption (µSvh)
Without Barrier	86.8	87,65891	0,00
BGSB 0	85,1	85,94191	1,71
BGSB 20	82	82,81091	4,84
BGSB 25	79,9	80,68991	6,96
BGSB 30	75,8	76,54891	11,10
BGSB 35	70,1	70,79191	16,86

Table-4. Results of 75 kV exposure radiation.

Test Code	Exposure	The Calculation Results	Absorption (µSvh)
Without Barrier	71,8	72,50891	0,00
BGSB 0	65,8	66,44891	6,06
BGSB 20	65,7	66,34791	6,16
BGSB 25	65,2	65,84291	6,67
BGSB 30	65	65,64091	6,87
BGSB 35	63,6	64,22691	8,28

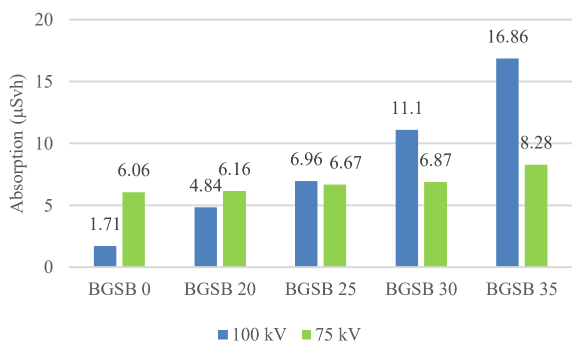

Figure-3. Radiation test results.

Based on Figure-3, the results of radiation tests with a dose of 100 kV, test objects with a percentage of iron slag of 35% were able to absorb 16.86 µSvh of radiation (8.85% higher than normal test objects without slag). Meanwhile, at a dose of 75 Kv, the test object with an iron slag percentage of 35% was able to absorb 8.28 µSvh of radiation (0.36% higher than the normal test object without slag). The higher the absorption number, the better the radiation absorption received by the test object. Based on the results above, it can be stated that a large percentage of iron slag is capable of becoming a material that can withstand radiation and has quite a good absorption capacity.

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Wijaya *et al*. (2018) using barite stone as a substitute for coarse aggregate was proven to increase the density or specific gravity of concrete by up to 53.68% when compared with the density or normal specific gravity of concrete [15]. Concrete with full barite as a coarse aggregate has good absorption of radiation compared to concrete with barite gravel. The higher the density or specific gravity, the better the ability to withstand radiation.

Concrete Compressive Strength

These results were obtained from the test object used in a cylindrical shape with a diameter of 150 mm and a height of up to 300 mm. Researchers made five variations of mixture composition with different percentages of iron slag, which overall produced 45 test object samples that will be used in this research. The compressive strength test was carried out at three different time stages, namely when the concrete reached 7 days, 14 days, and 28 days. Compressive test results data are presented in Figure-4.

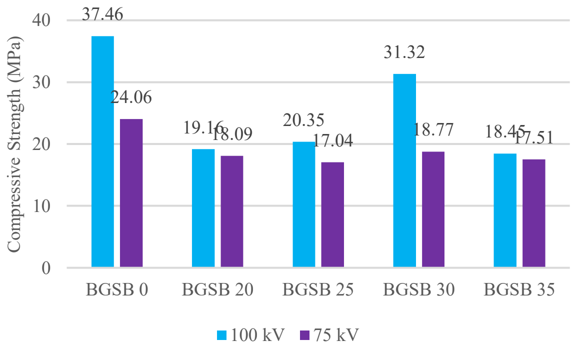

Figure-4. Compressive strength of concrete before and after radiation.

Figure-4 shows that the compressive strength of concrete at 28 days after radiation, has decreased compared to the compressive strength of concrete before radiation. This shows that radiation exposure with X-rays can affect the compressive strength of geopolymer concrete with iron slag coarse aggregate. Based on this research, it can be concluded that the compressive strength of 0% iron slag percentage decreased by 35.77%, 20% iron slag decreased by 8.50%, 25% iron slag decreased by 16.26%, and 30% iron slag decreased by 40.07%. The use of iron slag up to 35% results in a minimum reduction in compressive strength, namely 5.09%.

CONCLUSIONS

The main conclusions drawn from the results should be presented in a short Conclusions section. Radiation test results with a dose of 100 kV, the test object with a 35% iron slag percentage was able to absorb 16.86 µSvh of radiation (8.85% higher than the normal test object without slag). Meanwhile, at a dose of 75 kV, the test object with an iron slag percentage of 35% was able to absorb 8.28 µSvh of radiation (0.34% higher than the normal test object without slag). It can be stated that the addition of up to 35% iron slag can absorb X-ray radiation compared to other mixtures.

X-ray radiation hasan effect on concrete in the form of reducing the concrete's compressive strength. The addition of iron slag with a content of 35% was able to withstand the rate of decrease in the compressive strength of concrete exposed to radiation. It was recorded that with 35% slag, there was a decrease in compressive strength of 5.09% after radiation.

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