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Analysis Of Flexural Resistance And Environmental Feasibility Of Ferrocement Concrete Slabs From Fly Ash And Sandblasting Waste

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Abstract: Sandblasting waste from the shipbuilding industry and fly ash waste from industry and electric steam power plants in Indonesia are relatively high in quantity, are B3, and can potentially cause serious environmental pollution. This research aims to utilize this waste as material for ferrocement concrete, where the SiO_2 and Al_2O_3 content from fly ash replaces some of the cement, silica sand from sandblasting waste replaces sand, and additional wire mesh as reinforcement. The method used is a quantitative experiment, where the material to be used is tested for gradation and TCLP. The finished ferrocement concrete is tested for flexural strength. The test results show that the raw material meets the gradation standards in SNI 03 2834 2000, as well the TCLP test results which show that the B3 heavy metal content is Barium, Zinc, and Copper in the sandblasting waste value is below the quality standards of PP No. 22 of 2021 Appendix XI so that all materials can be used for mix designs. The mix design created has a composition ratio of 1S:1.5PB, 1S:1.5PB:50AT, 1S:2PB, and 1S:1PB:50AT. The 1S:2PB ratio composition has the highest average flexural strength, namely 17.46 MPa, which is suitable for light vertical load construction work

Keywords: Sandblasting waste, ferrocement concrete, Flexural strength, Environmental Feasibility

Introduction

Sandblasting is a method of blasting silica sand with high pressure to remove rust and marine biota on metal equipment (Alifiadi, R. and Slamet, A., 2022). Sandblasting waste can contain heavy metal elements such as Cr, Cu, Pb, and Zn (Qi et al., 2021). Dewantara et al. (2017) revealed that at one shipbuilding company, the largest amount of sandblasting waste that could be produced per month was 12,100 kg, while the amount for three months was 36,300 kg. If this sandblasting waste is put into a container, it will have a volume of 43.51 m3. Apart from the dangers of the presence of B3 waste from sandblasting, Indonesia also faces dangers from the presence of fly ash or coal fly ash waste. In SNI 03-6414-2002, coal fly ash is defined as waste resulting from burning coal in steam power plants (PLTU) which is smooth, round, and has pozzolanic properties. Heavy metal elements contained in coal fly ash include Cu, Pb, Zn, Cd, and Cr. The process of B3 waste pollution (especially from industry) can occur directly or indirectly. Direct processes, namely pollutants have a direct impact on poisoning,

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so they can affect the health of humans, animals, and plants, and can affect the ecological balance of water, air, and land, while indirect processes are where many chemicals react with water and soil which causes pollution to cause contamination. (Nursabrina, A., Joko, T., & Septiani, O. 2021).

Based on PP No.85 of 1999, the remaining results of activities from the sandblasting process are designated as B3 waste from specific sources. This waste is categorized as B3 waste because the heavy metal content is quite high and can endanger health and the ecosystem. The environmental suitability of the sandblasting waste materials used in this research was determined through the X-ray fluorescence spectrometer (XRF) test and the Toxicological Characteristic Leaching Procedure (TCLP) test. X-ray fluorescence spectrometer (XRF) testing is an analytical method used to determine the chemical composition contained in materials in solid, powder or other forms. The XRF test results showed the heavy metal content of barium (Ba) was 0.06%, zinc (Zn) was 0.76%, and copper (Cu) was 1.83%. The three heavy metals were then tested by TCLP to determine the amount of metal content of each heavy metal so that it could be compared with the applicable quality standards. As a result, the Ba content in sandblasting waste was 0.84 mg/L, Cu 5.86 mg/L, and Zn 4.95 mg/L. Based on Government Regulation no. 22 of 2021 attachment XI, the concentrations of these three heavy metals are below quality standards so they are not harmful to the environment, especially when used as ferrocement concrete materials.

Ferrocement concrete itself is a type of thin reinforced concrete construction where the cement is reinforced with a continuous layer of small diameter mesh (wire mesh). The main advantage of ferrocement is that it is easy to manufacture, raw materials are easy to find, and the volume of materials used is relatively small. Ferrocement concrete was chosen because it has a high level of elasticity and crack resistance. This has resulted in the successful application of ferrocement in ship hull fabrication, building construction (low-cost housing), rehabilitation of existing structures, and fabrication of floating marine structures and sewage pipe networks (Cheah, C. B., & Ramli, M. 2013).

2. Literature Review

2.1. Sandblasting Waste

Sandblasting is a method of blasting silica sand with high pressure to remove rust and marine biota on metal equipment (Alifiadi, R. and Slamet, A., 2022). Based on PP No.85 of 1999, the remaining results of activities from the sandblasting process are designated as B3 waste from specific sources. This waste is categorized as B3 waste because the heavy metal content is quite high and can endanger health and the environment. Sandblasting waste contains several heavy metals such as Cr, Cu, Pb and Zn (Qi et al., 2021).

2.2. Fly Ash Waste

SNI 03-6414-2002 defines coal fly ash as waste that arises from burning coal in PLTU, which is smooth, round and pozzolanic in nature. Coal fly ash contains chemical elements such as silica (SiO_2), alumina (Al_2O_3), iron oxide (Fe_2O_3) and calcium oxide (CaO). Silica (SiO_2) is a chemical that can improve the quality of concrete due to the reaction that occurs between silica and free lime in the concrete mixture (Sinta, et al. 2023).

2.3. Ferrocement Concrete

Ferrocement is a thin composite structure that has a uniform wiremesh distribution of smaller diameters in longitudinal, transverse directions, and is plastered with the strength of a cement mortar mixture. The main factors that determine the properties of ferrocement are the behavior of the mortar and the type of mesh used (Mohana, R., et al. 2021). Ferrocement is used for the construction of water tanks, ships, precast structural elements, floors, structural repairs/reinforcement work, construction of retaining walls, drainage, permanent formwork etc

2.4. TCLP Test

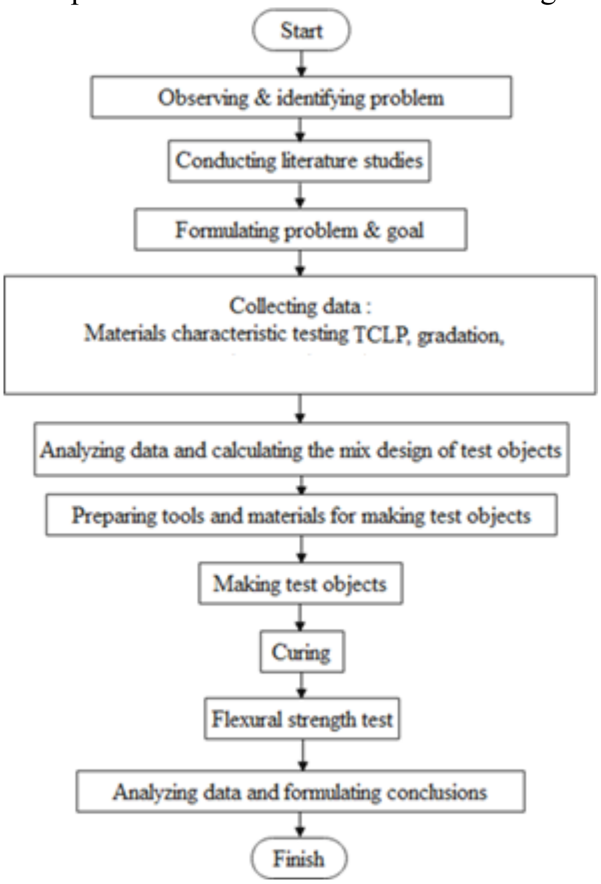
The Toxicological Characteristic Leaching Procedure (TCLP) test is a leaching test for dangerous compounds, such as heavy metals, which can pollute the aquatic environment of a sample. The TCLP test is one of the B3 waste toxicity tests, by ensuring that the concentration of the waste pollutant being tested is within the pollutant concentration in accordance with government regulations Appendix XI Number 22 of 2021. The environmental Feasibility of a material can be tested by TCLP in order to determine its toxicity content against quality standards that have been established through government regulations

2.5. Flexural Strength Test

Flexural strength is the ability of a concrete beam/slabs placed in two positions to withstand forces whose direction is perpendicular to the axis of the test object, applied to it until the test object breaks, expressed as the same as the Mega Pascal force (MPa) per unit. regional (SNI 8299:2017).

3. Method

This research uses an experimental method with the following flow diagram



Picture 1. Research flow diagram

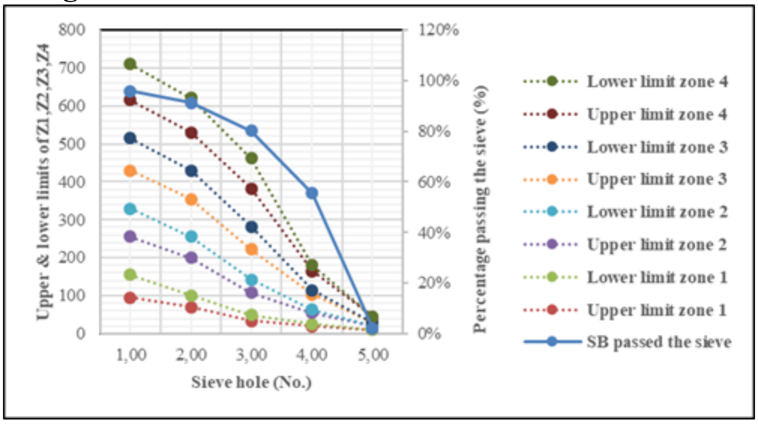
The flow diagram explains that based on observations the process of cleaning ship surfaces with sand has a problem, namely large volumes of sandblasting waste. The aim of the research is to utilize sandblasting waste as a replacement material for sand to be used as ferrocement concrete slabs. The sand material will be replaced with sandblasting waste, so It is necessary to test the initial characteristics of the sandblasting waste material.

Tabel 1. Standard of testings

Nama Pengujian	Standar yang Dipakai
Sandblasting waste gradation	ASTM C-136 dan SNI 03 3834 2000
Sand gradation	
TCLP	US EPA SW 846-1996 Method 6010 B
Flexural strength test	SNI 8299 2017

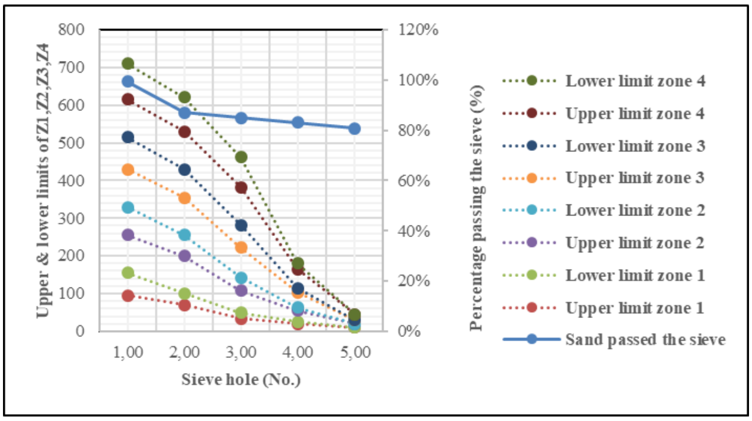
3. Results and Discussion

3.1. Gradation testing result



Picture 2. Sandblasting waste gradation graph for zones 1, 2, 3, and 4

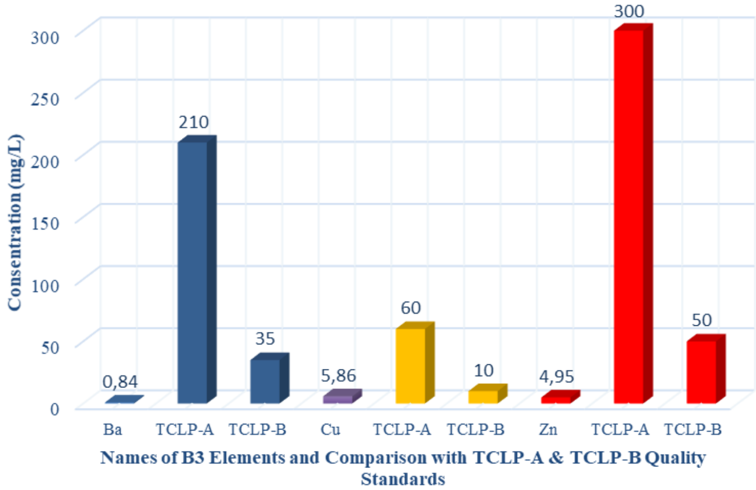
Basically, sandblasting waste is not a material commonly used in making concrete. However, considering the large amount of build-up, in making ferrocement concrete, sandblasting waste is applied as a substitute for fine aggregate. As a substitute that is assumed to be the same as sand, the standard used in the test is the same as the test standard for sand. Figure 2 shows the percentage of sandblasting waste that passes the sieve (thick blue line) is between the upper and lower limits in gradation zone no. 4 so it can be concluded that the sandblasting waste used is classified as fine granules. In making ferrocement concrete in this study, the sandblasting waste used was sandblasting waste that passed sieve no. 8 with a grain size between 2.38 – 1.18 mm.



Picture 3. Sand gradation graph for zones 1,2,3, and 4

Figure 3 shows the percentage of sand that passes the sieve (thick blue line) is between the upper and lower limits in gradation zone no. 4, so it can be concluded that the sand used is also classified as fine granules, the same as sandblasting waste. By paying attention to this, sandblasting waste can be used in ferrocement concrete mix designs, considering that the gradation results show similarities to sand. In making ferrocement concrete in this study, the sand used was sand that passed sieve no. 8.

3.2. TCLP Testing Result



Picture 4. TCLP test result graph

The Toxicological Characteristic Leaching Procedure (TCLP) test on the elements Ba, Cu, and Zn was carried out according to the US EPA SW 846-1996 method 6010 B. The test results in the figure above show that the Ba contained in sandblasting waste is 0.84 mg/L , Cu was 5.86 mg/L, and Zn was 4.95 mg/L. Based on Government Regulation no. 22 of 2021 Appendix It can be said that the sandblasting waste in the picture above does not exceed quality standards. The Cu quality standard concentration value for TCLP-A and TCLP-B is 60 mg/L and 10 mg/L respectively, so that the Cu concentration value in sandblasting waste is classified as not exceeding the quality standard. The Zn quality standard concentration values for TCLP-A and TCLP-B are 300 mg/L and 50 mg/L respectively, so that the Zn concentration values in sandblasting waste meet the quality standards. In conclusion, the B3 heavy metals in sandblasting waste as a whole are below the applicable quality standards so they have the potential to be used in making ferrocement concrete slabs.

3.3. Mix Design

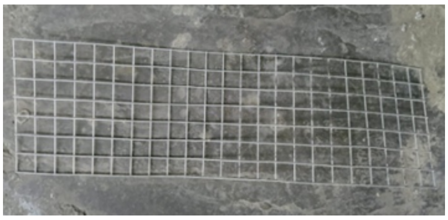
Based on the description of the characteristic tests above, it was found that the sandblasting waste material met the same characteristics of sand material and it was also found that the threshold value was below the quality standard for being safe for the environment. Next, the ferrocement concrete mix design mix plan by replacing sand with sandblasting waste material is determined in the following table.

Table 2. Ferrocement concrete mix design

No.	Description	S	AT	PS	PB	SP	Water
1	1S : 1.5PB	600 g	0 g	0 g	900 g	12 mL	180 mL
2	1S : 1.5PB : 50AT	420 g	180 g		900 g		
3	1S : 2PB	600 g	0 g		1200 g		
4	1S : 1PB : 50AT	420 g	180 g		600 g		

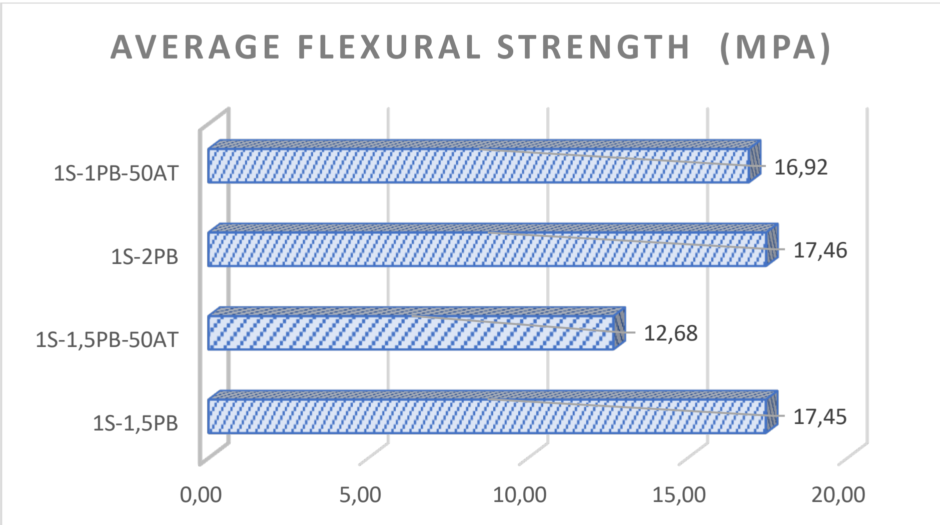
* S = Cement, AT = Fly ash, PB = Sandblasting, SP = Superplasticizer

In the ferrocement mortar mixture, an admixture in the form of superplasticizer (sp) of 2% of the binder (cement and/or fly ash) and w/c of 0.30 of the binder is added. The test specimens were made in the form of block plates with dimensions L 30 x W 10 x H 2 cm3 totaling 12 pieces (3 specimens per variation). The finished test object is then cured for 28 days covered with a wet cloth. The wire mesh used is 3 layers per 1 test object with a distance between the wires of 0.5 cm. This mesh wire functions as a place for the mortar to attach and will provide flexural strength to the ferrocement concrete. The specifications for the mesh wire used have a diameter of 0.5 cm with an opening of 1 x 1 cm2 which is shown in the picture below.



Picture 5. Wiremesh

3.4. Flexural Strength Testing Result



Picture 6. Graph of average flexural strength test results

The results of the flexural strength test above show that test object number 2 has the highest flexural strength value, namely 17.46 MPa. The value of the flexural strength is related to the gradation of the sandblasting waste used. 1S-2PB is the variation with the highest composition of sandblasting waste. Based on the results of gradation tests that have been carried out, sandblasting waste has a fineness modulus value of 1.75, greater than sand which is only 0.65. The grain fineness modulus is defined as the cumulative percent of sieve remaining on the sieve divided by 100 (Prasetyo, Y. E., & Widodo, S. 2015). The greater the fineness modulus of an aggregate, the greater the size of the aggregate grains. In the process of making ferrocement concrete, large sandblasting waste granules can fill the cavities of boxes or wire mesh nets more densely and more compressibly so that when tested for flexural strength the resulting value is higher. Based on SNI DT-91-2007, the flexural strength result is 17.46 MPa in the 1S-2PB variation this quality is suitable for construction work that does not require too heavy vertical loads.

4. Conclusion

Based on the results of material characteristic tests that have been carried out, the materials used in this research meet the gradation standards in SNI 03 2834 2000, TCLP contains B3 heavy metals in the form of barium, Zinc, Copper with the results are below the quality standards of PP No. 22 of 2021 Appendix XI. So that from the test results the material characteristics comply with the regulations, it is suitable and can be used as a mix design in making Ferrocement Concrete. Ferrocement concrete with a ratio of 1 cement: 2 sandblasting waste has the highest average flexural strength, namely 17.46 MPa. This quality is suitable for construction work that does not require too heavy vertical loads.

Acknowledgments

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