Performance of Self Compacting Concrete (SCC) with Precious Slag Ball as Fine Aggregate Substitute

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Abstract: Precisious slag ball (PS Ball) is a waste of residual steel processing which was originally liquid and then recycled using Slag Atomizing Technology (SAT) technology into small, compact granules. . PS ball has a grain size of 0.1-4.5 mm with a higher specific gravity and hardness than sand. The PS ball's granular structure is very powerful, weather resistant, and not easy to wear, so it can be used in SCC concrete as a replacement for fine aggregate. The purpose of this study was to examine the performance of SCC concrete with a PS ball as a substitute for some of the fine aggregate. The concrete performance of SCC studied consisted of fresh concrete performance and concrete mechanical performance. Concrete performance includes filling ability and passing ability, while concrete mechanical performance consists of compressive strength and concrete tensile strength. The specimens of 4 variations were obtained in PS Ball quantity, namely 0%, 10%, 20%, and 30% of the fine aggregate weight. The findings showed that the use of the PS ball as a fine aggregate would enhance SCC concrete's filling and passing abilities. The use of the PS ball as a replacement for fine aggregate will improve concrete's compressive strength and tensile strength by up to 20%.

1 INTRODUCTION

Precisious slag ball (PS Ball) is a steel processing residual waste which is originally liquid is then recycled to thetechnology slag atomizingTechnology (SAT) into small granules are solid. PS ball has a grain size of 0.1-4.5 mm with a higher specific gravity and hardness than sand. The PS ball grain structure is very strong, weather resistant, and not easy to wear. The chemical composition of this waste consists of: Fe (20.83%), SiO2 (12.69%), CaO (40.30%) and other elements up to 100% (PT. Purna Baja Harsco, 2020). The amount of this waste is approximately 150 million tonnes / year worldwide. The amount of PS Ball waste at Krakatau Steel that is processed by a subsidiary of PT Purna Baja Harsco is 5000 tons per month. With this large amount of waste, it is necessary to handle it so that the waste can be used optimally. Judging from the physical and chemical properties, PS Ball waste can replace sand in high performance concrete.

The results of research using PS Ball up to 40% in normal concrete can increase compressive strength and make concrete more durable (e.g. S. Sharath, BC., Gayana, Krishna, R., Reddy & K. Ram Chandar Chia, Lau, & Tan, 2019). Similar research conducted by Avinash. H. Talkeri and AU Ravi Shankar (2019) led to a rise in concrete compressive strength and resistance to fatigue using PS Ball as a fine aggregate in normal concrete compared to concrete using sand. In both of these studies, the concrete studied is conventional concrete which still uses a vibrating device to compact it, which causes noise, is difficult to implement on dense reinforced concrete, has the potential to disrupt the location of the reinforcement during compaction which can result in lowering the strength of the structure. Furthermore, the two studies have not examined concrete performance, especially the concrete tensile strength, flexural strength. and its ductility, so that the resulting concrete tends to be brittle and suddenly collapses. It can be seen that PS Ball has the ability to replace sand in concrete as a fine aggregate. The problems discussed in this paper are the performance of SCC concrete using PS Ball as a partial substitution material for SCC concrete. Concrete performance discussed includes the performance of fresh concrete consisting of filling ability and passing ability, while hard concrete work consists of compressive strength and tensile strength of concrete.

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2 LITERATURE REVIEW

Precious Slag Ball (PS Ball) is a steel processing waste which was originally liquid form processed by Slag Atomizing Technology (technology SAT) into granules of 0.1 mm - 4.5 mm in diameter. This waste chemical composition is made up of Fe (20.83%), SiO_2 (12.69%), CaO (40.30%) and other elements up to 100% (PT. Purna Baja Harsco, 2020). The granular structure of the PS ball is very strong, weather resistant, not easy to wear, with a specific gravity of 3.45 and a hardness of 739.8 HVC. The value of specific gravity and hardness of PS Ball is higher than natural sand. With its high density and hardness, PS Ball can be used as fine aggregate in high performance concrete.

Research on the performance of conventional concrete using PS Ball as a fine aggregate substitution of 20%, 40%, 60%, 80%, and 100%, findings of this research suggest that the optimum composition of PS Ball of 40% produces the maximim compressive strength of 62.89 MPa at 28 days age. Judging from the permeability of concrete, the use of a PS Ball of 40% and 100% results in a more durable /concretedurable (Sharath, Gayana, Krishna and Ram Chandar, 2019).

The use of GGBS as an added material and PS Ball as an aggregate in conventional concrete applied to rigid pavement roads showed that the PS Ball use in concrete for rigid pavement may increase the concrete compressive strength and 41-64 MPa is the resulting concrete compressive strength. In addition, the use of the PS Ball can also raise the concrete's resistance to fatigue (Avinash and Ravi Shankar, 2019).

The use of PS Ball as fine aggregate with a GGBS binder mixture of 443 kg / m3, Na_2SiO_3 / NaOH ratio (1,1.5,2 and 2.5) resulted in a higher slump value of 25 mm versus slump cones conventional. The compressive strength of concrete produced with these materials is 24-58 MPa under conditions of exposure to temperature. The use of PS Ball in concrete can also increase the fatigue life (Avinash and Ravi Shankar, 2018).

3 METHOD

The study was conducted by making SCC concrete specimens with the percentage of PS Ball as a substitute for fine aggregate of 0%, 10%, 20%, and 30% of the weight of fine aggregate and steel scrap waste fibers of 1% of the weight of Portland cement for all types test object. Fresh SCC concrete performance studied consisted of flowability, Passing Ability, Segregation Ressistance, and when tied concrete. To test the properties Flowability tool Slump flow T50cm is used, while to test the nature of Passing Ability and Segregation Ressistance usingtool L-Box. The method of testing the properties of fresh SCC refers to the EFNARC standard in 2002.

The performance of the hard concrete consists of: the concrete's weight, compressive strength and tensile strength. A Ø15 cm concrete cylinder with 30 cm high is the test sample to test the compressive strength and tensile strength. Each test was repeated 3 times. Tests were conducted at the ages of 3, 7, 14, and 28 days to assess the growth of the compressive strength of concrete. The tensile strength of the concrete was tested at the age of 28 days. All specimens were cured before measuring the properties of hard SCC concrete by immersing them in water at room temperature before the test was performed.

4 RESULTS

4.1 Properties of the Constituent Materials of Self Compacting Concrete

Table 1 presents the properties of the SCC concrete constituent components. The results presented in Table 1, the test results of SCC concrete constituent materials, it can be seen that all materials used meet the requirements for making SCC concrete.

Table 1. SCC Constituent Materials Properties

Material Properties	Value		
	fine aggregates	**coarse aggregates**	**Precious Slag Ball**
Specific gravity	2.48	2.28	3.67
SSD Specific gravity	2.53	2.30	3.67
apparent Specific gravity	2.62	2.33	3.67
Loose Unit Weight (kg/m3)	1565.10	1337.82	2481.33
Solid Unit Weight (kg/m3)	1702.55	1482.11	2557.98
water absorption (%)	2.19	0.92	0.05
Water content (%)	0.06	0.01	0.27
Fine Modulus	0.03	6.25	2.35
sieve analysis	Zona 2	maximum aggregate diameter 10 mm	Zona 2 (BS)
Sludge content (%)	1.10	0.17	0.15

4.2 Properties Fresh SCC Concrete Workability

Workability is the property of fresh concrete to demonstrate the ease with which concrete is stirred, poured, molded, and compacted. The fatigue, water retention and plasticity of the fresh concrete mix, which is inseparable from the material's properties and the fineness of the aggregates, affect this property. The fresh SCC concrete mixture must have the following characteristics: filling capacity, passing capacity, and segregation resistance or segregation resistance. In this study, the filling ability of the SCC concrete was tested by means of thetested using the T50cm Slump Flow Test, while the properties of the Passing Ability were tool L-Box. Results of SCC concrete PS Ball filling and passing abilities, shown in Figures 1 and 2.

Filling ability is the ability of fresh concrete mixers to fill spaces or voids. From Figure 1, it can be shown that the use of PS Ball in SCC concrete as a replacement for fine aggregate causes the SCC concrete to decrease fluidity. This can be seen from the longer it takes for the concrete flow to reach a diameter of 50 cm. However, using PS Ball up to 30%, the filling ability concrete still meets the requirements set by EFNARC, which is 2-5 seconds. The homogeneity of the concrete was also seen in the T50cm Slump Flow test. In fresh concrete, the use of the PS Ball on SCC concrete does not cause segregation and bleeding. Stir can be evenly and homogeneous.

Passing ability is the ability of the fresh concrete mixture to pass through reinforcement. This property is required when the concrete mix is used to create structures with tight reinforcement spacing. SCC concrete, which has good passing ability, can pass through tight reinforcement gaps without segregation. The results of the research on SCC concrete using PS Ball as a substitute for fine aggregate by 10% resulted in higher passing ability and segregation resistance values compared to SCC concrete without PS Ball. This condition can be seen from the h2 / h1 value of the L-Box test results that have increased (Figure 2). This means that the ability of SCC concrete with PS Ball aggregate to pass through tight reinforcement gaps is higher than that of concrete without PS ball. The concrete mix for all variations meets the requirements of concrete as SCC concrete as in the EFNARC provisions which require an h2 / h1 value of 0.8 - 1.0

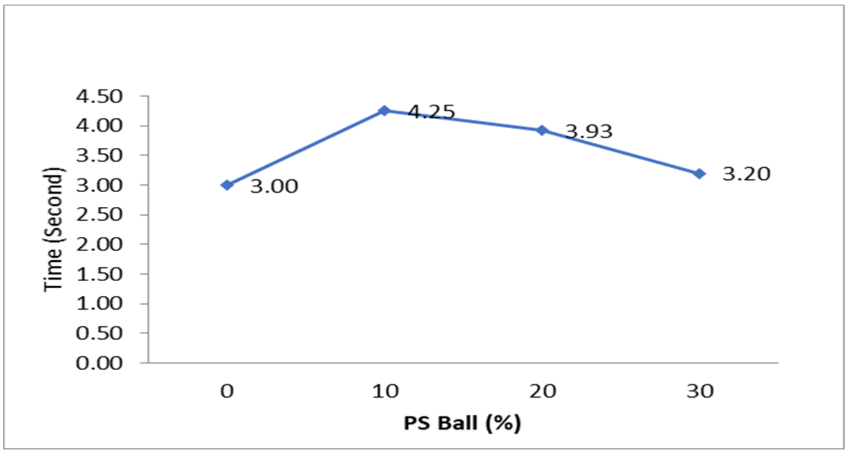

Figure 1. Filling Ability (Slump Flow TestT50) Concrete SCC PS Ball

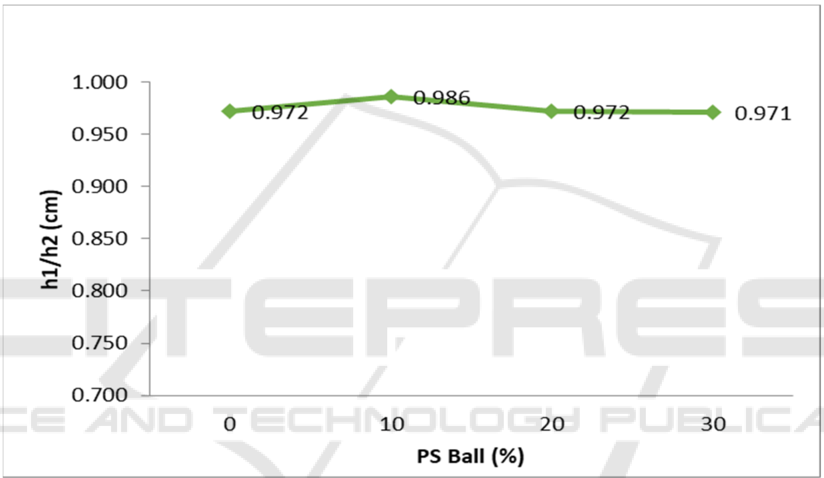

Figure 2. Passing Ability (L-Box) Concrete SCC PS Ball

4.3 Time of Initial Bonding of Concrete

Bonding time is the condition in which the concrete begins to harden. The initial bonding time needs to be known to determine how long it takes for the concrete to harden from the plastic state. It is important to know the initial bonding time in order to determine how long the concrete can be worked. The initial binding time of SCC PS Ball concrete with steel scrap waste fibers is presented in Table 2. binding time.

It can be seen from Table 2 that the initial binding time of concrete appears to be the same for all variants of the specimen. This means that the use of PS Ball on SCC concrete does not affect the initial bonding time of the concrete.

Table 2. Time of Initial bonding of SCC PS Ball

Percentage of Fiber Binding	Time (minutes)
0.00%	320
0.25%	320
0.50%	320
0.75%	310
1.00%	310

4.4 Unit Weight of Hard Concrete

Unit weight is used to calculate the structure's own weight. The greater the value of the weight, the larger the weight of the structure itself. The results of this study are shown in Figure 3.

Unit weight is a value that states the ratio between the weight and volume of concrete in a hard state. The weight of the concrete contents serves to calculate the structure's own weight. The greater the weight value, the larger the structure has its own weight. Concrete load weight is closely related to the concrete density, which will influence the concrete strength. It can be seen from Figure 3 that the use of the PS Ball on concrete can raise the concrete's weight. However, at 30% PS Ball content, the weight of the concrete content decreased. This happens because the use of the PS Ball is 30%, the concrete looks segregated and bleeding, so that the density of the concrete also decreases.

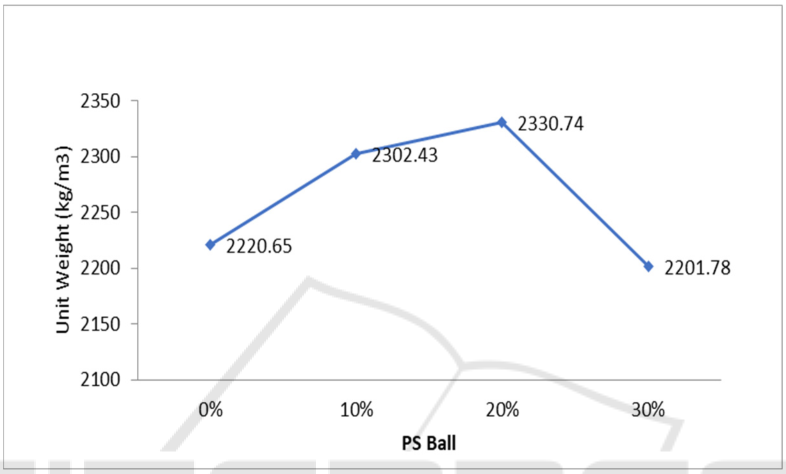

Figure 3. Unit Weight of SCC PS Ball Concrete Content

4.5 Compressive Strength of Concrete

Compressive strength was measured at the ages of 3, 7, 14, and 28 days to assess the development of concrete strength. At this age, the purpose of the compressive strength test is to assess the development of the concrete strength, so that it can be determined when the formwork/concrete mold can be opened, the structure can be installed, or the load can be accepted by the structure. Table 3 and Figure 4 summarizes the findings of the study on the compressive strength of PS Ball concrete.

Concrete compressive strength is the amount of load per unit area that causes the concrete sample to crumble when filled with a certain compressive force that the compression testing machine generates. The concrete compressive strength is the ability of concrete to bear loads that act on the structure. In comparison with other concrete properties, the compressive strength of concrete is the most significant and dominant feature of concrete. Concrete compression strength is highly affected by the quality of the aggregate, the quality of the adhesive and the composition of the mixture, and the level of density of the concrete.

It can be seen from table 3 that the use of PS Ball as a fine aggregate at the age of 3,7,14, and 28 days can increase the compressive strength of concrete. At the age of 28 days, consecutively concrete with a 10% PS Ball content had an increase in compressive strength by 1.27%, a 20% PS Ball level compressive strength increased by 13.22%, and a 30% PS Ball content increased compressive strength by 8.11%. The biggest increase in compressive strength occurred in concrete with a content of 20% PS Ball.

SCC concrete's compressive strength is closely linked to workability, where SCC concrete with high slump flow value and high filling ability can easily allow SCC concrete flow to fill the voids between the reinforcement and solidify itself easily. In this study, SCC concrete with fine aggregate PS Ball at 10% and 20% levels hasvalues which slump flow and filling ability tend to be the same as SCC concrete without PS Ball.

Table 3. Development of Compressive Strength SCC PS Ball

PS Ball percentage	Average Compressive Strength (Mpa)				% increased strength at 28 days
	3 days	7 days	14 days	28 days	
0%	10.65	12.53	16.36	24.43	
10%	11.35	13.19	16.76	24.74	1.27%
20%	12.6	14.23	19.53	27.61	13.02%
30%	10.44	11.57	13.33	26.41	8.11%

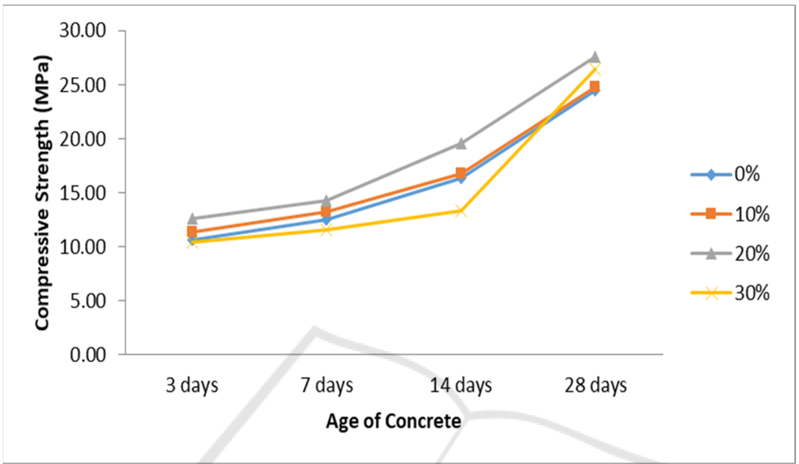

Figure 4. Development of Compressive Strength of SCC PS Ball

4.6 Tensile Strength of SCC PS Ball Concrete

Table 4 shows the reliability test results of concrete tensile strength. The concrete's tensile strength is the ability of the concrete to withstand the concrete's tensile stress. Concrete is a type of brittle material that has high compressive strength but low tensile strength. The tensile strength of concrete is usually 10%-15% of its compressive strength. The tensile strength of this concrete is therefore neglected in the design of reinforced concrete structures, in particular in order to quantify the need for reinforcement, and the concrete is deemed unable to withstand tensile strength. Concrete only functions to hold pressure, while the tensile area is held by reinforcement. However, the concrete must have a minimum tensile strength as required by SNI T 12 2005 article 4.4.1.1.2, which is equal to $0.33\sqrt{f'c}$.

The tensile strength of the concrete serves to prevent cracks due to shrinkage, but it is not taken into consideration. If there is shrinkage, concrete with high tensile strength is not susceptible to cracking. It can be seen from table 4 that the use of PS Ball as a fine aggregate in SCC concrete causes the concrete's tensile strength to raise at levels of 20%. In general, however, the use of the PS Ball as a fine aggregate in concrete causes the concrete to decrease its tensile strength. Concrete tensile strength is not directly proportional to its compressive strength, but concrete tensile strength is directly proportional to the square root of its compressive strength. The SCC concrete tensile strength with a 20 percent PS Ball content is greater than the tensile strength required by SNI 2847 2002, which is equal to $0.33\sqrt{f'c}$.

Table 4. Tensile Strength of SCC PS Ball

Percentage of PS Ball	Average Tensile Strength (MPa)	Tensile Strength Formula SNI = 0.33.√fc '(MPa)	% increase in Tensile Strength
0%	1.69	1.63	
10%	1.31	1.64	-22.70%
20%	2.29	1.73	34.96%
30%	1.48	1.7	-12.81%

5 CONCLUSIONS

Several conclusions can be reached as follows, based on the findings of analysis and discussion, show that (1) Up to 30 percent of SCC concrete with PS Ball as a substitute for fine aggregate results in the filling and passing abilities of SCC concrete that meets the criteria of EFNARC standards for SCC concrete and (2) The initial bonding time of the concrete with the PS Ball was not much different from the initial bonding time of the SCC concrete without the PS Ball. Properties of hard concrete show that (1) The weight of the concrete with the PS Ball substitution is 10% and 20% higher than the weight of the concrete without the PS Ball and (2) Using up to 30% of PS Ball as a replacement for fine aggregate can raise the concrete's compressive strength. At 20% PS Ball content, the highest increase in the compressive strength of concrete and (3) The highest tensile strength of concrete is produced by concrete with a level of 20% PS Ball.

From the results of this study, it is suggested (1) Further research on the use of the PS Ball for beam and plate structural elements needs to be carried out and (2) Further research was carried out on other concrete properties required for the design of structural elements.

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