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A sustainable environmental study on clamshell powder, slag, bagasse ash, fly ash, and corn cob ash as alternative cementitious binder

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Abstract. Concrete is one of the most commonly used construction materials, consisting of water, aggregate and cement. The use of Portland cement in the manufacture of concrete has a negative impact to the environment. Therefore, one alternative solution that can be done is to replace some of the cement content in concrete by utilizing waste such as Bagasse Ash, Fly Ash, and Corncob Ash, as a substitute material. In addition, the use of sand and gravel as aggregates can also be partial by utilizing Clamshell Powder as a partial substitute for fine aggregate and Nickel Slag as a partial substitute for coarse aggregate. This study aims to create high quality Self Consolidating Concrete (SCC) that is environmentally friendly with a simple steam curing method. The study used a tested object in the form of a 150x300 mm cylinder with the use of 3% bagasse ash, 10% fly ash, and 2% corncob ash as a partial substitute for cement, 9% Clamshell Powder as a partial substitute for sand, and 40% nickel slag that passed the 3/8 sieve and be restrained the No. 4 sieve as a partial substitute for gravel. Steam curing of the specimen was carried out at 7080 °C for 4 hours and continued with curing at room temperature until the testing time. Testing of concrete compressive strength aged 1 day is expected to produce concrete with a minimum strength of 30 MPa.

1. Introduction
The production of Portland cement, which is used as one of the raw materials for the manufacture of concrete, requires a large amount of energy and produces a lot of waste, so that it has a negative impact on the environment. Several weaknesses relating to the effect of using cement on the environment, it is less efficient in the use of raw materials, because in making 1 ton of OPC clinker, ± 1.7 ton of raw material is needed, large energy requirements (heating required in the furnace to ± 1450^{o}C) to obtain clinker. It is less environmentally friendly because its production produces large CO_2 emissions (1 ton of OPC clinker produces 1 ton of CO_2), has a high susceptibility to durability/ resistance problems because OPC cement hydration products produce the mineral $Ca(OH)_2$ which easily be dissolved, and the price is getting more expensive [1].
The things above encourage engineers to find alternative solutions that can reduce the negative impact on the environment by utilizing local waste as a partial substitute for cement and aggregate in order to create high quality concrete that is environmentally friendly. One of the problem solving efforts is to make self-compacting concrete (SCC) type concrete.

In general, SCC concrete has the same content as conventional concrete, but to make SCC concrete, requires additional superplasticizer material and other research results also show that to make SCC concrete, materials containing pozzolanic can be added [2]. The type of superplasticizer that will be used in this research is a product from PT. Sika Indonesia, that is Sika viscocrete-8760 MN. South Sulawesi is one of the region in Indonesia with great sugarcane potential, as proven by the existence of three sugar factories in Bone and Takalar Regencies. Bagasse is usually used as fuel in steam boilers which are then used as steam power plants and fuel in sugar production furnaces. Utilization of bagasse produces abundant bagasse ash [3].

The bagasse ash waste that is produced is just stored in the yard without being utilized so that it can pollute the air because of its fine size and easily fly. Bagasse ash contains high levels of silica (SiO_2) around 68.5% [3]. Apart from being known for its abundant potential for sugarcane, South Sulawesi is also one of the provinces with the largest maize commodity in Indonesia. In 2017, South Sulawesi contributed 2.3 million ton of maize production with a harvest area of 295,115 ha or 7.33 percent of the national maize production. Agricultural corncobs have not been widely used so that they are still being rubbish in the community, even though corncobs also contain 66.38% silica which is high [3]. The content of silica compounds (SiO_2) found in corncobs allows it to be used as an additional material in concrete. In addition, the use of fly ash as a partial substitution material for cement has been widely used. As a province with two large Steam Power Plants (PLTU) in Jeneponto, South Sulawesi has become a contributor to fly ash waste for the environment which is dangerous if it is not managed and utilized properly. Fly ash is the result of burning coal which is generally found in PLTU. With a tiny particle size (45 µm) and even smaller than the grain size of cement (75 µm), fly ash can minimize pores in the concrete so that it has a high compressive strength value. As an archipelagic country with a water area of 5.8 million km and a coastline of 81,000 km, Indonesia has great potential in terms of managing marine resources, one of which is clamshell. So far, most people only use clam meat, while clamshells have not been used optimally. It raises a problem such as clamshell waste that has accumulated in coastal areas, considering that the composition of shells is more than the meat, which is about 70% shell and 30% meat [3]. So far, only high quality clamshell and good shape are used for handicraft materials, while other shells that are not utilized cause other problems, especially environmental cleanliness. So that through this research, it is hoped that the shells can be a good partial substitution of fine aggregate to create environmentally friendly concrete. With a mission to create high quality concrete that is environmentally friendly, this study not only uses waste as a partial substitute for cement and fine aggregate, but also uses slag as a partial substitute for coarse aggregates. Indonesia has enormous slag potential with the presence of several mineral commodities and one of the largest is nickel. Based on ESDM data in a study of nickel mineral resources rents, it provides an overview of the total nickel reserves in Indonesia in 2016 reaching 4.5 billion tons of ore. Every one ton of nickel produces 50 tons of nickel slag by product. This will encourage the utilization of nickel slag by product as much as possible in the future. The urgency of the use of nickel slag became very important after the Indonesian government issued a policy of PP 101 of 2014 which designated nickel slag as category 2 of hazardous waste. Based on the results of experimental studies, the researchers were compelled to choose a review of the use of nickel slag as coarse aggregates in concrete in the evaluation of durability for corrosion resistance. The choice of slag as a part of coarse aggregate for environmentally friendly concrete is due to its physical and characteristic which almost resembles natural stone. Even nickel slag can fill 20-30% by volume of concrete to get maximum concrete compressive strength. If more than 30% is mixed, the compressive strength of the concrete will comply [4]. Based on the results of experimental studies, the researchers were compelled to choose a review of the use of nickel slag as coarse aggregates in concrete in the evaluation of durability for corrosion resistance [5]. The choice of slag as a part of coarse aggregate for environmentally friendly concrete is due to its physical and characteristic which almost resembles natural stone. Even nickel slag can fill 20-30% volume of concrete to get maximum concrete compressive strength. If more than 30% is mixed, the compressive strength of the concrete will comply [6]. In order to fulfill the required compressive strength, several alternative treatments for concrete are needed, including treatment using the steam curing method. Steam curing is a treatment process using evaporation where the concrete is put into a steam device (curing tank) after casting using the determined steam pressure, temperature, and time. The steam curing method can improve the cement binding process so that early strength concrete can be obtained. Therefore, this study aims to find out the effect of using bagasse ash, corncobs ash, and fly ash as a partial substitution of Portland cement, the use of clamshell powder as a partial substitution of fine aggregate, and nickel slag as a partial substitute for Portland cement. Utilization of clamshell powder as a partial substitution of fine aggregate, and nickel slag as a partial substitution of coarse aggregate with the steam curing method to obtain high-early strength and environmentally friendly concrete.

2. Location and research time

This research is conducted at Structure and Material laboratory, Department of Civil Engineering and Water Quality Laboratory, Department of Environmental Engineering, Faculty of Engineering, Hasanuddin University. The tested object used in this study is a cylindrical concrete specimen with a diameter of 10 cm and a height of 20 cm. This type of test is the compressive strength test and split tensile strength. Meanwhile, the treatment method used is steam curing which can accelerate the hydration process of cementitous materials (cement, fly ash, etc.). The amount of bagasse ash used is 3% by weight of cement. Fly ash used is 10% by weight of cement. The corncobs ash used is 2% by weight of cement. Meanwhile, the amount of clamshell powder used is 9% by weight of sand. The amount of nickel slag used was 40% by weight of gravel. The mix design of the tested objects is shown in Table 1.

Table 1. The mix design of the tested objects.

No	Concrete Materials	SSD Weight	
		kg/m^3	Kg
1	Water	173,83	0,40
2	Cemen	437,14	1,00
3	Bagasse ash (3%)	15,43	0,04
4	Fly ash (10%)	51,43	0,12
5	Corn cobs ash (2%)	10,29	0,02
6	River sand	459,70	1,05
7	Clamshell powder (9%)	45,47	0,10
8	Gravel	639,51	1,46
9	*Slag* (40%)	450,67	0,70
10	*Viscocrete* 8670 MN	6,17	0,01
11	$CaCl_2$	2,25	0,005147

3. Materials data

This research starts from the material preparation, casting, and testing the tested object. The concrete constituent materials used in this study consisted of cement type I Ordinary Portland Cement (OPC) with partial substitution from bagasse ash, fly ash, and corncobs.

Fine aggregate is sand with Clamshell Powder as a partial substitution which has a moisture content of 0.6%, a volume weight of 1.657 kg / liter, and a specific gravity in SSD conditions of 2.263, and gravel as coarse aggregate with partial substitution of nickel slag. The fine aggregate and coarse aggregate used in this study have undergone characteristic testing in the laboratory as shown in Table 4.2. The results of testing the composition of chemical compounds in substitution materials can be seen in Table 2.

Table 2. Data on the proficiency test for fine aggregates and coarse aggregates.

No.	The Testing	Unit	Sand	Gravel	Slag
1	Modulus of fineness	%	2,97	7,54	6,69
2	Apparent density		2,55	2,77	3,47
3	Dry density		2,35	2,59	3,4
4	SSD density		2,43	2,65	3,42
5	Water adsorption	%	3,31	2,44	0,57
6	Sludge levels	%	2,83		
7	Organic levels	No	1		
8	Aggregate wear	%		23,80	13,12

3.1. Material preparation
The fine aggregate and coarse aggregate to be used are cleanly washed from mud and dirt so as not to interfere with the binding process between the materials in the concrete. After ensuring that it is clean, the aggregate is soaked for approximately one night and then dried under the sun until it reaches a Saturated Surface Dry (SSD) condition. Meanwhile, the partial substitutes of cement, bagasse ash, fly ash, and corncobs ash, being filtered using sieve number 200. In addition, the partial substitutes of sand clamshell, is washed first then dried then being abrasive using a 700 rounds Los Angeles machine then filtered with sieve number 4. Likewise with nickel slag as a partial substitution of gravel, after being filtered using sieve number 3/8 and stuck in sieve number 4, the slag is then washed clean and then soaked for about one night and dried under the sun until it reaches SSD condition.

Figure 1. Material preparation.

3.2. Batching
Before being loaded into a mixer (mixer), the concrete material must be measured according to the calculated mix design. The batching is done using a digital balance with a maximum load of 60 kg.

3.3. Mixing
The material that has been measured then must be mixed until it is evenly distributed. The mixing is done by first adding coarse aggregate and partial substitutes, adding cement and partial substitutes, then fine aggregate and partial substitutes into a pan-type mixer. Then turn on the mixer while pouring

1/3 of the water that has been measured gradually. After that, pour viscocrete 8670 MN and add the remaining water slowly to get a good concrete mixture.

Figure 2. Mix design.

3.4. Placing

The casting concrete is then transported using an Artco Cart and then taken to a larger area to pour it into the prepared mold/ specimen. The pouring of fresh concrete from the cart into the mold is carried out using a standard sized spoon. Pouring is done carefully so that the concrete mixture does not fall and scatter around the mold. In pouring the concrete mix, there is no need to do the compaction (compacting) using a spoon or a rolling pin because the SCC concrete will compact independently.

Figure 3. The casting concrete.

3.5. Curing

The concrete that has been poured into the specimen is then stored at room temperature for 2 hours and then put into a steam device which is a large aluminum-based pot (curing box) and the temperature is slowly increased to 70-80 °C for 30 minutes. If the temperature has reached 70-80 ° C, then the temperature is maintained for the next 4 hours then lowered slowly to 30 °C for 30 minutes. Finally, the specimens are removed from the curing box and stored at room temperature until the time of testing. Temperature measurements were made using a mercury thermometer.

Figure 4. Steam curing.

4. Research results

4.1. The testing result of fresh concrete in the form of slumpflow and measurement t50 slumpflow

The amount of slump is obtained data directly from testing in the laboratory. The slumpflow test in the CALEG GALESONG concrete test used a circle pattern on a flat plane with an outer circle diameter of 50 cm. The fresh CALEG GALESONG concrete mix takes 3.7 seconds to reach the outer circle line and then spreads with a horizontal diameter of 74 cm and a vertical diameter of 63 cm so that the slumpflow test value for CALEG GALESONG concrete is 68.5 cm and T50 slumpflow for 3, 7 seconds.

4.2. The testing result of concrete compressive strength SCC aged 1 day

The results of the compressive strength of CALEG GALESONG concrete aged 1 day with 3 specimens in the form of 150 x 300 mm cylinders tested object can be seen in table 4.1 and the standard deviation analysis data can be seen in table 4.2. The use of bagasse ash, fly ash, and corncobs ash as partial cement is an alternative solution that should be considered in an effort to prevent environmental pollution caused by Portland cement production. Reviewed from the chemical composition contained by each material, our innovation of partial cement substitution contains compounds that have pozzolanic properties. By utilizing substitution materials such as bagasse ash, fly ash, and corncobs ash, the use of cement can be reduced by up to 15% so as to overcome the costs incurred in making concrete. Acceptance of the fact that bagasse ash, fly ash, and corncobs ash are quite abundant in South Sulawesi, we believe that the innovations we offer can be a solution to the problems regarding the adverse impacts on the environment caused by Portland cement production. The use of clamshell as a partial substitute for sand is also one of the innovations we offer in this research. As one of the main raw materials for manufacturing concrete, sand as a fine aggregate can be reduced by up to 9% with the use of clamshell. In South Sulawesi, clamshell is not hard to be found.

As an archipelago country with the second longest coastline in the world, Indonesia has the potential for amazing natural resources in the sea, one of that is the existence of clamshell. The use of clamshell that is not optimal has prompted us to process the clamshell into powder and use them as a partial substitution material for sand in CALEG GALESONG concrete. In addition, in terms of compressive strength, our concrete testing is based on the results of previous studies. This is our reference in choosing nickel slag as an alternative to the use of coarse aggregate material in concrete, it is hoped that this composition can produce high quality concrete that can be applied to buildings or constructions that require high quality concrete and fast construction times such as precast systems and pre-stressed.

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5. Conclusions

a. In this study we use AAT, fly ash, and ABJ as partial substitutes for cement that can produce high strength 1-day-old concrete with an AAT percentage of 3%, fly ash of 10%, and ABJ at 2%.
b. In this study also used SCK as a partial substitution of fine aggregate by 9% and nickel slag as a partial substitute for coarse aggregate by 40%.

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