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MECHANICAL CHARACTERISTICS OF SELF COMPACTING CONCRETE USING LATERITE STONE AS COARSE AGGREGATE

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ABSTRACT: Two types of SCC mixtures were made and compared, the first using crushed river stones and the second using crushed laterite stones where Portland composite cement (PCC) was used as the main cementitious material in this present study. PCC content, superplasticizer content, w/c ratio and fine aggregates fractions and volumes were kept fixed at same value for both mixtures. Testing of SCC in fresh and hardened conditions was carried out. At fresh state, slump flow and T500 of the two SCC mixture types had the similar shape that properly spread in all directions by own weight and met the SCC mixture requirements of ENERFAC. Adequate compaction result of SCC without help of vibration and tamping rod effort was shown by hardened cylindrical specimens where there were no large voids and no segregation appeared on the specimen surface. The compressive-strain stress relationship was almost same in both mixes as well as peak strain value at the age of 90 days was similar for both SCC mixtures. Physical properties which include compressive strength, elasticity and indirect tensile strength showed that SCC containing crushed laterite stone was slightly better compared to that used crushed river stone.

Keywords: Mechanical characteristics, Self compacting concrete, Laterite stone, Compressive-strain stress, Indirect tensile strength

1. INTRODUCTION

Laterite rocks are often found to cover a number of regions in the tropics and sub tropics. Laterite rocks have properties similar to other natural rocks, hence, in several areas where laterite rocks available abundantly, its utilization would provide economic benefits compared to other natural stones. Research conducted by Kasthurba A.K. et al. (2007) [1] and Muthusamy K. et al (2015) [2] showed that laterite rocks have the potential to be used as coarse aggregate in the manufacture of concrete. Based on those result studies, the use of laterite stones is expected suitable to replace the basalt, calcite stones which are conventionally widely used as coarse aggregate in the manufacture of concrete.

In eastern region of Kalimantan island, there are several areas contain the enormous sources of the laterite rock with have yet to be exploited for proper usage. Until now, because of the limited knowledge of the physical characteristics of laterite rocks, it is still classified as nonstandard material so that the current technical standards and specifications in Indonesia do not include laterite rocks as a material that can be used as building material. Fig. 1 shows the East Kalimantan-Indonesia laterite stone.

In Indonesia, particularly in East Kalimantan region, the use of laterite stones as a construction material is very limited and causes the demand to bring in the crushed rivers stones from the other regions instead of use the abundant laterite stone that increases the construction price. The main targets of government are to search methods to maximize the usage of laterite stone.

SCC was originally developed in Japan around the 1990s which aimed to anticipate the diminishing number of skilled workers in concrete casting. SCC is expected could be used to produce high quality concrete construction without considering the level of expertise and experience of concrete casting workers. SCC is a concrete in fresh condition capable to flow by own weight to achieve maximum compaction until the corners of the mold without the aids of vibration (Okamura H. and Ouchi M, 2003) [3].

Fig 1. East Kalimantan-Indonesia laterite stone

This research is conducted based on those aforementioned issues. This study uses crushed laterite stone to replace crushed river stone in the manufacture of SCC. This research consists of two parts, the first part was to test the physical properties of crushed laterite stones based on Indonesian standards. The test results were reported in the table of aggregates physical properties that also contain physical properties of crushed river stone and sand.

The second part of this study is to examine the feasibility of the physical properties of laterite stones to be used as concrete materials. A laboratory study was undertaken to investigate the effect of laterite stone as coarse aggregate on the properties SCC corresponding to slump flow of fresh concrete and strength of hardened concrete. The test results of laterite stones as coarse aggregate in production of SCC can add technical information about its feasibility which further empowers the laterite stones as building materials.

2. MATERIAL AND METHOD

2.1 Aggregates

Crushed laterite stone (maximum size of 20 mm, fineness modulus of 7.44, bulk specific gravity of 2.54, oven dry specific gravity of 2.15 and saturated specific gravity of 2.30) and river stone (maximum size of 20 mm, fineness modulus of 8.10, bulk specific gravity of 2.63, oven dry specific gravity of 2.82 and saturated specific gravity of 2.70)) and river sand (maximum size of 5 mm, fineness modulus of 2.44, bulk specific gravity of 2.47, oven dry specific gravity of 2.76 and saturated specific gravity of 2.52) conforming to Indonesia standard were used as coarse aggregate (laterite and river stone) and fine aggregate. Table 1 shows the physical properties of aggregates.

Table 1. Physical properties of aggregate

No.	Physical properties	Standard	Laterite stone	River stone	River sand
1	Maximum size (mm)	-	20	20	5
2	Fineness modulus	SNI 03-1968-1990 [4]	7.44	8.10	2.44
3	Spesific gravity				
	a. Bulk		2.54	2.63	2.47
	b. Oven dry	SNI 03-1970-2008* [5]	2.15	2.82	2.76
	c. Saturated surface dry	SNI 03-1969-2008** [6]	2.30	2.70	2.52
	d. Water absorption (%)		7.26	2.57	1.75
4	Weight volume				
	a. Loose condition	SNI 03-1973-1990 [7]	1.26	1.80	1.43
	b. Solid condition		1.40	1.90	1.74
5	Water content (%)	SNI 03-1971-1990 [8]	1.97	1.69	2.35
6	Organic content (%)	SNI 03-2816-1992* [9]	-	-	No. 1 (Lowly)
7	Abrassion (%)	SNI 2417-2008** [10]	46.25	24.36	-

*River sand

**Laterite stone and river stone

2.2 Portland Composite Cement (PCC)

The experiment was carried out using Portland composite cement produced by Indonesian cement manufacturer. This type of cement has been widely found in the market and most of the construction work in Indonesia uses this cement.

Oxide components which are important requirements such as MgO, SO_3 and ignition loss are 0.97%, 2.16% and 1.98%, respectively as shown in Table 2. Table 3 shows physical properties. The oxide components and PCC physical properties fulfil the requirements of SNI 15-7064-2004 (Indonesian Standard for Portland Composite Cement) [11].

Research conducted by Tjaronge M.W. et al [12] and Erniati et al [13] showed that SCC with good compressive strength and flowability can be made using PCC.

Table 2. Component oxides of PCC

No.	Oxide	SNI 15-7064-2004	Portland Composite Cement (PCC)
1	MgO (%)	6.0 max	0.97
2	SO_3 (%)	4.0 max	2.16
3	Loss of Ignation (%)	5.0 max	1.98

Table 3. Physical properties of PCC

No.	Physical properties	SNI 15-7064-2004	Cement used (PCC)
1	Air content of mortar (%)	12 max	11.5
2	Fineness/Blaine meter (m^2/kg)	280 min	382
3	Expansion, % (max)	0.8 max	-
4	Compressive strength		
	a. 3 days (kg/cm^2)	125 min	185
	b. 7 days (kg/cm^2)	200 min	263
	c. 3 days (kg/cm^2)	250 min	410
5	Time of setting (Vicat test)		
	a. Initial set, minutes	45 min	132.5
	b. Final set, minutes	375 max	198
6	False setting time (minutes)	50 min	-
7	Heat of hydration 7 days, cal/g		65
8	Normal consistency (%)		24.15
9	Spesific gravity		3.13

2.3 Concrete Mixture

Table 4 show the SCC mixtures. Crushed stone (river stone) was used as coarse aggregate in Mix I and Mix. II used crushed laterite stone as coarse aggregate. For both mixtures, the design slump flow and compressive strength were 650 ± 50 mm and 25 ± 2.5 MPa, respectively.

Table 4. Concrete mixture (in 1000 litre)

No.	Material	Weight Type SCC	
		I	II
1	Crushed laterite stone, kg	837	-
2	Crushed river stone, kg	-	837
3	Sand, kg	811	811
4	Cement, kg	559	559
5	Water, kg	170	170
6	Superplasticizer, kg	8.38	8.38

2.4 Slump Flow and T500 Tests

SCC mixing was carried out in the laboratory at temperature 27.5 ± 2.5°C. Testing of slump flow and T500 on SCC in fresh conditions was carried out immediately after completion of mixing according to ENERFAC 2005 [14].

2.5 Compressive Strength and Indirect Tensile Strength Test

This study includes determination of strength up to 90 days. SCC in fresh state was poured into the cylindrical molds with 100 mm diameter and 200 mm height without the aid of vibrator or tamping rod. SCC containing laterite crushed stone and that containing crushed river stone were prepared and tested for their compressive and indirect tensile strength. After 24 hours, the specimens were removed from the molds and cured in water at room temperature 27.5 ± 2.5°C until the testing day.

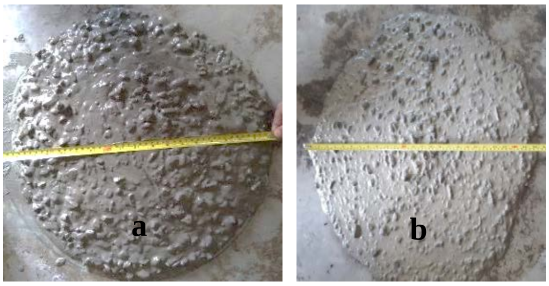
Compressive strength testing was carried out in accordance with SNI 1974-2011 [15]. The load speed used was 5 mm/minute. Strain meters were mounted on specimens to measure strains that occur due to compressive loads. Load and strains that occurs were monitored and recorded with a data logger and a computer system. Furthermore, the relationship between stress and strain was made for each specimen. Indirect tensile strength testing was carried out based on SNI 2491-2014 [16]. The load speed used was 5 mm/minute.

3. RESULTS AND DISCUSSION

3.1 Slump Flow and T500

Flowability of SCC containing crushed laterite stone is shown in Fig 1. SCC that used crushed river stone obtained slump flow and T500 values of 680 mm and 4.77 second, respectively. Flowability of SCC containing crushed river stone is shown in Fig 2. For SCC that use crushed laterite stone, the values of slump flow and T500 were 680 mm and 4.08 second, respectively. The utilization of crushed river stone was recorded to slightly decrease slump flow and T500 values because the higher specific gravity nature of crushed river stone compared to crushed laterite stone, which resulted in a slower deployment in all directions compared to crushed laterite stone SCC.

By comparing Fig. 2a with Fig. 2b, it can clearly be seen that here was not much variation in the flow pattern for both the crushed laterite stone SCC and crushed river stone SCC. Sufficient physical properties and volume fraction of crushed laterite stone along with the sufficient suspended matrix (paste and mortar) made with PCC provide SCC to maintain homogenous distribution of aggregate, resulted in satisfying flow.



a. SCC containing crushed laterite stone
b. SCC containing crushed river stone

Fig 2. Slump flow of SCC

3.2 Compactibility

Appropriate visual observation was conducted on the surface of the test specimen before carrying out the compressive strength and indirect tensile strength tests. It can be seen that all specimens containing both crushed laterite stone and crushed river stone had a smooth surface without the appearance of large honeycombs or voids. The properly shape and outer appearance of the test specimens showed that SCC containing crushed laterite stones and that crushed river stone were adequately flowed and tightly filled into the mold corners by their own weight without the aid of a vibrator or tamping rod effort.

3.3 Compressive Stress – Strain Behavior

Fig. 3 shows the stress and strain relationship due to compressive load on SCC containing crushed river stone. It can be seen that at ages 3, 7, 28 and 90, stress and strain relationships formed a straight line of about 60, 70, 80 and 80% of the peak stress, respectively. After passing these values that indicated the ability of the hardened SCC containing crushed river stone to accept the load under elastic conditions, the stress-strain relationship changed to no longer form a straight line that indicates the specimen had cracked.

Fig. 4 shows the stress and strain relationship due to compressive load on SCC containing crushed laterite stone. Based on Fig 4, it can be determined that the linear stress strain relationship of test specimens aged 3, 7, 28 and 90 days was respectively around 70, 80, 80 and 80% of the peak stress.

In can be seen in Fig. 3 and 4, both SCC with crushed river stone and crushed laterite stone had similar pattern in terms of compressive stress-strain relationships. It can be seen that with age increasing, the slope formed between the compressive stress and strain became greater. The ascending slope from each curve was related to the level of stiffness where the greater slope showed that hardened SCC became stiffer. After passing the linear stress-strain relationship, cracks arose in the specimen so that the stress-strain relationship was no longer linear until it reached the peak stress (Neville A. M.) [17].

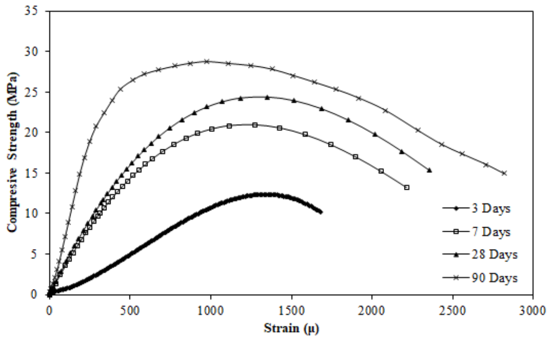


Fig 3. Stress and strain relationship due to compressive load on SCC containing crushed river stone

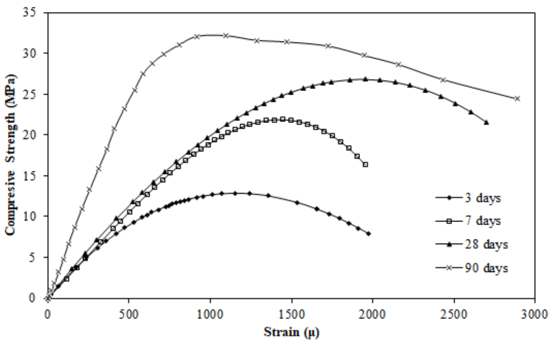


Fig 4. Stress and strain relationship due to compressive load on SCC containing crushed laterite stone

3.4 Maximum Vertical Strain at The Peak Stress

Fig. 5 shows peak vertical strain at the peak stress SCC containing crushed laterite stone. Based on the results shown in Table 7, 1458.0 µm, 1967.0 µm, 1976.4 µm and 2542.3 µm peak strain values were recorded for the crushed river stone SCC at 3, 7, 28 and 28 test days, respectively. For SCC containing crushed river stone, the peak strain of the test specimens aged 3, 7, and 90 days was 26.22%, 0,47% and 22.25%, respectively, compared to the peak strain of the specimens at 28 days. The peak strain values of crushed laterite stone SCC were found to be 1913,8 µm, 2483.7 µm, 2592.0 µm and 2826.3 µm at 3, 7, 28 and 90 test days, respectively. For SCC containing crushed laterite stone, the peak strain of the test specimens aged 3, 7, and 90 days was 26.16%, 4.17% and 8.28%, respectively, compared to the peak strain of the specimens at 28 days. The peak strain of the crushed laterite stone SCC were found to be higher compared the peak strain values of the crushed river stone at 3, 7 and 28 curing age. As reflected in the water absorption value (in Table 1), crushed laterite stone containing larger void volume than the crushed river stone therefore higher strains occurred due to the effect of the compressive loading on the framework of crushed laterite aggregate that containing larger void volume. Cement paste inside the voids has not been fully hydrated so that when it receives compressive loads, laterite river stones deformed larger. At the age of 90 days the cement paste inside the voids of laterite river stones had mostly been hydrated so that the deformation that occured became small when experiencing compressive load.

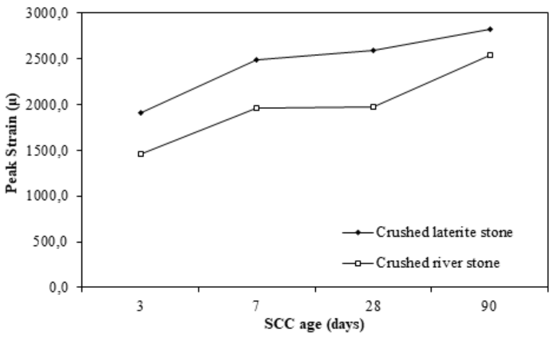


Fig 5. Maximum vertical strain at the peak stress

3.5 Compressive Strength

The peak stress values of crushed river stone SCC were found to be 12.18 MPa, 19.80 MPa, 24.36 MPa and 28.66 MPa at 3, 7, 28 and 90 test days, respectively. The peak stress values of crushed laterite stone SCC were found to be 13.31 MPa, 21.90 MPa, 27.78 MPa and 33.98 MPa at 3, 7, 28 and 90 test days, respectively. For both SCC with crushed laterite stone and SCC with crushed river stone, the compressive strength continued to increase over time. At each age of testing 3, 7, 28 and 90 days, SCC containing crushed laterite stone had higher compressive strength than the SCC containing crushed river stone.

This may be explained by the volume fractions of the ingredients in SCC mixture. Parameters influencing the strength such as compressive strength include the water and cement content, aggregates types and fractions as well as curing procedures. In this study, the w/c and fine aggregate fraction were kept constant for both SCC with crushed laterite stone and that with crushed river stone. So, the increment of compressive strength was due to utilization of crushed laterite stone. The compressive load was retained by the framework of crushed aggregate particles where the framework stiffness of the crushed laterite stone was higher than that of crushed river stone. Fig. 6 shows the results of the compressive strength test results.

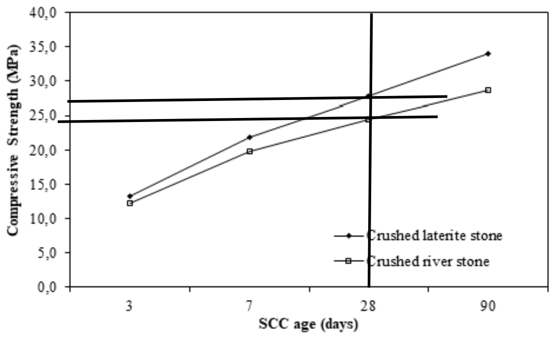


Fig 6. Compressive strength value

3.6 Indirect Tensile Strength

The peak stress values of crushed river stone SCC were found to be 1.05 MPa, 1.67 MPa, 2.09 MPa and 2.16 MPa at 3, 7, 28 and 90 test days, respectively. The peak stress values of crushed laterite stone SCC were found to be 1.16 MPa, 1.91 MPa, 2.41 MPa and 2.46 MPa at 3, 7, 28 and 90 test days, respectively. The tensile strength value is an important parameter for designing concrete mixtures and the dimensions of the structural layers for non-reinforced structures such as pavement slabs, container yards, warehouse floors, and airfield runways. Fig. 7 shows the results of the indirect tensile strength test results. It appears that indirect tensile strength increased as curing age rose where strength of SCC containing crushed laterite stone was consistently higher than those of SCC with crushed river stone. The results of the indirect tensile strength agreed with the results of the compressive strength tests.

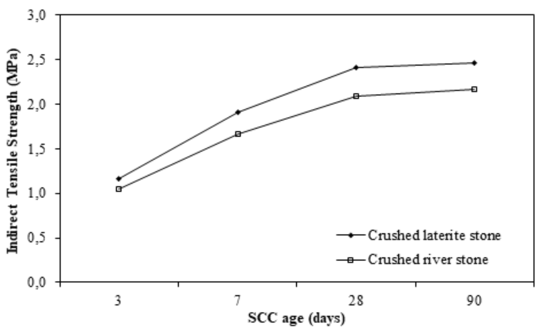


Fig 7. Indirect tensile strength value

4. CONCLUSIONS

This study used PCC as the main cementitious material. At the same w/c ratio, superplasticizer, fine aggregates fractions and volumes, two types of SCC mixtures were produced, the first using crushed river stones and the second using crushed laterite stones. Based on the test results it can be concluded as follows:

1. Slump flow and T500 from both types of SCC mixes met SCC mixture requirements of the fresh conditions required by ENERFAC.
2. Both SCC mixtures flowed and solids well, formed a specimen with a smooth surface, showing no large segregation and voids.
3. The compressive-strain stress relationship is almost the same in both mixes.
5. Physical properties which include compressive strength, indirect tensile strength and elasticity showed that SCC containing laterite stones was slightly better compared to SCC that uses crushed river stone.

6. ACKNOWLEDGEMENTS

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