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An investigation on the mechanical properties of concrete containing North-Sulawesi's coir fibre

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ABSTRACT

This paper presents the study into the mechanical properties of concrete incorporating coir fibre from North Sulawesi, Indonesia. Coir is a resilient natural fibre obtained from the husk of coconut fruit. The main objective of this research is to justify the usage of local natural resources in North Sulawesi as an alternative construction material by finding the optimum fibre percentage that can be used to achieve improved mechanical strength. Combining coir in the concrete mixture offers the potentiality of developing a high quality, economical and environmentally friendly construction material. Specifically, this research evaluates the compressive strength, flexural strength and split tensile strength of concrete samples containing variations of coir percentage of 0%, 0.25%, 0.5%, 0.75%, and 1% by weight of aggregates. Laboratory tests were conducted based on Indonesian National Standard (SNI) and American Society of Testing Materials (ASTM). Slump tests performed before casting of samples showed that the workability of concrete mixtures was reduced when fibre content was increased. Results of the mechanical properties tests showed that the 0.25% samples (BS-0.25) achieved optimum values of compressive strength and flexural strength.

1. INTRODUCTION

Coir fibre is a natural fibre obtained from the husks of coconut fruits. Haryanto, T. and D. Suheryanto (2004, cited in Oktavia, F. 2015) reported that a typical coconut fruit contains 35% of husk, 12% of shell, 28% of coconut flesh and 25% of coconut water. Furthermore, approximately 0.4 kg of husk can be obtained from 1 coconut fruit which contains approximately 30% of fibres and the rest is pith (Oktavia, F. 2015). In North Sulawesi where there are many coconut plantations, the major usage of coconut was for copra while the husk was usually wasted or used for traditional fire cooking. Recent development into the application of coir has opened the way of maximising the use of the husk hence has provided positive effects in elevating the economy that was once

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dropped due to fluctuations in the price of copra.

North Sulawesi is one of several places that have a big potential for production of coir due to the fact that it has relatively large smallholders' coconut plantation in Indonesia. According to the 2010-2014 statistics record of the Asian and Pacific Coconut Community (APCC), Indonesia has the largest area of coconut plantation among many countries in the world, followed by the Philippines and India. Furthermore, according to the statistics from Indonesian Directorate General of Estate Crops and Indonesian Bureau of Statistics, North Sulawesi is one of the major coconut producers in Indonesia. Data in 2010 from the Directorate showed that coconut plantations in Indonesia was about 3.7 million hectare which consisted of smallholders' plantations (98,14%), large state plantation (0,10%), and large private plantation (1,73%) (Lay & Pasang 2012). Furthermore, the data also showed that in 2010 it was recorded that Indonesian coconut production (copra equivalent) was approximately 3.26 million ton, with 3.18 million ton from smallholder plantations (Lay & Pasang 2012). Coconut processing in Indonesia contributes to the livelihood of approximately 7 million families or 35 milion people (Lay & Pasang 2012). However, this large production of coconut and its products has not yet been able to elevate the income of coconut farmers. Results of a survey by Cogent (*Coconut Germplasm Internasional*) in 2003 showed a concerningly low figure of US$ 200 annual income (Lay & Pasang 2012).

By researching on potential applications of coconut products, it is therefore expected that the livelihood of coconut farmers would improve. Furthermore, benefits of utilising local natural materials include a more continuous supply, relatively inexpensive and could add benefits to strength and durability. Current applications of coir range from floor mats and brushes to filling material for mattresses and car seats. Due to its properties, more applications of coir are also found in construction and composites industries. Many research into the mechanical properties of coir fibre has shown that coir fibre can be potentially used in developing coir fibre reinforced concrete (Ali & Chouw 2009, Ali et al. 2010, Ali et al. 2012, Filho et al. 1999, Bentur and Mindness 2007 cited in Ozerkan et al. 2013). Fig. 1 shows the extraction process of coir fibre that are used in this study.

Fig. 1 Extraction process of coir fibre at CV Puri Bitung Gemilang

Since the design of concrete structures requires information of the mechanical properties, it is therefore important to evaluate the compressive strength, split tensile strength and flexural strength of concrete containing coir fibre. The main objective of this research is to investigate the optimum value of the percentage of coir fibre as a reinforcement in concrete. The value is obtained based on the results from mechanical properties testing of concrete specimen.

2. MATERIALS AND METHODS

2.1 Coir fibre

Coir fibre was obtained from CV Puri Bitung Gemilang in bulky form. In the concrete laboratory at Manado State Polytechnic, the fibre filaments were prepared by cutting them into 30 mm length. The cut fibres were then rinsed with tap water to further remove impurities. Afterwards, they were soaked in water for 48 hours, air-dried for 1 week, then placed in plastic containers. Fig. 2 shows the preparation of coir fibre.

Fig. 2 Preparation of coir fibre

2.2 Concrete mix

Concrete mixes were prepared using Portland Composite Cement (PCC), sand and gravels. Mix design of concrete was based on SNI 03-2834-2000. Variations of the amount of coir fibre in the mixture are 0%, 0.25%, 0.5%, 0.75%, and 1% (by weight of aggregates), each was labelled BS-0, BS-0.25, BS-0.5, BS-0.75 and BS-1, respectively. A 0.7 m^3 capacity concrete mixer was used to mix each concrete batch.

Before every batch was cast into the mould, slump test was performed using Abrams cone. Values from the slump test provides indications of the consistency and workability of concrete mixture.

Concrete for compressive tests and tensile split tests were cast into 100/200 mm cylinders moulds. For flexural tests, the concrete was cast into 100x100x500 mm rectangular moulds. Fig. 3 shows the cast concrete in moulds. After 24 hours, the samples were demoulded, weighed and soaked in water until one day before the scheduled testing dates at 7, 14 and 28 days.

Fig. 3 Casting of concrete specimens

2.3 Mechanical properties testing

All mechanical tests were performed at the Concrete laboratory, Manado State Polytechnic, Manado, Indonesia. Indonesian National Standard (SNI) and related ASTM codes were used.

Compressive tests to the samples were performed on ELE Compressive Testing machine by applying incremental compression load to concrete cylinders as shown in Fig. 4(a).

Three-point bending test with distance between support of 450 mm was used to measure the flexural strength. Fig. 4(b) shows the test arrangement and positioning of a concrete sample.

Split tensile test is an indirect method of measuring the tensile strength of a concrete sample. It is done by splitting a concrete cylinder longitudinally. Fig. 4(c) shows the test configuration of split tensile test.

Fig. 4 Mechanical properties testing: (a) Compressive test, (b) Flexural test, (c) Tensile split test.

4. RESULTS AND DISCUSSIONS

4.1. Concrete workability

Results of slump test of each variation are presented in Table 1. As can be observed from the table, the control concrete without coir fibre exhibited 80 mm slump, which shows that the mixture was highly workable. The use of coir fibre resulted in reduced slump values which indicates reduced workability. Similar findings are also reported in Ozerkan et al. (2013) and Ali & Chouw (2009).

Table 1 Result of slump tests

Mixture Code	Slump (mm)
BS-0	80
BS-0.25	50
BS-0.5	45
BS-0.75	35
BS-1	30

4.2 Compressive strength

Fig. 5 shows a bar chart comparing the compressive strength of each concrete variation according to their test dates at 7, 14 and 28 days. Overall, the graph shows that the use of 0.25% by wt. of coir in the concrete mixture has the effect of increased compressive strength for all curing age. Lower compressive strengths, however, are noted for BS-0.5, BS-0.75 and BS-1. This shows that the use of more than 0.25% of coir in concrete has adverse effect on the compressive strength. Therefore, as seen from the graph, the optimum percentage of coir for compressive strength is 0.25% by wt. of aggregates.

At 7 days, compressive strength of control concrete was approximately 15 MPa. By adding 0.25% of coir fibre to the concrete mixture, the compressive strength shows an increased value of approximately 17 MPa. From BS-0.5 to BS-1, however, the 7-days compressive strength gradually decreased. Similar trends are also observed for 14 and 28-days results. Compressive strength of control concrete at 28 days was approximately 23 MPa while B-0.25 was 27.5 MPa. Lowest values of compressive strength were exhibited by BS-1, which indicates that 1% of coir by weight of aggregates is not effective in improving the strength of concrete.

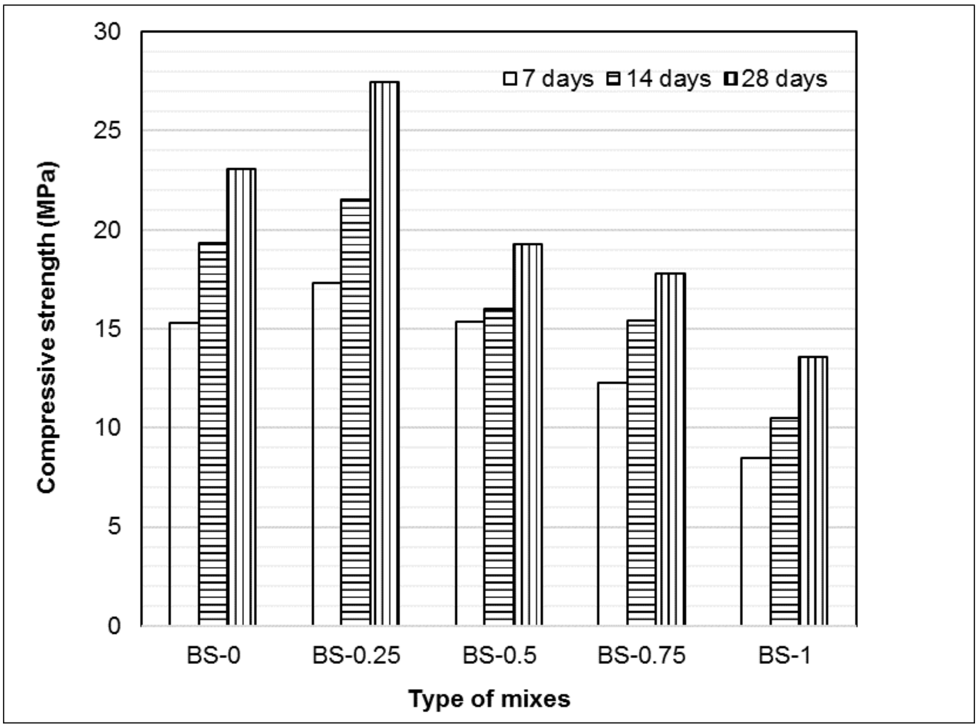

Fig. 5 Compressive strength of coir-concrete

4.2 Flexural strength

Results of three-point bending test are presented in Fig. 6. The bar chart shows the flexural strength of concrete samples at 7, 14 and 28 days. In general, the 7-days flexural strength of coir-concrete is between 1 Mpa – 5 MPa, the 14-days flexural strength is between 2 MPa to 5 MPa and the 28-days flexural strength of coir-concrete is between 2.5 MPa – 6 MPa. The addition 0.25% and 0.5% of coir in the concrete mixture has increased the flexural strength at 28 days, while the used of 0.75% and 1% of coir has decreasing effects.

As was observed previously with the compressive strength, BS-1 which has the highest content of coir in this study, also exhibited lowest flexural strength. Meanwhile, BS-0.25 exhibited the highest flexural strength. This means that 0.25% of coir in concrete mixture is the optimum amount.

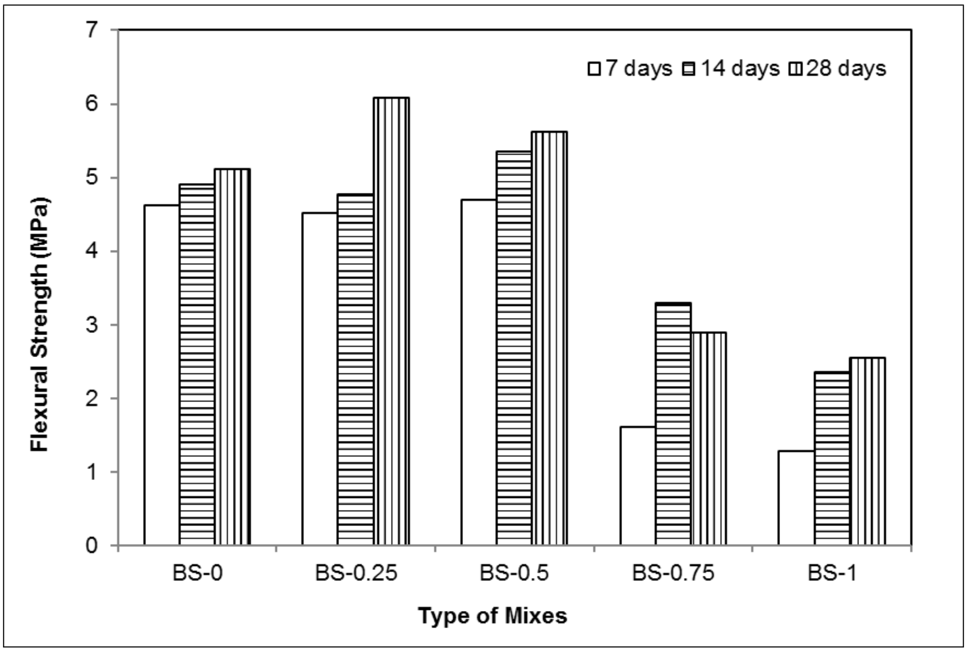

Fig. 6 Flexural strength of coir-concrete

4.3 Split tensile strength

Concrete has low tensile strength compared to its compressive strength. However, for design purposes, the tensile strength is also an important input. Split tensile test is the method used to obtain the tensile properties. Results of split tensile strength of coir fibre reinforced concrete can be observed from Fig. 7. The bar chart shows that the overall tensile strengths vary between 1 MPa to 3 MPa. The addition of coir fibre to concrete mixtures shows no improvement effect on the tensile strength for all curing ages.

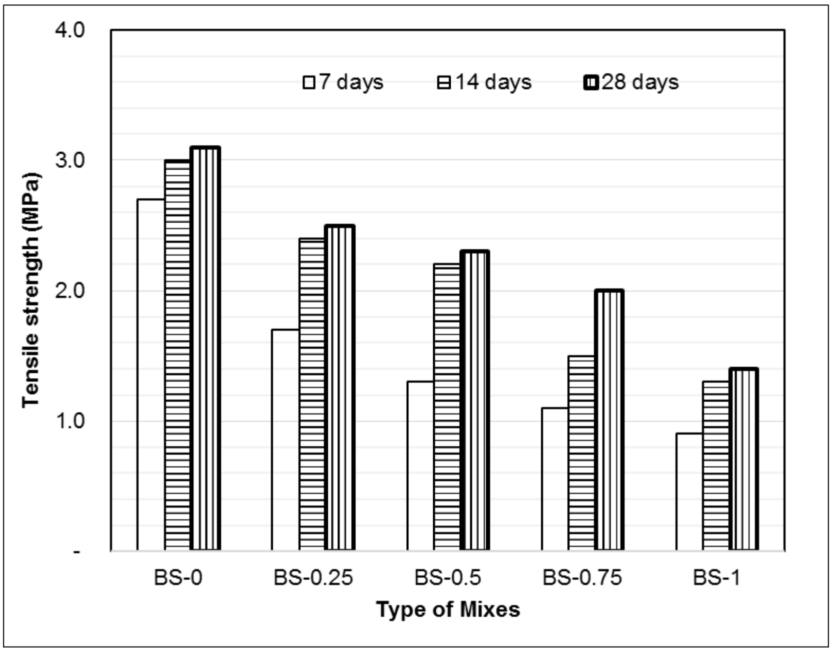

Fig. 7 Split tensile strength of coir-concrete

5. CONCLUSIONS

As a natural resources material with large amount of annual production in Indonesia and many other countries, coir fibre offers potentiality for many applications including as reinforcement to concrete mixture. In this study, the compressive, flexural and split tensile strength of coir-concrete were obtained and evaluated. Variations of coir amount were 0%, 0.25%, 0.5%, 0.75% and 1% by weight of aggregates. Results from this study showed that the optimum amount of coir fibre in concrete is 0.25%, which gives approximately 19% improvement in 28-days compressive strength and flexural strength. It was also found that the presence of fibre in the concrete has resulted in lower workability.

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