The Development of Coir- Concrete Blocks Aslightweight Construction Material

Rilya Rumbayan, Sudarno, Adriana Ticoalu

Abstract*:This paper presents the research into the incorporation of coir fiber in concrete blocks for construction purposes. Mechanical tests were performed on concrete samples containing different percentages of chopped coir fibers (0.25, 0.50, 0.75 and 1 by weight of aggregates). Density and water absorption characteristic of the samples were also measured and evaluated in relation to the mechanical properties. It was found that the average compressive strength of the blocks is in the range of 5–6 MPa and the average flexural strength is in the range of 1.04–1.47 MPa, which are lower compared to the results of samples without coir. Nevertheless, the compressive strength range of coir- concrete blocks in this study satisfies the requirements of relevant standards (SNI, AS and ASTM), specifically for non-structural or non-load-bearing concrete blocks. Furthermore, the density of the coir-concrete blocks is between 1230–1536 kg/m^3 which fit into the category of lightweight blocks. Based on the results, it can therefore be suggested that the development of coir-concrete blocks is feasible for non-structural, non-loadbearing, lightweight construction material.

***Keywords* :coir, concrete, blocks, bricks, coconut, materials**

I. INTRODUCTION

Concrete blocks are generally produced by mixing cement, sand and water. Depending on their specification, concrete blocks can be used for masonry, pavement or other special purposes. As it is with concrete, the properties and performance of concrete blocks can be personalized as required. Therefore, all around the world, the blocks come in different shapes, sizes and materials. Among the wide variations of types and shapes of concrete blocks, the two general types are hollow blocks and solid blocks. Extensive variations exist from these two general types.

Production of concrete blocks for masonry walls and pavements advanced significantly in recent decades due to high demand of building materials and also due to their advantages such as lightweight, cheaper and promote shorter labor time.

Nowadays, most concrete blocks are produced in large quantity using mechanized machineries. However, in many developing countries such as Indonesia, manual or traditional manufacturing dominates the production, especially for residential construction purposes.

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Therefore, the shapes, performance and qualities are greatly varied. These variations obviously affect the unit price of concrete blocks. In North Sulawesi, the price varies around Rp 2,000.00 – Rp 5,000.00 per block (approximately A$ 0.20–0.45). Many cheap blocks were produced and purchased to build budget residential housing with compromised quality and strength. One of the disadvantages in using concrete blocks especially with compromised quality and strength relates to the fact that they are relatively brittle and susceptible to cracks.

Incorporating natural fibers in concrete, mortar or cementitious mix has been found to have positive effects such as reducing cracks, minimize crack opening, enhance toughness, lowering density and increasing ductility [1]-[6].One of the natural fibers that has been found to improve ductility, minimize cracks and increase the toughness of concrete and cementitious mix is coir. Coir is obtained from the husk of coconut fruit. Recent research and developments in the inclusion of coir fiber in concrete, mortar or cementitious mix have provided valuable insights into the potentials of coir fiber. This paper aims to present the current study on the feasibility of adding coir in concrete blocks.

II. COIR FIBRE AND RESEARCH METHOD

A. Production and properties of coir fibre

Coir fiber is produced in many countries in the world such as India, China, The Phillipines, Indonesia, and many other countries where there are coconut tree plantations. The province of North Sulawesi in Indonesia has a large area of coconut plantation. Based on data from the Indonesian Directorate General of Estate Crops in 2015 [7], North Sulawesi had the third largest plantation area (287,705 ha) of the 33 provinces in Indonesia, after the provinces of Riau (502,185 ha) and East Java (285,537 ha).

Fig. 1 shows the traditional de-husking of coconut fruit. While many parts of coconut fruits and trees have been produced for some income-generating products, the production of coconut in Indonesia is mostly valued by the production of copra. The husks often go to waste or utilized as by products. Therefore, finding an effective alternative use of coir would be a significant contribution to the livelihood of many farmers.

Coir fibre itself offers some appealing properties. Being a natural material, it offers continuous supply and inexpensiveness. Furthermore, it is particularly known for its lower density and high elongation characteristics compared to other natural fibres[8].

Fig.1. Traditional coconut de-husking

B. Types and requirements for concrete blocks

Concrete blocks can be designed as structural or non-structural units, depending on the type of constituent materials and their proportions in the mix design. The mixture, when formed, is expected to produce blocks that satisfy the relevant standards as well as requirements from consumers. In some instances, the quality of the blocks was compromised causing unnecessary disastrous consequences. Such example was studied by Gordon et al. [9].

Indonesian Standard, the SNI 03-0349-1989 [10], categorizes concrete blocks into two general types, that are solid blocks and hollow blocks. It further classifies the blocks into four grades based on the minimum gross compressive strength. Grade IV, which is the lowest grade, requires the minimum average gross compressive strength of 25 kg/cm^2 (~2.45 MPa) and minimum individual gross compressive strength of 21 kg/cm^2 (~2.06 MPa).

In Australia, AS3700:2018 [11] grouped masonry unit into five categories, that are solid unit, cored unit, hollow unit, horizontally cored unit and special purpose unit (Standards Australia Limited, AS3700:2018). Based on this standard, for full bed concrete masonry unit, the characteristic unconfined compressive strength can be designed as 5 MPa, 10 MPa, 15 MPa, 20 MPa, 25 MPa, 30 MPa, 40 MPa or more than 50 MPa. Furthermore, AS/NZS 4455.1:2018 [12] specifies that to satisfy the requirement for integrity, the minimum characteristic unconfined compressive strength is 3 MPa for solid or vertically cored units, 2.5 MPa for horizontally cored units and 5 MPa for hollow units.

ASTM C129–17 [13] classifies concrete building bricks into three groups based on the density, i.e. lightweight (<1680 kg/m^3), medium weight (1680-2000 kg/m^3) and normal weight (>2000 kg/m^3). In this standard, the required minimum average net area compressive strength is 600 lb/in^2(~4.1 MPa), while the minimum compressive strength for individual unit is 500 lb/in2 (~3.4 MPa).

C. Materials And Methods

The strength and performance of concrete blocks greatly dependent on the aggregate and mix-design. Many local practices have used as low as 1:10 (1 part of cement to 10 parts of sand) for concrete block mix. In this study, 1:5 mix is designed using Portland Composite Cement (PCC) and locally sourced sand. To evaluate the effect of coir to mortar mix, five sample variations were designed, as shown in Table I.

All material preparation, sample casting and tests were performed at Manado State Polytechnic, North Sulawesi, Indonesia. The mortar mixture was cast with a concrete block press. The samples were then conditioned for testing at 7, 14 and 28 days. The size of the blocks in millimeters is 115(w) x 100(h) x 250(l). Compressive test was performed to half-size of the blocks, with surface area of 115mm x 125mm. Three point bending test was performed to obtain flexural test data. Before testing, the samples were weighed to evaluate the density. Furthermore, water absorption was measured at 28 days.

III. RESULTS AND DISCUSSION

A. Compressive strength

Results from compressive tests are presented in the chart in Fig. 2. As can be observed, the strengths of samples with coir are lower than the control sample. It is notable, however, that while the strength of control sample increased gradually by the test dates, the strength of samples with coir show significant increases from early ages (7 days and 14 days) to 28 days.

In this study, the inclusion of 0.25%, 0.50%, 0.75% and 1% of coir fiber in concrete block mix has resulted in compressive strength range of 5–6 MPa. Based on SNI 03-0348-1989 which specifies the grades of solid concrete blocks, this range satisfy the strength requirement of grade B40 (average minimum compressive strength of 40 kg/cm^2 ~ 3.92 MPa).

Comparable to the findings of Izquierdo et al. [1] with sisal fiber and Lertwattanaruk et al. [14] with coir and oil palm fibers, increasing the amount of coir fiber in this study has resulted in decreasing compressive strength, as can be observed from the test results at 28 days where the strength gradually decreased in relation to increased amount of coir.

Table I Mix design of coir-concrete blocks per 1 cubic meter

Sample name	Sample description	Cement (kg)	Sand (kg)	Coir (kg)
CC0	no coir	106.94	631.94	0
CC.25	0.25% coir bywt.	198.06	966.22	2.91
CC.50	0.5% coir bywt.	198.06	966.22	5.82
CC.75	0.75% coir bywt.	198.06	966.22	8.73
CC1	1% coir bywt.	198.06	966.22	11.64

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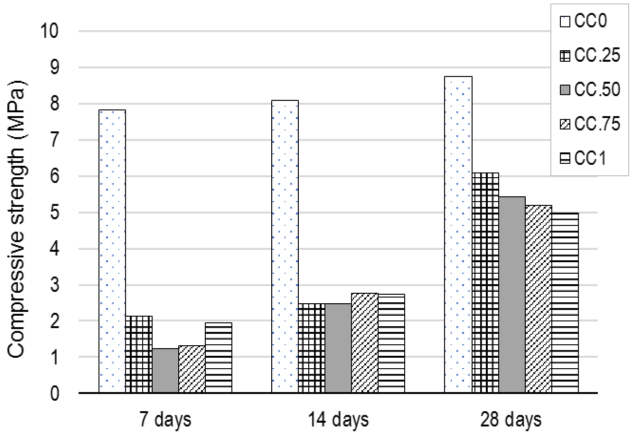

Fig.2. Compressive strength of coir-concrete block

B. Flexural Strength

Three point bending test was performed to concrete block samples and the results are shown in Fig. 3. The average flexural strength at 28 days of sample with coir is between 1.04–1.47 MPa, approximately 8–30% lower than the flexural strength of the blocks without coir.

Similar to the results of compressive strength, the increase of flexural strength from the early ages to 28-days is significant for samples with coir fibre. This is in contrast to the slight gradual increase shown by the control samples.

Unexpectedly, however, the results of blocks with 0.50% coir (CC.50) shows lowest flexural strength at all testing dates. Further investigations are underway to determine the causes.

C. Density

Results from density measurements show that the concrete block samples with coir fiber have average densities between 1230–1536 kg/m^3, while samples without coir have an average density of 1773 kg/m^3. It can be inferred, therefore, that the presence of coir fiber reduces the density of concrete blocks. Similar results have been reported in Sathiparan et al. [15].

Fig. 4 shows the density of the coir-concrete block samples relative to their compressive strength. The addition of coir has shown to reduce the compressive strength and also the density. Using the density classification in ASTM C55-2009, the coir-concrete blocks samples fit the lightweight group (<1680 kg/m^3). Therefore, coir-concrete blocks display good potentials for application in construction requiring lightweight and lower strength materials, especially for non-structural application.

D. Water absorption

Fig. 5 shows the percentage of water absorption in relation to the compressive strength of the samples. As can be observed, the presence of coir fibre in the samples has resulted in increased water absorption. Result from control samples (CC0) show water absorption rate of approximately 7.1%. The value is increased to 8.3% for CC.25, to 8.7% for CC.50 and significantly to 10.3% for CC.75. Unexpectedly, the water absorption rate dropped to 8.1% for CC1. This suggests that at a certain point, the amount of coir might have the effect of reducing the water absorption rate. This finding will be investigated further.

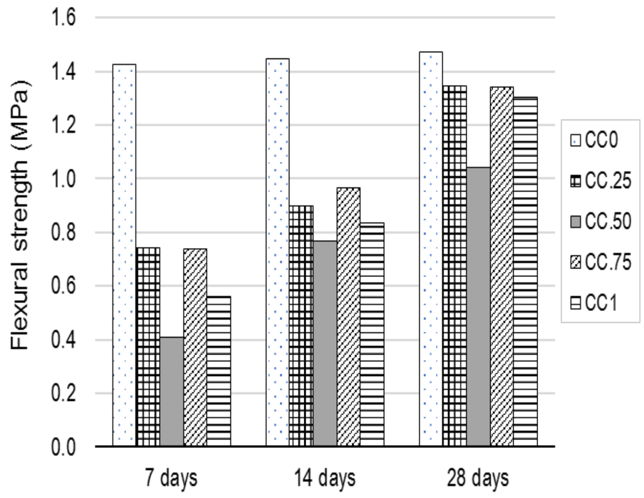

Fig. 3. Flexural strength of coir-concrete block

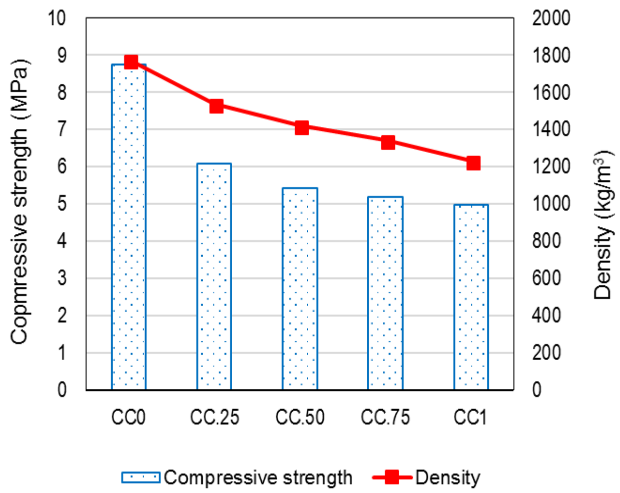

Fig. 4. Compressive strength and density of coir-concrete block

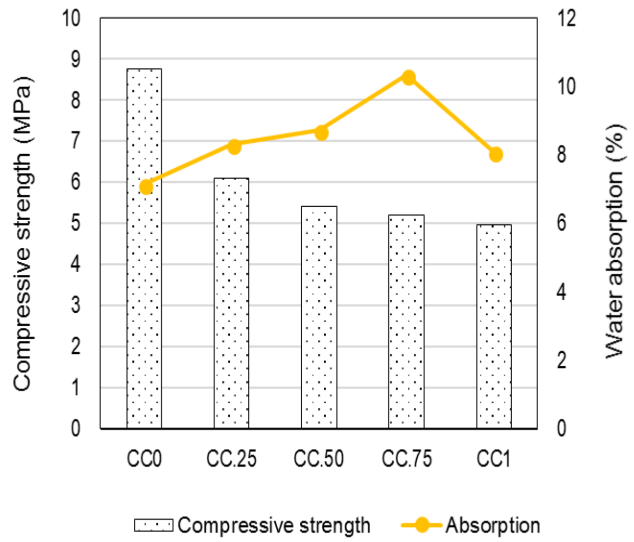

Fig.5. Compressive strength and water absorption of coir-concrete block

IV. CONCLUSION

With its natural characteristics and substantial production in many countries around the world including Indonesia, an effective utilization of coir fiber offers great potentials. In this paper, the research into the use of coir in concrete blocks has been presented and discussed. It was found that coir-concrete blocks having fiber percentage of 0.25, 0.50, 0.75 and 1 by weight of aggregates obtained average compressive strength between 5–6 MPa and average flexural strength between 1.04–1.47 MPa. It was found that the density of the blocks gradually reduced as the amount of fiber increased. This suggests the feasibility of coir-concrete blocks to be developed as lower strength, non-structural, lightweight construction material.

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Rilya Rumbayan specializes in Structural Engineering, with a focus on non-destructive evaluation for concrete structures. She studied in Department of Civil Engineering at The University of Tokyo, Japan for her Master degree and completed her Ph.D in 2013 in Department of Civil Engineering at University of Missouri, USA. Since 2002 until now, she works as Researcher and Lecturer at Civil Engineering Department, Manado State Polytechnic, Indonesia. Since March 2019, she holds a position as Secretary of Civil Engineering Department at Manado State Polytechnic. She actively participates in community service in the field of civil engineering.

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