Bamboo as Eco-Green Alternative for Concrete Reinforcement that use Sand Beach Fine Aggregate

Arbain Tata¹, Mufti Amir Sultan¹, M. Taufiq Yuda Saputra¹ and Imran¹
¹Civil Engineering Department, Faculty of Engineering, Universitas Khairun, Ternate, 97719-Indonesia.

[1] Corresponding e-mail: arbatata7@gmail.com

Abstract, Sand beach has been widely used at the archipelago as fine aggregate in concrete mixture. Sand beach's is available in huge quantities in many country side but the quality still needs to be investigated before using in construction. Sand beach can drive to corrosion on the steel reinforcement thus damaging the building. Previous studies have shown that bamboo has good tensile strength and flexural strength. This study aims to examine the use of bamboo as an alternative reinforcement in concrete beam made from sand beach's as fine aggregate. Sand beach of loto is one of three quarry sources chosen as a fine aggregate in making test specimens reinforced concrete beams as subjected study. Concrete beam specimens consist of 12 beams with 10x15 cm and a length of 120 cm of size. control beam (BN) was made from normal aggregate with steel reinforcement. the Variation of beam specimen (BF1, BF2, BF3, BF4, BF5) was made from sand beach's fine aggregate with bamboo reinforcement. Bamboo that applied as concrete beam reinforcement was Wulung bamboo kind that have about 3 years of age. bamboo's tensile test results were obtained average tensile strength is 185 MPa. The flexural test for all beam’s specimen was carried out with two-point loads to determine the amount of deflection that occurs in each beam. Analysis of relations of load-deflection was carried out to each beam specimen from the experiment result. test results showed that the bamboo reinforcement worked as well expected and no splitting occurred, so that the bamboo reinforcement appeared broken when ultimate strength exceeded. The maximum strength was obtained in BF5 beam specimen with an ultimate load 21,5 kN. Flexural test results show that on beams with steel reinforcement tends to occur flexural cracks while on beam with bamboo reinforcement also found shear cracks.

Keywords: bamboo reinforcement; deflection; sand

1. Introduction
The quality of fine aggregates used as concrete components has an important role in determining the strength of the concrete produced. because fine aggregates occupy most of the concrete volume. sand beach's is one type of fine aggregate that is available in huge quantities, but it’s still needs to be further investigated the effect as a concrete aggregate. generally, construction in North Maluku Province, especially in coastal areas, still uses a lot of sand beach's as fine aggregate in concrete mixture [1].

Aggregate characteristics are very important when dealing with the quality of concrete produced, because fine aggregates occupy most of the concrete volume. Sand beach's is one type of fine aggregate
that has a huge amount of availability, but the quality still needs to be further investigated before applied in concrete mixture. Generally, construction in North Maluku Province in the coastal areas, people still use sand beach's as fine aggregate in concrete construction. in the archipelago it is sometimes difficult to get good aggregate that accord to the SNI code. Coarse and fine aggregate quarries in the North Maluku province can be shown in Figure 1(a). The purpose of this study is to study the use of bamboo as an alternative reinforcement for concrete beam that made from sand beach's as fine aggregate. The water cement mixture will form cement paste which has a function as a binder, while coarse aggregates and fine aggregates function as fillers in concrete [1]. sand beach's is the sand that found at the coast which is fine-grained and round texture that shape from friction. sand beach's contains salt so that the sand beach's is considered not good enough to be used as a concrete aggregate. the Salt content in sand beach's make the aggregate always in rather wet conditions and cause expansion at the building [3], [4].

The result of experiment test of concrete compressive strength in previous studies with fine aggregate of sand beaches and sand from the mountain appear to have a significant decrease in strength. the compressive strength of concrete use fine aggregate from Mount Kalumata obtained 24.96 MPa as targeted which 25 MPa. And for concrete that use fine aggregate sand beaches from three different regions namely Mangoli, Sosowomo and Loto obtained a significant variation of compressive strength, namely, Loto sand obtained 22.84 MPa, Mangoli sand obtained 19.21 MPa, and Sosowomo sand obtained 16.25 MPa [1].

Reinforcing steel is a mining processes product whose existence will eventually run out, so that the price of steel will soar. One alternative so that the economic value of materials in building structure planning can be achieved is to use bamboo as a substitute for steel reinforcement. Bamboo is known to have good properties to be used as a substitute for tensile steel bars, including strong, ductile, straight, flat, hard, easy to split, easily formed and easy to work and lightweight rods, making it easy to transport. Bamboo is also relatively cheap compared to other building materials because it is easy to found around countryside. In previous studies, bamboo poles were used as concrete beam reinforcement, where the beams were planned to be under reinforced condition. All the beams were given a chosen bamboo reinforcement with a 12 mm of diameter and were given a waterproof layer. Improvement of stickiness can be done by lacquered the bamboo or twisted the bamboo [5].

Research using steel reinforced concrete beams to compare the results obtained for bamboo reinforced concrete beams. From the test results found about the tensile strength of bamboo about half of mild steel and modulus of elasticity of about one third of mild steel [6],[7],[8]. Bamboo has the same main tensile strength as mild steel at the yield point and combined with other benefits increases the use of bamboo as a construction material [9]. Bamboo is a versatile material because of its high strength-to-weight ratio, easy to do and approved. Analysis of steel replacements with bamboo as reinforcement shows reinforcement with bamboo is quite cheaper than steel reinforcement [10]. Using bamboo as
reinforcement was found to have increased bending and modulus of elasticity of bamboo beams with repeated bamboo [11] [12] [13]. The use of bamboo as a flexible reinforcement, it can be concluded bamboo can be used as unistructural in low cost construction [14] [15] [16]. Research using bamboo as the main reinforcement, researchers support bamboo can also be used as a structural construction [17],[18]. Testing of bamboo reinforcement models due to vertical loads, shows that the failure of the model frame is caused by lateral buckling. Tests show that laminated bamboo coils have adequate stiffness and strength [19] [8].

First step in this research is to determine the type of bamboo that will be used as beam reinforcement. The bamboo used in this study was bamboo Petung’s kind of. Another research uses Bamboo Apus’s which is stronger against tensile, especially the skin part of bamboo which is the protector and strongest part of the bamboo. In addition, this kind of bamboo is also more flexible than other types of bamboo, more durable even without preservation, and easier to obtain [2]. Meanwhile, choosing Petung bamboo is because it has a high tensile strength and this species bamboo is many found in the Ternate area. Petung bamboo is commonly used as a stick or booth, or Indonesian traditional house material. Javanese bamboo is usually used for simple flagpoles or banner poles. Next step was soaked the selected bamboo for about a week and then tested. Furthermore, is to take the strongest bamboo that have been tested of the two and is applied as reinforcement in concrete beam with compressive strength $f'c$-25 MPa. Bamboo petung's can be seen in figure 1(b).

2. Materials and Methods

2.1 Beam Specimen

The specimens for concrete compressive strength test and modulus of elasticity are 150x300 mm cylinders testing conducted after 28 days old. The cube specimen was put at pressure testing machine and then given a load until the object collapses, at the time of maximum load. Based on the Indonesian PBI-1989 (Peraturan Beton Indonesia), the amount of concrete compressive strength can be calculated by the formula below: $f'c = \frac{P}{A}$ [21].

$$f'c = \frac{P}{A}$$  \hspace{1cm} (1)

| Beams cross section | Specification | Number of test objects | Beams cross section | Specification | Number of test objects |
|---------------------|--------------|------------------------|---------------------|--------------|------------------------|
| Fine Aggregate      | Number of test objects |
| BN                  | (BN)         | 2                      | BF3                 | (BF3)        | 2                      |
| BF1                 | (BF1)        | 2                      | BF4                 | (BF4)        | 2                      |
| BF2                 | (BF2)        | 2                      | BF5                 | (BF5)        | 2                      |
The design of the concrete mixture in this study is based on the ASTM method with a 25 MPa concrete quality plan. Bamboo reinforced concrete beam 10x15x120 cm of dimension was tested at 28 days [20]. Details of the test specimen can be seen in the table 1. Concrete beam specimens consist of 12 beams with 10x15 cm and a length of 120 cm of size. control beam (BN) was made from normal aggregate with steel reinforcement. the Variation of beam specimen (BF1, BF2, BF3, BF4, BF5) was made from sand beach's fine aggregate with bamboo reinforcement.

2.2 Beam flexural test

The beams specimen was tested under simple supported beams subjected to two-point load using a universal testing machine. As shown in Figure 2(a) Each specimen was instrumented by manometer, respectively.

![Two-point load](image)

(a) Test setup

![Details of tested beams](image)

(b) Details of tested beams

**Figure 2.** Test setup & details of tested beams

Figure 2(b) shows the details of the prepared test beams. The concrete beam was prepared in the cross-sectional dimension of 100 mm x 150 mm with 1200 mm length. The beam is designed with 2 D 10 bamboo bar as a tensile reinforcement from the tensile D10 bamboo bar test, it was obtained average yield stress of 185 MPa.

3. Result and Discussion

3.1 Aggregate properties

Based on table 2, the fine aggregate used generally meets the specifications in accordance with SNI (Standard Nasional Indonesia). The water absorption in each Quarry is higher than the specifications that indicated the absorption of sand beach's more aggressive than normal fine aggregate for concrete.

3.2 Compressive strength

The compressive strength of the three coarse aggregate sources used for concrete mix has the same tendency, the smaller water-cement ratio WC, the higher the compressive strength obtained, conversely the greater the value of WC, the lower the concrete compressive strength value. the WC is very influential on the compressive strength of the concrete produced.
Table 2. Coarse aggregate properties

| Aggregate properties       | Aggregate sources | Standard range |
|----------------------------|-------------------|----------------|
|                            | Loto              | Kusu           | Ake Lamo       |
| Sand equivalent            | 0.67%             | 1.33%          | 1.5%           | 0.2% - 5%      |
| Water content              | 3.32%             | 4.44%          | 4.45%          | 3% - 5%        |
| Absorption                 | 3.09%             | 4.18%          | 5.82%          | 0.2% - 2%      |
| Specific gravity on dry basic | 2.55%        | 2.47%          | 2.42%          | 1.6 - 3.2      |
| apparent specific gravity  | 2.63%             | 2.57%          | 2.56%          | 1.6 - 3.2      |
| Bulk specific gravity      | 2.77%             | 2.76%          | 2.82%          | 1.6 - 3.2      |
| Fine modulus               | 1.80%             | 1.82%          | 1.82%          | 1.5% - 3.8%    |

Table 3. Fine aggregate properties

| Aggregate properties       | Aggregate sources | Standard range |
|----------------------------|-------------------|----------------|
|                            | Loto              | Kusu           | Ake Lamo       |
| Sand equivalent            | 0.67%             | 1.33%          | 1.5%           | 0.2% - 5%      |
| Water content              | 3.32%             | 4.44%          | 4.45%          | 3% - 5%        |
| Absorption                 | 3.09%             | 4.18%          | 5.82%          | 0.2% - 2%      |
| Specific gravity on dry basic | 2.55%        | 2.47%          | 2.42%          | 1.6 - 3.2      |
| apparent specific gravity  | 2.63%             | 2.57%          | 2.56%          | 1.6 - 3.2      |
| Bulk specific gravity      | 2.77%             | 2.76%          | 2.82%          | 1.6 - 3.2      |
| Fine modulus               | 1.80%             | 1.82%          | 1.82%          | 1.5% - 3.8%    |

Fig 3. Compressive strength – WC relationship

3.3 Beam deflection

Beam flexural test is conducted by placing the beam specimen on a simple support at both ends of the beam, then the beam loaded with two points loads at a predetermined distance according to the tool. Observation of beam deflection is obtained from the results of LVDT reading placed in the middle of the span that is precisely at a distance of 22.5 cm from the end of the beam.
Table 4. Summary of monotonic load ultimate

| Beams | Load Theoretical Max. (kN) | Load Experimental Max. (kN) | Deflection Max. (mm) | Moment Experimental Max. (kN.m) | Bending Moment % From (BN) |
|-------|-----------------------------|-----------------------------|----------------------|--------------------------------|--------------------------|
| BN    | 18.29                       | 18.02                       | 12.05                | 4.06                           | 0                        |
| BF1   | 13.27                       | 12.75                       | 9.62                 | 2.96                           | -27.1                    |
| BF2   | 19.30                       | 19.50                       | 13.12                | 4.29                           | 5.67                     |
| BF3   | 20.81                       | 20.08                       | 11.40                | 4.62                           | 13.8                     |
| BF4   | 21.32                       | 21.50                       | 10.23                | 4.73                           | 16.5                     |
| BF5   | 25.88                       | 22.75                       | 9.14                 | 5.73                           | 41.1                     |

Figure 4 shows the relationship of load-deflection of the beam specimen. The initial crack occurred at 6.45 kN of load. Deflection due to maximum load occurs on the specimen BF3 which is 13.12 mm. Beam deflection decreases with the addition of bamboo reinforcement on the tensile zone of the beam. Increase of the beam’s capacity to load along with the addition of bamboo reinforcement on the tensile zone of the concrete beam.

3.4 Crack pattern

The reinforced of beam specimen are designed at under reinforcement state. Failure mechanism begins with cracks at the tensile surface followed by weakening of the reinforcement and ends with the breaking of the bamboo reinforcement on. Based on the static load test on the beam, the maximum load obtained for the control concrete beam (BN) is 18.02 kN and the maximum load for the beam with bamboo reinforcement (BF5) is 22.75 kN. Figure 5(a) shows the condition of the beam that has experienced failure after under monotonic load on the control beam (BN), failure that occurs was bending failure that begins with the destruction of on the tensile surface upright perpendicular followed by the destruction of on the compressive side. Figure 5(b) also shows shear failure on the bamboo reinforced...
specimen beam right around the load point (BF4). Phenomenon in fig. 5(c) is a pattern of failure that occurs in bamboo reinforced concrete beam. The photo shows that pull and cohesive action between the concrete and bamboo reinforcement is quite good and this causes a break in the bamboo reinforcement after the ultimate load.

![Specimen beams pattern collapse](image)

**Fig 5.** Detail specimen beams pattern collapse

4. Conclusions
From the results of the study it can be concluded as follows: Sand beaches can be used as a fine aggregate for reinforced concrete that used bamboo. The use of sand beach's as fine aggregate can reduce the strength of concrete and the use of sea water in concrete mix can also reduce the strength of concrete by 2%. Bamboo reinforcement is good enough to be applied in simple construction because it has a high tensile strength up to 180 kN. Bamboo reinforcement is effective for use on concrete beam of simple buildings such as two-story buildings. Bamboo has good concrete adhesion so that it breaks after the ultimate load exceeded on flexural testing.

5. References
[1] A. Tata, I. Irnawaty, and C. Cavaruddin, “Studi Karakteristik Agregat Pasir Pantai Mangoli, Sosowomo dan Loto dalam Komposisi Beton,” TECHNO J. Penelit., 2018.
[2] Nobuaki Otsuki, Tsuyoshi Saito, and Yutaka Tadokoro, “Possibility of Sea Water as Mixing Water in Concrete,” J. Civ. Eng. Archit., 2012.
[3] T. Arbain, R. Anthonius Frederik, I. Muhammad, and D. Rudy, “Durability of RC Beams Strengthened Using GFRP-Sheet due to Fatigue Loads,” MATEC Web Conf., 2019.
[4] A. Tata, A. Frederik Raffel, I. Ihsan, and R. Djamaluddin, “GFRP-sheet strengthened RC beams after seawater immersion under monotonic and fatigue loads,” MATEC Web Conf., 2019.
[5] A. Sethia and V. Baradiya, “Experimental Investigation on Behavior of Bamboo Reinforced Concrete Member,” Int. J. Res. Eng. Technol., vol. 03, no. 02, pp. 344–348, 2014.
[6] I. K. Khan, “Performance of Bamboo Reinforced Concrete Beam,” Int. J. Sci. Environ. Technol., vol. 3, no. 3, pp. 836–840, 2014.
[7] S. Ahmad, A. Raza, and H. Gupta, “Mechanical Properties of Bamboo Fibre Reinforced Concrete,” in 2nd International Conference on Research in Science, Engineering and Technology (ICRSET’2014), 2014, vol. 1, pp. 162–166.
[8] M. R. Awall, M. H. Ali, M. A. Rahman, M. A. Hossain, and S. U. Khan, “Performance Evaluation of Bamboo As Reinforcement in Flexural Members,” in 3rd International Conference on Advances in Civil Engineering, 2016, vol. 8, no. April 2017, p. 2017.
[9] P. K. Singh, A. Jodhani, and A. P. Singh, “Bamboo as construction material and bamboo reinforcement,” Int. J. Civ. Struct. Eng. Res., vol. 4, no. 1, pp. 312–323, 2016.
[10] A. Nayak, A. S. Bajaj, A. Jain, A. Khandelwal, and H. Tiwari, “Replacement of Steel by Bamboo Reinforcement,” IOSR J. Mech. Civ. Eng., vol. 8, no. 1, pp. 50–61, 2013.

[11] K. Ghavami, “Bamboo as reinforcement in structural concrete elements,” Cem. Concr. Compos., vol. 27, no. 6, pp. 637–649, 2005.

[12] A. Shakeel, A. Raza, and H. Gupta, “Mechanical Properties of Bamboo Fibre Reinforced Concrete,” in 2nd International Conference on Research in Science, Engineering and Technology (ICRSET’2014), 2014, vol. 2, pp. 162–166.

[13] M. M. Rahman, M. H. Rashid, M. A. Hossain, M. T. Hasan, and M. K. Hasan, “Performance evaluation of bamboo reinforced concrete beam,” Int. J. Civ. Eng. Technol., vol. 11, no. 4, pp. 113–118, 2011.

[14] S. V Rayadu, A. P. Randiwe, and I. K. Gupta, “Study of Bamboo as Reinforcement in Concrete,” Int. Adv. Res. J. Sci. Eng. Technol., vol. 4, no. 11, pp. 245–251, 2017.

[15] S. Kavitha and F. Kala, “Experimental Investigation on Behavior of Bamboo Reinforced Concrete Member,” Int. J. Res. Eng. Technol., vol. 03, no. 02, pp. 344–348, 2014.

[16] J. K. Sevalia, N. B. Siddhpura, C. S. Agrawal, D. B. Shah, and J. V Kapadia, “Study on Bamboo as Reinforcement in Cement Concrete,” Int. J. Eng. Res. Appl., vol. 3, no. 2, pp. 1181–1190, 2013.

[17] P. Rama Mohan Rao and S. Karthik, “Investigation on flexural behaviour of beam with bamboo as main rebars,” Int. J. Recent Technol. Eng., vol. 7, no. 4, pp. 173–177, 2018.

[18] A. A. Mark and A. O. Russell, “A comparative study of Bamboo reinforced concrete beams using different stirrup,” Int. J. Civ. Struct. Eng., 2011.

[19] G. Chen, Y. Xiao, and B. Shan, “Experimental studies on glue-laminated bamboo trusses,” Adv. Mater. Res., vol. 639–640, no. 1, pp. 757–762, 2013.

[20] ASTM C496, “Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens,” ASTM Int., 2006.

[21] Departemen Pekerjaan Umum, Peraturan Beton Bertulang Indonesia. 1971.