Laboratory Testing on The Standard Mixed Designed Paving with Bamboo Material as Smooth and Rough Aggregate

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Abstract. The use of natural ingredients as a mixture of concrete such as bamboo waste to increase the absorption of paving but still meets the standards of minimum compressive strength. This study aims to obtain the optimum value of bamboo waste substitution in coarse and fine aggregate aggregates based on the standard of minimum paving compressive strength. Test objects measuring 15cm x 15cm x 15cm use substitution of powder mixture and bamboo pieces with a percentage of 10%, 15%, 20% and 25% as many as 5 pcs per percentage and laboratory testing of compressive strength at the age of 28 days is carried out. From the results of the compressive strength test, the average compressive strength of each variation is 10% = 22.16 MPa, 15% = 17.51 MPa, 20% = 15.27 MPa and 25% = 12.72 MPa. Based on the target of minimum compressive strength for paving (17 MPa), the results of mixed substitution are obtained by the percentage of optimum compressive strength of 16% with optimum absorption of 0.21%.

1. Introduction

Environmental-oriented development is being intensively carried out in Indonesia, basically to comprehensible response the vision of the President of the Republic of Indonesia toward better sustainability. In the construction industry, environmentally friendly not only be considered by utilizing the natural ingredients but also the recycling of useful materials from waste such as fibers and coconut shells, bamboo woven fiber as well as bamboo waste from unused building scaffolds. The use of bamboo waste for concrete paving mixes is used to increase the absorption of paving but still meets the minimum standard of compressive strength. The use of bamboo waste for concrete paving mixes is purposely innovated to overcome flood problems in the parking area (Figure 1). Therefore, in this study bamboo pieces were introduced as a substitute for coarse aggregates and bamboo powder as fine aggregate substitutions. The use of bamboo waste aims to obtain a tight and strong but lightweight concrete paving structure and the ability to absorb water, so that it can function as a water infiltration.
2. Standard paving and mix design materials

2.1. Mixed composition and properties
Paving block or normally called as concrete brick is a mixed composition between portland cement or other hydraulic cement, fine aggregate, coarse aggregate, and water, with or without other additives. This mixed composition provide good strength of paving block with specific attainment of physical properties as can be seen in Table 1. Basically, the physical properties of paving block are classified according its quality such as A for road, B for parking, C for pedestrians and D for parks and other usages.

Table 1. Physical properties [1-2].

| Quality | Compressive Strength (MPa) | Wear Resistance (mm/minute) | Maximum water absorption (%) |
|---------|----------------------------|-----------------------------|-----------------------------|
|         | Average | Min | Average | Min |     |
| A       | 40      | 35  | 0,090   | 0,103 | 3   |
| B       | 20      | 17,0 | 0,130   | 0,149 | 6   |
| C       | 15      | 12,5 | 0,160   | 0,184 | 8   |
| D       | 10      | 8,5  | 0,219   | 0,251 | 10  |

2.2. Cement
Cement is a hydraulic material that can react chemically with water, thus forming a dense material. In general, the chemical composition of Portland cement is as shown in Table 2.

Table 2. Portland cement composition [3-4].

| Oxide               | Composition (% weight) |
|---------------------|------------------------|
| Lime, CaO           | 60 – 65                |
| Silica, SiO₂         | 17 – 25                |
| Alumina, Al₂O₃      | 1 – 8                  |
| Iron, Fe₂O₃         | 0,5 – 6                |
| Magnesia, Mg O      | 0,5 – 4                |
| Sulfur, SO₃         | 1 – 2                  |
| Potash, Na₂O + K₂O  | 0,5 – 1                |

2.3. Aggregate
Aggregates are the most critical component of concrete in determining magnitude. In concrete, there is usually about 70% to 75% aggregate volume. This aggregate must be graded in such a way that the entire mass of the concrete can function as a whole, homogeneous, and dense object, in which small
aggregates serve as fillers of gaps between large aggregates [3]. The coarse aggregates in this study consisted of coconut shells in which the aggregate properties also affected the attachment between the totals and the water requirements of the mixers. Aggregates that have smaller grain sizes have the potential to produce high strength concrete. A good roughly aggregate gradient constraint according to [5] is shown in Table 3.

| Sieves Diameter | Percentage of Passed |
|-----------------|----------------------|
| 25.4 mm (1")    | 100                  |
| 19.0 mm (3/4")  | 95 – 100             |
| 9.50 mm (3/8")  | 20 – 55              |
| 4.75 mm (No. 4) | 0 – 10               |
| 2.36 mm (No. 8) | 0 – 5                |

Table 3. Gradation of aggregate.

Fine aggregates typically are sand, either natural and obtained directly from the river or quarry, or from the breakdown of rocks. Its size varies between the number 4 and number 100 US standard sieve. Good fine aggregate must be free of organic material, clay, particles smaller than 100 sieve numbers or other materials that can damage the concrete mix. Fine aggregate was natural sand as a result of the disintegration of the 'natural' rock or sand produced by stone crushers industries and has the largest grain size 5.0 mm [6].

2.4. Water
Water is meant here is water used as a mixture of building materials, must be clean water and does not contain ingredients that can reduce the quality of concrete. Water used for the best concrete-making process is clean water that meets drinking water requirements. Water used in the process of making concrete if too little it will cause the concrete will be difficult to work, but if the water content used is too much then the strength of the concrete will decrease and there is shrinkage after the concrete hardens. To obtain a concrete density with low water cement ratio you should use a vibrator. Maintain moisture and heat to keep it constant during the hydration process, for example by covering the surface with a wet sack [7].

2.5. Waste bamboo
Obtained from trees that are different from the Bambusoideae family. Bamboo culms, in general, are cylindrical shells, which are divided by the transverse diaphragm at the node. Bamboo shells are high strength orthotropic materials in the direction of fibers and low strength perpendicular to each fiber. Natural fibers like natural fibers from bamboo have low density, relatively cheap prices and low energy consumption, and can neutralize CO2 and produce O2 three times more than other plants. The most special thing is that bamboo fiber has high ductility besides strength that can be competed with other materials such as steel [8-9].

2.6. Modification of mix design
The test specimens used were cubes of size 15 x 15 x 15 cm consisting of 5 samples for each variation of 10%, 15%, 20%, and 25% and tested at 28 days as shown in Table 4.
Table 4. Matrix test specimens [10].

| Cement (kg) | Gravel (kg) | Bamboo Pieces | Fine Aggregate (kg) | Bamboo Powder | Water (kg) | Number of Sample |
|-------------|-------------|---------------|---------------------|---------------|------------|------------------|
|             |             | %            | %                   | %            | kg         |                  |
| 495         | 1098        | 10           | 122                 | 729          | 10         | 81               | 258             | 5               |
| 495         | 1037        | 15           | 183                 | 688          | 15         | 122              | 258             | 5               |
| 495         | 976         | 20           | 244                 | 648          | 20         | 162              | 258             | 5               |
| 495         | 915         | 25           | 305                 | 607          | 25         | 203              | 258             | 5               |

3. Methodology

3.1. Compressive strength testing

Testing of Concrete Pressure According to SNI 1974-2011 the standard test for concrete compressive strength with cylindrical samples with diameter 15 cm and height of 30 cm calculated by dividing the maximum load achieved during testing with concrete sample surface area, can be systematically written as follows [11]:

\[ f_c = \frac{P}{A} \]  

where, \( f_c \) is the compressive strength of concrete (MPa), \( P \) is the maximum compressive load (N) and \( A \) is the cross-sectional area (mm\(^2\)).

3.2. Absorption testing

Absorption test in paving block is done by weighing the weight of the test object when it is lifted from the immersion pond. Then weigh the specimen before the compressive strength test is dry. The difference in weight of the wet test object minus the weight of the test object in a dry state will be the value of its absorption.

4. Results and discussion

The results of the compressive strength test on the concrete paving press machine at 28 days of all samples of bamboo waste and bamboo powder waste mixtures in the mixed design matrix (Table 4) are shown in Table 5.

At the point of intersection of the compressive strength test results on average in 28 days with a minimum standard compressive strength of concrete paving optimum values obtained from the combination with a piece of bamboo and powder is 16% (Figure 2).

From the results of the observations obtained the average percentage of absorption values of each variation of 10%, 15%, 20% and 25% respectively 0.19%, 0.22%, 0.26% and 0.33% as in the table 6. From these results it can be concluded that the largest percentage of water absorption will be obtained if the substitution of bamboo pieces and bamboo powder is given to 16% paving block mixture.

To obtain optimal absorption values with the addition of bamboo percentage done by drawing a line perpendicular to the optimum moisture content is sought. Based on the results obtained in Figure 2, we can see the intersection of the average absorption line and the optimal percentage of replacement of bamboo pieces and powder resulting in an absorption value of 0.21% (Figure 3).
Table 5. Compressive strength test results.

| % of Bamboo Pieces and Powder | No | Strength of 28 day (kg/cm²) | Strength of 28 day (MPa) | Average Strength of 28 day (MPa) |
|-------------------------------|----|-----------------------------|--------------------------|---------------------------------|
| 10                            | 1  | 303                         | 25.16                    |                                 |
|                               | 2  | 303                         | 25.15                    |                                 |
|                               | 3  | 267                         | 22.13                    |                                 |
|                               | 4  | 236                         | 19.55                    |                                 |
|                               | 5  | 227                         | 18.82                    | 22.16                           |
| 15                            | 1  | 218                         | 18.10                    |                                 |
|                               | 2  | 210                         | 17.40                    | 17.51                           |
|                               | 3  | 209                         | 17.35                    |                                 |
|                               | 4  | 208                         | 17.30                    |                                 |
|                               | 5  | 210                         | 17.40                    |                                 |
| 20                            | 1  | 205                         | 17.00                    | 15.27                           |
|                               | 2  | 207                         | 17.16                    |                                 |
|                               | 3  | 183                         | 15.15                    |                                 |
|                               | 4  | 173                         | 14.37                    | 15.27                           |
|                               | 5  | 152                         | 12.65                    |                                 |
| 25                            | 1  | 171                         | 14.18                    | 12.71                           |
|                               | 2  | 173                         | 14.33                    |                                 |
|                               | 3  | 149                         | 12.35                    |                                 |
|                               | 4  | 140                         | 11.60                    |                                 |
|                               | 5  | 134                         | 11.10                    |                                 |

Figure 2. Optimal point of strength of compression substitution of pieces of bamboo and powder.
Table 6. Absorption Test Results Sample Age 28 Days.

| No | % of Bamboo Pieces and Powder | Weight of wet sample (kg) | Weight of dry sample (kg) | Percentage of absorption | Average |
|----|-------------------------------|---------------------------|---------------------------|--------------------------|---------|
| 10 | 1                             | 8.15                      | 8.00                      | 0.15                     | 0.19    |
|    | 2                             | 8.25                      | 8.00                      | 0.10                     |         |
|    | 3                             | 8.25                      | 8.00                      | 0.25                     |         |
|    | 4                             | 8.30                      | 8.10                      | 0.20                     |         |
|    | 5                             | 8.20                      | 7.95                      | 0.25                     |         |
| 15 | 1                             | 7.90                      | 7.70                      | 0.10                     | 0.20    |
|    | 2                             | 7.70                      | 7.50                      | 0.20                     |         |
|    | 3                             | 7.90                      | 7.70                      | 0.20                     |         |
|    | 4                             | 7.75                      | 7.60                      | 0.10                     |         |
|    | 5                             | 7.90                      | 7.65                      | 0.40                     |         |
| 20 | 1                             | 8.15                      | 7.90                      | 0.25                     | 0.26    |
|    | 2                             | 8.30                      | 8.15                      | 0.30                     |         |
|    | 3                             | 8.20                      | 8.00                      | 0.25                     |         |
|    | 4                             | 8.30                      | 8.15                      | 0.30                     |         |
|    | 5                             | 8.20                      | 8.00                      | 0.20                     |         |
| 25 | 1                             | 8.05                      | 7.90                      | 0.25                     | 0.33    |
|    | 2                             | 7.95                      | 7.70                      | 0.20                     |         |
|    | 3                             | 8.30                      | 8.00                      | 0.40                     |         |
|    | 4                             | 8.20                      | 8.00                      | 0.35                     |         |
|    | 5                             | 8.20                      | 8.00                      | 0.45                     |         |

Figure 3. Optimum absorption percentage.

5. Conclusion
Based on the research of compressive strength and absorption tests that have been carried out and the results of data analysis that have been obtained from these observations, it can be concluded as follows:

- The results of the paving compressive strength test with variations in the substitution of bamboo and powder pieces at 28 days have different compressive strength results. The value
of the average compressive strength of paving using variations of 10%, 15%, 20% and 25% are 22.16 MPa, 17.51 MPa, 15.27 MPa and 12.71 MPa, respectively.

- By cutting the curved line on the graph of compressive strength and drawing a line from the intersection point perpendicular to the percentage of substitution, the optimal percentage value of bamboo substitution is in accordance with the standard mixture of paving block design, so that paving can meet the minimum compressive strength of 17 MPa the optimum percentage that has been determined is 16%.
- Absorption testing shows that the average water absorption values are 0.19%, 0.20%, 0.26% and 0.33% for variations in woven bamboo waste 10%, 15%, 20% and 25%. The addition of the percentage of bamboo and powder pieces for water absorption is directly proportional, because of the nature and characteristics of bamboo which can absorb large amounts of water. While the optimal percentage of bamboo substitution is 16%, the absorption rate is 0.21%.

6. References

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