The Effect of Bending Strength of Concrete Using Machine Crushed Fine Aggregate

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Abstract: Concrete is a mixture of Portland cement or other hydraulic cement, fine aggregate, coarse aggregate, and water with or without additives to form a solid mass. Cement concrete pavement is a pavement construction with aggregate as raw material and uses cement as a binding material, so it has a relatively high level of rigidity, especially when compared to asphalt pavement. The fine aggregate commonly used is natural fine aggregate. Due to the increasing use of fine aggregate in construction so as to obtain the fine aggregate by means of sand mining, ecological damage in some areas. Therefore, the use of natural fine aggregate can be replaced with machine crushed aggregate. Based on this, this study aims to determine the maximum compressive strength of concrete, maximum flexural strength of concrete blocks using a mixture of machined aggregate percentage. The research method was carried out with 15cm x 15cm x 60cm beams. Variation of the test specimen mixture is a mixture that meets the maximum combined gradation limit of 30mm. Flexural strength testing was carried out at the age of 56 days. The highest flexural strength test results are found in variation 2, which is 4.85 MPa.

Keywords: Concrete, Fine Aggregate Broken Machine, Flexural Strength.

1. Introduction

Concrete is a mixture of Portland cement or other hydraulic cement, fine aggregate, coarse aggregate and water, with or without additional admixtures to form a solid mass.[1]. Concrete can be used for stiffening. Rigid pavement (concrete cement) is a pavement construction with aggregate as raw material and uses cement as the binding material, so it has a relatively high level of rigidity, especially when compared to asphalt pavement (flexible pavement), this pavement is also known as rigid pavement or rigid pavement. [2] . The standard concrete quality for rigid pavement based on the 2017 Freeway and Toll Road Technical Specifications has a flexural strength value (Sc') = 4.5 MPa [3] . In general, the materials needed for rigid pavements consist of a mixture of concrete, reinforcement, and joint sealant. While the components for the concrete mixture consist of cement, water, fine aggregate and coarse aggregate which are mixed in a certain ratio and to produce a certain strength. The function of aggregate in the concrete mixture is as a filler, but because of its large proportion, which is about 60% - 70% of the weight of the concrete mixture, this aggregate becomes an important part. So far, the aggregates used for mixing rigid pavements are coarse aggregate and natural fine aggregate. Due to the increasing use of fine aggregate in construction so as to obtain the fine aggregate by means of sand mining, which has an impact on people who are experiencing natural damage (the journal Nature Sustainability, published online March 24, 2022, it refers to ecological damage in several Asian and African countries as a result of sand mining activities). The need for natural aggregates increases from year to year, and in some areas there is a raw material crisis so that material prices increase. Natural aggregate is an aggregate that is spherical in shape and has a relatively slippery surface compared to artificial aggregate because this aggregate is eroded by water, this causes the strength of the concrete to be low. Meanwhile, crushed aggregate from the stone crusher has an angular shape and a rough surface that has a stronger binding capacity. Therefore, the use of natural fine aggregate can be replaced with machine crushed fine aggregate. Based on this, this study aims to determine the maximum flexural strength of concrete blocks using a mixture of machine-broken aggregate percentages. The results of the mixture that get the maximum flexural strength can be used as a rigid pavement design.

2. Method

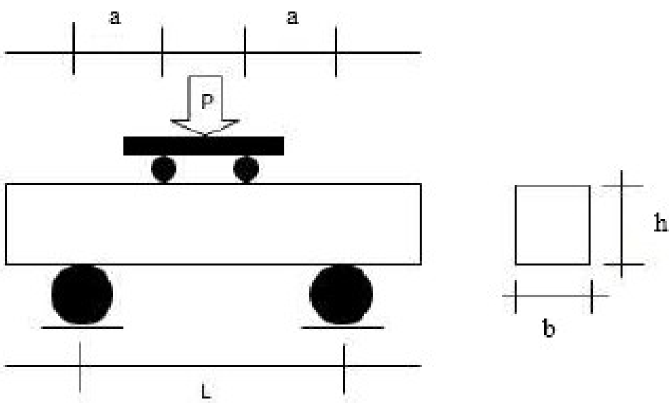
This research was conducted at the Civil Engineering Laboratory of the Padang State Polytechnic and the UPTD Construction Materials Laboratory of the Ministry of PUPR, West Sumatra. Concrete mix design refers to the American Concrete Institute (ACI) 211.4R-93. The flexural strength test of concrete refers to the Indonesian National Standard (SNI) 4431:2011.

In this study, there were five types of variation of the specimen based on the increase in the percentage of moderate aggregate that met the maximum combined gradation limit of 30mm. The number of test objects for each variation made can be seen in Table 1.

Table1. Number of Samples

Mixed Variations	Sample Age 56 Days
	Flexural Strength
Variation 1	2
Variation 2	2
Variation 3	2
Variation 4	2
Variation 5	2
Total	10

The flexural strength of concrete is the ability of a concrete block placed on two supports to withstand a force perpendicular to the axis of the test object, which is applied to it, until the test object breaks, expressed in MPa of force per unit area.[4]. An illustration of the flexural tensile strength test can be seen inImage 1.



Picture1. Flexural strength test

The calculation formulas used are:

a) For tests where the fracture plane is located in the center area (area 1/3 of the distance from the center point of the placement), the flexural strength of the concrete is calculated according to the following equation.

$$\sigma_I = \frac{P.L}{b.h^2} \quad (1)$$

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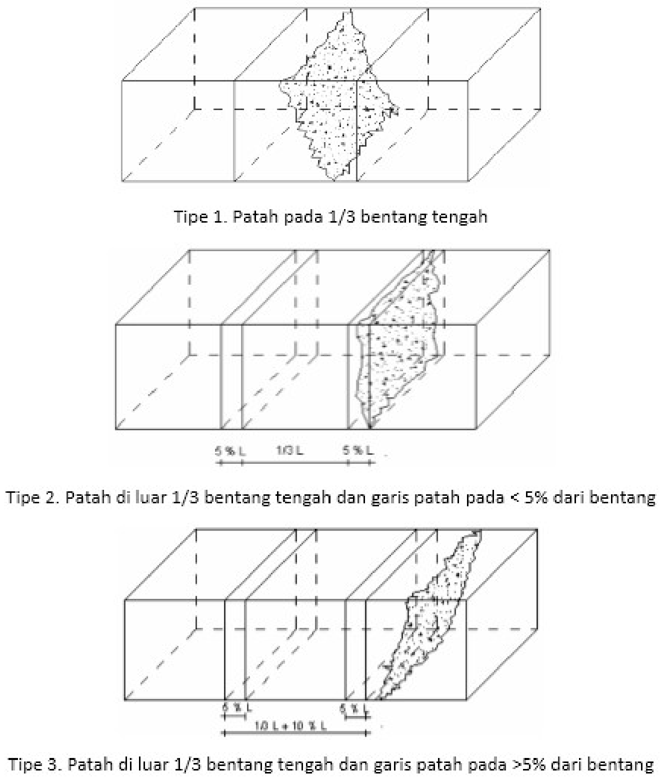
b) For tests where the fracture of the test object is outside the center (area 1/3 of the center distance of the center point), and the distance between the center point and the fracture point is less than 5% of the distance between the bearing points, the flexural strength of the concrete is calculated according to the following equation.

$$\sigma_I = \frac{P.a}{b.h^2} \qquad (2)$$

Information:

σ_I = flexural strength of the test object (MPa)
P = highest load read on the test machine (N)
L = Distance (span) between two linesplacement (mm)
a = distance fromlaying to force (mm)
b = cross-sectional width of the beam (mm)
h = cross-sectional height of the beam (mm)

The types of fractures in the beam are as follows:



Picture2. Beam crack pattern due to bending test

In the flexural test there are various types of cracks or fractures as shown in FigFigure 2. The types of crack patterns that can be used for the test results are type 1 and type 2 as shown in FigFigure 2. However, the flexural strength results for the type 1 and type 2 crack patterns are obtained using different equations as shown in equation 1 and equation 2. The beam crack pattern such as type 3 cannot be tested (SNI 4431:2011)

3. Results and Discussion

Before making a concrete mix design, it is necessary to determine the percentage of each aggregate mixture that meets the maximum combined gradation limit of 30mm. The percentage of each aggregate can be seen in Table 2.

Table2. Percentage of concrete mix

Mixed Variations	Fine Aggregate (%)	Medium Aggregate (%)	Coarse Aggregate (%)
1	49	22	29
2	49	24	27
3	54	29	17
4	53	31.5	15.5
5	50	33	17

3.1 Fresh Concrete Test

In the implementation of mixing, slump and bulk weight tests were carried out. The results of the slump and bulk weight tests can be seen in Table 3 and Table 4.

Table3. Fresh concrete slump test results

Mixed Variations	Addition of Water (kg)	*Slump*(cm)	
		Average	Plan
1	1.32	5.67	5 – 7.5
2	1.10	5.17	5 – 7.5
3	1.50	5.17	5 – 7.5
4	1.38	5.33	5 – 7.5
5	1.22	6.67	5 – 7.5

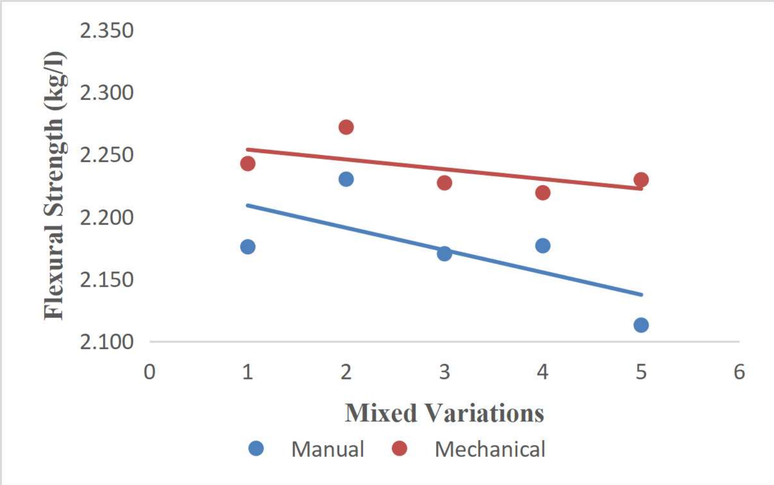
Table4. The results of the density test of fresh concrete

Mixed Variations	Block Filling Weight (kg/lt)	
	Manual Solid	Mechanical Solid
1	2,176	2,243
2	2,230	2,272
3	2,170	2,227
4	2,177	2,219
5	2,113	2,230

Slump is the level of concrete viscosity that affects the permeability, workability, and workmanship. Factors that affect slump include aggregate grain size, amount of water, and the effect of water on cement. The planned slump value limit is 5 – 7.5 cm. To achieve the planned slump value, water is added. The addition of water is caused by high aggregate absorption and the aggregate moisture content at the time of mixing is different from the initial moisture content due to aggregate storage not in a closed place.

In the manufacture of the mixture, it is necessary to add water to meet the slump criteria. The average addition of water for the manufacture of a mixture of test specimens is 1.308 kg.

The results of the concrete density test can be seen in Figure 3.



Picture3. Filling Weight of Concrete Block

Based on Figure 3, it is known that the concrete density value for all variations can be classified as normal concrete which has a density range of 2100 – 2550 kg/m3 (ACI 211, 1991). The density of the concrete is influenced by two things, namely the weight of the material and the density of the concrete mixture. Each sample variation of concrete uses the same type of material, so that the difference in the value of the density of the concrete lies in the density of the mixture. The higher the density of the mixture, the higher the density of the concrete.

The density of the concrete has increased from variation 1 to variation 2 and decreased from variation 3 to variation 4. Due to the increased density of the concrete mix due to the balanced amount of aggregate so that the binding power of the concrete mixture is dense and maximum in variation 2. decreased due to the amount of coarse aggregate being less than the fine aggregate in the concrete mixture.

3.2 Flexural Strength Test.

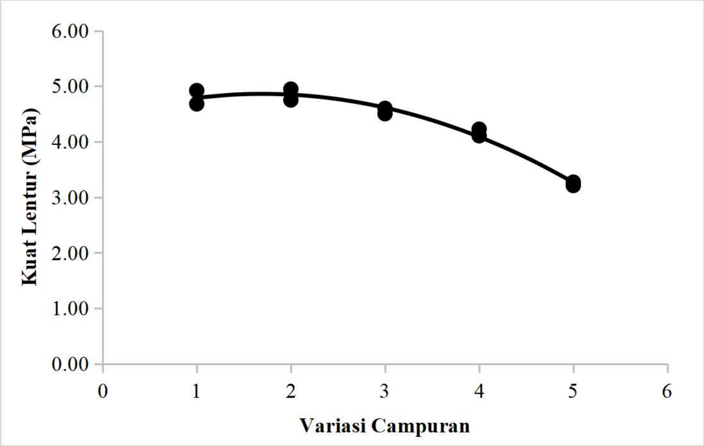
The results of the flexural strength test of 56 days old concrete can be seen in table 5.

Table5. The flexural strength of concrete aged 56 days

Mixed Variations	Flexural Strength (Mpa)	Average flexural strength (MPa)
1	4.68 4.92	4.8
2	4.75 4.95	4.85
3	4.60 4.50	4.55
4	4.23 4.11	4.17
5	3.27 3.21	3.24

The flexural strength test of concrete was carried out at the age of 56 days. The calculation of the flexural strength was obtained using the flexural strength equation formula for the test object with the fracture plane located in the center area (area 1/3 of the distance from the center point of placement). The location of the fracture can be seen in the pattern of concrete cracks that occur in the flexural strength of the concrete.

Based on the data from the compressive strength test of concrete, a graph of the tendency of the compressive strength is drawn which can be seen in FigFigure 4.



Picture4. Concrete flexural strength graph

The maximum flexural strength for the concrete mixture is found in variation 2. In variation 2 has a high density value because the concrete mixture in variation 2 is denser and binds to each other, so when pressing is needed a higher compressive force to make the concrete reach its strength capacity. Increased flexural strength of concrete atFigure 4proportional to the increase in the weight of the concrete atFigure 3. So it can be seen that the higher the density of the concrete, the higher the flexural strength of the concrete.

4. Conclusion

Based on the research that has been done, the highest flexural strength of concrete is found in variation 2 and decreases in variations 3 to 5 along with the addition of medium aggregate percentage. The percentage of aggregate in variation 2 is 49% fine aggregate, 24% medium aggregate and 27% coarse aggregate, with a maximum flexural strength of 4.85 MPa.

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