Bending capacity of reinforced concrete beam with a rough aggregate of 2/3 teak pieces.

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Abstract **-** The development of science, especially in civil engineering, demands a better concrete technology. Replacing the rough aggregate with teak pieces of length 2 cm, width 3 cm, and height 2 cm was tried to reduce the weight of the concrete. This wood was selected because of its light. The testing phases included: testing of concrete cylinders and testing of reinforced concrete beam bending. The bending beam test was done by making a specimen with dimension of beam: width 120 mm, height 150 mm, and length 1200 mm. The main reinforcements used were 2Ø10 mm and 3Ø10. For the chock, Ø6-50 reinforcement bar was used. On the test of concrete cylinder results with soaked rough aggregates, it was found that compressive strength at 28 days old was 5.09 MPa and 4.74 MPa for non-soaked aggregate. On the test of reinforced concrete beams with 2 pieces of tensile reinforcement, it was found the average maximum load of 26300 N and average deflection of 6.99 mm. The average of reinforced concrete beam with 3 pieces of tensile reinforcement was 30500 N and average deflection of 8.66 mm. The bending strength of reinforced beam with 3 pieces of tensile reinforcement average was 5.34.106 Nmm. The comparison of calculation result between experiment and theory was found that load and moment for 2 pieces of tensile reinforcement was 0,72%, while comparison between load and moment for 3 pieces of tensile reinforcement was 0,58%.

Keywords: *teak wood, lightweight concrete, load beam capacity.*

1. Preface

The development of science, especially science in civil engineering, demands a better concrete technology. To reduce the concrete weight, replacing the rough aggregate as well as the fine aggregate for the concrete mixture is done. One of them is by replacing the rough aggregate with teak pieces. The utilization of this wood type is because it has lighter weight than gravel. It can decrease the dead load from the concrete structure. The use of wood aggregate can be classified as a lightweight concrete type. The advances in concrete technology science will be able to meet the demands of local materials use.

Indonesia as a tropical country is very rich in timber as forest products. There are several thousand species of tree giving fairlyproud forest products, which are produced from forests in Java, Sumatra, Kalimantan and Sulawesi. Traditionally, wood has been used for various purposes of society and various building structures. In the development of building materials technology, wood still shows its reliability. In the mastery of wood technology, many ways and techniques of wood processing which is effective, practical, economical, and save the use of wood have not been developed. In wood cutting or processing places, there are still many pieces of unused wood and untapped waste. The waste is tried to use as a concrete-making material by replacing the rough aggregate with the pieces of wood. Not all Islands in Indonesia have sand and gravel aggregate. It must be brought from Java and, of course, the making of concrete will become very expensive. With the advancement of concrete technology, the waste of teak pieces can be utilized to meet the demands of the local materials use as concrete aggregates.

2. Literature Review

Aggregates are mineral granules that act as fillers in concrete mixtures. The properties considered important in aggregate selection are: specific gravity, unit of weight, water uptake, hardness, the wear and gradation. Normal aggregates are aggregates which thespecific gravity is between 2.5 and 2.7. It includes heavy aggregate if the specific gravity is more than 2.8 and light aggregate if the specific gravity is less than 2.0 (Tjokrodimuljo, 1996).

According to Murdock (1986), light aggregates have porous surface forms that cause very high water uptake and affect their strength. Before stirring, the rough aggregate should be soaked first and then dried until the surface is dry. After that, the process of mixing and stirring the concrete can be done.

According to Ismariana (1993), the specific gravity of teak at the age class of IV (36 years), based on the wet volume, is between 0.56-0.64 with average of 0.59; based on the dry volume of wind, is 0.63; and dry kiln, is 0.66. For the age class of VI (56 years), based on wet volumes, the specific gravity is 0.60, and based on dry volume of kiln, is0.67. For the age class of VIII (78 years), based on wet volume, the specific gravity is between 0.62, based on dry volume of wind is 0.66, while 0.69 ondry kiln.

General characters of teak wood are the color of its corewooden which is light brown, grayish brown to dark brown or red brown with the sapwood of white or grayish yellowish. The texture is somewhat rough and uneven. The surface of the wood is slippery or somewhat slippery. It is sometimes oily, with straight direction fibers or, sometimes, somewhat integrated and has a clear growing circle whether in transverse or radial area which gives a beautiful image (Martawijaya, 1981).

According to Mulyono (1974), the specific gravity of dry kiln varies from 0.44 to 0.82 with an average of 0.63. The specific gravity of dry wind ranges from 0.48 to 0.88 with an average of 0.67 (including its sapwood). Its longitudinal decrease from fresh to dry state is 0.8% for dry kiln, 3% for its radial, and 5.8%. for its tangential

According to Martawijaya (1981), who examines the teak, it is found that the specific gravity of teak wood is 0.62-0.75 with an average of 0.67. The radial decrease is 2.8% and the tangential direction is 5.2%. Teak wood is classified into strong class II and durable class I.

The water content in wood varies greatly among species, depending on the place of growth, age, and volume (Haygreen and Bowyer, 1989). According to Yudodibroto (1974), the water content in wood in addition to factors of growth place, age, and volume are also influenced by climate.

Pashin and De Zeew (1980) concluded that all characters of wood, both mechanical and non-mechanical, are strongly influenced by the changes in the water content.

3. Methodology Research

There were 6 beam testobjects createdthat can be seen inTable 1 and figure 1.

Table 1. Specification of Test Objects

Code	Length (mm)	Width (mm)	Height (mm)	Main Reinforcement		Chock Reinforcement
				Upper	Lower	
BL21	1200	120	150	2Ø10	2Ø10	Ø6-50
BL22	1200	120	150	2Ø10	2Ø10	Ø6-50
BL23	1200	120	150	2Ø10	2Ø10	Ø6-50

Code	Length (mm)	Width (mm)	Height (mm)	Main Reinforcement		Chock Reinforcement
				Upper	Lower	
BL31	1200	120	150	2Ø10	2Ø10	Ø6-50
BL32	1200	120	150	2Ø10	2Ø10	Ø6-50
BL33	1200	120	150	2Ø10	2Ø10	Ø6-50

Note:
- BL2 = Bending beam with 2 tensile reinforcements
- BL3 = Bending beam with 3 tensile reinforcements

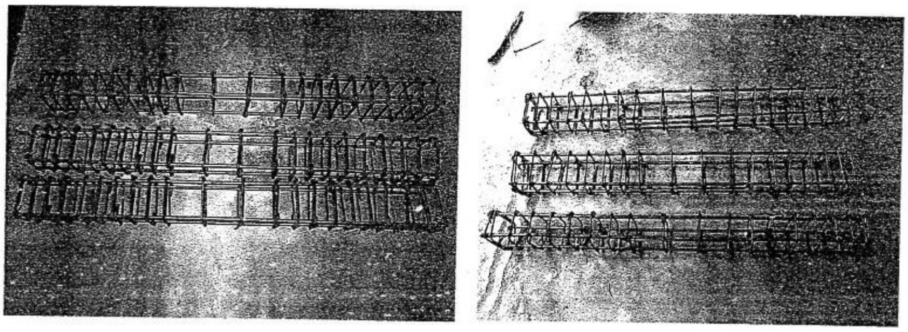

Figure 1. Bending Beam Test Material Object with 2 and 3 Tensile Reinforcements

4. The Testing of Beam Test Object

After the test object of the reinforced concrete beam was ready to test, the reinforced concrete beam was placed on the strong loading frame and stacked by the roll-joint on the both ends. The net span of the beam is 1200 mm, and loaded symmetrically at the points as far as 350 mm from each support, see Figure 2.

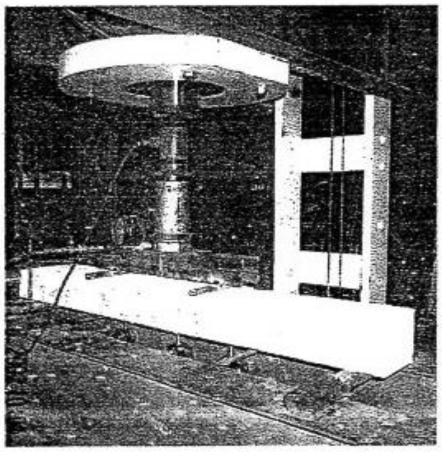

Figure 2. Setting Up the Beam Bending Test

At the center of 350 mm, pure bending was expected. Loading was done with the help of hydraulic jacks that had a capacity of 30 tons and load cell that had capacity of 10 tons. The loading was done gradually with increase interval of 100 kg. The loading was stopped if the transducer indicating the load from the load cell had reached the maximum load. Data to note in this beam test included:

A. The deflection during the loading process which was showed by dial gauge.
B. The amount of load at the time of cracking.
C. The maximum load that could be retained by the beam.
D. The pattern of cracks that occurred on reinforced concrete beams due to loading.

5. Results and Discussion

The Testing of Concrete Cylinder and Steel Reinforcement

The Compressive Strength of Concrete

The compressive strength of the concrete was determined by the highest voltage of the cylindrical test object with a diameter of 150 mm and a height of 300 mm. The concrete cylinder was tested after 28 days using a compressive test machine by gradually loading the load, until the test object was destroyed.

Table 2.The result of Concrete Compressive Strength with Rough Aggregate Soaked for 24 Hours withFasof 0.5

No	Code	Age (days)	Specific Gravity (t/m3)	Pressed Strength (MPa)	Average (MPa)
1	BKB-1	7	1,59	4,07	4,29
2	BKB-2	7	1,62	4,82	
3	BKB-3	7	1,55	3,99	
4	BKB-4	14	1,67	4,66	4,44
5	BKB-5	14	1,61	3,90	
6	BKB-6	14	1,68	4,75	
7	BKB-7	28	1,63	5,47	5,09
8	BKB-8	28	1,63	5,12	
9	BKB-9	28	1,66	4,68	

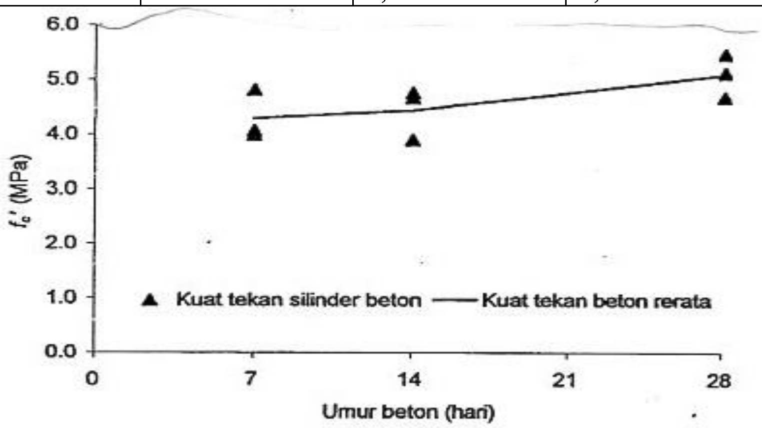

Figure 3. The Average Compressive Strength of Concrete with Rough Aggregate Soaked For 24 Hours

Table 3. The result of Concrete Compressive Strength with Rough Aggregate that was not soaked withFas of 0.5

No	Code	Age (days)	Specific Gravity (t/m3)	Pressed Strength (MPa)	Average (MPa)
1	BKK-1	7	1,54	4,53	5,00
2	BKK-2	7	1,56	4,36	
3	BKK-3	7	1,70	6,11	
4	BKK-4	14	1,55	4,82	4,97
5	BKK-5	14	1,56	4,61	
6	BKK6	14	1,61	5,47	
7	BKK-7	28	1,52	5,23	4,74

No	Code	Age (days)	Specific Gravity (t/m3)	Pressed Strength (MPa)	Average (MPa)
8	BKK-8	28	1,57	4,47	
9	BKK-9	28	1,51	4,52	

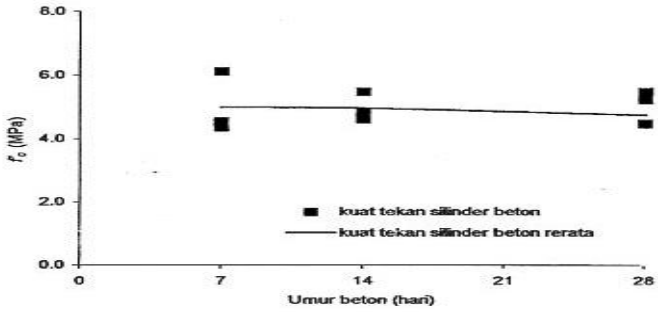

Figure 4. The Average Compressive Strength of Concrete with Non-soaked Rough Aggregate

6. The Specific Gravity Of Concrete

Based on the examination, the specific gravity values of concrete cylinders with aggregate of teak pieces can be seen in Tables 4 and 5 and Figures 4 and 5.

Table 4.The Specific Gravity of Concrete with Rough Aggregate Soaked With Fas 0.5

No	Code	Specific Gravity (t/m^3)	Average (MPa)
1	BKB-1	1,59	1,58
2	BKB-2	1,62	
3	BKB-3	1,55	
4	BKB-4	1,67	1,66
5	BKB-5	1,61	
6	BKB-6	1,68	
7	BKB-7	1,63	1,64
8	BKB-8	1,63	
9	BKB-9	1,66	

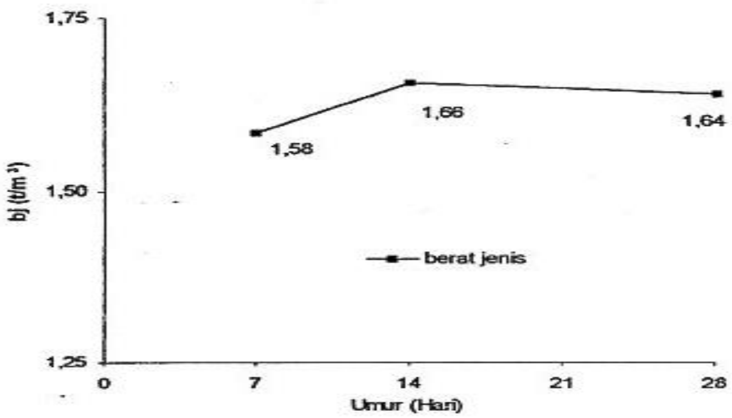

Figure 5. The Specific Gravity of Concrete with Rough Aggregate Soaked For 24 Hours

Table 5. The Specific Gravity of Concrete with Rough Aggregate that was not Soaked WithFas 0.5

No	Code	Specific Gravity (t/m^3)	Average (MPa)
1	BKK-1	1,54	160
2	BKK-2	1,56	
3	BKK-3	1,70	
4	BKK-4	1,55	1,57
5	BKK-5	1,56	
6	BKK6	1,61	
7	BKK-7	1,52	1,53
8	BKK-8	1,57	
9	BKK-9	1,51	

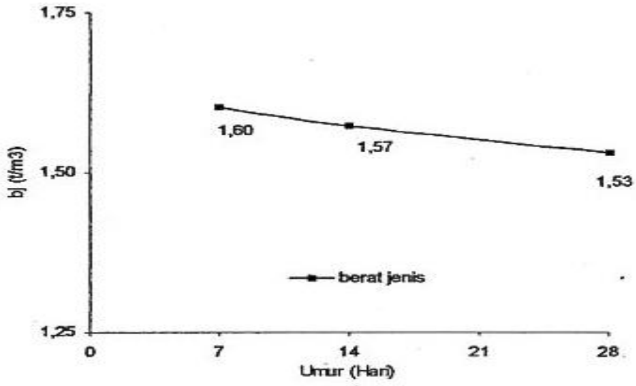

Figure 6. The Specific Gravity of Concrete with Non-soaked Rough Aggregat

7. The Relationship of Concrete's Stress-Strain

The ultimate relationship of concrete with rough aggregate in the form of teak pieces of 0.014 can be seen in Figure 6. When it was comparedto the normal concrete ultimate strain of 0.003, the ultimate strain in the concrete with the aggregate of teak pieces was bigger. It made the concrete with rough aggregates of teak pieces tend to be more ductile compared to normal concrete.

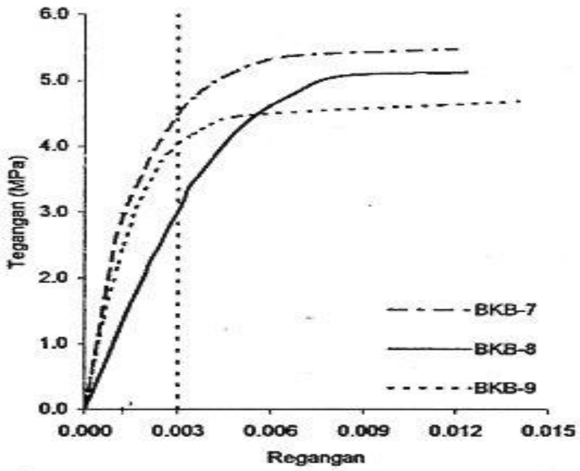

Figure 7. The Relation of Concrete Cylinder's stress-strain Age of 28 Days

8. The Testing of Reinforced Concrete Beam

The ability of reinforced concrete beams to withstand maximum load and maximum deflection is listed in Table 6 and the relationship of load with deflection in the middle of the span is showed in Figures 7 and 8.

Table 6.The Amount of Maximum Load and Maximum Deflection

Test Objects	Maximum Load (kN)	Deflection at Maximum Load (mm)
BL21	26,0	6,10
BL22	26,0	7,53
BL23	27,0	7,35
Average	26,3	6,99
BL31	30,0	6,68
BL32	31,6	10,95
BL33	30,0	8,35
Average	30,5	8,66

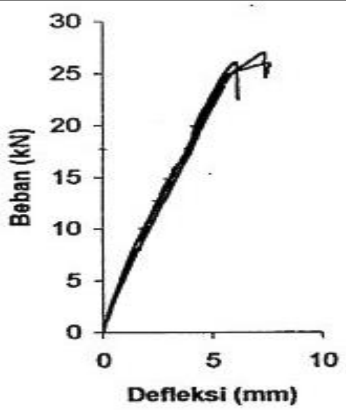

Figure 8. The Graph of Load-Deflection Relationship with 2 tensile reinforcements

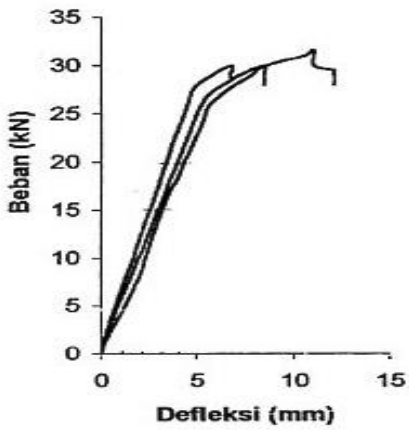

Figure 9. Graph of Load-Deflection Relationship with 3 tensile reinforcements

Experiment's Bending Strength

Test results found the amount of load that could be retained by reinforced concrete beam. The load was used to calculate the ultimate moment since the beam was loaded symmetrically at points of 350 mm from each support as seen in table 7.

Table 7.The Ultimate Moment of Experiment Results

Test Objects	Load (kN)	Deflection (mm)	Mu (kNm)
BL21	26,0	6,10	4,55
BL22	26,0	7,53	4,55
BL23	27,0	7,35	4,73
Average	26,3	6,99	3,61
BL31	30,0	6,68	5,25
BL32	31,6	10,95	5,53
BL33	30,0	8,35	5,25
Average	30,5	8,66	5,34

Crack Patterns

The most cracking happened was hair crack, which occurred almost on all surfaces. However, the actual crack occurred in the bending area. When the load was added, the crack widened to the maximum load, see Figs. 8 and 9.

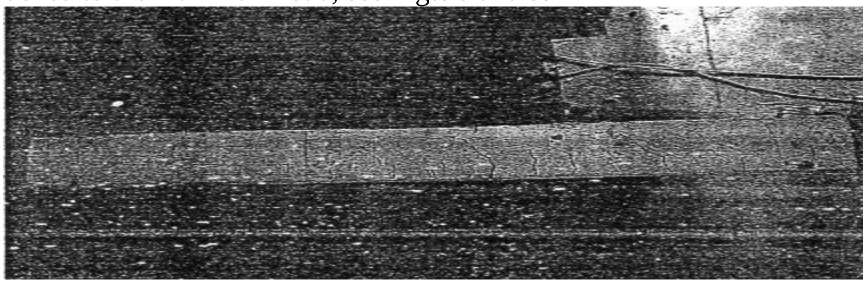

Figure 10. The crack pattern and collapse type of Reinforced Concrete Beam with 2 Tensile Reinforcements

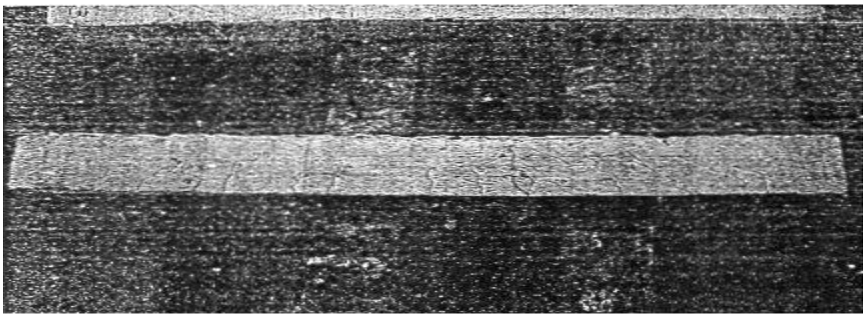

Figure 11. The crack pattern and collapse type of Reinforced Concrete Beam with 3Tensile Reinforcements.

9. Conclusions

From the test results, it can be drawn some conclusions as follows:

1) The slump test results in a reduction of 20.8 cm for the soaked aggregate and 19 cm for the non-soaked aggregate. The condensation condition is very watery and easy to work, but there is a separation between the rough aggregate and the fine

aggregate. The fine aggregate settles below, while the rough aggregate is floating on top.

2) The result of concrete cylinder test with teak aggregate which is soaked with compressive strength is 5.09 Mpa and with non-soaked aggregate is 4.74 Mpa.
3) Ultimate strain of concrete with rough aggregate of teak pieces is 0.014.
4) The average modulus of concrete with aggregate of teak wood is 1863,17Mpa.
5) The bending load capacity of the experimental results of 2 tensile reinforcements is 26.3 kN and theoretical of 36.54 KN. The experimental result of 3 tensile reinforcements is 30.5 kn, and theoretical of 52.62 kn. The comparison of experimental results with theoretical of 2 tensile reinforcements is0,725 and 3 tensile reinforcements of 0.58%. The result is too small due to the absence of a strong bond between the concrete with reinforcing steel. It causes the occurrence of selib or loose.
6) Damage occurs in the bending area that is focused on one of the crack lines, most of which are hair cracks that spread on the surface of reinforced concrete beam.

Suggestions

1) To obtain a high compressive strength of concrete, it is necessary to have a rough aggregate repair by covering it with asphalt, lacquering or soaking in alcohol. If the wood is still young, it can be repaired by boiling the wood. This way can cover or remove the oil contained in the teak wood, so that there will be a strong bond between the aggregate with its paste.
2) A further study of lightweight concrete is required when rough aggregate of teak pieces is used.

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