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The Study Bending Performance of Concrete Beam Using Bamboo Reinforcement and Fibres

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Abstract: The development of research on concrete used natural fibers has been conducted by many previous researchers. Where the fiber added to the concrete mix significantly increases the tensile strength of the concrete. In this study, natural fiber namely bamboo fiber, was used as micro reinforcement to strengthen the tensle strength of concrete. This study was conducted to determine how much strength bamboo is as the reinforcement as compared to steel reinforcement applied to high-performance concrete beams. It had expected that bamboo could be used as an alternative reiforcement to replace steel reinforcement in reinforced concrete bems. The study used four of beam specimen with dimension 150 × 300 × 2200 mm. The strength of Concrete is 60 Mega Pascal. The steel of tensile using four steel bars D16, while the steel of shear using two D12, and bamboo reinforced used 10 x 21 mm. The results shows maximum Deformation in concrete beams (HSC-SR) is 18.470 mm with the maximum loading 254.97 Kilonewtons, with ductility value is 1.713. The beams (HSC-SRBF) obtained Deformation10.260 mm at maximum load 264.78 Kilonewtons, and ductility is 1.832 mm. While the bamboo reinforced concrete beams (HSC-BR) obtained the maximum load is 106.89 Kilonewtons with Deformation is 28.700 mm, and ductility is 1.322, compare to beams (HSC-BRBF) obtained Deformation 24.440 mm at maximum load 158.87 Kilonewtons, with ductility is 1.162. The results give value of capacity beams for (HSC-BR) is 1.104, (HSC-SRBF) is 1.422, (HSC-SR) is 1.331 and (HSC-BRBF) is 0.877. In the beams (HSC-BRBF) use bamboo reinforced give the maximum load 158.87 Kilonewtons compare to (HSC-SRBF) have maximum load 254.97 KN.

Keywords: Bending Capacity, Ductility, Deformation, Reinforced and Fibers

1. The Preliminary

High strength concrete has high compressive strength but has weak tensile strength and flexibility, so it is necessary to find a way to increasing the flexibility value of strength concrete. The bending strength of concrete change after adding bamboo skin fibers, as research conducted by Suhardiman [1]. The yield point of steel used for flexural and shear reinforcement was 407.43 MPa. The diameter flexural tensile reinforcement was 15.8 mm, compression reinforcement was 11.9 mm, and shear reinforcement was 11.9 mm. The proportion of concrete includes 8% silica fume and 1.5% poly carboxylate ether-based super visco crete 10 by weigth of cement. The maximum diameter of the split was 15.9 mm, has cement content of 550 kg/m3, and a water cement ratio of 0.30. The target compressive strength was 70 MPa for a 15/30 cm cylinder. The results showed that all beams experienceed flexural failure as planned. The addition of fiber improves flexural behavior significantly, especially in flexural capacity, defection and ductility, Aulia and Rinaldi [2]. The mill effluent boiler has contributed to an increase in the strength of concrete, which has a wear value of not much different from the split, which is 4.7% compared to 6.7%. The fly ash was not contributing to an increase in shear capacity as well. Although the compressive strength has increased when compared to PBHS, Aulia et. al [3].

The loads that work on the structure, either in the form of loads (vertical direction) or other loads, such as wind loads (horizontal direction) or also loads due to shrinkage and loads due to temperature changes, which cause bending and deformation of the elements structure. Flexure in the beam is a result of the strain that to ensues due to external loads. explained that in areas experiencing bending collapse, fractureds mainly to ensue in one-third of the span, and are perpendicular to the main stress. These fractureds caused by a very small shear stress and a very dominant bending stress, which is almost close to the horizontal main stress. In such a bending collapse state, some vertical fine fractureds to ensue in the center span area about 50% of those used by the bending collapse load. If the load continues to increasing, the fractureds in middle of the span increase, and the early fractureds that have to ensuered will be wider and longer towards the neutral axis of the section. This coincides with greater Deformation in the middle of the span. If the beams is under-reinforced, then this collapse is a ductile strength, which is indicated by the melting of the tensile reinforcement. This ductile behavior provides a warning to building users before the total beam destruction to ensues. In order to behave in a ductile manner, the ratio between the shear span and the cross-sectional height must be greater than 5.5 in case of centered loads, and exceed 15 for distributed loads, Mindess [4].

Any structural design procedure needs to meet two requirements: The ultimate limit state requirements which is related to sections strength and capacity, and the serviceability limit state that is related to the workability of the section. Several examples of serviceability limit state components are: Deformation, Fractured width, and vibration. Deformation is a very important component that must satisfy code limits specially for structures that contain liquids such as water or oil. The main parameters that effects the Deformation id the bending stiffness of the element that is related to main components: the moment of inertia (I) and the modules of elasticity (E), Mindess [4].

The tested steel reinforced beams with bamboo reinforced beams that have triangular and circular cross sections. From the test results, it found that the tensile strength of bamboo is approximately one and a half times stronger than mild steel and the modulus of elasticity of bamboo is about one third stronger than mild steel. Load bearing capacity, Deformation, bending strength and shear strength of bamboo reinforced beams using a square section are higher than bamboo reinforced beams with triangular and circular sections. The results found that the load on the early fractured and the maximum load on the reinforced bamboo beam with a square section is 53% less than the lightweight steel reinforced concrete beam, Khan [5]. The addition of Betung bamboo fiber was very influential to the ultimate capacity of reinforced concrete, namely an increase in compressive strength of 24.31% and tensile strength of 77.12% at 0.4% fiber volume, but the flexural strength decreased, Purwanto et. al [6].

The reinforced beams tested for steel reinforcement, bamboo reinforcement and non-reinforcing respectively. The steel-reinforced beams, the maximum of Deformation of 4 mm to ensues at 162 Kilonewtons failure load, while the Deformation width of bamboo-reinforced beam specimens is 6 mm at 102 Kilonewtons failure load and the beam specimen Deformation width used as a control that has no reinforcement is 15 mm at failure load 95Kilonewtons. The results showed that steel reinforced beams have the highest strength to withstand loads. However, the strength of bamboo reinforced beams is higher than that of ordinary concrete beamss. Therefore, bamboo reinforcement can be used as reinforcement in beams, Raheem et. al [7]. The palm oil clinkers that have replaced silica fume in high-quality reinforced concrete were increased concrete ductility, Yusra et. al [8]. Research results have been reported in terms of deflection, crack, width strain in concrete and reinforcement, bending capacity, and failure mode; they are also employed to assess the accuracy of current deflection and fracture width was affected by the diameter and surface of the bar configuration while defelection was not significantly affected. In addition, the bond coeficient of 1.4 was very conervative for both sand-coated and helical grooved GRFP rods on NSC and HSC, El-Nemr et. al [9].

The bending strength test of bamboo of reinforced beams to ensue. This test conducted to determine the performance of bamboo as reinforcement. Beams measuring 150 mm x 150 mm x 750 mm made with single bamboo reinforcement and double bamboo reinforcement measuring 20 mm with a length of 1 m. The bending test of reinforced bamboo beams, shown that use bamboo as concrete reinforcement can increase the load of performance bending of concrete beams that have same dimensions. The single reinforced bamboo concrete beams, load bending strength increases two times, and the double reinforced bamboo concrte beams is two and a half times than for ordinary beams of concrete of the same size. The deformation of single reinforced bamboo concrete beams and double reinforced bamboo concrete beams is about 4.5 and 8 times that of ordinary beams of concrete, as research by Ramaswamy and Mathew [10].

The study states suitability of bamboo had reinforced in concrete will be evaluated. To rate the pull strength test of bamboo, which has three and five knots is done. Bamboo reinforces measuring 1 m with different cross-sections were used in this test. Also, testing the flexural strength of reinforced bamboo beams was carried out to characterize the performance of bamboo a shelp. Reinforced single and double bamboo beams from 750 mm in length by 150 mm in width and depth compared with plain concrete beam has conducted in this test, Ramaswamy and Mathew [10].

Twenty-one four-point loaded RC beams have been tested. The beam dimensions were 2400 mm length x 150 mm wide x 250 mm heigth, with a loading range of 2250 mm. The load has been applied in the center of the 550 mm spreader steel span beam. The FRP strips studied in this study were: specially manufactured hybrid glass-carbonpultrude strip. Which has unidirectional glass fiber and carbon fiber and contious (standing) glass-carbon fiber mats, Ebead and Saeed [11].

The results showed that all beams experienced flexural failure as planned. The addition of fibers improves the flexural behavior significantly, especially in flexural capacity, deflection and ductility. Compared with high-strength reinforced concrete beams without fiber, beams with polypropylene fiber experienced an increase in flexural strength of 115.24%, deflection of 306.56% and ductility of 298.9%; with fiber tie wire produced at an increase in flexural strength of 117.39%, deflection of 160.52% and ductility of 148.0%; as well as used rubber tires The fiber resulted in an increase in flexural strength of 112.13%, deflection of 184.56% and ductility of 178.3%. Can be concluded that the use of environmentally friendly synthetic fibers can reduce the brittleness of high-strength concrete, where: polypropylene fiber has provided the best value and can be used more effectively than the other two types of fiber, Aulia and Rinaldi [2]. Two design examples show that the proposed method is simple in application and straightforward in concept. Method gives good results, when prediction power was compared against failure loads for RC and PC beams, and provides the better result compared to ACI 318-14 for RC beam, Walther [12].

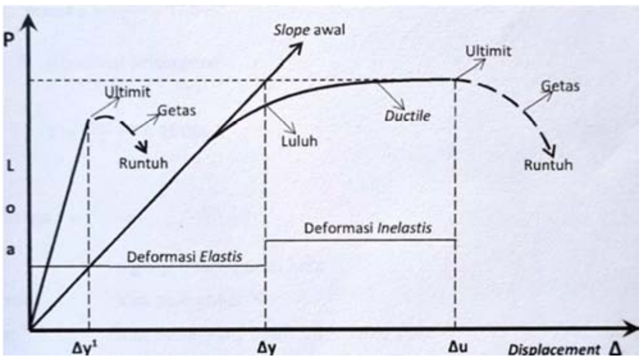

Figure 1. *Relationship of Load-Deformation.*

The content of silica fume and fly ash is 5% and 20% each based on the weight of cement. The water for cement material ratio is 0.25. Mixtures are produced by varying fiber types, and for each fiber type, the volume fraction varies from 0.5% to 4.0%, with a 0.5% increase in cement weight. 150 cube specimens (150×150×150mm), tested to study the effect type and fiber on compressive strength and workability of HSFRC. The results show a significant improvement in mechanics HSFRC properties, Moid and Rahul [13].

The contains silica fume and fly ash is 5% and 10% by weight of cement, respectively. The water to cement material ratio is 0.25. The concrete mix design was produced by different types of fiber and for each type of fiber. the volume fraction varies from 0.5% to 4.0%, with an increase of 0.5% weight of cement material. 147 specimens each cube (100×100×100mm), cylinder (100×200mm) and prisms (100×100×500mm) were tested to study the effect type and fiber volume fraction on compressive strength, split tensile strength, and flexural strength of HSFRC. The results show significantly improved mechanical properties of HSFR, Rahul and Pandit [14].

The percentage of The polypropylene fibers used were 0.5%, 1%, 1.5% by weight of cement. As a comparison, the concrete mix design made without the addition of fiber was 0%. The test for the compressive strength of concrete has performed at 28 days. The number of test objects is 24 cylinders (Ø15 cm, T=30cm). The results obtained from the average compressive strength test results at the percentages of 0%, 0.5%, 1%, and 1.5%, obtained of 57.35 MPa, 55.74 MPa, 54.87 MPa, and 50.54 MPa. The optimum condition has been obtained at a percentage of 0.5%. It could conclude that the addition of polypropylene fiber and palm clinker to high-quality concrete can increase the compressive strength of concrete, Yusra et. al [15].

$$\mu = \Delta u / \Delta y \qquad (1)$$

2. Materials and Method

2.1. Materials

The equipment used in this research is generally available at the Construction and Building Materials Laboratory for the Civil Engineering Study Program, Faculty of Engineering University of Syiah Kuala. The matter using on the study include Cement Portland, fine aggregates, consisting of fine sand and coarse aggregate, split aggregates, water, and palm shell ash as filler, plasticizer, D16 mm steel tensile reinforcement and shear reinforcement 12 mm, while for bamboo reinforced is 21 x 10 mm.

2.2. Method

The mix design of concrete beams is 60 Mega Pascal for specimen cylinder 15/30 cm. The concrete use water-cement ratio (w/c) is 0.25 and 2% of plasticizer by ammount of cement. The split aggregates use with diameter maximum is 12 mm, and 15% added filler by ammount of cement. The percentage use of fibers is 0%, 0.5%, 1%, 1.5%, as an addition to the concrete mixture used is the weight of cement. The mix design for the concrete beam use the trial and error method. The design concrete compressive strength is 60 Megapascal, ratio of cement-water is 0.25.

The beam specimen set-up seen in Figure 3. The results to be achieved in this study are early fracture and fractured patterns, Deformation, value of ductility, (P) maximum loading in beams of concrete and the pattern of fracture. The object test use four beams of concreta with dimensions is beam width=150 mm, beam height 300 mm, beam length=2200 mm, shows in Figure 2. The bending test of concret beams at 28 days-old, use a bending test machine. Steel of tensile using D16 with melt stress is 445.63 Mega Pascal and steel of shear D12 with melt stress is 381.97 Mega Pascal. The object test show in Figure 3. The result are bending capacity, maximum loading, Deformation, ductility of beams, and patern fractured of beams.

Table 1. *Number of Specimen.*

Specimens	Dimension (cm)	% of Bamboo Fiber	Amount of specimen
Beam (HSC-BR)	15 x 30 x 220	0	1
Beam (HSC-BRBF)	15 x 30 x 220	0	1
Beam (HSC-SR)	15 x 30 x 220	1.5	1
Beam (HSC-SRBF)	15 x 30 x 220	1.5	1

Table 2. *Design of Reinforcement.*

Specimens	Dimension (cm)	Reinforcement of Concrete Beams		
		Stress	Tensile	Shear
Beam (HSC-BR)	15 x 30 x 220	2 (21 x 10) mm	4 (21 x 10) mm	D 12 – 100
Beam (HSC-BRBF)	15 x 30 x 220	4 (21 x 10) mm	8 (21 x 10) mm	D 12 – 100
Beam (HSC-SR)	15 x 30 x 220	2 D 16	4 D 16	D 12 – 100
Beam (HSC-SRBF)	15 x 30 x 220	2 D 16	4 D 16	D 12 – 100

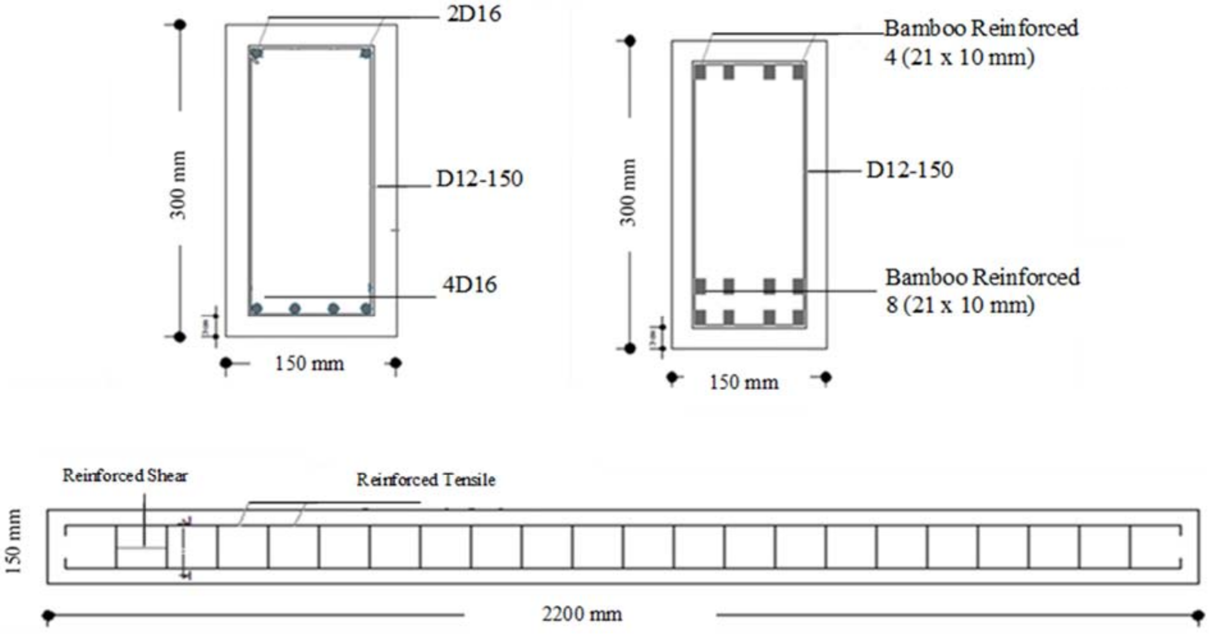

Figure 2. *Design of Concrete Beams.*

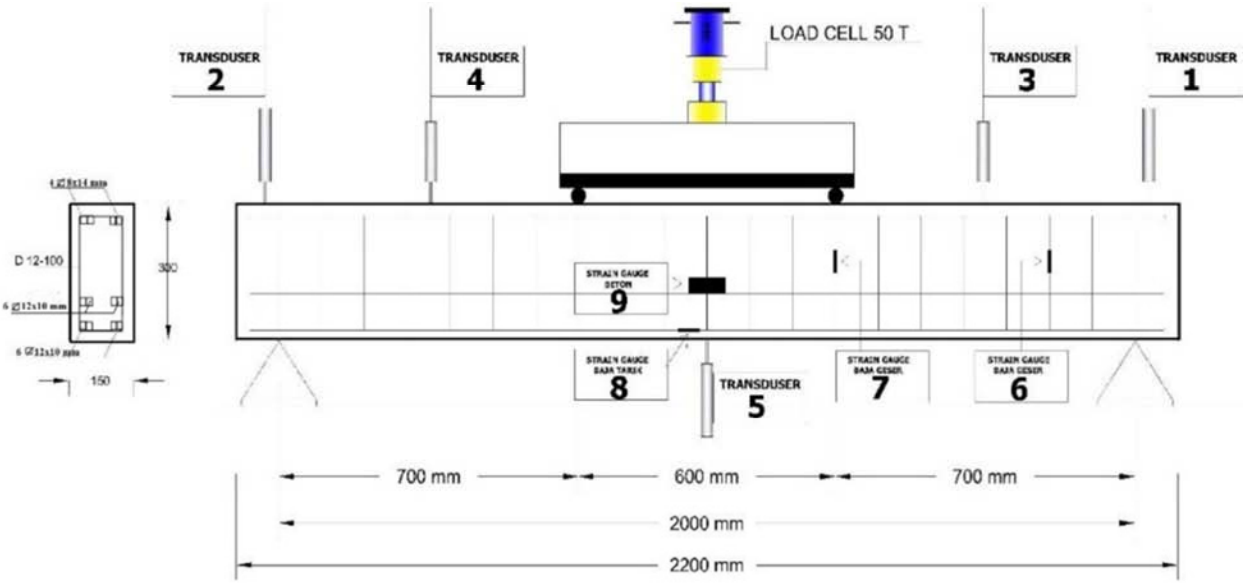

Figure 3. *Set-up of Concrete Beams.*

3. Results and Discussion

3.1. Performance Bending of Beam

The bending strength beams of concrete shows on Table 3. The conclusion is that the concrete beams use of fiber increasing the bending value of concrete beams. Base on beam bending testing obtained beam with addition fiber (1.5% addition Bamboo Fiber) is the maximum Deformation obtain 18.70 mm with load ultimate by 264.78 Kilonewtons, compare with beam of non-fiber obtained Deformation in the middle of beams of concrete 18.70 mm in (P) loading of maximum 243.874 Kilonewtons. While the bamboo reinforced concrete beams (non-fiber) obtained the maximum load is 106.89 Kilonewtons with the maximum Deformation is 28.7 mm, and then the bamboo reinforced concrete beams (with additional 1.5% bamboo fiber) obtained the maximum load is 158.87 Kilonewtons with the maximum Deformation is 24.44 mm.

Table 3. Performance *bending of concrete beams.*

Specimens	*f'c* (*Mega Pascal*)	Maximum Load (KN)		P Lab/P Theory	Bending Moment		M Lab/M (Theory)
		P Ultimate (Theory)	P Ultimate (laboratory)		M (Theory)	M (Laboratory)	
Beam (HSC-BR)	51.70	98.87	106.89	1.112	34.54	38.15	1.104
Beam (HSC-BRBF)	51.70	184.46	158.87	0.821	64.60	56.70	0.877
Beam (HSC-SR)	58.77	195.42	254.97	1.330	68.34	91.00	1.331
Beam (HSC-SRBF)	54.43	201.66	264.78	1.313	70.58	100.36	1.422

3.2. Ductility

Table 4 shows HSC-SRBF beams have ductility value is 1.823. The melt condition, there are a load (P) of 201.66 KN, and a Deformation of 10.260 mm, then increasing load value of 264.78 KN, with Deformation 18.700 mm. The result shows HSC-SR ductility is 1.713, at melt condition load (P) of 195.422 KN, and Deformation of 10.47 mm. The increased in an ultimate state with a load value of 254.97 KN, with Deformation 18.470 mm, while HSC-BR beams obtained the maximum load is 106.89 KN with a Deformation value of 28.700 mm (ultimate condition) and load (P) 98.87 KN, Deformation 21.07 mm (In melt condition). On the HSC-BRBR beams obtained the maximum load 158.87 KN with a Deformation value is 24.440 mm, in the melt condition obtained Load (P) 148.60 KN with Deformation value 21.02 mm.

The highest ductility value found in the HSC-SRBF beam, this indicates that the addition of bamboo fiber has an effect on the ductility value of strength concrete beamss. Whereas in concrete beams with bamboo reinforcement, the ductility value decreased in bamboo reinforced concrete beams, with the addition of fiber, however from the maximum load, the value increased. The concrete beams of bamboo have quite enough bending capacity value.

Table 4. *Value of Ductility of Reinforced Concrete.*

Specimens	Condition of Melt		Condition of Ultimate		Ductility μ=Δu/Δy
	(P) Kilonewtons	Deformation (Δy)	(P) Kilonewtons	Deformation (Δu)	
Beam (HSC-BR)	98.87	21.07	106.89	28.70	1.322
Beam (HSC-BRBF)	148.46	21.02	158.87	24.44	1.162
Beam (HSC-SR)	195.42	10.78	254.97	18.47	1.713
Beam (HSC-SRBF)	201.66	10.26	264.78	18.70	1.823

3.3. Load and Defection of Concrete Beams

The comparisson concrete beams with fiber and concrete beam non-fiber, and the loading-deformation relationship in the middle of reinforced concrete beams to ensue in this study shown in Figure 4. From the load and Deformation relationships shown in Figure 4. The Analysis is three main zone to ensues, which early fractured zone, melt strength zone and maximum load zone. In early fractured zone, concrete beams underwent the early fractured at a load of 66.29 KN and 52.07 KN. In transducer number 5 ensue of deformation is 1.112 mm and 1.03 mm. Transducer number 3; 4 are 6.12; 2.78 mm, and 5.90; 5.38 mm. In term of early fractured formation, it concluded that the use of filler as additives could enhance the load at early fractured formation of reinforced concrete beams. In transfer zone, bending reinforced early to melt. Loads and deformation in melt zone which was recorded for beams of concrete in (P) loading 24.52; 24.72 KN, deformation 10.78; 10.26 mm, 15.70; 8.81 mm, and 18.59; 2.89 mm in transducer number 5, 3 and 4. Figure 4 shows maximum of Deformation in Transducer number 5 is 18.470; 18.77 mm, transducer number 3 and transducer number 4 is 18.830; 12.130 mm and 20,150; 3.70 mm with (P) maximum loading is 254.97; 264.78 KN.

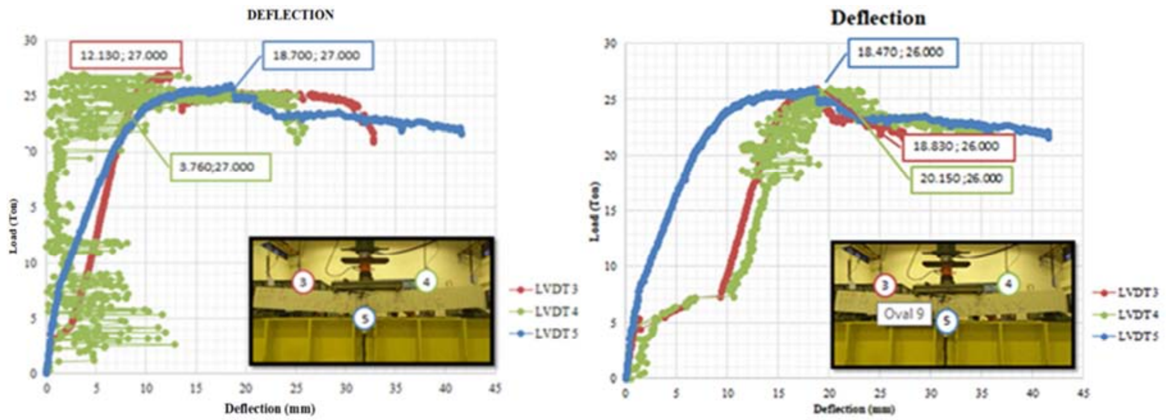

Figure 4. *The Relationship Deformation and Loading of Steel Reinforced Concrete Beam with addition Bamboo Fiber and non-fiber.*

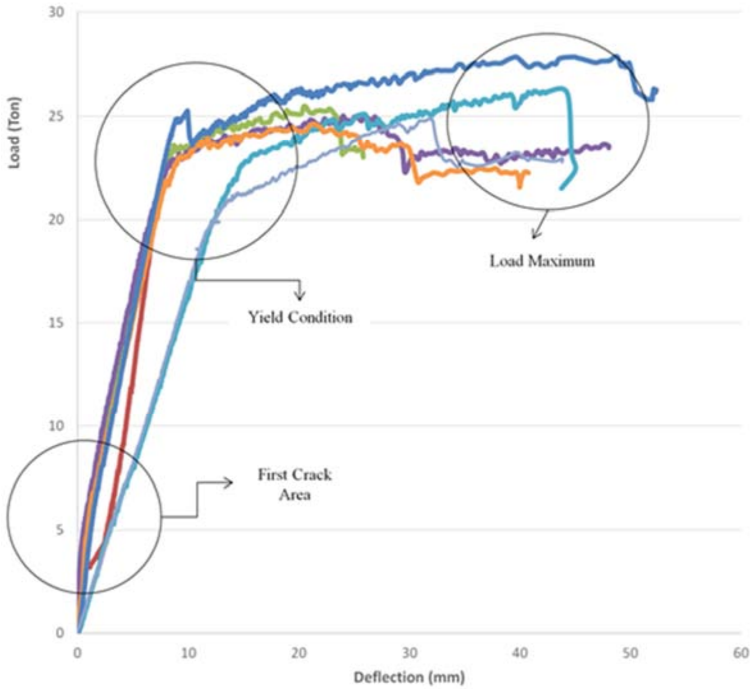

Figure 5. *Load and Deformation Steel Reinforced Concrete Beam with addition Bamboo Fiber and non-fiber.*

The condition in Figure 5, if we compare it with the theory in Figure 1, shows that the graph of the loading and Deformation relationship, condition of concrete beam is ductile.

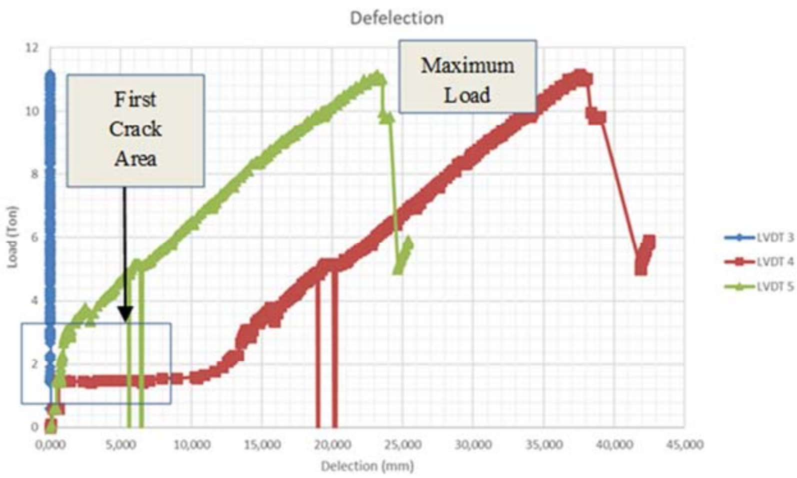

Figure 6. *Load and Deformation Bamboo Reinforced Concrete Beam.*

The condition in Figure 6, show that the condition of bamboo reinforced beams, for concrete beams using bamboo reinforcement, the melt area is not too significant.

3.4. Fracture of Concrete Beams

The destruction concrete to ensue in reinforced concrete beams (HSC-SRBF) use bamboo fiber (1.5% additional) shown in Figures 7 and 8, the collapse to ensue is flexible collapse. The early fractured to ensue in beam at (P) loading is 52.07 KN. The concrete beams (HSC-SR) non-fiber obtained early of fractured in (P) loading of 66.29 KN, and early fractured at load 32.36 KN. On concrete beams bamboo reinforced (HSC-BR), while concrete beams (HSC-BRBF) with additional fiber obtained early fractured at 33.34 KN. The value of fracture increasing along of the concrete beam load increased.

HSC-SRBF (1.5% Fiber), before loading HSC-SRBF (1.5% Fiber), maximum loading is 27 ton

HSC-SR (0% Fiber), before loading HSC-SR (0% Fiber), maximum loading is 26 ton

HSC-BR (0% Fiber),before loading HSC-BR (0% Fiber), maximum loading is 10.9 ton

HSC-BRBF (1.5% Fiber),before loading HSC-BRBF (1.5% Fiber), maximum loading is 16.2 ton

Figure 7. *The Bending test of beams specimen.*

Figure 8. *Pattern of Fractured of beams specimen use steel reinforced.*

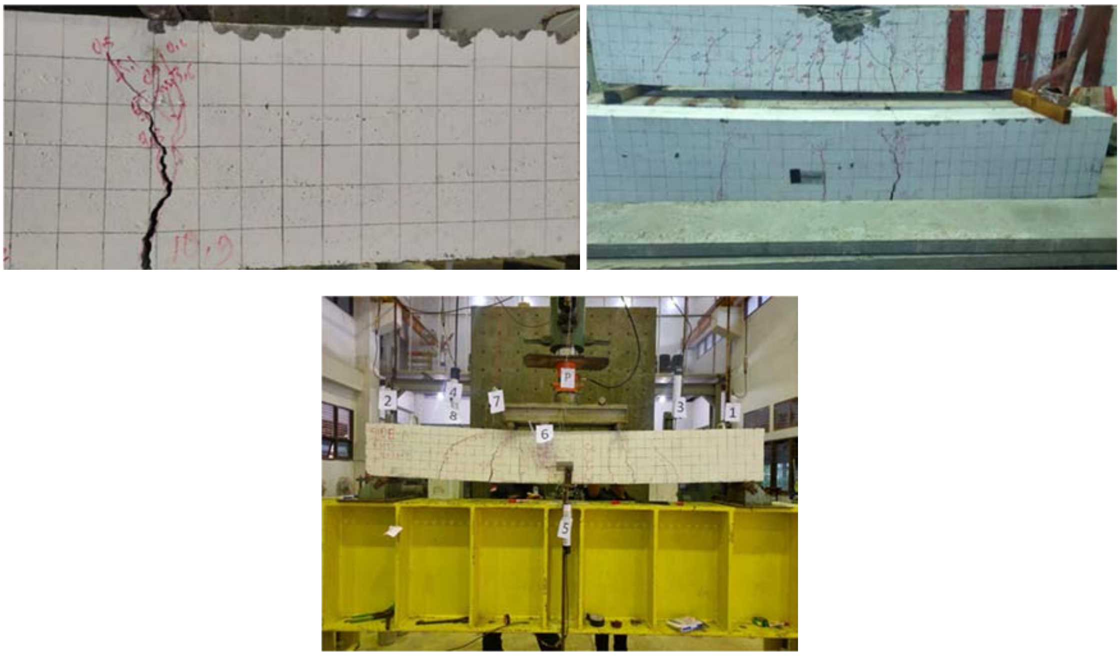

Figure 9. *Pattern of Fractured of beams specimen use Bamboo reinforced.*

4. Conclusions

The failure of beams (HSC-SRBF) as planned, which is bending failure. Bamboo fibre can increasing Deformation value and ductility of reinforced concrete beams. The maximum Deformation is 18.700 mm, with maximum load of 264.78 Kilonewtons on HSC-SRBF beams. The early of fractured to ensue at (P) loading is 52.07 KN, with Deformation 1.030 mm. Ductility in HSC-SRBF obtained by melt Deformation (Δy) of 10.780 mm and ultimate Deformation (Δu) of 18.700 mm of 1.823. The concrete beams (HSC-SRBF) have a bending capacity value is 1.422 and ductility value is 1.823. The concrete beams (HSC-SR) have bending capacity value is 1.331 and ductility value is 1.713. The maximum Deformation to ensue is 18.470 mm. (P) maximum loding is 254.97 KN. The pattern of fractureds indicates the concrete beam has failure of flexural, because fractured to ensue in flexural zone and no fracture to ensue in the foothold zone. Early of fractured to ensue in 66.29 KN, and Deformation is 1.12 mm. The bending capacity on concrete beams (HSC-BR) is 1.104 and ductility value is 1.322. The maximum Deformation to ensue is 28.700 mm. (P) maximum loading is 106.89 KN. The pattern of fractured indicates the concrete beam has failure of flexural, because fracture to ensue in flexural areas and no fracture to ensue in the foothold zone. Early fracture to ensue in 32.36 KN, and Deformation is 3.03 mm. The concrete beams (HSC-BR) obtained bending capacity is 0.877 and ductility value is 1.162. The maximum Deformation to ensue is 24.440 mm. (P) maximum loading is 158.87 KN. The pattern of fractured indicates that the beam has failure of flexural, because fractured to ensue in flexural areas and fractured to ensue in the foothold zone. Early of fractured to ensue at 33.34 KN, and Deformation is 1.68 mm.

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