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Bamboo Reinforced Concrete Truss Bridge for Rural Infrastructure

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ABSTRACT
Bamboo is one of a potential renewable construction material in the village. Bamboo is known to have a high mechanical strength in direction of the fibers. The weakness of bamboo in lateral direction of the fiber could be solved by constructing a composite structure with the concrete. The appropriate construction with hold the loads in axial direction is a truss structure. In a bamboo concrete truss structure, the bars are composed from the concrete column with a bamboo reinforcement.

The research studies about the performance of the bridge and the effect of loading position on the strain and deformation of bamboo reinforced concrete truss bridge. The bridge whose span and width are respectively 1.5 m and 1.2 m was prepared. Load applied to the truss bridge conducted by using vehicle load changes with position. Mounting the strains gauge in bamboo reinforcement of primary truss is to observe the strain. The LVDT is used to observe the deflection of the truss bridge.

The results show that the loading position influences the strain and deformation as well as a theoretical view.
Keywords – Bamboo, bridge, concrete, truss, infrastructure

I. INTRODUCTION

As an anisotropic material, bamboo has difference strength and stiffness in longitudinal and transversal directions. The strength of bamboo parallel to its fiber is quite high with about 90 to 200 MPa. It is almost approaching the strength of steel [1, 2]. The tensile strength generally is higher than compressive strength because lateral tensile force perpendicular to its fiber arises on compressive stress that is not capable to retained by the bamboo. However, the low modulus of elasticity perpendicular to fiber reduced the capability of bamboo to carry lateral load. To increase the stiffness in lateral directions, the bamboo needs the concrete for binding them becomes a composite structures.

The research of bamboo reinforced concrete composite has initiated by author since 2005. The problem at the beginning of the study concerns about the binding between bamboo and concrete [3]. To decrease the swelling and shrinkage, bamboo was coated with paint or varnish [4]. The bonding strength obtained by painting bamboo to seal the pores off and to prevent expansion. Rough surface and binding with concrete obtained by smear a soaked painting bamboo with sand as shown in Fig. 1.

Figure 1 Painting and smear bamboo reinforcement

Bamboo as the replacement of a steel reinforcement may not be able to bond in making a hook. These matters make some problems in transfer the force to the truss joint. One of the solutions is add stirups to confine the joints as shown in Fig. 2

Figure 2 Shear confinement on the joint

The bamboo reinforced concrete truss can be made either in precast concrete and in situ cast concrete.

The previous research by the author is a precast roof frame as shown in Fig.3.

Figure 3 Precast bamboo reinforced concrete roof frame

In the previous research, the roof truss has an adequate strength as well as the wooden truss.

II. RESEARCH METHOD

2.1 Location and research scope

Research is carried out in the Structural Laboratory and Construction Material, Civil Engineering Department, Engineering Faculty Brawijaya University and Mulyoredjo village in Malang, Indonesia. Research scope includes design and construction of bamboo reinforced composite truss bridge.

The precast abutments and bridge truss are molded in the laboratory, while, concrete floor slab is casted in situ to make easier the transport process. Then the load test is applied in the location where the bridge placed. The purpose of the test is to obtain the relationship between load position on deflection and the strain in the bridge truss compared with the theoretical approach.

2.2 Bridge component

The component of bridge construction consists of two primary precast trusses, three layers of abutments frame in each end support, four cast in situ transversal beams, and cast in situ of concrete slab. A scheme of primary truss and abutment frame is shown in Fig. 4.

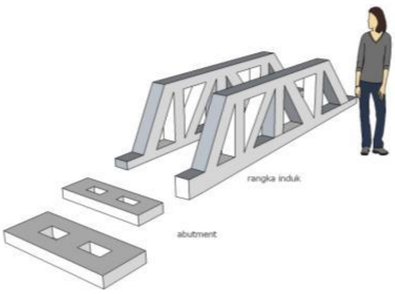

Figure 3 Element of composite bamboo bridge

The span of primary truss is 1.50 m and the bridge width is 1.20 m. The abutment consists of three layers of precast close tie in form of eight from bamboo concrete composite and the hole filled by cast in situ concrete. The amount of abutment can also be adjustable with the contour difference in both end support.

Transversal beam and concrete slab were casted in situ with bamboo reinforced concrete. The joint of the beam and the primary truss is prepared by inserting steel overstek in primary truss.

2.3 The bridge construction

2.3.1 The precast element

The bamboo reinforcement for primary trusses and abutment frames used Petung Bamboo (Dendrocalamus Asper) at the age of 3-4 years and traditionally preserved by submerged. The bamboo lath with 10 mm x 10 mm in sections coated with il-paint and smeared with coarse sand as shown in Fig.4.

Figure 4 The bamboo reinforcement

Four reinforcements were confined with steel bars in making truss reinforcement and then joined in bundle truss shape renforcement as shown in Fig. 5.

Figure 5 The truss reinforcement

The strain gauge layed on the truss reinforcement before casting. Two precast primary frames and eight precast abutments then casted with concrete use a fine coarse agregate.

2.3.2. The in situ beam and deck slab reinforcement

The reinforcement for the beams and the slabs were also prepared in the laboratory, with the arrangemant shown in Fig. 6.

Table 1 Loading Position

Loading Positions	**Length from the end support**
Position I	0 cm
Position II	40 cm
Position III	80 cm
Position IV	120 cm
Position V	160 cm

Figure 6 The slab reinforcement

2.3.3. The abutment and deck construction

All the precast elements and reinforcement were carried out to the bridge site plan, arranged and casted together.

2.4 Loading test

The testing was arranged to obtain strain record of three bars of primary truss elements. The elements are shown in Fig. 7. Strain test was measured with respect to position and magnitude of the load in deck slabs. The strain was measured at the same time with deflection measured. The positions of loading installed from the end support are shown in Table 1. For each position, the bridge was respectively loaded with 500 N, 1000 N and 1500 N.

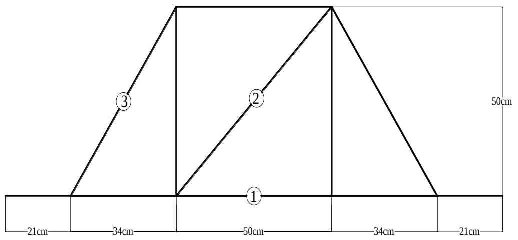

Figure 7 Position of strain gauge on three bar elements

Deflection instrument was conducted to measure the deflection in two points A and B by using LVDT. The position of LVDT on deflection test is shown in Fig. 8.

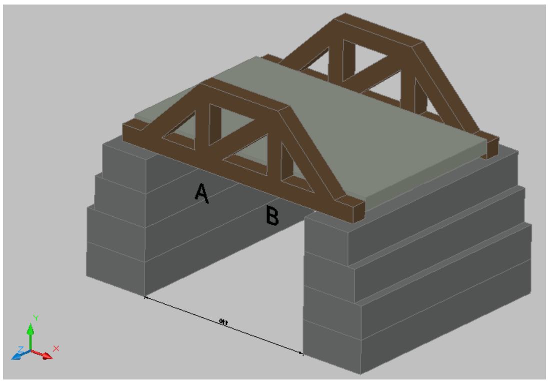

Figure 8 Installation of LVDT on deflection test

III RESULT AND DISCUSSION

The bridge elements including abutment, bridge truss and as floor slab reinforcement were prepared in the laboratory. The compressive strength of the concrete is shown in Table 2.

Table 2 Compressive Strength of Specimens Used for Truss Concrete

Specimen	Cross section area (cm2)	Weight (kg)	Age	Maximum Load (kN)	Maximum Load (kg)	Compressive strength (28 hari) (kg/cm2)	Compressive strength (28 hari) MPa
A1	225	7.48	7	362	36913.727	209.493	20.544
A2	225	7.34	7	348	35486.124	201.391	19.750
A3	225	7.42	7	361	36811.755	208.915	20.488
A4	225	7.6	28	530	54044.959	199.366	19.551
A5	225	7.24	28	502	51189.754	188.833	18.518
A6	225	7.24	28	475	48436.520	178.677	17.522
Average compressive strength						197.779	19.396

Design strength of concrete (f'c) in this research is 26,4 Mpa. Six cubes of 150 mm x 150 mm x 150 mm test specimens were used as concrete sample for primary truss. Three specimens were tested for 7 days and three other specimens were tested for 28 days. 7-day cube specimens were converted to 28-days cylinder specimens.

Test result shows that average compressive strength of cube specimen at 28 days for mix proportion 1: 2: 2 is about 19,396 Mpa. Actual compressive strength is used for theoretical computation.

3.1 Load and strain

The theoretical strain compares with experimental record for three bars in primary truss with five positions of loads are shown in Table 3.

Table 3 The Theoretical and Experimental Strain

Loads	Position	Bar truss no 1		Bar truss no 2		Bar truss no 3	
		Theoretical strain	recorded strain	Theoretical strain	recorded strain	Theoretical strain	recorded strain
500 N	I	$0.01x10^{-6}$	$0.1x10^{-6}$	$0.02x10^{-6}$	$0.15x10^{-6}$	$0.03x10^{-6}$	$0.1x10^{-6}$
	II	$0.1x10^{-6}$	$0.22x10^{-6}$	$0.2x10^{-6}$	$0.16x10^{-6}$	$0.3x10^{-6}$	$0.26x10^{-6}$
	III	$0.34x10^{-6}$	$0.22x10^{-6}$	$0.01x10^{-6}$	$0.05x10^{-6}$	$0.16x10^{-6}$	$0.38x10^{-6}$
	IV	$0.01x10^{-6}$	$0.15x10^{-6}$	$0.6x10^{-6}$	$0.2x10^{-6}$	$0.13x10^{-6}$	$0.25x10^{-6}$
	V	$0.01x10^{-6}$	$0.2x10^{-6}$	$0.01x10^{-6}$	$0.16x10^{-6}$	$0.01x10^{-6}$	$0.15x10^{-6}$
1000 N	I	$0.02x10^{-6}$	$0.15x10^{-6}$	$0.04x10^{-6}$	$0.17x10^{-6}$	$0.05x10^{-6}$	$0.15x10^{-6}$
	II	$0.2x10^{-6}$	$0.25x10^{-6}$	$0.4x10^{-6}$	$0.22x10^{-6}$	$0.6x10^{-6}$	$0.27x10^{-6}$
	III	$0.6x10^{-6}$	$0.4x10^{-6}$	$0.02x10^{-6}$	$0.12x10^{-6}$	$0.3x10^{-6}$	$0.5x10^{-3}$
	IV	$0.02x10^{-6}$	$0.17x10^{-6}$	$1.2x10^{-6}$	$0.24x10^{-6}$	$0.2x10^{-6}$	$0.3x10^{-6}$
	V	$0.02x10^{-6}$	$0.22x10^{-6}$	$0.02x10^{-6}$	$0.2x10^{-6}$	$0.02x10^{-6}$	$0.17x10^{-6}$
1500 N	I	$0.03x10^{-6}$	$0.22x10^{-6}$	$0.06x10^{-6}$	$0.2x10^{-6}$	$0.09x10^{-6}$	$0.19 x 10^{-6}$
	II	$0.3x10^{-6}$	$0.27x10^{-6}$	$0.6x10^{-6}$	$0.30x10^{-6}$	$0.9x10^{-6}$	$0.3x10^{-6}$
	III	$0.9x10^{-6}$	$0.5x 10^{-6}$	$0.03x10^{-6}$	$0.17x10^{-6}$	$0.5x10^{-6}$	$0.6x10^{-6}$
	IV	$0.03x10^{-6}$	$0.18x10^{-6}$	$1.2x10^{-6}$	$0.3x10^{-6}$	$0.4x10^{-6}$	$0.35x10^{-6}$
	V	$0.03x10^{-6}$	$0.25x10^{-6}$	$0.03x10^{-6}$	$0.25x10^{-6}$	$0.03x10^{-6}$	$0.21x10^{-6}$

3.2 Load and deflection

Test result based on LVDT analysis in Table 4 shows that deflection does not occur under point load of 2900 N. After incremental step loading up to 1500 N, deflection of truss with 2900 N load is 0,002 mm.

Table 4 The Theoretical and Experimental Deflection

Loads	position	Point-A		Point-B	
		Theoretical deflection	recorded deflection	Theoretical deflection	recorded deflection
500 N	I	0.0000	0.000	0.000	0.000
	II	0.00009	0.000	0.0002	0.000
	III	0.0006	0.000	0.00057	0.000
	IV	0.0002	0.000	0.00009	0.000
	V	0.000	0.000	0.000	0.000
1000 N	I	0.000	0.000	0.000	0.000
	II	0.00018	0.000	0.0004	0.000
	III	0.0012	0.000	0.00114	0.000
	IV	0.0004	0.000	0.00018	0.000
	V	0.000	0.000	0.000	0.000
1500 N	I	0.000	0.000	0.000	0.000
	II	0.00027	0.000	0.0006	0.000
	III	0.0018	0.000	0.0017	0.000
	IV	0.006	0.000	0.00054	0.000
	V	0.000	0.000	0.000	0.000
3000N	I	0.000	0.000	0.000	0.000
	II	0.00036	0.000	0.0008	0.000
	III	0.0018	0.001	0.0023	0.001
	IV	0.0008	0.000	0.00036	0.000
	V	0.000	0.000	0.000	0.000

There are a less sensitivity of the LVDT which causes the deflection record only occur at loads more than 2900 N.

IV. CONCLUSION

Bamboo reinforced concrete for truss bridge has used in this research. The primary truss and abutment were precasted members. Floor slab reinforcements were installed and casted in situ. The use of precasted members decreases the work-time on the location. According to testing loads compare with theoretical analysis, it can be concluded that:

1. Strain of primary truss increases with respect to applied load.
2. Deflection of primary truss increases with respect to applied load, but the value is quite small under 2500 N.
3. Loading position in the span of truss bridge influences the strain of primary truss.
4. Loading position in the span of truss bridge influences the deflection of primary truss.

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