Flexural behavior of hybrid beam prepared with RC and foam concrete

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Ismunandar Muchtar, M. W. Tjaronge and Rita Irmawaty

Flexural Behavior of Hybrid Beam Prepared with RC and Foam Concrete

Ismunandar Muchtar[a)], M. W Tjaronge, Rita Irmawaty

Department of Engineering, Hasanuddin University, Bontomarannu, Gowa, Indonesia

[a)]Corresponding author: ismunandar.muchtar@gmail.com

Abstract. Reinforced concrete beams become one of the elements discovered in structural buildings that function to withstand bending loads. Due to the bending load, the upper side of the beam is compressed and the lower side is tensile. In the flexural capacity analysis, the compressive side is considerably important in bearing the bending load, while the tensile side is excluded due to the low tensile strength of the concrete. The hypothesis of this study indicates that the tensile side of the concrete is replaceable with a material having a low volume weight correlated with a lower compressive strength such as foam concrete. Therefore, this study aims to analyze the flexural behavior of normal concrete hybrid beams and foam concrete. The specimen consists of a beam specimen with dimension of 150 mm (width) x 200 mm (height) with length of 3300 mm where foam concrete area with height of 7 cm in the concrete tensile area. The number of test specimens include normal concrete of BN beam specimen and foam concrete FC beam specimen. The research result indicates that under the flexural load, FC beam specimen presents similar behavior, where the ultimate load of BN specimen was 34.3 kN with deflection value of 46.67 mm, while the ultimate load of (FC) specimen was 33.3 kN with deflection value of 61.9 mm, as well as the ductility value and stiffness value of the BN specimen were 37% and 31% higher, compared to the FC beam specimen, respectively.

INTRODUCTION

In the present era of global construction development, concrete serves as one of the most widely used materials worldwide. Normal concrete has a volume weight of up to 2200 kg / m^3. Basically, concrete has reliable compressive strength but its tensile strength ranges from one tenth to one twentieth of its compressive strength. Therefore, the utilization of tensile strength in the flexible structural elements include beam and plate, yet excluding the compressive elements, such as columns in buildings [1]. In a beam element that sits on two supports and carries bending load, the lower part experiences tension stress and the upper part experiences compression stress. The tensile area of the beam should therefore be reinforced with steel bars.

Previous research and innovation in construction materials were commonly aimed at developing lightweight materials in accordance with the existing theories. The use of lightweight materials on structural elements will reduce the total weight of a building. As it is revealed that the use of lightweight building materials reduces the total weight of the building structure, thereby reducing the foundation load and the seismic load.

Hardened foam concrete which has a volume weight ranging from 800-1800 kg / m3 serves as a potential choice as a lightweight material in building construction [2]. Foam concrete is constructed from paste cement, mixed with stable foam where the foam is generated by mixing water with foam agent in a certain ratio. Figure 1 indicates that stable foam is further mixed with paste cement to produce foam concrete.

This research as a part of intensive research aims to establish a hybrid beam, constructed from normal concrete and foam concrete. This study reports the test results related to the flexural behavior of two beams, made of normal concrete and made of normal concrete with foam concrete. In sandwich beam production, foam concrete was utilized to fulfill the lower part of the beam while the upper part of the beam was filled with normal concrete.

FIGURE 1. Foam concrete

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The hypothesis of using foam concrete lies in the optimization of the steel bar function in bearing the bending load, hence in the tensile part, the bottom of the beam foam concrete was placed, due to the concrete tensile strength which is excluded in the bottom part of concrete reinforced beam.

METHODS

MATERIAL PROPERTIS

Table 1 indicates a number of physical properties in the form of compressive strength, tensile strength, volume weight and modulus of elasticity of normal concrete and foam concrete. The cement used to produce normal concrete and foam concrete contains a type of blended cement produced by a national cement factory. The blended cement meets the Portland composite cement (PCCI) [3]. A number of studies have indicated that the blended cement has good reliability to produce mortar [4], normal concrete (NC) and foam concrete (FC) with performance fulfilling the construction standards qualifications. The ratio of foam concrete to normal concrete is in accordance with its compressive strength, tensile strength, volume weight and modulus of elasticity

The ratio of foam concrete to normal concrete is in accordance with compressive strength, tensile strength, volume weight and modulus of elasticity are respectively [7].

This study utilizes plain bar with diameter of 8 as stirrups and deformed bar with diameter of 13 as longitudinal reinforcement. The yield stress and peak stress of the reinforcement bars used in this study are illustrated in Table 2.

TABLE 1. Material Properties of Concreate

No.	Sample	Specific gravity	Compressive Strength (f'c)	Split Tensile Strength (ft)
1	Normal Concrete (NC)	2,240	20.95 Mpa	1.07 MPa
2	Foam Concrete (FC)	1,383	7.38 Mpa	0.7 MPa
3	FC / NC	0.61	0.81	0.74

TABLE 2. Material Properties of Barr

No.	Sample	fy	Fs max
1	Ø 8	377.8MPa	429.96 MPa
2	D13	460 MPa	606 MPa

Condition of Fresh Foam and Fresh Normal Concrete

Figure 2 and Figure 3 indicate that normal concrete and fresh foam concrete, respectively. In fresh normal concrete, there is no visible segregation between coarse aggregate and mortar or paste. Bleeding was also not visible. Fresh foam concrete seems to flow in all directions, stably forming a circle where there is no visible segregation between the paste and the sand [5] [6].

(a) (b)

FIGURE 2. Slump Test of Normal Concrete and Slump Flow of foam concrete

SPECIMENT TESTING

Load cells are installed to measure the load on the beam. Linear Variable Displacement Transducer (LVDT) is installed below in the center of the beam span to measure deflection. All load and deflection measurements were monitored and recorded using a set of data acquisition device.

FIGURE 3. Set up of sample specimens

Beam Speciment

The cross section of the beam is 150 mm (width) x 250 mm (height) with a length of 3,300 mm. Normal concrete beam is labelled with the symbol of NB and FC is for symbol of foam concrete hybrid beam. The two reinforced concrete beam specimens present the same dimensions and reinforcements, as details is illustrated in Figure 4 and Figure 5. NB specimens are fully made of normal concrete having a volume weight of 2,200 kg / m^3. Meanwhile, the lower part of the FC specimen is filled with foam concrete and the supporting area is completely filled with normal concrete as illustrated in Figure 3.

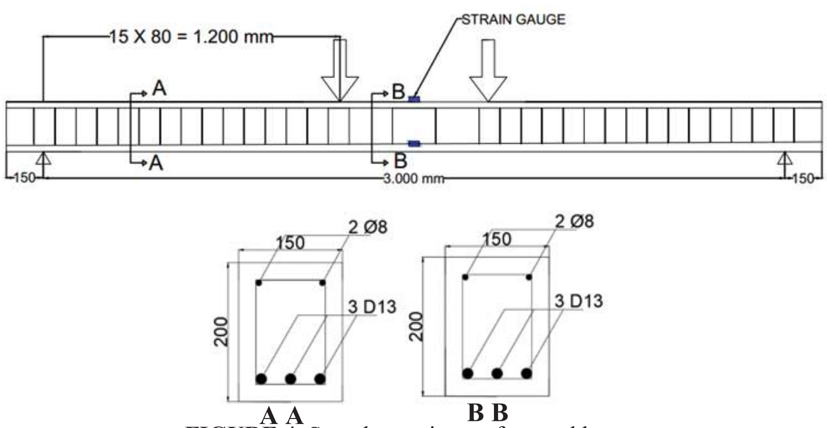

FIGURE 4. Sample specimen of normal beam

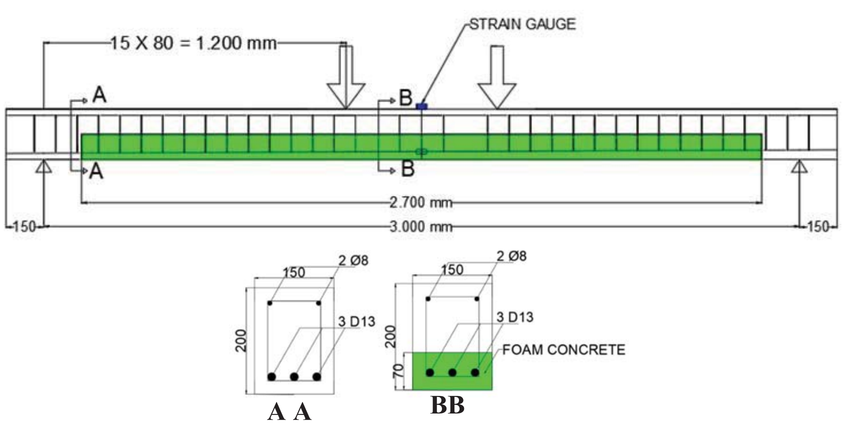

FIGURE 5. Sample specimen of hybrid beam with foam concrete

RESULTS AND DISCUSSION

Load and Deflection

Table 3 indecates The relationship between the load and the deflection of the BN specimen indicated the elastic condition until experience initial cracking at a load value of 4.93 kN with a deflection value of 1.83 mm. After initial cracking, the beam further indicated elasto-plastic properties until the load value reaching 32.92 kN with a deflection value of 19.34 mm. Furthermore, from the yielding stage to the peak load, the relationship between load and the deflection curve was plateau compared to the previous stage. Thus, this relationship occurs until the beam experiences failure, where the peak load was 34.78 kN and the ultimate load was 34.3 kN with the deflection value at the peak load of 44.67 mm and the ultimate load was 46.67 mm, respectively.

TABLE 3. Load-deflection of Normal Beam

No.	Test Object	Load (Kn)				Deflection (mm)			
		Pcr	Py	Ppeak	Pu	Δcr	Δy	Δpeak	Δu
1	Normal Beam (NB)	4.93	32.9	34.78	34.3	1.83	20.3	44.67	46.67
2	Foam Concrete Hybrid Beam (FC)	4.95	33.12	35.25	33.3	2.39	28	42.37	61.9

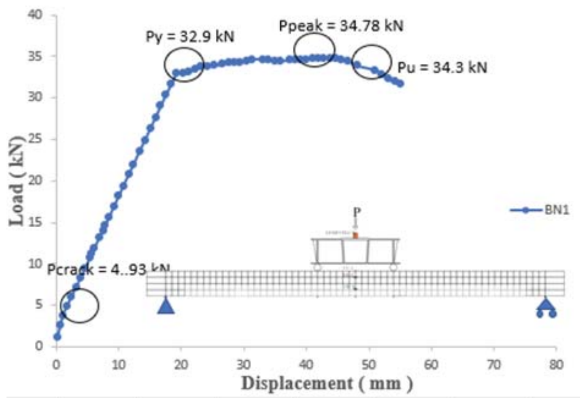

FIGURE 6. Load-deflection responses Normal Beam

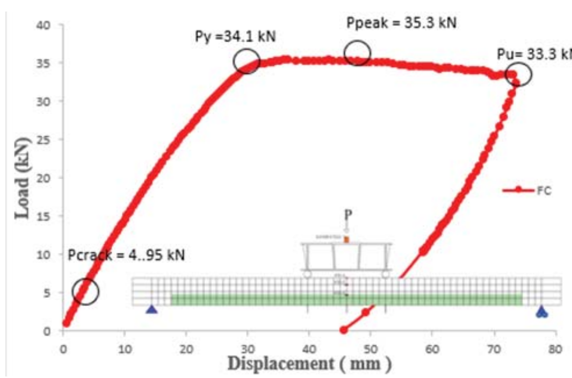

FIGURE 7. Load-deflection responses hybrid beam with foam concrete

The relationship between the load and the deflection of the FC specimen indicates the elastic condition until experience initial cracking at a load value of 4.95 kN with a deflection value of 2.39 mm. After initial cracking, the beam further indicated elasto-plastic properties until the load value reaching 33.12 kN with a deflection value of 28 mm. Furthermore, from the yielding stage to the peak load, the relationship between load and the deflection curve was plateau compared to the previous stage, this relationship occurred until the beam experiences failure, where the peak load was 35.25 kN and the ultimate load was 33.3 kN with the deflection value at the peak load of 42.37 mm and the ultimate load was 61.9 mm, respectively. As illustrated In Figure 6 and Figure 7.

Stiffness of Beam Speciment

Referring to the reinforced beam theory, the value of the stiffness is calculated by using Equation 1. Table 4 indicates that BN specimen and FC specimen have stiffness values of 2693.98 N /mm and 1689.24 N / mm, respectively. In Figure 8, BN specimen has 37% higher stiffness value than that of FC specimen.

$$k = \frac{P_{cr}}{\delta_{cr}} \tag{1}$$

TABLE 4. Stiffness of beam specimen

BEAM TYPE	Pcr (N)	δ cr (mm)	k (N /mm)
BN	4930	1.83	2693.98
FC	4950	2.93	1689.42

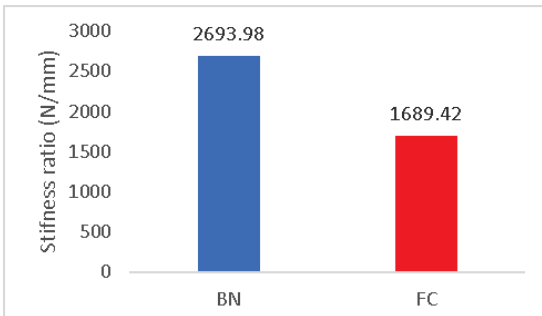

FIGURE 8. Stiffness ratio

Ductility

Referring to the reinforced beam theory, the value of the ductility is calculated by using Equation 2. Table 5 indicates that BN specimen and FC specimen have ductility values of 2 and 1.5, respectively. In Figure 9, ductility of BN specimen indicates 31% higher as compared to FC specimen.

$$\mu = \quad max/ \quad y \tag{2}$$

TABLE 5. Ductility of beam specimen

BEAM TYPE	Pmax Kn	Δmax (mm)	Δy (mm)	μ
BN	34.78	44.67	20	2
FC	35.25	42.37	28	1.5

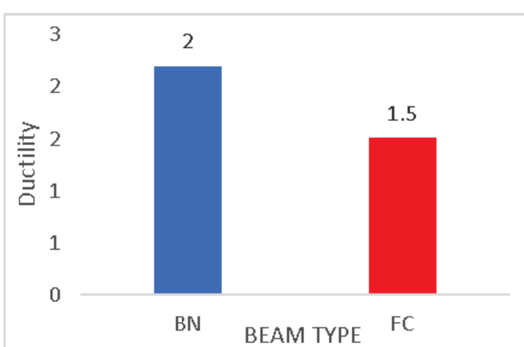

FIGURE 9. Ductility

CONCLUSIONS

From the research results it was concluded that:

1. Under the flexural load, FC beam specimen presented similar behavior, where the ultimate load of BN specimen was 34.3 kN with deflection value of 46.67 mm, while the ultimate load of (FC) specimen was 33.3 kN with deflection value of 61.9 mm.
2. The ductility value of the (BN) specimen was 37% higher than that of FC specimen, and the stiffness value of the (BN) specimen was 31% higher than that of the (FC) specimen.

REFERENCES

1. Nawy, Edward G. Reinforced concrete. Prentice-Hall, 1985.
2. Ramamurthy, K., EK Kunhanandan Nambiar, and G. Indu Siva Ranjani, "A classification of studies on properties of foam concrete," Cement and concrete composites, **31(6)**, 388-396 (2009).
3. SNI 15-7064-2012. Portland Composite Cement, National Standardization Agency (BSN).
4. Caronge, M. A., Tjaronge, M. W., Hamada, H., & Irmawaty, R., Effect of water curing duration on strength behaviour of portland composite cement (PCC) mortar, In IOP Conference Series: Materials Science and Engineering, **271**, 1-6 (2017).
5. Kearsley EP, Wainwright PJ, The effect of porosity on the strength of foamed concrete, Cem Concr Res, **32**,233–239 (2002).
6. Y.H. Mugahed Amran, N. Farzadnia, A.A. Abang Ali, Properties and applications of foamed concrete; a review, Constr, Build. Mater, **101**, 990–1005 (2015).
7. Kearsley EP, Wainwright PJ, Ash content for optimum strength of foamed concrete, Cem Concr Res, **32**, 241–6 (2002).