The 5th Annual Applied Science and Engineering Conference (AASEC 2020)  
IOP Conf. Series: Materials Science and Engineering  
1098 (2021) 022049  
doi:10.1088/1757-899X/1098/2/022049

Effect of FRP thickness on axial compressive behavior of Glass Fiber Reinforced Polymer–confined lightweight concrete cylinders

B A L Fanggi*, A G Lake, L Dumin, A Wadu, Y A A Lada and M C Mauta
Department of Civil Engineering, Politeknik Negeri Kupang, Kupang-NTT, 85148, Indonesia

*butje2017@gmail.com

Abstract. It is well known that FRP can improve the performance of concrete. However, the effectiveness of FRP to enhance the performance of lightweight concrete is less explored. This study aims to investigate the effect of FRP thickness on the axial compressive behavior of GFRP-confined lightweight concrete cylinders. Nine lightweight concrete specimens wrapped with 0, 1, 2, and 3 sheets of GFRP were manufactured and tested until failure. The test confirms that the thicker specimens experienced higher axial stress and strain compared to the thinner ones.

1. Introduction
Lightweight concrete has unique properties that are lightweight, heat resistant, and soundproof. It has 30% less weight than normal concrete that makes it suitable for application in the earthquake region such as Indonesia. However, it also has some disadvantages that are low compressive strength and strains [1].

Fiber-reinforced polymer (FRP) has been widely recognized as an effective material for strengthening/retrofit of concrete structures. Many studies have proven that the material can improve the performance of the strengthening/retrofitting concrete [2-10]. Therefore it can be used to mend the disadvantages of lightweight concrete.

The performance of lightweight concrete confined by FRP has been explored by some researchers [1,9,10]. The researchers report that compressive strength and strains of the confined concrete are significantly improved. However, it should be noted that all those published researches are only dealing with Carbon FRP. Therefore, it is necessary to conduct further research that involves other types of FRP, such as Glass FRP, to investigate the effectiveness of FRP in strengthening lightweight concrete.

2. Materials and method
2.1. Test specimens and materials
A total of 9 concrete specimens with a diameter of 100 mm and height of 200 mm were manufactured with a single concrete mix. All specimens were manufactured using coarse artificial lightweight aggregate with a maximum size of 10 mm. Six specimens were wrapped with 1, 2, and 3 layers of glass fiber sheets, with nominal ply thickness of 1.3 mm and ultimate tensile strength of 3240 MPa. Three specimens were left unwrapped and used to measure the average unconfined concrete strength ($f_{c0}$) of
all specimens as shown in Table. It should be noted that the $\varepsilon_{co}$ as shown in Table 1 is not measured directly from the specimens that are used to measure the $f_{co}$ but it was calculated using the equation provided by Tasdemir et al. [11]. The Detail of the specimens is presented in Table 1.

Table 1. Detail of tested specimens.

| Specimen | $f_{co}$ (M Pa) | $\varepsilon_{co}$ (%) | Number of layers | Number of Specimen |
|----------|-----------------|------------------------|------------------|-------------------|
| G1-1     | 18,26           | 0,16                   | 1                | 1                 |
| G1-2     |                 |                        | 1                | 1                 |
| G2-1     |                 |                        | 2                | 1                 |
| G2-2     |                 |                        | 2                | 1                 |
| G3-1     |                 |                        | 3                | 1                 |
| G3-2     |                 |                        | 3                | 1                 |

2.2. Testing procedures
All specimens were tested at the age of 28 days. Capping was applied to both end sides of all specimens before testing began. All specimens were tested under compression using a 1000-kN servo-hydraulic universal testing machine. Displacement control was applied at 0.003 mm per second until all specimen failure.

3. Results and discussion

3.1. Observed failure modes
All specimens experienced a rupture in the hoop direction. It was observed that the rupture became more severe on specimens with a thicker layer, as indicated in Figure 1. It was also observed that thicker specimens exhibited more explosive failure, as reported in many research, such as in Louk Fanggi et al. [11].

![Figure 1. Failure modes.](image_url)

3.2. Stress-strain behavior
The axial stress-strain behaviors of all tested specimens are presented in Figure 2. The figure shows that all specimens exhibited an almost monotonically ascending stress-strain curve, which indicates that the lightweight concrete was effectively confined by GFRP. A similar observation was also reported in Zhou et al. [1] and Louk Fanggi et al. [10].
The axial stress-strain relationships of specimens with different thicknesses are shown in Figure 3. It can be seen that thicker specimens exhibited higher ultimate stress ($f'_{cu}$) and strain ($\varepsilon_{cu}$) compared to the thinner ones. A similar observation was also reported in Zhou et al. [10] and Louk Fanggi et al. [10] for FRP confined lightweight concrete specimens.

The above observation is also can be seen through Table 2, which shows that thicker specimens exhibited higher ultimate stress ($f'_{cu}$) and strain ($\varepsilon_{cu}$) compared to the thinner ones.
**Table 2.** Compressive behavior of lightweight concrete confined by GFRP.

| Specimen | $f_{cu}$ (MPa) | Ave. $f_{cu}$ (MPa) | Ave. $f_{cu}$/ $f_{cu}$ (%) | Ave. $\varepsilon$ (%) | Ave. $\varepsilon$/$\varepsilon_{0}$ |
|----------|----------------|----------------------|-----------------------------|----------------------|-----------------------------|
| G1-1     | 41.49          | 43.62                | 2.39                        | 3.77                 | 4.36                        |
| G1-2     | 45.75          |                      | 4.94                        |                      |                             |
| G2-1     | 75.37          | 74.25                | 4.07                        | 6.90                 | 6.91                        |
| G2-2     | 73.13          |                      | 6.91                        |                      |                             |
| G3-1     | 94.12          | 94.12                | 5.16                        | 8.29                 | 8.29                        |
| G3-2*    | -              |                      | -                           |                      |                             |

*This specimen is excluded due to problem in testing*

4. **Conclusion**
This paper has presented the results of testing on lightweight concrete confined with different thicknesses of GFRP. Based on the test results reported in the present study, the following conclusions can be drawn.

- Lightweight concrete is confined effectively by GFRP
- Thicker specimens exhibited higher ultimate stress and strain compared to the thinner ones.

**Acknowledgments**
The authors would like to thank O. Taledoku, who has conducted the tests reported in this paper as part of his final year project. The authors also thank PT. Fyfe Fibrwrap Indonesia for providing the fibers used in this research.

**References**

[1] Zhou Y, Liu X, Xing F, Cui H and Sui L 2016 Axial compressive behavior of FRP-confined lightweight aggregate concrete: an experimental study and stress-strain relation model *Constr. and Build. Mater.* **119** 1–15.

[2] Barr B I G, Tasdemiry C S, Jefferson A D and Lydon F D 1998 Evaluation of strains at peak stresses in concrete: a three-phase composite model approach Li P, Sui L, Xing P, Huang X, Zhou Y and Yun Y 2018 Effects of aggregate types on the stress-strain behavior of fiber-reinforced polymer (FRP)-confined lightweight concrete *Sensors (Switzerland)* **18**.

[3] Tamuzs V, Tepfers R, Zile E and Ladnovo O 2006 Behavior of concrete cylinders confined by a carbon composite *3 Mech. Compos. Mater.* **42** 303–314.

[4] Wu G, Lu Z T, and Wu Z S 2006 Strength and ductility of concrete cylinders confined with FRP composites *Constr. and Build. Mater.* **20** 134–148.

[5] Almusallam T H 2007 Behavior of normal and high-strength concrete cylinders confined with E-glass/epoxy composite laminates *Compos. Part B: Engineering* **38** 629–639.

[6] Cui C, Sheikh S A and Asce M 2010 Experimental study of normal- and high-strength concrete confined with fiber-reinforced polymers *Compos. for Constr* **14** 553–561.

[7] Vincent T and Ozbakkaloglu T 2013 Influence of fiber orientation and specimen end condition on axial compressive behavior of FRP-confined concrete *Constr. Build. Mater.* **47**, 814–826, 2013.

[8] Vincent T and Ozbakkaloglu T 2013 Influence of concrete strength and confinement method on axial compressive behavior of FRP confined high- and ultra high-strength concrete *Compos. Part B: Engineering* **50** 413–428.

[9] Louk Fanggi B A, Muda H A, Mata A E, Umbu Nday A A, Bria M and Wayan A R L 2018 Kuat Tekan Kolom Beton Ringan yang Diperkuat Dengan Carbon Fiber Reinforced Polymer Tube *J. Tek. SIPIL* **111** 259–265.

[10] Louk Fanggi B A, Moata M R S, Wayan A R L, Mata A E and Benu M 2019 Influence of number of FRP layer on compressive behavior of FRP-confined lightweight concrete *Proc. of the Ist
Int. Conf. on Engineering, Science, and Commerce, ICESC 2019, Editors Tanesab J, Amheka A and Fanggi EAI 1–6.

[11] Barr B I G, Tasdemiry C S, Jefferson A D and Lydon F D 1998 Evaluation of strains at peak stresses in concrete: a three-phase composite model approach Cem. and Conc. Compos. 2 301–318.