The effect of Welded Wire Fabric (WWF) confinement on axial capacity of hollow columns

I W Suasira[1], I W Sudiasa[1], I M Jaya[1], I A Santiana[1], I M Tapayasa[1]

[1] Department of Civil Engineering, Politeknik Negeri Bali, Kampus Bukit Jimbaran, Bali, Indonesia

E-mail: suasira@gmail.com

Abstract. The aim of the study was to determine the effect of installing different sizes of Welded Wire Fabric (WWF) as a concrete restraint on axial carrying capacity of hollow columns. WWF is used with a wire spacing of 12.2 times 12.2 mm, 19 times 19 mm, 25 times 25 mm, with a diameter of 0.7 mm. A hole of 1 inch in the column causes a decrease in compressive strength of the column of 5.62 percent, i.e., from compressive strength of 226.697 kg per square cm (specimen A) to its compressive strength 214,065 kg per square cm (specimen B). The percentage increase in axial carrying capacity of the perforated column type C is 13.16 percent, W1 is 2.96 percent, W2 is 11.33 percent, W3 is 13.27 percent, SW1 is 0.51 percent, SW2 is 5.51 percent and SW3 is 9.08 percent. WWF is able to increase compressive strength of hollow concrete columns by W1 is 7.08 percent, W2 is 12.41 percent, W3 is 14.36 percent, SW1 is 4.53 percent, SW2 is 9.73 percent and SW3 is 14.59 percent.

1. Introduction

Article 6.3.4 of the ACI 318M-95 Regulation limits the use of a conduit of 4 percent of the cross-sectional area of a column if it is greater than 4 percent the effect of the hole needs to be taken into account against its strength. Given the importance of structural elements compared to other elements, it is necessary to know the extent of the influence of the pipe holes on the column ductility behaviour [1].

Previous research has been conducted by Sabariman *et al.* The effect of confining normal quality concrete hollow columns on curvature ductility states that if the hole ratio exceeds 4 percent, it will reduce curvature ductility [2-6]. If a small hollow is made in the middle of the beam, the stress distribution in the centre of the hole will change, but we can conclude from the Saint-Venant principle that the hollow effect is a centred character. Very high stress concentration on the practical side of the hole is very important [4-10]. Confined concrete using WWF with smaller diameters have not been widely studied, so this study was conducted to determine their effect on the axial capacity of reinforced concrete column. The effectiveness of WWF as a provider of concrete constraints will be seen from the maximum load that can be borne.

The effect of confined concrete has been investigated since several decades ago, especially regarding the effect of confinement given by stirrups. These studies prove that confinement can increase the carrying capacity of structural components, in this case are columns. Razvi and Saatcioglu (1989) conducted a study using Welded Wire Fabric (WWF) as a concrete confinement in reinforced concrete columns. In this study WWF was used which was installed in a different place with varying spacings and curves, and a relatively large wire diameter of WWF [11-13].

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2. Research methods

Sampling and data are carried out by making 54 specimens in the form of cylinders with a diameter of 150 mm high 300 mm. The proportion of the concrete mixture is planned to be 18.68 MPa (K225). The longitudinal reinforcement used is 4 diameters 8 mm and the stirring reinforcement is diameter 5.5 mm. WWF used is with a wire spacing of 12.2 × 12.2 mm, 19 × 19 mm, 25 × 25 mm, each with a diameter of 0.7 mm. Variations made on the test object will be shown in Table 3.1. To avoid confusion, each specimen is named as listed in Table 1.

Table 1. Variations in WWF installation of specimens.

No	Amount	Variation	Code
a	6 pcs	cylindrical columns with a diameter of 150 mm high 300 mm without holes, without longitudinal reinforcement, stirrups and WWF A1	A1 Up to A6
b	6 pcs	cylindrical columns with a diameter of 150 mm high 300 mm perforated, without longitudinal reinforcement, stirrups and WWF	B1 Up to B6
c	6 pcs	cylindrical columns with a diameter of 150 mm high 300 mm perforated, 4 diameters 8 mm, stirrup diameter 5.5 mm with 59 mm space	C1 Up to C6
d	6 pcs	cylindrical columns with a diameter of 150 mm high 300 mm perforated, 4 diameters 8 mm, with WWF 12.2 × 12.2 mm	W11 up to W16
e	6 pcs	cylindrical columns with a diameter of 150 mm high 300 mm perforated, 4 diameters 8 mm, with WWF 19 × 19 mm	W21 up to W26
f	6 pcs	cylindrical columns with a diameter of 150 mm high 300 mm perforated, 4 diameters 8 mm, with WWF 25 × 25 mm	W31 up to W36
g	6 pcs	Cylinder column with a diameter of 150 mm high 300 mm perforated, 4 diameters 8 mm, stirrup diameter 5.5 mm with 59 mm space, with WWF 12.2 × 12.2 mm	SW11 up to SW16
h	6 pcs	Cylindrical columns with a diameter of 150 mm high 300 mm perforated, 4 diameters 8 mm, stirrup diameter 5.5 mm with 59 mm space, with WWF 19 × 19 mm	SW21 up to SW26
I	6 pcs	cylindrical columns with a diameter of 150 mm high 300 mm perforated, 4 diameters 8 mm, stirrup diameter 5.5 mm with 59 mm space, with WWF 25 × 25 mm	SW31 up to SW36

3. Results and discussion

3.1. Variations in WWF installation of specimens

3.1.1. Cylindrical columns without holes, confinement and longitudinal reinforcement (A1-A6). The average of axial load of the cylindrical column without confinement and longitudinal reinforcement is 343.429 kN where the compressive strength of the concrete at the age of 28 days is 18.824 MPa or 226.800 kilograms per square centimetre. The behaviour of this specimen is very brittle because of the

absence of confinement and longitudinal reinforcement. When receiving a load until it approaches its peak load cracks on the side of the cylinder occur and continue to increase until they reach their maximum load. After the maximum load is reached, the concrete is destroyed quickly and is no longer able to accept the load.

3.1.2. Hollow cylinder column, without confinement and longitudinal reinforcement (B1-B6). The average of axial load of hollow cylinder column with hole diameter 1" without confinement and longitudinal reinforcement 326.667 kN, smaller 4.81 percent than column without holes. The compressive strength of the concrete at the age of 28 days is 17.767 MPa or 214.065 kilograms per square centimetre, experiencing a decrease in concrete compressive strength of 5.62 percent from the column without holes.

3.1.3. Hollow cylindrical column with stirrup as confinement and longitudinal reinforcement (C1-C6). This test object uses 4 diameters 8 mm longitudinal reinforcement and diameter 5.5 mm stirrup, 59 mm spacing. Stirrup is formed in a spiral with a diameter of 100 mm or 25 mm of decking concrete and perforated with a diameter of 1" from the pipe. The average maximum load of this specimen is 369.667 KN. The concrete compressive strength at the age of 28 days is an average of 20.910 MPa or 251.933 kilograms per square centimetre. When compared with test specimens (B), this type of test object has an increase in maximum axial load of 13.16 percent, although not in a relatively large amount and has increased concrete compressive strength 17.69 percent.

3.1.4. Hollow cylinder column with longitudinal reinforcement and WWF 12.2 × 12.2 (W11-W16). In this specimen, a longitudinal reinforcement of 4 diameter 8 mm and WWF was installed with a wire diameter of 0.7 mm with a distance between 12.2 mm wire to vertical and horizontal directions. Like the stirrup installation, the WWF is also installed with a diameter of 100 mm or 25 mm of concrete decking and perforated 1" in diameter from the pipe. The average maximum load of this specimen is 336.333 KN. The concrete compressive strength at the age of 28 days is an average of 19.025 MPa or 229.216 kilograms per square centimetre. When compared with test specimens (B), this type of test object has an increase in maximum axial load of 2.96 percent, although not in a relatively large amount and has increased concrete compressive strength 7.08 percent.

3.1.5. Hollow cylinder column with longitudinal reinforcement and WWF 19 × 19 (W21-W26). This cylinder is almost similar to the cylinder (W1), the thing that distinguishes it is the distance between the WWF wires which is 19 mm in the vertical and horizontal direction. Like the stirrup installation, the WWF is also installed with a diameter of 100 mm or 25 mm of concrete decking and perforated 1" in diameter from the pipe. The maximum load is 363.7 KN. The concrete compressive strength at the age of 28 days is 19.972 MPa or 240.652 kilograms per square centimetre. When compared with the specimen (B), this type of test object has an increase in maximum axial load of 11.33 percent, and has increased concrete compressive strength of 12.41 percent. The behaviour of this cylinder at the time of loading is also almost similar to the test object (W1).

3.1.6. Hollow cylinder column with longitudinal reinforcement and WWF 25 × 25 (W21-W26). The 4 diameters 8 mm longitudinal reinforcement is also attached to this specimen. WWF installed has a distance between 25 mm wires in a vertical and horizontal direction. Like the stirrups installation, the WWF is also installed with a diameter of 100 mm or 25 mm of concrete decking and perforated 1" in diameter from the pipe. This test object at the time of loading behaves that is very similar to specimens of type Wl and W2. The peak load that can be achieved averaged is 370 KN. The compressive strength of the concrete at the age of 28 days is an average of 20.320 MPa or 244.816 kilograms per square centimetre. When compared with the specimen (B), this type of test object has an increase in maximum axial load of 13.27 percent, and has increased concrete compressive strength of 14.36 percent.

3.1.7. Hollow cylinder column, longitudinal reinforcement, stirrup, WWF 12.2 × 12.2 (SW11-SW16). The SW1 type specimen uses 4 diameter 8 mm longitudinal reinforcement, diameter 5.5 mm cross section and WWF diameter 0.7 mm with a wire spacing of 12.2 mm in a vertical or horizontal direction. Like the installation stirrup, the WWF is also installed with a diameter of 100 mm or 25 mm of concrete decking and perforated 1" in diameter from the pipe. When the cylinder reaches its maximum load an average of 328.3 KN, the compressive strength of the concrete at the age of 28 days is 18.572 MPa or 223.764 kilograms per square centimetre. When compared with test specimens (B), this type of test object has a maximum axial load increase of 0.51 percent, and has a 4.53 percent increase in concrete compressive strength.

3.1.8. Hollow cylinder column, longitudinal reinforcement, stirrup, WWF 19 × 19 (SW21-SW26). This SW1 type specimen uses 4 diameter 8 mm longitudinal reinforcement, diameter 5.5 mm cross section and WWF diameter 0.7 mm with 19 mm wire intervals in vertical and horizontal directions. Like the stirrup installation, the WWF is also installed with a diameter of 100 mm or 25 mm of concrete decking and perforated 1" in diameter from the pipe. At the beginning of loading vertical cracks around it are increasingly widening until finally the concrete blanket is released when the load indicator shows the numbers 344.7 KN, the longitudinal reinforcement began to bend. The compressive strength of the concrete at the age of 28 days averaged 19.496 MPa or 234.895 kilograms per square centimetre. When compared with the test object (B), this type of test object has an increase in maximum axial load of 5.51 percent, and has an increase in concrete compressive strength of 9.73 percent.

3.1.9. Hollow cylinder column, longitudinal reinforcement, stirrup, WWF 25 × 25 (SW31-SW36). The specimen is 4 diameter 8 mm in diameter, diameter 5.5 mm in diameter and WWF diameter 0.7 mm in 25 mm × 25 mm spacing. As with stirrup installations, WWF is also installed with a diameter of 100 mm or decking concrete of 25 mm and perforated with a diameter of 1in from the pipe. The peak stresses of the three columns are 368, 350, 350, 350, 370 and 350 kN, which averages 356.3 KN. The concrete compressive strength at the age of 28 days is an average of 20.36 MPa or 245.299 kilograms per square centimetre. When compared with the specimen (B), this type of test object has an increase in maximum axial load of 9.08 percent, and has increased concrete compressive strength of 14.59 percent.

3.2. Effects of mounting stirrups

With longitudinal reinforcement, WWF (12.2 × 12.2, 19 × 19, 25 × 25), the axial capacity of the test object has increased, not as much as an increase when fitted with stirrup as a confinement. The biggest increase in carrying capacity occurred in the test material with WWF 25 × 25 then WWF 19 × 19 and WWF 12.2 × 12.2. Increased axial bearing capacity of hollow columns using the average value of load readings (P test) perforated columns without stirrups and longitudinal reinforcement:

- Percentage of increase in axial capacity of column C is 13.16 percent
- Percentage of increase in axial capacity of column W1 is 2.96 percent
- Percentage of increase in axial capacity of column W2 is 11.33 percent
- Percentage of increase in axial capacity of column W3 is 13.27 percent
- Percentage of increase in axial capacity of SW1 column is 0.51 percent
- Percentage of increase in axial capacity of SW2 column is 5.51 percent
- Percentage of increase in axial capacity of SW3 column is 9.08 percent

The test results show that the concrete confinement by WWF is able to increase the axial capacity of the column. Increases arising from the installation of WWF to 13.27 percent are given by W3 specimens (hollow columns with longitudinal reinforcement and WWF 25 × 25). Increasing axial capacity of hollow columns due to confinement is seen in Figure 2.

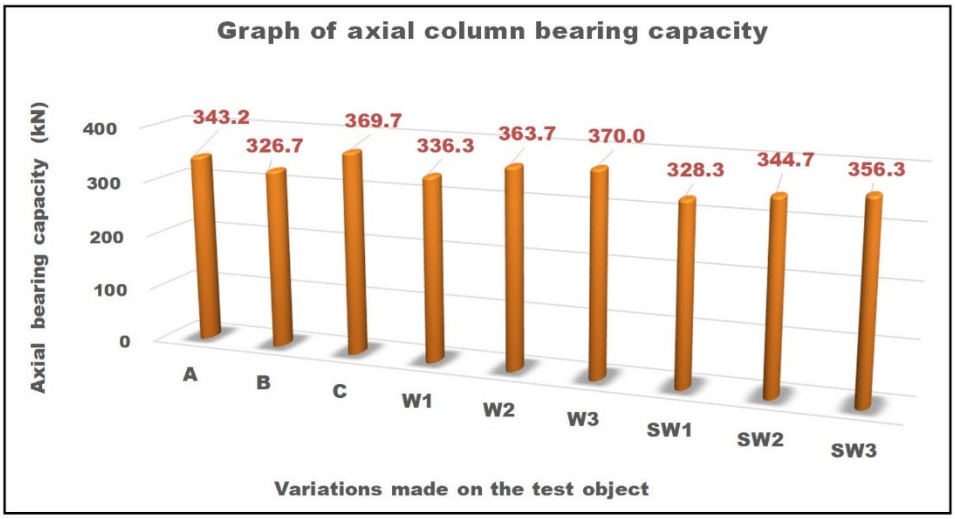

Figure 1. Graph of the axial capacity of column.

Increasing the compressive strength of the hollow column using the average value of the compressive strength of the hollow column without stirring and longitudinal reinforcement:

- Percentage of increase in compressive strength of column C is 17.69 percent
- Percentage of increase in compressive strength of column W1 is 7.08 percent
- Percentage of increase in compressive strength of column W2 is 12.41 percent
- Percentage of increase in compressive strength of column W3 is 14.36 percent
- Percentage of increase in compressive strength of column SW1 is 4.53 percent
- Percentage of increase in compressive strength of column SW2 is 9.73 percent
- Percentage of increase in compressive strength of column SW3 is 14.59 percent

The test results show that the concrete confinement by WWF is able to increase the compressive strength of the hollow column. Increases arising from the installation of WWF up to 14.59 percent were given by SW3 specimens (hollow columns with longitudinal reinforcement, stirrup and WWF (25 × 25). Increasing the compressive strength of the hollow column due to confinement can be seen from Figure 3.

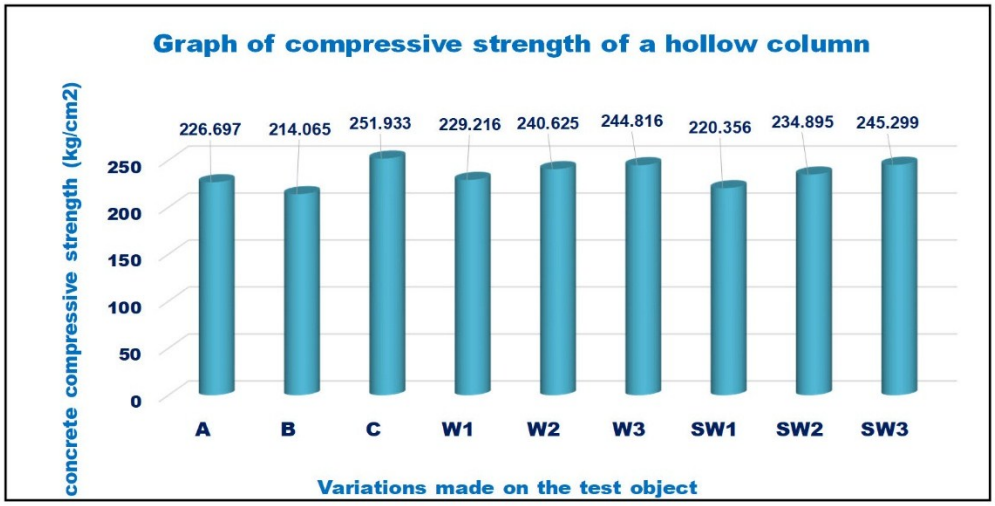

Figure 2. Graph of compressive strength of a hollow column.

4. Conclusions

A hole of 1" in the column causes a decrease in compressive strength of the column 5.62 percent, from compressive strength 226.697 kilograms per square centimeter (specimen A) to compressive strength 214.065 kilograms per square centimeter (specimen B). WWF is able to increase the axial capacity of hollow concrete columns by 2.96 percent, 11.33 percent, 13.27 percent, respectively for WWF 12.2 × 12.2, WWF 19 × 19, WWF 25 × 25, If WWF is combined with stirrups with 59 mm spacing as confinement, the axial capacity of the column increased by 0.51 percent, 5.51 percent, 9.08 percent respectively for the stirring combination with WWF 12.2 × 12.2, WWF 19 × 19, and WWF 25 × 25. WWF (Welded Wire fabric) can increase compressive strength of hollow concrete columns by 7.08 percent, 12.41 percent, 14.36 percent, respectively for WWF 12.2 × 12.2, WWF 19 × 19, WWF 25 × 25. If WWF is combined with stirrup 59 mm spacing as confinement, column compressive strength increased by 4.53 percent, 9.73 percent, 14.59 percent respectively for stirrup combination with WWF 12.2 × 12.2, WWF 19 × 19, WWF 25 × 25.

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