Confinements of concrete cylinders using bamboo spiral stirrups

N Nindyawati¹, M Sulton¹, M M A Pratama¹ and T Rahayuningsih¹

¹Civil Engineering, Universitas Negeri Malang, Malang, Indonesia

nindyawati.ft@um.ac.id

Abstract. Confinement affects the increase in beam flexural capacity. The strain stress relationship of concrete cylinder compressive strength is used to analyze the beam and column capacity. The area of the curve of the concrete cylinder core with confinements is wider than the curve without confinements. Confinements can also increase ductility and shear strength of reinforced concrete structural elements. The paper aims to determine the effect of bamboo spiral stirrups distance on normal strength concrete. Concrete cylinder size 150 mm x 300 mm. Variation in crossing distance of 30 mm, 50 mm, 70 mm and without confinement. Confinements on cylinders are bamboo and steel spiral stirrups. The results show that concrete cylinders with steel confinements increase the compressive strength by 45% of the concrete cylinder without confinements. Concrete cylinders with bamboo confinements increase the compressive strength by 28 %.

1. Introduction
Stress-strain relations for confined and unconfined concrete are aim to overcome some shortcomings of existing commonly used models. Existing models are neither easy to integrate to obtain equivalent rectangular stressblock parameter for analysis and design. The stress-strain relations proposed are validated for a whole range of concrete strength and confining stresses. Then confinement are derived for the equivalent rectangular stress-block parameters. The wider the curve, the greater the concrete compressive strength for beams and columns [1][2].

Kent and Park [3][5] developed a stress-strain relation of confined concrete from the stress-strain relation of unconfined concrete. Mander at al. [4] proposed a stress-strain relation of confined concrete with according the confinement effects to the various configurations of lateral ties. Park at al. [7] modified the stress-strain relation proposed by Kent and Park [5].

Several classical studies [6][7][8][10] about flexural behavior of reinforced concrete beams section is permit the simulation but, in these classical studies the concrete confinement is often neglected. The spiral reinforcement or the rectilinear ties in reinforced concrete play an important role in enhancing the strength and ductility. Under axial loads, concrete pressure in lateral direction of the sections acts on the lateral ties and resistance of the ties may restrain the core of concrete to a degree. The mechanical behaviour of the confined concrete is characterized by the increase in strength and ductility. Beams with bamboo stirrups affect the flexural strength that occurs. Flexural strength increases with increasing beam stirrup distance. The stirring distance of 5 cm shows optimal flexural strength [1].
The objective of this study is to present an empirical stress-strain relation according to the confinement effect to various parameter variables (stirrup type, stirrup material and stirrup distance). This paper presents an empirical and experimental relationship to describe the behavior of confined concrete. Confinement material is iron and bamboo.

2. Confinement
Concrete cylinder compressive test have proposed stress-strain relationships for concrete. Figure 1 presents typical stress-strain curves obtained from concrete cylinders loaded in compression test [5]. The curves are almost linear up to about one-half the compressive strength. The peak of curve for high-strength concrete relatively sharp, but for low-strength concrete the curve has a flat top. The strain at the maximum stress is 0.002.

![Figure 1. Stress-strain curves obtained from concrete cylinders loaded in compression test [5]](image)

The circular section in figure 2 to the same of effectively confined concrete, steel/bamboo spiral and unconfined concrete.

![Figure 2. Flowchart of Idriss and Boulanger’s Method](image)

The compressive strength is developed by Mander at al. [4] and it can be defined by:

\[
f_{c2} = f_{ce} \left( 1 - 1.254 + 2.254 \sqrt{1 + \frac{7.94 f'_{t}}{f_{c0}} - \frac{2 f'_{t}}{f_{ce}} } \right)
\]

(1)

The confinement coefficient is defined by Mander at al. [6] as

\[
k_{e} = \frac{1 - \frac{s'}{2d}}{1 - \rho_{cc}}
\]

(2)

The loads equilibrium in the section can be written as
The confinement stress is given by

\[ 2f_{yh} \times A_{sp} = f_l \times s \times d_t \]  \hspace{1cm} (3)

\[ f'_{l} = \frac{1}{2} \rho_{s} \times k_{e} \times f_{yh} \]  \hspace{1cm} (4)

\( f_{ch} \) : Compressive strength of unconfined concrete.
\( e_c \) : Confined concrete strain.
\( e_{65} \) : The strain corresponding to the stress equal 0.65\( f_{ch} \).
\( E_{bc} \) : Initial confined concrete Young modulus.
\( \sigma_{ce} \) : Confined concrete stress.
\( f_l \) : Lateral confinement stress.
\( f_{yh} \) : Yield strength of lateral ties.
\( k_{e} \) : Effective confinement coefficient.
\( \rho_{cc} \) : Longitudinal reinforcement ratio.
\( A_{sp} \) : Transverse reinforcement area.
\( s \) : Distance between longitudinal steels bounded by perimeter ties.
\( \rho_{s} \) : Volumetric ration of circular ties.

3. The Results and Discussion
The test specimen is a concrete cylinder with a diameter of 15 cm with a height of 30 cm to test the compressive strength of concrete. Figure 3 presents variation of the test specimens consisted of 3 concrete cylinders without stirrups, each 3 concrete cylinders with iron and bamboo stirrups distance away 3 cm, 5 cm and 7 cm. The total number of test specimens is 21 concrete cylinders. Steel and bamboo for reinforcement measuring Ø 8 mm, steel and bamboo spirals used for stirrups measuring Ø 6 mm as confinement on reinforced concrete and testing was carried out on the 28th day.

![Figure 3. Variations of sample](image-url)
The concrete cylinder compressive test was carried out using the universal testing machine as shown in Figure 4. The Compressive test is performed only on the core area with a diameter of 12 cm. The results of the compressive strength test will be divided by the area of concrete contact with an instrument that is equal to 11304 mm².

![Sample](image1)

![Universal Testing Machine](image2)

**Figure 4.** Compression Test

| Stirrup Distance | CODE | Diameter (mm) | H (mm) | Load (N) | Compression Strength (N/mm²) | Average |
|------------------|------|---------------|--------|----------|------------------------------|---------|
| Unconfinement    |      |               |        |          |                              |         |
| k1               | 120  | 293           |        | 226883   | 20,071                       |         |
| k2               | 120  | 290           |        | 225865   | 19,981                       |         |
| k3               | 120  | 292           |        | 218179   | 19,301                       |         |
| Confinement bamboo 30 mm |      |               |        |          |                              |         |
| C3.1             | 120  | 295           |        | 327646   | 28,985                       |         |
| C3.2             | 120  | 300           |        | 323690   | 28,635                       |         |
| C3.3             | 120  | 300           |        | 324187   | 28,679                       |         |
| Confinement bamboo 50 mm |      |               |        |          |                              |         |
| C5.1             | 120  | 290           |        | 268255   | 23,731                       |         |
| C5.2             | 120  | 295           |        | 280701   | 24,832                       |         |
| C5.3             | 120  | 287           |        | 261122   | 23,1                         |         |
| Confinement bamboo 70 mm |      |               |        |          |                              |         |
| C7.1             | 120  | 295           |        | 246427   | 21,8                         |         |
| C7.2             | 120  | 300           |        | 239645   | 21,2                         |         |
| C7.3             | 120  | 293           |        | 243036   | 21,5                         |         |
Table 2. Compression strength of concrete cylinder with bamboo stirrup

| Stirrup distance | CODE | Diameter (mm) | H (mm) | Load (N) | Compression strength (N/mm) of research results | Average |
|------------------|------|---------------|--------|----------|-----------------------------------------------|---------|
| Unconfinement    | k1   | 120           | 293    | 226883   | 20,071                                        |         |
|                  | k2   | 120           | 290    | 225865   | 19,981                                        |         |
|                  | k3   | 120           | 292    | 218179   | 19,301                                        |         |
| Confinement bamboo 30 mm | C3.1 | 120           | 295    | 301817   | 26,7                                           |         |
|                  | C3.2 | 120           | 300    | 280339   | 24,8                                           | 25,37   |
|                  | C3.3 | 120           | 300    | 278078   | 24,6                                           |         |
| Confinement bamboo 50 mm | C5.1 | 120           | 290    | 233993   | 20,7                                           |         |
|                  | C5.2 | 120           | 295    | 246427   | 21,8                                           | 21,80   |
|                  | C5.3 | 120           | 287    | 258862   | 22,9                                           |         |
| Confinement bamboo 70 mm | C7.1 | 120           | 295    | 232862   | 20,6                                           |         |
|                  | C7.2 | 120           | 300    | 221558   | 19,6                                           | 20,33   |
|                  | C7.3 | 120           | 293    | 235123   | 20,8                                           |         |

There is a difference between confined and unconfined on a concrete cylinder. For steel material as confinement with a distance of 3 cm increase 45% compared to concrete cylinders unconfined in Table 1 (unconfinement = 19,78 N/mm² and confinement = 28,77 N/mm²). The longer the stirrups, the effect of the confinement does not affect.

Spiral stirrup with bamboo material increased by only 28% in Table 2. The bamboo stirrup in confine is not very good. This is proven when applied to bamboo stirrup for beam, it does not greatly increase the flexural capacity than steel stirrup [1][2]. While the beam with steel stirrup increased flexural strength.

Table 3. Comparison of Experimental Results With Mander Calculations (Steel Stirrup)

| Distance stirrup (mm) | Compression Strength (N/mm) of research results | Compression Strength (N/mm) by Mander | Different |
|-----------------------|-----------------------------------------------|--------------------------------------|-----------|
| no stirrup            | 19,78                                        | 19,78                                | 5%        |
| 30                    | 28,77                                        | 27,23                                | 4%        |
| 50                    | 23,89                                        | 24,82                                | 6%        |
| 70                    | 21,50                                        | 22,83                                | 5%        |

Table 4. Comparison of experimental results with Mander calculations (bamboo stirrup)

| Distance stirrup (mm) | Compression strength (N/mm) of research results | Compression strength (N/mm) by Mander | Different |
|-----------------------|------------------------------------------------|--------------------------------------|-----------|
| No stirrup            | 19,78                                          | 19,78                                | 4%        |
| 30                    | 25,37                                          | 24,27                                | 6%        |
| 50                    | 21,80                                          | 20,59                                | 1%        |
| 70                    | 20,33                                          | 20,04                                | 4%        |
Confinement increases the compressive strength of concrete cylinders. Confinement affects the capacity of beams and columns. Calculations using the formula from Mander produce different values from the results of the experiment (table 3 and table 4). There is a difference of 4% -5% between the Manders formula [4][5] and the results of the compressive test. So the Manders formula can be used to predict the contribution of stirrups, with a difference of approximately 4%-5%.

The smoothing surface of concrete cylinder can improve strength of concrete by 1%-21% [9]. Porosity of concrete was also predicted to be another factor that led decreasing strength of concrete. Previous research stated that the higher porosity percentage of concrete, the lower compressive strength owned [11]

4. Conclusions

- Steel material as confinement with a distance of 3 cm increase 45 % compared to concrete cylinders unconfinement. The longer the stirrups, the effect of the confinement does not affect.
- Spiral stirrup with bamboo material increased by only 28%

References

[1]  N Nindayawati et al. 2017 Effects of Variations in Overlap Length and Stirrup Spacing on Flexural Capacity of Bamboo Reinforcement Concrete Beams. AIP Conference Proceedings 1887, 020044 (2017); doi: 10.1063/1.5003527.
[2]  N Nindayawati, Risdanareni P and Ummiati 2017 Flexural Test of Fly Ash Based Geopolymer Concrete Beam. MATEC Web of Conferences. 1:10.1051/matecconf/20179701030.
[3]  Kent DC and Park R 1971 Flexural members with confined concrete. J. Struct. Div., ASCE 1971 ; 97(7): 1969-90.
[4]  Mander JB, Priestley MJN and Park R 1988 Theoretical stress-strain model for confined concrete. J. Struct. Engin., ASCE 1988 ; 114(8): 1804-26
[5]  Park R, Priestley MJN and Gill WD 1982 Ductility of square-confined concrete columns. J. Struct. Div., ASCE 1982 ; 108(4): 929-50
[6]  Saatcioglu and Razvi SR 1982 Strength and ductility of confined concrete. J. of Structural Engineering, vol. 118, n° 6. 1590-1607.
[7]  Sargin M 1968 Stress-strain relationship for concrete and analysis of structural concrete sections. PHD Thesis, University of Waterloo, Ontario, Canada. March 1968.
[8]  Sheikh SA and Uzumeri SM 1982 Analytical model for concrete confined in tied J. Struct. Div., ASCE 1982; 108(12): 2703-22
[9]  SushilKD, Sajal KA, Abu ZM,MosaddekhM and GiashD 2012 Effect Capping on compressive Strength of Concrete (ICETCESD 2012)
[10] Yong YK, Nour MG and Nawy EG 1988 Behaviour of laterally confined concrete highstrength concrete under axial load. J. Struct. Engin., ASCE 1988 ; 114(2): 333-51.
[11] Chen X, Huang W and Zhou J 2012 Indian J. Eng. Mater.Sci, 19(6) 427 (2012)

Acknowledgement

This work was supported by PNBP research grant of Universitas Negeri Malang