Study of flexural strength on concrete bundled bars beams

E Walujodjati1,*, J A Tjondro2, S Permana1 and G J Johari1

1 Department of Civil Engineering, Sekolah Tinggi Teknologi Garut, Jalan Mayor Syamsu 1, Garut 44151, Indonesia
2 Department of Civil Engineering, Parahyangan Catholic University, Bandung, Jl. Ciumbuleuit, Bandung, Indonesia

*eko.walujodjati@sttgarut.ac.id

Abstract. Reinforced concrete beams as structural elements that are often found are elements that are quite large in their role in bearing loads. Judging from the function of support as a bearer of tensile force, it is possible if the reinforced concrete beams are made with different numbers and areas of reinforcement. Reinforcement bundles are used if there is a cross-sectional dimension limitation without the distance between the reinforcement conditions being met. Beams with 2 reinforcement bundles are made to see the flexural capacity obtained. With the dimensions of the beam 150 mm x 200 mm x 1050 mm, a bundle of 2 reinforcement with a diameter of 10 mm is mounted on the tensile section of reinforced concrete beams. With a four-point bending test, a nominal bending moment is obtained. Single-section square cross-section analysis with cross-sectional area obtained using the equivalent diameter of the reinforcement bundle compared to the flexural test results. The bending moment capacity between experiment and analysis obtained the appropriate results. The bending capacity value of the two reinforcement bundles is still large so that the bending failure has not been reached.

1. Introduction
In reinforced concrete construction, it is sometimes necessary to place reinforcement by bundling [1-3]. Bundling is required because of the structural dimension restrictions. Reinforcement bundles can produce structural elements with smaller dimensions, and facilitate the placement of concrete mixes and facilitate vibrations to achieve concrete homogeneity [4]. Research related to the use of reinforcement bundles has not been done much [5-9]. Therefore, it is necessary to conduct an experimental study on the use of reinforcement bundles on concrete beams. Will be carried out a review of the flexural strength of the reinforcement bundle beam produced through experiments [10]. The current standard recommends as many as one, two, three, and four maximum reinforcement in one bundle in planning (figure 1). The purpose of this study is to provide an understanding of the bonding mechanism in the reinforcement bundle. Provide experimental/test data to improve the understanding of reinforcement bundle behavior.

Figure 1. Arrangement of reinforcement in one bundle [1-4].
2. Problem formulation
Research on the flexural of reinforced concrete beams has been carried out [10-12]. Experimental studies are needed to see the ability of reinforcement bundles on reinforced concrete beams, associated with the resulting flexural strength. An experimental test will be carried out on a concrete beam with a reinforcement bundle on the flexural ability of the beam.

3. Research objectives
The purpose of this study is to determine the flexural strength of the two reinforcement bundles concrete beam.

4. Benefits of research
With this research, it is expected that the flexural strength produced from concrete beams with bundles of two reinforcement as flexural reinforcement can be known. Further research is expected to review the other parameters of structural elements (beams, columns, joint columns, exterior and interior columns), such as shear strength, ductility, and behavior of the load.

5. Theoretical foundation

In Figure 2, the distance between the reinforcement is very tight with the possibility of trapping air in the concrete, thereby reducing the level of homogeneity of the concrete, which results in reduced strength of the concrete. There are several ways to overcome these problems, including using high-quality materials (additives) or using bundle bars. The use of additive materials requires a large number of costs, while the use of reinforcement bundles can reduce costs (figure 3).

![Figure 2](image1.png)

**Figure 2.** Reinforcement with tight spaces.

![Figure 3](image2.png)

**Figure 3.** Conventional and bundle reinforcing [2].
5.1. The technical requirements.
The technical requirements for using reinforcement bundles in structural elements are as follows [1]:
- The maximum diameter of the reinforcement used must not be greater than 36 mm.
- For the same diameter of reinforcement in one bundle, the equivalent diameter is
  \[ D_e = d \sqrt{2} \] for two rebars in one bundle
  \[ D_e = d \sqrt{3} \] for three rebars in one bundle
  \[ D_e = 2d \] for four rebars in one bundle

5.2. Single reinforcement beam analysis (figure 4)

![Diagram of single reinforcement beam analysis](image)

Figure 4. Single reinforcement beam analysis [3,13,14].

6. Methodology
Tests are carried out on beams with two rebars in one bundle, to understand the behavior of the bundle of reinforcement on a concrete beam. Test the bundle of two reinforcement using the concept of an "equivalent reinforcement" [1]. Where the equivalent diameter of the reinforcement has been included in the standard, which means that the need for spacing/distance between reinforcement based on the diameter of the reinforcement has been fulfilled. The number of specimens consisted of:
- (1) 9 concrete cylinders with a diameter of 100 mm and a height of 200 mm, to test the compressive strength of concrete.
- (2) 9 reinforcement steel bars with a diameter of 10 mm with a length of 50 cm to test the tensile strength.
- (3) 3 concrete two reinforcement bundles concrete beam of 150x200x1200 mm size, to test the flexural behavior of two reinforced bundle bars on concrete beam. As for the specimen bundle two reinforcement concrete beam using 10 mm diameter steel bars with 25 MPa concrete quality. The illustration as follows figure 5.
Figure 5. Cross-section of the beam.

7. Results and discussion
Flexural strength testing of 2 reinforcing concrete bundle beams was carried out on 3 test pieces with a size of 150 mm x 200 mm x 1200 mm with four-point loading testing [15,16]. The test span is 1050 mm with a distance of 1/3 span at each loading point (Figure 6).

Figure 6. Set-up specimens.

Following are the results of tests on the 3 concrete beams 2 reinforcement bundles (Figure 7).

Figure 7. Momen and deflection graph to 3 beams.
Cross-section analysis as follows:

With Cover = 50 mm  \( f_y = 462.86 \text{ MPa} \)  \( f'c = 30 \text{ MPa} \)

\( B = 150 \text{ mm} \)  \( d = 144 \text{ mm} \)

\( H = 200 \text{ mm} \)  \( f'c = 30 \text{ MPa} \)

\( Cc = 0.85.f'c.b.a = 0.85.30.150.a \)

\[ = 3825.a \]

equilibrium \( Cc = Ts \),

\( Ts = As.f_y = 2.1/4.22/7.(10.\sqrt{2})^2.462.86 = 144.336 \)

\( a = 38 \text{ mm} \)

\( M_n = As.f_y.(d – a/2) = 144.336.(144-38/2) = 18.061.138 \text{ N,mm} \)

from experiments result as follows:

\( M_n = 1/6.P.L = 1/6.70000.1050 = 12.250.000 \text{ N,mm} \)

There is a pretty big difference compared to the results of the cross-section analysis. Which means that the flexural capacity of the two reinforcement bundles on testing has not yet been achieved.

8. Conclusion

- The nominal bending moment of the experimental results yields values that are far different from the results of the cross-section analysis using the equivalent diameter of the provisions (ACI 318-14) and from the experiments.
- None of the conditions of the concrete reinforcement bundle 2 test pieces produce bending failure, it is estimated that the load obtained has not yet reached the flexural capacity of the reinforcement bundle.

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