The influence of concrete compressive strength on bonding of concrete bundled bars

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Abstract. The reinforced concrete, one of the things that cause reinforcement and concrete to work together is bonding. Where the perfect attachment between the concrete and reinforcement produces a strain on the reinforcement is the same as the strain on the concrete around it. Reinforcement bundles as an alternative solution to the limitations of the cross-sectional dimensions are feasible to be developed. Experimental studies are needed to see the ability of the reinforcement bundle associated with the bonding stress produced by several parameters. Concrete strength as an important parameter in reinforced concrete is related to the use of reinforcement bundles that need to be examined. Concrete compressive strength test produces 27 MPa, 36 MPa, and 39 MPa. The reinforcement steel tensile test produces 462 MPa yielding stress and 628 MPa ultimate stress. With the pull-out test of the concrete cylindrical specimen diameter of 150 mm x 200 mm produces a variety of bonding stress values. Variations in the compressive strength of concrete in the reinforcement bundle did not appear to influence the value of bonding stress significantly. Only the visible increase in bonding stress increases with the strength of the concrete and the number of bars in the bundle.

1. Introduction

Reinforced concrete beams that can support the load are dependent on the concrete attachment and reinforcement [1-4]. In calculating the strength of reinforced concrete structures that the stress on reinforcement is equal to the stress of the concrete that surrounds it [3-4]. Or there is attachment between the concrete and reinforcement which does not cause slippage [5]. In the design of reinforced concrete structures, there are limitations to the minimum distance between reinforcing bars and restrictions on the cross-sectional dimensions of structural elements (architect's needs), causing the area of reinforcement to be necessary or the number of reinforcements to be large enough for the structural elements to be able to support the load. The maximum aggregate size requirement used in requires that the maximum aggregate size of the concrete mix used must not exceed ¾ clean space between reinforcement [6]. However, this limitation is often forgotten in a construction work. There are several ways to overcome these problems, including using high-quality materials (additives) or using bundle bars (bundle bars).
2. Problem formulation
Bonding stress is the ability of a combination of reinforcement bars and concrete that surrounds it in resisting external forces or other factors that can result in the detachment of bonding between reinforcing bars and concrete [7-9]. The reinforcement bundle has the following advantages [10]:

- It is possible to use with a cement water factor that is low enough to obtain concrete with high compressive strength
- Avoiding air cavities (honeycombs) in the concrete.
- Speed up processing time because of the ease of casting and shaking.
- Possible substitution bars are likely when certain single reinforcement diameters are not obtained.

For this reason, it needs to be further investigated how strong the bonding bundle is produced with variations in the quality of concrete.

3. Research objectives
The purpose of this study was to knows the bonding strength of a reinforcement bundle with variations in concrete quality.

4. Benefits of Research
With this research, it is expected to know the strength of the reinforcement bundles with a variety of concrete quality variations that have been determined. Further research in the form of application to structural elements (beams, columns, joint columns, exterior, and interior columns), and their behaviour towards the load.

5. Theoretical foundation
The most important properties of reinforcing steel are modulus of elasticity (\(E_s\)), yielding stress (\(f_y\)), and tensile stress (\(f_u\)). Steel yielding stress is the stress of steel, where the increase in strain is not accompanied by an increase in stress. Whereas the modulus of elasticity of steel is determined based on the initial slope of the stress-strain curve in the elastic region[11]. The relationship between stress and strain of steel can be obtained from the relationship of the load and the extension of the tensile steel test results. The load and extension diagram are then converted to a stress-strain diagram with the equation,

\[
f = \frac{P}{A}
\]

(1)

\[
\varepsilon = \frac{\Delta L}{L_0}
\]

(2)

\[
E_s = \frac{f_s}{\varepsilon_s}
\]

(3)

With, \(f = \) stress, Mpa \(E_s = \) modulus of elasticity, Mpa 
\(A = \) cross-sectional area, mm2 \(\varepsilon = \) strain 
\(\Delta L = \) extension, mm \(L_0 = \) initial length, mm 
\(P = \) load, N 

The use of reinforcement bundles can overcome the difficulties that arise in the implementation of casting and shaking due to the presence of a tight group of reinforcement. In a close group of reinforcement, there will be the possibility of a hollow concrete section so that the resulting detachment of concrete with steel reinforcement will occur. It shows the comparison of using reinforcement bundles and single reinforcement with a minimum net distance equal to the diameter itself [10]. For the same diameter of reinforcement in one bundle the equivalent diameter (\(d_e\)) is:
According to ACI 318-14 [12], Strong values/bonding stress can be obtained using the following equation:

\[ f_{\text{bond}} = \frac{P_{\text{max}}}{(\pi d l_d)} \]  

With,
- \( f_{\text{bond}} \) = Bond Strength, MPa
- \( P_{\text{max}} \) = maximum load, N
- \( d \) = reinforcement diameter (equivalent), mm
- \( l_d \) = Length of embedment, mm

Reinforcing steel used is 10 mm diameter reinforcing steel. The reinforcement bundle is formed from two reinforcement with the same diameter. Subsequent variations in the shape of the fins are different and the number of reinforcements in one bundle. The steel reinforcement is used as a pull-out test bar. Tensile strength test was carried out with the Universal Testing Machine (UTM) Laboratory of the Structural Laboratory of the Faculty of Civil Engineering, Parahyangan Catholic University, Bandung.

6. Methodology
Test specimens are made of concrete cylinders with single and double reinforcement with variations in the length of the embedment in the concrete cylinder. Test specimens carried out by the Pull Out method (Figure 1) [10-12].

![Figure 1. Set up pull out test.](image-url)

7. Results and discussion
The peak load is obtained starting from the extension of the reinforcement bundle. This can be seen from the linear P-Delta relationship (as in the tensile steel tensile test), which means it is still in an elastic condition [13,14]. Some of these peak loads are obtained even though the reinforcement bundle has not yet reached its melting limit. However, most of the peak load is obtained after the reinforcement bundle passes through the melt. And peak load is obtained when the reinforcement bundle has not yet reached the peak load of the reinforcing bar.

Based on the pull-out test results (figure 2), it can be seen that the variation of concrete quality does not affect the change in bonding stress [15,16]. Based on the bond stress formula used, the absence of concrete quality variables causes the bond stress values not to significantly increase or decrease the bond...
stress values. It is expected that new formula will be obtained by calculating the value of concrete quality as a variable that can affect the value of bond stress (figure 3).

![Test graph passed the tensile bundle 1 tensile test object with concrete quality consecutively 27, 36 and 39 MPa as well as on specimens with bundles of 2 reinforcement.](image)

**Figure 2.** Test graph passed the tensile bundle 1 tensile test object with concrete quality consecutively 27, 36 and 39 MPa as well as on specimens with bundles of 2 reinforcement.

![Test graph passed the tensile bundle 1 tensile test object with concrete quality consecutively 27, 36 and 39 MPa as well as on specimens with bundles of 2 reinforcement.](image)

**Figure 3.** Test graph passed the tensile bundle 1 tensile test object with concrete quality consecutively 27, 36 and 39 MPa as well as on specimens with bundles of 2 reinforcement.
8. Conclusion

The effect of differences in the quality of concrete on the bonding of reinforcement bundles has not been seen to affect this study. Only the amount of reinforcement in the reinforcement bundle adhesion affects the value of the bond stress. Where the more the number of amplifiers in the bundle, the greater the value of bond stress in this study.

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