Confinement influence in cracking areas single reinforced concrete

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Abstract. The combination of concrete and reinforcement in collaboration with the load is determined by the perfect bond of the two materials. The axial load is given in reinforced concrete results in internal cracking of reinforced concrete around the threaded reinforcement area. An area within the radius of cracking of the concrete around the reinforcement has also been obtained. The action is needed to reduce the area of cracked concrete by giving restraints using spherical spiral reinforcements within the concrete crack radius. It is expected to increase the strength of the reinforcement and concrete around it. The methodology used is Pull Out on single reinforced concrete cylindrical specimens with confinement and without confinement. Concrete cylindrical test specimens with a diameter of 150 mm 200 mm high with single reinforcement with a diameter of 10 mm, and spiral reinforcement as confinement with an identification diameter of 4 mm. Placed within the radius of cracking of the concrete around the reinforcement. The Pull Out test results indicate a cesarean movement from the edge that is loaded to the free end. The restrained specimen produces a larger cesarean at the end of the load, when the initial cesarean occurs at the free end.

1. Introduction
Reinforced concrete structures can support loads that depend on the bond between concrete and reinforcement [1,2]. One assumption in the calculation of the strength of reinforced concrete structures is that the strain on reinforcement is the same as the concrete strain that envelops it [3,4]. Or there is a perfect bond between concrete and reinforcement which does not cause slippage between the two materials [5]. Compared to the plain bar, the use of deform bar will naturally increase the bond of the surface [6].

In the design of reinforced concrete structures, there are restrictions on the minimum distance of reinforcement and the cross-sectional dimensions of structural elements can cause the area or number of reinforcement to be large enough so that the structural elements are still able to support the load that occurs [7]. To overcome these restrictions, among others, by the use of high-quality materials, as well as the perfect bond between the reinforcement and the surrounding concrete [8].

If a deform bar in a concrete cylinder is loaded axially, internal cracking will occur around the reinforcing steel [6]. The position of the cracked area and the area does not crack. If the crack area is given confinement using reinforcing steel surrounding the reinforcement, it is expected that the cracks will be confined, but it will also be expected to increase the reinforcement bond with the surrounding concrete.

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2. Problem formulation
From the background above the problem was formulated "How is the effect of confinement in the crack radius of concrete to increase the bond between steel reinforcement and concrete."

3. Research objectives
The purpose of this study was to determine the bond strength between a single reinforcement with normal concrete in variations with restraints and without restraints.

4. Benefits of research
This research is expected to be able to know the effect of spiral steel bar reinforcement within the radius or concrete crack area. Can also be known data bond and cesarean in the restrained part and without restraints. It is expected to be used to design the development length of alternative or efficient.

5. Theoretical foundation
The use of high-quality materials can result in increased costs, while the use of confinement is expected to maintain the capacity to its limit. Bond tension is the bonding strength of reinforcing steel and concrete which covers it in resisting external force or other factors that cause the attachment to be removed between reinforcing steel and concrete [9]. Bond stress is produced by chemical bonds on the contact surfaces of reinforcing steel and concrete, by the surface roughness of reinforcing steel in both plain steels and deform reinforcing steel which results in a greater interlocking effect between the two materials [10].

Some recent studies related to the confinement of concrete include progressively producing innovative thinking thoughts on developing the theory of confined on concrete [11-14]. Among them are restraints that have been carried out using FRP (fiber reinforced polymer) sheets. There are also those who use woven reinforcement. Etc.

Confined concrete is concrete that experiences compressive stress from various directions by restraint in the form of spiral windings with reinforcing steel or wire in concrete which functions as confinement. Confined concrete will have high compressive strength and more ductile [15].

When low stress occurs in concrete, the transverse reinforcement does not curb and is called unconfined concrete. But if the stress that occurs in concrete is close to its boundary strength, the concrete will be confined due to the presence of the transverse reinforcement and is called confined concrete. Then followed by the greater strain on the transverse reinforcement because there is an internal cracking in the concrete which results in the concrete going out but being held back by the presence of transverse reinforcement. In this case, the transverse reinforcement is called passive confinement. From the tests that have been carried out by several previous researchers, it can be seen that spiral reinforcement as a transversal or restraint reinforcement is more effective than square or square reinforcement. As shown in Figure 1.

![Figure 1. Strength by square and spiral transverse reinforcement [15].](image)

To determine the approximate area or radius of the cracked concrete around reinforcing steel [6] uses the following equation:
Figure 2. Cylinder cross-section with single reinforcement and crack boundary area [6].

\[ \bar{r} = \frac{D}{3} \left( \frac{1 + \frac{d}{D}}{1 + \left( \frac{d}{D} \right)^2} \right) \]  
(1)

With, \( r \) = radius of the crack area \( D \) = cylinder diameter \( d \) = diameter of reinforcing steel

6. Methods

The test begins with material testing consisting of reinforcing steel tensile testing and concrete press testing. Concerning ASTM C234-91a testing of the test, the object is carried out using Pull Out. The test object is made with a cylindrical shape with a single reinforcement embedded in a concrete cylinder. The reinforced concrete cylinders embedded in it are made, referring to single reinforced concrete cylindrical specimens with plain reinforcement.

Figure 3. Variation of single reinforcement with confinement and reinforcement without confinement.

Figure 4. Set up pull out test.

The load is increased gradually. Record additional load. Also, note the slip that occurs both at the loaded end and at the free end. The readings of the dial gage at the free end state the actual slip, while at the end of the load it still needs correction due to the increase in the length of the pulling steel bar. From the Pull Out test, the relationship between load (P) and slip (\( \delta \)) can be changed which can be transformed into a relationship between bond stress (\( \sigma \)) and slip (\( \delta \)).
Slip propagation between reinforcement and concrete propagates from the edge to the free end. In Fig 5 he slips propagation and bond stress are shown in the pullout test [16].

The magnitude of reinforcement against concrete is measured from the tip loaded and the free end. The load which, although small, causes the slip to cause a high bond tension near the loaded edge, but in the other part of the reinforcement there is no stress. When loading is continued, the slip at the loaded end increases, and the two stress adhere, and the slip runs into the specimen. The maximum bond stress will occur when slip occurs near the free end.

7. Results and discussion
Mix design carried out resulted in a comparison of the weight of cement, sand and split stone with a cement water factor of 0.48. The composite composition obtained 1 m³ volume of water mix concrete 225 kg, cement 469 kg, PC 653 kg, agr. Rough 977 kg with a total weight of 2325 kg. The results of the mixture planning after the concrete cylinder press test showed higher results than the planned results. This happens because of several factors, including a high margin number of 12, broken stone gradations and good surface texture. The average compressive strength produced is 33.907 MPa. This result will be used in analyzing bond stress.

The test results of the tensile strength of 10 mm diameter reinforced steel obtained average yield stress of 474 Mpa and maximum average stress of 668.5 Mpa. For 4 mm diameter reinforcing steel obtained the average yield stress of 635 Mpa and the maximum stress average of 744.605 Mpa. This result will also be used to analyze bond stress.

Pull Out testing is done after the concrete cylinder test object is 28 days old. The load is carried out in stages every 200 Kg which can be known from the transducer reading with a loading speed of no more than 22 kN / min. From the relationship between bond stress and slip, it was found that for all specimens in the initial stages of loading there was a linear increase between loading and sliping (at the loaded end), after that the increase in slips was quite large with a relatively small load up to the maximum load. Then the curve slowly descends. As shown in Figure 6.

![Figure 6. The curve at the end is loaded.](image-url)
At the initial loading, there is a concrete movement towards the level plate, while the free end has not moved. In some specimens, when the load has reached about 70% of the maximum load, there is melting of the reinforcement, this can be seen in the transducer where the readable load is unstable while the reinforcement extension is still stable. When the load is close to the maximum when the reinforcement is lifted, the movement of concrete against the level plate starts to stabilize. After the maximum load has been exceeded, unstable load readings (seen on the transducer) occur which are indicated by the ups and downs of the load. This refers to the effect of a threaded reinforcing surface. The test is stopped when the load on the specimen decreases and approaches zero.

After obtaining the data from the Tensile Pass test results, a graph of the relationship between the slip and the bond stress at the free end and the end is loaded. Bond stress is calculated using equation (2), free end slip can be measured directly during testing, while slip at the loaded end is calculated using equation (5).

\[
\sigma_b = \frac{P_{\text{max}}}{A_b} \quad (2) \\
\delta_{\text{total}} = \delta_{\text{bar}} + \delta_{\text{slip2}} \quad (3) \\
\delta_{\text{bar}} = \frac{P.\rho_o}{A_s.\varepsilon_s} \quad (4) \]

\[
\delta_{\text{slip2}} = \delta_{\text{total}} - \delta_{\text{bar}} - \delta_{\text{concrete}} \quad (5)
\]

Note the slip and the load that occurs 15 times the reading to the 0.25 mm slip occurs at the end of the load. Readings and records are carried out simultaneously without stopping the loading. Loading and recording are stopped after the melting reinforcement, the concrete is split, and a slip or slip occurs at the loaded edge of 2.5 mm.

When the curve at the end is loaded, and the free end is compared, it can be seen that when a load is reached a certain slip is reached, or after the available fixed stress at the plant length is exceeded, a free slip begins. This behavior shows that when the initial load is given, there is a strain on the reinforcement relative to the surrounding concrete so that the slip at the end is loaded. The strain on the reinforcement runs towards the free end relative to the concrete, giving rise to a larger slip than before and the slip begins to occur at the free end.

There is no effect of the spiral restraint in adding value to the bond strength. Like the initial hypothesis. From the curve, it appears that the bond strength varies, where the specimen with the restraint does not always have a greater bond strength value than the specimen without restraint.

This is possible because the spiral restraint is located in the area of the escape of the reinforcement so that the spiral does not work in resisting the reinforcement.

Where the value of load / tensile force and development length become constants, will result in a bond stress decreasing with increasing length of the development length. Also seen is the bond stress increased by 30% in the test object with restraints compared to without restraints.

Table 1. Bonding tension with restraints and without restraints.

| No | Development Length, mm | Bond Stress with Confinement, MPa | Bond Stress without Confinement, MPa |
|----|-------------------------|-----------------------------------|--------------------------------------|
| 1  | 100                     | 7.544                             | 7.398                                |
| 2  | 125                     | 5.515                             | 8.109                                |
| 3  | 150                     | 5.216                             | 3.156                                |

8. Conclusion

The conclusion of this study is that there have not been any visible contributions to bridging in the area of concrete cracks around the reinforcement. The test object with restraint produces a larger slip at the end of the load when the slip starts at the free end, compared to the specimen without restraints. Thus the test object with restraint is more ductile than the specimen without restraints. The steel spiral as a restraint has not shown a significant increasing in bond stress.
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