Development length on concrete with bundle bars

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Abstract. The Development Length is an essential factor in the design of reinforced concrete structures. On the other hand, reinforced concrete allows the existence of bundle bars as one of the solutions in overcoming dimensional limitations. However, the use of bundle bars causes some of the reinforcing surfaces not to be covered with concrete, resulting in bond strength between the reinforcement and the concrete will reduce. So, it is necessary to research how far the development length on the concrete with bundle bars, can achieve the desired performance. The methodology used with Pull Out on concrete cylindrical test objects with bundle bars and single bar. Variations in the development length are given to 100 mm, 125 mm, and 150 mm. Gradual loading until a break occurs. Pull Out test results indicate a caesarean movement from the loaded end to the free end. The variation in the development length given appears to affect the greater load tensile requirements of the bundle bars compared with the single bar. This can be seen from the amount of bond stress generated which tends to decrease with increasing length of the development length.

1. Introduction
The reinforced concrete structure has the capability of supporting the load that depends on the attachment between the concrete and reinforcement [1] [2]. One of the assumptions on the calculation of the strength of reinforced concrete structures is, that the strain on the reinforcement is the same as the concrete strain enclosing it [3] [4], or, that there is a perfect attachment between the concrete and the reinforcement which does not cause a slip between two materials.

In the design of reinforced concrete structures, there is a minimum restriction of the distance of reinforcement and dimension cross-section of structural elements that could cause the width or the number of reinforcement to be large enough, so that the element of the structure is still able to support the occurred loads [5] [6] [7] [8]. To overcome such restrictions, we can use of high-quality material and the use of reinforcement files [9] [10].
Figure 1. Cross-section of reinforced concrete beam/columns [3].

Bond Stress is the strong adhesive of the reinforcing steel and concrete covering it, in resisting the outer forces or other factors that cause the loosening of attachment between reinforcing steel and concrete [4]. The Development Length is the minimum length of reinforcement where the stress on the reinforcement start with zero to yield stress. if the length of reinforcement embedded in the concrete is less than that required, the reinforcement will be pulled out before it reaches the yield stress [5]. The balance will be filled in the following formulation,

\[ L_d = \pi \cdot d \cdot \frac{f_y}{4} \cdot P \]  

(1)

Figure 2. The development length of bar on concrete [9].

\[ f_b = \left( \frac{f_y}{4} \cdot L_d \right) \cdot d \]  

(2)

So, it is necessary to research how far the development length on the concrete with bundle bars, can achieve the desired performance.

2. Methodology

Testing begins with investigation material properties like tensile strength of steel and strength of compression concrete. With reference [11] the test object is done by Pull Out. The test specimen is made with a cylindrical shape with a reinforcing embedded in the concrete. Concrete cylinders with bundled bar are made with reference to a single repeating concrete cylindrical test object. The load is increased gradually. Record the increase in load. Also note the failure occurring both at the load end and at the free end. The result of the reading of the gage at the free end represents the actual failure, whereas at the loaded end still needs correction due to the increase in the length of the bar. From this Pull-Out test, the relationship between load (P), the stresses (\( \sigma \)) and development length (Ld) can be written.
3. Result and discussion

Of all test specimens produce curves that have a similar trend, where at the loaded end has cesarean, the free end has not occurred cesarean. After the cesarean movement beyond the length of the development length, the free end begins to cesarean. This also shows the movement of the cesarean from the loaded end towards the free end [12]. There is also a decreasing attachment stress on the use of the reinforcement bundle according to the hypothesis where there is a surface from the bundled bars has not covered by concrete. [3]

Where the value of the tensile force and the development length into a constant, only the cross-sectional area of the variable, will produce a decreasing bond stress with increasing length of the development length. In other words, it requires a greater load / tensile force on bundled bars if the constant is the bond stress and the development length, and the variable on the cross-sectional area.

Figure 3. Variations of test objects of bundled bars and single bar.

Figure 4. Bond stress with caesarean [12].
Table 1. Development length variations with bond stress of single and bundled bars.

| No | Development Length, mm | Bond Stress Single Bar, MPa | Bond Stress Bundled Bars, MPa |
|----|------------------------|----------------------------|----------------------------|
| 1  | 100                    | 7,586                      | 3,310                      |
| 2  | 125                    | 6,221                      | 2,701                      |
| 3  | 150                    | 3,990                      | 2,665                      |

4. Conclusion
In summary, the contribution of the development length to bundled bars will provide a greater pull load requirement than for a single reinforcement.

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