MATEC Web of Conferences **97**, 01110 (2017) DOI: 10.1051/matecconf/20179701110
ETIC 2016

Anchor Bolt Position in Base Plate In Terms Of T and J Anchor Bolt

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Abstract. Generally, L anchor bolt system has been used for a long period of time in construction industry as one of the distributing load structures. However, there are some weaknesses in L anchor bolt which may straighten and pullup when charged with tensile load. Current practices prefer to use other types of anchor bolt systems, such as headed studs anchor bolt system to replace the L anchor bolt design. There has been lack of studies to prove that it is more effective in terms of performance. A new T anchor bolt which was basically modified from headed studs anchor bolt was proposed in this study to compare its performance of tensile loading in concrete failure to typical L design. This study aims to determine whether the T anchor bolt system gives better performance as compared to an L anchor bolt system. The performance was rated based on tensile loading on concrete failure pattern. A pullout test was conducted on two different anchor bolt systems, namely L and T. The anchor bolt embedded depth, *h* in concrete were varied according to their hook or bend radius. Each sample was repeated twice. There were totally eight samples. The hook or bend radius used were 50 mm and 57.5 mm for sample L1 and L2, respectively. 90-degree bend were used on sample T1 and T2. Based on test results, it can be seen that the performance of concrete failure pattern under tensile load on both L and T anchor bolt design samples with 200 mm embedment depth was better than deeper embedment depth of 230 mm. But the L anchor bolt design gives the best results as compared to T design. Although T anchor bolt design shows higher resistance before first bond failure to the concrete sample. T anchor bolt was analysed and needed deeper embedment depth to allow formation of cone pull-out shape to acquire better performance.

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1 Overview of anchor bolt

Anchor bolt on column base plate plays important role to transfer loads (i.e. compression, tension and shear) from column to foundation. The main purpose of the anchor bolt is to hold down the column by transferring tensile loads to the corresponding foundation. These loads may appear in form of pure tension or tension in one side of the column caused by a bending moment. There are various types of anchor bolts, as shown in Fig. 1, and they should be chosen carefully according to appropriate conditions.

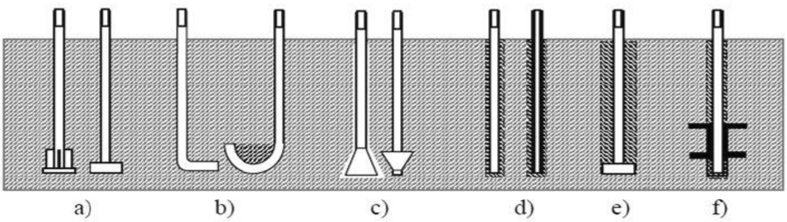

Fig. 1. Types of anchor bolts a) cast in-situ anchor bolts b) hooked bars c) undercut anchor bolts d) bonded anchor bolts e) grouted anchor bolt f) anchoring to grillage beams

There have been a few studies carried out for T anchor bolt to prove that it performs better on tensile loading and in concrete failure as compared to J anchor bolt system. This study aims to design a new anchor bolt that produces better performance on tensile load. The proposed design is T shape which is similar to the design of a headed anchor bolt and is commonly used in industry. A proper experiment was conducted to compare the two different anchor bolt designs. The main objectives of this research are to study the performance using Tensile Strength Test on "T" anchor bolt in concrete under tensile load compare to "J" anchor bolt.

Cast in-situ bolt is the simplest anchor bolt available today. There are many types of cast in-situ anchor bolts. The end of the bolt has some hooked or bend-like-hook, as shown in Fig.2 below. Cast in-situ anchor bolts are the strongest type of fastener, but unfortunately the casting for in-situ anchor bolt is difficult. They are usually used for heavy machines mounted on poured floor or foundations. Another application for this anchor bolt is to connect concrete foundation of a building to its walls.

Fig. 2. Cast in situ

2 Experimental works

Tensile strength test has been carried out to obtain capacity load for anchor bolt. The experiment used 8 samples having same concrete block dimensions of 150mm x 150mm x 300mm. Portland Cement was used for the samples and have been casted with an anchor bolt each and the anchor bolt embedded in certain depth from the surface for sample L anchor bolt (200mm and 230 mm) and "T" anchor bolt (200 mm and 230 mm). The anchor bolt that has been used are "T" shaped anchor bolt that cast in-situ for 4 samples and "L"

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shaped anchor bolt that cast in-situ for the remainder 4 samples. Both "T" and "L" anchor bolts were bought from Metal Shop at Taman Maju, Parit Raja. Concrete mix has been designed for the grade 30 concrete based on DOE method. The depth of concrete block for "L" and "T" are shown in Table 1 and 2.

Table 1. "L" anchor bolt Tensile Strength Tests

Samples	Tensile Strength	
	300 mm Block Depth	400 mm Block Depth
L1A	√	
L1B	√	
L2A		√
L2B		√

Table 2. "T" anchor bolt Tensile Strength Test

Samples	Tensile Strength	
	300 mm Block Depth	400 mm Block Depth
T1A	√	
T1B	√	
T2A		√
T2B		√

Fig. 3. T and L Anchor Bolts

The samples positioned inside a rig and have been tested using Universal Testing Machine (UTM) as shown in Fig.5 to measure and record tensile strength for each anchor bolt that casted in in-situ concrete block. While gathering the results for tensile strength for each block, the concrete blocks were examined while being tested. The concrete blocks have been recorded using camera for further observation and references for data analysis.

Fig. 4. Design of cast in-situ anchor bolt with rig

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Fig. 5. Sample for pullout test using UTM machine

2.1 Pull-out Test

UTM has been used to perform the pull-out test. It consists of two solid bars and two rail solid bars for attaching upper and lower holders as shown in Fig.5 above. The samples are placed in the middle between the upper and lower holders and it is attached at lower holder. The machine pulls or pushes the sample until it reaches maximum length.

3 Results and discussions

The results of Pullout test is shown in Fig. 6 and 7 below.

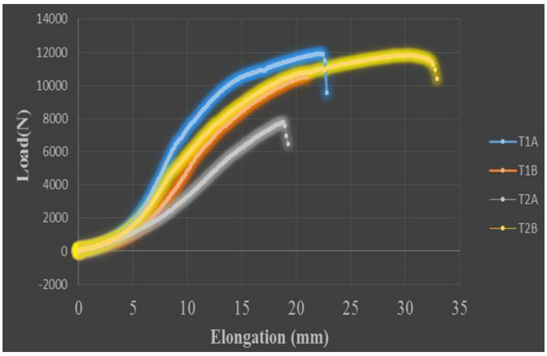

Fig. 6. Relationship between Load and Elongation of Sample T for 28 days

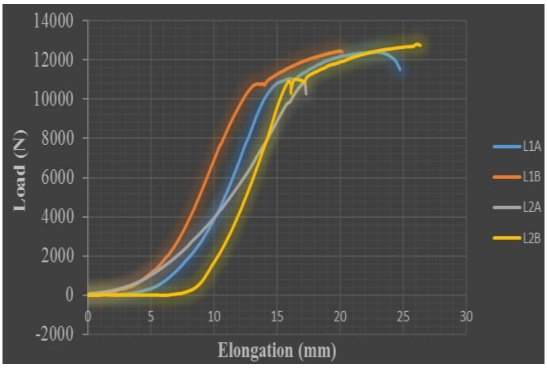

Fig. 7. Relationship between Load and Elongation of Sample L for 28 days

Based on Fig. 6, the relationship between load and elongation of anchor bolt sample 'T' for 28 days had been recorded and it has been found that sample T1A gave highest tensile load reading at 11.702 kN, on the contrary, sample T2A gave the lowest reading of tensile load. The graph shows that the shorter the embedded depth, the higher the tensile load to be received by sample structure. The lowest load was archived by sample T2A due to early failure of the anchor bolt grip. The surplus bolt length of sample T2A was less than 150 mm when installed in the machine. The load was not transferred completely to the concrete in the rig plate. The graph also shows the pattern of 'T' sample, where the load decreasing as concrete failure occur and starts to form a cone failure with an angle. The same bond failure occurred between the concrete and anchor bolts. The structure then resist from failure by frictional bond of the concrete cone and the anchor bolt until ultimate tensile load was reached. Fig.7 shows the relationship between Load and Elongation for Sample 'L' which was named as 'L1' and 'L2' with embedded depth of 200 mm and 230 mm, respectively. The highest tensile load failure occurred at sample L2B at 12.583 kN, while the lowest tensile load reading before failure occurred at L2A at 10.625 kN. The same graph also shows the pattern of 'L' sample where the load decreases as the concrete failure occur and starts to form a cone failure with an angle. This is where the bond failure between the concrete and anchor bolts occurred. The structure then resisted from failure by frictional bond of the concrete cone and the anchor bolt until the ultimate tensile load had been reached.

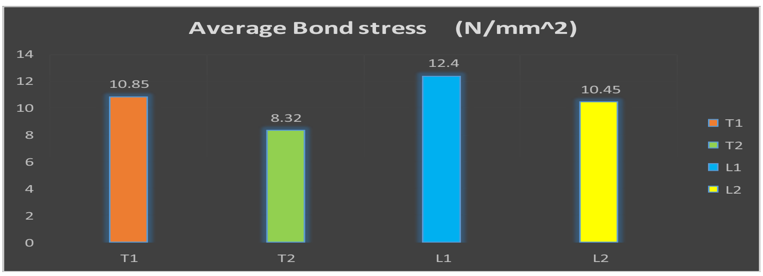

Fig. 8. Relationship between different Anchor Bolts and Average Bond Stress (N/mm^2)

Fig.8 shows the same ranking of samples' performance according to anchor bolt sample and design. The highest bond stress fell on sample L1 at 12.4 N/mm^2, while the lowest bond stress was held by T2. This could due to failure of anchor bolt in concrete and loss connection of transferring loads. The results above show that L performs better and this is because the value of tensile strength depends on steel surface area on concrete. The friction that occurred on the surface of steel contributed the value of tensile strength.

4 Conclusions

Based on the results above, the samples with lower embedment at 200 mm give better results in tensile loading. It can be concluded that the optimum depth in this study is found to be 200 mm and sample L gives higher performance. But it does not tally with the hypothesis that with shallower embedment depth, the better is the performance in tensile loading. This is because the T samples show higher resistance to tensile loading before occurrence of bond failure between anchor bolt and concrete. The T samples require deeper embedment to prevent fracture failure. When insufficient embedment depth is used, T sample could distribute load to the concrete in standard cone shape which causes the anchor bolt fail without affecting the concrete structure. Thus, there wasn't any support of friction bond to resist more tensile loading. The anchor bolt design T is still relevant to be used in the industry but further research need to be conducted to find the optimum embedment depth for the same design.

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