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Research Article

Diameter–embedment depth interaction of post-installed adhesive anchors in low-strength concrete

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ABSTRACT

Türkiye lies across multiple tectonic plates, resulting in numerous active fault lines that generate destructive earthquakes. Given the vulnerability of the existing building stock, effective retrofitting is critical. In line with the Türkiye Earthquake Code (TEC 2018) for C25, minimum reinforcement diameters for adhesive-anchored bars were reduced to 16 mm. However, because many existing buildings in Türkiye exhibit low concrete strengths (<10 MPa), this study comprehensively investigates the tensile performance of post-installed adhesive anchors under weak concrete conditions. Monotonic pull-out tests were conducted on 192 specimens utilizing four reinforcement diameters (Ø8, Ø10, Ø12, Ø14) and four embedment depths (8Ø, 10Ø, 12Ø, 14Ø) in concrete blocks with four compressive strengths (f_c) of 4.51, 5.35, 7.77, and 10.45 MPa. The results show that increasing the embedment ratio from 8Ø to 14Ø substantially enhances tensile capacity—by up to 95% for Ø8 bars at 4.51 MPa. Moreover, a multiple linear regression model calibrated using the dataset demonstrated a high coefficient of determination ($R^2 = 0.91$), confirming that anchorage performance is primarily governed by geometric parameters rather than material strength. Notably, adequate bond performance is severely limited below 10 MPa, often making failure modes bond-controlled. Based on these findings, it is recommended to evaluate anchorage design on a project-specific basis and avoid standard strengthening interventions in structures with concrete strengths below 10 MPa. In addition, it has been observed that under low concrete strength conditions, the anchor diameter must be reduced to ensure that the expected ductile failure mode via steel bar yielding can be achieved.

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1. Introduction

Türkiye is located in one of the world's most seismically active regions, intersected by major fault systems that expose a substantial portion of the country to significant seismic risk. Catastrophic earthquakes in Erzincan, Gölcük, Van, and most recently Kahramanmaraş have repeatedly demonstrated the severe consequences of this exposure, highlighting the urgent necessity for systematic assessment and retrofitting of the existing building

stock. Seismic vulnerability assessment methodologies provide an effective framework for quantifying the expected damage and seismic risk of existing reinforced concrete buildings by considering structural characteristics that influence their earthquake response (Kassem et al. 2022a, 2022b). A critical vulnerability in much of the existing building stock, particularly in structures constructed prior to the implementation of modern seismic design codes, is the widespread use of substandard materials. Post-earthquake reconnaissance studies con-

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sistently reveal that reinforced concrete structures in Türkiye frequently exhibit low compressive strength, often ranging between 10 to 15 MPa and, in some cases, falling as low as 5 MPa due to poor construction practices and construction defects (Kaltakçı et al. 2010; Kaplan et al. 2004; Odacıoğlu et al. 2022; Yurdakul et al. 2021).

Post-earthquake observations following the 2023 Kahramanmaraş earthquakes revealed out-of-plane overturning of reinforced concrete shear walls in some previously retrofitted buildings (Doğan and Karadağlı 2024), as shown in Fig. 1. These observations indicate that post-installed connections anchored into weak existing concrete may exhibit brittle, non-ductile failure. Although TEC (2018) specifies the use of reinforcing bars with a diameter of at least 16 mm for such anchorage applications, smaller-diameter reinforcing bars may enable a more distributed force-transfer mechanism (Çalışkan et al. 2013; Odacıoğlu et al. 2022) and reduce the likelihood of brittle concrete-related failure. Therefore, their potential to provide a more ductile connection response requires further investigation.



Fig. 1. Out-of-plane overturning and separation of an added reinforced concrete shear wall from the existing structure due to anchorage failure following the 2023 Kahramanmaraş earthquakes (Doğan and Karadağlı 2024).

Post-installed adhesive anchors, such as epoxy-based systems, are widely employed to connect newly added structural elements to existing reinforced concrete members. Typical applications include the connection of externally added reinforced concrete shear walls, column jackets, foundation extensions, and other strengthening components to the existing structural system (Arslan 2016; Cihan et al. 2023; Kaltakçı et al. 2010; Mazılıgüney 2007). The effectiveness of these strengthening interventions depends considerably on the ability of the post-installed adhesive anchors to transfer tensile and shear forces safely into the existing concrete.

The strengthening provisions of the Türkiye Earthquake Code (TEC 2018) specify geometric and detailing requirements for post-installed adhesive anchors used in existing reinforced concrete structures. However, many existing buildings in Türkiye contain concrete with compressive strengths considerably lower than those typically considered in anchor qualification procedures and conventional design models. Most current design provisions, including those published by the American Concrete Institute, have predominantly been calibrated using experimental data obtained from normal- and high-strength concrete (ACI 318 2014; ACI 355.4 2019). Consequently, the applicability of these provisions to anchors installed in concrete with compressive strengths close to or below 10 MPa remains uncertain.

The tensile resistance of post-installed adhesive anchors is governed by a load-transfer mechanism involving the steel bar, the adhesive layer, and the surrounding concrete. Tensile forces are transferred from the reinforcing bar to the adhesive and subsequently from the adhesive to the concrete through a combination of chemical adhesion, mechanical interlocking, and friction (Cook 1993; González et al. 2018; Krishnaveni and Rajendran 2024). The resulting anchorage performance depends on several geometric, material, and installation-related parameters, including concrete compressive strength, bar diameter, embedment depth, edge distance, spacing, confinement, hole-cleaning quality, and adhesive properties.

Under monotonic tensile loading, post-installed adhesive anchors may exhibit steel failure, concrete cone failure, bond or pull-out failure, combined concrete cone-bond failure (Cook 1993; Mahrenholtz et al. 2015). Shallow embedment depths commonly promote concrete breakout, whereas longer embedment depths may increase the contribution of bond resistance and shift the governing mechanism toward combined failure or steel failure. In low-strength concrete, brittle splitting and concrete-controlled failures may become more critical because the radial stresses generated around the reinforcement ribs can exceed the limited tensile resistance of the surrounding concrete (Akgül et al. 2022; Boonmee and Rodsin 2019). Edge distance and concrete cover also substantially influence these failure mechanisms (Ding et al. 2022).

Concrete compressive strength is one of the primary material parameters influencing bonded anchorage performance. Previous experimental studies have generally shown that bond strength and ultimate tensile resistance increase with concrete compressive strength, although the degree of improvement depends on the governing failure mechanism (Ahmed et al. 2021). In concretes with compressive strengths below approximately 15 MPa, brittle concrete breakout and bond-controlled failures may govern the response before the tensile capacity of the reinforcing bar is fully developed (Ahmed et al. 2021). Increasing the embedment depth and providing sufficient confinement may improve anchorage resistance; however, the effectiveness of these measures depends on the concrete properties, anchor geometry, and test configuration (Arslan 2016; Yılmaz et al. 2013).

Anchor diameter also plays an important role in determining both ultimate tensile capacity and failure mode. Larger-diameter bars generally provide a greater bonded surface area and therefore a higher total pull-out resistance. However, increasing the diameter may also generate greater radial stresses and more pronounced local stress concentrations within the surrounding concrete. These effects may increase the likelihood of brittle concrete breakout or splitting, particularly in low-strength concrete (Arslan 2016; Çalışkan et al. 2013). Therefore, an increase in anchor diameter does not necessarily produce a proportional improvement in anchorage efficiency in the low-strength concrete (Çalışkan and Aras 2017).

This study aims to identify suitable anchorage parameters for strengthening existing buildings in Türkiye, particularly those with insufficient concrete strength. Considering the low-quality concrete commonly observed in the national building stock, four different concrete strength classes were produced by varying cement and water ratios to represent weak concrete conditions. For each concrete strength level, four different anchor embedment depths and four different anchor diameters were employed. The type of adhesive system was kept constant, and adequate edge distances and spacing were ensured in accordance with previous studies. For each combination of concrete strength, anchor diameter, and embedment depth, three identical anchors were installed to ensure statistical reliability. In total, 192 post-installed adhesive anchors were subjected to pull-out tests. This experimental program enables a comprehensive evaluation of anchorage performance under varying concrete strength, anchor diameter, and embedment depth, and provides essential data for establishing suitable anchorage parameters for the seismic retrofitting of deficient reinforced concrete buildings.

2. Experimental Program

The experimental program was systematically designed to investigate the multi-parametric interactions governing the ultimate tensile resistance and associated failure mechanisms of post-installed adhesive anchors. To accurately replicate the structural deficiencies and concrete compressive strength classes of 10.45 MPa or lower prevalent in the existing building stock, a comprehensive testing matrix was established. This methodology isolates and evaluates three critical design variables: the base concrete substrate strength, the effective anchor diameter, and the structural embedment depth. By rigorously controlling these geometric and material parameters across 192 test specimens, the investigation aims to delineate the operational boundary conditions and performance thresholds of bonded anchoring systems under monotonic tensile loading, thereby providing an empirical foundation for optimized seismic retrofitting designs.

2.1. Materials

In this context, concrete blocks with four different strength levels were cast by varying the amount of cement and water to represent buildings with low concrete strength considering the existing building stock. The mix proportions and compressive strengths of low-strength concretes are given in Table 1. It should be noted that the relatively high w/c ratios used in this study do not represent standard structural concrete mixtures. They were intentionally selected to obtain low compressive strength levels and to simulate poor-quality concrete conditions observed in deficient existing reinforced concrete buildings. No curing was applied to the concrete blocks or to the cube specimens taken for measuring compressive strength, as intended, in order to represent low-strength buildings and actual construction practice.

Table 1. Concrete mix proportions and compressive strengths.

	1. Specimen	2. Specimen	3. Specimen	4. Specimen
Sand (0.00-4.00 mm) - kg	560.03	531.75	520.60	510.75
Gravel (4.00-11.20mm) - kg	560.03	531.75	520.60	510.75
Cement (CEM II 32.5) - kg	190.00	300.00	345.00	375.00
Water - kg	275.04	274.10	273.81	272.32
W/C	1.45	0.91	0.79	0.73
Average concrete compressive strengths (f_c - Mpa)	4.51	5.35	7.77	10.45

The Fischer FIS EM Plus 390 S is a high-performance pure epoxy resin anchoring system developed for demanding structural applications. The material has a density in the range of 1.4–1.6 g/cm³ and a compressive strength of at least 80 MPa. It also exhibits a tensile adhesion strength of at least 20 MPa, while maintaining a bond strength greater than 11 MPa after 20 days, indicating reliable long-term anchorage performance under heavy-duty loading conditions. In addition, the resin exhibits an elongation at break of 1.1% and a curing shrinkage, defined as the volumetric shrinkage occur-

ring during the hardening of the epoxy resin, of less than 0.01% according to ASTM D2566. These properties indicate excellent dimensional stability and effective contact within the drilled hole, making FIS EM Plus 390 S suitable for critical structural and seismic-resistant applications.

B420C steel was selected as the anchorage element, and 48 reinforcing bars with diameters of 8, 10, 12, and 14 mm and a length of 70 cm were prepared. The average yield strengths of the bars, according to their diameters, were found to be 536.30 MPa, 496.42 MPa, 477.16

MPa, and 466.78 MPa, while the average tensile strengths were determined as 656.25 MPa, 600.12 MPa, 558.46 MPa, and 543.36 MPa, respectively. To prevent concrete cracking, Q131/131 welded wire mesh reinforcement was used, consisting of 5 mm diameter bars spaced at 15×15 cm, with an average yield strength of 516.67 MPa and an average tensile strength of 633.67 MPa.

2.2. Test specimens

For each concrete mix, reinforced concrete blocks with dimensions of 75 cm × 195 cm × 25 cm were produced by placing Q131/131 welded wire mesh with a concrete cover of 4 cm from the top surface. In order to simulate low-performance buildings and common con-

struction practice, no curing conditions were applied to either the concrete blocks prepared for compressive strength testing. After 28 days, when the concrete was assumed to have completed hydration and reached its compressive strength, drilling of the anchor holes was initiated, maintaining a center-to-center spacing of 15 cm. The holes were drilled perpendicular (90°) to the concrete surface with a diameter 4 mm larger than the anchor bar and to embedment depths corresponding to 8, 10, 12, and 14 times the respective anchor diameters, as shown in Fig. 2. Subsequently, the holes were cleaned using an air compressor to ensure that no dust or debris remained inside. The chemical adhesive was then injected into the holes to eliminate any voids between the ribbed anchor bar and the concrete, after which the installation of the anchors was completed.

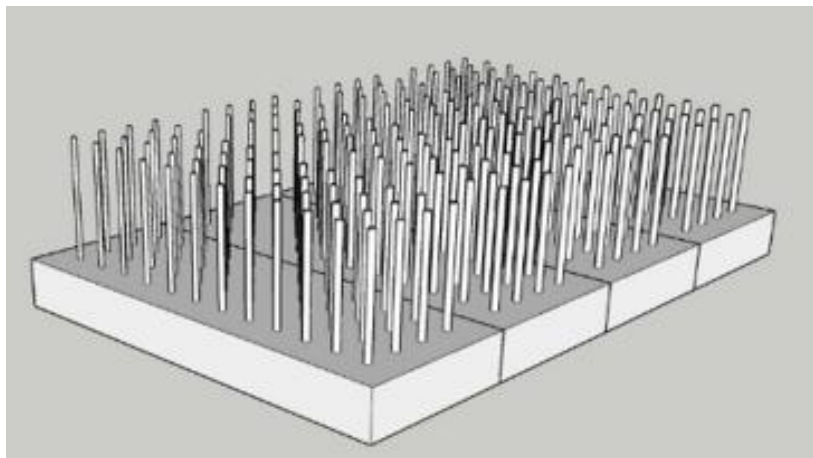


Fig. 2. Three-dimensional drawing of the experimental specimens.

2.3. Pull-out test

The pull-out tests were performed under manually controlled, monotonically increasing tensile loading until failure. The tensile force was applied through a hydraulic cylinder and transferred to the anchor bar by means of a conical pulling head positioned concentrically with the bar axis, as shown in Figs. 3(a–c). The reaction force of the hydraulic cylinder was taken from the concrete block surface around the anchor location. It should be noted that the reaction force of the hydraulic cylinder was transferred to the concrete surface around the anchor location. This contact may have generated a local compression zone beneath the hydraulic jack, producing a confinement effect around the anchor. Such confinement may influence the failure mechanism and may partially restrict the formation of a concrete cone failure. Therefore, the results should be interpreted as ultimate pull-out capacities obtained under the adopted test configuration. Since the same test setup was used for all specimens, the comparative evaluation of anchor diameter, embedment ratio, and concrete compressive strength remains consistent. Care was taken to align the loading axis with the longitudinal axis of the reinforcing bar in order to minimize eccentric loading effects. During the tests, the applied load was monitored using the manometer connected to the hydraulic system, and the maximum tensile force reached before failure was rec-

orded for each specimen. The pull-out tests were initiated 24 hours after anchor installation to allow the chemical adhesive to cure and develop sufficient strength. Since the primary aim of the experimental program was to determine the ultimate pull-out capacity, continuous displacement or slip measurements were not performed. This limitation was considered in the interpretation of the results, and the discussion was restricted to ultimate tensile capacity and observed failure modes.

3. Experimental Results and Evaluation

The experimental dataset presented in Table 2 enables a detailed quantitative assessment of the average tensile performance of post-installed adhesive anchors in low-strength concrete. To improve the interpretation of the triplicate tests, Fig. 4 presents the mean pull-out loads as a histogram, together with the corresponding minimum and maximum ranges. It should be noted that Fig. 4 includes only the specimens in which failure occurred as concrete breakout together with the adhesive anchor; specimens exhibiting steel anchor failure were excluded from the plotted mean values. A clear trend is observed across the test configurations, indicating that the pull-out capacity is influenced by embedment ratio, concrete compressive strength, and anchor diameter.



Fig. 3. Pull-out test: (a) Modeling; (b) Hydraulic cylinder setup; (c) Experimental setup.

In the test groups shown with a dark gray background in Table 2, failure occurred directly in the anchor elements rather than as concrete breakout or pull-out together with the adhesive anchor. Anchor failure became more pronounced particularly in the test groups with increased embedment depth and higher concrete compressive strength. This indicates that, as the embedment depth increases, the bond performance between the adhesive anchor and concrete, as well as the load-bearing capacity of the concrete, improves; consequently, the failure mechanism becomes governed by the tensile capacity of the anchor rod rather than by the concrete or bond interface.

In addition, for the $\varnothing 14$ specimen with a concrete compressive strength of 7.77 MPa, failure occurred in the anchor due to mechanical interlocking with the welded wire mesh reinforcement. The numbers shown inside the circles indicate the number of failed anchors in the corresponding test group. Accordingly, while only one anchor failed in some specimens, the failure of multiple anchors in others demonstrates that, under these

parameters, failure of the anchor element became the governing failure mechanism.

For the $\varnothing 8$, $\varnothing 10$, $\varnothing 12$, and $\varnothing 14$ reinforcing bars, the interaction plots showing the relationship between tensile force, embedment depth, and concrete compressive strength are presented in Figs. 5–8. A parametric evaluation of embedment depth reveals that increasing the embedment ratio from $8\varnothing$ to $14\varnothing$ results in a substantial increase in tensile capacity. For instance, for $\varnothing 8$ anchors in concrete with a compressive strength of 4.51 MPa, the pull-out capacity increases from 13.65 kN to 26.65 kN, corresponding to an increase of approximately 95%. Similarly, for $\varnothing 14$ anchors at 10.45 MPa, the capacity increases from 56.90 kN to 87.38 kN, representing a gain of about 53.6%. These results indicate that while embedment depth is the dominant parameter influencing tensile resistance, its relative effectiveness decreases as both concrete strength and anchor diameter increase. This behavior suggests a nonlinear relationship between embedment depth and pull-out capacity, consistent with bond stress redistribution along the anchorage length.

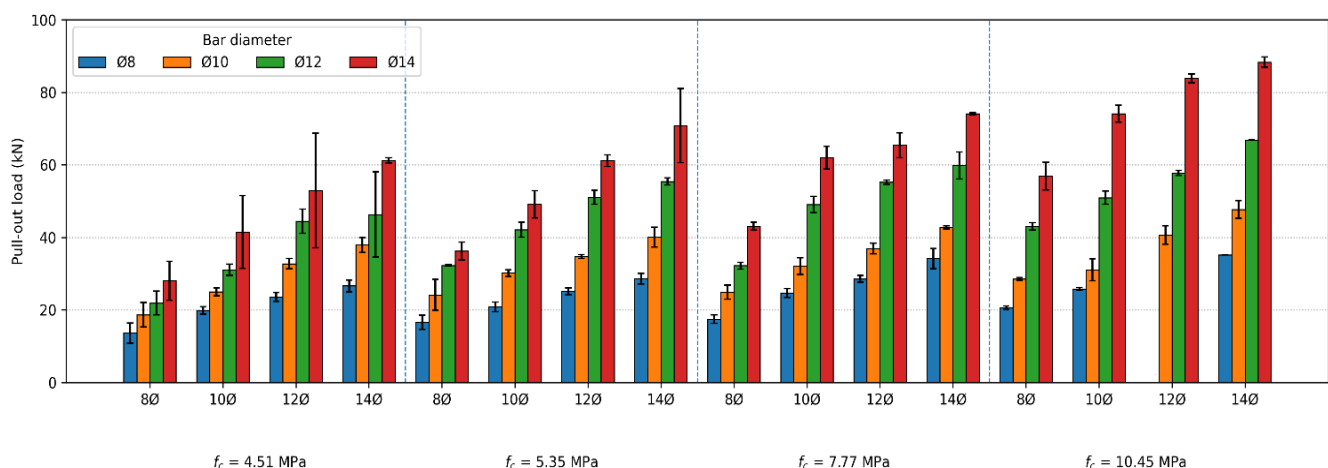


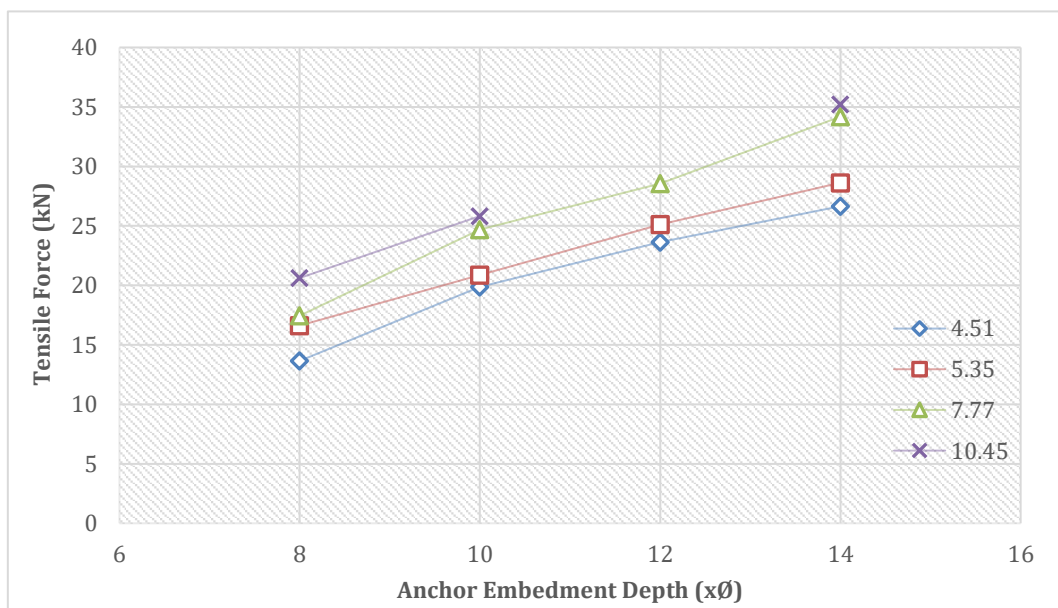
Fig. 4. Mean pull-out loads are presented for different bar diameters and embedment ratios, with error bars showing the minimum and maximum test results.

Table 2. Pull-out test tensile force data obtained for different anchor diameters and embedment depths in low-strength concrete.

Anchor Diameters	Strength Concrete (f_c)	Anchor Embedment Depths (L_d)			
		8Ø	10Ø	12Ø	14Ø
(mm)	(MPa)	(kN)	(kN)	(kN)	(kN)
Ø8	4.51	13.65	19.88	23.63	26.65
	5.35	16.62	20.87	25.13	28.63
	7.77	17.45	24.68	28.57	34.18
	10.45	20.62	25.83 [24.70] ¹	N/A [30.60] ³	35.20 [36.23] ²
Ø10	4.51	18.68	25.00	32.78	37.97
	5.35	24.17	30.17	34.73	40.10
	7.77	24.90	32.13	36.97	42.75
	10.45	28.52	31.10 [40.00] ¹	40.68 [45.00] ¹	43.10 [50.15] ¹
Ø12	4.51	21.93	31.08	44.52	46.33
	5.35	32.28	42.17	51.08	55.43
	7.77	32.23	49.08	55.22	59.85
	10.45	43.07	50.98	57.82	66.90 [66.65] ²
Ø14	4.51	28.05	41.48	52.97	61.25
	5.35	36.3	49.13	61.18	70.82
	7.77	43.10	61.95	65.36 [70.40] ¹	74.08
	10.45	56.90	74.15	83.87	88.33 [85.50] ¹

Note 1: N/A indicates that no concrete-controlled mean value was available because all three specimens exhibited anchor failure.

Note 2: The cells with square brackets indicate test groups in which anchor failure occurred. The values in square brackets represent the average tensile force of the specimens that failed in the anchor itself, and the superscript numbers indicate the number of specimens with anchor failure.

**Fig. 5.** Interaction diagram of pull-out capacity as a function of embedment depth and concrete compressive strength for the Ø8 anchor bar.

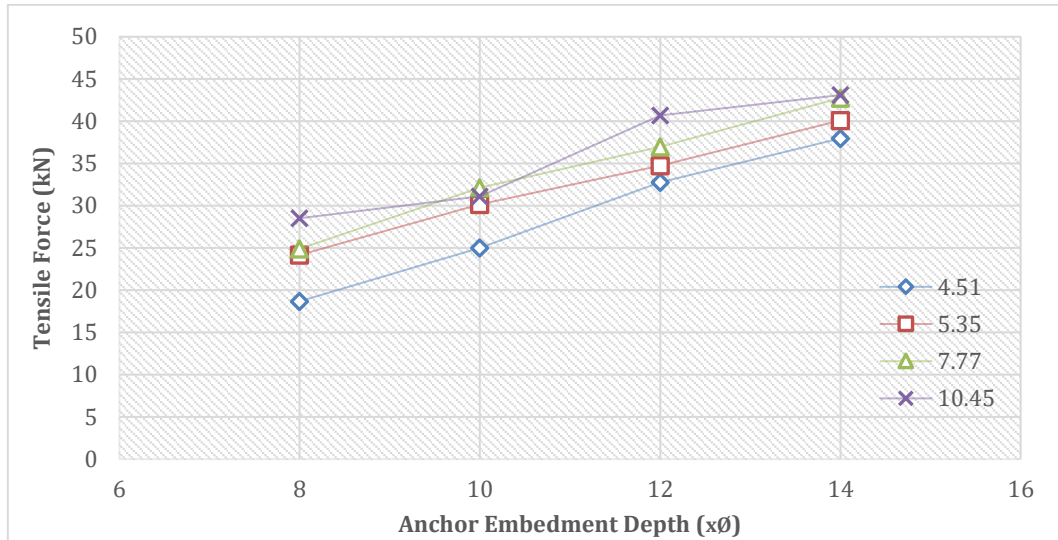


Fig. 6. Interaction diagram of pull-out capacity as a function of embedment depth and concrete compressive strength for the Ø10 anchor bar.

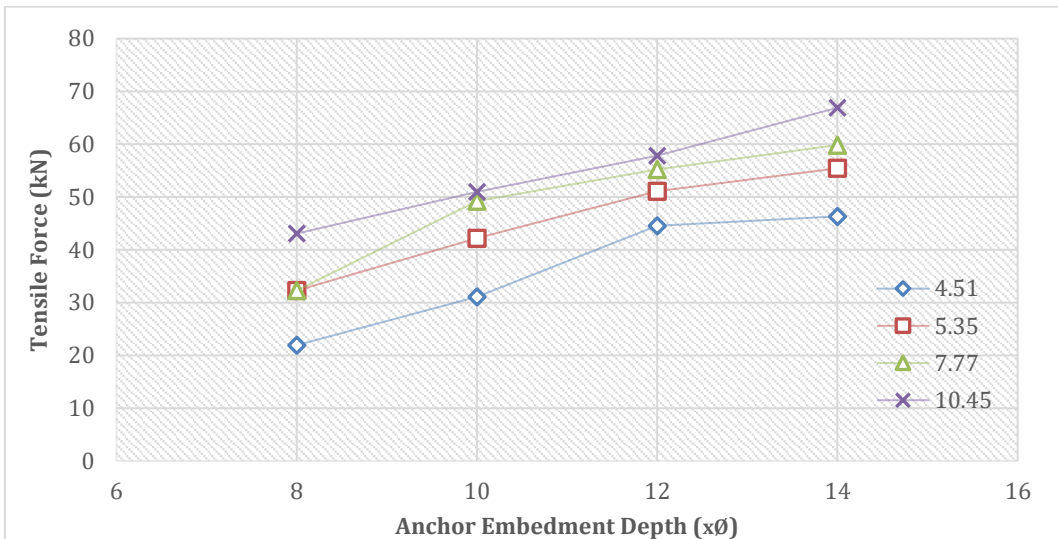


Fig. 7. Interaction diagram of pull-out capacity as a function of embedment depth and concrete compressive strength for the Ø12 anchor bar.

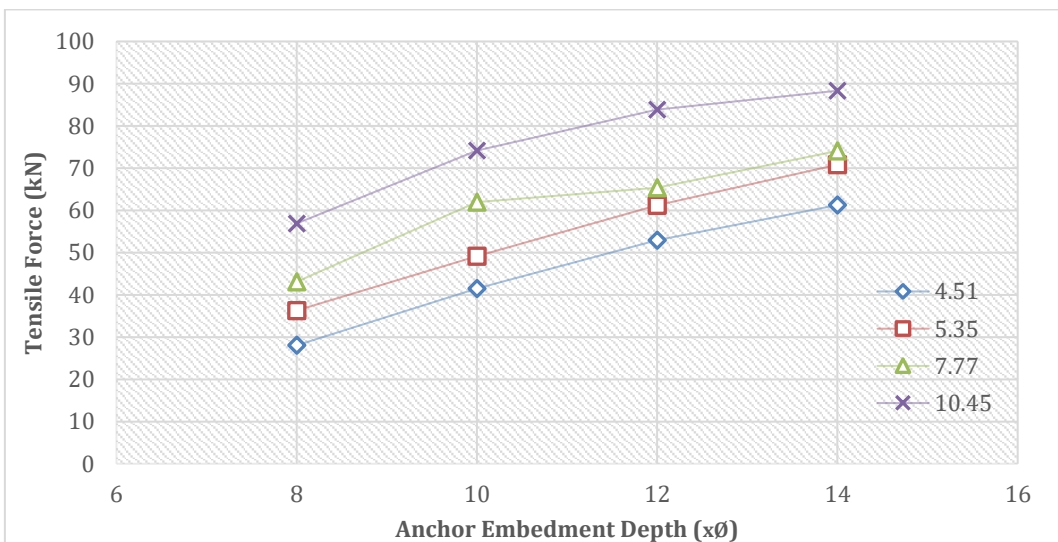


Fig. 8. Interaction diagram of pull-out capacity as a function of embedment depth and concrete compressive strength for the Ø14 anchor bar.

The influence of concrete compressive strength is also evident across all anchor diameters and embedment depths, as shown in Figs. 5–8. It should be noted that these interaction diagrams include only the specimens in which failure occurred as concrete breakout together with the adhesive anchor; specimens exhibiting anchor failure were excluded from the plotted values. Therefore, the values presented in these figures represent the mean pull-out capacities associated with concrete-controlled failure. For example, for Ø10 anchors at an embedment depth of 12Ø, the pull-out capacity increases from 32.78 kN at 4.51 MPa to 40.68 kN at 10.45 MPa, corresponding to an increase of approximately 24%. This trend confirms that higher concrete strength enhances the bond performance by improving the mechanical interlock and confinement provided by the surrounding matrix. However, the rate of increase in pull-out capacity with respect to compressive strength is generally less pronounced than the increase associated with embedment depth and anchor diameter, indicating that bond surface area, governed by both the anchor diameter and embedment depth, plays a critical role in low-strength concrete conditions.

The effect of anchor diameter is similarly significant but exhibits a more complex behavior. At a constant concrete strength of 4.51 MPa and embedment depth of 10Ø, increasing the diameter from Ø8 to Ø14 results in an increase in pull-out capacity from 19.88 kN to 41.48 kN, corresponding to more than a twofold increase. This indicates that larger anchor diameters provide a greater bonded surface area and thus improve the load-carrying capacity. However, this increase may also be accompanied by higher radial stresses in the surrounding concrete, particularly in weak substrates. This observation highlights that while larger diameters enhance load capacity, the failure mechanism and reliability of anchorage performance should also be carefully considered in low-strength concrete.

An important aspect of the experimental findings is the observed transition in failure modes. In the specimens, failure occurred in the form of bond failure or concrete breakout, indicating that the adhesive–concrete interface governs the behavior. However, in selected specimens—particularly those with higher concrete strength (10.45 MPa), larger diameters, and deeper embedment ($\geq 12\text{Ø}$)—failure occurred in the anchor itself. This transition from bond-controlled to steel-controlled failure represents a critical threshold in anchorage performance, indicating that the full tensile capacity of the reinforcement can be mobilized under favorable conditions.

From a comparative perspective, the data suggest that embedment depth is the most effective parameter for improving anchorage performance, followed by anchor diameter and concrete compressive strength. However, the relative contribution of each parameter varies depending on the specific configuration. In ultra-low-strength concrete ($f_c \leq 5$ MPa), bond failure dominates regardless of diameter, emphasizing the limited effectiveness of increasing anchor size under such conditions. In contrast, for higher strength levels, the combined effect of increased embedment depth and diameter can shift the governing failure mode toward a more ductile response.

These findings have direct implications for engineering practice. The results indicate that in low-strength concrete, increasing embedment depth is a more reliable strategy than increasing anchor diameter, as it enhances bond performance without significantly increasing stress concentrations. Moreover, the observed failure mode transitions suggest that achieving steel failure should be considered a desirable design objective, as it ensures ductile behavior and more predictable performance.

Overall, the experimental results demonstrate that anchorage design in low-strength concrete requires a careful balance between geometric parameters and material properties. The conventional design assumptions embedded in current standards may not adequately capture this behavior, particularly in the low-strength regime investigated in this study. Therefore, the development of modified design approaches that explicitly account for these effects is essential for ensuring safe and reliable anchorage performance in existing structures.

A multiple linear regression analysis was performed to evaluate the combined effects of anchor diameter, embedment ratio, and concrete compressive strength on the ultimate pull-out capacity, as given in Eq. (1). The dependent variable was the mean concrete-controlled pull-out capacity (P_u) in kN. The independent variables were anchor diameter ($\emptyset$) in mm, embedment ratio (l_d), and concrete compressive strength (f_c) in MPa. Here, l_d represents the embedment ratios of 8Ø, 10Ø, 12Ø, and 14Ø used in the experimental program. The regression model was calibrated using 63 concrete-controlled mean values. The configuration in which all three specimens exhibited steel anchor failure was excluded because no concrete-controlled mean value was available.

$$F = 5.85\emptyset + 3.68l_d + 2.46f_c - 81.38 \quad (1)$$

The model provided a coefficient of determination of $R^2=0.9123$ and an adjusted $R^2=0.9078$, indicating a strong correlation between the predicted and experimental pull-out capacities. The standard error of the estimate was 5.32 kN. ANOVA results showed that the regression model was statistically significant, with $F=204.60$ and $p=3.90 \times 10^{-31}$. The p-values of all regression coefficients were less than 0.05, indicating that anchor diameter, embedment ratio, and concrete compressive strength had statistically significant effects on the ultimate pull-out capacity. The 95% confidence intervals of the regression coefficients were also evaluated and confirmed the statistical reliability of the proposed model within the investigated parameter range.

4. Conclusions

In this study, considering the characteristics of the existing building stock, pull-out tests were conducted on 192 post-installed adhesive anchors embedded in reinforced concrete blocks with low compressive strengths of 4.51 MPa, 5.35 MPa, 7.77 MPa, and 10.45 MPa. Anchor bars with diameters of 8, 10, 12, and 14 mm were embedded at depths corresponding to 8, 10, 12, and 14

times the respective anchor diameters. Based on the results of these experiments:

- It was observed that the embedment depth of the anchor significantly influences the pull-out capacity. As the embedment depth increases, the tensile pull-out resistance of the anchor correspondingly increases.
- Considering the observed failure modes, it was determined that adequate bond between the reinforcement bar and the concrete was not achieved in structures with a compressive strength below 10 MPa. Therefore, it is recommended that no strengthening interventions be carried out on buildings with concrete compressive strengths lower than 10 MPa.
- It should be emphasized that the use of large-diameter anchors can generate significant stress concentrations within low-strength concrete, potentially resulting in pull-out or crushing-type failure mechanisms. However, Section 15 of TEC (2018), 'Special Rules for the Assessment and Strengthening Design of Existing Building Systems Under Seismic Effects', recommends a single anchor diameter of Ø16 without considering the concrete strength of the building to be strengthened. Furthermore, it states that reinforced concrete buildings with concrete strength below a certain value should not be strengthened due to insufficient anchor performance. Consequently, the diameter of post-installed adhesive anchors should be carefully selected as a function of the concrete compressive strength to ensure reliable anchorage performance and to prevent premature local failures.

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Conflict of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this manuscript.

Data Availability

The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author upon reasonable request.

AI Assistance

During the preparation of this manuscript, ChatGPT (OpenAI) was used exclusively for language editing and stylistic refinement. The authors take full responsibility for the content, interpretation, and conclusions of the published article.

Author Contributions

All authors made substantial contributions to the conception and design of the study, acquisition of data, analysis and interpretation of data; drafted or critically revised the manuscript for important intellectual content; and approved the final version to be published.

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