pti Technical NOTES

From PTI DC-35: Prestressed Rock and Soil Anchor Committee Issue 23 • June 2024

Non-ASTM A722 Alternative Post-Tensioned Bar Considerations

OVERVIEW

The use of prestressing steel bars conforming to ASTM A722/A722M[1] in prestressed rock and soil anchors is a common approach for designers and contractors. In recent years, however, designers have increasingly been specifying alternative steels, such as threaded bars conforming to ASTM A615[2] (Grades 75, 80, and 100), hollow-core threaded bar self-drilling anchors, or a similar type of bar for which no ASTM standard exists for use in rock and soil anchor tendons.

PTI DC35.1-14,[*3] "Recommendations for Prestressed Rock and Soil Anchors," considers the steel behavior, yield and tensile strengths, modulus of elasticity, stress relaxation, and corrosion characteristics of high-strength bars conforming to ASTM A722. While PTI DC35.1 does include Section 4.2.5 for special prestressing materials, that section requires that special materials be tested to ensure that their properties are equal to or better than those specified in PTI DC35.1 (ASTM A416/A416M[4] and ASTM A722/A722M). Because many alternative steel materials do not meet this requirement, the recommendations in PTI DC35.1 for aspects of use, design, and construction do not apply to all steel materials. The intent of this paper is to point out some of the differences in these alternative steel materials when used in prestressing applications, with a focus on bars for rock and soil anchors.

[*]The current version at the time of this writing is 2014.

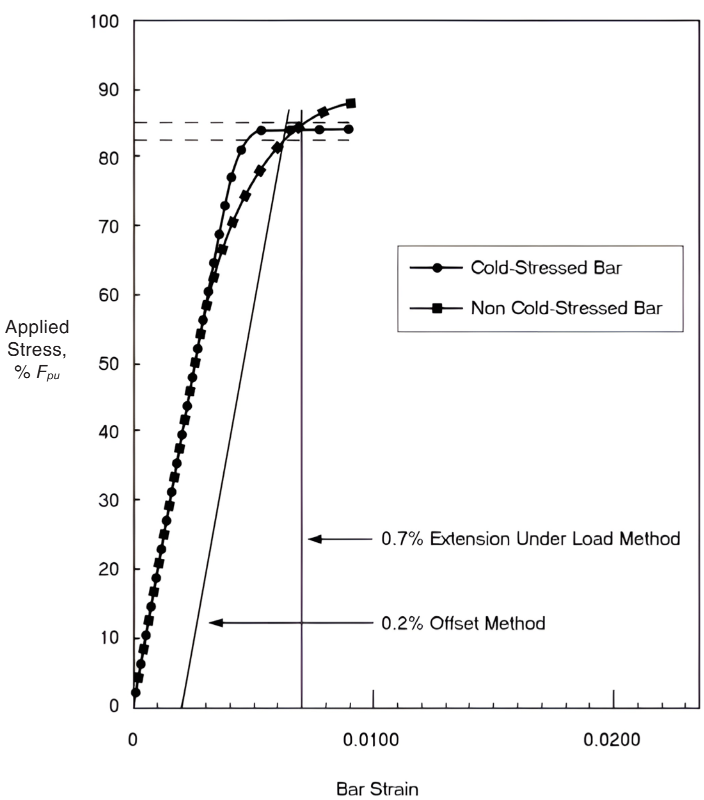

Fig. 1—Difference in strain behavior between cold-stressed and non-cold-stressed bars.

STRESS-STRAIN BEHAVIOR UNDER TENSILE LOAD

ASTM A722 specifies a minimum yield stress (F_y) of 120 ksi (827.4 MPa) and minimum tensile stress (F_{pu}) of 150 ksi (1034.2 MPa) for Type II bars. In addition, ASTM A722 requires that bars be subjected to cold stressing to not less than $0.80F_{pu}$ and then stress-relieved. The cold stressing produces an essentially linear stress-strain relationship up to F_y, as well as proof-stresses the bar to ensure no metallurgical defects would cause a failure during testing of the anchors in the field. Figure 1 shows the difference in stress-strain behavior between cold-stressed and non-cold-stressed bars. Bars that have not been cold stressed, such as bars conforming to ASTM A615, will exhibit plastic behavior prior to reaching the yield point defined by ASTM A722.

Table 1 presents the mechanical properties of ASTM A722, ASTM A615, and hollow bars for comparison. The ratio of F_{pu} to F_y varies by ASTM designation and bar grade. PTI DC35.1 allows a maximum design load of $0.60F_{pu}$ and a maximum test load not exceeding $0.80F_{pu}$. If these recommendations are applied to other materials, such as ASTM A615 reinforcing bars, the test load, in many cases, can exceed F_y of the bar. Testing a ground anchor with a steel bar that does not conform to ASTM A722 to a load near or above F_y will result in unexpectedly high deformation, higher residual movement, structural creep, and risk to personal safety during testing.

ELASTIC MODULUS

Steel elastic modulus is considered in the design of ground anchors with respect to anchor grout to ground behavior and

Table 1—Mechanical properties of ASTM A722, ASTM A615, and hollow bars

	Grade	ASTM	Specified F_y, ksi (MPa)	Specified minimum F_{pu}, ksi (MPa)	F_{pu}/F_y	60% F_{pu}/F_y	80% F_{pu}/F_y
Deformed bar	60	A615	60 (413.7)	80 (551.6)	1.33	0.80	1.07
	75	A615	75 (517.1)	100 (689.5)	1.33	0.80	1.07
	80	A615	80 (551.6)	100 (689.5)	1.25	0.75	1.00
	100	A615	100 (689.5)	115 (792.9)	1.15	0.69	0.92
	150	A722	120 (827.4)	150 (1034.2)	1.25	0.75	1.00
Hollow bar (for comparison)	N/A	A519/A513*	75* (517.1)	105* (723.9)	1.4	0.84	1.12

*ASTM A519[5] and ASTM A513[6] are tubing specifications that are commonly used as raw materials and do not have minimum strength values. Different hollow bar suppliers have varying F_y and F_{pu}. Values shown are an example for illustrative purposes. Note: 1 ksi = 6.89 MPa.

evaluation of load transfer during testing. Per ANSI/AISC 360-22,[7] the steel modulus of elasticity for mild-grade steel is 29,000 ksi (199,948 MPa), and per ASTM A722, the steel modulus of elasticity of steel bar is 29,700 ksi (204,774.3 MPa). The difference in elasticity is approximately 2.5%. The ground anchor testing acceptance criteria in PTI DC35.1 requires the actual tendon elongation to exceed 80% of the theoretical elastic elongation of the unbonded length; therefore, it is important to consider the appropriate modulus for the steel tendon being used.

STRESS RELAXATION AND CREEP

A critical property of a prestressing steel is to hold a sustained prestressing force tension load with minimal load loss over the design service life. Stress relaxation will cause loss of load over time. For prestressing steels, relaxation is defined as the time-dependent decrease in stress when the strand, wire, or bar is maintained at a constant strain (AS/NZS 4672.1[8]). Prestressing steels, such as strands conforming to ASTM A416, are manufactured using alloy steel materials and processes that will produce a steel with relaxation losses of less than 2.5% when held at $0.70F_{pu}$ for 1000 hours.

For this reason, PTI DC35.1 provides specific recommendations for the use of prestressing steel bars that conform to ASTM A722. It is not widely known that ASTM A722 is a "process specification" that requires bars to be cold stressed to $0.80F_{pu}$ and then stress-relieved, which is done with a thermal heating process. While ASTM A722 does not contain specific relaxation requirements, this process produces a high-strength, low-relaxation bar. Typical expectations for relaxation losses in ASTM A722 bars are less than 4% when held at $0.70F_{pu}$ for 1000 hours. Nonprestressing steel is expected to have greater relaxation losses.

If using an alternative steel that does not possess low-relaxation properties, such as all grades of ASTM A615 or hollow-core threaded bars, significant load loss over time may be experienced. The effects of relaxation on the structure should be understood by the Licensed Design Professional (LDP) and meet the intent of the application. For some permanent applications, the relaxation of a prestressed ground anchor over the service life of a structure it supports may result in unintended consequences, such as detrimental deformations of that structure if the actual relaxation is significantly greater than anticipated.

Higher-relaxation properties will also manifest in higher creep magnitudes during ground anchor load testing. The creep testing acceptance criteria for ground anchors recommended in PTI DC35.1 are independent of the free stressing length and are intended to measure the creep of the soil adjacent to and consequently stressed by the anchor. However, longer free stressing lengths will exhibit higher creep from the steel, which may result in a creep failure of the anchor, even though the creep of the adjacent soil may be acceptable.

CORROSION PROTECTION

The corrosion of steel that is under constant tensile stress may lead to sudden failure due to stress corrosion conditions. This stress corrosion condition exists regardless of the type of steel. Mild carbon steels are susceptible to corrosion, and guidance is available for sacrificial steel loss in the ground in non-aggressive environments. The Federal Highway Administration's "FHWA Soil Nail Walls Reference Manual" (FHWA-NHI-14-007[9]), as well as other FHWA publications, provides further guidance for the evaluation of the corrosivity of the ground and corrosion-protection systems. However, this guidance is for nonprestressed steel, and there have not been sufficient studies to confirm the guidance is applicable to a prestressed ground anchor. For permanent prestressed ground anchor applications, PTI DC35.1 recommends a Class 1 protected anchor, which is encapsulated in a pregrouted corrugated sheathing. It is not feasible to encapsulate hollow bars, as the sheathing would likely be severely damaged during the drilling process.

CONCLUSIONS

PTI DC35.1 applies to prestressed ground anchors using prestressing steel conforming to ASTM A416 strands and ASTM A722 bars. While PTI DC35.1 does allow for special prestressing steel materials, the properties of that steel must be equal to or better than ASTM A416 or ASTM A722. This discussion describes the differences between using prestressing steel bars conforming to ASTM A722 and alternative steel bars that are being used in some post-tensioning applications. Direct use of PTI DC35.1 with alternative steel must be carefully considered by the LDP to avoid unsafe conditions and unexpected results during load testing and unexpected behavior during the design life of the structure.

REFERENCES

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