Frequently Asked Questions

Stressing single strand unbonded tendons in PT repair projects

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Q: Is it important to know the grade and type of prestressing strand in a repair project?

Yes, it is important to know the grade and type of the prestressing strand that exists in a repair project. The grade of prestressing strand determines the tensile strength and other mechanical properties, which are important factors in determining the final effective prestress force provided by the PT. Additionally, knowledge of the steel grade enables the engineer to make informed decisions about the appropriate jacking forces, anticipated losses, and overall performance of the PT repair. Since the first edition, ASTM A416 has allowed strand with ultimate tensile strength of both 250 ksi and 270 ksi. PT construction in the 1960's through the early 1980's used **stress-relieved normal-relaxation** prestressing strand. In 1971, ASTM A416 added **stress-relieved low-relaxation prestressing strand**, and the industry began to adopt low-relaxation strand in the 1970's. By the mid 1980's most PT projects were constructed using **low-relaxation** prestressing strand, and normal-relaxation strand was eliminated from ASTM A416 in 2006. Normal-relaxation strand has higher long-term losses due to steel relaxation than low-relaxation strand for a given grade of steel. Steel relaxation losses are 8%-12% of the initial stress in the prestressing steel for normal-relaxation strand versus 2.5%-3.5% for low-relaxation strand.[1] Therefore, it is important to know not only the ultimate tensile strength of strand, but also if the strand is normal-relaxation or low-relaxation as these factors affect the final effective force of the tendon.

The grade of existing strand can be determined by extracting a steel sample and performing tensile testing in a laboratory. The testing requires several feet of undamaged strand, and the laboratory should be consulted prior to obtaining the sample to ensure that the length is sufficient. Alternatively, the Licensed Design Professional (LDP) should use engineering judgement based on the age, construction, and geographic location of the structure. In this case, extreme care must be taken during initial stressing operations utilizing appropriate safety precautions as stressing 250 ksi tendons to levels typically used for 270 ksi can result in breakage. The vast majority of CIP post-tensioned concrete buildings constructed in North America since the 1960's have been constructed using ½" diameter 7 wire, 270 ksi unbonded prestressing strands. The scope of Question 2 of this FAQ is limited to this type of strand.

Table 1 - History of ASTM A416

ASTM Specification	Steel Grade	Steel Type
ASTM A416-57	250 ksi	SR
ASTM A416-62	250 ksi & 270 ksi	SR
ASTM A416-71	250 ksi & 270 ksi	SR & LR
ASTM A416-06	250 ksi & 270 ksi	LR
ASTM A416-24	250 ksi & 270 ksi	LR

SR = Stress-Relieved Normal-Relaxation Strand
LR = Stress-Relieved Low-Relaxation Strand

1. ASTM A416 states that strand shall have relaxation losses of not more than 2.5% when initially loaded to 70% of the specified minimum breaking strength or not more than 3.5% when loaded to 80% of the specified minimum breaking strength of the strand after 1000 hours of testing.

Q: Should you stress tendons to the same force in a repair project as you would in a new project?

In a rehabilitation project, it is generally not necessary to stress tendons to the same force as in a new project. In general, PT repair projects in which strands and anchorages exhibit some wear due to age and exposure, stressing to a force higher than necessary increases the risk of breakage. To expand on this answer, it is helpful to review some basics of how jacking force and final effective force are established for an unbonded ½" dia. 7-wire, 270 ksi single-strand tendon in new construction. A reduction in the pre-stressing force from the jacking force occurs due to immediate short-term losses and from time-dependent long-term losses. Immediate short-term losses occur during stressing due to friction, wobble, wedge seating, and elastic shortening of the prestressed member. Time-dependent long-term losses occur due to factors such as shrinkage and creep of concrete, and relaxation of the prestressing steel. In North America, the jacking force for a ½ inch 7-wire 270 ksi single strand unbonded tendon has typically been set at 80 percent of the tendon's minimum ultimate tensile strength (the maximum allowed by ACI 318), or 33 kips (0.80 f_{pu}). As an example, for a typical tendon with a common/average length and profile, after immediate losses, including wedge seating losses, friction, and wobble, the average force in the tendon is reduced to approximately 28.9 kips (0.70 f_{pu}). Long-term losses further reduce the final effective prestress force to approximately 27 kips (0.65 f_{pu}) for low-relaxation strands and 24.8 kips (0.60 f_{pu}) for normal-relaxation strands. For new construction, the final effective prestress force for a PT tendon is the force that the LDP uses for the design. It is important to understand that the magnitude of losses provided in the above example are viewed as industry standards; however, short-term and long-term losses vary by project and by structural member and these values are normally calculated and confirmed by the PT supplier in their loss calculations provided in the shop drawings submittal.

In a PT repair project, it is desirable to reestablish the final effective prestress force that existed in the original construction while also reducing the jacking force to minimize risk of strand breakage during restressing. To attain these goals, the jacking force for PT tendons in a repair project should be selected by adjusting for the difference between the long-term losses that existed at original construction and the long-term losses expected after the repair. In new and recently constructed structures, immediate and short-term losses have occurred but long-term losses may not have significantly progressed. Jacking forces specified for repair of PT tendons in these circumstances may be very similar to the jacking forces in the original design.

In a rehabilitation project of older structures, the concrete in a slab or beam being repaired has already experienced shrinkage and creep, and the existing PT strand has already experienced relaxation. Therefore, while immediate short-term losses will occur in a repaired PT tendon, long-term losses generally will not occur.

There are exceptions to the general statement that long-term losses do not occur in a repair project. The LDP should carefully consider long-term losses when a significant length of strand is replaced with new strand that will undergo relaxation, or when large sections of concrete are replaced with new concrete that will experience shrinkage and creep.

To ensure that the repair achieves the intended final effective prestress force, the jacking force for the PT tendon should be adjusted down by the difference between the original long-term losses and the repair long-term losses. Expanding on the example above, if we assume no new long-term losses will occur, the jacking force for the repair can be reduced by the magnitude of long-term losses assumed at original construction, or 1.9 kips (0.05 f_{pu}) for low-relaxation strand. This translates to a jacking force of 33 kips – 1.9 kips = 31 kips (rounded to the nearest

kip) for low-relaxation strand. If the original strand in the project was 270 ksi normal-relaxation strand, then the original long-term losses can be assumed to be 4.1 kips (0.10 f_{pu}). This translates to a jacking force of 33 kips – 4.1 kips = 29 kips for normal-relaxation strand.

In older systems (typically pre-1980s) grease degradation or the presence of paper-wrapped sheathing can greatly increase the level of friction that must be overcome to restore force in existing tendons being repaired. In these cases, it may not be possible to fully restore the original intended design force into the tendon. The LDP must use their best judgement to estimate the likely level of force that can be restored into the tendon without creating an excessive risk of breakage, as well as the overall effect of the change in force levels in the structure. Under no circumstances should a jacking force be applied that is greater than 80 percent of the minimum ultimate strength of the tendon.

It is the responsibility of the LDP to consider all factors related to the PT repair that influence the final effective prestressing force. The approach presented in this FAQ ensures the structural performance of the rehabilitated structural member aligns with the original design intent. Alternatively, the LDP may judge that an increase in the final effective force in the repaired tendons is not detrimental to the structure and therefore a reduction of the jacking force is not necessary. Ultimately it is the LDP's responsibility to specify the jacking force for the PT tendons undergoing repair.

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