Something BOLTED this Way Comes

BY TOBY ANDERSON

The toil of revising the F1554 standard will help reduce the trouble of specifying anchor bolts.

THERE ARE A LOT of memorable scenes from *Macbeth*.

The knife floating through the air, the "Tomorrow and tomorrow and tomorrow" soliloquy and Lady Macbeth trying to scrub her hands clean all come to mind.

For me, the scene with three witches and their bubbling cauldron is the one that stands out the most. And it's not just because it's such a great scene, but also because the brew's disparate and unfamiliar ingredients mimicked the disparate components that came together in a recently completed standard. This past November, colleagues representing bolt suppliers have completed a revision of ASTM F1554-15, *Standard Specification for Anchor Bolts, Steel, 36, 55, and 105 ksi Yield Strength*. The group took into consideration strength, ductility, the effects of heat treatment and cold work, the capabilities of producers and the needs of designers—albeit with fewer poisoned entrails and eyes of newt.

Prior to 1994, designers commonly used other bolt standards to call out anchor rods, because there was no standard written specifically for them. ASTM adopted F1554 that year and AISC soon recommended it for anchor rods, but it has seen only minor revisions since then. As design codes adopted it, engineers and other specifiers designed with it, and suppliers naturally have seen increased requests. However, over the last few years, designers and producers noticed a few inconsistencies that complicated what ought to be clear requirements. Hearing such concerns, the ASTM-led task group met, drafted and completed an important update to this increasingly vital standard. With the goal in mind of a clear and economical standard that meets engineering requirements, the group made many changes; a few of the important ones are described here.

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New Ingredients

First, ACI 318-11 Appendix D design provisions defined ductile anchor rods with multiple parameters: reduction of area (ROA) that varied by grade and diameter and two measures of elongation. Two grades within F1554 straddled the requirements, with some parameters meeting the ductility limits while others did not. This led to designers using the lower resistance factors required for non-ductile materials, a 15% decrease in available strength. The "brittle" designation (vs. "ductile" anchors) may have necessitated additional design considerations, unless users specified higher reduction-of-area requirements than those in F1554. After consulting mills, manufacturers, bolting suppliers and ACI, the task group found that Grade 55 bars in most diameters were certified already to ROA's higher than F1554 required. To avoid the complications of the "brittle" designation, then, stakeholders agreed to raise F1554 Grade 55 ROA requirements to a minimum of 30% for all diameters.

The more recent standard, ACI 318-14, moved the definition of "steel element, ductile" to Section 2.3 ("Terminology"), but kept it essentially the same: "element with a tensile test elongation of at least 14% and reduction in area of at least 30%."

While the actual term "brittle" is not contained in the ACI 318, one can assume that if an anchor does not meet the definition of "steel element, ductile," it may be classified as brittle.

Due to ACI 318's definition, it still is possible, technically, to have a brittle Grade 105 bolt in ASTM F1554. Therefore, if a ductile Grade 105 is required, designers need to modify their contract specifications to require a 14% minimum elongation. (All other F1554 grades are ductile.)

Second, the original standard did not anticipate the growth of cold-drawn threaded rod ("all-thread") as an anchoring product, and certain sections allowed such rods' *pre-drawn* tensile properties to qualify its *finished* tensile properties. Conceivably, a finished Grade 36 all-thread rod—e.g., after it had been drawn and threaded—could have exceeded the standard's upper limit for ultimate tensile strength, even though its original raw material did not. The task group revised and clarified these sections to make the requirement clear: All tensile properties are to be determined only after all cold-drawing (and heat-treating, if performed) is completed. (What is not new is that Grades 36 and 55 anchor rods in sizes through 1½ in. and Grade 105 rods through 1¼ in., when tested full-size, still need to meet only yield strength and ultimate tensile requirements. ROA and elongation need not be reported for those sizes.)

Next, answering frequent queries, the group clarified that Grade 36 anchors are considered weldable, and to help ensure such weldability for even cold-drawn all-thread (which are often cut into shorter studs for anchoring), they lowered the grade's maximum carbon content by 0.01% (to 0.25%). In addition, recognizing a current industry process, the members revised the standard to allow all-thread rod manufacturers to perform qualifying tensile tests on coupons that have been drawn to pitch diameter, but not yet threaded. (Tensile properties are then extrapolated from the standard's full-size test requirements.)

The task group made minor revisions as well. They provided dimensional guidance for hex-head anchors, deleted extraneous metric equivalents, replaced references to "certifications" with "test reports" (the ASTM Fastener Committee's preferred usage) and consolidated and standardized certain sections (which had no other than mere editorial impact). Finally, the group deleted sizes under ½ in., having found no structural anchoring applications that specify such small diameters.

Ghosts of the Past

In addition to the changes in F1554-15, this is a good place to review some other areas of this specification. Like other ASTM product standards, F1554 includes an "ordering information" section (Section 5) that includes: quantity, product name, ASTM Designation and year, grade and class, copper content, nominal diameter and thread pitch, bolt length, thread length, head type (if required), hook angle and hook length (if required), coatings, number of nuts, number of washers, source inspection requirements, color marking (if different from the standard's), test reports, supplementary requirements (if required) and special packaging requirements (if required).

Something else that is not new: The actual minimum body diameters are smaller than the nominal diameters, and they are smaller for rolled threads than for cut threads. Designers ought to account for this variance. (See the adjacent table.) AISC and ACI have different ways to design threaded rod and in light of the minimum diameter for F1554, yield on the body of the rod might need to be checked. On the next page is an example using a 2-in.-diameter Gr 105 threaded rod:

F1554 Anchor Rod Minimum Body Diameters[A]

Nominal Diameter, in.	Threads/in.	Body Diameter, min, in.		
		Rolled Threads[B]		Cut Threads[C] Classes 1A and 2A
		Class1A	Class2A	
Unified Coarse Thread Series (UNC)				
½	13 UNC	0.4411	0.4435	0.4822
⅝	11 UNC	0.5561	0.5589	0.6052
¾	10 UNC	0.6744	0.6773	0.7288
⅞	9 UNC	0.7914	0.7946	0.8523
1	8 UNC	0.9067	0.9100	0.9755
1⅛	7 UNC	1.0191	1.0228	1.0982
1¼	7 UNC	1.1439	1.1476	1.2232
1½	6 UNC	1.3772	1.3812	1.4703
1¾	5 UNC	1.6040	1.6085	1.7165
2	4½ UNC	1.8385	1.8433	1.9641
2¼	4½ UNC	2.0882	2.0931	2.2141
2½	4 UNC	2.3190	2.3241	2.4612
2¾	4 UNC	2.5686	2.5739	2.7111
3	4 UNC	2.8183	2.8237	2.9611
3¼	4 UNC	3.0680	3.0734	3.2110
3½	4 UNC	3.2110	3.3233	3.4610
3¾	4 UNC	3.5674	3.5730	3.7109
4	4 UNC	3.8172	3.8229	3.9609
8 Thread Series (8 UN)				
1⅛	8 UN	. . .	1.0348	1.1004
1¼	8 UN	. . .	1.1597	1.2254
1½	8 UN	. . .	1.4093	1.4753
1¾	8 UN	. . .	1.6590	1.7252
2	8 UN	. . .	1.9087	1.9752
2¼	8 UN	. . .	2.1584	2.2251
2½	8 UN	. . .	2.4082	2.4751
2¾	8 UN	. . .	2.6580	2.7250
3	8 UN	. . .	2.9077	2.9749
3¼	8 UN	. . .	3.1575	3.2249
3½	8 UN	. . .	3.4074	3.4749
3¾	8 UN	. . .	3.6571	3.7248
4	8 UN	. . .	3.9070	3.9748

[A] Extracted from ASME B 1.1.
[B] Minimum body diameter is the same as minimum pitch diameter.
[C] Minimum body diameter is the same as minimum major diameter.

AISC:
Tensile from Table J3.2 $F_{nt} = 0.75\ F_u$
$R_n = F_n A_b = 0.75\ (125)(3.14) = 294$
Design Strength = $\phi R_n = 0.75(294) = 221k$

ACI:
$R_n = F_{nt}(A_b)$ where $F_{nt} = F_u$ and $A_b =$
Net tension area of the threaded bolt = 125 (2.5) = 312
(see *Steel Construction Manual* Table 7-17 for A_b value.)
Design strength = $\phi R_n = 0.65(262) = 203k$

AISC yield on the body:
$R_n = F_y\ A_{min} = 105[(\pi\ (1.83852/4)] = 278.7$
Design strength = $\phi R_n = 0.90\ (278.7) = 250k$

During the F1554 revision process, ASTM, AISC and ACI members endeavored to gather many industry voices, realizing that creating and amending product standards is much like creating a forging (though generally at lower temperatures and with less slag). The best standards are clear, concise and forged by groups that have all the information-consumers—mills, manufacturers, distributors, specifiers, and end users—represented, and where each listens, collaborates and contributes their bit to the chemistry (or the hammering).

Writing the Play

This new publication is the result of disparate industry players joining forces to coordinate, unify and rationalize the standard for anchor rods. I encourage all industry members to join the standards organizations linked to their specialty and to participate in similar collaborative processes, if only to combat the occasional impression that standards are brewed up with dragon scales and wolf teeth and foisted on an industry to create toil and trouble. ■

F1554 Anchor Rod Tensile Properties[A]			
	Grade		
	36	55	105
Tensile strength, ksi	58–80	75–95	125–150
Yield strength, min, ksi (0.2% offset)	36	55	105
Elongation in 2 in., min, % (machined specimens)[A]	23	21	15
Elongation in 8 in., min, % (bar stock)[A]	20	18	12
Reduction of Area, min %	40	30	45

[A] Elongation and ROA need not be reported for rods tested full-size.

F1554 Anchor Rod Welding Colors	
Grade	**Color**
36	Blue
55	Yellow
55- Weldable[A]	Yellow (projecting end) and White (encased end)
105	Red

[A] When Supplementary S1 is used.