Over-Steeling Provisions of ASTM A1064

ASTM A1064 establishes the ground rules for the manufacture of welded wire reinforcement. Within this manufactured material specification there are provisions for permissible variations in wire size included on the finished product. These provisions are summarized herein as follows.

Section 10.4.2

Unless otherwise precluded by the purchaser, the manufacturer shall be permitted to use over-sized plain wire. The size difference shall not exceed two "W" size increments on sizes W8 and smaller, and four "W" size increments on sizes larger than W8. A "W" size increment is a whole number (for example, W5 to W6 or W5.4 to W6.4). In all cases where such over-steeling is practiced, the manufacturer shall identify the welded wire reinforcement with the style originally ordered.

Section 10.5.1

Unless otherwise precluded by the purchaser, the manufacturer shall be permitted to apply over-sized deformed wire. The size difference shall not exceed two "D" size increments on sizes D8 and smaller and four "D" size increments on sizes larger than D8. A "D" size increment is a whole number (for example, D5 to D6 or D5.4 to D6.4). In all cases where such over-steeling is practiced, the manufacturer shall identify the welded wire reinforcement with the style originally ordered.

Note the language "Unless otherwise precluded by the purchaser" in the above excerpts. The specification includes explicit reference to over-steeling in Section 4 "Ordering Information" as follows:

Section 4.2

The purchaser shall have the option to specify additional requirements, including, but not limited to, the following:

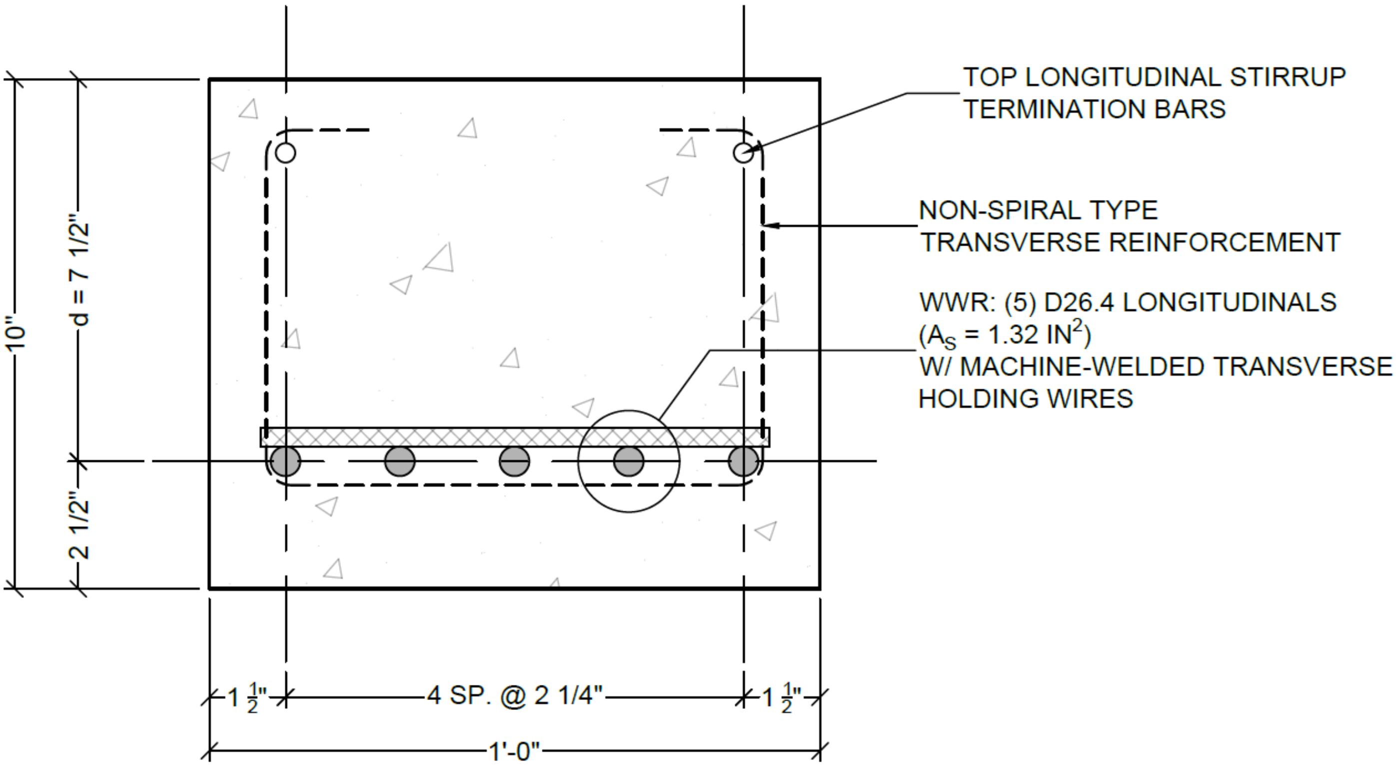
Section 4.2.1

Exclusion of over-steeling (see 10.4.2 and 10.5.1)

So ASTM A1064, by default, allows for over-steeling, but makes very clear to the purchaser the option to exclude over-steeling in the ordering process.

Over-steeling is a practice that in certain scenarios can actually impact calculated structural design capacities. This makes it important for the purchaser – by way of clear and concise contract document language prepared by the project design professional – to have a good handle on whether a project allows it. It is not uncommon for such language to be included in the structural contract documents.

A good example of over-steeling and its impact on calculated structural design capacity is illustrated below.



PRECAST BEAM SECTION VIEW

Calculation of the flexural capacity of the isolated, singly-reinforced precast concrete beam section is as follows:

Depth to the centroid of the compression block, "a", for a beam with 4 ksi (f'c) concrete and 70 ksi (fy) reinforcing steel:

$$a = \frac{A_s f_y}{0.85 f'_c b}$$

$$a = \frac{1.32 \times 70}{0.85 \times 4 \times 12} = 2.2647\ inches$$

Neutral axis depth, "c", with β_1 = 0.85 for 4 ksi concrete:

$$c = \frac{a}{\beta_1} = \frac{2.2647}{0.85} = 2.664\ inches$$

Tensile strain, ε_t, in longitudinal reinforcement by similar triangles, with the assumption that ultimate concrete strain in the extreme compression fiber, ε_c, is equal to 0.003 in/in:

$$\varepsilon_t = \frac{0.003 \times \beta_1 \times d}{a} - 0.003 = \frac{0.003 \times 0.85 \times 7.5}{2.2647} - 0.003 = 0.00544\ in/in$$

For tension-controlled behavior, per ACI 318, we need the following:

$$\varepsilon_t \geq \varepsilon_{ty} + 0.003$$

$$0.00544\ in/in \geq \frac{70}{29{,}000} + 0.003 = 0.00541\ in/in$$

$$\therefore\ section\ is\ tension\ controlled\ per\ ACI\ 318\ Table\ 21.2.2, and\ the\ strength\ reduction\ factor\ \varphi = 0.9$$

Design flexural strength is then calculated as follows (top longitudinal stirrup termination bars are ignored in this calculation)

$$\varphi M_n = \varphi A_s f_y \left(d - \frac{a}{2}\right) = 0.9 \times 1.32 \times 70 \times \left(7.5 - \frac{2.2647}{2}\right) = 44.1\ kip \cdot ft$$

In the above design, the engineer specified five (5) D26.4 flexural wires. But in the absence of explicit language precluding over-steeling, per ASTM A1064 Section 10.5.1 a manufacturer could conceivable furnish (5) D30.4 wires in lieu of those which were originally specified.

The impact of such a manufacturing substitution is presented below.

Depth to the centroid of the compression block, "a", for a beam with 4 ksi (f'c) concrete and 70 ksi (fy) reinforcing steel:

$$a = \frac{A_s f_y}{0.85 f'_c b}$$

$$a = \frac{1.52 \times 70}{0.85 \times 4 \times 12} = 2.6078\ inches$$

Neutral axis depth, "c", with β_1 = 0.85 for 4 ksi concrete:

$$c = \frac{a}{\beta_1} = \frac{2.6078}{0.85} = 3.068\ inches$$

Tensile strain, ε_t, in longitudinal reinforcement by similar triangles, with the assumption that ultimate concrete strain in the extreme compression fiber, ε_c, is equal to 0.003 in/in:

$$\varepsilon_t = \frac{0.003 \times \beta_1 \times d}{a} - 0.003 = \frac{0.003 \times 0.85 \times 7.5}{2.6078} - 0.003 = 0.00433\ in/in$$

For tension-controlled behavior, per ACI 318, we need the following:

$$\varepsilon_t \geq \varepsilon_{ty} + 0.003$$

$$0.00433\ in/in < \frac{70}{29{,}000} + 0.003 = 0.00541\ in/in$$

$$\therefore\ section\ is\ transitional, and\ \varphi = 0.81\ \ per\ ACI\ 318\ Table\ 21.2.2.$$

The issue that arises here is that nonprestressed beams must be tension-controlled per ACI 318 Section 9.3.3.1. Since this beam is not tension-controlled, it is prohibited for use as a flexural member, regardless of its calculated design flexural strength ϕM_n (which ironically enough turns out to be 44.5 kip-ft; about the same strength as the tension-controlled section). ACI notes that the purpose of the limitation that beams be tension-controlled is to mitigate brittle flexural failure in case of an overload. Note that Section 7.3.3.1 of ACI 318 has a similar requirement for slabs.

For reinforced concrete design, any instance in which the amount of nonprestressed reinforcing steel is increased for a concrete section of constant compressive strength and cross-section will result in reduced tensile strain in the steel. When the amount of reinforcing steel is so high that tensile strain falls below the tension-controlled limit of ε_{ty} + 0.003, the section is unsuitable for flexural use.

To avoid potential issues related to the design impact of over-steeling, the solution is quite simple. For structural flexural applications, design professionals should consider taking advantage of ASTM A1064 Section 4.2.1 and including language on contract documents that precludes over-steeling, which in turn ensures that the WWR sizes manufactured for the project match the project's specified WWR sizes.

For more information visit www.wirereinforcementinstitute.org.

References:

1. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19)," American Concrete Institute, Farmington Hills, MI, 2019 (Reapproved 2022).

2. "Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete (ASTM A1064/A1064M-22)", ASTM International, West Conshohocken, PA, 2022.