Structural Engineering Guidance No. 15-02

Date: July 29, 2015

Distribution: Internal Bridge Designers and Technicians Only

SUBJECT: NEW AASHTO LRFD 5.11 Development and Splices OF REINFORCEMENT

 Implementation TRIAL

Contact: Gregory Sanders, Boyd Denson and Alec Schlotzhauer (DS Intern)

EPG Status: To Be Submitted

Std. Drawing Status: To Be Revised

Effective Date: Immediately

Expiration/Duration: Active until 90-Day Trial Period Completed and Incorporated into EPG (Oct. 31)

Attachments: 1 – New table for straight deformed bars in tension (three sheets)

 2 – New table for hooked deformed bars in tension (one sheet)

 3 – Comparison of new 2015 Interim provisions versus current practice (three sheets)

BACKGROUND AND PURPOSE:

The 2015 Interim Revisions to the AASHTO LRFD Bridge Design Specifications adopted new provisions for development and splices of reinforcement. These provisions were adapted from ACI 318-11 with the extension of criteria to high-strength concrete up to 15 ksi being verified in NCHRP Report 603. ACI had already adopted provisions for incorporating high strength reinforcement up to 100 ksi.

These new provisions:

* Allow for strength of reinforcement up to 100 ksi and strength of concrete up to 15 ksi.
* Change formula for development length of straight deformed bars in tension equivalent to that in ACI.
* Eliminate Class C splice

These new provisions produce significant changes to the current EPG tables for development and splices of straight bars in tension and for development of standard hook bars in tension.

These new provisions will also require updating most references to development or splice lengths provided in other locations of the EPG and in the standard drawings, plans and specifications.

Programs that compute splice lengths (box culvert quantity programs) may not be updated at this time. A new spreadsheet that calculates development and splice lengths will be available at the end of the trial period located on the Development Section’s SharePoint site thru the Structural Software tab in the QuickSheets folder.

The purpose of this guidance is twofold:

* Provide opportunity for internal designers and technicians, project managers and liaisons to become familiar with the AASHTO interim provisions.
* Allow a trial period for productive use of new tables for feedback: error discovery, improvements. Use of the new provisions on a case by case basis is easy; however standardizing for all inclusive cases is difficult.

The trial period will be 90 days. The new tables are ok to use for new jobs immediately and not turned in to Preliminary and Review Section since these are effective 2015 AASHTO LRFD interims.

GUIDANCE:

**I. Review AASHTO LRFD 2015 Interim Revisions to Article 5.11 (available in web version only):**

IN GENERAL:

* No. 14 and 18 bars are excluded from the new AASHTO LRFD provisions. Therefore the values provided for these bars in the EPG tables are based on ACI 318 with the following limitations:
	+ The specified compressive strength of concrete shall not exceed 10 ksi.
	+ Compression or tension lap splices shall not be used except for compression lap splices to No. 11 or smaller bars shall be permitted if in accordance with ACI 318 provision 25.5.5.4.

OF SIGNIFICANCE FOR STRAIGHT BARS IN TENSION:

* Replaced five formulas for various reinforcement sizes with one new formula.
* Removed “Top” from the description for the modification factor used with 12 inches of fresh concrete case below the reinforcement and revised this factor from 1.4 to 1.3.
* Added a 1.3 factor for when no more than 12 inches of fresh concrete is cast below the bars (EPG currently refers to this location as “Other Than Top Bars”) and f*′*c > 10 ksi. For f*′*c ≤ 10 ksi the factor for this bar location is still 1.0.
* Removed the existing 0.8 factor for ≥ 6ʺ spacing & ≥ 3ʺ cover in the direction of spacing.
* Added a reinforcement confinement factor adapted from ACI 318-11.

OF SIGNIFICANCE FOR HOOKED BARS IN TENSION:

* Revised from 0.7 to 0.8 the factor for adequate side and end cover.
* Modification factors are stackable as before but not easily inferred in the case of the reinforcement confinement factor for the development of hooked bars (two reinforcement confinement factors should be considered for each scenario, one based on cover and the other based on stirrup placement).

**II. Review new tables for straight bars (Attachment 1) and for hooked bars (Attachment 2):**

IN GENERAL:

* Check logic and practicality of tables. Do they flow nicely?
* Development and splices of reinforcement follows directly from AASHTO except as noted.
* The new tables are mainly for 3 and 4 ksi concrete and Grade 60 reinforcement but steps and examples are provided for calculating development and splice lengths for other strength materials.
* Table for bars in compression (existing EPG 751.5.9.2.7.4) remain unchanged and therefore is not attached.
* Existing tables for Grade 40 (existing EPG 751.5.9.2.7.6 and 751.5.9.2.7.7) will be removed from the EPG.

DETAILS OF THE NEW TABLE FOR STRAIGHT DEFORMED BARS IN TENSION (EXISTING EPG 751.5.9.2.7.2 AND 751.5.9.2.7.3) – ATTACHMENT 1 (THREE SHEETS):

* The two existing tables (top bars and other than top bars) were combined into one table with the selection of location being the first step of the table.
* No longer use “top bar” and “other than top bar” and instead provide descriptions of casting location in accordance with AASHTO. Inclined bars are considered same as horizontal bars in accordance with ACI 318. Vertical bars are added to the description of the location case with the default modification factor of 1.0.
* The first step of the existing tables relating to spacing and cover in the direction of the spacing was removed in accordance with the removal of this criterion from AASHTO LRFD.
* The new table is based on the minimum allowed reinforcement confinement factor (*λrc*) of 0.4 because the majority of reinforcement cases for a typical structure will use this value. In all cases, it is best practice to check to ensure that this is the case and calculate the actual *λrc* (Step 6 of table) and adjust the lengths obtained from the table if the actual *λrc* is greater than 0.4.
* When calculating *λrc* the transverse reinforcement term of *Atr* may be assumed conservatively as zero ignoring the presence of any transverse bars crossing the potential plane of splitting. To test this assumption, *λrc* can be quickly estimated as *db*/*cb* to determine if it exceeds 0.4 in which those cases of minimal cover or close spacing *Atr* may need to be calculated in order to shorten unreasonably long development and splice lengths.
* The figure shown in Step 6 is reprinted unedited from AASHTO LRFD and is marginally incorrect. The correct *λrc* would be the maximum *λrc* of the three beam cases shown and calculated separately, or of the two column cases shown and calculated separately. Thre is an associated relationship between specific cases involving the parameters *cb*, *Atr*, *s* and *n* that must be maintained in determining correct development lengths.
* Follow drilled shaft transverse reinforcement spacing requirements in the lap splice zone between column and shaft and in accordance with AASHTO LRFD 5.11.5.2 when lap splices do not meet noncontact lap splice requirements.

DETAILS OF THE NEW TABLE FOR HOOKED DEFORMED BARS IN TENSION (EXISTING EPG 751.5.9.2.7.5) – ATTACHMENT 2 (ONE SHEET):

* Rearranged the table to follow the same flow of steps used for the straight bars. This placed the coating step before the f*′*c step.
* Step 5 is a check for assuring 6 inches of clearance at free edge or construction joint. This requirement is not from AASHTO and is carried over from the current table. Any knowledge on the background of this requirement would be helpful in determining if the requirement is still required.
* Added various instructions relating confinement reinforcement all based on AASHTO provisions. Footnote b specifies one such provision requiring stirrups at discontinues ends of members with both side cover and top or bottom cover less than 2.5 inches. These stirrups will be required at the ends of typical intermediate beam caps. As an alternative to adding stirrups, a non-standard clear cover could be specified.

**III. Review Attachment 3 - Comparison of new 2015 Interim provisions versus current practice:**

* New development lengths are typically longer until bars get larger. New splice lengths are similarly trending. No more Class C splice. Only A and B remain and Class B will be made required with exception. Class C was removed and is accounted for in the new development length formula. For this reason the new Class B splice is compared to the pervious Class C splice.
* Cost savings is minimal but positive.
* Only lap splices were considered in the comparison. More savings could be available with smaller development lengths and in some situations where hooked bars or mechanical bar splices are avoided.

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Anticipated revisions related to Implementation:

* EPG 751.5.9.2.7 Development and Lap Splices: complete rewrite.
* EPG 751.12 Protective Barriers: 35ʺ splice to 37ʺ and 24ʺ splice to 31ʺ.
* EPG 751.22 P/S Concrete I Girders: Add A1 bar splices based on f*′ci*.
* EPG 751.24 LFD Retaining Walls: “top bar” terminology & Section 2.4 to EPG 751.5.
* EPG 751.31 Open Concrete Intermediate Bents: Class C to Class B.
* EPG 751.37 Drilled Shafts: add transverse reinforcement spacing requirements in the lap splice zone between column and shaft in accordance with AASHTO 5.11.5.2 when lap splices do not meet noncontact lap splice requirements.
* EPG 751.50 Standard Detailing Notes: In note K1.5 revise 21ʺ splice to 29ʺ.
* Bridge Standard Drawings: revise splices lengths for barrier curbs (elevation and at end bents) and bridge approach slabs.
* Sec 701 and 706: Add total slip requirements of mechanical bar connections in accordance with AASHTO LRFD in certifying acceptable mechanical bar connections.
* Sec 706: Splice table revised accordingly.

Suggestions and recommendations concerning this guidance or procedure should be directed to the Development Section for review and updating the Engineering Policy Guide.