CODE | COMMENTARY

where members do not extend beyond the joint. In contrast, if calculated bar stress is so low that the hook is not needed for bar anchorage, the ties or stirrups are not necessary. Also, provisions of 12.5.4 do not apply for hooked bars at discontinuous ends of slabs with confinement provided by the slab continuous on both sides normal to the plane of the hook.

12.5.5 — Hooks shall not be considered effective in developing bars in compression.

R12.5.5 — In compression, hooks are ineffective and may not be used as anchorage.

12.6 — Development of headed and mechanically anchored deformed bars in tension

12.6.1 — Development length for headed deformed bars in tension, ℓ_{dt}, shall be determined from 12.6.2. Use of heads to develop deformed bars in tension shall be limited to conditions satisfying (a) through (f):

(a) Bar f_y shall not exceed 420 MPa;

(b) Bar size shall not exceed No. 36;

(c) Concrete shall be normalweight;

(d) Net bearing area of head A_{brg} shall not be less than $4A_b$;

(e) Clear cover for bar shall not be less than $2d_b$; and

(f) Clear spacing between bars shall not be less than $4d_b$.

12.6.2 — For headed deformed bars satisfying 3.5.9, development length in tension ℓ_{dt} shall be $(0.19\psi_e f_y/\sqrt{f_c'})d_b$, where the value of f_c' used to calculate ℓ_{dt} shall not exceed 40 MPa, and factor ψ_e shall be taken as 1.2 for epoxy-coated reinforcement and 1.0 for other cases. Length ℓ_{dt} shall not be less than the larger of $8d_b$ and 150 mm.

R12.6 — Development of headed and mechanically anchored deformed bars in tension

The development of headed deformed bars and the development and anchorage of deformed bars through the use of mechanical devices within concrete are addressed in 12.6. As used in 12.6, *development* describes cases in which the force in the bar is transferred to the concrete through a combination of a bearing force at the head and bond forces along the bar. Such cases are covered in 12.6.1 and 12.6.2. In contrast, *anchorage* describes cases in which the force in the bar is transferred through bearing to the concrete at the head alone. Design requirements for anchors are given in Appendix D. Headed bars are limited to those types that meet the requirements of HA heads in ASTM A970M because a wide variety of methods are used to attach heads to bars, some of which involve significant obstructions or interruptions of the bar deformations. Headed bars with significant obstructions or interruptions of the bar deformations were not evaluated in the tests used to formulate the provisions in 12.6.2. The headed bars evaluated in the tests were limited to those types that meet the criteria in 3.5.9 for HA heads.

The provisions for headed deformed bars were written with due consideration of the provisions for anchorage in Appendix D and the bearing strength provisions of 10.14.[12.15,12.16] Appendix D contains provisions for headed anchors related to the individual failure modes of concrete breakout, side-face blowout, and pullout, all of which were considered in the formulation of 12.6.2. The restrictions on normalweight concrete, maximum bar size of No. 36, and upper limit of 420 MPa for f_y are based on the available data from tests.[12.15-12.17]

The provisions for developing headed deformed bars give the length of bar ℓ_{dt} measured from the critical section to the bearing face of the head, as shown in Fig. R12.6(a).

For bars in tension, heads allow the bars to be developed in a shorter length than required for standard hooks.[12.15-12.17] The minimum limits on clear cover, clear spacing, and head size are based on the lower limits of these parameters used in the tests to establish the expression for ℓ_{dt} in 12.6.2. The clear cover and clear spacing requirements in 12.6.1 are

CODE

COMMENTARY

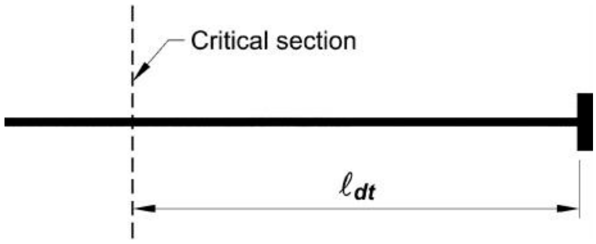

Fig. R12.6(a)—Development of headed deformed bars.

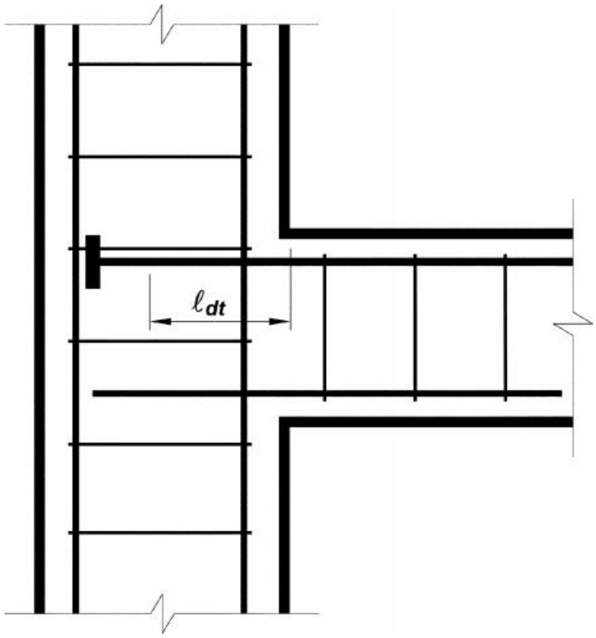

Fig. R12.6(b)—Headed deformed bar extended to far side of column core with anchorage length that exceeds ℓ_{dt}.

12

based on dimensions measured to the bar, not to the head. The head is considered to be part of the bar for the purposes of satisfying the specified cover requirements in 7.7, and aggregate size requirements of 3.3.2(c). To avoid congestion, it may be desirable to stagger the heads. Headed bars with $A_{brg} < 4A_b$ have been used in practice, but their performance is not accurately represented by the provisions in 12.6.2, and they should be used only with designs that are supported by test results under 12.6.4. These provisions do not address the design of studs or headed stud assemblies used for shear reinforcement.

A 1.2 factor is conservatively used for epoxy-coated headed deformed reinforcing bars, the same value used for epoxy-coated standard hooks. The upper limit on the value of f_c' in 12.6.2 for use in calculating ℓ_{dt} is based on the concrete strengths used in the tests.[12.15-12.17] Because transverse reinforcement has been shown to be largely ineffective in improving the anchorage of headed deformed bars,[12.15-12.17]

CODE | COMMENTARY

additional reductions in development length, such as those allowed for standard hooks with additional confinement provided by transverse reinforcement in 12.5.3, are not used for headed deformed reinforcing bars. Transverse reinforcement, however, helps limit splitting cracks in the vicinity of the head and for that reason is recommended.

In 2011, the excess reinforcement factor for headed bars was removed from the Code. The excess reinforcement factor ($A_{s\ required}/A_{s\ provided}$), applicable to deformed bars without heads, is not applicable for headed bars where force is transferred through a combination of bearing at the head and bond along the bar. Concrete breakout due to bearing at the head was considered in developing the provisions of 12.6. Because the concrete breakout capacity of a headed bar is a function of the embedment depth to the 1.5 power (see Appendix D Eq. (D-6)), a reduction in development length with the application of the excess reinforcement factor could result in a potential concrete breakout failure.

Where longitudinal headed deformed bars from a beam or a slab terminate at a supporting member, such as the column shown in Fig. R12.6(b), the bars should extend through the joint to the far face of the confined core of the supporting member, allowing for cover and avoidance of interference with column reinforcement, even though the resulting anchorage length exceeds ℓ_{dt}. Extending the bar to the far side of the column core helps to anchor compressive forces (as identified in a strut-and-tie model) that are likely to form in such a connection and improves the performance of the joint.

12.6.3 — Heads shall not be considered effective in developing bars in compression.

R12.6.3 — No data are available that demonstrate that the use of heads adds significantly to anchorage strength in compression.

12.6.4 — Any mechanical attachment or device capable of developing f_y of deformed bars is allowed, provided that test results showing the adequacy of such attachment or device are approved by the building official. Development of deformed bars shall be permitted to consist of a combination of mechanical anchorage plus additional embedment length of deformed bars between the critical section and the mechanical attachment or device.

R12.6.4 — Headed deformed bars that do not meet the requirements in 3.5.9, or are not anchored in accordance with 12.6.1 and 12.6.2, may be used if tests demonstrate the ability of the head and bar system to develop or anchor the desired force in the bar, as described in 12.6.4.

12.7 — Development of welded deformed wire reinforcement in tension

12.7.1 — Development length for welded deformed wire reinforcement in tension, ℓ_d, measured from the point of critical section to the end of wire shall be computed as the product of ℓ_d, from 12.2.2 or 12.2.3, times welded deformed wire reinforcement factor, ψ_w, from 12.7.2 or 12.7.3. It shall be permitted to reduce ℓ_d in accordance

R12.7 — Development of welded deformed wire reinforcement in tension

Figure R12.7 shows the development requirements for welded deformed wire reinforcement with one cross wire within the development length. ASTM A1064M for welded deformed wire reinforcement requires the same strength of the weld as required for welded plain wire reinforcement. Some of the development is assigned to welds and some assigned to the

CODE

with 12.2.5 when applicable, but ℓ_d shall not be less than 200 mm except in computation of lap splices by 12.18. When using ψ_w from 12.7.2, it shall be permitted to use an epoxy-coating factor ψ_e of 1.0 for epoxy-coated welded deformed wire reinforcement in 12.2.2 and 12.2.3.

12.7.2 — For welded deformed wire reinforcement with at least one cross wire within ℓ_d and not less than 50 mm from the point of the critical section, ψ_w shall be the greater of

$$\left(\frac{f_y - 240}{f_y}\right)$$

and

$$\left(\frac{5d_b}{s}\right)$$

but not greater than 1.0, where s is the spacing between the wires to be developed.

12.7.3 — For welded deformed wire reinforcement with no cross wires within ℓ_d or with a single cross wire less than 50 mm from the point of the critical section, ψ_w shall be taken as 1.0, and ℓ_d shall be determined as for deformed wire.

12.7.4 — Where any plain wires, or deformed wires larger than MD200, are present in the welded deformed wire reinforcement in the direction of the development length, the reinforcement shall be developed in accordance with 12.8.

COMMENTARY

length of deformed wire. The development computations are simplified from earlier Code provisions for wire development by assuming that only one cross wire is contained in the development length. The welded deformed wire reinforcement factor, ψ_w, in 12.7.2 is applied to the deformed wire development length computed from 12.2. The factor ψ_w was derived using the general relationships between welded deformed wire reinforcement and deformed wires in the ℓ_{db} values of the 1983 Code.

Tests[12.18] have indicated that epoxy-coated welded wire reinforcement has essentially the same development and splice strengths as uncoated welded wire reinforcement because the cross wires provide the primary anchorage for the wire. Therefore, an epoxy-coating factor of 1.0 is used for development and splice lengths of epoxy-coated welded wire reinforcement with cross wires within the splice or development length.

Deformed wire larger than MD200 is treated as plain wire because tests show that MD290 wire will achieve only approximately 60 percent of the bond strength in tension given by Eq. (12-1).[12.19]

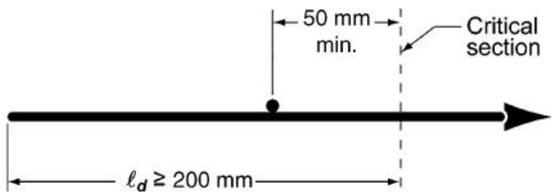

Fig. R12.7—Development of welded deformed wire reinforcement.

3

CODE

3.5.7.2 — Steel pipe or tubing for composite compression members composed of a steel encased concrete core meeting requirements of 10.13.6 shall conform to one of the following specifications:

(a) Black steel, hot-dipped, zinc-coated: Grade B of ASTM A53M;

(b) Cold-formed, welded, seamless: ASTM A500M;

(c) Hot-formed, welded, seamless: ASTM A501.

3.5.8 — Steel discontinuous fiber reinforcement for concrete shall be deformed and conform to ASTM A820M. Steel fibers have a length-to-diameter ratio not smaller than 50 and not greater than 100.

3.5.9 — Headed deformed bars shall conform to ASTM A970M including Annex A1 Requirements for Class HA Head Dimensions.

3.6 — Admixtures

3.6.1 — Admixtures for water reduction and setting time modification shall conform to ASTM C494M. Admixtures for use in producing flowing concrete shall conform to ASTM C1017M.

3.6.2 — Air-entraining admixtures shall conform to ASTM C260.

3.6.3 — Admixtures to be used in concrete that do not conform to 3.6.1 and 3.6.2 shall be subject to prior approval by the licensed design professional.

3.6.4 — Calcium chloride or admixtures containing chloride from sources other than impurities in admixture ingredients shall not be used in prestressed concrete, in concrete containing embedded aluminum, or in concrete cast against stay-in-place galvanized steel forms. See 4.3.1 and 6.3.2.

COMMENTARY

R3.5.8 — Deformations in steel fibers enhance mechanical anchorage with the concrete. The lower and upper limits for the fiber length-to-diameter ratio are based on available test data.[3.6] Because data are not available on the potential for corrosion problems due to galvanic action, the use of deformed steel fibers in members reinforced with stainless-steel bars or galvanized steel bars is not recommended.

R3.5.9 — The limitation to Class HA head dimensions from Annex A1 of ASTM A970M is due to a lack of test data for headed deformed bars that do not meet Class HA dimensional requirements. Heads not conforming to Class HA limits on bar deformation obstructions and bearing face features could cause unintended splitting forces in the concrete that may not be characteristic of the heads used in the tests that were the basis for 12.6.1 and 12.6.2. For heads conforming to Class HA dimensional requirements, the net bearing area of the head can be assumed to be equal to the gross area of the head minus the area of the bar. This assumption may not be valid for heads not conforming to Class HA dimensional requirements.

R3.6 — Admixtures

R3.6.4 — Admixtures containing any chloride, other than impurities from admixture ingredients, should not be used in prestressed concrete or in concrete with aluminum embedments. Concentrations of chloride ion may produce corrosion of embedded aluminum (e.g., conduit), especially if the aluminum is in contact with embedded steel and the concrete is in a humid environment. Corrosion of galvanized steel sheet and galvanized steel stay-in-place forms