CHAPTER 2

DETAILS OF REINFORCEMENT

2-1. General

This chapter presents guidance for furnishing and placing steel reinforcement in various concrete members of hydraulic structures.

2-2. Quality

The type and grade of reinforcing steel should be limited to ASTM A 615 (Billet Steel), Grade 60. Grade 40 reinforcement should be avoided since its availability is limited and designs based on Grade 40 reinforcement, utilizing the procedures contained herein, would be overly conservative. Reinforcement of other grades and types permitted by ACI 318 may be permitted for special applications subject to the approval of higher authority.

2-3. Anchorage, Bar Development, and Splices

The anchorage, bar development, and splice requirements should conform to ACI 318 and to the requirements presented below. Since the development length is dependent on a number of factors such as concrete strength and bar position, function, size, type, spacing, and cover, the designer must indicate the length of embedment required for bar development on the contract drawings. For similar reasons, the drawings should show the splice lengths and special requirements such as staggering of splices, etc. The construction specifications should be carefully edited to assure that they agree with reinforcement details shown on the drawings.

2-4. Hooks and Bends

Hooks and bends should be in accordance with ACI 318.

2-5. Bar Spacing

a. Minimum. The clear distance between parallel bars should not be less than 1-1/2 times the nominal diameter of the bars nor less than 1-1/2 times the maximum size of coarse aggregate. No. 14 and No. 18 bars should not be spaced closer than 6 and 8 inches, respectively, center to center. When parallel reinforcement is placed in two or more layers, the clear distance between layers should not be less than 6 inches. In horizontal layers, the bars in the upper layers should be placed directly over the bars in the lower layers. In vertical layers, a similar orientation should be used. In construction of massive reinforced concrete structures, bars in a layer should be spaced 12 inches center-to-center wherever possible to facilitate construction.

b. Maximum. The maximum center-to-center spacing of both primary and secondary reinforcement should not exceed 18 inches.

2-6. Concrete Protection for Reinforcement

The minimum cover for reinforcement should conform to the dimensions shown below for the various concrete sections. The dimensions indicate the clear distance from the edge of the reinforcement to the surface of the concrete.

CONCRETE SECTION	MINIMUM CLEAR COVER OF REINFORCEMENT, INCHES
Unformed surfaces in contact with foundation	4
Formed or screeded surfaces subject to cavitation or abrasion erosion, such as baffle blocks and stilling basin slabs	6
Formed and screeded surfaces such as stilling basin walls, chute spillway slabs, and channel lining slabs on grade:	
Equal to or greater than 24 inches in thickness	4
Greater than 12 inches and less than 24 inches in thickness	3
Equal to or less than 12 inches in thickness will be in accordance with ACI Code 318.	

NOTE. In no case shall the cover be less than:
1.5 times the nominal maximum size of aggregate,
or
2.5 times the maximum diameter of reinforcement.

2-7. Splicing

a. General. Bars shall be spliced only as required and splices shall be indicated on contract drawings. Splices at points of maximum tensile stress should be avoided. Where such splices must be made they should be staggered. Splices may be made by lapping of bars or butt splicing.

b. Lapped Splices. Bars larger than No. 11 shall not be lap-spliced. Tension splices should be staggered longitudinally so that no more than half of the bars are lap-spliced at any section within the required lap length. If staggering of splices is impractical, applicable provisions of ACI 318 should be followed.

c. Butt Splices

(1) General. Bars larger than No. 11 shall be butt-spliced. Bars No. 11 or smaller should not be butt-spliced unless clearly justified by design details or economics. Due to the high costs associated with butt splicing of bars larger than No. 11, especially No. 18 bars, careful

consideration should be given to alternative designs utilizing smaller bars. Butt splices should be made by either the thermit welding process or an approved mechanical butt-splicing method in accordance with the provisions contained in the following paragraphs. Normally, arc-welded splices should not be permitted due to the inherent uncertainties associated with welding reinforcement. However, if arc welding is necessary, it should be done in accordance with AWS D1.4, Structural Welding Code-Reinforcing Steel. Butt splices should develop in tension at least 125 percent of the specified yield strength, f_y, of the bar. Tension splices should be staggered longitudinally at least 5 feet for bars larger than No. 11 and a distance equal to the required lap length for No. 11 bars or smaller so that no more than half of the bars are spliced at any section. Tension splices of bars smaller than No. 14 should be staggered longitudinally a distance equal to the required lap length. Bars Nos. 14 and 18 shall be staggered longitudinally, a minimum of 5 feet so that no more than half of the bars are spliced at any one section.

(2) Thermit Welding. Thermit welding should be restricted to bars conforming to ASTM A 615 (billet steel) with a sulfur content not exceeding 0.05 percent based on ladle analysis. The thermit welding process should be in accordance with the provisions of Guide Specification CW-03210.

(3) Mechanical Butt Splicing. Mechanical butt splicing shall be made by an approved exothermic, threaded coupling, swaged sleeve, or other positive connecting type in accordance with the provisions of Guide Specification CW-03210. The designer should be aware of the potential for slippage in mechanical splices and insist that the testing provisions contained in this guide specification be included in the contract documents and utilized in the construction work.

2-8. Temperature and Shrinkage Reinforcement

a. In the design of structural members for temperature and shrinkage stresses, the area of reinforcement should be 0.0028 times the gross cross-sectional area, half in each face, with a maximum area equivalent to No. 9 bars at 12 inches in each face. Generally, temperature and shrinkage reinforcement for thin sections will be no less than No. 4 bars at 12 inches in each face.

b. Experience and/or analyses may indicate the need for an amount of reinforcement greater than indicated in paragraph 2-8a if the reinforcement is to be used for distribution of stresses as well as for temperature and shrinkage.

c. In general, additional reinforcement for temperature and shrinkage will not be needed in the direction and plane of the primary tensile reinforcement when restraint is accounted for in the analyses. However, the primary reinforcement should not be less than that required for shrinkage and temperature as determined above.