CHAPTER FOUR
REINFORCED CONCRETE DESIGN

Cast-in-place, reinforced concrete is used extensively for many bridge elements. These elements include abutments, wingwalls, piers, foundations, decking, and cast-in-place girders to name a few. Although reinforced concrete is widely used it does have its limitations for its use as the primary structural members.

Superstructures are rarely constructed of conventionally reinforced concrete. Prestressed concrete is much more common. The exception is the slab bridge which has a proven record of being a very durable long lasting structure.

The span lengths that can be achieved with a slab bridge are fairly short, between 20 feet and 40 feet; therefore, they tend to be used on small stream crossings. The superstructure depth for slab bridges generally ranges between 12 inches and 18 inches. Where site conditions require a shallow superstructure, the slab bridge is quite often the best choice. A skew greater than 45 degrees, however, may eliminate the feasibility of using a slab bridge.

4.1 MATERIAL STRENGTHS AND PROPERTIES

The NMDOT Standard Specifications for Highway and Bridge Construction contains requirements for materials used in bridge construction. There are designated classes of concrete, each having a minimum compressive strength, to which concrete structures must conform. The following section gives the concrete class and the minimum material properties on which to base design.

4.1.1 Concrete

Concrete compressive strengths usually used for design are listed below. The strength listed for substructure design may be increased to 4000 psi if the increase is advantageous for the design under consideration.

Superstructure elements:	4000 psi
Substructure elements:	3000 psi
Drilled shafts:	3000 psi

Each of these bridge components are discussed in the following paragraphs.

Superstructure concrete is Class AA. All cast-in-place concrete placed in bridges above the bearings is superstructure concrete with the exception of abutment backwalls and wingwalls where the backwall type abutment is used. The wingwalls, end diaphragms, and concrete above the bearings in bridges with integral and semi-integral abutments is constructed of superstructure concrete.

Bridge substructure elements, box culverts, and retaining walls are constructed with Class A concrete. Substructure elements include abutments, bents, and piers.

Drilled shafts concrete bearing piles are constructed of Class G concrete.

4.1.2 Reinforcing Bars

Reinforced concrete structures are designed and constructed with Grade 60 rebar having a yield strength of 60 ksi. An exception is made for reinforcing in vertical backwalls and for rebar that are required to be field bent. In these cases, bars are to be Grade 40 rebar because the ductile nature of the Grade 40 bar minimizes breakage during construction operations.

When checking flexural reinforcement distribution per AASHTO LRFD Section 5.7.3.4, moderate concrete exposure conditions are assumed for all areas, statewide. Therefore, use

$z = 170$ k/in

in Equation 5.7.3.4-1.

Epoxy coated, galvanized or MFX bars are used for:

a) All bars in cast in place elements of the deck, superstructure and approach slabs.
b) The bars projecting from a prestressed beam's top flange.
c) The prestressed beam's reinforcement that is within 4 feet of the end.

4.2 DETAILING REQUIREMENTS

Information on the proper practice for detailing of reinforcing bars is available in the Manual of Standard Practice by the CRSI (Concrete Reinforcing Steel Institute). Designers and detailers should to be familiar with this publication. All dimensions on plans are to centerlines of bars unless otherwise noted on the details. Bend radii are also to the centerline of the bar unless otherwise noted. Calculated weights of bars are based on centerline lengths.

Minimum bend diameters for both uncoated and coated bars are listed in NMDOT Standard Specifications.

4.2.1 Lengths and Splices

All sizes of bars are readily available in lengths up to 60 ft, including epoxy coated rebar. Shorter length bars may be used and spliced preferred; however, the extra splices should not be detailed unless there are special reasons for detailing the splices.

Mechanical splices/ connectors may be used if conditions of the construction require them. The mechanical splices/ connectors used must be capable of developing 125% of the specified yield strength of the spliced bar.
Splices at critical locations should be avoided whenever possible. If mechanical splices need to be placed at a critical location, stagger the splices one half of a class A splice length if possible.

4.2.2 Reinforcing for Bearing Piles

The use of spiral reinforcement in cast-in-place concrete bearing piles (drilled shaft and augercast piles) has created problems with constructing these foundations. Tie reinforcement should be used instead.

4.2.3 Concrete Cover

Concrete cover should be as specified in the NMSHTD Standard Specifications for Highway and Bridge Construction Section 540 Steel Reinforcing. The Standard practice at NMDOT is to detail to the centerline of bar. The cover dimensions shown on the plans should therefore be greater than the clear cover requirement by half the diameter of the bar.

4.3 STANDARD DECK SLABS

The Bridge Design Section first made deck slab design tables and standard details available in the 1979 Bridge Design and Detailing Instructions. Slabs designed using these tables have proved to be more rigid and durable than those of conventional design. The NMDOT has noted less durability and a shorter deck life in decks thinner than those specified in the standard design tables. The use of the standard designs should therefore continue.

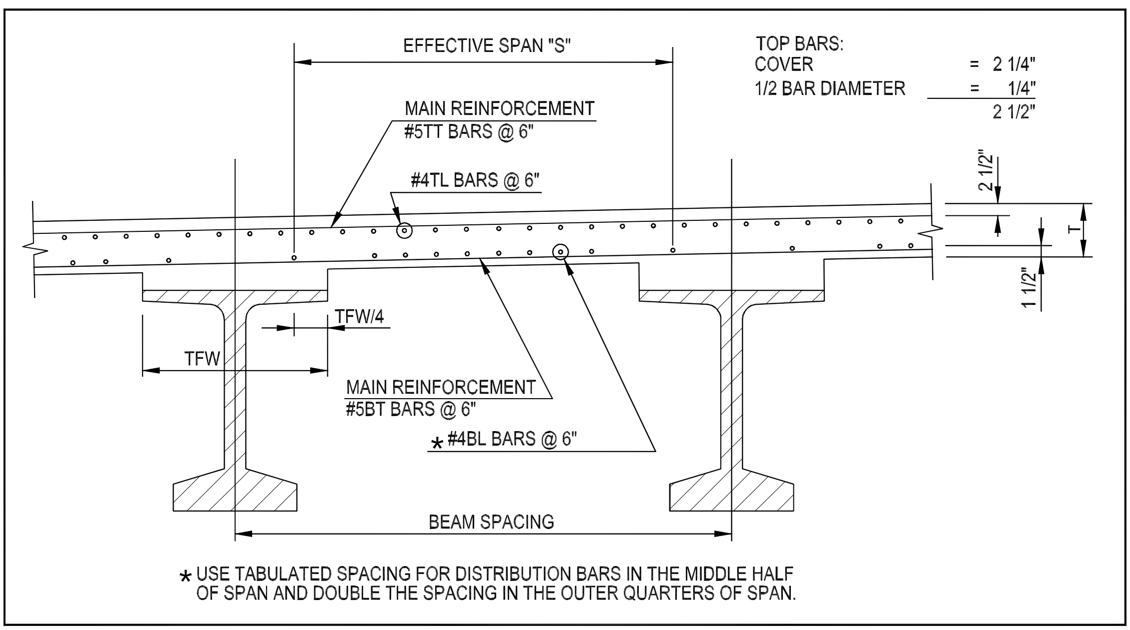
4.3.1 Deck Slab Design

The standard deck slab detail shown in Figure 4.3A are basically the 1979 designs, but some minor modifications have been made to them. Because the slab has already been designed, the designer simply needs to determine the slab thickness and distribution reinforcement from the corresponding table, based on the beam spacing, and include them into the standard slab detail. The standard slab is based on the design presented in the 1979 Bridge Manual.

The standardized slab design can be used for most deck slabs; however caution should be exercised if the bridge has a large skew or some other unusual features. Additionally, if deck slab cantilevers are longer than about 4 feet, the adequacy of the tabulated amount of reinforcing to carry the loads imposed on the cantilever needs to be checked.

NMDOT has used thinner decks in a few instances over the years. Experience has shown that thinner decks do not have the long-term durability of the standard deck slab details of figure 4.3A. The standard deck should therefore always be used unless approval to use a thinner deck is obtained from the State Bridge Engineer. Approval has historically been granted in cases where rehabilitation budgets haven't allowed for superstructure modifications to carry a heavier deck.

Figure 4.3A
Standard Deck Slab Detail for MS 18 Loading and Corresponding Design Table



T (in)	S (ft)	NEG M_s (ft-k)	NEG ϕM_n (ft-k)	POS M_s (ft-k)	POS ϕM_n (ft-k)	Operating Rating (From BRASS)
7 ½”	5’-7”	7.40	12.52	9.08	16.95	HS 46
8”	6’-7”	8.24	13.90	9.87	18.34	HS 44
8 ½”	7’-7”	9.10	15.28	10.67	19.72	HS 43
9”	8’-6”	9.95	16.66	11.49	21.10	HS 43
9 ½”	9’-5”	10.81	18.04	12.32	22.48	HS 42
10”	10’-3”	11.67	19.42	13.15	23.86	HS 41
10 ½”	11’-1”	12.53	20.8	13.99	25.24	HS 41
11	11’-10”	13.39	22.18	14.84	26.62	HS 41

NOTE: FLEXURAL MOMENTS ARE PER FT OF SLAB WIDTH

T=Slab Thickness S=Effective Span M_s=Service Bending Moment

ϕM_n=Resisting Moment

4.3.2 Slab Details

To reduce transverse cracking in newly constructed bridge decks, the transverse bars in the top and bottom mats of deck slab reinforcement should be offset by 1/2 of the bar spacing.

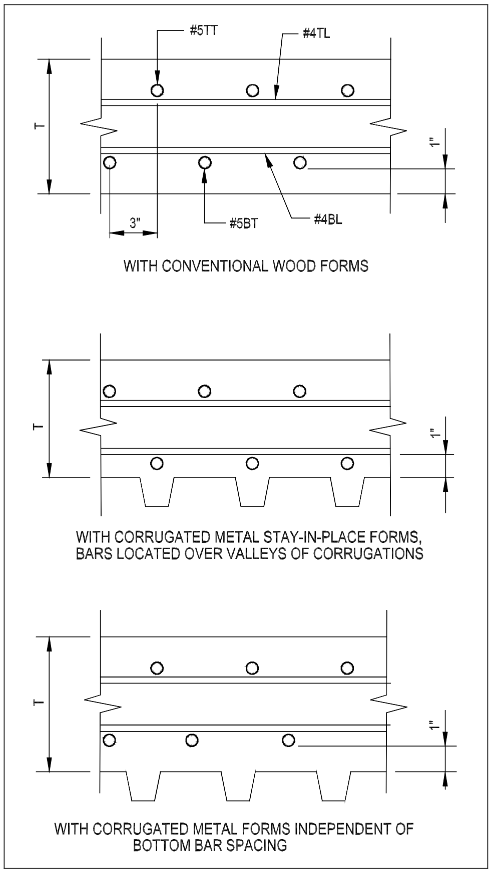
In New Mexico it has historically been the practice to add ¼ inch to the deck thickness as a sacrificial wearing surface. This additional ¼ inch of wearing surface is no longer required.

The use of staggered splices in adjacent lines of longitudinal bars was initially thought to control cracking. However, there is scant evidence that staggering the splices in this manner has any effect on reducing the amount of cracking that occurs in the deck slab. Designing deck slabs to provide for the staggered splices is also quite time consuming. Therefore, the practice of staggering splices is at the discretion of the designer. It is not suggested for use as a crack control measure, but may be reserved to clear the congestion that results from having splices in one location.

When using corrugated steel stay-in-place forms, special attention should be given to the amount of cover on the bottom bars. If the bottom transverse bars are parallel to and located over the valleys of the corrugations, then one inch of cover is provided relative to the bottom longitudinal bar. Otherwise, one inch of cover shall be provided relative to the transverse bars. See Figure 4.3B for a comparison of bridge deck cover and thickness requirements for conventional wood forms and corrugated metal stay-in-place forms. Other design requirements for metal deck forms may be found in the NMDOT Standard Specifications.

When an existing bridge is being redecked, saving weight on the new deck is sometimes an important issue. In such cases, one weight saving option that can be used is to specify that the corrugations in the metal forms be filled with Styrofoam. This will eliminate the extra weight caused by the use of the forms and the 15psf dead load allowance required for using them need not be considered in the design. The drawings need to clearly state the design loads used and if styrofoam is required. The design load for metal deck plus styrofoam is 2.5psf.

Figure 4.3B - Comparison of Deck Thickness and Cover Requirements



4.3.3 Concrete Deck Placement

To reduce the severity of shrinkage cracking in the deck slabs of continuous beam bridges, deck slabs are placed sequentially. The sequence specified in the plans requires that positive moment areas are placed first and that negative moment areas are placed last. A detail and note specifying such a sequence is shown in Figure 4.3C.

Dimension A is as close as practicable to the pier, but far enough away so that all longitudinal bars may be spliced or terminated within the Placement 2 areas. It is important that the longitudinal bars be spliced in the placement 2 areas to allow for thermal movement of the bars in the time interval between placements 1 and 2. Full width placement, as shown in the detail, is the preferred manner to place concrete. However, if the total skewed width of the deck slab exceeds 60 ft, or if full width placements at the placement rate specified (typically 30 ft/hr) results in a volumetric rate of placement greater than 45 cu yd/ hr, the State Bridge Engineer should be contacted for instructions regarding placement width.

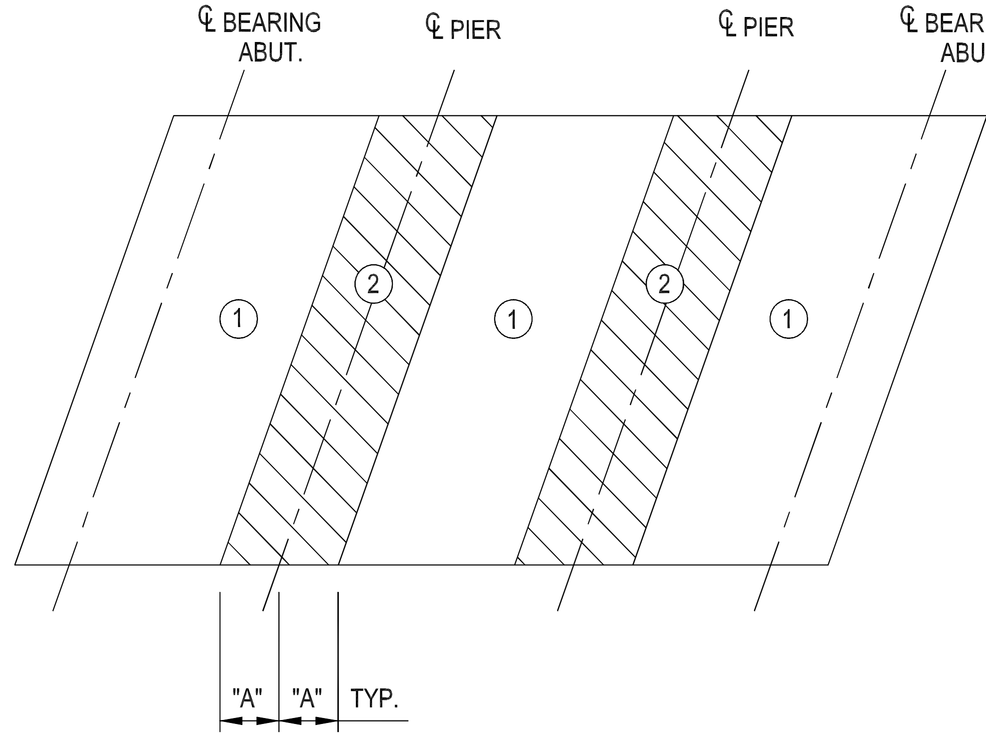
In the recent past, some contractors have been permitted to place deck slabs continuously from one end of the deck to the other provided a 2nd backup concrete pump is available on the job site. This practice has for the most part been successful. However, the Bridge Sections policy is that this procedure still needs to be considered on a case by case basis. The contractors proposed deck placement procedure needs to be reviewed to make sure that it is adequate to insure that the end to end placement is successful. The practice of including the deck placement sequences in the bridge plans should therefore be continued.

An additional item of concern is placement of concrete diaphragms. Integral abutment diaphragms and pier diaphragms for continuous for live load bridges must be place monolithically with the deck slab concrete. If preplaced, they can severely spall when the deflections due to deck slab placement occurs.

4.3.4 Deck Overhang Design

It has been considered by some bridge engineers to be a good practice to design the deck slab overhang such that the railing system will fail before the deck does. The rationale behind this practice seems to be that deck slabs are difficult to repair. While in theory this seems to be reasonable, it does lead to an excessive amount of reinforcing steel in the overhang. Additionally, it is not true that deck slab overhangs are hard to repair. For a skilled bridge crew the process is quite straight forward and quickly accomplished. This practice should therefore not be used in New Mexico and deck slab overhangs need not be designed stronger than the deck to rail connection.

Figure 4.3C
Concrete Deck Placement Detail



NOTE:

CONCRETE SHALL BE PLACED THE FULL WIDTH OF THE DECK SLAB IN THE SEQUENCE SHOWN ABOVE AT A FORWARD RATE OF PROGRESS OF NOT LESS THAN 30 FEET PER HOUR. PLACEMENTS (1) MAY BE MADE ON THE SAME OR SEPARATE DAYS AND PLACEMENTS (2) MAY BE MADE ON THE SAME OR SEPARATE DAYS. PLACEMENTS (2) SHALL NOT BE MADE UNTIL THE CONCRETE IN ADJACENT PLACEMENT (1) AREAS HAS BEEN IN PLACE AT LEAST 48 HOURS. SET RETARTDANT SHALL NOT BE USED IF THE ATMOSPHERIC TEMPERATURE AT THE TIME OF PLACEMENT IS LESS THAN 60° F.
"A" SHOULD NOT EXCEED 5'-0".

Note: The finishing machine shall operate parallel to the bridge skew. The note needs to be included on the bridge plan.