

**BRIDGE AND CULVERT PLANS
MANUAL**

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Project Development Division of the Iowa Department of Transportation.

ABSTRACT

This Plan Reading Course was developed by the Department of Civil and Construction Engineering of Iowa State University under contract with the Iowa Highway Research Board, Project HR-324. It is intended to be an instructional tool for Iowa DOT, county and municipal employees within the state of Iowa.

Under this contract, a previous Plan Reading Course, prepared for the Iowa State Highway Commission in 1965, has been completely revised using a new format, new plans, updated specifications, and new material.

This course is a self-taught course consisting of two parts; Highway Plans, and Bridge and Culvert plans. Each part consists of a self-instruction book, a set of plans, a question booklet, and an answer booklet.

This is the self-instruction book for the Bridge and Culvert Plans part of the course. The example structures included in this part of the course are a prestressed concrete beam bridge and a reinforced concrete box culvert. The accompanying plans for those structures are:

BRIDGE ON U.S. 65 - OVER RELOCATED U.S. 18

This is a 70.5 m x 27.3 m pretensioned, prestressed concrete beam bridge in Cerro Gordo County, Design No. 1895, September 1996.

REINF. CONC. BOX CULVERT, 2.4 m x 1.5 m x 66.2 m, Cerro Gordo County, Design No. 895, April 1996.

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James K. Cable, Ph.D., P.E.

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INTRODUCTION

This is an introductory course in plan reading for Bridges and Culverts. It presumes that you have completed the companion course on Highway Plan Reading. If you have not completed the latter, you should, as you are not prepared to take this course. After you have finished with this manual, you should be able to read and understand any set of bridge and culvert plans. Two specific sets of plans accompany this manual. They are:

BRIDGE ON U.S. 65 - OVER RELOCATED U.S. 18

This is a 70.5 m x 27.3 m pretensioned prestressed concrete beam bridge in Cerro Gordo County, Design No. 1895, September 1996.

REINF. CONC. BOX CULVERT, 2.4 m x 1.5 m x 66.2 m, Cerro Gordo County, Design.No. 895, April 1996.

As with the Highway Plan Reading course, this course will not have an instructor. You will go through the material at your own speed. You do not have to advance to a new topic until you are ready. Likewise, if you believe you understand something particularly well, you may move on at your own pace. How quickly you learn to read the plans is entirely up to you.

BRIDGE COMPONENTS

According to the Standard Specifications, a bridge is:

"any structure, including supports, erected over a depression or an obstruction, as water, a highway or railroad, and having a track, or passageway for carrying traffic or other moving loads and having a length measured along the center of the roadway of more than 6.1m between undercopings of abutments or extreme ends of openings for multiple boxes."

Bridges typically span obstacles, such as streams, rivers, roads and railroads. They can be concrete, a combination of steel and concrete, or wood. Special bridges, such as suspension bridges, truss bridges, wood bridges, lift-span bridges, etc., are not covered in this course.

A typical open-span bridge consists of a superstructure and substructure. See Figure 1. The superstructure consists of the part of the bridge above the piers and abutments, but including the bearings. This would include the barrier rails, deck, supporting beams or girders, and the bearings upon which those beams or girders rest. The substructure consists of that part of the structure below the bearings. Typically, this would include abutments and piers. Figure 2 shows a side view of a typical bridge. It is a three span bridge with two abutments and two piers.

The roadway is supported by beams or girders. These may be concrete or steel. You will examine both types during this course. Figure 3a shows a bridge which uses steel I-beams. Figure 3b shows a bridge which uses prestressed precast concrete beams, and Figure 3c shows a bridge which uses cast-in-place concrete beams.

Abutments (Figure 4) support the ends of the beams at each end of the bridge. Abutments usually consist of a main wall, a backwall, wingwalls, and a footing, with or without piles. The main abutment wall holds back the soil at either end of the bridge, and it also transmits loads to the footing. The footing and piles, which are the bottom part of the abutment, transmit the loads to the ground. The footing may rest on natural ground, or it may transmit its load to piling.

The intermediate supports of a bridge are called piers (Figure 5). A single-span bridge does not have any piers; just two abutments. A multiple-span bridge has piers at the intermediate support points. Piers are composed of a cap, columns, and a footing, with or without piles. The cap receives the loads of the beams or girders. The columns transmit those loads to the footing. The footing and piles transmit the loads to the soil. As with abutments, pier footings may be supported by the natural ground, or they may be supported by piling.

This brief introduction should help you in understanding the names of the major components of bridges and their roles, and it will make it easier for you to review the accompanying sets of bridge plans. Other components will be described as you encounter them in the plans.

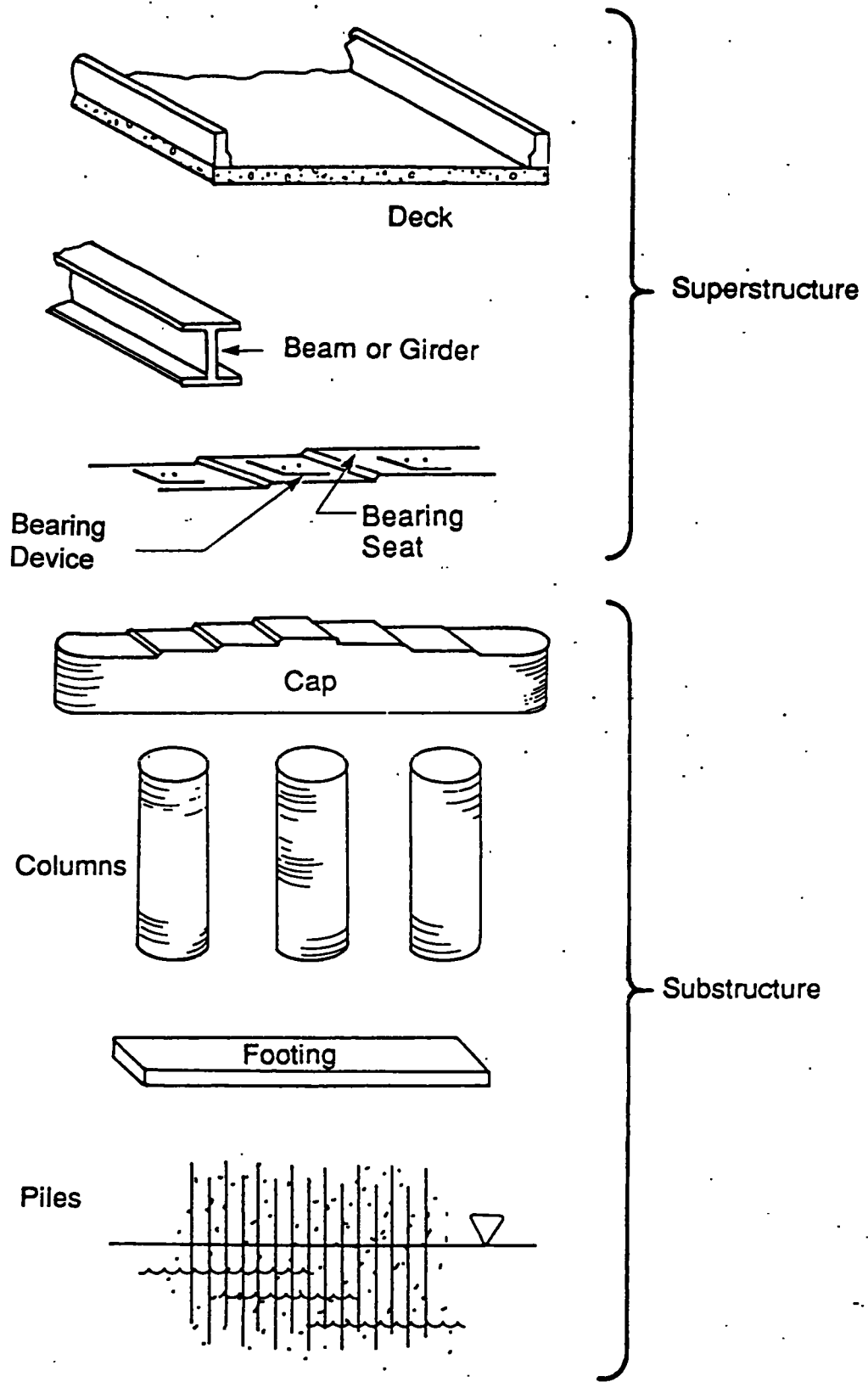


Figure 1. Bridge Components

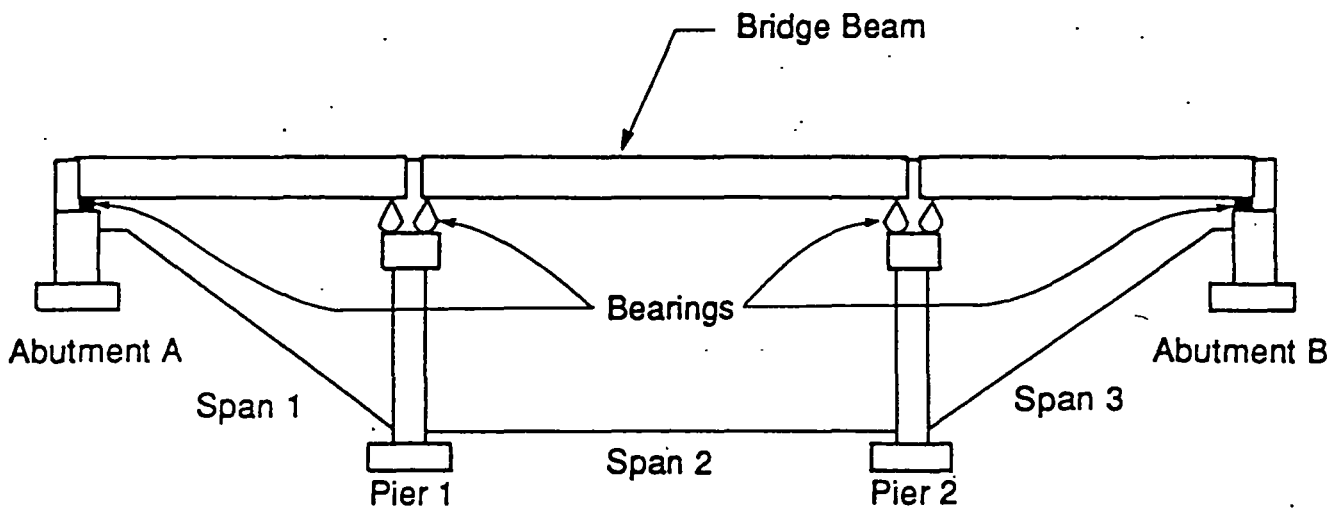
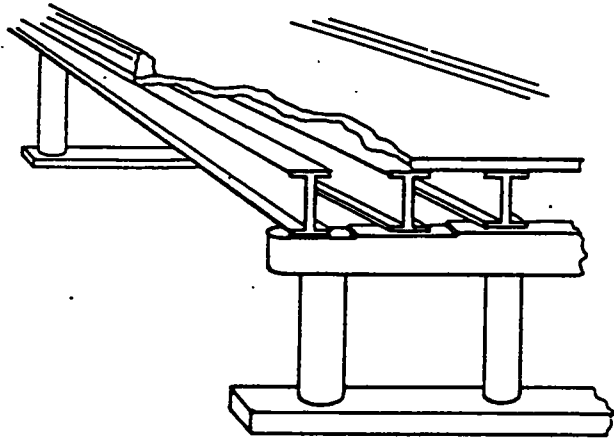
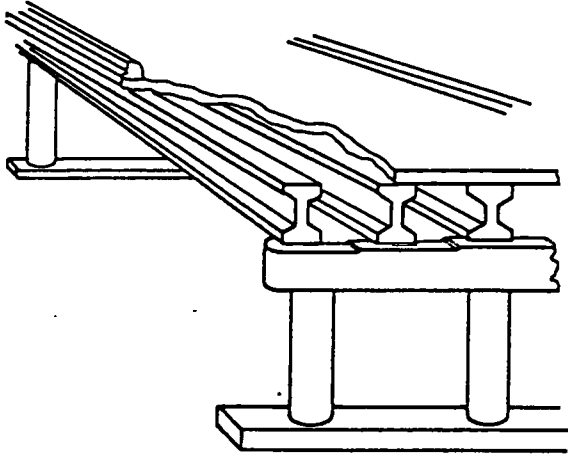


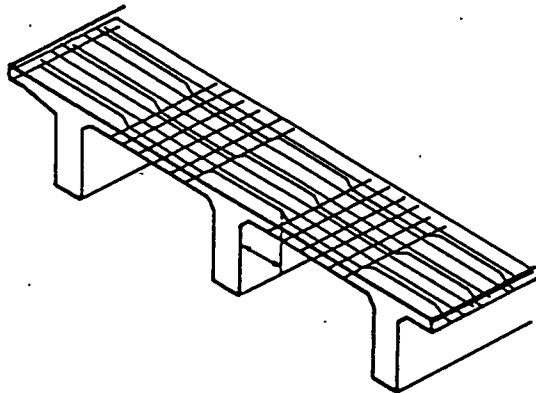
Figure 2. Bridge Schematic



a) Steel Beams



b) Prestressed Precast Concrete Beams



c) Cast in Place Beams

Figure 3. Bridge Beams

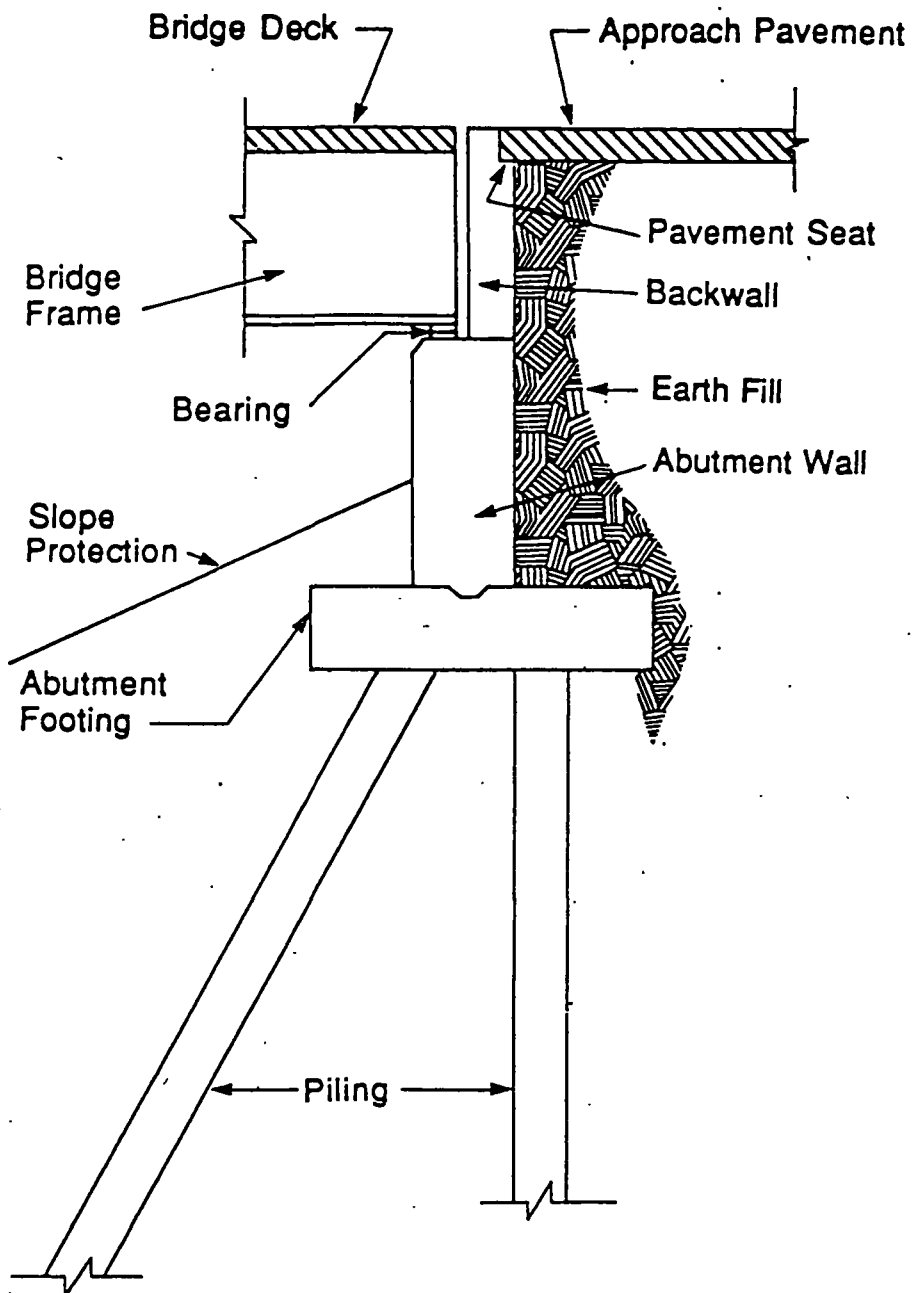


Figure 4. Bridge Abutment

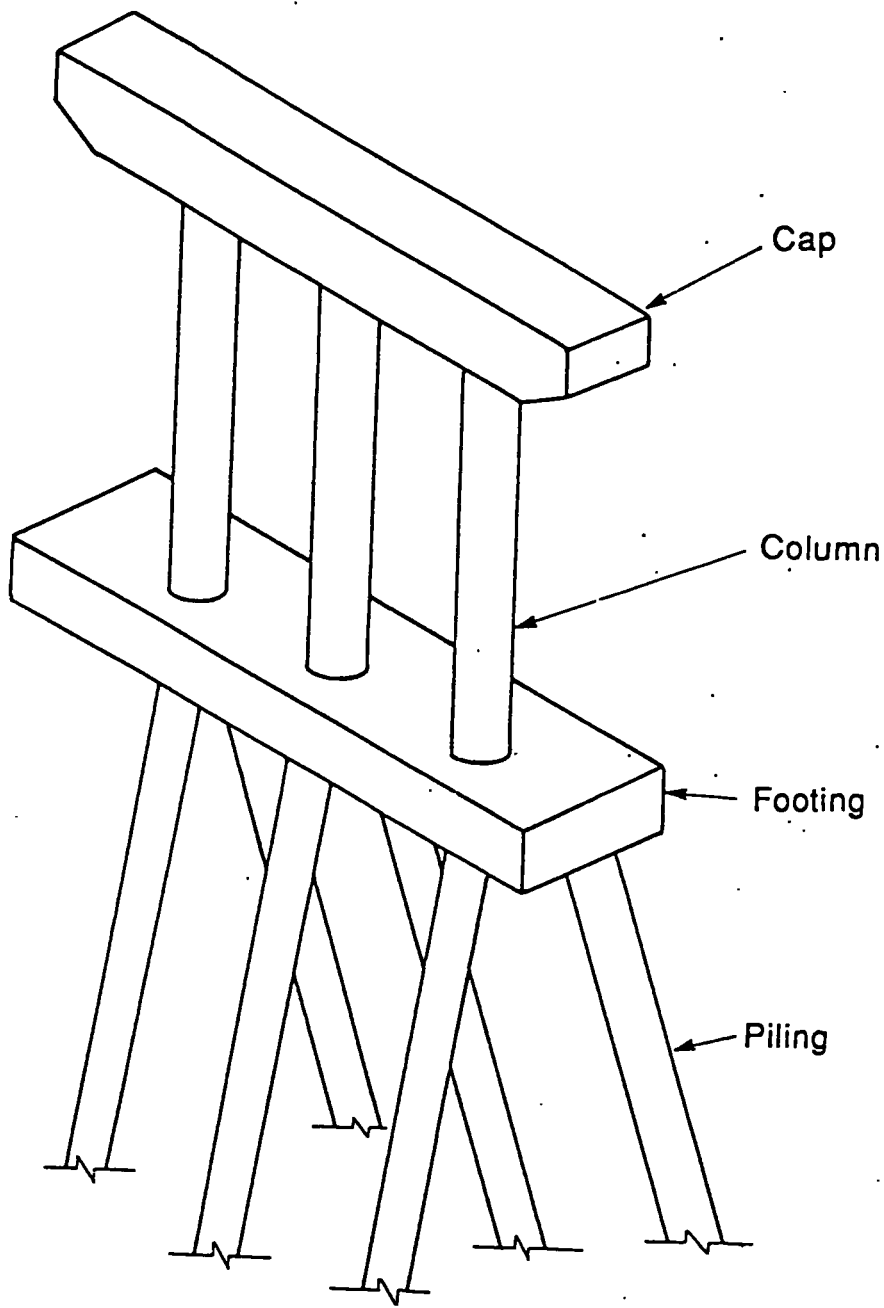


Figure 5. Bridge Pier

BRIDGE ON U.S. 65 - OVER RELOCATED U.S. 18

TITLE SHEET

Refer to the set of plans for the project above. Let's review the information contained on the Title Sheet, which is similar in format to the Title Sheet contained in the Highway Plan Reading Course.

PROJECT NAME/LOCATION/TYPE

This information is located in the top center of the Title Sheet. It identifies the plans as being prepared by the Iowa Department of Transportation Highway Division, and that the plans are for the proposed improvements on the Primary Road System, Cerro Gordo County, and that the project is a Bridge on U.S. 65 OVER RELOCATED U.S. 18.

SCALES

The notation concerning scales is located immediately below the words OVER RELOCATED U.S. 18 near the middle of the sheet. It indicates that the Scales are "As Noted," which means that the scales will be noted separately on the sheets and drawings to which they apply.

STANDARD SPECIFICATIONS

This block, located below SCALES: As Noted, states that the metric Standard Specifications of 1995 apply to this project. It also states that current supplemental specifications and special provisions apply. The listing of supplemental specifications and special provisions that apply to this project would be included with the contract documents.

You should review the contract documents for any project with which you are involved. Be familiar with the supplemental specifications and special provisions that are required for that project.

PROJECT NUMBER

The PROJECT NUMBER is located in several places on the sheet. It is located in the block at the upper right hand corner of the sheet, at the bottom right of the sheet, and also in the left margin. The PROJECT NUMBER is BRF-18-5(95)--38-17. Also shown in the block in the upper right hand corner of the sheet are the R.O.W. (Right of Way) PROJECT NUMBER, which in this case, is NHSN-18-5(67)--2R-17, and the PIN, or Project Identification Number, which is 92-17400-4 for this bridge. The PIN is a DOT number assigned when a project first enters the system. It is used for planning and accounting purposes.

INDEX OF SHEETS

The INDEX OF SHEETS block, located above the STANDARD ROAD PLANS and STANDARD BRIDGE PLANS block, shows that there are 23 sheets in this set of drawings. The first sheet, Sheet No. 1, is the TITLE SHEET. (This can be verified by noting that Sheet No. 1 appears in the lower right hand corner of the Title Sheet.) The remaining sheets, 1A-22, are part of the BRIDGE DESIGN NO. 1895. The design number, 1895, is assigned by Iowa DOT. It indicates that this is the eighteenth bridge project designed for Cerro Gordo County in the calendar year 1995. "

STANDARD ROAD PLANS

The STANDARD ROAD PLANS block above the REVISIONS block, shows that there are no standard road plans applicable to this project.

STANDARD BRIDGE PLANS

The STANDARD BRIDGE PLANS block, located to the right of STANDARD ROAD PLANS block, indicates that there are no standard bridge plans which are applicable to this project. This is not to say that there are no standard sheets in this set of plans. If you leaf through the plans and examine the bottom margin of each sheet, you will note that there are two standard sheets in this set of plans. However, even though this set of plans contains standard sheets, it is not a standard set of plans. Standard plans are normally associated with county bridges. They can be modified to fit each situation.

Standard sheets are also modified to fit the situation. Dimensions, elevations, and notes for each project are added to the standard sheets before they are included in a set of plans.

REVISIONS

The REVISION block, located lower-right of center, shows that here have been revisions made to this set of drawings.

CONVENTIONAL SYMBOLS

The signs and symbols used in this set of drawings are shown in the upper left hand corner of the Title sheet.

PROJECT LOCATION

The project location map is shown in the center of the Title sheet. The exact location of the project is indicated by an arrow pointing to relocated U.S. 18. The Township is T-96N, and the Range is R-20W. The scale for the location map is shown below it, and north is indicated by the compass arrow located near the left margin of the title sheet.

LETTING DATE

The LETTING DATE for this project is shown in the lower left margin. The LETTING DATE is the date that bids for the project are due. It is September 24, 1996.

STATE CONTROL SECTION NUMBER

The STATE CONTROL SECTION NUMBER, 17-1600, is assigned by the planning Division of Iowa DOT. The number 17 refers to Cerro Gordo County, and the number 1600 refers to a particular segment of U.S. 65.

FILE NUMBER

The file number, FILE NO., is assigned by Iowa DOT. All correspondence and contract documents related to this project will be filed and archived using this number, 28908. You have completed the portion of this course that examines the information on the TITLE SHEET. There are no questions for you at this time. You can now go on to the next segment of the course which examines the GENERAL NOTES AND QUANTITIES.

GENERAL NOTES AND QUANTITIES

TITLE BLOCK

Turn now to Sheet number 2, which follows revision sheet number 1A. This is also Design Sheet 1. From now on, the plan sheets will be referred to by their Design Sheet number. The title block in the lower right hand corner of the sheet indicates that this sheet contains TOTAL QUANTITIES AND GENERAL NOTES. The title block also indicates that this sheet is part of the design for a 70.5 m x 27.3 m PRETENSIONED PRESTRESSED CONCRETE BEAM BRIDGE. The bridge has two 35.250 m spans. The center of the bridge is located at STA. 2257 + 77.884. This drawing was prepared in July, 1996. The bridge is located in CERRO GORDO COUNTY, and this is DESIGN SHEET #1 OF 20 SHEETS. This is DESIGN NO. 1895.

TOTAL ESTIMATED BRIDGE QUANTITIES

The TOTAL ESTIMATED BRIDGE QUANTITIES table is located in the upper right hand corner of the sheet. For each item for which quantities have been determined, the following information is provided: ITEM CODE, ITEM, UNIT, quantity in the PIER, quantity in the SUPERSTRUCTURE AND 2 ABUTMENTS, and the TOTAL quantity. For example, 2403 - 100010 is STRUCTURAL CONCRETE. The units for structural concrete are m³. The quantity of structural concrete in the 2 Piers is 96.8 m³. The quantity of structural concrete in the SUPERSTRUCTURE AND 2 ABUTMENTS is 635.0 m³, for a total of 731.8 m³. Note the other materials, their units, and their quantities.

Note that the designation for the bearing piling is HP 250 x 62. This is one of the standard designations for structural steel shapes as determined by the American Institute of Steel Construction (AISC). HP refers to piling which is H-shaped. The number 250 refers to the distance between the flanges, outside to outside, which in this case, is 250 mm. The number

62 refers to the weight of the piling per linear meter, which in this case is 62 kilograms per meter.

Sometimes it is more convenient to treat an item as Lump Sum, rather than to determine quantities. This has been done for item 2533 - 100000 MOBILIZATION. The abbreviation for Lump Sum is LS.

Examine items 2407 - 100435. There are a total of 28 pretensioned, prestressed concrete beams. The beams are of one type, D35M. Turn to Design Sheet 18, BEAM DETAILS. This is a standard detail sheet for pretensioned, prestressed beams. This sheet will be explained later. Return now to Design Sheet 1.

The next item to examine in this table is item 2402 - 120000, which is the excavation quantity. Classes of excavation have a definite meaning, but in order to understand them, you must refer to the Iowa D.O.T. Standard Specifications for Highway and Bridge Construction, Series of 1995, sometimes referred to as the Orange Book. The Classification of Excavation for Structures is found in Division 24, Structures. From paragraph 2402.11, the definitions for each Class are as follows:

"Class 20: Includes all excavation for bridges above the excavation classification line shown on the plans and not classified as Class 22.

For clarification:

"Class 22: The measured volume of granite, trap, quartzite, chert, limestone, sandstone, hard shale, or slate in natural ledges or displaced masses. It shall also include the estimated or measured volume of rock fragments or boulders having a volume 0.03 m³ or greater."

ESTIMATE REFERENCE INFORMATION

This series of notes provides information concerning the items in the table above it on the sheet.

For item 2403 - 100010 preformed expansion joint filler is specified. Paragraph 4136.03 indicates that there are four types of preformed expansion joint filler and sealer, namely:

- A. Resilient Filler
- B. Polyethylene Joint Filler
- C. Elastomeric Joint Seals
- D. Preformed Urethane Foam Expansion Joint Filler

The types of fillers to be used on this project will be detailed later in the plans. You should then review paragraph 4136.03 of the standard specifications to see what requirements and standards (ASTM, AASHTO) apply.

Item 2403-100010 includes costs of all preformed expansion joint filler required and all preformed elastometric compression joint sealer required. Includes cost of furnishing and placing subdrain (including excavation, granular backfill and porous backfill at abutments). Includes cost of all rubberized membrane waterproofing.

SPECIFICATIONS

In the lower right hand corner of the page, there is a note regarding the design and construction specifications. AASHTO series of 1992 governs the design of this bridge. AASHTO stands for the American Association of State Highway and Transportation Officials.

DESIGN STRESSES

The next note relates to the design stresses for the various materials in the bridge. AASHTO specifications govern the stresses for the reinforcing steel, which is Grade 400. Grade 400 refers to the yield strength of the steel, as specified by ASTM specifications. Deformed reinforcing bars typically used in structural concrete are covered by ASTM A-615. There are two minimum yield strength levels for reinforcing steel covered by that specification. They are 276 MPa, designated as Grade 270, and 414 MPa designated as Grade 400.

The specified compressive strength for the concrete for this bridge, designated as f'_c , is 24 MPa.

For the prestressed concrete beams, the note on design stresses refers you to Design Sheet 18. Turn now to Design Sheet 18, BEAM DETAILS. Note DESIGN STRESSES in the bottom center. The concrete for the beams is required to have a specified compressive strength of 52 MPa at 28 days. Note that this value is higher than that specified above for the other structural concrete in the bridge. This is not unusual. Various parts of a bridge, depending on the loads they are required to carry, may have different specified strengths.

GENERAL NOTES

The GENERAL NOTES begin on the left side of Design Sheet 1. These notes provide information which is useful to the contractor and which clarifies the scope and condition of the work. Most of the notes are self explanatory. You should review all of the notes now so that you know what is contained in them.

Before going on, you should answer the questions which pertain to this sheet.

SITUATION PLAN

Turn now to Design Sheet 2, SITUATION PLAN. This sheet shows both a section view of the bridge, at the top of the page, and a plan view.

LONGITUDINAL SECTION

See Design Sheet 2, SITUATION PLAN, for the Longitudinal Section Along R/L U.S. 65. Running from left to right, through the section view are numbered horizontal lines. These are reference lines for elevation. They range from 360 m to 380 m above mean sea level.

Starting with the elevations at the top left of the section, let's review the various elevation notes. We will proceed from top to bottom, starting at the left. The first note indicates that at the centerline of the west abutment bearing the GR. elevation is 377.423 m. GR. stands for Grade.

The elevation, 377.423, is that of the top surface of the pavement directly over the centerline of the abutment. It is not the elevation of the abutment bearing surface.

The bottom of the abutment footing is at EL 374.470. The adjacent berm has an elevation of 375.070. Thus, it will be necessary to excavate below the final berm level to prepare a place for the concrete for the abutment footing.

The dotted line below the abutment footing is a representation of the steel bearing piles that must be driven to support the bridge abutment. As the note indicates, the piles are 17.5 meters long, and they are 250 x 62 Kg/m piles. The note also states that the hole for the bearing pile is to be prebored to an elevation of 372.000. The cross hatched area that is intersected by the bearing pile represents the existing grade of the project. From it we can see that it will be necessary to fill to the new grade at the bridge elevation. The berm under the bridge is designated at a 2.5:1 slope. This means that for every two and one half meters horizontally, the berm drops one meter vertically.

Moving to the right, there is a note pointing out the concrete barrier rail that is to be installed along the sides of the bridge.

Below that, the contractor can see that the minimum clearance here between the bottom of the bridge beam and the proposed grade line is 5003 mm. Next to it is a note that shows the proposed grade line elevations for relocated U.S. 18 to be 370.446 and 370.200.

The 12.5 m HP 250 x 62 steel bridge piles are necessary under the pier because the pier footings themselves do not bear directly on the bedrock (limestone). These piles will rest on the bedrock (limestone).

SITUATION PLAN

Examine Design Sheet 2, which is an overhead view of the bridge site, and SITUATION PLAN. A series of rectangles and pie shapes outlined by solid lines run along the west and east of the roadway near the bridge, and they also continue under the bridge as dotted lines. These lines represent the slopes of the embankments supporting the bridge approaches and the abutments. Near the center and top of the SITUATION PLAN, the horizontal dimensions

between key features of the bridge are noted here. For example, you can see that the distance between centers of the pier and abutment bearings is 30.25 m.

The distance between the centerlines of the south abutment, pier and north abutment are also shown. Verify for yourself that the two dimensions add up to 70.5 m.

The dotted lines within the bridge represent two things. The dotted lines made up of the shorter dashes represent the edge of the pavement for relocated U.S. 18. The dotted lines with the longer dashes represent the substructure of the new bridge.

At either end of the bridge is a parallel set of dotted lines running perpendicular to the bridge. These lines represent a horizontal drain tile.

Near the right end of the bridge the width of the roadway is shown as 12 m. This is measured from inside of the bridge rail to the 3.3 m median.

There is a note on the east side of the berm which says "subdrain sloped downward 0.02 m per 1.0 m from Centerline of Roadway to extend through fill (TYP at both abutments)". This provides needed information with respect to the slope of the drain.

The subdrain is described in the fourth paragraph of the GENERAL NOTES, Design Sheet 1. Turn now to those notes. They are self-explanatory, but you should re-read them at this time. Note that the contractor has a choice of using flexible tubing or short lengths of concrete or clay tile, but that the ends must be 1830 mm lengths of corrugated metal pipe (CMP) that protrude a minimum through the foreslope. Also note the requirement for a 10.0 mm galvanized mesh screen to serve as a rodent guard. You should also read section 4143.01C of the Standard Specifications. That section details the specification requirements for standard subdrains.

Return to Design Sheet No. 2, in the center right of the figure, there is the note SURVEY CENTERLINE U.S. 65. This note indicates that the survey centerline is not the same as the bridge centerline. This is the result of an office relocation of the road centerline relative to the bridge location.

BENCHMARK LOCATION

Refer now to the top right corner of Design Sheet 2. You will see the note: B.M. (Benchmark) No. 50 STA. 2273 + 31.8 - 173.7 m LT., RR SPIKE N POWER POLE, ELEV. 371.683 m. This indicates that there is a rail road spike in an existing power pole that serves as a bench mark. It is 173.7 m left of the road centerline, and the elevation (top of spike) is 371.683. This benchmark can be used for reference until such time as demolition of the existing bridge is begun. It will then have to be transferred to another location.

PROPOSED GRADE

Below the PROFILE information on the sheet, there is a pair of intersecting lines labeled PROPOSED GRADE ON U.S. 18. Because the bridge is over a relocated highway and not a river or stream it is helpful for the contractor to know the profile of the highway. In this case, the proposed grade on U.S. 18 is a vertical curve with a P.I., point of intersection of tangents, at 188 + 00.000 and an elevation of 371.350. The exiting tangent of this curve is -0.205%. Therefore, the tangent drops 205 mm vertically for every 100 m horizontally. The second profile is for the proposed grade on U.S. 65. These lines are the tangents for the vertical curve for the bridge and its approaches. You have already covered vertical curves in detail in the Highway Plan Reading Course. You may wish to review that material now. The slope of the tangent of the curve approaching from the south is +1.400%. This means that the tangent rises 1.4 m vertically in every 100 m horizontally. The slope of the tangent to the curve departing to the north is -1.550%, which means that the tangent drops 1.55 m vertically in every 100 m horizontally. V.C.= 320 m means that the length of the vertical curve, measured horizontally, is 320 m. P.I. stands for point of intersection of tangents. The P.I. is an imaginary point located at station 2257 + 50.000, which is slightly west of the center of the bridge. The elevation of the Point of Intersection is 378.600. This is above the roadway.

TRAFFIC ESTIMATE, LOCATION, CURVE DATA CENTERLINE U.S. 18

Continuing on the right side of the Design Sheet 2 there are three more important pieces of information. The first is a TRAFFIC ESTIMATE. The estimate for 1989 was 4510 vehicles per day (vpd). A projected traffic volume for 2016 was estimated to be 6900 vehicles per day with 13% trucks. This information aides the designer in determining the required strength and components for the bridge in question.

The LOCATION section tells the contractor that the bridge is located in Township 96 North, Range 20 West, Section 27/28, Mason Township, Cerro Gordo County.

CURVE DATA CENTERLINE U.S. 18 gives the contractor the new alignment data for relocated U.S. 18. The PI station is at 192 + 67.567. The delta angle is 14° 46' 55" LT and the tangents are 252.950 m long. The length of the curve is 503.092 m with an external of 16.34 m. The contractor can also see that the radius of the curve is 1950 m, and the "e" value of the curve is 0.033. The "e" value refers to the maximum rate of superelevation in the curve.

Well, what does this all mean in terms of building the bridge, and how is it to be used? Primarily, the information is for the use of the designers of the bridge. They use the information above to calculate the elevation of the bridge deck surface at various points along the curve. The calculations, which are beyond the scope of this course, are not shown in these plans, but the results are. Please turn now to Design Sheet 12. This sheet shows the top of slab elevations for the bridge. The elevations were determined by calculating offset distances between the tangents to the curve and the curve itself. These elevations are those that the contractor must achieve in constructing the bridge and roadway. Remember, the top of the roadway follows the same geometry as the curve. Other elevations for the roadway surface within this set of plans have also been determined by calculating an offset distance between the tangent and the vertical curve.

Design Sheet 3 is also a situation plan. At the top of this sheet is a simplified view that shows the contractor the location of the six test holes that were drilled for the project. These are marked by a small circle containing a dark hour glass. They are labeled F-6705 through F-6710; Design Sheet 4 provides the detailed information about what type of soil has been encountered in each test hole, and the location of the water table. Below the plan, on Design Sheet 3, is a profile

of the soil borings, showing the profile of the soil encountered and an approximate water table. This view gives the station and location of the test hole shown. The horizontal lines on the profile designate the elevation above sea level. This sheet will be discussed in detail later.

The remainder of the information on Design Sheet 3 is self-explanatory. You have now completed the information related to the SITUATION PLAN. Complete the questions pertaining to this sheet before going on to the next section.

SOIL PROFILE SHEET

SOUNDINGS

Now turn to Design Sheet 4. The data represented here is for the six test holes that were drilled in order to determine the soil conditions in the immediate vicinity of the bridge. There is a separate set of data for each of the six holes. Look at the information for two holes, i.e., Test Hole F-6709 and Test Hole F-6710. To determine the location of these two holes you will need to refer back to Design Sheet 3. Test Hole F-6710 is located at the south-west corner of the proposed bridge at the site of the west end of the footing for the south abutment. Test Hole F-6709 is located at the site of the west footing for the pier. Return back to Design Sheet 4.

The sounding data for TH# F-6710 shows the following information:

- The hole is located at STA. 2257 + 39
- The hole is located 2.1 m left of the centerline of the bridge. (LT 2.1 m)
- The elevation of the water level in the hole at the time of the boring was 369.25 m
- The depth of the hole is 13.50 m
- The first 0.30 m of the hole contains stiff sandy silty clay
- The next 11.0 m contains firm glacial clay with occasional sand seams and occasional silt seams
- The next 0.70 m contains limestone.
- The remaining 1.5 m contains medium hard limestone with occasional separation.

- The bottom of the hole has an elevation of 357.25 m
- The date of the boring was 12-14-94

Below the title SOUNDING DATA, Design Sheet 5, there is a note: “* N=Number of blows per 0.3 meters of penetration.” This pertains to Test Hole F-6709 and it relates to the boring test procedure. Geotechnical engineers use this data to measure the probable bearing capacity of the soil. The higher the number of blows per foot of penetration, the higher the probable bearing capacity of the soil. Such tests are normally conducted in accordance with AASHTO T206, penetration Test and Split-Barrel Sampling of Soils. As you can see the number of blows per meter of penetration goes from 11 blows near the surface to 100 blows in the limestone. Good quality limestone is a good bearing material, so the number of blows to penetrate limestone is understandably much higher than for the surface soil.

The remainder of Design Sheet 5 is self explanatory. You should answer the questions for this sheet before advancing to the next section.

WEST PIER DETAILS

Turn now to Design Sheet 5, West Pier Details. This sheet shows the details of the dimensions and reinforcing for the West Pier. It provides a plan view, elevation view, two section views, a column section, a footing end view, a pile plan and a list of the types and quantities of reinforcing required. This bridge has two piers. Note that this bridge has two spans however, the pier and superstructure were designed with a construction joint along the centerline of the bridge, therefore there is a west pier and east pier. Each bridge pier has a pier cap, a set of three pier columns, and a footing for each pier column. Each pier cap provides stepped bearing surfaces for the longitudinal bridge beams. The caps transfer the beam loads to the pier columns which transfer the loads to their footings. The footings transfer the loads to the limestone. Piling is necessary because the pier footings do not bear directly on the limestone.

PIER CAP PLAN

The PIER CAP PLAN shows a view of the pier cap from above. The right side of the plan shows the top of the pier cap, whereas the left side of this view shows the top part of the cap cut away to reveal the placement of the reinforcing steel. As you can see from the illustration:

- The length of the bridge pier cap is 13.650 m
- The centerline of the first beam is 609 mm in from the left end of the pier cap.
- There are seven beams between the left end of the pier and the center of the pier. The spacing between the beams is 2072 mm except between the third and fourth beam which is 2021 mm. The bridge requires a total of 14 beams per span. Note that the beams are oriented with an 8° 20' skew.
- The distance between the east and west faces of the pier cap is 13650 mm.
- A small grid appears in the top of the pier cap, with the notations m1 and n1 with arrows pointing to the lines of the grid. The grid represents reinforcing steel in the concrete at that location.

At this point, it is probably wise to discuss reinforcing in general, and postpone our discussion of this grid and the Pier Cap Plan View.

REINFORCING STEEL

One of the most important tasks in reading structural plans is to be able to understand the configuration of the reinforcing steel that is used to reinforce the concrete. Reinforcing steel comes as round rods called bars. These bars normally have a raised pattern on the surface to assist in providing a good bond to the concrete (see Figure 6). This surface pattern is called a deformation, and such bars are called deformed bars. Reinforcing bars vary in type and grade of steel, length, shape, diameter and placement. Because of the heavy loads that highway structural elements carry, there is often a significant amount of reinforcing present. This not only makes it difficult to determine where each bar should be placed, but space limitations often make it difficult to get the bars in the right location. Nevertheless, if the structure is to safely carry the

loads intended, the contractor must place the bars where the designer intends for them to go. The placement of every bar must be verified in the field. Some of the things that can go wrong include using the wrong size bar, placing bars in the wrong location, placing bars too close together, not providing for the required amount of concrete (cover) over the bar(s), turning bends in the wrong direction, and omitting bars. Perhaps the best place to begin is to look at section A-A and the Reinforcing Bar list for the West Pier, located in the lower right hand corner and upper right portion of Design Sheet 5, respectively. Section A-A is a cut-away view of the pier cap.

It corresponds to the view that you would get if you were to cut the pier cap at line A-A. It shows the placement of the reinforcing steel in the cap. You will see arrows and lines pointing to parallel lines and solid dots.

The parallel lines and dots are reinforcing steel in the concrete. Consider the line leading from a1 near the top of Section A-A. The line and its eleven branches point to 11 dots near the top of the cap. Each dot represents a bar of reinforcing steel which runs in a direction perpendicular to the sheet. They are called longitudinal bars because they run the length of the top of the pier cap. You can see this if you look at the left side of the PIER CAP PLAN. You will note the designation a1 with 7 arrows pointing to the top bars.

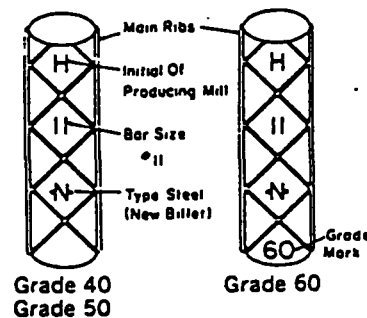


Figure 6. Deformations and Markings on Steel Reinforcing Bars
(Courtesy of the Concrete Reinforcing Steel Institute)

ASTM STANDARD REINFORCING BARS (Figure 7)

The a in a1 is a convention used by Iowa DOT to indicate the location of the bar. "a" bars are often located near the top of a structural element. "b" bars are often located near the bottom of an element. As an example, the bars in the bottom of the pier cap are labeled as b1. Bars in the footing are given the designation f. Note the designation f1, f2, etc., in the reinforcing list. Those bars are located in the footing.

The last number in the bar designation is used to differentiate between types of bars in the same location. Note the designations a1, and a2 in the reinforcing bar list. The a tells us that these bars are near the top of the pier cap. The a1 bars are #25's; the a2 bars are #15's.

To determine more information on the a1 bars, look at the reinforcing bar list. That list tells us that the a1 bars are located in the top of the cap and that they are longitudinal bars. There are 11 of those bars in the cap. Each bar is 13550 mm long, and the total mass of all 11 bars is 585 kg.

Reinforcing steel is normally cut to length and shaped by the supplier before shipping it to the site. The reinforcing steel for this bridge would be cut and bent by the fabricator then bundled and tagged for shipment. These bars would probably be cut to their exact length, and would be shipped bundled together and tagged as to their identity (a1).

Let us now examine Sections A-A and B-B, PIER CAP PLAN and NON-COATED REINF. BAR LIST - PIER. Section A-A is taken through the deepest portion of the cap. The solid line near the top represents the top of the lower step. The dimensions on the left side of Section A-A are center-to-center dimensions. The distance between the upper face of the concrete at the lowest step and the center of the a1 bars varies, and the distance between the upper seven and lower four is 100 mm. The a1, a2, b2, and b1 bars will be tied with wire to the inside of the cap hoops, c1, c2, and c3. The center to center distance between the a1 bars and the a2 bars is 164 mm. The distance between the center of the b1 bars and the bottom face of the pier cap is 80 mm.

**ASTM A615 CHART
FOR REINFORCING STEEL BARS**

| Inch-Pound Bar Size Designation | Nominal Mass lb./ft (kg/m) | | Nominal Dimensions | | | |
|---------------------------------------|------------------------------------|---------|---------------------------|--------|--|--------|
| | | | Diameter in. (mm) | | Cross Sectional Area in ² (mm ²) | |
| #3 | 0.376 | (.560) | 0.375 | (9.5) | 0.11 | (71) |
| #4 | 0.668 | (.994) | 0.500 | (12.7) | 0.20 | (129) |
| #5 | 1.043 | (1.552) | 0.625 | (15.9) | 0.31 | (200) |
| #6 | 1.502 | (2.235) | 0.750 | (19.1) | 0.44 | (284) |
| #7 | 2.044 | (3.042) | 0.875 | (22.2) | 0.60 | (387) |
| #8 | 2.670 | (3.974) | 1.000 | (25.4) | 0.79 | (510) |
| #9 | 3.400 | (5.060) | 1.128 | (28.7) | 1.00 | (645) |
| #10 | 4.303 | (6.404) | 1.270 | (32.3) | 1.27 | (819) |
| #11 | 5.313 | (7.907) | 1.410 | (35.8) | 1.56 | (1006) |
| #14 | 7.65 | (11.39) | 1.693 | (43.0) | 2.25 | (1452) |
| #18 | 13.60 | (20.24) | 2.257 | (57.3) | 4.00 | (2581) |

**ASTM A615M CHART
FOR REINFORCING STEEL BARS**

| Metric Bar Size Designation | Nominal Mass (kg/m) | Nominal Dimensions | |
|-----------------------------------|------------------------|--------------------|--|
| | | Diameter (mm) | Cross Sectional Area (mm ²) |
| #10 | 0.560 | 9.5 | 71 |
| #13 | 0.994 | 12.7 | 129 |
| #16 | 1.552 | 15.9 | 199 |
| #19 | 2.235 | 19.1 | 284 |
| #22 | 3.042 | 22.2 | 387 |
| #25 | 3.973 | 25.4 | 510 |
| #29 | 5.060 | 28.7 | 645 |
| #32 | 6.404 | 32.3 | 819 |
| #36 | 7.907 | 35.8 | 1006 |
| #43 | 11.380 | 43.0 | 1452 |
| #57 | 20.240 | 57.3 | 2581 |

Figure 7. ASTM Charts For Reinforcing Steel

Note that the length of the b1 bars is 11 060 mm. They span from column pier to column pier, but they do not extend into the ends of the piers. You can see by looking at the elevation view that the b2 bars continue on the same line as the b1 bars into the ends of the pier caps. The ends of the b2 and b1 bars are lapped at the columns. This can be seen by examining the elevation view of the pier and noting that the line which represents these bars.

The b2 bars are 2 120 mm long; there are 8 of them, and their combined mass is 40 kg. They are shaped with an upturn at the end. The detail of that upturn is shown in the BENT BAR DETAILS, underneath the REINFORCING BAR LIST. The horizontal portion is 800 mm long, and the sloped portion is 1 320 mm long, measured along the bar.

The cap hoops are labeled c1, c2 and c3. The c1 hoops are used in the center portion of the pier cap, as you can see in Section A-A and the elevation view of the pier. The c2 and c3 hoops are used in the cantilevered ends of the pier cap. Two hoops are used at each transverse location. They overlap each other at the centerline of the cap. The details of the hoops are shown in the BENT BAR DETAILS. The bar that forms each hoop is bent into a rectangular shape. The length of the bar that is used to shape the rectangle is 300 mm longer than needed to form the rectangle. The 150 mm ends are then bent over as shown. There are 64 cap hoops, type c1, spaced out at 32 locations in the central portion of the cap, and 18 cap hoops, type c2, spaced out at 9 locations in the eastern cantilevered end, and 18 cap hoops, type c3, spaced out at 9 locations in the western cantilevered end.

There are eight lengths of a2 bars along the sides of the cap. These bars are 15 mm in diameter, 13 550 mm long, and collectively, have a mass of 170 kg. These bars start 50 mm from the outside of the pier cap, run over the column, and into the central portion of the pier cap. Two inches of cover is provided between the face of the end of the pier cap and the end of the a2 bars. You can verify that the dimension is 50 mm by subtracting the length of the bars, i.e., 13 550 mm from the 13 650 mm length shown at the top of the plan drawing. It might appear to you that they start 85 mm in from the outside face of the concrete because there is a dimension 85 which appears at the left side of the WEST PIER ELEVATION view of the pier. That 85 refers to the 85 mm distance between the outside face of the pier and the centerline of the last pair of c3 hoops. The a2 bars go 35 mm beyond that line of hoops.

At this time we can continue our discussion of the grid of reinforcing shown on the PIER CAP PLAN at the centerline of the third beam in from the right. The bars are labeled m1 and n1. This grid represents additional reinforcing in the concrete of the cap under each beam. Below the cap is a note that reads: "NOTE: PLACE m1 AND n1 BARS UNDER ALL BEAMS EXCEPT AT LOW STEP." This tells us to place a grid of reinforcing bars of the type m1 and n1 at the location where each beam is to bear on the bridge cap except the beam at the low step. To determine what this means, we must look at the REINFORCING BAR LIST - PIER, in the upper right hand corner of the sheet.

Near the bottom of the table it shows that the m1 type bars are located in the steps and are oriented in the longitudinal direction. The shape is a straight bar. There are 24 of these bars; four at each of the interior beam locations. Each is 2 200 mm long, and their total mass is 83 kg.

The n1 bars run in the transverse (North-South) direction, at an 8°20' skew to the m1 bars. They are bent over on the ends. There are 49 such bars; eight at each of the five interior beam locations and nine bars in the highest step area. Each is 2 020 mm long (this includes the bends on each end), and their total mass is 155 kg. The actual dimensions are shown in the box labeled BENT BAR DETAILS, underneath the Reinforcing Bar List. The lower left hand corner of this box shows the n1 bars. Each is 1000 mm from outside of bend to outside of bend. The diameter of the pin that would be used by the fabricator to make the bend is given as 60 mm. The length of each bent leg is 510 mm.

Next, we will examine the reinforcing in the three pier columns. We will need to examine the WEST PIER ELEVATION and the COLUMN SECTION. The reinforcing in the column consists of vertical bars and a column spiral. The vertical bars are labeled d1. There are 14 of them, 6 200 mm long. They are 810 mm longer than the columns. The extra length sticks up into the pier cap and ties the two together. This is shown on the elevation view.

The spiral is prefabricated from one length of #15 rod. The note to the right of the column indicates that the spiral is to have a 800 mm outside diameter, with a 300 mm pitch. The pitch is the distance between spirals. As you can see from the COLUMN SECTION, the spiral is outside of the vertical reinforcing bars d1. The reinforcing bar list indicates that there are three spirals required, one for each column; the length of #15 bar in each is approximately 55 800 mm, and

collectively, the three spirals have a mass of 263 kg. The spirals also require spacers. These spacers are specified as L22x22x3. This is the designation for a very small steel angle which has equal legs of 22 mm and a thickness of 3 mm. There are four of them required for each spiral. They will be as long as the column and they are spaced 90 degrees apart around the spiral. The spacers maintain the 300 mm pitch distance between spirals.

Within the footings, as shown in WEST PIER ELEVATION and FTG. END VIEW, there are five different bars, i.e., f1, f2, f3, f4, and d2. The f1 and f2 bars are perpendicular to each other near the bottom of the footings. There are 48 f1 bars, 16 in each footing, spaced 150 mm on center, running in the longitudinal east-west direction. There are also 48 f2 bars, 16 in each footing, spaced 150 mm on center, running in the transverse north-south direction. Longitudinal and transverse in this case means with respect to the longitudinal and transverse axes of the pier, not the bridge.

The d2 bars are called dowels. There are 42 of them, 14 in each footing. They are bent bars, with the shorter (400 mm) legs tied to the bottom mat of reinforcing in the footings. The longer (2 100 mm) dowel legs extend upward from the footing, so they can be spliced to the d1 bars in the columns. This provides the reinforcing link between the column and footing, and ties the two together. This completes our discussion of the reinforcing for the various components of the bridge's west pier.

Pier Cap Plan, Continued

Let's return now to our general discussion of the features and dimensions of the pier cap. You will notice in the plan view that key ways are shown in the intermediate step and the pier top.

These key ways are depressions formed in the concrete by placing beveled 50.0 mm x 200.0 mm pieces of lumber in the top of the concrete at those locations. The notch formed by the key way is shown.

The purpose of these key ways is to provide for a mechanical interlock between the concrete of the diaphragms and the concrete of the pier. The mention of the diaphragm may come as a surprise to you, because it has not been mentioned or shown on the plans so far. The space between the prestressed concrete beams over each pier is to be filled with concrete. These rigid fillers are called diaphragms, and they serve to prevent lateral movement of the beams. Diaphragms will be discussed in more detail later. Right now, all you need to know is that the space between the beams at the piers will be filled with reinforced concrete diaphragms, and that the keys in the top of the pier are there to help provide for a mechanical interlock between the piers and the diaphragms.

Turn now to Design Sheets 9 and 10. The section view of the bridge superstructure is split, showing one half section near the abutment and one half section near a pier. If you examine the half section near the pier, you will note a grid of reinforcing between the bridge beams. That reinforcing is for the diaphragms at that location. This completes our discussion of the Pier Cap Plan. Return now to Design Sheet 5.

WEST PIER ELEVATION

The WEST PIER ELEVATION has been covered to some extent discussing reinforcing. However, let's finish it up now. First of all, note that the view is taken looking north. This means that the left side of the pier is to the west, and the right side is to the east. Secondly, observe the note SYMMETRICAL ABOUT CENTERLINE PIER EXCEPT AS SHOWN at the center of the view. This means that all of the elements of the pier to the right of the centerline are a mirror image of those to the left except where shown differently.

The vertical dimensions are shown to the sides of the piers.

Starting at the top:

- The distance between the top of the pier cap and the bottom of the footing is 7 675 mm.
- The distance between the top of the low step to the bottom of the west end of the pier cap is 900 mm.
- The distance between the top of the pier cap and the bottom of the east end of the pier cap is 985 mm.
- The pier cap bottom slopes down toward the column. The vertical fall is 300 mm. The horizontal distance for that sloped portion is 1 292 mm.
- The column length from the bottom of the pier cap to top of the footing is 5 390 mm.
- The distance from the top of the footing to the bottom of the footing is 1 000 mm.

Reviewing the horizontal dimensions:

- The distance between the point where the bottom of the pier cap stops sloping and the outside of the column is 75 mm.
- The outside diameter of the column is 915 mm.
- The distance between the outside (west) face of the pier cap and the centerline of the west column is 1 825 mm.
- The distance from the east side of the west column to the west side of the center column is 4085 mm.
- The distance between the centerline of the column and the centerline of the next column is 5 000 mm.

- The footing is 2500 mm². This can be determined by noting that it is 2500 mm from east to west, as shown on this elevation view, and that it is also 2500 mm from north to south as shown on the FTG. END VIEW.
- The distance from the sides of the footings to the sides of the columns they support is 792 mm.
- A square, beveled key way is required at the top of the column and the top of each column footing. The key way is formed by placing a 300 mm length of 75 mm x 300 mm wood, beveled on the edges, in the top of the concrete for each column and each footing. The key ways provide for mechanical linkage between the column and bridge cap, and also between the column and bridge footing.

Most of the information shown in the left hand portion of the WEST PIER ELEVATION was previously covered when the reinforcing steel was discussed. However, if you examine the west footing, you will see some notation that was not covered. The notation 300 CL. appears at the right of the footing. This means that there must be 300 mm of cover or clearance below the bottom bars in the footing.

CONCRETE PLACEMENT QUANTITIES

Concrete placement quantities on Design Sheet 5 are listed in a table below the Bent Bar Details. The cap contains 18.7 m³ of concrete, the columns contain 10.8 m³, and the footings contain 18.9 m³, for a total of 48.4 m³.

ESTIMATED WEST PIER QUANTITIES

The estimated quantities for this pier are listed in the table on Design Sheet 5 below Concrete Placement Quantities. The totals for structural concrete and reinforcing steel are a summary of the totals above. The total cubic meters of excavation, by class and meters of bearing piling are also shown.

PILE PLAN

Because the piers do not rest directly on the limestone, it is necessary to provide steel bearing piles under the footings of the pier. The pile plan at the bottom left hand corner of Design Sheet 5 is typical for each footing. It shows that there are 8-HP 250 x 62 steel bearing piles per footing. Each is centered 460 mm in from the edge. There is one pile on each corner of the footing and a pile between each of those piles on the east and west side of the footing. They are parallel to the center line of the pier cap. The eighth and ninth piles are located under the center of the footing. The corner piles that are in a line parallel to the center line of the pier cap, are at a 45 degree angle to the face of the footing. All of the other piles along the edge are perpendicular to the footing edge. The contractor is told in the pier notes that the piles shall be at an 8:1 slope in the direction shown on the plan.

PIER NOTES

Several important notes appear near the bottom left of Design Sheet 5. They are labeled PIER NOTES. The second note tells us that the exposed corners on the concrete are all to be filleted with a 20 mm beveled strip. This strip, often called a chamfer strip, is a piece of lumber about 20 mm wide, usually cut on a 45 degree angle, that is placed on the inside surface of the formwork at the corners to prevent sharp 90 degree corners for the concrete.

The first note requires 50 mm of concrete cover over reinforcing steel. This minimizes the chances of corrosion of the reinforcing steel, and hence, it minimizes the chance of the concrete spalling.

The third note states that all reinforcing steel must be wired in place.

The fourth note gives the design bearing for the pier piles as 490 kN.

The fifth note states that the dimensions shown on the pile plan are at the bottom of the footing. The piles are to be battered at a slope of 8:1 in the direction shown on the plan. Eight 12.5 m long HP 250 x 62 steel bearing piling are required for each footing.

The last note tell us that all dimensions are in millimeters unless otherwise noted.

This completes the discussion of the west pier. You should now go to Design Sheet 6, EAST PIER DETAILS. Questions relating to the pier details will follow the section on the next sheet.

EAST PIER DETAILS

Design Sheet 6 EAST PIER DETAILS is very similar to Design Sheet 5, except that it is for the East Pier . What is important here is to take notice of the differences between the East Pier and the West Pier. Let us start by examining the NON-COATED REINF. BAR LIST - PIER, and comparing it with the same list for the West Pier. There are no differences in the reinforcing of the two piers.

Note the difference in elevations for the bottoms of the footings and the steps on the pier caps are different for East Pier than they are for the West Pier. There is also a difference in the distance between the top of the pier cap and the west end of the pier cap.

This completes the discussion of the EAST PIER DETAILS. You should now complete the questions for this sheet and for the EAST PIER DETAILS before advancing to the section.

ABUTMENT DETAILS

Now turn to Design Sheet 7 and 8, ABUTMENT DETAILS. These sheets show some of the details of the two abutments. The abutments are identical in construction except that their elevations are different and each is supported by a different length of piling. From our review of Design Sheet 2 we know that the south abutment uses 17.5 m long piling, and the north abutment uses 18.0 m long piling.

PART REAR ELEVATION AT ABUTMENT shows the view one would see if one were standing behind the abutment, facing the bridge. The abutment consists of the abutment footing, which is the bottom part of the drawing, and an abutment diaphragm which surrounds the prestressed beams. The diaphragm is poured integrally with the pavement slab (See the SUPERSTRUCTURE NOTES, Design Sheet 9), and for this reason, the abutment is called an "integral abutment." The left section of the view has its right half cut away to reveal some of the vertical reinforcing in the diaphragm and the beams it surrounds.

WINGWALLS

Let's start at the left hand side of, Design Sheet 7, PART REAR ELEVATION AT ABUTMENT. The first item we encounter is a wingwall. To properly interpret the information on wingwalls, we need to examine several drawings on several sheets. PART PLAN, in the lower left hand corner of Design Sheet 11, is an overhead view of the south end of the bridge. The north end would be the same, except that it would be a mirror image. The wingwalls extend along the roadway, in back of the bridge. Their function is to retain the earth and pavement in the immediate vicinity of the bridge, and to serve as a guide for vehicles entering the bridge. As you can see, the end section of the barrier rail that sits on top of each wingwall is turned outward. This is done for safety. If a vehicle were to approach the bridge too far to the left or right, the wingwalls would force the vehicle back to the roadway, thus reducing the chance of a head-on collision with the bridge barrier rail.

The view PART LONGITUDINAL SECTION NEAR GUTTER, top left, Design Sheet 11, shows a side view of the wingwall and the 2 100 mm extension of the barrier rail on top of the wingwall. You can see that the top to bottom dimension tapers from 1 930 mm nearest the bridge to 1 020 mm at the ends. The wingwall also tapers in thickness. As shown on the PART PLAN and PART SECTION C-C, same sheet, it is 480 mm nearest the bridge, and 355 mm at the outer end.

The views PART END VIEW AT ABUTMENT and PART SECTION C-C, Design Sheet 11, show some of the details of the reinforcing. There are 12 h1 bars in each wingwall; six in the road-side face and six on the outside face. The top three bars in each face run horizontally, and the bottom three bars run at an angle to the horizontal. As shown in the REINF. BAR LIST on Design Sheet 15, there are a total of 48 of these bars. Each is 2000 mm long.

Protruding into the wingwall in Design Sheet 11 from the abutment footing and abutment diaphragm are h2 and d9 bars. These bars and the h1 bars must lap a minimum of 710 mm. Note that the bottom two bars are bent in the field to conform to the alignment of the h1 bars. These bars are also shown in SECTION A-A, which is a section view of the wingwall looking

toward the abutment. A section view of the "key" portion of the wingwall is also shown in this view.

The PART END VIEW AT ABUTMENT, Design Sheet 11, shows that there are also vertical bars, labeled s1, in the wingwall. The lengths of each are shown, i.e., 1 790 mm, 1 650 mm, etc., reading from left. As shown in PART SECTION C-C: the spacing between each of these s1 bars is 325 mm

- There are 6 spaces.
- The dimension between the outside face of the end of the wingwall and the center of the first s1 bar, is 75 mm.
- The s1 bars are outside of the horizontal h1 bars.
- A vertical keyway, mentioned above, formed in the abutment diaphragm by a nominal beveled 50 mm x 200 mm helps tie the diaphragm and wingwall together.

The fact that there is a keyway in the diaphragm tells us that the diaphragm would be placed first; then the wingwall. Likewise, the keyway in the top of the wingwall, shown in SECTION D-D, same page, tells us that the wingwall will be placed prior to the barrier rail extension.

At the top of each wingwall, as shown in PART END VIEW AT ABUTMENT, c bars tie into the extension of the barrier rail. These same bars are shown in SECTION D-D. The details of these c bars are shown on Design Sheet 19 and will be discussed later because they are considered part of the barrier rails.

ABUTMENT FOOTING

The overall shape of the abutment footing is shown in the NORTH AND SOUTH ABUTMENT STEP DIAGRAMS, in the lower left portion of Design Sheet 8. You will note that it is stepped, and that the two diagrams show the elevations of these stepped bearing surfaces as well as the elevations of the bottoms of each footing. For example, the elevation of the highest step on the south footing is 375.831 m, and the elevation of the bottom of the footing of that same abutment is 374.761 m at the same location. As shown in PART SECTION B-B, the

footing is 920 mm thick from front to back face. In examining the drawings of the abutment, be careful to distinguish between the footing and the diaphragm which it supports. Everything above the stepped bearing surfaces of the footing is part of the diaphragm. The footing has a keyway formed in its top surface, as shown in PART SECTION A-A, Design Sheet 7. This will key the abutment diaphragm concrete to the footing concrete. The footing concrete will be placed first. The resulting joint between the footing and the diaphragm is shown as a solid line in the section views, and is labeled as a CONSTRUCTION JOINT in the HALF SECTION NEAR NORTH ABUTMENT view on Design Sheet 9.

Look now at PART REAR ELEVATION AT ABUTMENT, Design Sheet 7. You can see that the total width of the footing is 28260 mm.

Note now the long vertical bars shown in PART REAR ELEVATION AT ABUTMENT. In this view, they are labeled g1. However, as with the horizontal bars, their label depends on whether they are in front or back face. Look at the view, PART SECTION B-B, Design Sheet 8. The vertical bars on the embankment side (Back Face) of the footing are labeled g1. The vertical bars on the bridge side are labeled g2. These vertical bars, g1 and g2, tie the footing and the diaphragm together. They are tied to the upper two rows of f1 and f2 bars. Note that the bottoms of these bars do not maintain the same elevation across the footing. This is because the tops of these bars follow the profile of the roadway. You can see that they maintain a constant distance from the top of the slab.

Just as the bridge piers had hoops that run transversely to the long axis of the piers, the abutment footings have hoops that do the same. They are shown in view PART SECTION B-B, Design Sheet 8. They are labeled p1. These hoops are placed in lapped pairs. The bottom hoop of each pair goes around the bottom three rows of horizontal reinforcing, and the top hoop of each pair goes around the top three rows of horizontal reinforcing. Note that there must be 75 mm of clearance between the bottom of the hoops and the bottom of the abutment footing. The REINF. BAR LIST, Design Sheet 15, tells us that there are 352 of these hoops, or 88 pairs per footing. To determine the spacing, we must look at the ABUTMENT PILE PLAN at the top of Design Sheet 8. One pair of hoops is placed 300 mm from each pile. In between, the spacing

between pairs of hoops is 230 mm. On the outside of each of the outer piles, there is one set of hoops, located 300 mm from the centerline of each pile.

PART SECTION B-B shows the spiral reinforcing required around each pile. The note explains the size of the spiral and the number of turns required. Note that 2 spacers are required to hold the spirals apart. There are 24 piles used in each footing. The space between each is 1 290 mm. The top of each pile extends 600 mm into the abutment footing.

ABUTMENT DIAPHRAGM

The abutment diaphragm consists of the reinforced concrete that is placed above the footing and around the prestressed concrete beams. The abutment diaphragms are to be placed monolithically with the slab. This means that the slab and diaphragms will be poured together, and no cold joint between them will be permitted.

The scheme of reinforcement is shown in several views. Let's start with the PART REAR ELEVATION AT ABUTMENT, Design Sheet 7 and PART SECTION B-B, Design Sheet 8. The longer vertical bars are labeled g1 on the back face, and g2 on the front face. There are 164 g1 bars, 2 630 m long, and they are epoxy coated as shown on design Sheet 15. There are 168 g2 bars, 2 250 mm long, and they are not epoxy coated.

Return to the PART REAR ELEVATION AT ABUTMENT, Design Sheet 7. This view shows three more set of vertical bars: g3, g4 and k1. Side views of these bars are shown in PART SECTION B-B, this sheet, and PART LONGITUDINAL SECTION NEAR GUTTER, Design Sheet 11. The configuration and dimensions of the bent shape are shown in the BENT BAR DETAILS, Design Sheet 15. The REINF. BAR LIST indicates that there are 156 of the g3 bars, and they are epoxy coated. PART SECTION A-A, Design Sheet 7, shows the plan view with the required spacing and laps for these bars as well as some of the longitudinal and all of the vertical bars in the diaphragm. Note that at the beam locations, these bars must be bent to the side to avoid the beam. As the note indicates, this is a field bend. This view shows that the first set of k1 bars adjacent to each beam is 400 mm from the centerline of the beam. Then there are four spaces at 330 mm and a space at 352 mm. These are noted on the plan view but may not be

visible on this plan sheet. The note to the right of the section indicates that there are 70 of these bars in the back face.

The horizontal longitudinal reinforcing for the abutment diaphragms and approach paving seat consists of d2, d3, d5, d6, and d7 bars. You should be able to identify the location, length and quantity of each of these bars by referring to Design Sheets 7-15. Note the lap specified for the d6 and d7 bars in PART SECTION A-A.

BEAM SEATING DETAILS

As shown in PART REAR ELEVATION AT ABUTMENT, each beam rests on a small steel beam labeled S 75 x 11 on top of the abutment. "S" stands for American Standard Beam. "75 mm" is the depth of this small beam in millimeters. "11" is its weight in kilograms per linear meter. The length of each of these small beams is 520 mm", as shown in Design Sheet 9.

Also shown on the elevation view is a horizontal rod labeled coil rod. Figure 8a shows a coil rod. Prior to placing the diaphragm concrete, the coil rods are threaded into ties (Figure 8b) which are cast into each of the precast beams. PART SECTION B-B, Design Sheet 8, shows that this rod is located very near the end of the beam. The COIL TIE DETAILS, Design Sheet 18, shows that these coil ties are 19 mm diameter.

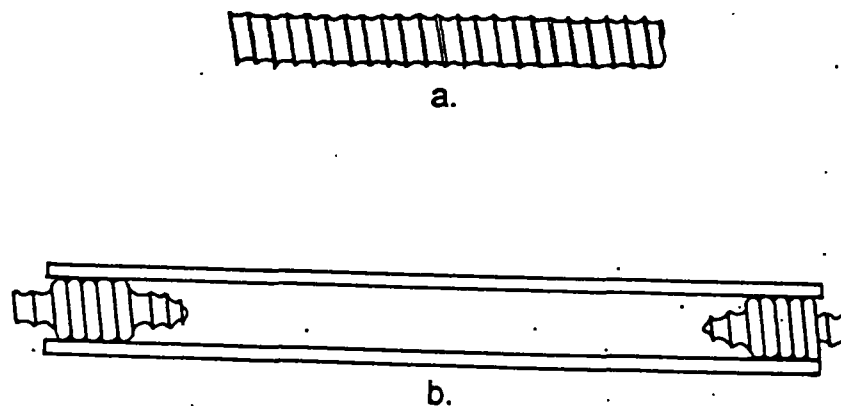


Figure 8. a.) Coil Rod b.) Coil tie showing rods inserted in threaded ends.

PART REAR ELEVATION AT ABUTMENT, Design Sheet 7, also shows a tl bar at the beam bearing locations. This bar is placed between the beam and the abutment footing. It is horizontal under the beam, then it is turned up at the ends. The detail of the bend can be seen in the BENT BAR DETAILS, Design Sheet 15. As shown in the section views, this bar is placed inside the g2 bars.

BACKFILL DETAILS

The requirements for backfill behind the abutment are entailed in the view GRANULAR BACKFILL DETAIL on this Design Sheet 8. The dotted lines and notes show the limits of Class 10 and Class 20 excavation. You will remember that the Class 10 excavation is normally performed by the road contractor, and the Class 20 excavation is done by the bridge contractor. Porous backfill is to be placed under and around the subdrain, with a minimum of 100 mm under the drain. Porous backfill is specified by Section 4131 of the Standard Specifications.

Granular backfill is placed above the porous backfill up to a level 700 mm below the approach paving seat. Granular backfill is covered by section 4133 of the Standard Specifications. The special backfill above the granular backfill is to be placed by another contractor and is not included in this contract.

Note the pay limit for the granular backfill. It is defined by a 1:1 backslope starting at a point which is 660 mm measured horizontally from the bottom of the abutment footing.

ABUTMENT NOTES

These notes on Design Sheet 7 are self explanatory. This completes your examination of ABUTMENT DETAILS. You should now complete the questions for this sheet before advancing to the next section.

SUPERSTRUCTURE DETAILS

Design Sheets 9-15 are titled SUPERSTRUCTURE DETAILS. However, not all of the superstructure details are on these seven sheets. Design Sheets 16-19 also deal with superstructure details even though they are not labeled as such. You may remember that the superstructure is defined as all of those portions of the bridge above the bearing seats at the abutments and piers. Included are the bridge roadway, barrier rails, beams, diaphragms, and bearings. The abutment diaphragms have already been discussed, and they will be mentioned here only in passing.

Let us start by examining the HALF SECTION NEAR NORTH ABUTMENT and HALF SECTION NEAR PIER, Design Sheets 9 and 10. The section near the abutment shows the vertical and longitudinal horizontal reinforcing in the front (north) face of the abutment diaphragm. It also shows the details of the crown, slope, and reinforcing in the bridge deck slab. Among the dimensions shown at the top of the diagram is the overall width of the roadway, measured from inside toe to inside toe of the barrier rails. The outer 480 mm of the deck surface on each side of the deck is level and the next 6 600 mm on each side has a slope of 3% and is tangent to the parabolic crown. The center portion of the roadway is at a 2% slope distance of 5 400 m on either side of the centerline of the roadway.

Note that the barrier rails are keyed to the slab with a 25 mm deep, 200 mm x 200 mm square indentation. These indentations are spaced every 600 mm, center to center.

There are fourteen beams across the bridge. They are spaced 2 050 mm between centers.

SLAB TRANSVERSE REINFORCEMENT

As shown in the section views of Design Sheet 13, the primary transverse reinforcing (transverse means perpendicular to the long axis) in the bridge deck slab consists of "a" bars, in both the top and bottom reinforcing mat. A mat is a layer of reinforcing, usually having bars running in both directions. This slab has two mats; one near the top surface, and one near the bottom surface. The a1 bars, both in the top and bottom of the slab are spaced 210 mm on center. However, the top bars start 70 mm from the ends of the slab, and the bars in the bottom

of the slab start 175 mm from the ends. You can see in the REINF. BAR LIST that these bars are 13 720 mm long, hence, they extend across the roadway under the median. They do not lap with the a1 bars on the other half of the roadway.

There are also some a2 and a3 transverse bent bars at the beam locations. You can verify that there are 36 of these a2 and 36 of these a3 bars by referring to the REINFORCING LIST, sheet 15.

To understand where the number 36 comes from, refer back to the CONCRETE PLACEMENT DIAGRAM AND REINFORCING LAYOUT, Design Sheet 13. This shows that the a2 bars are used on top at the ends. The a3 bars are used on the bottom ends.

SLAB LONGITUDINAL REINFORCEMENT

The primary longitudinal reinforcing in both the top and bottom of the slab consists of b1 bars. The CONCRETE PLACEMENT DIAGRAM AND LONGITUDINAL REINFORCING LAYOUT, Design Sheet 13, shows a plan view of their placement. It takes five bars to span the length of the bridge at each line of bars. They must lap a minimum of 730 mm. A better view of the details of the transverse spacing of these bars is shown in the half section views, Design Sheets 9 and 10.

The HALF SECTION NEAR PIER, Design Sheet 10, shows that there are additional longitudinal bars, labeled b2, near the piers. The b1 and b2 bars are both shown in this view. Vertical lines are extended up from each bar to indicate the spacing. Note that the b2 bars are located in the top of the slab only, and the b1 bars are located in both the top and bottom of the slab. Note the spacing outside the outer beams is 2 050 mm. Note also that there are no b1 bars over the centerline of the beams. Between beams, the spacing of the b1 bars is 200 mm center to center. The plan view on sheet 13 shows that the b2 bars are centered over the piers.

BRIDGE SLAB

Besides width and length, several dimensional requirements apply to the slab. One relates to meeting the specified top surface elevations, and the other relates to the thickness of the slab.

The required elevations are shown on Design Sheet 12. The roadway has been divided into a grid, shown in the upper half of the sheet. The intersections of the horizontal and vertical gridlines correspond to the points where the elevations are specified. For example, the required top of slab elevation at the intersection of lines F and 4 is 377.502 m. The elevation of the top surface at location G4 immediately to the east of F4 is 377.526 m. It is higher than F4 because G4 is on top of the median. The contractor meets these elevations by adjusting the elevation of the form work for the slab and by adjusting slab thickness, within specified limits.

As shown in the EXTERIOR BEAMS TYPICAL SLAB AND HAUNCH DETAIL, Design Sheet 9, the thickness of the deck slab at the outer edge is 230 mm. This thickness increases as it approaches the outer beam. The asterisk refers to the note below the detail view. The note instructs us to refer to Design Sheet 16 for Slab Thickness over the beams.

Turn now to Design Sheet 15. On the left side, there are three details of interest. The BEAM CAMBER DATA shows the amount of camber anticipated when the beams are erected and when the slab is in place. "Camber" is the amount of vertical "arch" built into a beam. Camber offsets the deflection that the beam will undergo when loads are applied. This avoids a "saggy" appearance when the beam is under load, and it also avoids cracks in the bottom of the beam (See Figure 9).

As shown in the BEAM CAMBER DATA, the camber will be reduced when the slab is in place. For example, the anticipated camber for the beams, as erected, but before the slab is poured, is 115 mm at the center of the beam. After the slab is in place, this camber is expected to be 40 mm. This must be taken into consideration in determining slab thickness. This is done by raising or lowering the bottom of the slab along the length of the beams so that the top surface is not affected. The effect of this is shown in the view SLAB THICKNESS AT BEAMS (T). This gives a profile view of the slab thickness at the beams, and gives numerical values at the interior quarter points of each beam. For example, the slab thickness for the center beams is 225 mm at the pier, where the top of the beam is at its lowest point. The slab thickness decreases to 215 mm at the center, where the camber is greatest, and where the top of the beam is at its highest point.

The note at the left of this view indicates that the design provides for a nominal slab thickness of 200 mm, and a haunch of 15 mm at the beams.

The note below the view SLAB THICKNESS DETAILS is very important. In part it states:

"The slab thickness (T) at beams is based on the anticipated beam camber remaining after placing the slab, but is not guaranteed for construction. If beam is under cambered, increase slab thickness (T) at beams to compensate."

An under-cambered beam means that the beam does not have as much "arch" as intended. As a result, the points along the top of it are lower than anticipated. When this happens, the thickness of the slab (T) must be increased over the beam. This is done by increasing the depth of the haunch. However, when this must be done, there is a limit to how deep the haunch can be. As the note below SLAB THICKNESS DETAILS states, "if the haunch exceeds 60 mm, the grade line is to be revised." This means that a re-design is required if a haunch deeper than 60 mm is necessary.

The note also states,

"if the beam is over-cambered, the slab thickness (T) may be decreased to a maximum of 15 mm embedment at the beam (T)."

This situation is shown in the right hand portion of the view SLAB THICKNESS DETAILS. The slab thickness at the beam (T) has been reduced by allowing the slab to come down around the top surface of the beam. This would be done when the camber of the beam is greater than anticipated. However, as the note states, "if more than 15 mm embedment is required or if the haunch exceeds 60 mm, the grade line is to be revised," which means that a re-design is necessary.

Between beams, the slab thickness is to be maintained at 200 mm. This is shown in the view INTERIOR BEAMS, Design Sheet 9, and SLAB THICKNESS DETAILS, Design Sheet 15. Thus, the contractor, when setting the form work for the slab, must adjust the elevation of the slab forms so that he maintains a minimum slab thickness of 200 mm between beams, achieves

the top surface elevations specified on Design Sheet 12, and meets the requirement for maximum embedment (15 mm) and maximum haunch (60 mm) at the beams.

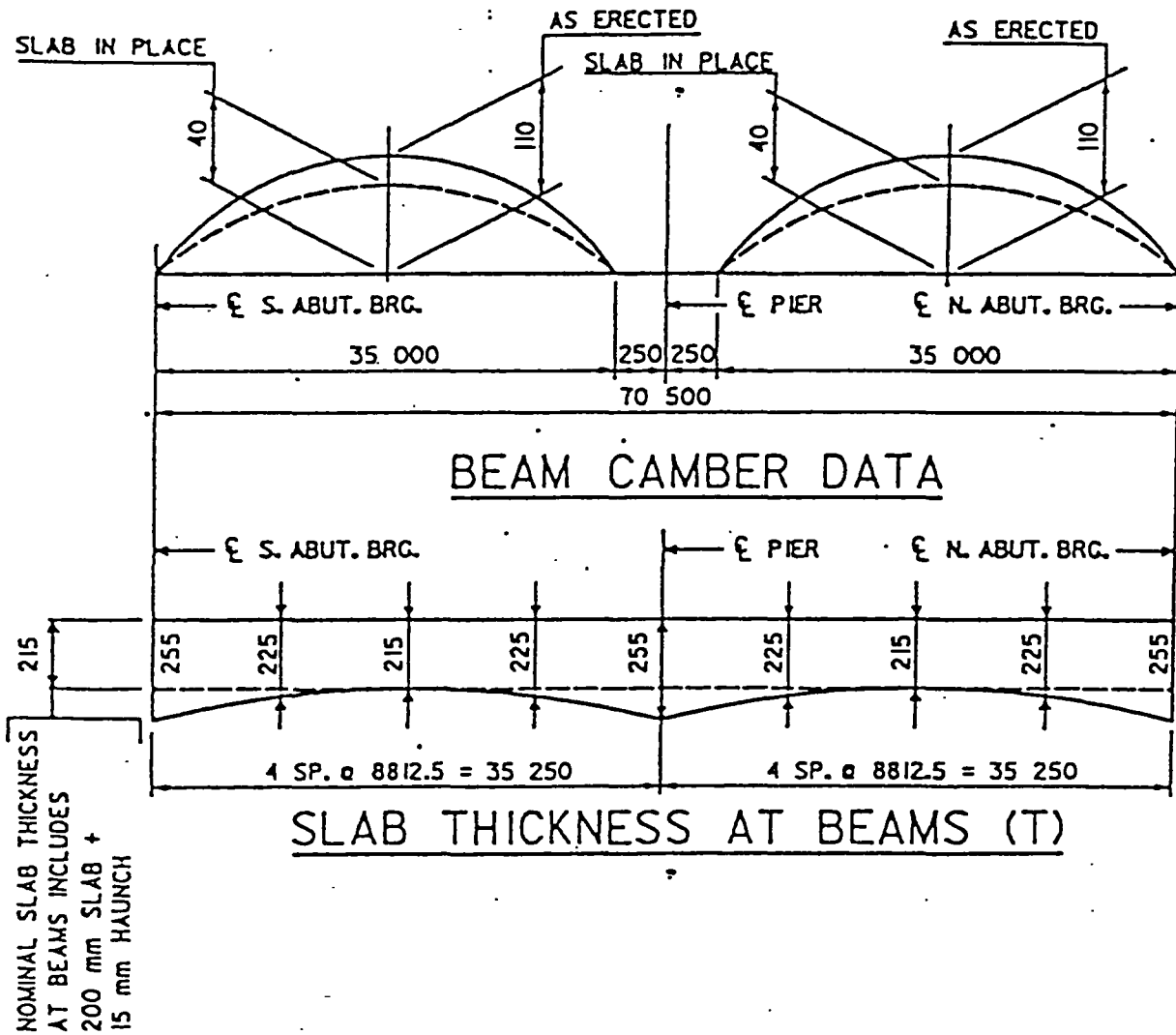


Figure 9.

CONCRETE PLACEMENT LOCATIONS AND QUANTITIES

Details with respect to the sequence of concrete placement are shown on Design Sheet 13 in the CONCRETE PLACEMENT DIAGRAM AND REINFORCING LAYOUT. The concrete is divided into six sections, as shown. The first section shall be at the south end of the bridge on east side; the second section to be placed shall be in the north-eastern corner of the bridge; and so forth. As the note below the diagram indicates, the contractor may propose alternate procedures.

At each section, a construction joint will exist between the concrete in the section already placed and the fresh concrete being placed in an adjacent section. This joint must be formed as shown in TRANSVERSE SLAB CONSTRUCTION JOINT, Design Sheet 15. A header must be cut and placed at the location where the sections are to meet. The header will probably be made from 50 mm thick lumber. It forms a vertical edge between adjacent sections of the deck slab. The header must be removed before placing the concrete for the adjacent section.

As noted in the SUPERSTRUCTURE NOTES, Design Sheet 9, the pier and abutment diaphragm concrete are to be placed monolithically with the floor slab. The quantities of concrete, by section, for the slab, pier, abutment diaphragms, abutment footings, paving blocks and abutment wings are listed by location in CONC. PLACEMENT QUANTITIES, Design Sheet 15. The totals for all reinforcing, concrete, prestressed beams, and excavation for the superstructure work are recapped in ESTIMATED QUANTITIES, also on Design Sheet 15.

CONCRETE COVER OVER REINFORCING

There are specific requirements with regard to the placement of the reinforcing and the amount of concrete cover over the bars. Turn now to Design Sheet 9 and examine the SUPERSTRUCTURE NOTES. For example, there is a requirement for 65 mm clearance above the top-most reinforcing bars in the slab and 25 mm clearance below the bottom bars. This requirement is very important. Bars which are too close to the surface of the concrete are more susceptible to corrosion, even though they are epoxy coated. Note that the requirement for cover varies with the location of the reinforcing. In general, the requirement is for a minimum of 50 mm of cover, unless otherwise stated.

TEMPORARY PAVING BLOCK

As previously noted, there is a notch at the top of the rear face of the abutment diaphragms on which the approach pavement rests. This is shown in the views PART SECTION B-B, Design Sheet 8, and PART LONGITUDINAL SECTION NEAR GUTTER, Design Sheet 11. Temporary precast concrete paving blocks are placed on this notch until it is time to place the approach pavement. These blocks are shown in section in the views above, and are shown in plan view in PLAN OF TEMPORARY PAVING BLOCK, Design Sheet 11. The blocks are 300 mm high, 190 mm deep, and 2 425 mm long. These blocks have incorporated in them an r1 bar to assist in their removal. The bars are designated "Paving Block Lifting Loops," and they are shown in the REINFORCING BAR LIST, Design Sheet 15.

PIER DIAPHRAGMS

There is a concrete diaphragm at each pier. The reinforcing for these diaphragms can be seen in HALF SECTION NEAR PIER, Design Sheet 10. The e1 bars appear to be vertical reinforcing. However, these bars are really hoops. The details of their dimensions after bending are shown in BENT BAR DETAILS, Design Sheet 15. The unlabeled view at the top of the sheet, above PART SECTION AT PIER, Design Sheet 11, provides a side view of these hoops. Returning to Design Sheet 10, the upper three rows of horizontal bars between beams are d2's. There are 144 of these bars.

The section views on Design Sheet 11 show a transverse slice through the pier diaphragm. There are d4, d3, and e3 bars near the bottom of the diaphragm. The d4 bars are the bottom center bars in the diaphragm. There is one in each pier diaphragm. The d3 bars span between the coil rods. There are two of these bars in each of the spaces between beams. The e3 bars are U-shaped bars tied to the bottom of and adjacent to the e1 hoops. They are designated "pier diaphragm ties."

As at the abutments, each precast beam has a 19 mm diameter coil rod inserted into each end of the coil tie cast into each beam. Note in the section views, Design Sheet 10 and Design Sheet

11 that the outer coil rods are bent over the outside hoops. The outside hoops and ties at the ends of the piers are different from the interior hoops and ties. The outside (end) hoops are e4 bars, and the outside (end) ties are e2 bars. There are four of each, two of each per pier. Note also that at the ends of the piers, there are U-shaped horizontal bars, d1, which run outside of the end hoops. There are twelve of these bars per pier.

BARRIER RAIL DETAILS

Turn now to Design Sheet 19, BARRIER RAIL DETAILS. Let's start by examining ELEVATION OF BARRIER RAIL LAYOUT at the top of the sheet. This shows a side view of the barrier rail, part of it cut away to reveal the reinforcing. As indicated by the dimensions at the top of this view, each rail consists of a 74 470 mm long standard section, and two 2 100 mm end sections, for a total of 78 670 mm, end to end. The barrier rail will be formed and poured after the bridge deck has been placed. Typically, the barrier rails are slip-formed by equipment that forms and extrudes the concrete to the prescribed shape.

The principal reinforcing in the standard barrier rail section consists of c1 and c2 vertical bars, and d1 horizontal bars. Note that the minimum lap specified for the d1 bars is 630 mm. These bars are shown in more detail in the view PART SECTION C-C, which is a section view through the standard barrier rail section. The vertical bars are bent as shown in BENT BAR DETAILS, same page.

In the end sections, the principal reinforcing consists of the vertical bars c3, c4, and c5-10, and horizontal bars d2 and d3. These bars are shown in more detail in PART SECTION D-D and PART SECTION B-B. Note that the c5 through c10 bars vary in the length of the "X" dimension, as shown in the small table in BENT BAR DETAILS. You should refer back to Design Sheet 11, SUPERSTRUCTURE DETAILS, SECTION D-D, to observe the configuration of the lap between the "c" bars and "s" bars in the wingwall. Note that the "c" bars in the back side of the barrier rail are tied inside the "h" bars in the wingwall. The "c" bars in the front face of the barrier rail are tied outside the "s" bars in the wingwall. The "c" bars must extend of 350

mm into the wingwall. Although the "c" bars are considered barrier rail reinforcing, they must be placed and tied along with the wingwall reinforcing, before the wingwall concrete is placed.

Returning to Design Sheet 19, PART ELEVATION, you will note that there are seven 25 mm diameter horizontal holes called for. They run transversely through the barrier rail. These holes are to be formed with 25 mm plastic conduit, cut to the appropriate length. These holes are formed so that anchor bolts can be placed through the concrete barrier rail to attach the guardrail to the bridge. The guard rails are part of another contract.

Construction joints in the 74470 mm long standard section are not required; they are permitted. Construction joints are joints created when it is necessary to break up a concrete placement into multiple placements. For example, if a contractor places a portion of the standard barrier rail section on one day, and continues with another section the following day, the joint that is created between the pours is called a "construction joint." The location of these joints is covered in the Standard Specifications, Par. 2403.22. The way in which these joints are to be constructed and treated for bonding are covered in the Standard Specifications, Par. 2403.14. In the BARRIER RAIL NOTES, you can read the joints are to be located no closer than 6000 mm from each other. The details of the joints are shown in BARRIER RAIL JOINT DETAILS. Note that a bond breaking coating must be used to prevent sections from bonding to each other. A sealant must also be used on the top and sides of the joint.

This completes your review of BARRIER RAIL DETAILS, Design Sheet 19. Be sure to answer all questions pertaining to this sheet before advancing.

BEAM DETAILS

We are going to skip over a few sheets at this time, because it will be easier to understand the material on bearings and Precast Deck Panels if we cover the information on the Precast, Prestressed Beams first.

Turn now to Design sheet 18, D35M BEAM DETAILS. The beam shown on this sheet is a PRETENSIONED PRESTRESSED beam. This means that some of the reinforcing in the beam has tensile loads applied before the beam concrete is poured. This is done at the plant where the beams are made. Both the reinforcing steel and the prestressing strands are placed in the forms for the beams before placing the concrete. Prestressing strands are steel cable. In this case, they are 12.7 mm diameter. Special jacks pull on the prestressing strands, putting them in tension. This is done before the concrete is poured, hence, the name "prestressing." After the concrete is placed and cured, the jacking tension can be released. The strands then try to return to their original condition. However, because of the bond strength between the concrete and the strands, and because of special anchors at the ends of the beams, the strands cannot shorten without compressing the beam. Thus the prestressing cables cause the bottom of the beam to be in compression. This compression results in the camber already discussed. When the beams are in-service, this cambered condition keeps the beams from sagging down below the horizontal when loads are applied.

The longitudinal section views at the center of the sheet show the arrangement of the reinforcing steel and prestressing strands for these precast beams. To understand the arrangement of the reinforcing, we need to examine both a longitudinal section view and a transverse section view of the beam.

The elevation section view in the center side of the sheet shows one half of the beam, the other half being symmetrical. Note that there are some reinforcing bars at the top of the beam, and some reinforcing strands running at a diagonal, from the top of the beam at its end, to near the bottom of the beam at a point 3 510 mm from the center of the beam. These "deflected strands" are labeled as 6 strands at 50 mm in BEAM D35M. In the NOTES, the hold down points may be moved toward the ends of the beam a maximum distance of 0.05 span length

maximum. This means that during the manufacture of the beams, when the prestressing strands are placed inside the forms, there is some flexibility allowed in their placement. The purpose of the deflected strands is to help support the shear stresses which are higher near the ends of the beam than they are at the center.

There are also five horizontal lines representing prestressing strands near the bottom of the beam. The top line is identified with the number "4" shown below the beam. The "4" indicates that there are four strands at that level. The next line is identified with the number "6" shown below the beam. The "6" indicates that there are six strands at that level. The same explanation applies to the number "8" which is identified with the strands closest to the bottom of the beam. If you add these numbers up, they total "34", which means there are a total of 34 straight strands in the bottom of the beam. Look now at the table labeled BEAM DATA in the upper right-hand corner of the sheet. Note that for the D35M beam there are 34 straight strands. The transverse view BEAM D35M shows that there are 10 rows of reinforcing in the bottom layer, 8 straight strands, and the two columns of deflected strands at that level. You should examine the transverse section view and the longitudinal section view together, to determine how the reinforcing is distributed across the cross section of the beam.

The elevation beam D35M views show both reinforcing bars and prestressing strands. The elevation shows two a2 bars which run at the top of the beam near each end, and two a1 bars, which run at the top of the beam to the end, and two a3 bars, which run along the top of the beam near the center. Vertical bars include the b1 bars, which protrude from the top of the beam. There are 95 of these bars in the beam; located in singles at 95 locations. At each of those locations, there is also one c1 and a d bar. The b2 bars are "U" shaped. There are six of them at each end of the beam. Note the shape of the b3 bars. Their vertical ends are tied to the legs of the "U" shaped b2 bars.

The b3 bars are vertical bars, bent so that they have a shallow "V" shape. They are located near the end of each beam. Each beam has 20 of them, 10 at each end. Their function is to resist splitting stresses in the anchorage area.

The e1 bars are located at the ends of the beams around the lower prestressing strands. There are eight of these bars at each end. Note that the legs are pointed down. Their function is to resist splitting in the bearing area.

BEAM PROPERTIES

There are also transverse section views for the beams which do not show the reinforcing, but which show other beam properties. One of these is located near the bottom, right of center, and is labeled D35M BEAM CROSS SECTION, Design Sheet 18. This view shows the exterior dimensions for the D35M beams. The area is 413825 sq. mm. " Y_b " is the distance from the bottom of the beam to the center of gravity of the cross-section, a property used in designing the bridge. " $I = 89\,222\,120\,000\text{ mm}^4$ " is the Moment of Inertia of the beam cross-section, which is another property used in design.

LIFTING LOOP AND COIL TIE DETAILS

The illustration LIFTING LOOP DETAILS BEAM D35M on Design Sheet 18 shows that there are to be two lifting loops at the ends of each beam. These are to be fabricated from 32 mm diameter extra strong steel pipe. The end of the loop is to extend 100 mm above the top of the beam. Two 12.7 mm grade 270 strands are threaded through each pipe sleeve and extend downward as shown.

The illustration COIL TIE DETAIL shows the required dimensions for the coil tie inserts and coil rods. You may want to refresh your memory on the coil ties. They were covered in the discussion of Design Sheets 7 and 8, ABUTMENT DETAILS. The exact location of the coil ties from the ends of the beams and the bottom of the beams is shown in the illustration BEAM COIL TIE LOCATIONS, Design Sheets 7 and 18.

STRAND PROJECTION AT BEAM ENDS WHEN EMBEDDED IN CONCRETE END DIAPHRAGMS

Design Sheet 18 provides information on what to do with the ends of the prestressing strands which protrude from the ends of the beams. Each cable should be cut 350 mm beyond the ends of the beams. The cables are then bent as shown. The bottom strands are bent up; the top strands are bent up and to the side.

NOTES, DESIGN STRESSES, AND SPECIFICATIONS

The information regarding design stresses is for the information of all parties. It will be most useful to the manufacturer of the beams. The information regarding the Specifications tells us that. The Standard Specifications of the Iowa Department of Transportation, Current series, plus current special provisions and supplemental specifications apply to the construction. The AASHTO Specifications, Series of 1992 with minor modifications, were used in the design of the beams.

This concludes your review of Design Sheet 18, D35M BEAM DETAILS. Be sure to complete the questions for this sheet before advancing.

POLLUTION PREVENTION PLAN

Sheet 22 (note this is not a design sheet) alerts the contractor that he or she shall be responsible for compliance and implementation of the pollution prevention plan for their entire contract. The site description includes information about the characteristics of the site, potential sources of pollution, rural agricultural, commercial and industrial activities. The rest of the sections give the contractor guidelines which they are to follow in controlling pollution and runoff. The contractor must also maintain all erosion control measures and is subject to inspection following a rain event. These items are self explanatory.

TWIN 3.0 m x 2.4 m x 56.8 m REINF. CONC.
BOX CULVERT
CERRO GORDO COUNTY

POLLUTION PREVENTION PLAN - NOTES AND QUANTITIES

Refer to the set of plans for the project above. This is a partial set of plans which includes only those sheets necessary to adequately describe a box culvert.

A box culvert performs the same functions as many bridges, in that it carries traffic over the top of it, and it permits water to flow under the roadway. According to the Standard Specifications, a culvert is defined as "Any structure not classified as a bridge which provides an opening under any roadway, except that such term shall not, include tiles crossing the road, or intakes thereto, where such tiles are part of a tile line or system designed to aid subsurface drainage."

The box culvert represented by these plans is a twin (side-by-side) culvert constructed of reinforced concrete. It consists of a top slab, two exterior walls, one interior wall, and a floor. The tube of any culvert, whether round, elliptical, rectangular, or other shape, in cross-section, is known as a "barrel." This culvert has two "barrels." In addition, there are headwalls at each end.

Let's start our review of the plans by reviewing the information on Design Sheet 2, POLLUTION PREVENTION PLAN NOTES AND QUANTITIES. This sheet is very similar to the estimate sheet and general notes sheet and pollution prevention sheet for the bridge previously discussed and is assumed understood.

SITUATION PLAN

The SITUATION PLAN is located in the center of Design Sheet 3. The culvert is located so as to intercept the flow of Crane Creek, which flows from southwest to northeast, which is from left to right in this view. The culvert is crossed south to north by Jonguil Avenue.

This view gives some dimensional information which will be discussed in more detail later. However, you can see for now that the culvert is 66 200 mm long between parapets and that it

appears to be composed of five interior sections and two end sections plus the headwalls at each end. A parapet is the raised portion at the end of the barrel. Each of the end sections is 4 400 mm long. Each of the interior sections is 11 480 mm long.

HYDRAULIC DATA

These data on Design Sheet 3 shows information concerning the drainage area, elevations and flow quantities associated with 50 and 100 year high water, and the elevation and flow necessary to over top the culvert. Here we see that the drainage area is 179 Ha. The drainage area is that surface area surrounding the site that contributes water runoff to the Crane Creek at this point. $Q_{25} = 6.8 \text{ m}^3/\text{s}$ indicates the magnitude of the maximum flow that might occur during a 25 year period. Q stands for quantity. It is expressed in m^3/s , or cubic meters per second. At that flow, the elevation of the water, or natural stage, would be 366.22 m. The maximum flow that might be anticipated every 50 years (Q_{50}) would be $8.5 \text{ m}^3/\text{s}$. The extreme high-water state would be 362.51 m.

LONGITUDINAL SECTION ALONG CULVERT CENTERLINE

This view shows the elevations of the significant features of the culvert and indicates the cross sectional feature of the roadway on Design Sheet 3, lower left corner.

TABULAR DATA

The tables CONCRETE PLACEMENT QUANTITIES, and SUMMARY OF REINFORCING STEEL, shown on Design Sheet 4, are similar to information that you have already covered. They are self-explanatory.

CULVERT NOTES

The Notes on the right side of Design Sheet 3 are self explanatory.

CULVERT NOTES

The Notes on the right side of Design Sheet 3 are self explanatory.

LOCATION

The location data shown on the upper right corner of Design Sheet 3 is similar to that already discussed in the bridge section.

TRAFFIC ESTIMATE

This is used as a guideline for the designer. Located in the upper right corner of Design Sheet 3, it is shown that in the year 1985 there were 60 vehicles per day while there is no data predicted for the year 2016.

This completes your review of Design Sheet 3. Go on now to Design Sheet 4. There are no questions for just this sheet.

BARREL DETAILS

At the top of Design Sheet 4 you will notice a table entitled VARIABLE DIMENSIONS AND QUANTITIES FOR BARREL SECTIONS. This table is similar to the one for the concrete bridge in Cerro Gordo County that you have already studied. It is broken down to show the reinforcing required for each barrel section, based on the height of fill over the culvert.

This sheet also shows the various views of the culvert as to show the location of reinforcing in various sections of each barrel.

CULVERT BELL JOINTS

Design Sheet 5, entitled CULVERT BELL JOINTS, illustrates the construction details at each joint. In the upper right hand corner is the ESTIMATE OF QUANTITIES - ONE JOINT - 2400 SPAN. This table shows quantities, location, size, length, and mass of reinforcement that occurs in one joint.

On the left half of the sheet you will notice the different sectional views. You should pay attention to the reinforcement that is used and also note that there is a 13 mm PREFORMED EXPANSION JOINT FILLER used at these joints.

This completes your review of the plans for the twin box culvert. You should answer the questions for this set of plans.

APPENDIX
Abbreviations

| | |
|---------------------|---|
| AADT | average annual daily traffic |
| AASHTO Officials | American Association of State Highway and Transportation Officials |
| Abut. | abutment |
| ACC | asphalt cement concrete |
| B.F. | back face (of an abutment, pile cap, or wall) |
| B.M. | bench mark |
| BRF | bridge federal |
| BRG. | bearing, such as the bearing plate for a beam |
| BTM. | bottom, such as the bottom of a footing |
| bu. | bushel |
| CA | controlled access |
| C.M. | concrete monument |
| CMP | corrugated metal pipe |
| cor. | corner |
| corr. | corrugated |
| csk. | countersunk |
| culv. | culvert |
| cu. m. | cubic meters |
| DA | drainage area |
| DDHV | directional design hourly volume |
| des. | design |
| des. H.W. | design high water |
| DHV | design hourly volume |
| dia.. | diameter |
| div. | division |
| EL. | elevation |
| Ent. | entrance |
| Exp. | expansion |
| fd. | found; such as a survey point which has been found |
| Fed Rd Dist | Federal Road District |
| F.F. | front face (of an abutment, pier cap, or wall) |
| FHWA | Federal Highway Administration |
| Fin. | Finished (as in finished roadway) |
| F.L. | flow line |

| | |
|----------|--|
| Ftg. | footing |
| F.Y. | fiscal year |
| GR. | grade |
| GR. EL. | grade elevation, such as the elevation at the top of the pavement at that point. |
| H | hilly; pertains to drainage area |
| H.W. | high water |
| hdwl | headwall; such as on box culvert |
| ident. | identification |
| IDOT | Iowa Department of Transportation |
| I.H.C. | Iowa Highway Commission; now the Iowa D.O.T. |
| I.S.H.C. | Iowa State Highway Commission; now the Iowa D. O. T |
| kg | kilograms |
| lin. m. | lineal meter |
| L.S. | lump sum |
| Lt. | left |
| M | mountainous; pertains to drainage area |
| M.L. | main line |
| M.P. | mile post |
| min. | minimum |
| O.R. | office relocated |
| P.C. | Point of Curvature |
| PCC | Portland cement concrete |
| P.I. | Point of Intersection |
| PIN | project identification number |
| P.O.C. | Point on Curve |
| P.O.T. | Point on Tangent |
| Po. | power; such as in power pole |
| P.R.C. | Point of Reverse Curvature |
| Prop | proposed |
| P.T. | Point of Tangency |
| P.V.C. | Point of Vertical Curvature (IDOT: V.P.C.) |
| P.V.I. | Point of Vertical Intersection (IDOT: V.P.I.) |

| | |
|-----------|---|
| P.V.T. | Point of Vertical Tangency (IDOT: V.P.T.) |
| Q | Volume of flow in cubic feet per second |
| R | rolling; pertains to drainage area |
| R-24W | range line; such as Range 24 West |
| R.C.B. | reinforced concrete box |
| R.C.P. | reinforced concrete pipe |
| R.E.C. | Rural Electric Co-operative |
| R.O.W. | right of way (also RW, or R/W) |
| Ret. | retaining, such as a retaining wall |
| RR | railroad |
| Rt. | right |
| sec. | section |
| Sho. | shoulder |
| spk | spike; used to help locate points surveying |
| sq. m. | square meters |
| S.R. | side road |
| stat. | station |
| T-78N | township line; such as Township 78 North |
| Tel. Per. | telephone pedestal |
| typ. dwg. | typical drawing |
| U.C. | use as constructed |
| U.S.G.S. | United States Geological Survey |
| vari | variable |
| VH | very hilly; pertains to drainage area |
| V.P.D. | vehicles per day |
| V.P.H. | vehicles per hour |
| x-ing | crossing |

Glossary

abutment - bridge end supports, usually with the additional function of retaining earth fill for the bridge approaches.

admixture - material such as Portland cement, asphalt, or lime that is used to stabilize a base course.

ahead - term used in stationing; designates direction that station numbers are increasing.

apron - flared-out end section placed at both the inlet and outlet ends of pipe culverts which provides a smooth transition for the flow between the pipe and the adjacent grade. Also the level surface of concrete at the flow line between the wingwalls of a box culvert.

artesian well - a deep-bored well in which water rises under pressure from a permeable stratum overlaid by impermeable rock.

back - term used in stationing; designates direction that station numbers are decreasing.

backfill - material used in filling an excavation, generally granular, porous, or special.

backslope - embankments; that portion of the earth grade or roadway beyond the side ditches which rejoins the original ground.

balance - relates to earthwork; length of roadway construction in which cut plus borrow equals fill plus shrinkage plus waste.

barn roof section - a typical grading cross-section with slopes that resemble the slopes on a barn roof.

base - layer of the pavement structure, placed on sub-base or sub-trade to support a surface course.

bearing - as in soil or surface; a designated area used to support the weight of another structure.

bench - an approximate horizontal space introduced in a slope.

bench mark - a relatively permanent point of known or assumed elevation along the course of a survey line.

berm - additional fill, placed for additional support.

borrow - additional excavated material needed for embankments that is not available from the cut section.

box culvert - a concrete culvert, rectangular in shape, with the top slab, floor, and sides composed of concrete.

bridge - any structure, including supports, erected over a depression or an obstruction, as water, a highway or railroad, and having a track, or passageway for carrying traffic or other moving loads and having a length measured along the center of the roadway of more than 6.1 m between undercopings of abutments or extreme ends of openings for multiple boxes.

camber - upward curvature in the length of a member. Camber can be built into shop fabricated members, or built into the formwork or site-cast concrete members. Beams are usually cambered to provide for settlement due to their own dead weight and subsequent live loads. Pipes can also be cambered so that when they are covered with earth, the weight will force the flow line back down to level.

centerline - a line marking the center of a roadway on which traffic moves in opposite directions, or the line of survey.

channelization - the direction of separation of traffic into definite paths, by means of traffic markings, islands or other means to facilitate the safe and orderly movements of both vehicles and pedestrians.

climbing lane - an additional right hand lane on hills used by slower moving traffic.

conventional signs - a descriptive section usually found on the first sheet of a set of plans describing common road signs.

cross section - the transverse profile of the roadway showing horizontal and vertical dimensions.

longitudinal cross section - a cut through the earth showing hills and valleys through that line on the project

cross slope - transverse grade of a road; from the centerline to the edge of the roadway.

culvert - any structure not classified as a bridge which provides an opening under any roadway, except that such term shall not include tiles crossing the road, or intakes thereto, where such tiles are part of a tile line or system designed to aid subsurface drainage.

cut - see excavation.

datum - any level surface to which elevations are referred, such as mean sea level; also called datum plane although not actually a plane.

degree of curve - the central angle formed by an arc that is a segment of a curve.

delineator - a reflective marker usually placed at the edge of a roadway having the primary purpose of guiding night drivers.

delta angle - the exterior or deflection angle formed by two intersecting tangents.

detail - an illustration, often enlarged, showing different parts of a drawing such as location or dimension which would normally be difficult to determine in the original scale.

dike - a small earthen dam used to control or direct surface water.

ditch - a long, channel-like excavation used to control or direct surface water.

dowel - a steel pin, reinforcing bar or rod extending into two members of a structure, or into two pavement slabs, to connect them.

drop wall - a foundation wall which helps provide support to the edges of concrete slabs, concrete slope protection, etc.

elevation - altitude; height of a point in relation to sea level or any assumed datum.

embankment - raised earth structure designed to elevate the roadbed above natural ground; typically the material composing the fill must be spread in layers called lifts which must not be greater than 200 mm thick before compaction.

engineering fabric - see geotextile

entrance - a road structure used as access to private property from a public road.

Type A - heavy commercial

Type B - light commercial

Type C - field, farm or residential

equation - a location where one series of station numbers changes to another, such as Sta.309+51.00 back = Sta.1100+00.000 ahead. The first number is for the station series which is ending, while the second number is the beginning station for the new series.

excavation - loosening and removal of earth or rock from its original position. There are different classes of excavation based on whether it is roadway and borrow excavation or excavation for structures. The classes also vary based on the type of material and its location:

Roadway and Borrow Excavation:

class 10 - normal earth materials

class 12 - rock or rocky materials

class 13 - unclassified materials

Excavation for structures:

class 20 - excavation for bridges, above classification line, not classified as class 22.

class 21 - excavation for bridges, below classification line, not classified as class 22.

class 22 - granite, trap, quartzite, chert, limestone, sandstone, hard shale, or slate in natural ledges or displaced masses, and rock fragments having a volume of 0.03 m³ or greater.

class 23 - all excavation included in the definitions for classes 20, 21 and 22, and any other encountered, regardless of its nature, except for removal of old structures or parts of structures.

class 24 - additional excavation necessary to provide material for backfills, approach fills, berms, or a roadway over the structure when materials resulting from other classes of excavation for the structure is of insufficient quantity or of unsatisfactory quality for these purposes.

expansion joint - a separation between two parts of a structure or two pavement slabs filled with an elastic material to provide opportunity for expansion or contraction movement.

expansion tube - a tube placed in the concrete of an expansion joint allowing the dowel bars to move.

external (E) - the shortest distance from the Point of Intersection (P.I.) to the curve.

faying surface - any surface which is intended to be in contact with another.

fill - see embankment

fill plate - a plate used to fill a gap between steel surfaces which are being welded.

flow line - the lowest point in the cross section of a stream, culvert or sewer.

foreslope - embankments; that portion of the earth grade or roadway which slopes downward from the shoulder to the side ditches.

free-haul - a certain distance that material is hauled and placed or disposed of that is included in the contract price for excavating the material (i.e. 300 m).

geotextile - a permeable membrane made of synthetic fibers used primarily for soil reinforcement but also for erosion control, filtration, and drainage.

grade - a certain elevation that a point or surface has, as in top of subgrade or profile grade; also may be used in reference to the vertical alignment profile.

header - additional concrete added to the end of pavement to protect against damage; often used when construction of the road is proposed to continue at a later date.

haunch - on a bridge deck, it is a place where the deck concrete is deepened so that the concrete can come in contact with the supporting surface (beam, girder) below.

hinge point - point on the transverse cross section of the roadway, which falls between the outer edge of the subgrade and the top of the foreslope.

incidental - of such a small amount in quantity or money that it is considered to be a part of another item of work. Not an individual bid item.

intake - a drainage structure which collects the run-off from a road surface; connected to sewer.

longitudinal ~ - of, or relating to, length or the lengthwise dimension; such as being parallel to the horizontal alignment of the roadway.

office relocation - original centerline has been relocated in the office.

maskwall - a section of wall that "masks" the structural elements behind it.

metric station - a unit of overhaul; one metric station equals one cubic meter of excavated material that is moved one hundred meters (1 station).

overhaul - excavated material that must be hauled a stipulated free-haul distance.

parting strip - a strip of material such as wood or bituminous filler, 1/8" thick, inserted in the concrete where a crack is desired, thus creating a plane of weakness along its length, causing the concrete to crack at that location rather than in a random manner.

plumb distance - horizontal distance between two points, determined by use of a plumb-bob.

primary road system - arterial highway system intended for long-distance, high-speed traffic.

proctor density - typical test performed on disturbed sample material.

profile grade - indicates the gradient slope of the vertical alignment, generally corresponding to the pavement centerline elevation of non-divided roadways.

range - east-west unit of geographical location measured from a known reference line running north-south.

rate of slope - the change in elevation over a given distance; horizontal distance to vertical distance.

revisions - changes that have been made to original documents; such as a set plans or a contract proposal.

right of way - a general term denoting land, property, or interest acquired for or devoted to a highway.

rip rap - a protective covering of stones, with or without mortar, on an earth bed; generally utilized for stream bank stabilization.

rumble strip - grooves cut in pavement which are used to alert drivers to an upcoming intersection and Stop sign.

scarify - to tear up the ground or road surface often prior to removal.

secondary road system - state, county, and local roads which are feeders to the primary road system.

section - a township division; each township has 36 sections each of which is one square mile.

Shelby tube - a method for taking undisturbed samples of cohesive soils that do not contain stone fragments or gravel which involves pushing with a continuous force a thin-wall tube around the sample producing minimum disturbance to the soil.

skew angle - the complement of the acute angle between two centerlines which cross. The angular deviation of the axis of a culvert or bridge from a true right-angular crossing of a road.

soil class

select - high quality soils, usually, loam or clay loam with a minimum proctor density around 1750 kg/m^3 ; designated by the A-6 AASHTO classification.

unsuitable - soil inappropriate for certain uses; typically designated by A-7-5 or A-7-6 AASHTO classification and further described in Road Plan RL-1.

class 10 - includes all soils that are not select or unsuitable.

soil sampling

disturbed - soil typically obtained by a shovel or by drilling with an auger and collected for later analysis with no attempt to maintain natural state; gives information about location and type of soils encountered.

undisturbed - also called standard field boring or consistency type boring; used to determine natural or "cut" density, typically more difficult and expensive to obtain than a disturbed sample.

spall - pavement damage; when pieces of pavement break out of the top at joints or at pavement ends.

standard road plans - a set of typical details and drawings to which designers refer, but which are not included in a set of plans so as to reduce the amount of material reproduced.

station - unit of measure for highway and other road work; one station equals one hundred meters.

subbase - bottom layer of the pavement structure, generally with less stringent requirements than those for the base course.

subgrade - generally consists of original soil in a cut or borrow material placed in suitable lifts for a fill; not actual part of pavement structure.

superelevation - the elevation of the outside of a curve in which the roadway has been banked so that the outside elevation on a curve is higher than the inside elevation.

tablet - a brass disk which has been set in a concrete monument.

tangent (T) - length; part of the tangent from the point of Curvature or Point of Tangency to the Point of Intersection.

taper - a gradual reduction in width such as when lanes are added or dropped; also used on curve pavement to limit cracking of the narrow part at curve end.

template - standard representation of a roadway cross section; includes all design features such as subgrade widths, foreslopes and backslopes, and ditch lines.

temporary easement - temporary use of land for purposes stated in the contract but with no change of ownership.

three centered curve - for an intersection; a curve composed of three circular arcs, each tangent to the previous and each having a different radius and radius point. This requires less material than a curve with only one center.

tie-in - make a smooth connection between new and old; have the same elevation.

tile - sub-surface, perforated pipe used to keep certain sites free of groundwater.

top of subgrade - the elevation that an excavation is cut to, or a fill is placed to; the line immediately below the subbase.

township - north-south unit of geographical location measured from a known reference line running east-west.

township - a square, six miles per side, which is bounded by township and range lines.

transverse - of, or relating to, width, or the width dimension; such as being perpendicular to the horizontal alignment of the roadway.

wash - a sloped surface which permits water run-off

waste - extra excavation material that is not expressly needed on the construction site, often is used to widen fills or flatten fill slopes.