Arizona Department of Transportation
Bridge Group

BRIDGE PRACTICE GUIDELINES

SECTION 1- GENERAL

PURPOSE

The purpose of these Guidelines is to document ADOT Bridge Group design criteria and to provide guidance on interpretations of the various AASHTO publications and other documents as related to highway bridges and appurtenant structures.

The Guidelines are intended to be used for general direction. It will continue to be the responsibility of the designer to ensure that these guidelines are applied properly and modified where appropriate with the necessary approvals. The guidelines should be used with judgment to ensure that the unique aspects of each particular design are properly considered.

STRUCTURE IDENTIFICATION

The procedures for structure identification are established by the National Bridge Inspection Standards. Refer to the Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges prepared by FHWA and the Arizona Structure Inventory prepared by ADOT Bridge Management Section.

Bridge Definition

"A 'bridge' is defined as a structure including supports erected over a depression or an obstruction, as water, highway or railway and having a track or passageway for carrying traffic or other moving loads and having an opening measured along the center of the roadway of more than 20 feet between undercopings of abutments or springlines of arches or extreme ends of openings for multiple boxes; it may include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening."

Structure Name

Names of State bridges are assigned by the Bridge Management Section Leader. Structures are named in accordance with the kind of facility that goes under or over the principal route. A traffic interchange structure will have "T.I." as part of the name. Overpasses carrying one-way traffic will also include the direction of traffic as part of the name. The name is limited to a 20 digit field.

Term	**Description**
Bridge	The term "bridge" is usually reserved for structures over water courses or canyons.
Overpass	A structure carrying the principal route over a highway, street or railroad.
Underpass	A structure which provides for passage of the principal route under a highway, street, railroad or other feature.
Traffic Interchange (T.I.)	An overpass or underpass is also called a T.I. if on and

	off ramps are provided to the intersecting roadway.
Viaduct	A structure of some length carrying a roadway over various features such as streets, waterways or railroads.
Tunnel	A structure carrying a roadway through a hill or mountain.
Pedestrian Overpass	A structure carrying a pedestrian walkway over a roadway.
Pedestrian Underpass	A structure which provides for passage of a pedestrian walkway under a roadway.

Structure Number

Each defined 'bridge' has a unique number assigned by the Bridge Management Section according to the group of numbers allotted to each maintenance responsibility. Twin or parallel structures are numbered individually if there is an open median.

Structure number identification remains unique and permanent to that structure. The structure number will be retired only for structures totally removed, for one of two twin structures where the median is closed by subsequent construction or for transfer between state and local agency jurisdiction.

The structure numbers allotted to each maintenance responsibility category are as follows:

Structure Number	**Maintenance Responsibility Category**
0001-2999	State jurisdiction bridges
3000-3999	Federal jurisdiction bridges
4000-7999	State jurisdiction culverts
8000 and above	Local jurisdiction bridges and culverts

Station (Principal Route)

The station identification of the structure is located along a construction centerline of the principal route on or under the structure as determined from the State Highway System Log.

For overpass structures with the principal route on the structure, the beginning bridge station is used which is located at the backwall of abutment 1.

For underpass structures with the principal route under the structure, use the station of the point of intersection between the principal route under and the construction centerline on the structure.

For culvert structures, under 20 feet use the station of the point of intersection between the principal route and the construction centerline of the culvert. For culvert structures 20 feet and over, use the station of the beginning backwall.

Route and Milepost

The principal route and milepost identification shall be shown on all plan sheets. The milepost of the route on or under the structure is determined from the Arizona Highway System Milepost Log. The milepost is recorded to the nearest 1/100th of a mile as calculated from the Station (Principal Route).

BRIDGE DESIGN PHASES

General

The design of a major structure consists of three design phases: Initial Design, Preliminary Design and Final Design.

The **Initial Design Phase** consists of examination of bridge concepts including type, length and depth. These studies may be prepared prior to submitting a project in the 5 Year Program or in conjunction with the preparation of a Project Assessment (PA) or a Design Concept Report (DCR). These studies will form the basis for the Bridge Selection Report and provide the Geotechnical Engineer with sufficient information to order one or two initial borings to be used in providing a preliminary foundation recommendation.

The **Preliminary Design Phase** consists of two distinct activities. The first activity is the Alternatives and Selection Study Phase where different bridge types with varying span lengths, girder spacings and foundation types are investigated along with other structure types and comparative cost estimates. This activity results in a Preliminary Bridge Selection Report which will be distributed for comments and provide the Geotechnical Engineer with the required information to perform a final drilling program and produce a Bridge Geotechnical Report. The second activity consists of finalizing the Bridge Selection Report based on the final Bridge Hydraulics Report and Bridge Geotechnical Report.

The **Final Design Phase** consists of performing the required design calculations, drawing the plan sheets, preparing a final estimate and preparing the Special Provisions for bridge related items.

Initial Design

The Initial Design Phase consists of developing an Initial Bridge Study. The purpose of the Initial Bridge Study is to:

- Provide the structure depth for setting profile grades.

- Establish the best possible early cost estimate.

- Allow for Bridge Group input in scoping activity.

- Familiarize Bridge Design with upcoming projects.

- Describe and document the design assumptions used in the development stage.

- Document the existing bridge condition, including waterway adequacy if appropriate, for bridge replacement projects.

Up to three studies could be made during this phase; one as a study to determine a project's merits prior to becoming a project to be included in the 5 Year Program, one as for development of the Project Assessment and one as information for development of a Design Concept Report. The purpose of these studies is to develop as early as possible a feasible type of structure, cost and design restrictions for each site. The completeness of the study will depend on when the study is performed. For example, a study for a Design Concept Report should have more information than a pre-programmed study. Each of the three possible study times should be viewed as part of a continuous effort to define the scope of the project with each new study building on the previous study.

An Initial Bridge Study will be performed for all major bridge projects to be nominated to the 5 Year Program by the Bridge Group or the Districts prior to nomination. For existing bridges, this study will be performed in conjunction with the Bridge Candidate List for the Highway Bridge Replacement and Rehabilitation Program to help determine which candidate bridges should be programmed for replacement. Close coordination with Bridge Management Section, Drainage Section and the Districts will be required. These studies will examine the condition of qualified existing bridges to determine which bridges should be developed into replacement projects.

An Initial Bridge Study will be performed for all major structures during the Project Assessment Stage. If a study has already been performed, the original study should be updated and enhanced based on whatever additional data has become available. The project manager will initiate the process and establish the schedule for this activity.

When concensus can not be reached at the Project Assessment Stage, the project will require a Design Concept Report. Previous studies should be used as a basis for a new Initial Bridge Study; however, additional alignments will be investigated requiring additional studies of alternates.

On projects involving rehabilitation or replacement of existing bridges, the project manager shall identify the historical significance of the bridge before concept studies are initiated. The historical significance is determined from the Arizona Structure Inventory and involves a variety of characteristics: the bridge may be a particularly unique example of the history of engineering; the crossing itself might be significant; the bridge might be associated with a historical property or area; or historical significance could be derived from the fact the bridge was associated with significant events or circumstances. A copy of the Arizona Structure Inventory is on file.

For projects where existing bridges are involved, a thorough review of the Bridge Inspection File and coordination with Bridge Management Section will be required. The major study emphasis will be to verify the condition of the existing bridge, to develop concepts for replacement including the feasibility of widening or rehabilitating versus replacement, and to determine project costs. At this stage, bridge costs will be based on square foot of deck.

These Initial Bridge Studies are concepts based on the best available information and are subject to change. Assumptions used as the basis for these studies should be clearly documented and items that are likely to be subject to change as more information is obtained should be identified.

An Initial Bridge Study will consist of a title sheet, report body and concept sketch. Refer to figures 1,2 and 3 for a sample of format and contents.

FIGURE 1
INITIAL BRIDGE STUDY TITLE SHEET

ARIZONA DEPARTMENT OF TRANSPORTATION

BRIDGE GROUP

BRIDGE DESIGN SECTION A, B or C

INITIAL BRIDGE STUDY

DATE

HIGHWAY NAME

PROJECT NAME

PROJECT NUMBER

TRACS NUMBER

BRIDGE NAME

EXISTING STRUCTURE NUMBER

MILEPOST

Prepared by ________________________________ Date ____________

FIGURE 2
INITIAL BRIDGE STUDY REPORT BODY

GENERAL:

This section should contain a general discussion of the project including location of the bridge and purpose of the study.

EXISTING ROADWAY:

This section should contain a discussion of the existing roadway geometrics including identification of any deficiencies.

EXISTING DRAINAGE:

This section should contain a discussion of the hydrology and hydraulics of the site including design Q, high water, capacity, bank protection and scour vulnerability of existing bridge.

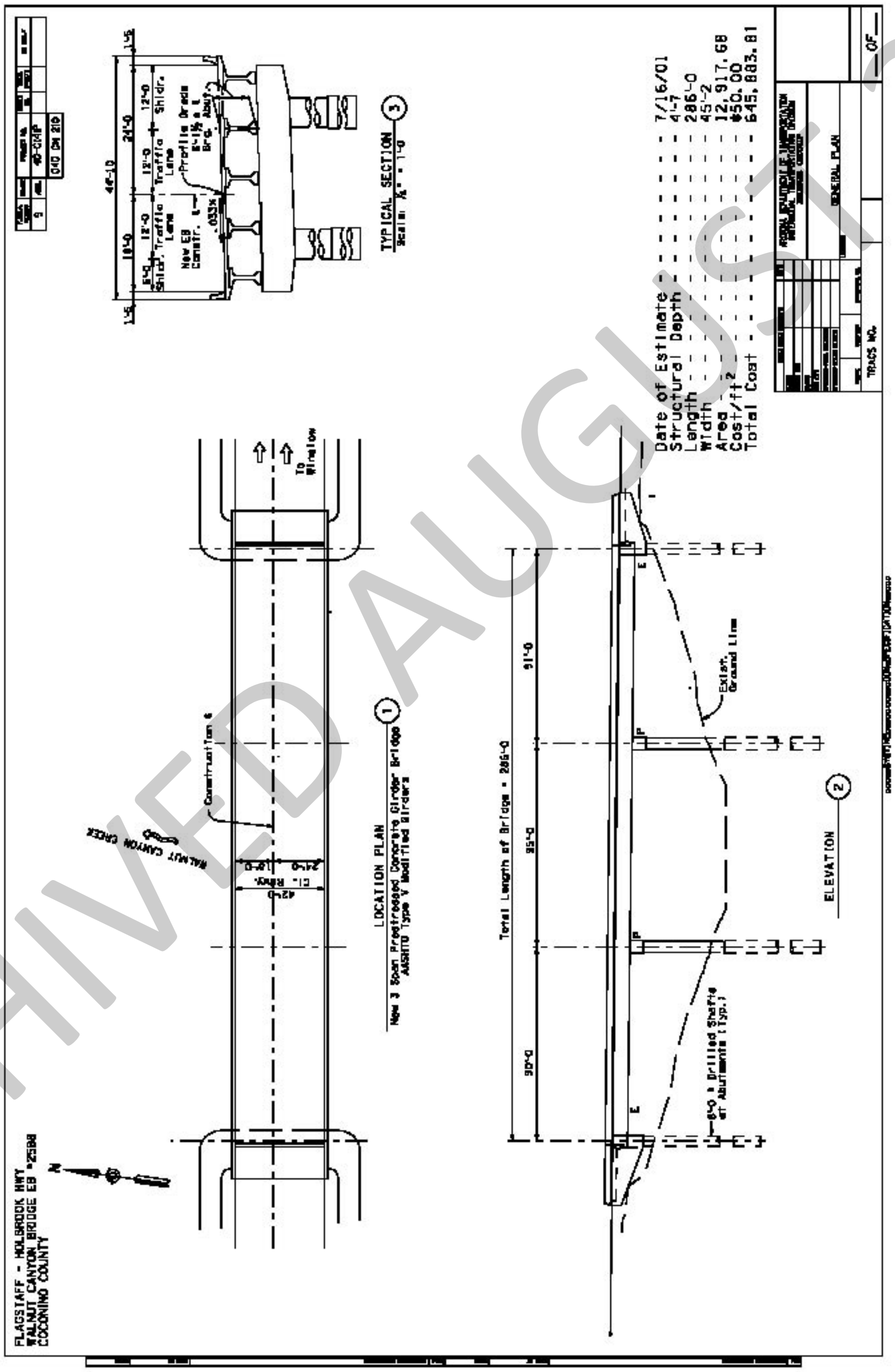
EXISTING BRIDGE:

This section should contain a discussion of the bridge geometrics and condition of the existing bridge including: rating of the deck and superstructure, adequacy of existing bridge rail, whether bridge is designed for a future wearing surface, the seismic vulnerability, condition of the bearings, expansion joints and approach slabs and a recommendation on whether the bridge could be widened or rehabilitated.

ALTERNATES:

This section should contain a discussion of the various alternates investigated including: structure type, superstructure depth, girder spacing, column type and spacing, foundation alternates, construction phasing, traffic handling and costs.

FIGURE 3
INITIAL BRIDGE STUDY CONCEPT SKETCH



Preliminary Design

Preliminary design consists of three distinct activities: (1) performing concept studies and producing a Preliminary Bridge Selection Report, (2) development of preliminary plans for the chosen alternate and finalizing the Bridge Selection Report and (3) obtaining FHWA approval of the Bridge Selection Report.

Preliminary Bridge Selection Report

The Preliminary Bridge Selection Report consists of performing concept studies as a continuation of the Initial Bridge Study. These studies involve investigating alternate superstructure and foundation types including variations of span length, structure depth and number of girders to determine the best bridge type and arrangement for a particular site. This portion of the Preliminary Design Phase is an iterative phase where assumptions must be made and later verified or modified during the process. Detailed in-depth design should not be performed in this phase unless it is necessary to confirm the adequacy of the concept.

When performing the concept studies the following shall be considered as a minimum:

- Cost
- Constructability
- Maintenance
- Aesthetics

Sketches should be made of the various alternates.

During this phase, both the vertical and horizontal clearances should be checked to ensure that the adequate clearances are provided. Inadequate vertical clearance will necessitate a change in either profile grade or superstructure depth while inadequate horizontal clearance may necessitate a change in span length.

During this phase, the geotechnical aspects of the site should be considered since the foundation type and associated cost may influence the type of bridge selected. Since a preliminary drilling program has been performed following the Initial Design Phase, a preliminary Bridge Geotechnical Report will be available for use in determining foundation type and costs.

During this phase, the traffic requirements must be investigated including any detours or phasing requirements. These details should be worked out with Traffic Design.

The need for a deck protection system and type of system will be determined during this phase. Details of the system should be worked out with Bridge Management Section.

Bridges over Waterways

For waterway crossings, the Preliminary Design Phase will require coordination with Drainage Section or the drainage consultant, as appropriate. The designer should obtain the Bridge Hydraulics Report and thoroughly review the contents before starting the concept study phase.

Widenings/Rehabilitation

On projects involving widenings, in addition to the requirements for new bridges, the following items should be investigated during the Preliminary Design Phase:

- Comments from the environmental process concerning the historical significance of the structure, if any, should be added to the discussion of the historical significance contained in the Initial Bridge Study.

- The existing structure should be checked for structural adequacy. The main superstructure girders should be checked for adequacy to carry the appropriate design live load. If the bridge does not rate sufficiently high, the girders may need to be strengthened, respaced or replaced, or a new bridge may be recommended. The deck slab should also be checked. Decks that are severely overstressed may require replacement.

- The condition of the existing deck joints should be investigated. If the existing joints are not working or are inadequate, they may require replacement.

- The condition of the existing bearings should be investigated. If the existing bearings are not performing adequately, they may require modification or replacement. This can affect cost and traffic phasing.

- The condition of existing diaphragms on steel girder bridges should be investigated. The need for this or any other repair work should be determined at this time. Welded diaphragms have caused past problems.

- The existing foundations should be checked for adequacy against predicted scour and if inadequate, appropriate means taken to upgrade the foundations against failure.

- The existing waterway opening should be checked to ensure that it can properly handle the design frequency event. Assessment of scour vulnerability and condition of bank protection should be included.

- The need for adding approach slabs and/or anchor slabs, if missing, should be investigated.
- The adequacy of existing bridge rail, that would be left in place, should be investigated.

- The need for earthquake retrofit measures should be determined.

- Existing or proposed utility conflicts should be investigated.

When the above items have been investigated, preliminary design can proceed by studying alternatives. Possible alternatives include: widening to one side, widening symmetrically on both sides or replacing the bridge with a new structure. Approximate costs based on preliminary quantities and unit costs associated with each solution will be required.

Approval

When a decision has been reached concerning the type of bridge selected, the justification for the choice along with comparative cost estimates and sketches should be summarized in the Preliminary Bridge Selection Report. This report should be submitted to the Section Leader and State Bridge Engineer for approval.

When approved, the Preliminary Bridge Selection Report should be presented to the Geotechnical Engineer for their use in conducting a final geotechnical investigation.

Bridge Selection Report

The finalization of the Bridge Selection Report is the second activity in the preliminary design phase. This activity involves incorporating the contents of the final Bridge Hydraulics Report and final Bridge Geotechnical Report into the Preliminary Bridge Selection Report to produce a final Bridge Selection Report and develop the preliminary plans for the approved alternative. The preliminary plans consist of the General Plan and the General Notes and Quantities Sheets. The preliminary plans are not considered complete until the Bridge Hydraulics Report and Bridge Geotechnical Report are received and incorporated in the plans. There may be up to a six month delay between ordering drilling and receiving a recommendation.

FHWA Approval

This activity consists of obtaining FHWA approval of the Bridge Selection Report for Federal Aid Projects. Upon receipt of FHWA approval, the Preliminary Plans are considered complete and the Final design of the bridge may start.

Final Design

The Final Design Phase consists of performing the required structural analysis for the bridge and drawing the required details for the development of the construction drawings, producing the final cost estimate and preparing the Special Provisions. This phase should not start until the preliminary documents have been approved.

Final design consists of two phases: the first phase consists of designing and producing drawings for the Stage III document submittal, the second phase consists of completing the Stage IV final documents.

Stage III

This activity involves completion of most of the structural analysis; some of the drawings, a preliminary cost estimate with quantities and unit costs; and any required special provisions.

This phase will also include reviewing the 60% project plans, submitting comments and attending the office and/or field review.

Stage IV

This activity consists of incorporating the Stage III review comments in the design, completing the structural analysis and drawings, producing final quantities and a final cost estimate, and reviewing the Special Provisions.

When the project design is complete and quantities are calculated, a cost estimate shall be made. Unit costs may be obtained from the latest copy of the Unit Cost Summary and from the Bridge Group Bridge Costs Records. Unit prices should be adjusted for site location, size of project and other pertinent data.

PS & E Submittal - Stage V

The Plans, Specifications and Estimate (PS & E) Submittal is the final review of the project. This submittal shall be made when requested by the Control Desk. Complete plans and final quantities should always be finished by this date.

Bid Advertisement Date

The Bid Advertisement Date is the date the project is advertised. The Active Project Status Report refers to this date as the Bid Date. When requested by the Control Desk, the complete, signed and stamped tracings shall be sent to the Control Desk for printing of the bid sets.

Bid Opening

The Bid Opening is the date when the bids are opened. This activity normally ends the design phase. The construction contract for the project is then awarded at the next scheduled Arizona Transportation Board meeting.

Post Design Services

Post design services include the following activities: attending partnering sessions, making plan changes as a result of errors or changed conditions, approving falsework and shop drawing submittals, supervising structural steel inspections, producing as-built plans and reviewing the final as-built structural drawings for evaluation of design work and study for improvement.

BRIDGE PROJECT ENGINEER'S RESPONSIBILITY

General

Bridge Project Engineers are to be assigned to all new projects in which structure plans are required. The Bridge Engineer or Bridge Designer will be designated as the Bridge Project Engineer when the project study report or final Project Assessment becomes available and will be responsible for project delivery for all structure related items thru PS & E completion and subsequent construction contract completion.

Bridge Project Engineers are hereby given the authority and will be responsible for seeing that all Bridge Group design features comprising the PS & E package on projects are delivered on time, within budget, and in conformance with standards, to meet established schedules. Such features include structure plans for bridges, earth retaining structures, hydraulic structures, highway sign and lighting support structures, specifications for structures, and cost estimates for structures.

Bridge Project Engineers may also have responsibility for coordinating work efforts for completion of all work tasks if they are assigned as Project Managers according to the provisions of the Project Management process.

Selection of Bridge Project Engineers

Bridge Designers and Bridge Engineers interested in being selected as Bridge Project Engineers must obtain their Professional Engineer License and they must exhibit a majority of the following skills or traits:

- Has developed the technical skill.
- Gets along well with people.
- Is an innovator.
- Has initiative.
- Communicates effectively.
- Is practical.
- Has leadership abilities and will make decisions.
- Keeps abreast of technical developments.

- Has an understanding of ADOT policies and procedures.
- Understands the importance of project deadlines.

Duties of Bridge Project Engineers

A Bridge Project Engineer is assigned to support or act as the Project Leader or Project Manager and to direct the specific work effort assigned to Bridge Group. The duties of the Bridge Project Engineer shall include:

- Remain completely knowledgeable about the specific project tasks assigned.
- Direct the project work activities assigned.
- Coordinate with the project leader or project manager, as appropriate, on schedule, budget and quality control.
- Provide input for establishing a project's network model and on a continuous basis, provide input to update schedule data in the Management Scheduling and Control System.
- Review all preliminary reports for the project.
- Review bridge maintenance records for widening and rehabilitation projects.
- Review prior commitments to other agencies and coordinate commitments with ADOT policies.
- Direct preparation of Bridge Selection Reports and submit for approval as required.
- Coordinate structural details and design features within the project. Conduct meetings with designers and detailers as required.
- Work closely with other groups and services so that decisions in these areas are timely and consistent throughout the project.
- Attend scheduled progress meetings and site visits and provide information as required.
- Submit structure plans, special provisions and cost estimate on schedule.
- Coordinate all bridge construction liaison activities such as shop drawing review, construction modifications and final as-building.

CONSULTANT REVIEW PROCEDURES

General

This section is intended to provide procedures to be followed by the Bridge Design Sections in their review of consultant designs. The intent of these procedures is to produce consultant designs which have the same appearance (format and content) as ADOT Bridge Group in-house designs and to promote consistency among the three Design Sections and the consultants.

A Project Engineer will be assigned to each consultant review project. Large bridge projects will usually also have a designer assigned to the project to assist in the review.

Documentation

Reviews will be performed on scoping documents such as Project Assessments or Design Concept Reports whether prepared by a consultant or ADOT. Reviews will also be performed on consultant bridge designs at the 30%, 60%, 95% and 100% stages.

All submittals shall be stamped with the date received and a log book of all consultant review submittals shall be kept by each Section. The log shall track the type of review document, the date each submittal is received, the date when comments are due, and the date comments are returned.

An official project review file, consisting of hard grey filing folders, and a working file should be maintained for each project. The official project review file shall be organized the same as for in-house designs with a title sheet, an index and correspondence on the left side and review comments on the right side. The working file shall contain the submittal documents, special provisions and reviewer calculations.

Review comments should be returned to the project manager and be submitted on a Bridge Group Comment Review Form. A copy of all review comments shall be kept in the Official Project Review File.

Reviews

At each review stage, the reviewer should verify that all previous comments have been resolved and are properly reflected in the new submittal. When all old comments have been resolved, the old submittal documents may be discarded.

Reviews should be made to ensure that each submittal meets the requirements for the appropriate submittal stage. Reviews should also verify major features of the design but should not include number by number calculation checks. Calculations will not usually be submitted unless requested by the reviewer.

30% Submittal

For a 30% submittal, the following items should be included as a minimum:

- General Plan
- Bridge Selection Report
- Cost Estimate
- Final Bridge Geotechnical Report
- Final Bridge Hydraulics Report

Review of 30% submittals should be limited to ensuring that the proper bridge type, span lengths, widths and structure depth have been selected. An independent preliminary superstructure analysis should be performed to verify the structure depth. The reviewer should also check for consistency between the Geotechnical and Hydraulics Reports as related to the recommended foundation type. The General Plan and General Notes and Quantity Sheets should be complete except for the quantity box. Unit costs should be reviewed and bid items compared to the Approximate Quantity Manual guidelines.

60% Submittal

For a 60% submittal the following items should be included as a minimum:

- 60% Bridge Plans
- Superstructure completed
- Boring logs completed
- Substructure started
- Draft Bridge Special Provisions
- Cost Estimate including Bid Items, Item numbers and unit costs

Review of 60% submittals should consist of ensuring that major bridge items have not changed from the 30% submittal and that all 30% comments have been incorporated into the plans. The deck and superstructure designs should be checked. The superstructure plan sheets should be complete. The reviewer should verify that the substructure is consistent with the Bridge Geotechnical Report.

95% Submittal

For a 95% submittal the following items should be included as a minimum:

- 95% Bridge Plans
- Final Special Provisions
- Final Cost Estimate

Review of 95% submittals should consist of ensuring that 60% review comments have been incorporated into the plans. A review of the substructure for clarity and completeness should be made.

100% Submittal

The 100% submittal should be reviewed to ensure that the 95% comments have been incorporated into the plans and that all outstanding issues have been resolved.

Project Review

In addition to the review of bridge documents, the reviewer should review the project plans for consistency between the bridge plans and the civil and traffic plans. Items such as roadway profiles, bearings and width should be reviewed.

Other items which should be reviewed include the appropriate use of Standard Drawings including such design features as CBCs, retaining walls, pipe headwalls and tubular sign supports. Items involving special design should be given oversight review. Such items might include light poles, sign supports, tubular signs, FMS, retaining walls, CBCs, miscellaneous structural items, sound walls and Barrier Summary Sheets.

COMPUTING APPROXIMATE QUANTITIES

General Guidelines

The Purpose of this section is to establish guidelines and methods for the computation of approximate quantities for bridges and related structures and to identify the proper Bid Item Numbers. Quantities are used in the preparation of the Engineer's estimates and in establishing bid schedules. Contractors use the quantities as a basis for making contract bids. Box Culvert quantities are to be computed in accordance with the Reinforced Concrete Box Culvert Manual.

Sample approximate quantities sheets, Table 1, are provided to show the accuracy required for calculations.

A second set of computations for each structure should be made by a checker independently of the original calculations. This rigorous check is needed to minimize error and prevent the omission of a major item.

Small sketches of the items being calculated should be shown on the calculation sheets when the item description is not completely self-explanatory. The effort made to keep the calculation sheets easy to follow will be invaluable during back-checking.

This section identifies commonly used Standard Bid Items with Descriptions, Materials, Construction Requirements, Methods of Measurements and Basis of Payments in accordance with ADOT Standard Specifications. If a new Bid Item is required, a Special Provision will have to be written. Contracts and Specifications Section should be contacted for the proper number to be used.

If the structure drawings do not give enough information to compute the quantities, it is evident they are deficient and should be revised.

Concrete

The total figure of each item entered in the approximate quantities table as superstructure, pier or abutment is to be rounded to the nearest C.Y. The degree of accuracy required in deriving this total is outlined on Table 2, titled "Sample Approximate Quantities for Concrete".

In cases where the designer has used more than one class or strength of concrete, caution should be exercised so that each part of the item figured is grouped in the proper class and strength of concrete.

TABLE 1
APPROXIMATE QUANTITIES

APPROXIMATE QUANTITIES

ITEM	STRUCT. EXCAV. C.Y.	STRUCTURE BACK FILL C.Y.	CLASS 'S' CONCRETE		REINF. STEEL LBS.	STRUCT. STEEL LBS.	PEDESTRIAN RAIL L.F.	SLOPE PAVING S.Y.	60" DIA. DRILLED SHAFT L.F.
			f'C= 3000 C.Y.	f'C= 4500 C.Y.					
ABUT. #1	60	10	20		2,105			400	
PIER #1	65	15	64		4,885				110
PIER #2	75	15	64		4,885				
ABUT. #2	65	10	20		2,105			400	115
SUPERSTRUCTURE			21	268	51,520	132,415	238		
TOTALS	265	50	189	268	65,500	132.415	238	800	225
AS-BUILT									

ROUND TO NEAREST 5 C.Y.

ROUND TO NEAREST C.Y.

ROUND TO NEAREST 5 LBS.

ROUND TO NEAREST FOOT

ROUND TO NEAREST 5 S.Y.

ROUND TO NEAREST FOOT

TABLE 2
SAMPLE APPROXIMATE QUANTITIES FOR CONCRETE

ARIZONA DEPARTMENT OF TRANSPORTATION

APPROXIMATE QUANTITIES

TRACS NO.:

SHEET 1 OF 3

STATION ______________ **STRUCTURE NAME** ______________________________ **NB/EB** **SB/WB**

DATE: 3-15-2001

BY ABC CHKD DEF

PROJ. NO.:

OTHER:

CLASS “S” f’c = psi ☐ **STRUCT. BKFL.** ☐ **STRUCTURAL EXCAVATION** ☐

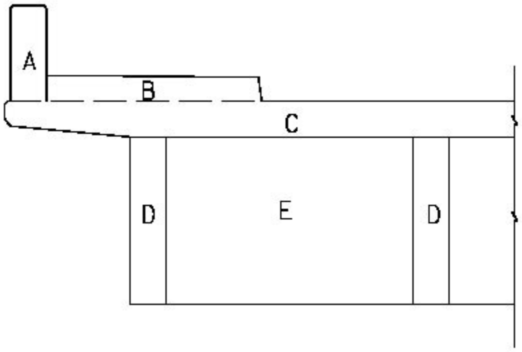
FOR: Superstructure-Class ‘S’ Concrete

ITEM DESCRIPTION	UNIT DEPTH (ft)	UNIT WIDTH (ft)	UNIT LENGTH (ft)	NO OF UNITS (PER ITEM)	TOTAL CU. FT		REVISION
Class “S” f’c=3000							
Parapet “A”	1.500	0.920	160.000	1	2	442	
Curb “B”	0.750	1.250	160.000	1	2	300	
						742 / 27=27 c. y.	
Class “S” f’c=4500							
Deck “C”	0.542	41.333	160.000	1	1	3,584	
Girders-Inter. “D”	3.167	1.167	48.000	7	2	2,484	
Girders-ends “D”	3.167	1.167	25.080	7	2	1,298	
Diaph. @abut. “E”	2.250	1.292	37.170	1	2	216	
Diaph.-Inter. “E”	2.167	0.833	4.830	6	2	105	
						7,687 / 27 c. y. = 285 c. y.	

ROUND TO NEAREST CUBIC FOOT.

CARRY TO THREE DECIMAL PLACE ACCURACY.

ROUND TO NEAREST CUBIC YARD (TO BE COMPARED WITH CHECK SET).



IT IS RECOMMENDED THAT SMALL SKETCHES BE DRAWN OF PARTS BEING FIGURED.

Bid Item Numbers for concrete quantities vary based on the specific concrete strength. If a concrete strength not shown is required, Bid Item Number 6010010 should be used. A list of Bid Item Numbers, Items and Units for various concrete strengths follows:

ITEM NO.	ITEM	UNIT
6010001	STRUCTURAL CONCRETE (CLASS S) (F’c=2500PSI)	CY
6010002	STRUCTURAL CONCRETE (CLASS S) (F’c=3000PSI)	CY
6010003	STRUCTURAL CONCRETE (CLASS S) (F’c=3500PSI)	CY
6010004	STRUCTURAL CONCRETE (CLASS S) (F’c=4000PSI)	CY
6010005	STRUCTURAL CONCRETE (CLASS S) (F’c=4500PSI)	CY
6010006	STRUCTURAL CONCRETE (CLASS S) (F’c=5000PSI)	CY
6010007	STRUCTURAL CONCRETE (CLASS S) (F’c=5500PSI)	CY
6010010	STRUCTURAL CONCRETE (CLASS S) (F’c=)	CY

Reinforcing Steel

The total accumulated figure for each listed Item (Abutment, Pier, Superstructure, etc.) used for reinforcing steel in the approximate quantities table is rounded to the nearest 5 pounds.

The following items are omitted from reinforcing steel weights:

- Round smooth bars or bolts.
- Reinforcing in piles or reinforcing extending into abutments or piers from piles or drilled shafts. For reinforcing transitioning from a drilled shaft to a column refer to Drilled Shafts Section.
- Reinforcement not shown on the project drawings required for anchorage zone recess blocks, duct ties and grillage assemblies as recommended by the post-tensioning system used.

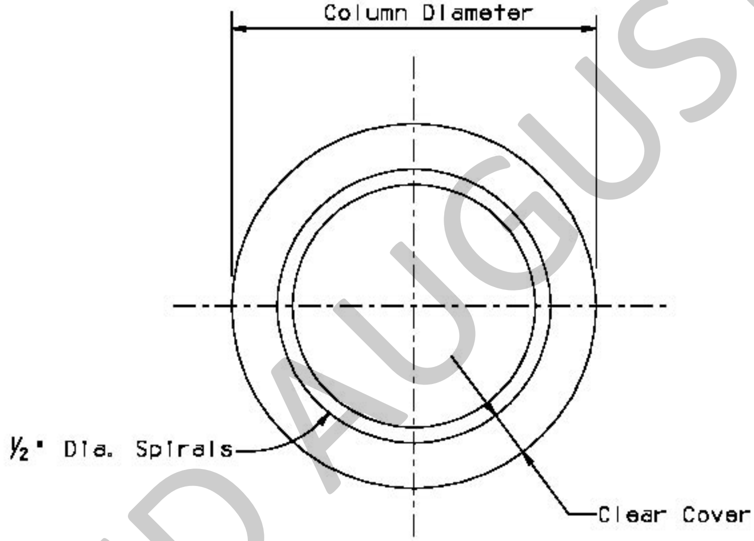
The length of each item of reinforcement not detailed on the drawings is figured to the nearest 3 inches. An amount of 2 feet is added for any lap not detailed. A lap is figured for every 40 running feet of bar. As an example, a bar required to be 90 feet in length would have a length of 4 feet added to it for 2 laps unless detailed for 46 feet or more. For lapped ends of loops, a total of 8 inches is considered adequate for all sizes of bars. Section 5, Table 1, 2 and 3 give the additional length of bar needed for end hooks on stirrups, dowels, etc. according to the size of the bars in consideration. Table 3, below, is given for the weights of standard deformed reinforcing bars.

TABLE 3
WEIGHTS IN LBS OF DEFORMED REINFORCING BARS

SIZE	#2	#3	#4	#5	#6	#7
WEIGHT	.167	.376	.668	1.043	1.502	2.044
SIZE	#8	#9	#10	#11	#14	#18
WEIGHT	2.670	3.400	4.303	5.313	7.65	13.60

A special Table 4, shown below, is given for weight of ½" diameter spiral reinforcing for round concrete columns according to the diameter, cover and pitch.

TABLE 4
WEIGHTS OF ½" SPIRALS PER VERTICAL FOOT



Col. Dia. (Ft.)	Clear Cover (inches)	Pitch (inches)								
		3	3 ½	4	4 ½	5	5 ½	6	9	12
7'-0	2	55.6	47.7	41.7	37.1	33.4	30.3	27.8	18.6	14.1
	3	54.2	46.5	40.7	36.1	32.5	29.6	27.1	18.2	13.7
	6	50.0	42.9	37.5	33.3	30.0	27.1	25.0	16.8	12.7
6'-6	2	51.4	44.1	38.6	34.3	30.8	28.0	25.7	17.3	13.0
	3	50.0	42.9	37.5	33.3	30.0	27.1	25.0	16.8	12.7
	6	45.8	39.3	34.4	30.5	27.5	25.0	22.9	15.4	11.6
6'-0	2	47.2	40.5	35.4	31.5	28.3	25.8	23.6	15.9	12.0
	3	45.8	39.3	34.4	30.5	27.5	25.0	22.9	15.4	11.6
	6	41.6	35.7	31.2	27.7	25.0	22.7	20.8	14.0	10.6
5'-6	2	43.0	36.9	32.3	28.7	25.8	23.5	21.5	14.5	11.0
	3	41.6	35.7	31.2	27.7	25.0	22.7	20.8	14.0	10.6
	6	37.4	32.1	28.1	24.9	22.5	20.4	18.7	12.6	9.6
	2	38.8	33.3	29.1	25.9	23.3	21.2	19.4	13.1	9.9

5’-0	3	37.4	32.1	28.1	24.9	22.5	20.4	18.7	12.6	9.6
	6	33.2	28.5	24.9	22.2	19.9	18.1	16.6	11.3	8.6
4’-6	2	34.6	29.7	26.0	23.1	20.8	18.9	17.3	11.7	8.9
	3	33.2	28.5	24.9	22.2	19.9	18.1	16.6	11.3	8.6
	6	29.0	24.9	21.8	19.4	17.4	15.8	14.5	9.9	7.6
4’-0	2	30.4	26.1	22.8	20.3	18.3	16.6	15.2	10.4	7.9
	3	29.0	24.9	21.8	19.4	17.4	15.8	14.5	9.9	7.6
	6	24.8	21.3	18.6	16.6	14.9	13.5	12.4	8.6	6.6
3’-6	2	26.2	22.5	19.7	17.5	15.7	14.3	13.1	9.0	6.9
	3	24.8	21.3	18.6	16.6	14.9	13.5	12.4	8.6	6.6
	6	20.6	17.7	15.5	13.8	12.4	11.3	10.3	7.2	5.6
3’-0	2	22.0	18.9	16.5	14.7	13.2	12.0	11.0	7.6	5.9
	3	20.6	17.7	15.5	13.8	12.4	11.3	10.3	7.2	5.6
	6	16.4	14.1	12.3	11.0	9.9	9.0	8.2	5.9	4.6
2’-6	2	17.8	15.3	13.4	11.9	10.7	9.7	8.9	6.3	4.9
	3	16.4	14.1	12.3	11.0	9.9	9.0	8.2	5.9	4.6
	6	12.2	10.5	9.2	8.2	7.3	6.7	6.1	4.6	3.7
2’-0	2	13.6	11.7	10.2	9.1	8.2	7.4	6.8	5.0	4.0
	3	12.2	10.5	9.2	8.2	7.3	6.7	6.1	4.6	3.7
	6	8.0	6.9	6.0	5.4	4.8	4.4	4.0	3.5	3.0

Special attention is called to the sample approximate quantities for weights on Table 5, which shows the required accuracy for computation of reinforcing weights. As illustrated in the sample, a short description of the item being figured will be beneficial for comparing quantities between estimator and checker.

Quantities for epoxy coated reinforcing steel shall be separated from regular reinforcing steel quantities. A list of Bid Item Numbers, Items and Units for reinforcing steel follows:

ITEM NO.	ITEM	UNIT
6050002	REINFORCING STEEL	LB
6050012	REINFORCING STEEL (EPOXY COATED)	LB

Structural Steel

The total figure for structural steel as entered in the approximate quantities table under the item “Superstructure” is to be rounded to the nearest 5 pounds. The degree of accuracy required in computing this total is outlined on Table 6, titled “Sample Approximate Quantities for Structural Steel”.

Structural steel weights are not figured for concrete structures; that is, structures that are dependent on reinforced or prestressed concrete slabs, girders or beams for their load carrying capacity. The cost of structural steel for these structures is included in the price bid for the concrete or other items.

TABLE 5
SAMPLE APPROXIMATE QUANTITIES FOR REINFORCING STEEL

ARIZONA DEPARTMENT OF TRANSPORTATION
APPROXIMATE QUANTITIES

TRACS NO. ____________ **SHEET** 2 **OF** 3
STATION **STRUCTURE NAME**
____________ NORTHERN AVE. UP **NB/EB** ☒ **DATE** 3-15-01.
PROJ. NO.: I-10-4(24) **SB/WB** ☐ **BY** ABC **CHKD** DEF.
REINF. STEEL ☐ **STRUCT. STEEL** ☐ **FOR** **Abutment #1**

ITEM DESCRIPTION	**UNIT SIZE**	**UNIT WEIGHT (PER FT)**	**UNIT LENGTH (FT)**	**NO OF UNIT (PER ITEM)**	**NO OF ITEMS**	**TOTAL**	
						WEIGHT	REVISION
Cap beam long.	#5	1.043	40.75	11	1	468	
Back wall long.	#4	.668	38.00	8	1	203	
Hoops in cap ☐	#4	.668	13.00	37	1	321	
Back wall verticals	#4	.668	4.00	76	1	203	
					Subtotal	1,195	
Wing cap long.	#5	1.043	12.00	6	2	150	
Hoop in wing cap	#4	.668	10.75	7	2	101	
Wing long.	#5	1.043	9.50	12	2	238	
Wing long.	#4	.668	9.50	8	2	96	
Wing stirrups ⊓	#4	.668	15.00	11	2	220	
Parapet verticals	#4	.668	4.25	22	2	126	
		↑	↑		Subtotal	931	
STANDARD WEIGHT FROM TABLE 4							
					Total	2,126	
ROUND TO NEAREST 3 INCHES UNLESS DETAILED ON PLANS					Use	2,125 lbs.	
						↑	
				ROUND TOTAL TO			
				NEAREST 5 LBS.			

TABLE 6
SAMPLE APPROXIMATE QUANTITIES FOR STRUCTURAL STEEL

ARIZONA DEPARTMENT OF TRANSPORTATION
APPROXIMATE QUANTITIES

TRACS NO.: **SHEET** ____ **OF** ____

STATION **STRUCTURE NAME** **NB/EB** **DATE** ____________
623+ ______________________ **SB/WB** **BY** ____ **CHKD** ____

PROJ. NO. : I-10-4(24)

REINF. STEEL ☐ STRUCT STEEL ☐ **FOR** ______________________

ITEM DESCRIPTION	UNIT SIZE	UNIT WEIGHT (PER FT)	UNIT LENGTH (FT)	NO OF UNITS (PER ITEM)	NO OF ITEMS	TOTAL	
						WEIGHT	REVISION
Main Girders	W36x135	135	247.16	5	1	166,833	
Cover PL@Pier #1&#3	PL 3/8x11	14.00	13.00	2	10	3,640	
Cover PL@Pier #1&#3	Ends	9.56	1.50	2	20	574	
Cover PL@Pier #2	PL 5/8x11	23.40	16.00	2	5	3,744	
Cover PL@Pier #2	Ends	15.90	1.50	2	10	477	
Splices	PL ½x11½	19.60	2.54	2	20	1,992	
Bolts in Splices	7/8 ϕ	.924		94	20	1,737	
Welds for Cover PL	5/16”Fillet	.166	204	1	5	169	
					Subtotal	183,622	
Shear Connector							
Studs	¾”ϕx4”	.615				415	
					Subtotal	415	
Stiff PL	PL ½ x5	8.5	2.83	20	1	481	
Welds for above	5/16”Fillet	.166	7.78	114	1	147	
Diaphragms	[18x42.7	42.7	7.0	8	1	2,391	
Diaphragms	[15x33.9	33.9	7.00	44	1	10,441	
Bolts for above	7/8”ϕ	1.101		114	8	1,004	
Stiff PL	PL ¾x5	12.80	2.80	30	1	1,086	
Stiff PL	PL 3/8x5	6.38	2.83	8	8	1,155	
Exp Joint	3x3x3/8	7.20	28.00	2	2	806	
Anchors for above	5/8ϕ	1.33	29.00	1	2	77	
Welds	¼ Fillet	.106	29.00	.167	4	2	
					Subtotal	885	
			Round TOTAL TO NEAREST 5 LBS. →		**Total**	201,629	Lbs.
					Use	201,630	Lbs.

Listed below are the items which are to be included or excluded in the total of structural steel:

Inclusion List for Structural Steel

1. Structural steel for use in bridge structures consists of rolled shapes, plate girders, shear connectors, plates, bars, angles and other items as defined in this inclusion list. Areas and weights of steel sections amy be found in the A.I.S.C. Manual of Steel Construction. As shown in the A.I.S.C. Manual, the weight of rolled beams is given in pounds per linear foot. In figuring weight for welded plate girders, it is necessary that each plate differing in width, thickness or length be listed separately. The weight of plates greater than 36 inches in width should be increased by a percentage of the basic weight according to Table7 below. This is to allow for the A.S.T.M. permissible overrun of plates.

TABLE 7

STRUCTURAL STEEL PLATE WEIGHT INCREASE
EXPRESSED IN PERCENTAGE OF NOMINAL WEIGHT

Specified Thickness Inches	Over 36 to 48 Incl	Over 48 to 60 excl	60 to 70 excl	72 to 84 excl	84 to 96 excl	96 to 108 excle	108 to 120 excl	120 to 132 excl	132 to 144 excl	144 to 168 excl	168 and over
3/16 to ¼ excl		4	4.5	5	6	7	8	9			
¼ to 5/16 "	3	3.5	4	4.5	5	6	7	8	9.5		
5/16 to 3/8 "	2.5	3	3.5	4	4.5	5	6	7	8	9.5	
3/8 to 7/16 "	2.3	2.5	3	3.5	4	4.5	5	6	7.5	8	9
7/16 to ½ "	2	2.3	2.5	3	3.5	4	4.5	5	6.5	7	8
½ to 5/8 "	2	2	2.3	2.5	3	3.5	4	4.5	5.5	6	6
5/8 to ¾ "	2	2	2	2.3	2.5	3	3.5	4	4.5	5	6
¾ to 1 "	1.8	2	2	2	2.3	2.5	3	3.5	4	4.5	5.5
1 to 2 Incl.	1.8	1.8	2	2	2	2.3	2.5	3	3.5	4	4.5

TABLE 8

WEIGHT OF STUD SHEAR CONNECTORS

Stud Diameter	Weight in pounds per 100 studs having in-place length of				
	3 in.	4 in.	5 in.	6 in.	7 in.
½	21.0	27.0	33.0	45.0	39.0
5/8	33.6	43.2	52.8	72.0	62.4
¾	49.0	61.5	74.0	99.0	86.5
7/8	64.0	81.0	98.0	132.0	115.0

2. BOLTS - All fasteners shall be high-strength bolts, AASHTO M164 (ASTM A325) or AASHTO M253(ASTM A490). Weights of components, including washers, may be found in the A.I.S.C. Manual of Steel Construction. Add 3% if galvanized.

3. WELDS - The weight of fillet welds shall be included in the weight of structural steel. In Table 9 below, a weight per linear foot is given for different sizes of fillet welds. For butt welds, plug welds, etc. no addition or deduction is made for weight calculations.

TABLE 9
WEIGHT IN LBS OF WELDS PER LINEAR FOOT
45 degree fillet weld

SIZE	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16
WEIGHT	.027	.060	.106	.166	.239	.326	.425	.538
SIZE	5/8	11/16	3/4	13/16	7/8	15/16	1”	
WEIGHT	.664	.804	.956	1.12	1.30	1.50	1.70	

4. The weight of deck drains should be included in the weight of structural steel for the deck.

Exclusion List for Structural Steel

1. Erection bolts.
2. Pedestrian rail and accessories.
3. Bumper (nose) angles for approach slabs.
4. Steel “H” piling or steel encased in concrete piles.
5. Fabricated steel supports or strengthened sections for erection.
6. Deck joint assemblies.
7. Abutment and pier steel bearings.

Structural Steel (Miscellaneous)

All other structural steel items including rockers, rollers, bearing plates, pins and nuts, plates, shapes for bridge sign supports, corresponding weld metal, nuts and bolts, and similar steel items not covered in other contract items will be measured for payment as structural steel (miscellaneous).

Quantities should be separated by grade for structural steel. For steel bridges, A36 steel should be listed under Item No. 6040001 while other grades should be listed under Item No. 6040002 with the appropriate grade filled in with the parenthesis. Structural steel weights are not figured for concrete structures. A list of Bid Item Numbers, Items and units for various structural steel follows:

ITEM NO.	ITEM	UNIT
6040001	STRUCTURAL STEEL	LB
6040002	STRUCTURAL STEEL ( )	LB
6040003	STRUCTURAL STEEL (MISC)	LB

Structural Excavation

Each amount of structural excavation as shown in the approximate quantities table for items such as abutments and piers is to be rounded to the nearest 5 cu. Yds.

Structural excavation limits for piers are bounded on the sides by vertical planes 1'-6" outside the limits of the footing, by the ground line on the top and the bottom of the footing on the bottom. When neat line excavation is called for on the plans or by the standard, the volume not excavated shall be deducted from the above.

Structural excavation for abutments is figured with the same limits as described for pier excavation. In many instances abutments are built on approach fills. The depth of structural excavation into the approach fill is figured from the berm elevation to the bottom of the abutment cap beam and no neat line excavation is figured.

For pier footings and abutment cap beams on piles, do not use neat line excavation.

Excavation for abutment wings has the same 1'-6" limit as the main cap beam and neat line excavation where applicable.

Figure 10, Structural Excavation Payment Limits, is shown for typical conditions. Actual payment limits for each structure shall be included with the structure drawings.

A list of Bid Item Numbers, Items and Units for structural excavation follows:

ITEM NO.	ITEM	UNIT
2030501	STRUCTURAL EXCAVATION	CY

Structure Backfill

Each amount of structure backfill as shown in the approximate quantities table for items such as abutments and piers is to be rounded to the nearest 5 cubic yards.

Structure backfill for abutments is figured as follows:

When an abutment falls below the existing ground level, structure backfill is figured within structural excavation limits on the approach slab side of the abutment only. When an abutment is built above the existing ground level, an additional area under the approach slab is added. Measuring is to be parallel to the centerline of the roadway. The abutment wings enclose this area.

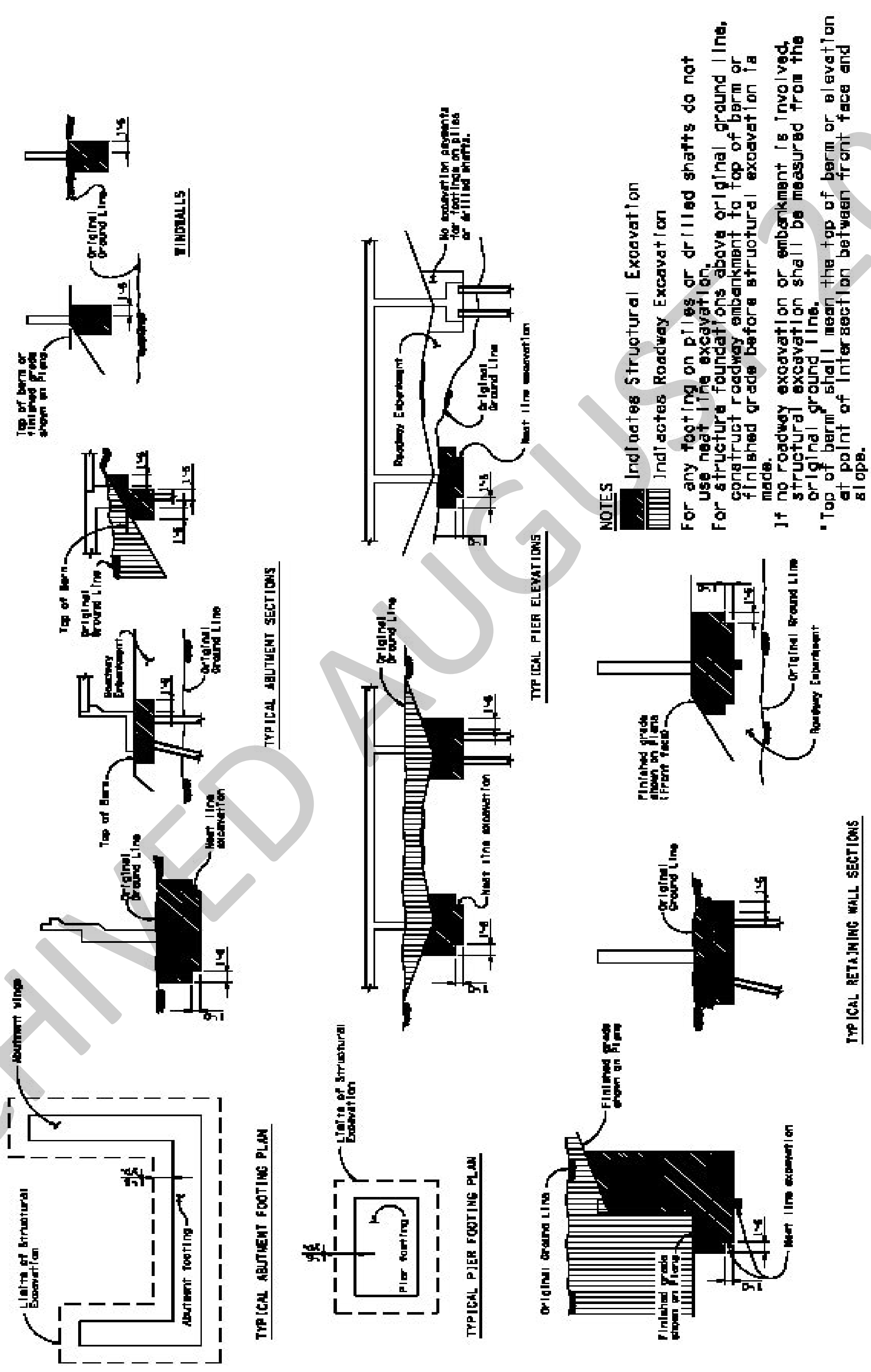
Structure backfill is required for piers only when the pier falls within the roadway prism. When the roadway is on one side of a pier only, structure backfill is figured only on the side of the pier. Figure 11, Structure Backfill Payment Limits, is shown for typical conditions. Actual payment limits for each structure shall be included with the structure drawings.

A list of Bid Item Numbers, Items and Units for structure backfill follows:

ITEM NO.	ITEM	UNIT
2030506	STRUCTURE BACKFILL	CY

FIGURE 10

STRUCTURAL EXCAVATION PAYMENT LIMITS.



NOTES

▨ Indicates Structural Excavation

▥ Indicates Roadway Excavation

For any footing on piles or drilled shafts do not use neat line excavation.

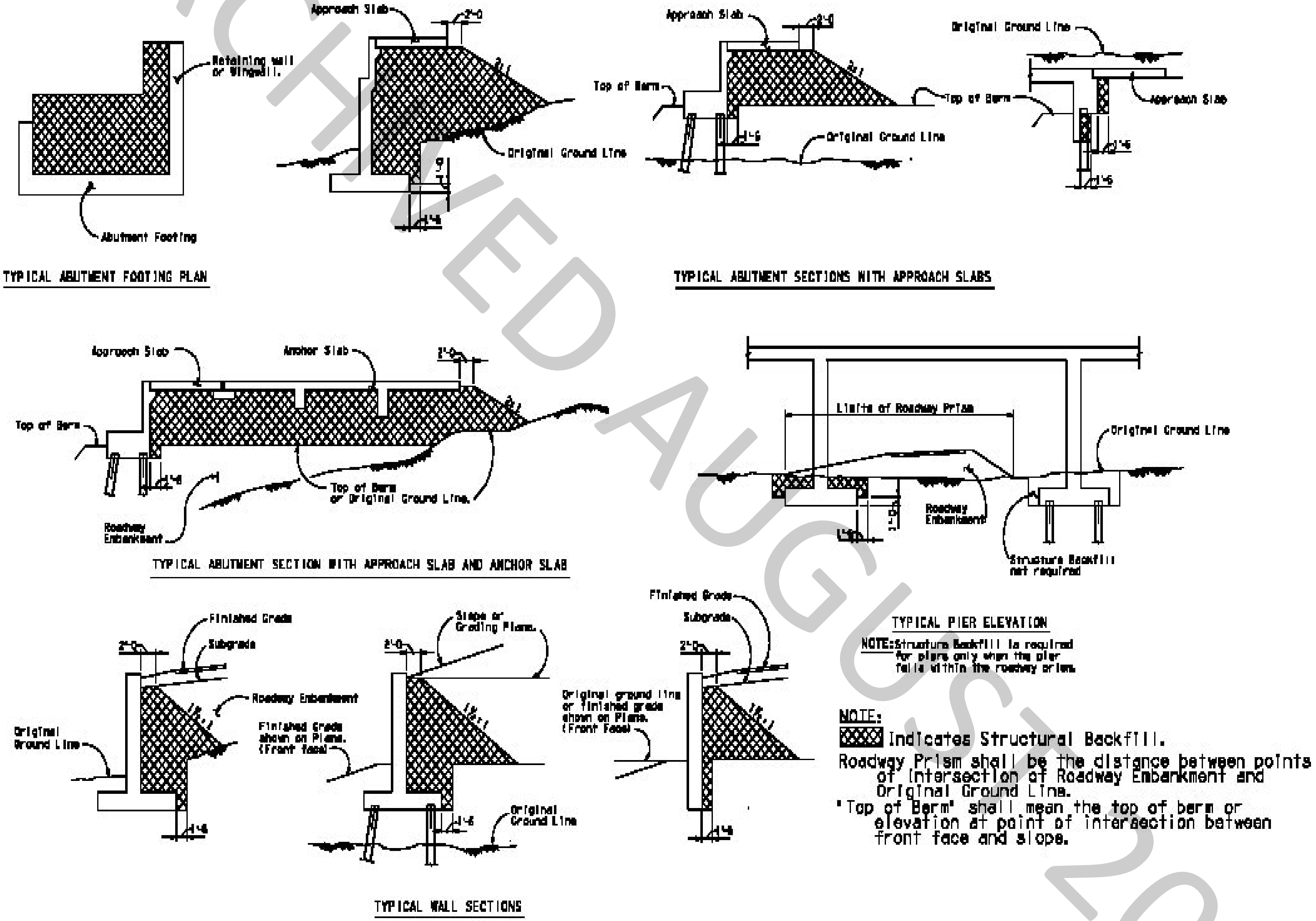
For structure foundations above original ground line, construct roadway embankment to top of berm or finished grade before structural excavation is made.

If no roadway excavation or embankment is involved, structural excavation shall be measured from the original ground line.

* Top of berm* shall mean the top of berm or elevation at point of intersection between front face and slope.

FIGURE 11

STRUCTURE BACKFILL PAYMENT LIMITS.



TYPICAL ABUTMENT FOOTING PLAN

TYPICAL ABUTMENT SECTIONS WITH APPROACH SLABS

TYPICAL ABUTMENT SECTION WITH APPROACH SLAB AND ANCHOR SLAB

TYPICAL PIER ELEVATION

NOTE: Structure Backfill is required for piers only when the pier falls within the roadway prism.

TYPICAL WALL SECTIONS

NOTE:

▨ Indicates Structural Backfill.

Roadway Prism shall be the distance between points of intersection of Roadway Embankment and Original Ground Line.

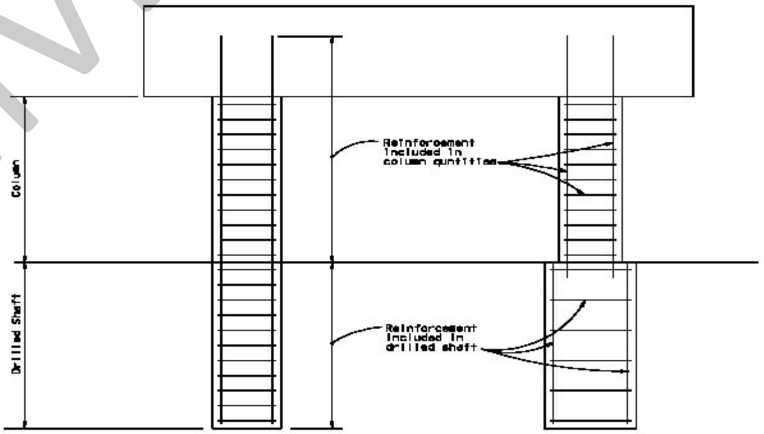
"Top of Berm" shall mean the top of berm or elevation at point of intersection between front face and slope.

Drilled Shafts

Drilled shafts are bid by the linear foot. The item for drilled shafts includes the drilling, any casing, the concrete and all reinforcing steel embedded in the shaft. Quantities are rounded to the nearest foot for each sub item such as abutments and piers. Quantities are figured separately for each size and separated into two categories: drilled shafts drilled into rock and drilled shafts drilled into soil. Standard sizes are listed below. For special size shafts use Item Number 6090148 and fill in the specified diameter in inches within the parenthesis. For shafts in rock use Item Number 6091030 and fill in the specified diameter in inches within the parenthesis.

A list of Bid Item Numbers, Items and Units for drilled shafts follows:

ITEM NO.	ITEM	UNIT
6090018	DRILLED SHAFT FOUNDATION (18”)	LF
6090024	DRILLED SHAFT FOUNDATION (24”)	LF
6090030	DRILLED SHAFT FOUNDATION (30”)	LF
6090036	DRILLED SHAFT FOUNDATION (36”)	LF
6090042	DRILLED SHAFT FOUNDATION (42”)	LF
6090048	DRILLED SHAFT FOUNDATION (48”)	LF
6090054	DRILLED SHAFT FOUNDATION (54”)	LF
6090060	DRILLED SHAFT FOUNDATION (60”)	LF
6090066	DRILLED SHAFT FOUNDATION (66”)	LF
6090072	DRILLED SHAFT FOUNDATION (72”)	LF
6090078	DRILLED SHAFT FOUNDATION (78”)	LF
6090084	DRILLED SHAFT FOUNDATION (84”)	LF
6090096	DRILLED SHAFT FOUNDATION (96”)	LF
6090148	DRILLED SHAFT FOUNDATION ( )	LF
6091030	DRILLED SHAFTS (ROCK) ( )	LF



TYPICAL DRILLED SHAFTS

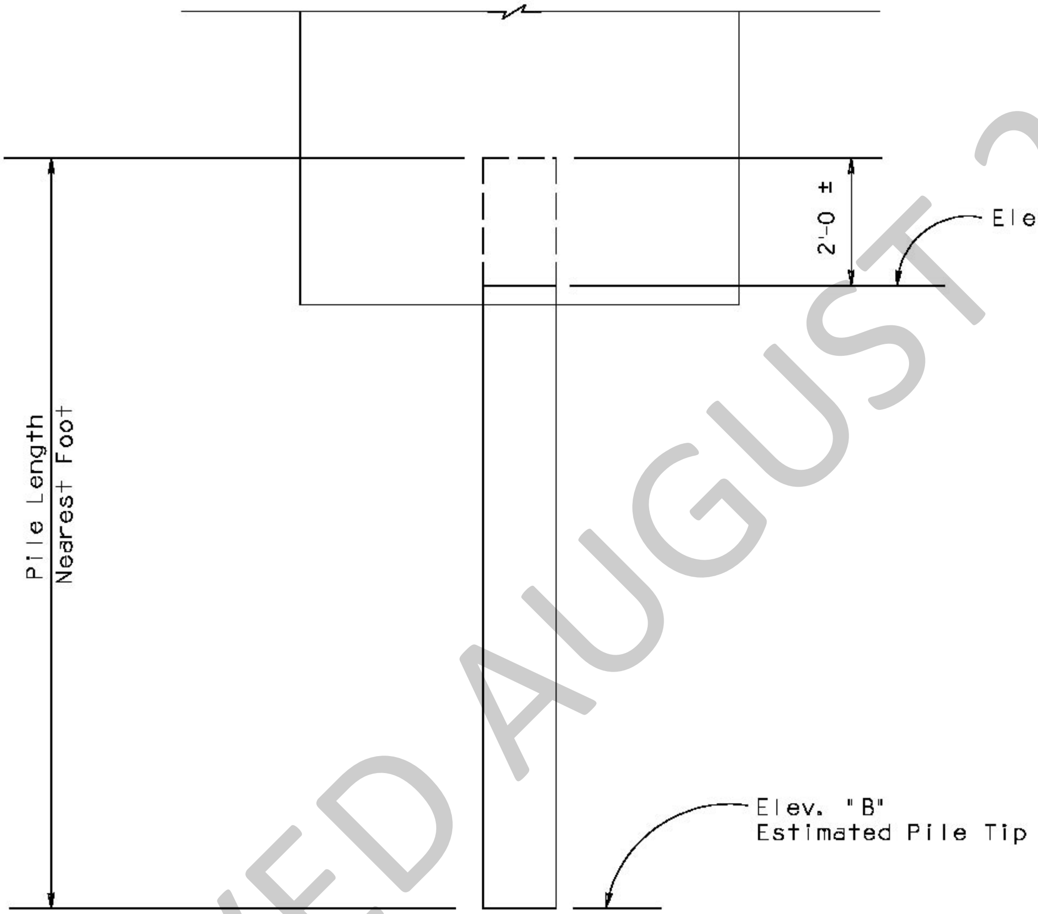
Driven Piles

Driven piles consist of H-piles, pipe piles and precast piles. Payment is divided into furnishing the pile, driving the pile and splicing, when required. There is no direct estimate for splicing. When an H-pile is specified other than the four sizes shown, items 6030012 and 6030194 should be used and the size placed in the parenthesis. When driven piles other than H-piles are specified, items 6030194 should be used and the type of pile used placed in the parenthesis. When piles must be driven deeper than specified on the plans to develop their strength, the contractor is paid to splice a new section onto the portion of the pile already driven. The cost equals five times the bid price for furnishing the piles. For quantity and payment purposes, two feet is added to the estimated length of a pile. Refer to Figure 12 for a diagram.

A list of Bid Item Numbers, Items and Units for driven piles follows:

ITEM NO.	ITEM	UNIT
6030003	FURNISHING PILES (STEEL) (HP12x53)	LF
6030005	FURNISHING PILES (STEEL) (HP12x74)	LF
6030008	FURNISHING PILES (STEEL) (HP14x89)	LF
6030010	FURNISHING PILES (STEEL) (HP14x117)	LF
6030012	FURNISH HP PILES	LF
6030013	FURNISH PILES ( )	LF
6030190	DRIVE HP 12 x 53 PILES	LF
6030191	DRIVE UP 12 x 74 PILES	LF
6030192	DRIVE HP 14 x 89 PILES	LF
6030193	DRIVE HP 14 x 117 PILES	LF
6030194	DRIVE HP PILES ( )	LF
6030195	DRIVE PILES ( )	LF
6030303	SPLICING PILE STEEL (5 TIMES UNIT PRICE OF 6030003)	EA
6030305	SPLICING PILE STEEL (5 TIMES UNIT PRICE OF 6030005)	EA
6030308	SPLICING PILE STEEL (5 TIMES UNIT PRICE OF 6030008)	EA
6030310	SPLICING PILE STEEL (5 TIMES UNIT PRICE OF 6030010)	EA
6030312	SPLICING PILE STEEL (5 TIMES UNIT PRICE OF 6030012)	EA
6030313	SPLICING PILE (5 TIMES UNIT PRICE OF 6030013)	EA

FIGURE 12
LENGTH OF PILING



Length = (Elev. "A" - Elev. "B") + 2'-0 (To nearest zero)

Precast Prestressed Concrete Members

Precast prestressed concrete members consist of AASHTO standard or modified I-girders, box beams and voided slabs. The bid items are calculated by the linear foot. The total sum of the lengths of all girders are rounded to the nearest foot. The bid item includes reinforcing, concrete, prestressing strand, anything else embedded in the girder and also includes transportation and erection in place.

A list of Bid Item Numbers, Items and Units for these members follows:

ITEM NO.	ITEM	UNIT
6014950	PRECAST, P/S MEMBER (AASHTO TYPE 2 GIRDER)	LF
6014951	PRECAST, P/S MEMBER (AASHTO TYPE 3 GIRDER)	LF
6014952	PRECAST, P/S MEMBER (AASHTO TYPE 4 GIRDER)	LF
6014953	PRECAST, P/S MEMBER (AASHTO TYPE 5 GIRDER)	LF
6014954	PRECAST, P/S MEMBER (AASHTO TYPE 6 GIRDER)	LF
6014955	PRECAST, P/S MEMBER (AASHTO TYPE 5 MOD. GR.)	LF
6014956	PRECAST, P/S MEMBER (AASHTO TYPE 6 MOD. GR.)	LF
6014957	PRECAST, P/S MEMBER (BOX BEAM TYPE BI-36)	LF
6014958	PRECAST, P/S MEMBER (BOX BEAM TYPE BII-36)	LF
6014959	PRECAST, P/S MEMBER (BOX BEAM TYPE BIII-36)	LF
6014960	PRECAST, P/S MEMBER (BOX BEAM TYPE BIV-36)	LF
6014961	PRECAST, P/S MEMBER (BOX BEAM TYPE BI-48)	LF
6014962	PRECAST, P/S MEMBER (BOX BEAM TYPE BII-48)	LF
6014963	PRECAST, P/S MEMBER (BOX BEAM TYPE BII-48)	LF
6014964	PRECAST, P/S MEMBER (BOX BEAM TYPE BIV-48)	LF
6014965	PRECAST, P/S MEMBER (VOIDED SLAB TYPE SI-36)	LF
6014966	PRECAST, P/S MEMBER (VOIDED SLAB TYPE SII-36)	LF
6014967	PRECAST, P/S MEMBER (VOIDED SLAB TYPE SII-36)	LF
6014968	PRECAST, P/S MEMBER (VOIDED SLAB TYPE SIV-36)	LF
6014969	PRECAST, P/S MEMBER (VOIDED SLAB TYPE SI-48)	LF
6014970	PRECAST, P/S MEMBER (VOIDED SLAB TYPE SII-48)	LF
6014971	PRECAST, P/S MEMBER (VOIDED SLAB TYPE SIII-48)	LF
6014972	PRECAST, P/S MEMBER (VOIDED SLAB TYPE SIV-48)	LF
6014973	PRECAST, P/S MEMBER ( )	LF

Miscellaneous Items

A list of miscellaneous Bid Item Numbers, Items and Units follows:

ITEM NO.	ITEM	UNIT
2020002	REMOVE BRIDGE	LUMP SUM
2020008	REMOVAL OF STRUCTURAL CONCRETE	LUMP SUM
2020009	REMOVAL OF STRUCTURAL CONCRETE	CY
6010501	BRIDGE REPAIR	LUMP SUM
6010801	BRIDGE DECK DRAIN ASSEMBLY	LS
6010831	GROOVE BRIDGE DECK	SQ YD
6011130	32 IN. F-SHAPE BRIDGE CONCRETE BARRIER AND TRANSITION (SD 1.01)	LF
6011131	42 IN. F-SHAPE BRIDGE CONCRETE BARRIER AND TRANSITION (SD 1.02)	LF
6011132	COMBINATION PEDESTRIAN-TRAFFIC BRIDGE RAILING (SD 1.04)	LF
6011133	PEDESTRIAN FENCE FOR BRIDGE RAILING SD 1.04 (SD 1.05)	LF
6011134	TWO TUBE BRIDGE RAIL (SD 1.06)	LF
6011371	APPROACH SLAB (SD 2.01)	SF
6011372	ANCHOR SLAB-TYPE 1 (SD 2.02)	SF
6011373	ANCHOR SLAB-TYPE 2 (SD 2.03)	SF
6015101	RESTRAINERS, VERTICAL EARTHQUAKE (FIXED)	EA
6015102	RESTRAINERS, VERTICAL EARTHQUAKE(EXPANSION)	EA
6015200	HIGH-LOAD MULTI-ROTATIONAL BEARINGS	EA
6020001	PRESTRESSING CAST-IN-PLACE CONCRETE	LS
6041001	JACKING BRIDGE SUPERSTRUCTURE	LUMP SUM
6050101	PLACE DOWELS	EA
6050201	LOAD TRANSFER DOWELS	EA
6060040	BRIDGE SIGN STRUCTURE (TUBULAR) (40' TO 70')	EA
6060041	BRIDGE SIGN STRUCTURE (TUBULAR) (70' TO 94')	EA
6060042	BRIDGE SIGN STRUCTURE (TUBULAR) (94' TO 106')	EA
6060043	BRIDGE SIGN STRUCTURE (TUBULAR) (106' TO 130')	EA
6060044	BRIDGE SIGN STRUCTURE (TUBULAR) (130' TO 142')	EA
6060045	TUBULAR FRAME SIGN STRUCTURE (TYPE 1F) (SD 9.20)	EA
6060046	TUBULAR FRAME SIGN STRUCTURE (TYPE 2F) (SD 9.20)	EA
6060047	TUBULAR FRAME SIGN STRUCTURE (TYPE 3F) (SD 9.20)	EA
6060048	TUBULAR FRAME SIGN STRUCTURE (TYPE 4F) (SD 9.20)	EA
6060075	FOUNDATION FOR TUBULAR FRAME SIGN STRUCTURE (TYPE 1F) (SD 9.20)	EA
6060076	FOUNDATION FOR TUBULAR FRAME SIGN STRUCTURE (TYPE 2F) (SD 9.20)	EA

6060078	FOUNDATION FOR TUBULAR FRAME SIGN STRUCTURE (TYPE 3F) (SD 9.20)	EA
6060079	FOUNDATION FOR TUBULAR FRAME SIGN STRUCTURE (TYPE 4F) (SD 9.20)	EA
6060131	TUBULAR CANTILEVER SIGN STRUCTURE (TYPE 1C) (SD 9.10)	EA
6060132	TUBULAR CANTILEVER SIGN STRUCTURE (TYPE 2C) (SD 9.10)	EA
6060133	TUBULAR CANTILEVER SIGN STRUCTURE (TYPE 3C) (SD 9.10)	EA
6060134	TUBULAR CANTILEVER SIGN STRUCTURE (TYPE 4C) (SD 9.10)	EA
6060161	SIGN STRUCTURE (MEDIAN, TWO SIDED) (SD 9.01)	EA
6060162	SIGN STRUCTURE (MEDIAN, ONE SIDED) (SD 9.02)	EA
6060247	FOUNDATION FOR SIGN STRUCTURE (MEDIAN) (SD 9.01 OR SD 9.02)	EA
6060254	FOUNDATION FOR TUBULAR CANTILEVER SIGN STRUCTURE (TYPE 1C) (SD 9.10)	EA
6060255	FOUNDATION FOR TUBULAR CANTILEVER SIGN STRUCTURE (TYPE 2C) (SD 9.10)	EA
6060256	FOUNDATION FOR TUBULAR CANTILEVER SIGN STRUCTURE (TYPE 3C) (SD 9.10)	EA
6060257	FOUNDATION FOR TUBULAR CANTILEVER SIGN STRUCTURE (TYPE 4C) (SD 9.10)	EA
6100001	PAINTING STRUCTURAL STEEL	LUMP SUM
6100011	PAINT BRIDGE	LUMP SUM
7320471	BRIDGE JUNCTION BOX	EA
7379111	VARIABLE MESSAGE SIGN ASSEMBLY INSTALLATION	EA
9050430	THRIE BEAM GUARD RAIL TRANSITION SYSTEM (SD 1.03)	EA
9100008	CONCRETE BARRIER (TEMPORARY BRIDGE)	LF
9120001	SHOTCRETE	SQ YD
9140136	SOUND BARRIER WALL (CONCRETE) (SD 8.01)	SF
9140137	SOUND BARRIER WALL (MASONARY) (SD 8.02)	SF
9210001	SLOPE PAVING (STD. B-19.20 AND B-19.21)	SQ YD

Arizona Department of Transportation
Bridge Group
BRIDGE PRACTICE GUIDELINES

SECTION 2 - GENERAL DESIGN & LOCATION FEATURES

SCOPE

This section is intended to provide the Designer with sufficient information to determine the configuration and overall dimensions of a bridge.

In recognition that many bridge failures have been caused by scour, hydrology and hydraulics are covered in detail.

For a complete discussion of the information presented here, refer to the AASHTO LRFD Bridge Design Specifications, Section 2.

DEFINITIONS

Aggradation: A general and progressive buildup or raising of the longitudinal profile of the channel bed as a result of sediment deposition.

Bridge Designer: The design team who produced the structural drawings and supporting documents for the bridge.

Clear Zone: An unobstructed, relatively flat area beyond the edge of the traveled way for the recovery of errant vehicles. The traveled way does not include shoulders or auxiliary lanes.

Clearance: An unobstructed horizontal or vertical space.

Degradation: A general and progressive lowering of the longitudinal profile of the channel bed as a result of long-term erosion.

Design Discharge: Maximum flow of water a bridge is expected to accommodate without exceeding the adopted design constraints.

Design Flood for Bridge Scour: The flood flow equal to or less than the 100-year flood that creates the deepest scour at bridge foundations. The highway or bridge may be inundated at the stage of the design flood for bridge scour. The worst-case scour condition may occur for the overtopping flood as a result of the potential for pressure flow.

Detention Basin: A stormwater management facility that impounds runoff and temporarily discharges it through a hydraulic outlet structure to a downstream conveyance system.

Drip Groove: Linear depression in the bottom of components to cause water flowing on the surface to drop.

Five-Hundred-Year Flood: The flood due to storm and/or tide having a 0.2 percent chance of being equaled or exceeded in any given year. Commonly referred to as the Superflood, used to check the structural adequacy of bridge foundations for that extreme design event.

General or Contraction Scour: Scour in a channel or on a floodplain that is not localized at a pier or other obstruction to flow. In a channel, general/contraction scour usually affects all or most of the channel width and is typically caused by a contraction of the flow.

Hydraulics: The science that deals with practical applications (as the transmission of energy or the effects of flow) of water or other liquid in motion.

Hydrology: The science concerned with the occurrence, distribution, and circulation of water on the earth, including precipitation, runoff, and groundwater. In highway design, the process by which design discharges are determined.

Local Scour: Scour in a channel or on a floodplain that is localized at a pier, abutment, or other obstruction to flow.

One-Hundred-Year Flood: The flood due to storm and/or tide having a 1 percent chance of being equaled or exceeded in any given year.

Overtopping Flood: The flood flow that, if exceeded, results in flow over a highway or bridge, over a watershed divide, or through structures provided for emergency relief. The worst-case scour condition may be caused by the overtopping flood.

Stable Channel: A condition that exists when a stream has a bed slope and cross-section that allows its channel to transport the water and sediment delivered from the upstream watershed without significant degradation, aggradation, or bank erosion.

Stream Geomorphology: The study of a stream and its floodplain with regard to its land forms, the general configuration of its surface, and the changes that take place due to erosion and the buildup of erosional debris.

Superelevation: A tilting of the roadway surface to partially counterbalance the centrifugal forces on vehicles on horizontal curves.

Superflood : Any flood or tidal flow with a flow rate greater than that of the 100-year flood but not greater than a 500-year flood. Estimated magnitude equals 1.7 times the 100-year flood.

Watershed : An area confined by drainage divides, and often having only one outlet for discharge; the total drainage area contributing runoff to a single point.

Waterway: Any stream, river, pond, lake, or ocean.

Waterway Opening: Width or area of bridge opening at a specified stage, and measured normal to principal direction of flow.

LOCATION FEATURES

Route Location

GENERAL

The choice of location of bridges shall be supported by analyses of alternatives with consideration given to economic, engineering, social, and environmental concerns as well as costs of maintenance and inspection associated with the structures and with the relative importance of the above-noted concerns.

Attention, commensurate with the risk involved, shall be directed toward providing for favorable bridge locations that:

- Fit the conditions created by the obstacle being crossed;
- Facilitate practical cost effective design, construction, operation, inspection and maintenance;
- Provide for the desired level of traffic service and safety; and
- Minimize adverse highway impacts.

WATERWAY AND FLOODPLAIN CROSSINGS

Waterway crossings shall be located with regard to initial capital costs of construction and the optimization of total costs, including river channel training works and the maintenance measures necessary to reduce erosion. Studies of alternative crossing locations should include assessments of:

- The hydrologic and hydraulic characteristics of the waterway and its floodplain, including channel stability and flood history.
- The effect of the proposed bridge on flood flow patterns and the resulting scour potential at bridge foundations;
- The potential for creating new or augmenting existing flood hazards; and
- Environmental impacts on the waterway and its floodplain.

Bridges and their approaches on floodplains should be located and designed with regard to the goals and objectives of floodplain management, including;

- Prevention of uneconomic, hazardous, or incompatible use and development of floodplains;
- Avoidance of significant transverse and longitudinal encroachments, where practicable;
- Minimization of adverse highway impacts and mitigation of unavoidable impacts, where practicable;
- Consistency with the intent of the standards and criteria of the National Flood Insurance Program, where applicable;
- Long-term aggradation or degradation; and
- Commitments made to obtain environmental approvals

It is generally safer and more cost effective to avoid hydraulic problems through the selection of favorable crossing locations than to attempt to minimize the problems at a later time in the project development process through design measures.

Experience at existing bridges should be part of the calibration or verification of hydraulic models, if possible. Evaluation of the performance of existing bridges during past floods is often helpful in selecting the type, size, and location of new bridges.

Bridge Site Arrangement

GENERAL

The location and the alignment of the bridge should be selected to satisfy both on-bridge and under-bridge traffic requirements. Consideration should be given to possible future variations in alignment or width of the waterway, highway, or railway spanned by the bridge.

Where appropriate, consideration should be given to future addition of mass-transit facilities or bridge widening.

TRAFFIC SAFETY

Protection of structures

Consideration shall be given to safe passage of vehicles on or under a bridge. The hazard to errant vehicles within the clear zone should be minimized by locating obstacles at a safe distance from the travel lanes.

Pier columns or walls for grade separation structures should be located in conformance with the clear zone concept as contained in Chapter 3 of the AASHTO Roadside Design Guide. Where the practical limits of structure costs, type of structure, volume and design speed of through traffic, span arrangement, skew, and terrain make conformance with the Roadside Design Guide impractical, the pier or wall should be protected by the use of guardrail or other barrier devices. The guardrail or other device should, if practical, be independently supported, with its roadway face at least 2.0 FT from the face of pier or abutment, unless a rigid barrier is provided. The intent of providing structurally independent barriers is to prevent transmission of force effects from the barrier to the structure to be protected.

The face of the guardrail or other device should be at least 2.0 FT outside the normal shoulder line.

Protection of Users

Railings shall be provided along the edges of structures conforming to the requirements of Section 13 of AASHTO LRFD Bridge Design Specifications.

All protective structures shall have adequate surface features and transitions to safely redirect errant traffic.

Geometric Standards

Requirements of the AASHTO publication A Policy on Geometric Design of Highways and Streets shall either be satisfied or exceptions thereto shall be justified and documented. Width of travel lanes and shoulders shall meet the requirements established by the roadway engineer.

Road Surfaces

Road surfaces on a bridge shall be given antiskid characteristics, crown, drainage, and superelevation in accordance with A Policy on Geometric Design of Highways and Streets.

Clearances

NAVIGATIONAL

Permits for construction of a bridge over navigable waterways shall be obtained from the U.S. Coast Guard and/or other agencies having jurisdiction. Navigational clearances, both vertical and horizontal, shall be established in cooperation with the U.S. Coast Guard.

The Colorado River is the only navigable waterway in Arizona with U.S. Coast Guard jurisdiction. Certain reservoirs have bridges over navigable waterway passage with other agencies having jurisdiction.

VERTICAL CLEARANCE AT STRUCTURES

The following are minimum vertical clearance standards for highway traffic structures, pedestrian overpasses, railroad overpasses, tunnels and sign structures. Lesser clearances may be used only under very restrictive conditions, upon individual analysis and with the approval of the Assistant State Engineer-Roadway Group and the State Bridge Engineer.

HIGHWAY TRAFFIC STRUCTURES

The design vertical clearance for overpass and underpass structures, regardless of the highway system classification, shall be at least 16'-6 over the entire roadway width, including auxiliary lanes and shoulders. An allowance of 6 inches is included to accommodate future resurfacing.

The designer is reminded that this is a minimum requirement and that consideration should be given to possible future widening of the roadway under the structure and the possible future widening of the structure.

PEDESTRIAN OVERPASSES

Because of their lesser resistance to impacts, the minimum design vertical clearance to pedestrian overpasses shall be 17'-6 regardless of the highway system classification. An allowance of 6 inches is included to accommodate future resurfacing.

TUNNELS

The minimum design vertical clearance for tunnels shall be at least 16'-6 for freeways, arterials, and all other State Highways and at least 15'-6 for all other highways and streets.

SIGN STRUCTURES

Because of their lesser resistance to impacts, the minimum design vertical clearance to sign structures shall be 18'-0 regardless of the highway system classification. An allowance of 6 inches is included to accommodate future resurfacing.

HORIZONTAL CLEARANCE AT STRUCTURES

The bridge width shall not be less than that of the approach roadway section, including shoulders or curbs, gutters, and sidewalks.

No object on or under a bridge, other than a barrier, should be located closer than 4.0 FT to the edge of a designated traffic lane. The inside face of a barrier should not be closer than 2.0 FT to either the face of the object or the edge of a designated traffic lane.

RAILROAD OVERPASSES

Structures designed to pass over a railroad shall be in accordance with standards established and used by the affected railroad in its normal practice. These overpass structures shall comply with applicable federal, state, county, and municipal laws.

Structures over railways shall provide a minimum clearance of 23'-6 above top of rail, except that overhead clearance greater than 23'-6 may be approved when justified on the basis of railroad electrification. No additional allowance shall be provided for future track adjustments.

Regulations, codes, and standards should, as a minimum, meet the specifications and design standards of the American Railway Engineering and Maintenance-of-Way Association (AREMA), the Association of American Railroads, and AASHTO.

Requirements of the individual railroads in Arizona are contained in regulations published by the Arizona Corporation Commission.

Attention is particularly called to the following chapters in the Manual for Railway Engineering (MRE):

- Chapter 7 – Timber Structures,
- Chapter 8 – Concrete Structures and Foundations,
- Chapter 9 – Seismic Design for Railway Structures,
- Chapter 15 – Steel Structures, and
- Chapter 18 – Clearances.

The provisions of the individual railroads and the AREA Manual should be used to determine:

- Clearances,
- Loadings,
- Pier protection,
- Waterproofing, and
- Blast protection.

Environment

The impact of a bridge and its approaches on local communities, historic sites, wetlands, and other aesthetically, environmentally, and ecologically sensitive areas shall be considered. Compliance with state water laws; federal and state regulations concerning encroachment on floodplains, fish, and wildlife habitats; and the provisions of the National Flood Insurance Program shall be assured. Stream geomorphology, consequences of riverbed sour, and removal of embankment stabilizing vegetation, shall be considered.

Stream, i.e., fluvial, geomorphology is a study of the structure and formation of the earth's features that result from the forces of water. For purposes of this section, this involves evaluating the stream's potential for aggradation, degradation, or lateral migration.

FOUNDATION INVESTIGATION

General

A subsurface investigation, including borings and soil tests, shall be conducted in accordance with the provisions of AASHTO to provide pertinent and sufficient information for the design of substructure units. The type and cost of foundations should be considered in the economic and aesthetic studies for location and bridge alternate selection. For bridge replacement or rehabilitation, existing geotechnical data may provide valuable information for initial studies.

Topographic Studies

Current topography of the bridge site shall be established via contour maps and photographs. Such studies shall include the history of the site in terms of movement of earth masses, soil and rock erosion, and meandering of waterways.

DESIGN OBJECTIVES

Safety

The primary responsibility of the Bridge Designer shall be providing for the safety of the public.

Serviceability

DURABILITY

Materials

The contract documents shall call for quality materials and for the application of high standards of fabrication and erection.

Structural steel shall be self-protecting, or have long-life coating systems.

Reinforcing bars and prestressing strands in concrete components, which may be expected to be exposed to airborne or waterborne salts, shall be protected by an appropriate combination of epoxy and/or composition of concrete, including air-entrainment and a nonporous painting of the concrete surface.

Prestress strands in cable ducts shall be grouted or otherwise protected against corrosion.

Attachments and fasteners used in wood construction shall be of stainless steel, malleable iron, aluminum, or steel that is galvanized, cadmium-plated, or otherwise coated. Wood components shall be treated with preservatives.

Aluminum products shall be electrically insulated from steel and concrete components.

Protection shall be provided to materials susceptible to damage from solar radiation and/or air pollution.

Consideration shall be given to the durability of materials in direct contact with soil, sun and/or water.

Self-Protecting Measures

Continuous drip grooves shall be provided along the underside of a concrete deck at a distance not exceeding 10.0 IN from the fascia edges. Where the deck is interrupted by a sealed deck joint, all top surfaces of piers and abutments, other than bearing seats, shall have a minimum slope of 5 percent toward their edges. For open deck joints, this minimum slope shall be increased to 15 percent. In the case of open deck joints, the bearings shall be protected against contact with salt and debris.

Wearing surfaces shall be interrupted at the deck joints and shall be provided with a smooth transition to the deck joint device.

INSPECTABILITY

Inspection ladders, walkways, catwalks, covered access holes, and provision for lighting, if necessary, shall be provided where other means of inspection are not practical.

Where practical, access to allow manual or visual inspection, including adequate headroom in box sections, shall be provided to the inside of cellular components and to interface areas, where relative movement may occur.

MAINTAINABILITY

Structural systems whose maintenance is expected to be difficult should be avoided. Where the climatic and/or traffic environment is such that the bridge deck may need to be replaced before the required service life, either provisions shall be shown on the contract plans for the replacement of the deck or additional structural resistance shall be provided.

Areas around bearing seats and under deck joints should be designed to facilitate jacking, cleaning, repair, and replacement of bearings and joints.

Jacking points shall be indicated on the plans, and the structure shall be designed for the jacking forces. Inaccessible cavities and corners should be avoided. Cavities that may invite human or animal inhabitants shall either be avoided or made secure.

RIDEABILITY

The deck of the bridge shall be designed to allow for the smooth movement of traffic. On paved roads, a structural transition slab should be located between the approach roadway and the abutment of the bridge. Construction tolerances, with regard to the profile of the finished deck, shall be indicated on the plans or in the specifications or special provisions.

The number of deck joints shall be kept to a practical minimum. Edges of joints in concrete decks exposed to traffic should be protected from abrasion and spalling. The plans for prefabricated joints shall specify that the joint assembly be erected as a unit, if feasible.

Where concrete decks without an initial overlay are used, an additional thickness of 0.5-IN to permit correction of the deck profile by grinding, and to compensate for thickness loss due to abrasion will be provided.

UTILITIES IN STRUCTURES

Where utility conflicts exist; water, power, telephone, cable TV and gas lines will be relocated as required for construction of the project. Where it is feasible and reasonable to locate utility lines elsewhere, attachment to structures will not be permitted. Trenching in the vicinity of existing piers or abutments shall be kept a sufficient distance from footings to prevent undercutting of existing footings or to prevent disturbing foundation soils for future foundations.

Where other locations prove to be extremely difficult and very costly, utility lines, except natural gas, may be allowed in the structures.

Natural gas encroachments will be evaluated under the following policy:

A. Cases were gas line attachments to structures will not be considered under any condition:

   1. Grade separation structures carrying vehicular traffic on or over freeways.

   2. Inside closed cell-type box girder bridges.

   3. High pressure transmission lines over 60 psi and/or distribution lines of over 6 inches in diameter.

   4. Gas lines over minor waterway crossings where burial is feasible

B. Gas line attachments on structures will be considered under the following cases or conditions:

   1. Each case will be judged on its own merit with the utilities providing complete justification as to why alternative locations are not feasible.

   2. Economics will not be a significant factor considered in the feasibility issue.

   3. Open girder type structures across major rivers.

   4. Pedestrian or utility bridges where proper vented casings and other safety systems are used.

   5. All lines are protected by casements.

Provisions for accommodation of relocated and future utilities on structures shall be coordinated through the Utility and Railroad Engineering Section for ADOT projects, or as appropriate, through Statewide Project Management Section and/or a consultant for other projects.

General Policy

Support bracket details and attachments for all utilities will require Bridge Group approval.

All approved utilities shall have individual sleeved casings, conduits or ducts as appropriate.

All utilities carrying liquids shall be placed inside casing through the entire length of the structure. The casing shall be designed to carry full service pressure so as to provide a satisfactory containment in case the utility is damaged or leaks.

Water lines, telephone conduits, power lines, cable TV lines, supports or other related items will not be permitted to be suspended below or attached to the exterior of any new or existing structure.

Product lines for transmitting volatile fluids will not be permitted to be attached to or suspended from or placed within any new or existing structure.

Manholes or access openings for utilities will not be permitted in bridge decks, webs, bottom slabs or abutment diaphragms.

On special major projects, ADOT design costs will be assessed to the company

Utility Company Responsibility

The utility company is responsible for obtaining necessary information regarding the proposed construction schedule for the project. The company shall submit a request including justification for attaching to the structure and preliminary relocation plans including line weights and support spacing as early as possible but no later than the completion of preliminary structural plans. The company shall submit complete plans and specifications of their proposed installation at least 20 working days prior to the schedule C & S Date.

The utility company shall be responsible for the design of all conduits, pipes, sleeves, casings, expansion devices, supports and other related items including the following information:

1. Number and size of conduits for power, telephone and cable TV lines.
2. Size and schedule of carrier pipe for water lines.
3. Size and schedule of sleeved casings.
4. Spacing and details of support brackets.

5. Expansion device details.

6. Total combined weight of carrier pipe and transmitted fluids, conduits, casings, support brackets, expansion joints and other related items.

7. Design calculations.

8. Submit permit request through the District.

Bridge Designer Responsibility

The Bridge Designer shall be responsible for the following aspects of the design :

1. Determination of how many lines, if any, the structure can accommodate.

2. Determination of where such lines should be located within a structure.

3. Determination of the size of the access openings and design of the required reinforcing.

4. Identification of installation obstacles related to required sequencing of project.

5. Tracking man-hours associated with utility relocations for cost recovery, when appropriate.

Usually utilities will be accommodated by providing individual access openings for casings and sleeves to pass through. Access openings should be 2 inches larger than the diameter of the casings or sleeves and spaced as required by structural considerations.

For box girder bridges, access openings should be located as low as possible but no lower than 10 inches above the top of the bottom slab to allow for support brackets to be supported from the bottom slab. Where possible all utilities shall be supported from the bottom slab for box girder bridges.

For precast or steel girder bridges, the utilities shall not be placed in the exterior girder bay and they shall be supported from the deck slab, rather than from the diaphragms.

Constructibility

Bridges should be designed in a manner such that fabrication and erection can be performed without undue difficulty or distress and that locked-in construction force effects are within tolerable limits.

When the method of construction of a bridge is not self-evident or could induce unacceptable locked-in stresses, at least one feasible method shall be indicated in the contract documents. If the design requires some strengthening and/or temporary bracing or support during erection by the selected method, indication of the need thereof shall be indicated in the contract documents.

Details that require welding in restricted areas or placement of concrete through congested reinforcing should be avoided.

Climatic and hydraulic conditions that may affect the construction of the bridge shall be considered.

Economy

GENERAL

Structural types, span lengths, and materials shall be selected with due consideration of projected cost. The cost of future expenditures during the projected service life of the bridge should be considered. Regional factors, such as availability of material, fabrication, location, shipping, and erection constraints, shall be considered.

If data for the trends in labor and material cost fluctuation is available, the effect of such trends should be projected to the time the bridge will likely be constructed.

Cost comparisons of structural alternatives should be based on long-range considerations, including inspection, maintenance, repair, and/or replacement. Lowest first cost does not necessarily lead to lowest total cost.

ALTERNATIVE PLANS

In instances where economic studies do not indicate a clear choice, the State Bridge Engineer may require that alternative contract plans be prepared and bid competitively. Designs for alternative plans shall be of equal safety, serviceability, and aesthetic value.

Movable bridges over navigable waterways should be avoided to the extent feasible. Where movable bridges are proposed, at least one fixed bridge alternative should be included in the economic comparisons.

Bridge Aesthetics

Bridges should complement their surroundings, be graceful in form, and present an appearance of adequate strength.

Significant improvements in appearance can often be made with small changes in shape or position of structural members at negligible cost. For prominent bridges, however, additional cost to achieve improved appearance is often justified, considering that the bridge will likely be a feature of the landscape for 75 or more years.

Engineers should seek more pleasant appearance by improving the shapes and relationships of the structural component themselves. The application of extraordinary and nonstructural embellishment should be avoided.

The following guidelines should be considered:

- Alternative bridge designs without piers or with few piers should be studied during the site selection and location stage and refined during the preliminary design stage.
- Pier form should be consistent in shape and detail with the superstructure.
- Abrupt changes in the form of components and structural type should be avoided. Where the interface of different structural types cannot be avoided, a smooth transition in appearance from one type to another should be attained.
- Attention to details, such as deck drain downspouts, should not be overlooked.
- The use of the bridge as a support for message or directional signing or lighting should be avoided wherever possible.
- Transverse web stiffeners, other than those located at bearing points, should not be visible in elevation.
- For spanning deep ravines, arch-type structures should be preferred.

The most admired modern structures are those that rely for their good appearance on the forms of the structural components themselves:

- Components are shaped to respond to the structural function. They are thick where the stresses are greatest and thin where the stresses are smaller.
- The function of each part and how the function is performed is visible.
- Components are slender and widely spaced, preserving views through the structure.

- The bridge is seen as a single whole, with all members consistent and contributing to that whole; for example, all elements should come from the same family of shapes, such as shapes with rounded edges.

- The bridge fulfills its function with a minimum of material and minimum number of elements.

- The size of each member compared with the others is clearly related to the overall structural concept and the job the component does, and

- The bridge as a whole has a clear and logical relationship to its surroundings.

HYDROLOGY AND HYDRAULICS

General

Hydrologic and hydraulic studies and assessments of bridge sites for stream crossings shall be completed as part of the preliminary plan development. The detail of these studies should be commensurate with the importance of and risks associated with the structure.

Temporary structures for the Contractor's use or for accommodating traffic during construction shall be designed with regard to the safety of the traveling public and the adjacent property owners, as well as minimization of impact on floodplain natural resources. ADOT may permit revised design requirements consistent with the intended service period for, and flood hazard posed by, the temporary structure. Contract documents for temporary structures shall delineate the respective responsibilities and risks to be assumed by ADOT and the Contractor.

Evaluation of bridge design alternatives shall consider stream stability, backwater, flow distribution, stream velocities, scour potential, flood hazards, and consistency with established criteria for the National Flood Insurance Program.

Site Data

A site-specific data collection plan shall include consideration of:

- Collection of aerial and/or ground survey data for appropriate distances upstream and downstream from the bridge for the main stream channel and its floodplain;

- Estimation of roughness elements for the stream and the floodplain within the reach of the stream under study;

- Sampling of streambed material to a depth sufficient to ascertain material characteristics for scour analysis;
- Subsurface borings;
- Factors affecting water stages, including high water from streams, reservoirs, detention basins, and flood control structures and operating procedures;
- Existing studies and reports, including those conducted in accordance with the provisions of the National Flood Insurance Program or other flood control programs;
- Available historical information on the behavior of the stream and the performance of the structure during past floods, including observed scour, bank erosion, and structural damage due to debris or ice flows; and
- Possible geomorphic changes in channel flow.

Hydrologic Analysis

The following flood flows should be investigated, as appropriate, in the hydrologic studies:

- For assessing flood hazards and meeting floodplain management requirements – the 100-year flood;
- For assessing risks to highway users and damage to the bridge and its roadway approaches – the overtopping flood and/or the design flood for bridge scour;
- For assessing catastrophic flood damage at high risk sites – a check flood of a magnitude selected by the Bridge Designer as appropriate for the site conditions and the perceived risk;
- For investigating the adequacy of bridge foundations to resist scour – the check flood for bridge scour;
- To satisfy ADOT design policies and criteria – design floods for waterway opening and bridge scour for the various functional classes of highways, as described in the ADOT Roadway Design Guidelines;
- To calibrate water surface profiles and to evaluate the performance of existing structures – historical floods, and
- To evaluate environmental conditions – low or base flow information

Hydraulic Analysis

GENERAL

The Bridge Designer shall utilize analytical models and techniques that have been approved by ADOT and that are consistent with the required level of analysis as described in the ADOT Roadway Design Guidelines.

STREAM STABILITY

Studies shall be carried out to evaluate the stability of the waterway and to assess the impact of construction on the waterway. The following items shall be considered:

- Whether the steam reach is degrading, aggrading, or in equilibrium;
- For stream crossing near confluences, the effect of the main stream and the tributary on the flood stages, velocities, flow distribution, vertical and lateral movements of the stream, and the effect of the foregoing conditions on the hydraulic design of the bridge;
- Location of favorable stream crossing, taking into account whether the stream is straight, meandering, braided, or transitional, or control devices to protect the bridge from existing or anticipated future stream conditions;
- The effect of any proposed channel changes;
- The effect of aggregate mining or other operations in the channel;
- Potential changes in the rates or volumes of runoff due to land use changes;
- The effect of natural geomorphic stream pattern changes on the proposed structure; and
- The effect of geomorphic changes on existing structures in the vicinity of, and caused by, the proposed structure.

For unstable streams or flow conditions, special studies shall be carried out to assess the probable future changes to the plan form and profile of the stream and to determine countermeasures to be incorporated in the design, or at a future time, for the safety of the bridge and approach roadways.

BRIDGE WATERWAY

The design process for sizing the bridge waterway shall include:

- The evaluation of flood flow patterns in the main channel and floodplain for existing conditions, and

- The evaluation of trial combinations of highway profiles, alignments, and bridge lengths for consistency with design objectives.

Where use is made of existing flood studies, their accuracy shall be determined.

BRIDGE FOUNDATIONS

General

The structural, hydraulic, and geotechnical aspects of foundation design shall be coordinated and differences resolved prior to approval of preliminary plans.

To reduce the vulnerability of the bridge to damage from scour and hydraulic loads, consideration should be given to the following general design concepts:

- Set deck elevations as high as practical for the given site conditions to minimize inundation, or overtopping of roadway approach sections, and streamline the superstructure to minimize the area subject to hydraulic loads and the collection of ice, debris, and drifts.

- Utilize relief bridges, guide banks, dikes, and other river training devices to reduce the turbulence and hydraulic forces acting at the bridge abutments.

- Utilize continuous span designs. Anchor superstructures to their substructures where subject to the effects of hydraulic loads, buoyancy, ice, or debris impacts or accumulations. Provide for venting and draining of the superstructure.

- Where practical, limit the number of piers in the channel, streamline pier shapes, and align pier columns with the direction of flood flows. Avoid pier types that collect ice and debris. Locate piers beyond the immediate vicinity of stream banks.

- Locate abutments back from the channel banks where significant problems with ice/debris buildup, scour, or channel stability are anticipated, or where special environmental or regulatory needs must be met, e.g., spanning wetlands.

- Design piers within floodplains as river piers. Locate their foundations at the appropriate depth if there is a likelihood that the stream channel will shift during the life of the structure or that channel cutoffs are likely to occur.

- Where practical, use debris racks to stop debris before it reaches the bridge. Where significant debris buildup is unavoidable, its effects should be accounted for in determining scour depths and hydraulic loads.

- A majority of bridge failures in the United States and elsewhere are the result of scour. The added cost of making a bridge less vulnerable to damage from scour is small in comparison to the total cost of a bridge failure.

Bridge Scour

As required by Section 3, scour at bridge foundations is investigated for two conditions:

- For the design flood for scour, the streambed material in the scour prism above the scour line shall be assumed to have been removed for design conditions. The design flood storm surge, tide, or mixed population flood shall be the more severe of the 100-year events or from an overtopping flood of lesser recurrence interval.

- For the check flood for scour, the stability of the bridge foundation shall be investigated for scour conditions resulting from a designated flood storm surge, tide, or mixed population flood not to exceed the 500-year event or from an overtopping flood of lesser recurrence interval. Excess reserve beyond that required for stability under this condition is not necessary. The extreme event limit state shall apply.

If the site conditions, due to debris jams, and low tailwater conditions near stream confluences dictate the use of a more severe flood event for either the design or check flood for scour, the Bridge Designer may use such flood event.

Spread footings on soil or erodible rock shall be located beyond the scour potential of the waterway. Spread footings on scour-resistant rock shall be designed and constructed to maintain the integrity of the supporting rock.

Deep foundations with footings shall be designed to place the top of the footing below the estimated contraction scour depth where practical to minimize obstruction to flood flows and resulting local scour. Even lower elevations should be considered for pile-supported footings where the piles could be damaged by erosion and corrosion from exposure to stream currents. Where conditions dictate a need to construct the top of a footing to an elevation above the streambed, attention shall be given to the scour potential of the design.

When fendering or other pier protection systems are used, their effect on pier scour and collection of debris shall be taken into consideration in the design.

The design flood for scour shall be determined on the basis of the Bridge Designer's judgment of the hydrologic and hydraulic flow conditions at the site. The recommended procedure is to evaluate scour due to the specified flood flows and to design the foundation for the event expected to cause the deepest total scour.

The recommended procedure for determining the total scour depth at bridge foundations is as follows:

- Estimate the long-term channel profile aggradation or degradation over the service life of the bridge;

- Estimate the effects of gravel mining on the channel profile, if appropriate;

- Estimate the long-term channel plan form changes over the service life of the bridge;

- As a design check, adjust the existing channel and floodplain cross-sections upstream and downstream of bridge as necessary to reflect anticipated changes in the channel profile and plan form;

- Determine the combination of existing or likely future conditions and flood events that might be expected to result in the deepest scour for design conditions.;

- Determine water surface profiles for a stream reach that extends both upstream and downstream of the bridge site for the various combinations of conditions and events under consideration;

- Determine the magnitude of contraction scour and local scour at piers and abutments; and

- Evaluate the results of the scour analysis, taking into account the variables in the methods used, the available information on the behavior of the watercourse, and the performance of existing structures during past floods. Also consider present and anticipate future flow patterns and the effect of the flow on the bridge. Modify the bridge design where necessary to satisfy concerns raised by the scour analysis and the evaluation of the channel plan form.

Foundation designs should be based on the total scour depths estimated by the above procedure, taking into account appropriate geotechnical safety factors. Where necessary, bridge modifications may include:

- Relocation or redesign of piers or abutments to avoid areas of deep scour or overlapping scour holes from adjacent foundation elements,

- Addition of guide banks, dikes, or other river training works to provide for smoother flow transitions or to control lateral movement of the channel,

- Enlargement of the waterway area, or

- Relocation of the crossing to avoid an undesirable location.

Foundations should be designed to withstand the conditions of scour for the design flood and the check flood. In general, this will result in deep foundations. The design of the foundations of existing bridges that are being rehabilitated should consider underpinning if scour indicates the need. Riprap and other scour countermeasures may be appropriate if underpinning is not cost effective.

The stability of abutments in areas of turbulent flow shall be thoroughly investigated. Exposed embankment slopes should be protected with appropriate scour countermeasures.

ROADWAY APPROACHES TO BRIDGE

The design of the bridge shall be coordinated with the design of the roadway approaches to the bridge on the floodplain so that the entire flood flow pattern is developed and analyzed as a single, interrelated entity. Where roadway approaches on the floodplain obstruct overbank flow, the highway segment within the floodplain limits shall be designed to minimize flood hazards.

Where diversion of flow to another watershed occurs as a result of backwater and obstruction of flood flows, an evaluation of the design shall be carried out to ensure compliance with legal requirements in regard to flood hazards in the watershed.

Deck Drainage

GENERAL

The bridge deck and its highway approaches shall be designed to provide safe and efficient conveyance of surface runoff from the traveled way in a manner that minimizes damage to the bridge and maximizes the safety of passing vehicles. Transverse drainage of the deck, including roadway, bicycle paths, and pedestrian walkways, shall be achieved by providing a cross slope or superelevation sufficient for positive drainage. For wide bridges with more than three lanes in each direction, special design of bridge deck drainage and/or special rough road surfaces may be needed to reduce the potential for hydroplaning. Water flowing downgrade in the roadway gutter section shall be intercepted and not permitted to run into the bridge. Drains at bridge ends shall have sufficient capacity to carry all contributing runoff.

In those unique environmentally sensitive instances where it is not possible to discharge into the underlying water course, consideration should be given to conveying the water in a longitudinal storm drain affixed to the underside of the bridge and discharging it into appropriate facilities on natural ground at bridge end.

Where feasible, bridge decks should be watertight and all of the deck drainage should be carried to the ends of the bridge.

A longitudinal gradient on bridges should be maintained. Zero gradients and sag vertical curves should be avoided. Design of the bridge deck and the approach roadway drainage systems should be coordinated.

The "Storm Drainage" chapter of the AASHTO Model Drainage Manual contains guidance on recommended values for cross slopes.

DESIGN STORM

The design storm for bridge deck drainage shall not be less than the storm used for design of the pavement drainage system of the adjacent roadway, unless otherwise specified.

TYPE, SIZE AND NUMBER OF DRAINS

The number of deck drains should be kept to a minimum consistent with hydraulic requirements.

In the absence of other applicable guidance, for bridges where the highway design speed is less than 45 MPH, the size and number of deck drains should be such that the spread of deck drainage does not encroach on more than one-half the width of any designated traffic lane. For bridges where the highway design speed is not less than 45 MPH, the spread of deck drainage should not encroach on any portion of the designated traffic lanes. For bridges with adjacent pedestrian sidewalk, the spread of deck drainage should not encroach on any portion of the adjacent designated traffic lanes. Gutter flow should be intercepted at cross slope transitions to prevent flow across the bridge deck.

DISCHARGE FROM DECK DRAINS

Deck drains shall be designed and located such that surface water from the bridge deck or road surface is directed away for the bridge superstructure elements and the substructure.

Consideration should be given to:

- A minimum 4.0-IN projection below the lowest adjacent superstructure component,
- Location of pipe outlets such that a 45-degree cone of splash will not touch structural components.
- Use of free drops or slots in parapets wherever practical and permissible,
- Use of bends not greater than 45 degrees, and
- Use of cleanouts.

Runoff from bridge decks and deck drains shall be disposed of in a manner consistent with environmental and safety requirements.

Consideration should be given to the effect of drainage systems on bridge aesthetics.

For bridges where free drops are not feasible, attention should be given to the design of the outlet piping system to:

- Minimize clogging and other maintenance problems, and
- Minimize the intrusive effect of the piping on the bridge symmetry and appearance.

Free drops should be avoided where runoff creates problems with traffic, rail, or shipping lanes. Riprap or pavement should be provided under the free drops to prevent erosion.

DRAINAGE OF STRUCTURES

Cavities in structures where there is a likelihood for entrapment of water shall be drained at their lowest point. Decks and wearing surfaces shall be designed to prevent the ponding of water, especially at deck joints. For bridge decks with nonintegral wearing surfaces or stay-in-place forms, consideration shall be given to the evacuation of water that may accumulate at the interface.

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BRIDGE PRACTICE GUIDELINES

SECTION 3- LOADS AND LOAD FACTORS

SCOPE

This section contains guidelines to supplement provisions of Section 3 of the AASHTO Specifications which specifies minimum requirements for loads and forces, the limits of their application, load factors, and load combinations used for the design of new bridges. The load provisions may also be applied to the structural evaluation and modification of existing bridges.

In accordance with the applicable provisions of the AASHTO Specifications, the Service Load Design method (Allowable Stress Design) shall be used for the design of all members except columns, sound barrier walls and bridge railings. Columns and sound barrier walls shall be designed by the Strength Design method (Load Factor Design). Bridge railing design for new bridges shall be based on the AASHTO LRFD Bridge Design Specifications.

For load applications and distributions for specific bridge types, refer to the following sections.

TYPES OF LOADS

Loads shall be as specified in **Section 3** of **AASHTO** except as clarified or modified in these guidelines. **AASHTO** loading specifications shall be the minimum design criteria used for all bridges.

Dead Loads (AASHTO 3.3)

The dead load shall consist of the weight of entire structure, including the roadways, curbs, sidewalks, railing. In addition to the structure dead loads, superimposed dead loads such as pipes, conduits, cables, stay-in-place forms and any other immovable appurtenances should be included in the design.

SHORTENING

Dead load should include the elastic effects of prestressing (pre or post-tensioned) after losses. The long-term effects of shrinkage and creep on indeterminate reinforced concrete structures may be ignored, on the assumption that forces produced by these processes will be relieved by the same processes.

BOX GIRDER DECK FORMS

Where deck forms are not required to be removed, an allowance of 5-10 lb/ft^2 for form dead load shall be included.

DIFFERENTIAL SETTLEMENT (AASHTO 3.3.2.1)

Differential settlement shall be considered in the design when indicated in the Geotechnical Report. The Geotechnical Report should provide the magnitude of differential settlement to be use in the design. Differential settlement shall be considered the same as temperature and shrinkage forces and included in **Group IV**, **V** and **VI** load combinations.

FUTURE WEARING SURFACE (AASHTO 3.3.3)

All new structures shall be designed to carry an additional dead load of 25 pounds per square foot from curb to curb of roadway to allow for a future wearing surface. This load is in addition to any wearing surface, which may be applied at the time of construction. The weight of the future wearing surface shall be excluded from the dead load for deflection calculations.

WEARING SURFACE (AASHTO 3.3.5)

The top ½" of the deck shall be considered as a wearing surface. The weight of the ½" wearing surface shall be included in the dead load but the ½" shall not be included in the depth of the structural section for all strength calculations including the deck, superstructure and the pier cap, where appropriate.

Live Load & Impact (AASHTO 3.4 - 3.8, 3.11, 3.12)

The design live load shall consist of the appropriate truck or lane loading in accordance with **AASHTO 3.7.3**. As a minimum, all bridges in Arizona will be designed for HS20-44 loading. In addition, bridges supporting Interstate highways, or other highways which carry heavy truck traffic, will be designed for Alternative Military Loading (**AASHTO 3.7.4**).

The lane loading or standard truck shall be assumed to occupy a width of 10 feet. These loads shall be placed in 12-foot wide design traffic lanes, spaced across the entire bridge roadway width measuring between curbs. Fractional parts of design lanes shall not be used, but roadway width from 20 to 24 feet shall have two design lanes each equal to one-half the roadway width. The traffic lanes shall be replaced in such numbers and positions on the roadway, and the loads shall be placed in such positions within their individual traffic lanes, so as to produce the maximum stress in the member under consideration. Where maximum stresses are produced in any member by loading with three or more traffic lanes simultaneously, the live load may be reduced by a probability factor as covered in **AASHTO 3.12**. This would apply to members such as transverse floor beams, truss, and two-girder bridges, pier caps, pier columns or any member that has been loaded more than two traffic lanes. This does not apply to deck slab or longitudinal beams designed for fractional wheel loads since less than three traffic lanes will produce the maximum stress. Generally, a reduction factor will be applied in the substructure design for multiple loadings.

An impact factor shall be applied to the live load in accordance with **AASHTO 3.8**. The live load stresses for the superstructure members resulting from the truck or lane loading on the superstructure, shall be increased by an allowance for dynamic, vibratory and impact effect. Impact should be included as part of the loads transferred from the superstructure to the substructure, but shall not be included in loads transferred to the footing nor to those parts of piles or columns that are below ground (**AASHTO 3.8.1-3.8.2**).

Longitudinal Forces (AASHTO 3.9)

Provision shall be made for the effect of a longitudinal force of 5 percent of the live load in all lanes carrying traffic headed in the same direction without impact.

Centrifugal Forces (AASHTO 3.10)

Centrifugal forces are included in all groups which contain vehicular live load. They act 6 feet above the roadway surface and are significant when curve radii are small or columns are long. They are radial forces induced by moving trucks. See **AASHTO 3.10.1, Equation (3-2)** for force equation.

Wind Loads (AASHTO 3.15)

Wind loads shall be applied according to Section 3.15 of the Standard Specifications.

Thermal Forces (AASHTO 3.16)

Thermal movement and forces shall be based on the following mean temperatures and temperature ranges.

		Concrete		**Steel**	
Elevation (ft)	**Mean (^{o}F)**	**Rise (^{o}F)**	**Fall (^{o}F)**	**Rise (^{o}F)**	**Fall (^{o}F)**
Up to 3000	70	30	40	60	60
3000 - 6000	60	30	40	60	60
Over 6000	50	35	45	70	80

The effects of differential temperature between the top slab and bottom slab of concrete box girder bridges is normally not considered. However, when approval is obtained for structures which warrant such consideration, the following temperature ranges should be used.

DL + Diff Temp	Delta = 18 degrees
DL + LL + I + Diff Temp	Delta = 9 degrees

Stream Forces (AASHTO 3.18.1)

A Bridge Hydraulics Report as outlined in Section 2 shall be produced by Roadway Drainage Section or a consultant, when appropriate, for all stream crossings. The designer should review the Bridge Hydraulics Report for a full understanding of waterway considerations. The report should contain as a minimum the following information for both the critical flow and superflood conditions.

- High water elevation
- Mean Velocity
- Scour Elevations (General and Local)
- Angle of attack
- Required bank protection
- Special drainage considerations

For design for the most critical flow and the superflood condition, the following criteria shall be used unless more severe criteria are recommended in the Bridge Hydraulics Report.

- Design calculations of stream forces on piers over natural water courses shall assume a 2 foot increase in pier width per side due to blockage by debris with a shape factor k = 1.40 for the first 12 feet of depth of flow. For flows with depths greater than 12 feet, only the top 12 feet shall be assumed blocked by debris with lower sections using the actual pier width and a shape factor in accordance with AASHTO. For uncased drilled shafts, a 20% increase in diameter should be assumed to account for possible oversizing of the hole and any irregular shape. The force distribution on the pier shall be assumed to vary linearly from the value at the water surface to zero at the bottom of the scour hole as described in AASHTO.

- When the clear distance between columns or shafts is 16 feet or greater, each column or shaft shall be treated as an independent unit for stream forces and debris. When the clear distance is less than 16 feet the greater of the two following criteria shall be used:
  1) Each column or shaft acting as an independent unit or 2) All columns or shafts acting as one totally clogged unit.

- The mean main channel velocity for the appropriate flow condition shall be used in calculating the stream forces. The water surface elevation shall be the high water elevation for the appropriate flow condition. A minimum angle of attack of 15 degrees shall be assumed.

- Scour may be categorized into two types: general and local. General scour is the permanent loss of soil due to degradation or mining while local scour is the temporary loss of soil during a peak flow. Local scour may consist of two types: contraction scour and local pier or abutment scour. Contraction scour occurs uniformly across the bridge opening when the waterway opening of the bridge causes a constriction in the stream width. Local pier and abutment scour occurs locally at substructure units due to the turbulence caused by the presence of the substructure unit.

- Bridge foundation units outside the highwater prism need not be designed for scour or stream forces. Spread footing bearing elevations shall be minimum 5 ft. below the channel thalweg elevation. Tip of drilled shaft elevations shall be minimum 20 ft. below the channel thalweg elevation unless in rock sockets.

- Bridges over natural watercourses shall be investigated for four different streambed ground lines. Refer to Figure 1 for an illustration of these cases.

1. Case 1 is the as-constructed stream cross section. For this case, the bridge shall be designed to withstand the forces from the **AASHTO Groups I** to **VII** load combinations.

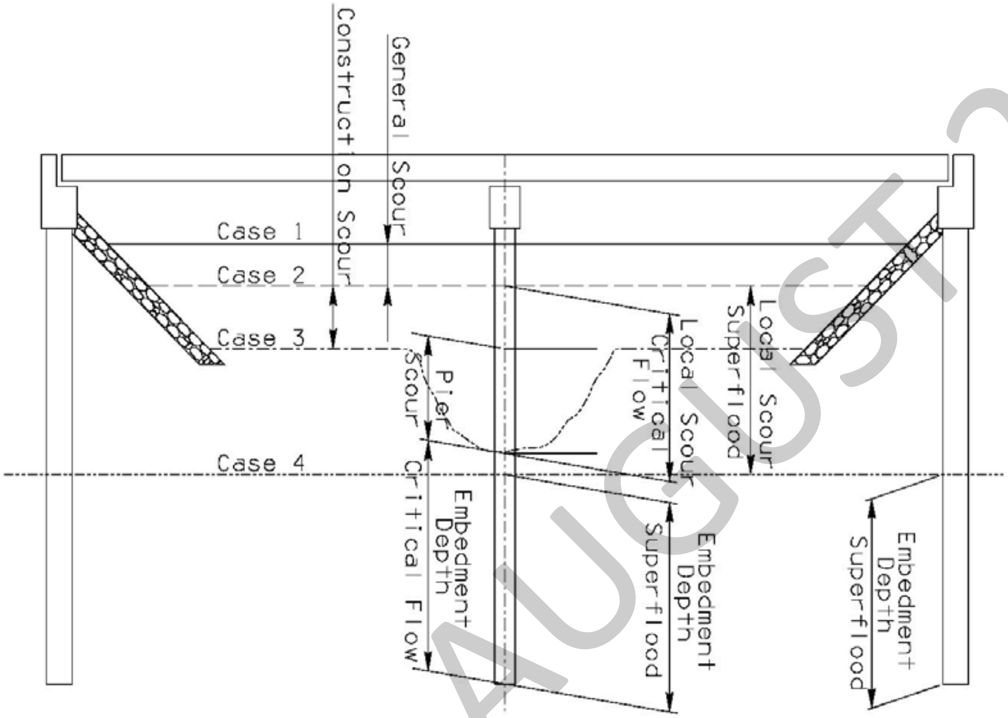
2. Case 2 represents the long-term dry streambed cross section (i.e. the as-constructed stream cross section minus the depth of the general scour). For this case, the bridge shall be designed to withstand the same forces as for case 1. Bridges need only be designed for Seismic Forces for the case of general scour. The requirements contained in **AASHTO 4.4.5.2** need not be met.

3. Case 3 represents the streambed cross section condition for the most critical design flow. Abutment protection is designed to withstand this event and abutments may be assumed to be protected from scour for this condition. Piers will experience the full general and critical flow local scour. For this case, the bridge shall be designed to withstand the forces from the **AASHTO Groups I** to **VI** load combinations.

4. Case 4 represents the streambed cross section conditions for the superflood condition. For this case, all bank protection and approach embankments are assumed to have failed.

Abutments and piers should be designed for the superflood scour assuming all substructure units have experienced the maximum scour simultaneously. For this case, the bridge shall be designed to withstand the following forces: **DL + SF + 0.5W**. For members designed using the **WSD** Method an allowable overstress of 140% shall be used. For members designed using the **LFD** Method a gamma factor of 1.25 shall be used.

FIGURE 1
GROUNDLINE VARIATIONS DUE TO SCOUR



Lateral Earth Pressure (AASHTO 3.20.1)

For backfills compacted in conformance with the **AASHTO Standard Specifications**, active pressure for unrestrained walls should be calculated using an internal angle of friction of 34 degrees unless recommended otherwise in the Geotechnical Report.

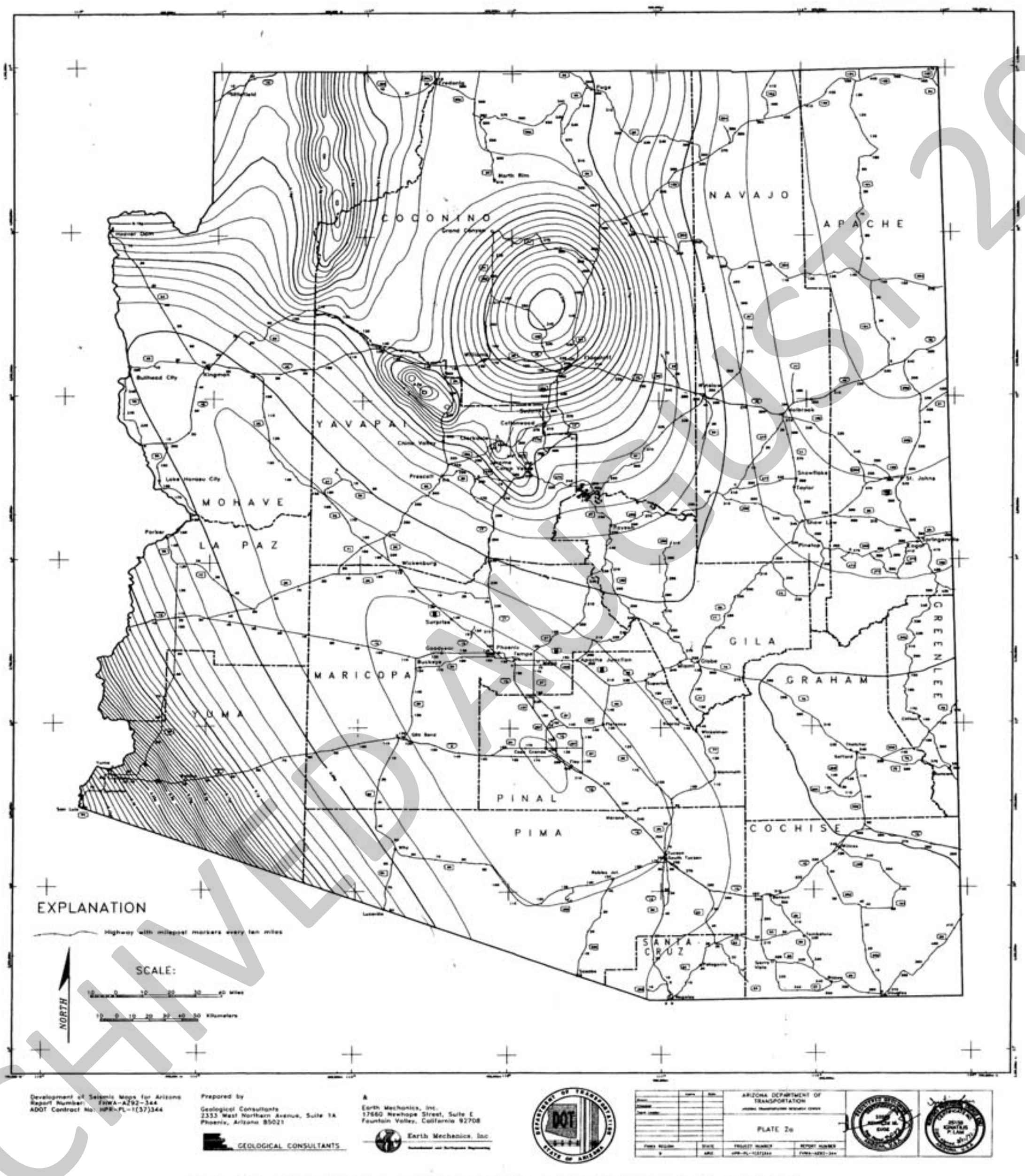
Earthquakes (AASHTO 3.21)

The Standard Specifications for Highway Bridges shall be used for the seismic design of all new structures. However, the **Seismic Acceleration Map**, Figure 1-5, contained in **AASHTO Division I-A Seismic Design** shall not be used to determine the Acceleration Coefficient A. A seismic map for Arizona developed through the Arizona Transportation Research Center is contained in **Report Number FHWA-AZ 92-344**. This map provides horizontal accelerations in rock with 90% probability of not being exceeded in 50 years considering the effects of local faults. This map shall be used for all designs. A reduced copy of this map is included in Fig. 2 for information purposes. A full size map may be obtained by contacting Bridge Technical Section at (602) 712-7910 and should be used in actual designs.

All new or widened bridge designs shall consider some form of vertical restraints. Vertical restraints shall be provided for all expansion seat abutments except for multi-span continuous box girder bridges with integral piers. Vertical restraints shall be provided between all substructure and superstructure units for steel and precast prestressed girder bridges. When required, the vertical restraints shall be designed for a minimum force equal to 10 percent of the contributing dead load unless the Standard Specifications, Division I-A Seismic Design require a higher value.

For Seismic Performance Category A Bridges, horizontal restrainers for hinges shall be designed for a force equal to 0.25 x DL of the smaller of the two frames with the column shears due to EQ deducted. For Seismic Performance Category B, C and D bridges, horizontal restrainers for hinges shall be designed in accordance with the Standard Specifications, Division I-A Seismic Design.

FIGURE 2
MAP OF HORIZONTAL ACCELERATION AT BEDROCK FOR ARIZONA



MAP OF HORIZONTAL ACCELERATION AT BEDROCK FOR ARIZONA
with 90 Percent Probability of Non-Exceedance in 50 Years
By
Ignatius Po Lam, Bruce A. Schell and Kenneth M. Euge, 1992

DISTRIBUTION OF LOADS

Loads shall be distributed as specified in **Section 3** of **AASHTO** except as clarified or modified in these guidelines.

Truck wheel loads are delivered to a flexible support through compressible tires, which make it very difficult to define the area of the bridge deck significantly influenced. Computerized grid systems and finite element programs can come close to reality, but they are complicated to apply and are limited by mesh or element size and by the accuracy with which the mechanical properties of the composite materials can be modeled. These two- or three dimensional problems are reduced to one dimension through various empirical distribution factors given in the **AASHTO Standard Specifications**.

These distribution factors have been derived from research involving physical testing and/or computerized parameter studies. In order to simplify the design procedure, the number of variables was reduced to a minimum consistent with safety and reasonable economy, according to the judgment of the AASHTO Subcommittee on Bridges and Structures. The factor S/5.5, so developed, has been used for many years to determine the portion of a wheel load to be supported by steel or prestressed concrete girders under a concrete slab. Other variables, such as span aspect ratio, skew angle and relative stiffness between stringer and slab, are not considered except for occasional special bridges. The conservatism of this approach may account for some of the reserve strength regularly observed when redundant girder bridges are load tested. Similarly, concrete slab spans and slabs on girders will invariably support much more load than predicted by empirical analysis.

Treatment of wheel load distribution to the various bridge components in the **AASHTO Standard Specifications** is as follows:

Longitudinal Beams (Girders)

Distribution factors given in the **AASHTO 3.23.1, 3.23.2 and Table 3.23.1** are used almost exclusively. Occasionally, special conditions will justify the use of a discrete element grid and plate solution.

For simplicity of calculation and because there is no significant difference, the distribution factor for moment is used also for shear.

Composite dead loads (such as curbs, barriers and wearing surfaces) are distributed equally to all stringers except for extraordinary conditions of deck width or ratio of overhang to beam spacing. Live load is distributed to all types of outside beams assuming the deck to act as a simple cantilever span supported by the outside and the first inside stringer.

Concrete Box Girders AASHTO 3.23.2.3.2.2)

In calculating the number of lanes of live load on the superstructure, the entire cross section of the superstructure shall be considered as one unit with the number of lanes of live load equal to the out-to-out width of the deck divided by 14. Do not reduce this number for multiple lanes as specified in **AASHTO 3.12.1** nor round to a whole number as specified in **AASHTO 3.6.3**.

Transverse Beam (Floorbeams, AASHTO 3.23.3)

For the few cases where floorbeams have been used without stringers on highway bridges, it has appeared proper to calculate reaction assuming the deck slab to act as a continuous beam supported by the floorbeams. No transverse distribution of wheel loads is allowed unless a sophisticated analysis is used.

Multi-beam Decks(AASHTO 3.23.4.1)

Refer to Bridge Practice Guidelines, Section 5, Page 23.

Concrete Slabs – Reinforced Perpendicular to Traffic (Slab on Stringer)

For this component, distribution of wheel load is built into a formula for moment. ADOT designs are standardized according to the requirements of the current **AASHTO 3.24.3.1**. Span length of slabs on prestressed concrete stringers may be taken as the clear distance between flanges.

Concrete Slabs – Reinforced Parallel to Traffic (Slab Spans)

Loads are distributed according to **AASHTO 3.24.3.2**. The approximate formula for moment is not used.

For skews up to 30 degrees, main reinforcing is parallel to traffic and no additional edge beam strength is needed for usual railing conditions. For 30 degree skew and greater, reinforcing is perpendicular to the bents and edge beam strength is provided and reinforced parallel to traffic.

Concrete Slabs – Reinforced Both Ways (AASHTO 3.24.6)

Divide the load between transverse and longitudinal spans according to the formulae for slabs supported on four sides. Use the appropriate load distribution in each direction.

Timber Flooring, Composite Wood – Concrete Members and Glued Laminated Timber Decks (AASHTO 3.25 & 3.26)

Timber is not normally used in bridge construction in Arizona.

Steel Gird Floors (AASHTO 3.26)

Follow the Specifications Closely. This type of construction is seldom used in Arizona.

Spread Box Girders (AASHTO 3.28)

Follow the Specifications Closely. This type of construction is seldom used in Arizona.

Live Load Distribution (AASHTO 3.6.3. and 3.12.1)

In designing the superstructure, the live load distribution factors shall not be reduced for multiple lanes as specified in **AASHTO 3.12.1** or rounded to a whole number as specified in **AASHTO 3.6.3**. These two reductions apply to substructure design only.

Horizontal loads on the superstructure distribute to the substructure according to a complicated interaction of bearing and bent stiffness. For continuous steel units, the following method will usually be sufficiently accurate:

- Apply transverse loads times the average adjacent span length.
- Apply longitudinal loads times the unit length to the fixed bent according to their relative stiffness.
- Calculate deformations due to temperature changes given in this guideline and convert to forces according to the stiffness of the fixed bent.
- Centrifugal force is based on the truck load reaction to each bent.

Friction in expansion bearings can usually be ignored but, if its consideration is desirable, the maximum longitudinal force may be taken as 0.10 times the dead load reaction for rocker shoes and PTFE sliding bearings.

For prestressed concrete beam spans and units on elastomeric bearings, fixity is superficial and all bearings are approximately the same stiffness. It will usually be sufficiently accurate to distribute horizontal loads in the following manner:

- Apply transverse and longitudinal loads times the average adjacent span length. The concentrated live load for longitudinal force would be located at each bent.
- Forces due to temperature deformations may be ignored.
- Centrifugal force is based on the truck load reaction to each bent.

If temperature consideration is desirable, deformations may be based on the temperature changes given in this guideline.

LOAD COMBINATIONS

Group numbers represent various combinations of loads and forces which may act on a structure. Group loading combinations for both Load Factor and Service Load Design are defined by **AASHTO 3.22.1** and **Table 3.22.1A**. The loads and forces in each group shall taken as appropriate from **AASHTO 3.3** to **3.21**.

Structures may be analyzed for an overload that is selected by the owner. Size and configuration of the overload, loading combinations, and load distribution will be consistent with procedures defined in the permit policy. The load shall be applied in Group IB as defined in **AASHTO Table 3.22.1A**. For all loadings less than H 20, **Group IA** loading combination shall be used (**AASHTO 3.22.5**).

Arizona Department of Transportation
Bridge Group

BRIDGE PRACTICE GUIDELINES

SECTION 4- STRUCTURAL ANALYSIS & DESIGN METHODS

SCOPE

This section describes methods of analysis suitable for the design and evaluation of bridges and is limited to the modeling of structures and the determination of force effects. Other methods of analysis that are based on documented material characteristics and that satisfy equilibrium and compatibility may also be used.

DEFINITIONS

Aspect Ratio – Ratio of the length to the width of a rectangle.

Compatibility – The geometrical equality of movement at the interface of jointed components.

Component – A structural unit requiring separate design consideration; synonymous with member.

Deformation – A change in structural geometry due to force effects, including axial displacement, shear displacement, and rotations.

Design – Proportioning and detailing the components and connections of a bridge to satisfy the requirements of these Specifications.

Elastic – A structural material behavior in which the ratio of stress to strain is constant, the material returns to its original unloaded state upon load removal.

Element – A part of a component or member consisting of one material.

Equilibrium – A state where the sum of forces and moments about any point in space is zero.

Equivalent Beam – A single straight or curved beam resisting both flexure and torsional effects.

Equivalent Strip – An artificial linear element, isolated from a deck for the purpose of analysis, in which extreme force effects calculated for a line of wheel loads, transverse or longitudinal, will approximate those actually taking place in the deck

Finite Difference Method – A method of analysis in which the governing differential equation is satisfied at discrete points on the structure.

Finite Element Method – A method of analysis in which a structure is discretized into elements connected at nodes, the shape of the element displacement field is assumed, partial or complete compatibility is maintained among the element interfaces, and nodal displacements are determined by using energy variational principles or equilibrium methods.

Finite Strip Method – A method of analysis in which the structure is discretized into parallel strips. The shape of the strip displacement field is assumed and partial compatibility is maintained among the element interfaces. Model displacement parameters are determined by using energy variational principles or equilibrium methods.

Folded Plate Method – A method of analysis in which the structure is subdivided into plate components, and both equilibrium and compatibility requirements are satisfied at the component interfaces.

Force Effect – A deformation, stress, or stress resultant, i.e., axial force, shear force, flexural, or torsional moment, caused by applied loads, imposed deformations, or volumetric changes.

Foundation – A supporting element that derives its resistance by transferring its load to the soil or rock supporting the bridge.

Grillage Analogy Method – A method of analysis in which all or part of the superstructure is discretized into orthotropic components that represent the characteristics of the structure.

Inelastic – Any structural behavior in which the ratio of stress and strain is not constant, and part of the deformation remains after load removal.

Large Deflection Theory - Any method of analysis in which the effects of deformation upon forces effects is taken into account.

Member – Same as components.

Method of analysis – A mathematical process by which structural deformations, forces, and stresses are determined.

Model – A mathematical or physical idealization of a structure or component used for analysis.

Node – A point where finite elements or grid components meet; in conjunction with finite differences, a point where the governing differential equations are satisfied.

Nonlinear Response – Structural behavior in which the deflections are not directly proportional to the loads due to stresses in the inelastic range, or deflections causing significant changes in force effects, or by a combination thereof.

Orthotropic – Perpendicular to each other, having physical properties that differ in two or more orthotropic directions.

Small Deflection Theory – A basis for methods of analysis where the effects of deformation upon force effects in the structure is neglected.

Stiffness – Force effect resulting from a unit deformation.

Strain – Elongation per unit length.

Yield Line – A plastic hinge line.

Yield Line Method – A method of analysis in which a number of possible yield line patterns are examined in order to determine load-carrying capacity.

DESIGN METHODS

Under the current ADOT/Bridge Group **Bridge Practice Guidelines**, two basic methods are used – Service Load Design and Strength Design. The Service Load Design (Allowable Stress Design) shall be used for the design of all steel members and reinforced concrete members except columns, sound barrier walls and bridge railings. Columns and sound barrier walls shall be designed by the Strength Design Method (Load Factor Design). Bridge railing design for new bridges shall be based on the AASHTO LRFD Bridge Design Specifications.

In Service Load Design, loads of the magnitude anticipated during the life of the structure are distributing empirically and each member analyzed assuming completely elastic performance. Calculated stresses are compared to specified allowable stresses which have been scaled down from the tested strength of the materials by a factor judged to provide a suitable margin of safety.

In Strength Design, the same service loads are distributed empirically and the external forces on each member are determined by elastic analysis. These member forces are increased by factors judged to provide a suitable margin of safety against overloading. These factored forces are compared to the ultimate strength of the member scaled down by a factor reflecting the possible consequences from construction deficiencies. Serviceability aspects, such as deflection, fatigue and crack control, must be determined by Service Load Analysis.

The Strength Design Method produces a more uniform factor of safety against overload between structures of different types and span lengths. Strength Design also tends to produce more flexible structures.

A third method is Load and Resistance Factor Design which was adopted by AASHTO in 1994 and will replace Service Load Design and Strength Design in October, 2007 for all

Federal-Aid projects. This method will have more consistent load and resistance factors based on the probabilistic theory and reliability indices that will generate more uniform and realistic safety factors between different types of bridges. Currently, ADOT/Bridge Group is not using this method for bridge design except for the concrete bridge barrier design.

DESIGN PHILOSOPHY

New structure types were developed to meet specific needs. Concrete slab, T-Girder and Box Beam bridges were developed in the late 1940's because many short span stream crossings were being constructed uneconomically with steel beams and trusses. These bridges are still used very economically in considerable numbers today. Precast pretensioned beams were developed in the 1950's for medium span stream crossings and grade separations because steel beams became expensive and sometimes slow on delivery. Fewer plans are assembled from standard prestressed girder drawings today because bridge geometry has become more complicated and variable so that most details must be specially prepared. The beams themselves are still the standard shapes developed in the beginning and the accessories required to complete the span are covered with standard details. Cast-In-Place Post-Tensioned Box Girder bridges were introduced the 1970's and became one of the most common types of bridges used in Arizona in addition to precast prestressed girder bridges.

Bridge design has become more sophisticated and complicated. Prestressed concrete girders continue to be the most economical and durable solution for spans up to 140 feet but aesthetics are occasionally dictating concrete box girders with wide overhangs for this span range. This requires a higher order of analysis while considering time dependent effects and erection conditions. Cable stayed bridges are competing for longer spans. This adds more complication to the design procedure and challenges the specification writers to establish realistic controls.

The Bridge Design Service has performed all types of design in-house, except for cable stayed and segmental bridges. The more advanced structure types have as yet required only a small portion of the overall effort. The most important part of the routine work is to design and to prepare drawings for multitudes of ordinary bridges which usually have some variations in geometry that prohibits the use of straight standard details.

Geometry is considered an important part of bridge design. Framing dimensions and elevations must be accurate in order to avoid expensive field correction. Design engineers are primarily responsible for geometry accuracy.

Constructability is highly desirable. There have been designs which looked good on paper but were virtually impossible to construct. Designers need to consider how to build the component being designed. Construction experience remains a valuable asset.

Details may be the most critical aspect of the design process. Failure to provide for proper stress flow at discontinuities has often caused local stress and sometimes mortal injury to a system. Engineers and technicians should recognize and carefully evaluate untested details.

The bottom line on bridge design is maintenance. It is usually much more expensive to repair a bridge than it was to build it. Unfortunately, maintenance problems tend to occur many years after the structure is built. During that time there may be many more bridges designed with the same problem. Experience is a good teacher, but the lesson is sometimes slow to be learned. It takes a good designer to anticipate maintenance problems and spend just enough of the taxpayers' money to prevent or delay them.

Design engineers are expected to learn the system quickly. Based on education and experience, they should develop engineering judgment to recognize the degree of design complication and accuracy justified by the type and size of member under consideration. A number of computer programs are available. Some are so complicated as to be useful in very special investigations only (GT-STRUDL). Others, although complicated, offer the only realistic solution to a problem (BDS). Others are very useful and time saving in design production (CONSPAN). Longhand methods may even be desirable for some items, especially in the learning stage.

Design calculations are the documentation for structural adequacy and accuracy of pay quantities for each bridge. These will be kept on file for a reasonable period after construction of the bridge. The condition of the calculations reflects the attitude of the designer and checker. The design calculations should consist of a concise, but complete, clear, and easily followed record of all essential features of the final design of each structure. It is often necessary to refer to these calculations because of changes or questions which arise during the construction period. If properly prepared and assembled, these calculations are of great value as a guide and time saver for preparing a similar design of another structure.

The following essential features are to be observed in preparing, checking and filing design calculations:

- The headings at the top of each sheet are to be completely filled in and each sheet has to be numbered.
- The first sheet of calculations should list such governing features as roadway width, curb or sidewalk widths and heights, and design loads. If any deviations are to be made from standard design specifications, they also need to be listed.
- The first sheet of calculations of any superstructure unit should show sketches, a layout of units, giving number of spans and length (c-c bearing) of each span. A line diagram will suffice.
- The first sheet of calculations of any substructure unit should show an appropriate sketch or diagram of the units, properly dimensioned, and the superstructure should be shown.

- Appropriate headings and subheadings such as “Live Load Moments, Center Girder”, “Summary of Shears, Outside Girders”, etc., should be freely used. These headings should be supplemented by explanatory notes wherever necessary to clarify the portion of structure under consideration, the load combinations being used, or the method of analysis being employed.
- In checking the calculations, do not make up a separate set of design calculations. Follow the original calculations and check them thoroughly, or at least check the final results. In case when a portion of original calculations are incomplete or inaccurate, a portion of the revised set must be prepared by the designer or checker. This revised set will replace the original set as a portion of the final calculations.
- In checking calculations, don’t carry through corrections that are so minor in amount as to have no real effect on the structure.
- Superstructure calculations should be placed in front of substructure calculations. Quantity calculations shall be placed at the end of the file. Preliminary designs, trial designs and comparative designs are not to be included in the design folder as finally filed.

Supplement the above guidelines with good judgment and plenty of common sense. The extra ten minutes you spend in making your calculation sheet clear and complete may save the checker an hour, and may two years hence, save some bridge designer a week or more of computations.

STRUCTURAL ANALYSIS

In general, bridge structures are to be analyzed elastically which are based on documented material characteristics and satisfy equilibrium and compatibility. However, exceptions may apply to some continuous beam superstructures by using inelastic analysis or redistribution of force effects.

This section identifies and promotes the application methods of structural analysis that are suitable for bridges. The selected method of analysis may vary from the approximate to the very sophisticated, depending on the size, complexity, and importance of the structure. The primary objective in the use of more sophisticated methods of analysis is to obtain a better understanding of structural behavior. Such improved understanding may often, but not always, lead to the potential for saving material.

These methods of analysis, which are suitable for the determination of deformations and force effects in bridge structures, have been successfully demonstrated, and most have been used for years. Although many methods will require a computer for practical implementation, simpler methods that are amenable to hand calculation and/or to the use of existing computer programs based on line-structure analysis have also been provided. Comparison with hand calculations should always be encouraged, and basic equilibrium checks should be standard practice. With rapidly improving computing technology, the more refined and complex methods of analysis are expected to become commonplace. It is important that the user understand the method employed and its associated limitations.

In general, the suggested methods of analysis are based on linear material models. This does not mean that cross-sectional resistance is limited to the linear range. The Load Factor Design present such inconsistency that the analysis is based on material linearity and the resistance model may be based on inelastic behavior.

ACCEPTABLE METHODS OF STRUCTURAL ANALYSIS

Any method of analysis that satisfies the requirements of equilibrium and compatibility and utilizes stress-strain relationships for the proposed materials may be used, including but not limited to:

- Classical force and displacement methods (Moment Distribution, and Slope Deflection Methods, etc.),
- Finite difference method,
- Finite element method,
- Folded plate method,
- Finite strip method,
- Grillage analogy method,
- Serious or other harmonic methods, and
- Yield line method.

Many computer programs are available for bridge analysis. Various methods of analysis, ranging from simple formulae to detailed finite element procedures, are implemented in such programs. Many computer programs have specific engineering assumptions embedded in their code, which may or may not be applicable to each specific case. The designer should clearly understand the basic assumptions of the program and the methodology that is implemented. The designer shall be responsible for the implementation of computer programs used to facilitate structural analysis and for the interpretation and use of results. The name, version and release date of software used should be indicated in the design calculations.

MATHEMATICAL MODELING

Mathematical models should include loads, geometry, and material behavior of the structure, and, where appropriate, response characteristics of the foundation. In most cases, the mathematical model of the structure should be analyzed as fully elastic, linear behavior except in some cases, the structure may be modeled with inelastic or nonlinear behavior.

Structural Material Behavior

ELASTIC BEHAVIOR

Elastic material properties and characteristics of concrete, steel, aluminum and wood shall be in accordance with the sections given by **AASHTO Specifications**. Changes in these values due to maturity of concrete and environmental effects should be included in the model, where appropriate.

INELASTIC BEHAVIOR

Sections of components that may undergo inelastic deformation shall be shown to be ductile or made ductile by confinement or other means. Where inelastic analysis is used, a preferred design failure mechanism and its attendant hinge locations shall be determined. It should be ascertained in the analysis that shear, buckling, and bond failures in the structural components do not precede the formation of a flexural inelastic mechanism. Unintended overstrength of a component in which hinging is expected should be considered. Deterioration of geometrical integrity of the structure due to large deformations shall be taken into account. The inelastic model shall be based either upon the results of physical tests or upon a representation of load-deformation behavior that is validated by tests.

Geometry

SMALL DEFLECTION THEORY

If the deformation of the structure does not result in a significant change in force effects due to an increase in the eccentricity of compressive or tensile forces, such secondary effects may be ignored. Small deflection theory is usually adequate for the analysis of beam-type bridges. Columns, suspension bridges, and very flexible cable-stayed bridges and some arches other than tie arches and frames in which the flexural moments are increased or decreased by deflection tend to be sensitive to deflection considerations. In many cases, the degree of sensitivity can be assessed and evaluated by a single-step approximate method, such as the Moment Magnification Factor Method. Due to advances in material technology the bridge components become more flexible and the boundary between small- and large-deflection theory becomes less distinct.

LARGE DEFLECTION THEORY

If the deformation of the structure results in a significant change in force effects, the effects of deformation shall be considered in the equations of equilibrium. The effect of deformation and out-of-straightness of components shall be included in stability analyses and large deflection analyses. For slender concrete compressive components, those time- and stress-dependent material characteristics that cause significant changes in structural geometry shall be considered in the analysis.

Because large deflection analysis is inherently nonlinear, the loads are not proportional to the displacements, and superposition can not be used. Therefore, the order of load application can be important and should be applied in the order experienced by the structure, i.e., dead load stages followed by live load stages, etc. If the structure undergoes nonlinear deformation, the loads should be applied incrementally with consideration for the changes in stiffness after each increment.

STATIC ANALYSIS

Plan Aspect Ratio

Where transverse distortion of a superstructure is small in comparison with longitudinal deformation, the former does not significantly affect load distribution, hence, an equilibrium idealization is appropriate. The relative transverse distortion is a function of the ratio between structural width and height, the latter, in turn, depending on the length. Hence, the limits of such idealization are determined in terms of the width-to-effective length ratio.

Simultaneous torsion, moment, shear, reaction forces, and attendant stresses are to be superimposed as appropriate. In all equivalent beam idealizations, the eccentricity of loads should be taken with respect to the centerline of the equivalent beam.

Structures Curved in Plan

- Segments of horizontally curved superstructures with torsionally stiff closed sections whose central angle subtended by a curved span or portion thereof is less than 12 degrees may be analyzed as if the segment were straight.
- The effects of curvature may be neglected on open cross-sections whose radius is such that the central angle subtended by each span is less than the value given in the following table taken from **AASHTO LRFD Specifications**.

Number of Beams	Angle for One Span	Angle for Two or More Spans
2	2 °	3 °
3 or 4	3 °	4 °
5 or more	4 °	5 °

- Horizontally curved superstructures other than torsionally stiff single girders may be analyzed as grids or continuums in which the segments of the longitudinal beams are assumed to be straight between nodes. The actual eccentricity of the segment between the nodes shall not exceed 2.5 percent of the length of the segment.
- V-load method may be used to analyze a horizontally curved continuous steel bridge.

Approximate Methods of Analysis

Current **AASHTO Specifications** has provided the approximate methods of load distribution factor for deck, beam-slab bridges, slab bridges and other types of structures. Please follow the provisions of **AASHTO Specifications** for specific type of structure to obtain design parameters. Also, please refer to these **Bridge Practice Guidelines** for the design parameters listed in the various types of structures.

Refined Methods of Analysis

Refined methods, listed below, may be used to analyze bridges. In such analyses, consideration should be given to aspect ratio of elements, positioning and number of nodes, and other features of topology that may affect the accuracy of the analytical solution. When a refined method of analysis is used, a table of live load distribution coefficients for extreme force effects in each span shall be provided in the contract documents to aid in permit issuance and rating of bridges.

DYNAMIC ANALYSIS

For analysis of the dynamic behavior of bridges, the stiffness, mass and damping characteristics of the structural components shall be modeled.

The minimum number of degree-of-freedom included in the analysis shall be based upon the number of natural frequencies to be obtained and the reliability of the assumed mode shapes. The model shall be compatible with the accuracy of the solution method. Dynamic models shall include relevant aspects of the structure and the excitation. The relevant aspects of the structure may include the:

- Distribution of mass,
- Distribution of stiffness, and
- Damping characteristics.

The relevant aspects of excitation may include the:

- Frequency of the forcing function,
- Duration of application, and
- Direction of application.

Typically, analysis for vehicle- and wind-induced vibration is not to be considered in the bridge design. Although a vehicle crossing a bridge is not a static situation, the bridge is analyzed by statically placing the vehicle at various locations along the bridge and applying a dynamic load allowance as stated in **AASHTO Specifications**. However, in flexible bridges and long slender components of bridges that may be excited by bridge movement, dynamic force effects may exceed the allowance for impact. In most observed bridge vibration problems, the natural structural damping has been very low which no dynamic analysis is needed.

Dynamic analysis of the bridge must be considered if the bridge site is located in the area of high seismic active zone, such as Yuma and Flagstaff area. Please refer the **AASHTO Specifications** and Section 3 for seismic design.

SECTION 9: DECKS AND DECK SYSTEMS

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9.1 SCOPE

This Section contains guidelines to supplement provisions of Section 9 of the AASHTO LRFD Bridge Design Specifications for the design of bridge decks and deck systems of reinforced concrete, prestressed concrete, metal, or various combinations thereof.

9.4 GENERAL DESIGN REQUIREMENTS

Bridge decks minimum concrete strength f'c shall be 4.5 ksi at 28 days. Refer to Section 5, Article 5.4 (Material Properties) of these guidelines for other requirements.

To provide protection against corrosion the minimum clear cover for reinforcing steel in new deck slabs shall be 2½ inch for top reinforcement and 1 inch for the bottom reinforcement.

Only #5 or #6 bar sizes shall be used as primary reinforcement in the transverse direction and shall be spaced at 1/2-inch increments. Minimum reinforcement spacing shall be 5 inches. Maximum transverse reinforcement spacing shall be 9 inches.

Bar sizes up to #11 may be used as primary reinforcement in the longitudinal direction in slab bridges. This also applies to continuity reinforcement over piers.

All new bridge deck construction or bridge deck replacement located above an elevation of 4,000 feet, or for areas where de-icing chemicals are used, the deck reinforcement shall be epoxy coated (see section 5.4.3 for requirements covering use of epoxy coated reinforcing).

Silica-fume concrete shall be used for new deck construction located at or above an elevation of 4000 feet.

Deck protection systems shall be discussed in the Bridge Selection Report. Recommended options, other than epoxy coated reinforcing, shall be coordinated with ADOT Materials Group and shall be approved by ADOT Bridge Group.

For existing bridges, latex modified concrete overlay, silica-fume concrete overlay or a membrane system with a bonded wearing surface are alternate protection systems that may be considered. Implementation of either one of these alternatives requires coordination with ADOT Materials and Bridge Groups.

A 3/4" V-drip groove shall be located on the underside of the deck overhang for all bridges.

Bridge construction plans shall include the deck pour schedule including a plan view with joint locations, deck pour sequence, and direction of pour (see bridge construction section for more details).

For structural concrete overlay on precast deck bridges, see section 5 for design requirements.

9.5 LIMIT STATES

9.5.2 Service Limit States

Deck design is controlled by Service Limit State I. The behavior of bridge decks shall be considered elastic. Decks shall be designed by the working stress method and as stated in this section.

Allowable tensile stress in reinforcing steel, fs shall be limited to 24 ksi.

9.6 ANALYSIS

9.6.1 Methods of Analysis

The most typical deck system used in Arizona is a cast-in-place deck slab spanning transversely over a series of girders. This type of deck shall be designed using an approximate elastic method and the criteria stated in this section.

Refined methods of analysis, such as the Finite Element Method, shall only be used for unconventional, complex structures and with prior approval from ADOT Bridge Group.

Dead load analysis shall be based on a strip method using the following simplified moment equation for both positive and negative moments:

$\frac{wS^2}{10}$, for deck slabs that are continuous over three spans or more
$\frac{wS^2}{8}$, for all other cases

where:

S = the effective span length specified in AASHTO LRFD Article 9.7.2.3
w = the uniformly distributed dead load of the slab system

The unfactored live load moments shall be obtained from AASHTO LRFD Section 4, Appendix A, Table A4-1. Negative moment values shall be based on a distance of 0.0 inch from the centerline of girder to the design section.

9.7 CONCRETE DECK SLABS

9.7.1 General

9.7.1.1 Minimum Depth and Cover

The thickness of new deck slabs shall be designed in 1/2" increments with the minimum thickness as follows:

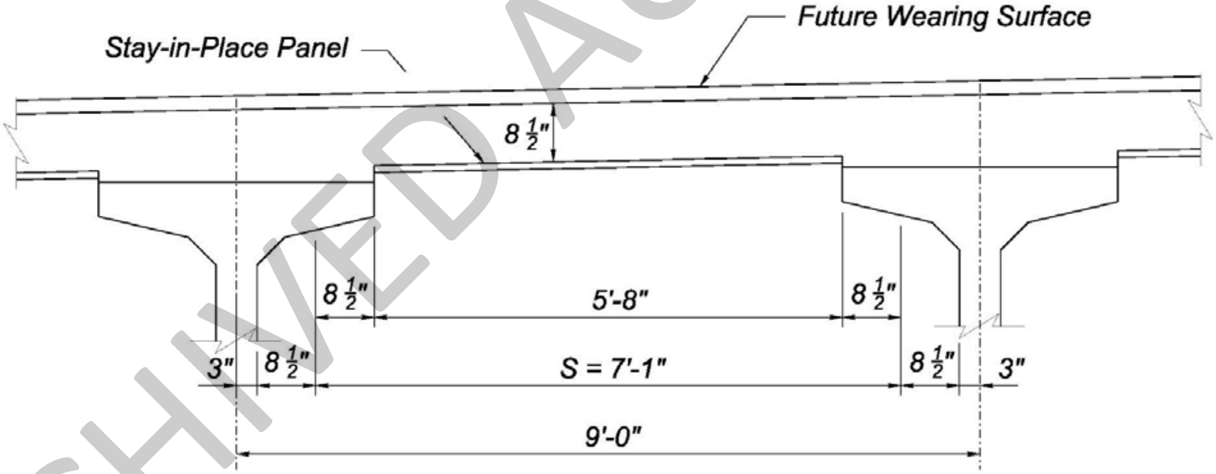
S (ft)	< 7	> 7 and ≤ 8.5	> 8.5 and ≤ 10	> 10 and ≤ 11.5	> 11.5 and ≤ 13
t (in)	8.0	8.5	9.0	9.5	10.0

where:

S = the effective span length specified in AASHTO LRFD Article 9.7.2.3
t = Minimum thickness of deck slab

Note that the slab thickness, t, includes a 1/2 inch wearing surface, which must be excluded from strength and service analysis.

Effective Span Length Example



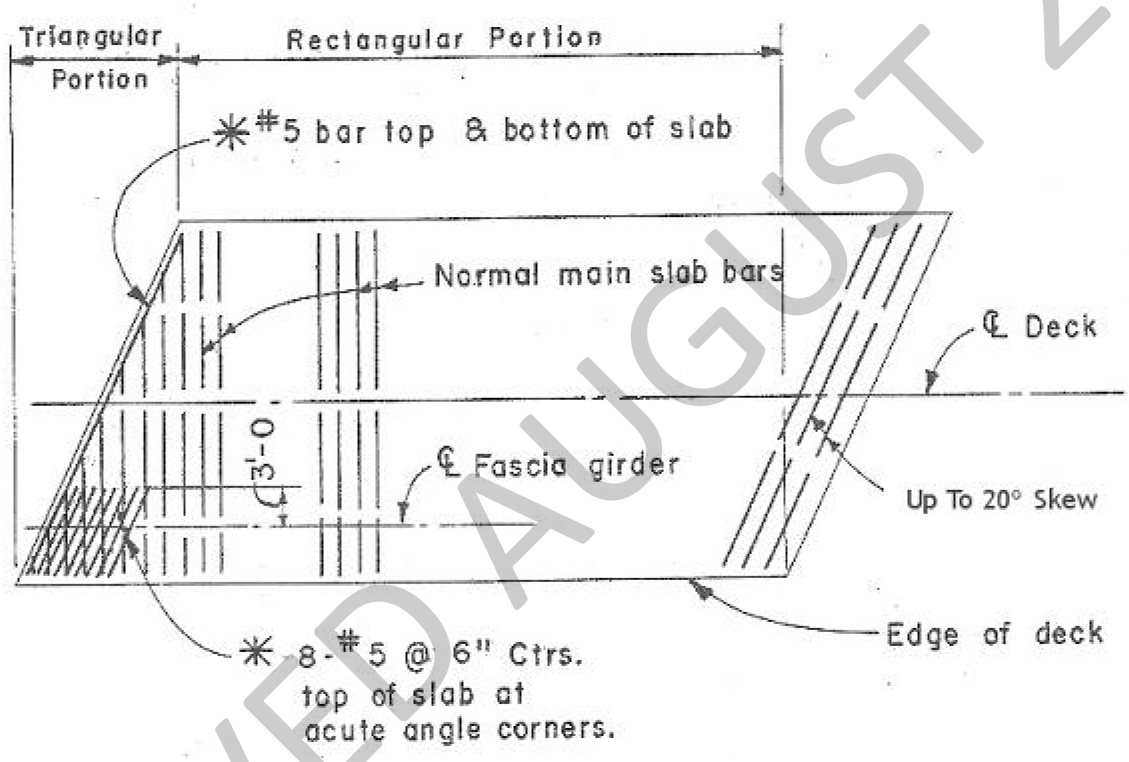
TYPICAL SECTION

For this example with a centerline-to-centerline web spacing of 9.00 feet and a top flange width of 40 inches, clear spacing = 9-0' – 40"/12 = 5.67 feet. The effective length is 5.67' + (17"/12) = 7.08 feet. The resulting minimum deck slab thickness is 8.5 inches, of which 8 inches will be used in strength and service analysis.

9.7.1.3 Skewed Decks

For skew angles less than or equal to 20 degrees, the primary reinforcement shall be placed parallel to the skew. For skew angles greater than 20 degrees the reinforcing shall be placed perpendicular to the main supporting members. The effects of the skew shall be accounted for by providing additional short bars at the deck corners as shown in the figure below. Truss bars shall not be used.

Skewed Girder Bridges



* Use for skew angles of 20° or more at each skewed corner.

9.7.3 Traditional Design

9.7.3.2 Distribution Reinforcement

Distribution reinforcement shall be calculated in accordance with AASHTO LRFD Article 9.7.3.2. The required reinforcement shall be placed in the secondary direction throughout the effective span length between girders in the bottom of the slab.

9.7.4 Stay-in-Place Formwork

9.7.4.1 General

Use of stay-in-place (SIP) formwork shall be investigated for each bridge site during preliminary design and a discussion of this issue shall be included in the Bridge Selection Report. Use of a SIP formwork system may be considered for the following situations:

- When bridges span high traffic volume roadways, deep canyons, perennial streams or canals.
- Where removal of conventional formwork would be difficult or hazardous.

When a SIP formwork system is selected, the contract documents shall include conceptual design and connection details for the SIP system. The contractor shall submit all SIP formwork design calculations and connection details to the design engineer for approval. Shop drawings for the girders including the location of inserts and the SIP formwork, shall be submitted concurrently for review and approval.

9.7.4.2 Steel Formwork

Steel formwork is the preferred stay-in-place formwork for bridge deck construction. The design engineer shall assume an additional 15 psf of dead load due to the weight of the forms and the concrete in the flutes. SIP formwork flutes shall only be filled with structural concrete. The use of foam or polystyrene in the flutes is not allowed.

Steel formwork shall not be considered to be composite with the concrete deck slab. The construction plans shall state the assumed additional weight that the deck, girder and substructure have been designed for due to this method of construction.

Stay-in-place metal forms for cast-in-place concrete decks are considered a falsework system. The additional concrete in the metal flutes shall not be included in the deck concrete quantities and the following note shall be included in the plans when stay-in-place forms are allowed to be used:

No additional payment will be made for the stay-in-place metal forms and the additional concrete placed in the flutes, the cost being considered as included in the contract unit price for deck concrete quantities.

The steel formwork shall be galvanized for corrosion protection.

9.7.4.3 Concrete Formwork

Precast stay-in-place concrete panels used with a cast-in-place concrete topping to create a final composite deck are another form of formwork for deck construction. The panels are designed to span transversely between the girders and are usually prestressed. A full discussion justifying the use of precast concrete deck panels over steel formwork, including all design and construction parameters, shall be included in the Bridge Selection Report before final approval can be considered.

9.8 DECK OVERHANG DESIGN

The deck overhang shall be designed in accordance with AASHTO LRFD Section 13, Appendix A, Article A13.4. For Design Case 1, the deck shall be designed to resist both the axial force and the bending moments due to the dead load and the horizontal railings impact load. The vertical wheel load shall not be applied simultaneously with these loads. The net tensile strain in the extreme tension steel in the overhang reinforcing for Design Case 1, Extreme Event Load Combination II limit state, shall not exceed 0.025.

For Design Case 3 both the strength and service limit states shall be investigated. For the Service Limit State, the design live load distribution shall be determined using AASHTO LRFD Table 4.6.2.1.3-1.

When traffic barriers are located at the edge of the deck, the minimum slab thickness of the overhang shall be as shown on the barrier standard drawings. Deck reinforcement resisting overhang loadings shall be fully developed at the section under consideration. Reinforcing steel larger than #5 bars may require hooks at the edge of the deck for development length.

Concrete barriers continuous over intermediate supports such as piers shall have a 1/2 inch open joint filled with bituminous joint filler. The joint shall extend from the top of the barrier to within 10 inches of the deck surface with reinforcing below this level made continuous.

The values in the following table shall be used for the design of the deck overhang in conjunction with ADOT Bridge Group Standard Drawings (SD) for concrete barriers. Refer to AASHTO LRFD Section 13, Appendix A13, for definition of the symbols contained in the table.

Barrier Type	M_b	R_w	M_c	M_w	Top rail M_p	Bottom rail M_p	Post M_p	Weight
SD 1.10 38” Single Slope Bridge Concrete Barrier	0	97.38 k	11.29 [a]	35.18	--	--	--	0.457 klf
SD 1.11 42” Single Slope Bridge Concrete Barrier	0	205.6 k	18.65 [b]	78.13	--	--	--	0.574 klf
SD 1.12 Combination Predestrail-Traffic Bridge Railing	0	--	12.69 [d]	57.40 [e]	9.80	9.80 [f]	15.03	0.675 klf

a. M_c = 18.10 at open joints
b. M_c = 19.17 at open joints

c. Assumes 10-inch curb height at parapet
d. M_c = 15.39 at open joints
e. M_w = 47.70 at open joints
f. When fence is omitted
g. Excluding widewalk weight

Arizona Department of Transportation
Bridge Group

BRIDGE PRACTICE GUIDELINES

Section 11 – Retaining Walls & Sound Barrier Walls

SECTION 14: JOINTS AND BEARINGS

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14.1 SCOPE

This section contains guidelines to supplement provisions of Section 14 of the AASHTO LRFD Bridge Design Specifications for the design and selection of bridge expansion joints, bearings and restraining devices.

It is ADOT Bridge Group's policy to promote the design of bridges with minimal number of joints. Bridge joints account for a large portion of bridge inspectors' repair recommendations and maintenance personnel complaints; reducing the number of joints would lower life cycle costs.

14.4 MOVEMENTS AND LOADS

14.4.1 General

Provisions shall be made in the design of structures to resist induced stresses or to provide for movements resulting from variations in temperature, shortening of structure length due to creep, shrinkage, and prestressing or a combination of thereof. Accommodation of thermal and shortening movements will entail consideration of deck expansion joints, bearing systems, restraining devices and the interaction of these three items.

The main purpose of deck joints is to seal the joint opening to obtain a watertight joint while allowing for vertical, horizontal and rotational movement. The bearings are required to transmit the vertical and lateral loads from the superstructure to the substructure and to allow for movement in the unrestrained directions. Restraining devices are required to limit the displacement in the restrained directions. Improper design or construction of bearings or restrainers could adversely affect the movement of the structure.

The calculated displacements used in determining the required displacement (i.e. the difference between the widest and the narrowest opening of a joint) shall be the sum of 1.2 times the movements caused by temperature changes and 1.0 times the shortening movement caused by creep and shrinkage.

14.4.2 Design Requirements

Temperature Movement:

> Temperature ranges shall be as specified in the following table which replaces AASHTO LRFD Table 3.12.2.1-1 for Procedure A.

		Concrete		Steel	
Elevation (ft)	Mean (°F)	T $_{min}$ (°F)	T $_{max}$ (°F)	T $_{min}$ (°F)	T $_{max}$ (°F)
Up to 3000	75	35	105	15	135
3000 - 6000	60	20	90	0	120
Over 6000	50	5	85	-30	120

The differential movement in inches, ΔL, due to temperature difference for joints and elastomeric bearings shall be calculated as specified below:

Joints: $\Delta L = \alpha L (T_{max} - T_{min})$
Elastomeric Bearings: $\Delta L = 0.65\alpha L (T_{max} - T_{min})$

where:

Steel: $\alpha = 6.5\text{x}10^{-6}$, coefficient of thermal expansion, inch / inch / °F
Concrete: $\alpha = 6.0\text{x}10^{-6}$, coefficient of thermal expansion, inch / inch / °F
L = span length, inch

Unless a more precise method of measuring the temperature of the main superstructure members is used, the setting temperature of the bridge or any component thereof shall be taken as the actual air temperature averaged over the 24-hour period immediately preceding the setting event. The setting temperature is used in installing expansion bearings and deck joints.

Shortening Movement:

Displacement of concrete structures must account for the shortening due to creep, shrinkage, and prestressing force. For concrete structures, change in length shall be calculated as specified below.

For conventionally reinforced concrete members the anticipated long-term shortening due to shrinkage shall be:

Joints:	0.36 inch per 100 feet.
Bearings:	0.60 inch per 100 feet

For precast prestressed concrete members, the anticipated long term shortening including creep and shrinkage shall be:

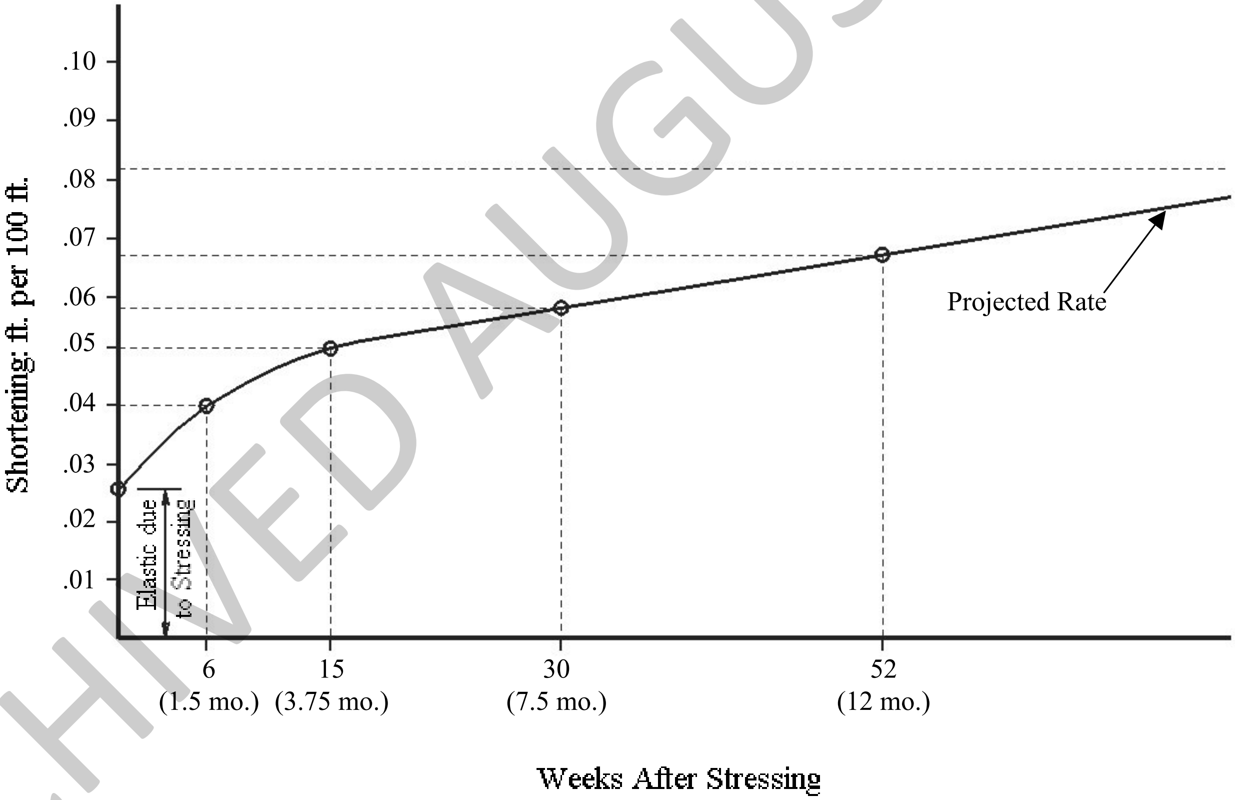
Joints:	0.25 inches per 100 feet.
Bearings:	0.60 inches per 100 feet.

For cast-in-place post-tensioned concrete box girder bridges, the anticipated shortening including creep for deck joints shall be 0.50 inch per 100 feet.

For cast-in-place post-tensioned concrete box girder bridges, the effects of elastic shortening due to prestressing shall be considered in determining the movement for the bearings. The anticipated total shortening including elastic shortening, creep, and shrinkage for bearings shall be 1.20 inch per 100 feet.

For bridges where the construction schedule is short or delayed past a reasonable time, such as a winter shutdown, design engineers may want to estimate shortening factors using the graph shown below, which is reproduced for convenience, from Caltrans Memo to Designers 7-1, Attachment 1, June 1994, Technical Publications, Section 7-Bearing and Expansion Devices, September 2004.

Figure 1 – Prestress Shortening Assuming Total Long Term Shortening 0.10 ft / 100 ft



In addition, the effects of bridge skew, curvature, and neutral axis location shall be considered. The neutral axis of the girder and the neutral axis of the bearing seldom coincide resulting in the rotation of the girder inducing either additional horizontal displacement or forces at the joint or at bearing level. Bearing design should include the effects of the additional displacement or force.

14.4.2.1 Elastomeric Pads and Steel Reinforced Elastomeric Bearings

The maximum unfactored service rotation due to total load, which include dead load and live load plus impact, shall be the sum of the rotations caused by applicable unfactored loads. Additionally, a 0.005 radians allowance for uncertainties in rotation shall be included unless an approved quality control plan justifies a smaller value. These uncertainties include allowances for fabrication and installation tolerances.

14.5 BRIDGE JOINTS

14.5.1 Requirements

14.5.1.2 Structural Design

The design and performance of the deck joints are critical to the bearing performance and future maintenance of the structure. The selection of the joint type shall be based on the displacement requirement of the structure.

The displacement for joints for steel structures shall be based primarily on the thermal expansion and contraction characteristics of the superstructure. For concrete structures, the effects of shortening due to creep, shrinkage, and prestressing shall also be included in determining the displacement. Displacements shall be based on temperature variations as measured from the assumed mean temperature.

Published displacements from a manufacturer are usually based on the difference between the maximum and minimum openings without consideration to the required minimum installation width. In determining the displacement, consideration must be given to the installation width required to install the seal element.

Other factors to be considered in determining the required displacement include consideration of the effects of any skew, and anticipated settlement and rotations due to live loads and dead loads, where appropriate.

Displacement calculations should account for the following items:

The type of anchorage system to be used.

The method of joint termination at the ends.

The method of running joints through barriers, sidewalks and medians.

Physical limitation on size of joints.

Susceptibility of joint to leakage.

Possible interference with post-tensioning anchorages.

Selection of appropriate modular proprietary systems that meet design requirements.

Forces applied to the surrounding concrete by the joint.

Specifying the use of a continuous seal element.

Long term maintenance and life-cycle analysis.

For skewed bridges, the transverse movement along the joint shall be the calculated displacement along the bridge centerline times the sine of the skew angle. The longitudinal displacement normal to the joint shall be the calculated displacement along the bridge centerline times the cosine of the skew angle. A skew angle is defined as the angle subtended between the normal to the bridge centerline and the alignment of the bridge abutment or piers.

For a curved superstructure that is laterally unrestrained by guided bearings or shear keys, the direction of longitudinal movement at a bearing joint may be assumed to be parallel to the chord of the deck centerline.

The rolling resistance of rocker and rollers, the shear resistance of elastomeric bearings, or the frictional resistance of bearing sliding surfaces will oppose movement. In addition, the rigidity of abutments and the relative flexibility of piers of various heights and foundation types will affect the magnitude of the movement of the bearing and the forces opposing the movement. These forces should be considered during the substructure design.

14.5.3 Design Requirements

14.5.3.1 Movements During Construction

Where practicable, construction staging should be used to delay construction of abutment and piers located in or adjacent to embankments until the embankments have been placed and consolidated. Otherwise, deck joints should be sized to accommodate the probable abutment and pier movements resulting from embankment consolidation after their construction.

Closure pours in concrete structures may be used to minimize the effect of prestress-induced shortening on the width of seals and the size of bearings and to ensure proper placement of the joint and consolidation of the surrounding concrete.

For concrete superstructures, consideration shall be given to the opening of joints due to creep and shrinkage, which may require initial minimum openings of less than 1-inch.

14.5.3.3 Protection

Joints in concrete decks should be armored with steel shapes. Such armor shall be recessed below roadway surfaces and be protected from snowplows. Snowplow protection for deck joint armor and joint seals may consist of:

> Concrete buffer strips 12 to 18 inches wide with joint armor recessed 1/4 to 3/8 inches below the surface of such strips.
>
> Tapered steel ribs protruding up to 1/2-inch above roadway surfaces can be used to lift the plow blades as they pass over the joints.

Additional precautions to prevent damage by snowplows should be considered where the skew of the joints coincides with the skew of the plow blades, typically 30 to 35 degrees. Details for snowplow protection shall be coordinated with ADOT Bridge Group and the District Construction Office.

14.5.3.5 Armor

Joint-edge armor embedded in concrete should have 1/2-inch diameter vertical vent holes spaced no more than 9 inch centers along the length of the armor. These vent holes are necessary to expel entrapped air and facilitate the attainment of a consolidated concrete support under the joint edge armor.

14.5.5 Installation

14.5.5.3 Field Splices

Joint designs shall include details for transverse field splices for staged construction and for joints longer than 60 feet. Where practicable, splices should be located at the crown, cross slope break point, or along the traffic lane line. Details of splices should be selected to maximize fatigue life. The contract documents shall require that permanent seals not be placed until after joint installation has been completed. Where practicable, only those seals that can be installed in one continuous piece should be used. Where field splicing is unavoidable, splices should be vulcanized. Splices should not be located within a lane or gutter area.

14.5.6 Considerations for Specific Joint Types

Available joint types are: compression seals, strip seals, and modular joints. Compression seal joints and strip seal joints are generic and should be detailed on the plans by referencing the appropriate Structure Detail (SD) Drawings (click here). Modular joints are proprietary items and require that the design engineer specify acceptance criteria on the plans and reference ADOT Standard Specifications for Road and Bridge Construction for additional details.

The following issues shall be addressed in the detailing or in the specifications special provisions:

Secondary pour, block-out dimensions, and additional reinforcement requirements should be included in the block-out details.

End treatment in barriers or curbs, including details or explanation to accommodate potential proprietary systems. This should include the need for cover plates and method of termination of the joint in sidewalks and separation barriers.

Consideration to traffic control in determining section pattern lengths.

Displacements.

Assumed temperature and opening at time of installation with temperature correction table showing the joint opening at various temperatures.

Actual horizontal length of joint measured from inside of barrier face to inside of barrier face corrected for skew and super elevation.

The method of seal termination in barriers, sidewalks and raised medians. In general the seal should be turned up a minimum of 6 inches or 2 inches above the high water depth at the curb to keep the roadway water in the roadway drainage collection system. To better seal the joint, and to minimize construction errors, the seal should be turned up at both the low and high sides.

The special provisions shall specify that the method of measurement is linear foot from face to face of barrier or face of parapet, including sidewalk width.

For modular joints, the acceptance criteria, steel edge beam material, and the requirements for a trained manufacturer's representative shall be specified in both the special provisions and the plans.

For bridges located in non-corrosive environments, the exposed steel armor surfaces shall be painted for ASTM A36 steel or left unpainted for ASTM A588 steel. For bridges subjected to de-icing salts and for bridges located above 4,000 feet, the armor should be galvanized. The need for galvanizing shall be specified on the plans and in the special provisions.

14.5.6.6 Compression and Cellular Seals

Compression seal joints shall conform to the details shown in SD 3.01 (click here). Proprietary alternates to the details shown in the SD drawing will not be allowed. The compression seal element should have a shape factor of 1:1 (width to height) to minimize sidewall pressure. The size of the compression seal shall be specified on the plans.

For these types of joints, the effective displacement range is up to 2.5 inches. Advantages for these joints include their comparatively lower cost, proven performance and acceptance for use on pedestrian walkways without the need for cover plates.

These joints are not suitable for high skews or horizontally curved bridges. For skewed bridges, the transverse movement should be less than 20 percent of the nominal seal dimension. This longitudinal movement should be less than the specified movement rating for the seal. The maximum allowed skew for use of a compression seal is 45 degrees with 30 degrees being the preferred limit.

If not properly sized, compression and cellular seals joints may be difficult to maintain. For instance, when the seals are too small for the displacement they can pull away from the angle iron and either drop down or come out of the joint. On the other hand, if the seals are too large they will bulge out of the joint and could be damaged by traffic.

Compression seals shall be supplied without splicing. Where the length of the deck joint is less than 60 feet, the deck joint shall be supplied in one piece and the seal may be factory installed. Where phase construction is required or where the deck joint is longer than 60 feet, the armor may be supplied in pieces and spliced in the field. However, the seal shall be installed in one piece. Since the design engineer has no prior knowledge of the manner the seal will be supplied, consideration must be made for the minimum installation width of the seal. Typically the seal can be installed if the opening is as low as 50% of its nominal dimension. As a general practice, the joint opening is set at the mean temperature for 60% of the required width. This will allow easy installation at the mean temperatures but still allow for installation at higher temperatures.

The following table, which lists contract bid item numbers, joint description, and units of measurements, is included for convenience:

Bid Item	Description	Measurement
6011346	Deck Joint Assembly (2x2 compression seal)	LF
6011347	Deck Joint Assembly (3x3 compression seal)	LF
6011348	Deck Joint Assembly (4x4 compression seal)	LF
6011349	Deck Joint Assembly (5x5 compression seal)	LF

14.5.6.7 Sheet and Strip Seals

Strip seals shall conform to the details shown in SD 3.02 (click here). Alternative details, other than those shown in the drawing, which are proprietary, will not be allowed.

For this type of joint, effective displacement range may be up to 4 inches. This type of joint is recommended when the displacement is beyond the capacity of compression seals and for large skews. Strip seal joints will require cover plates for pedestrian walkways.

The seals shall be supplied continuous in one piece. Since the seal must be installed after the armor is set in concrete, a minimum installation opening must be provided. In general, a minimum opening of 1.75 inches is preferred for easy installation but the seal can be installed in openings as small as 1.5 inches. The opening at the mean temperature should be set to 1.75 inches whenever possible.

The following table, which lists the contract bid item number, joint description, and unit of measurement, is included for convenience:

Bid Item	Description	Measurement
6011345	Deck Joint Assembly (strip seal joint)	LF

14.5.6.9 Modular Bridge Joint Systems (MBJS)

Modular joint systems are proprietary with effective displacement ranging from 4 inches up to 30 inches. Modular joints are the best choice for displacements over 4 inches; however, these joints should be avoided whenever possible due to their high initial and lifecycle costs.

MBJS shall satisfy all requirements specified in the specifications special provisions and ADOT Standard Specifications for Road and Bridge Construction. Information concerning specific design parameters and installation details of modular joints should be obtained from literature supplied by the manufacturer of the system. It is the responsibility of the design engineer to review the literature of the proprietary joint and related manufacturer’s specifications to ensure that the selected joint types are properly specified and compatible with the design requirements.

The following table, which lists the contract bid item number, joint description, and unit of measurement, is included for convenience:

Bid Item	Description	Measurement
6011355	Deck Joint Assembly (Modular, Movement Rating)	LF

14.6 REQUIREMENTS FOR BEARINGS

14.6.1 General

Unlike joints, where the opening can be adjusted if the ambient temperature at the time of construction is different than the assumed mean temperature, bearings must be designed to be installed at temperatures other than the mean temperature. For this reason, the displacement should be based on 65% of the full temperature range and not the rise or fall from a mean temperature.

Calculation of the displacement shall include thermal movement and anticipated superstructure shortening due to creep, shrinkage and prestressing force, where applicable. For cast-in-place post-tensioned concrete box girder bridges, both the elastic and long term prestress shortening effects shall be included.

Bearing types include neoprene strips, elastomeric bearing pads, sliding elastomeric bearings, steel bearings and high-load multi-rotational bearings, such as pot; disc or spherical bearings.

Neoprene strips, elastomeric bearing pads, and steel bearings are generic and shall be detailed in the plans. The special provisions shall include performance specifications for these bearing types.

High-load multi-rotational bearings are proprietary bearings. When using these bearings, the design engineer shall include a bearing schedule in the plans, review the applicability of the manufacturer's specifications, and the adequacy of the manufacturer's design.
All bearing types except elastomeric bearing pads shall be designed for dynamic impact allowance, IM. For all limit states, IM shall be 75%; refer to AASHTO LRFD Article 3.6.2.

For bearings with sliding surfaces, an initial offset of the top sliding surface from the centerline of bearing should be calculated and shown in the plans. The calculated offset is the sum of the superstructure displacement due to creep, shrinkage, and prestressing force, where applicable. The objective is to align the top and bottom sliding surfaces with the centerline of the bearing after all losses have occurred.

14.7 SPECIAL DESIGN PROVISIONS FOR BEARINGS

14.7.1 Metal Rocker and Roller Bearings

Steel bearings may consist of metal rockers or of fixed or expansion assemblies, the mechanical properties of which shall conform to the requirements specified in AASHTO LRFD Bridge Design Specifications, Section 6.

Steel bearings are not a preferred bearing type and their use should normally be limited to situations where new bearings are to match the existing once on bridge widening projects. On widening project the designer should investigate whether it would be feasible to replace the existing steel bearings with new elastomeric bearings.

The following table, which lists the contract bid item number, bearing description, and unit of measurement, is included for convenience:

Bid Item	Description	Measurement
6040003	Structural Steel (Miscellaneous)	Each

14.7.2 PTFE Sliding Surfaces

Sliding elastomeric bearings accommodate horizontal movements through polytetrafluoroethylene (PTFE) sliding surfaces and rotations through elastomer pads. The thickness of the elastomeric bearing is determined by the rotational and frictional force requirements.

Sliding elastomeric bearings consist of an upper steel bearing plate anchored to the superstructure, a stainless steel undersurface and an elastomeric pad with a teflon coated upper surface. The teflon surface shall be attached to a 3/8-inch minimum thick plate which is vulcanized to the elastomeric pad. Keeper plates may be used for horizontal restraint of the pads. Vertical restraint may be provided by anchor bolts with slotted keeper plates or individual vertical restrainers as appropriate.

Bearing pad dimensions and all details of the anchorage and restraint systems shall be shown in the plans. The required coefficient of friction must also be shown in the plans with the stipulation that the bearing be tested for the required value of the frictional force. This coefficient should be consistent with the values shown in AASHTO LRFD Table 14.7.2.5-1 for a given normal stress. Specifications special provisions are required and should allow for proprietary alternates.

Sliding elastomeric bearings should be considered for applications where regular elastomeric bearing pads would exceed 4 inches in height or where special access details would be required for other proprietary bearings in locations such as at hinges.

The following table, which lists the contract bid item number, bearing description, and unit of measurement, is included for convenience:

Bid Item	Description	Measurement
6015203	Bearings (Sliding Elastomeric)	Each

Neoprene Strips:

Neoprene strips consist of a sliding plate on a continuous neoprene pad conforming to the details shown in Figure 2.

Where appropriate, neoprene strips are the preferred bearing type for post-tensioned box girder bridges. However, neoprene strips are not appropriate for the following applications:

Curved bridges

Bridges with cross slopes greater than 0.02 ft/ft

Bridges skewed greater than 20 degrees

Bridges with spans greater than 125 feet

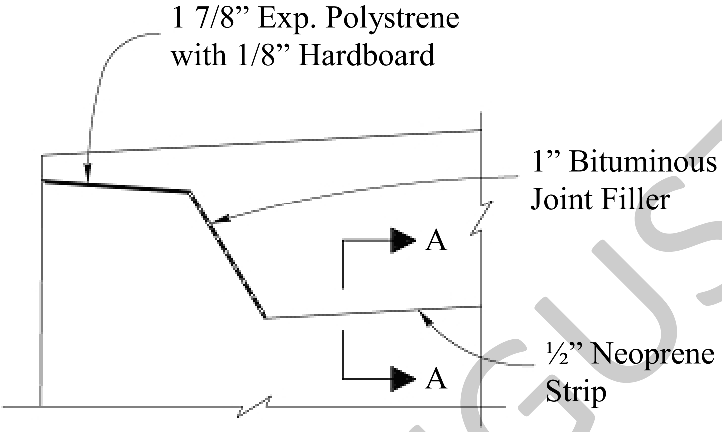
Bridges where initial shortening due to prestressing is greater than 1 inch

Bridges where the movement including elastic shortening, long term creep, and shrinkage and temperature is greater than 1.5 inches

When neoprene strip bearings are used on wide bearing seats the deflection of the box girder superstructure can chip the corners of the seat. To eliminate this, the corners of the bearing seat should be notched.

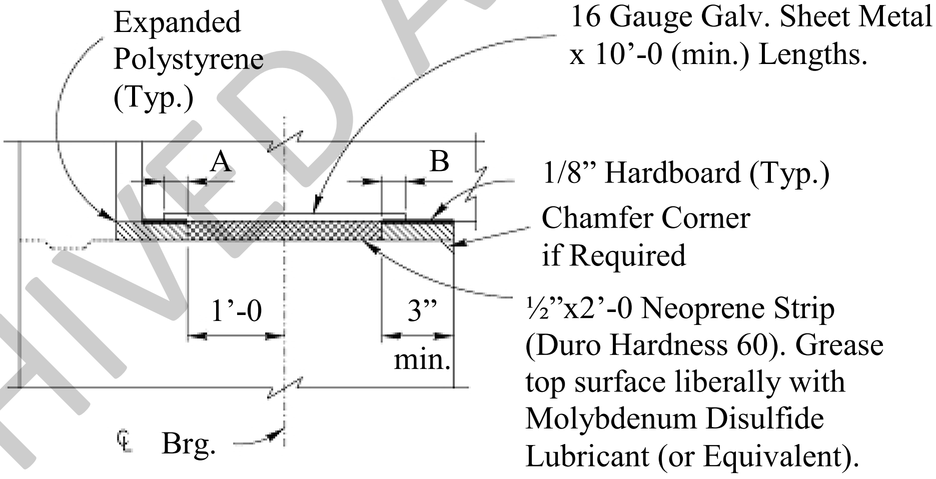
No additional bid item number is required for neoprene strips as the cost is included in the bid item for concrete or prestressed member as appropriate.

Figure 2 – Neoprene Strip Details



PARTIAL ELEVATION

No Scale



SECTION A-A

No Scale

A = Calculated Displacement+1 inch (min.)

B = 1.2 * (Bearing Temperature Movement) + ½ inch (min.)

14.7.5 Steel-Reinforced Elastomeric Bearings – Method B

14.7.5.1 General

Steel-reinforced elastomeric bearings may be designed using either of two methods, referred to as Method A and Method B.

Due to their higher load capacity and superior performance, steel reinforced elastomeric bearings constructed using steel laminates should be used in lieu of fiberglass reinforced pads.

Pads shall have a minimum thickness of one inch and be designed in 1/2-inch increments. The use of elastomeric bearing pads should generally be limited to a thickness not greater than 5 inches. If the design pad thickness is 4½ inches or greater, a sliding plate bearing system should be investigated.

Holes will not be allowed in the pads. Tapered pads are not allowed. When the rotation demand exceeds the pad capacity, tapered steel plates shall be used.

The width and length dimensions shall be detailed in increment of one inch. When used with prestressed I-girders, pads shall be sized a minimum width of 2 inches less than the nominal width of the girder base to accommodate the 3/4 inch side chamfer and shall be set back 2 inches from the end of the girder to avoid spalling of concrete from the girder ends.

???Elastomeric bearing pads should not be used at locations where deck joints or bearings limit vertical movements of the superstructure, such as, in older style sliding steel plate joints. Also, these bearings should not be used for bridge widening projects where existing steel bearings are to remain in place.

Elastomeric bearing pads are the preferred bearing type for new steel girders, precast prestressed girders and post-tensioned box girder bridges where neoprene strips are not appropriate.

Elastomeric bearing pads with greased sliding plates used on post-tensioned box girder bridges to limit the required thickness of the pad shall conform to the details shown in Figure 3. For this situation, the pad thickness should be determined based on temperature movements only. The sliding surface will accommodate the initial and long term shortening.

The cost of elastomeric bearing pads or elastomeric bearing pads with greased sliding plates is included in the bid item of the superstructure elements. As such these bearings are not bid as a separate item.

The following data shall be shown on the plans:

Length, width and thickness of pad

Design Method (A or B)

Design Load

Low Temperature Zone (A, B or C)

Elastomer Grade (0 or 2)

Shear Modulus

Durometer Hardness

The following note shall be added to the plans:

> Elastomeric bearing pads shall be steel laminated neoprene pads.

The number and type of laminates shall not be detailed on the plans but are covered in the ADOT Standard Specifications for Road and Bridge Construction.

Normally, Design Method A shall be used. However, for bridges with large reaction forces, Design Method B may be used provided more rigorous testing will be performed.

14.7.5.2 Material Properties

Only the following three combinations of shear modulus and durometer hardness should be specified:

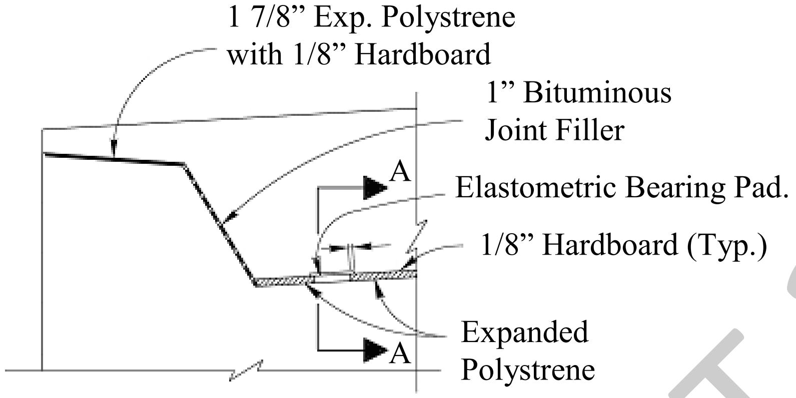
Shear Modulus (psi)	Durometer Hardness
110	50
130	55
160	60

The following should be used as a guide for determining low temperature zones and elastomer grade:

Elevation (ft)	Zone	Elastomer Grade
Below 3000	A	0
3000 - 6000	B	2
Above 6000	C	2*

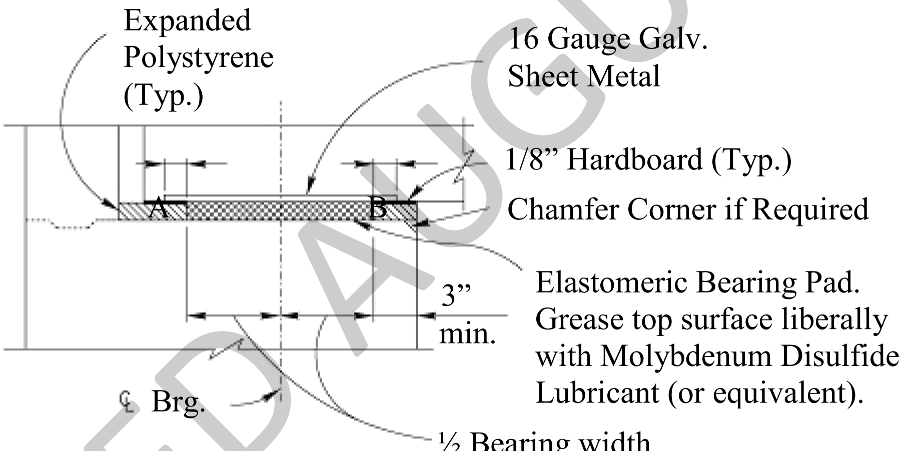
* To specify an Elastomer Grade 2 for application above an elevation of 6000 feet the design engineer should incorporate the special provisions described in AASHTO LRFD Article 14.7.5.2. This will eliminate the need for the stringent testing requirements of the higher elastomer grades that may result in construction delays.

Figure 3 – Elastomeric Bearing Pads with Greased Sliding Plates



PARTIAL ELEVATION

No Scale



SECTION A-A

No Scale

A = Calculated Displacement+1 inch (min.)

B = 1.2 * (Bearing Temperature Movement) + ½ inch (min.)

14.7.6 Elastomeric Pads and Steel-Reinforced Elastomeric Bearings - Method A

Normally, Design Method A shall be used. However, for bridges with large reaction forces, Design Method B may be used provided more rigorous testing will be performed.

14.7.6.3 Design Requirements

14.7.6.3.5 Rotation

The current AASHTO LRFD Design Specifications equation for stress due to rotation for steel reinforced elastomeric bearings is very restrictive and difficult to satisfy. In lieu of this, the AASHTO rotation criteria prior to 1997 should be used. The equation from the AASHTO Standard Specifications, fifteenth edition, is as follows:

$$\Theta_s < 2\delta_c/L$$

Where:

δ_c is the compressive deflection of the pad as based on the durometer hardness and the appropriate stress strain curve.

High-Load Multi-Rotational Bearings:

High-load multi-rotational fixed bearings consist of a rotational element of the Spherical-type, Pot-type, or Disc-type. High-load multi-rotational expansion bearings consist of a rotational element of the Spherical-type Pot-type, or Disc-type, sliding surfaces to accommodate translation and guide bars to limit movement in specified directions when required. These bearing types can be found in AASHTO LRFD Specifications, Articles14.7.3, 14.7.4, and 14.7.8 respectively.

Spherical bearings consist of a rotational element comprised of a spherical bottom convex plate and mating spherical top concave plate. Pot bearings consist of a rotational element comprised of an elastomeric disc totally confined within a steel cylinder. Disc bearings consist of rotational element comprised of a polyether urethane disc confined by upper and lower steel bearing plates and restricted from horizontal movement by limiting rings and a shear restriction mechanism.

Knowledge and performance of this bearing type is constantly being upgraded. As such, when its usage is required, the design engineer shall research the current AASHTO LRFD Specifications, the most up-to-date bearing research and ADOT design requirements to develop the most current state-of-the-art Special Provisions. The design and manufacture of multi-rotational bearings relies heavily on the principles of engineering mechanics and extensive practical experience in bearing design and manufacture. Therefore, in special cases where structural requirements fall outside normal limits, a bearing manufacturer should be consulted. Design engineers are responsible for determining the applicability of the AASHTO LRFD Specifications and advances in bearing technology to the above criteria on their specific project. Close coordination with ADOT Bridge Group shall be maintained. These high performance bearings shall be included in contract bid document and measured as each.

The following table, which lists the contract bid item number, bearing description, and unit of measurement, is included for convenience:

Bid Item	Description	Measurement
6015200	High-Load Multi-Rotational Bearings	Each

14.7.9 Guides and Restraints

14.7.9.1 General

Guides and restraining devices are used to contain movements in a specified direction. Restraining devices shall be designed to resist the imposed loads including seismic loads as specified in AASHTO LRFD Article 3.4.

Restraining devices could include concrete shear keys or end blocks, horizontal or vertical cable restrainers or mechanical restraining devices which could be an integral part of a bearing or a separate system. Restraining devices, containing vertical displacements at expansion ends, shall be designed to allow for inspection and future replacement of bearings.

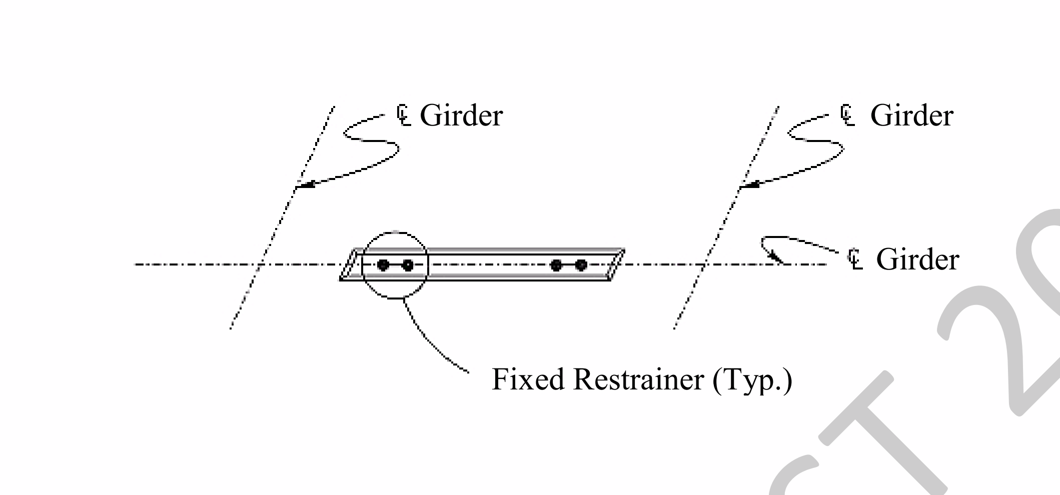
Allowable restraining devices include, but are not limited to the followings:

Vertical fixed restrainers,
Vertical expansion restrainers,
External shear keys,
Internal shear keys, and
Keyed hinges.

Vertical Fixed Restrainers:

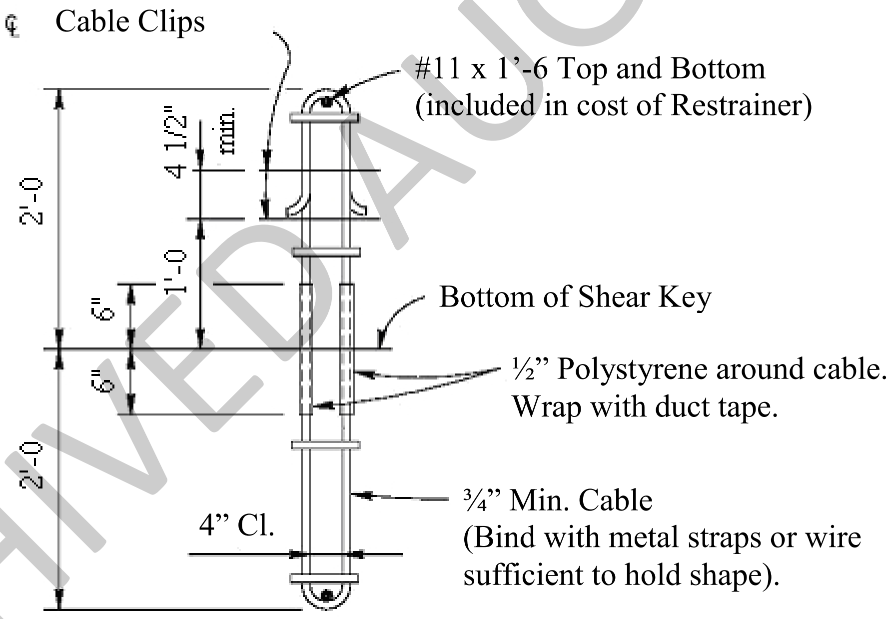
Vertical fixed restrainers consist of cable and appropriate hardware as shown in Figure 5. These restrainers are designed to allow rotation but no translation in either horizontal or vertical directions. Vertical fixed restrainers should be designed for a minimum vertical uplift force of 10% of the dead load reaction. Each cable may be assumed to have an allowable working load of 21 kips. Fixed restrainers are typically orientated with cables placed along the centerline of bearing as shown in Figure 4.

Figure 4 – Orientation Plan – Fixed Restrainer



Refer to Figure 5 for the fixed restrainer detail. This vertical fixed restrainer detail can be found in the Bridge Cell Library under the cell name VR2 (Fix Restr. Det).

Figure 5 – Fixed Restrainer Detail



NOTES:

Restrainer Cables shall be ¾" preformed 6 x 19 galvanized with the minimum breaking strength of 42 Kips. One sample of cable 3 feet in length shall be furnished to the Engineer for testing.

The following table, which lists the contract bid item number, restrainer description, and unit of measurement, is included for convenience:

Bid Item	Description	Measurement
6015101	Restrainers, Vertical Earthquake (Fixed)	Each

Vertical Expansion Restrainers:

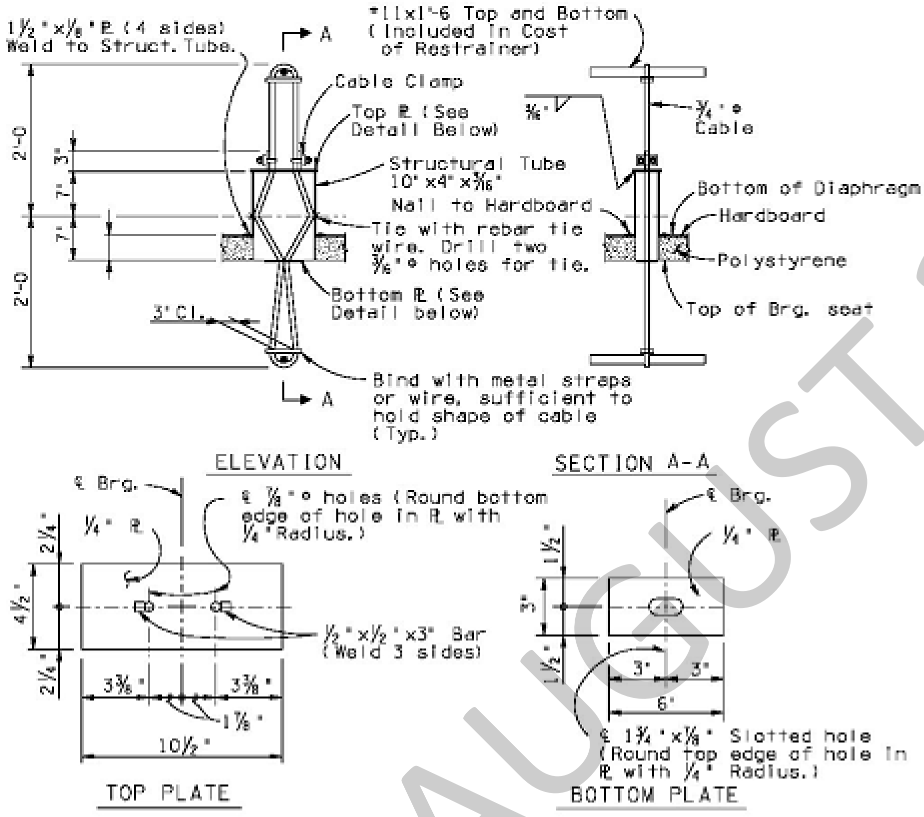
Vertical expansion restrainers consist of cable and appropriate hardware as shown in Figure 6. These restrainers are designed to allow rotation and longitudinal translation. These restrainers do not prohibit transverse movement. Shear keys are required to arrest transverse movement. Some limited vertical displacement is allowed to permit replacement of bearings if required. These devices are designed for a maximum movement of 4 inches. Vertical expansion restrainers should be designed for a minimum vertical uplift force of 10% of the dead load support reaction. Each cable may be assumed to have an allowable working load of 21 kips.

Refer to Figure 6 for expansion restrainer detail. This vertical expansion restrainer detail can be found in the Bridge Cell Library under the cell name VR1 (Exp Restr. Det).

The following table, which lists the contract bid item number, restrainer description, and unit of measurement, is included for convenience:

Bid Item	Description	Measurement
6015102	Restrainers, Vertical Earthquake (Expansion)	Each

Figure 6 – Expansion Restrainer Detail



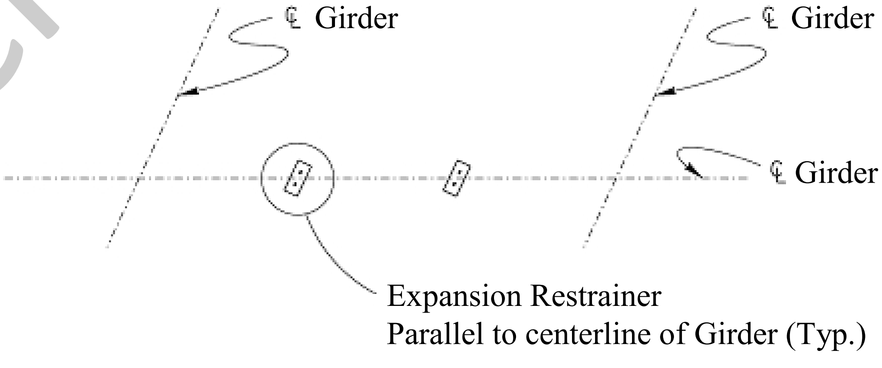
NOTES:

Seal all openings in structural tube to prohibit concrete intrusion.

Restrainer Cables shall be ¾"⌀ preformed 6x19 galvanized with the minimum breaking strength of 42 kips. One sample of cable 3 feet in length shall be furnished to the Engineer for testing.

Expansion restrainers are placed along the center of bearing with the long side of the cable box placed parallel to the girders see Figure 7.

Figure 7 – Orientation Plan - Expansion Restrainer



External Shear Keys:

External shear keys are reinforced concrete blocks designed to limit transverse displacement while allowing longitudinal and rotational movements. External shear keys are preferred to internal shear keys because of ease of construction. Also, external shear keys are more accessible for inspection and maintenance.

Internal Shear Keys:

Internal shear keys are reinforced concrete blocks designed to limit transverse displacement while allowing longitudinal and rotational movements.

Keyed Hinges:

A keyed hinge is a restraining device, which limits displacements in both horizontal directions while allowing rotation. Vertical fixed restrainers should be considered as reinforcing steel for shear friction design on the concrete shear key with an allowable working load of 21 kips per cable.

Restrainer Applications:

For a typical expansion seat abutment where restraining devices are required, the restraining devices will consist of vertical expansion restrainers and external shear keys.

For a typical pinned seat abutment for a post-tensioned box girder bridge, restraining devices will consist of vertical fixed restrainers and external shear keys. For a typical pinned seat abutment for a prestressed girder bridge, restraining devices will consist of vertical fixed restrainers and external or internal shear keys.

For a typical expansion pier, restraining devices will consist of vertical expansion restrainers and internal shear keys.

For a typical pinned pier, restraining devices will consist of vertical fixed restrainers and internal shear keys or a keyed hinge.