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Bridge Design Guide, Chapter 1 : General, 2003

Maine Department of Transportation

BRIDGE DESIGN GUIDE

Cover photos (clockwise from top): Mill Bridge, Alton-Old Town; Presumpscot Falls Bridge, Falmouth; Lows Covered Bridge, Guilford-Sangerville; and Middle Branch Bridge, T05 R09 (Ebeemee)

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AUGUST 2003
Maine Department of Transportation

Chapter 1

GENERAL

Deer Isle-Sedgwick Bridge, Deer Isle-Sedgwick

Bailey Island Bridge, Harpswell

1 GENERAL

1.1 Introduction

This document is intended to provide guidance to those performing design for the Bridge Program of the Maine Department of Transportation (MaineDOT). It should provide clarity to the design thought process, and serves as a supplement to the applicable AASHTO standards. It should be used in conjunction with good engineering judgment.

This document is a companion volume to the MaineDOT "Project Management Guide" and the "Plan Development and Estimating Guide."

The Mission and Goals of the Bridge Program are on the following page.

Mission

The Bridge Program delivers safe, cost effective, quality bridge projects to our customers on schedule.

Goals and Objectives

1. Reduce backlog of deficient bridges

- Comprehensive planning effort to prioritize bridge needs
- Resources to deliver the Bridge Program

2. Ensure project timeliness

- Complete construction on schedule
- Meet project schedule needs

3. Assure project quality and cost effectiveness

- Provide quality projects that meet the purpose and need at optimum cost
- Improve staff effectiveness through continuous employee development

4. Foster public satisfaction

- Share information, seek public input, and build public trust

1.2 General Team Approach Guidelines

The Bridge Program is regionally organized into Self-Directed Work Teams (SDWTs), each led by a Project Manager. In addition to the Project Managers, each team is composed of Structural Designers, Design Technicians, a Geotechnical Designer, Construction Residents, Construction Inspectors, a Utility Coordinator, a Mapper, an Appraiser, and a Team Coordinator. The environmental coordination function is managed by the Environmental Coordinator from MaineDOT's Environmental Office, while survey functions are managed by the Survey Coordinator within the Program.

Each team member has a specific role that is integral to the success of the project as it moves through the project development process. The Structural Designer and the Geotechnical Designer provide the design expertise, and use the resources of the team to provide input into the decision-making that is part of every design.

1.3 Final Design Issues

1.3.1 Plans, Specification and Estimate (PS&E)

This documentation includes a package of information that is used to prepare the bid documents for advertising a project. The package is prepared by the project team and further assembled by the Contracts Technician within the Program. It includes the following items, with the responsibility of the Designers noted:

1.3.1.1 Plans

The plans consist of complete contract drawings that adequately display the design with enough detail to construct the project. The plans are the responsibility of the Design Technician, but must be reviewed by the Designers for conformance to the design. During the development of the plans, communication is essential to avoid rework. Standard notes are found in Appendix D. Plan layouts and detailing practices can be found in the "Plan Development and Estimating Guide."

1.3.1.2 Structural Design Computations

Detailed design computations from the selected alternate are bound, dated, and submitted by the Structural Designer as part of the PS&E package. Design computations should include all references and assumptions used during design. After submission, they are retained in the Computations file cabinet of the Bridge Program.

1.3.1.3 Geotechnical Design Computations

Geotechnical design computations are included as an appendix of the Geotechnical Design Report. Design computations include all references and assumptions used during design. After completion of the project, the geotechnical file is retained in the Materials, Testing, and Exploration archives in Bangor.

1.3.1.4 Bridge Ratings

Each bridge must be rated by the Structural Designer with a live load rating. Currently, bridges are being rated by the LFD method. Refer to the Manual for Condition Evaluation of Bridges 1994, with interims thru 2001, for guidance in the live load rating calculation.

1.3.1.5 Special Provisions

In most cases, Supplemental Specifications, commonly used Special Provisions, and/or project specific Special Provisions will be necessary to complement the Standard Specifications. Current Supplemental Specifications and commonly used Special Provisions are available for review. The Designers review and format these specifications for necessary inclusion in the contract documents. If project specific specifications are warranted, the Designers write and format them for the PS&E Package. The Project Manager may be involved in writing some project specific specifications that are not design related.

1.3.1.6 Engineer's Estimate

This confidential document consists of a detailed estimate of quantities and costs necessary to construct the project. Typically, the Design Technician, with input from the Designers and Project Manager, develops the pay item list and computes the estimated quantities. The Design Technician then inputs the quantities into ESTIMATOR, which will provide automatic weighted average costs for each of the pay items. The Designers are responsible for reviewing those costs and adjusting them where needed, using engineering judgment. For a complete guide to developing an estimate or check, refer to the Bridge Program's "Plan Development and Estimating Guide."

Bridge Information Form

Project

PIN ____________________
Location ____________________
Bridge Number ____________________
Project Manager ____________________
Lead Designer ____________________
Lead Technician ____________________
Resident ____________________

Design Code

- ☐ LFD
- ☐ LRFD

Work Attribute

- ☐ Consultant LARGE
- ☐ Consultant MEDIUM
- ☐ Consultant SMALL
- ☐ Over Water Replacement X-LARGE
- ☐ Over Water Replacement LARGE
- ☐ Over Water Replacement MEDIUM
- ☐ Over Water Replacement SMALL
- ☐ Over Water Replacement X-SMALL
- ☐ Overpass Replacement LARGE
- ☐ Overpass Replacement MEDIUM
- ☐ Rehab X-LARGE
- ☐ Rehab LARGE
- ☐ Rehab MEDIUM
- ☐ Rehab SMALL
- ☐ Paint SIMPLE
- ☐ Paint COMPLEX
- ☐ Other (explain)____________________

Bridge Parameters

Number of Spans ____________________
Span Configurations ____________________ ft
Bridge Length (CL Brg Abut to CL Brg Abut) ____________________ ft
Skew ____________________ o
Bridge Width (Fascia to Fascia) ____________________ ft
Roadway Width (Curb to Curb) ____________________ ft
Buried Structure Barrel Length ____________________ ft
Beam Spacing ____________________ ft
Slab Thickness ____________________ in
Approach Length (excluding bridge) ____________________ ft

Scope

- ☐ BIKEWAY
- ☐ BRIDGE CONSTRUCTION-NEW
- ☐ BRIDGE CULVERT REHABILITATION
- ☐ BRIDGE CULVERT REPLACEMENT
- ☐ BRIDGE DECK REHABILITATION
- ☐ BRIDGE DECK REPLACEMENT
- ☐ BRIDGE IMPROVEMENT
- ☐ BRIDGE PAINTING
- ☐ BRIDGE RAIL & CURB IMPROVEMENT
- ☐ BRIDGE REHABILITATION
- ☐ BRIDGE REMOVAL
- ☐ BRIDGE REPLACEMENT
- ☐ BRIDGE SUBSTRUCTURE REHABILITATION
- ☐ BRIDGE SUPERSTRUCTURE REPLACEMENT
- ☐ BRIDGE WEARING SURFACE REPLACEMENT
- ☐ BRIDGE WIDENING
- ☐ TEMPORARY BRIDGE
- ☐ Other (explain)____________________

Bridge Information Form

Estimated Quantities

Volume of Abutment Concrete________________ yd^3
Volume of Pier Concrete________________ yd^3
Volume of Rigid Frame Concrete________________ yd^3
Volume of Structural Slab Concrete________________ yd^3
Total Length of Concrete Beams/Girders________________ ft
Weight of Structural Steel________________ lb
Weight of Bituminous on Bridge________________ lb
Weight of Substructure Rebar________________ lb
Weight of Superstructure Rebar________________ lb

Abutment Type

- ☐ Stub Cantilever
- ☐ Medium Cantilever (5'<Breastwall<15')
- ☐ High Cantilever (Breastwall>15')
- ☐ Mass
- ☐ Integral
- ☐ Other (explain)____________________________

Abutment Foundation Type

- ☐ H-Pile
- ☐ Pipe Pile
- ☐ Spread Footing
- ☐ Spread Footing on Bedrock
- ☐ Drilled Shaft
- ☐ MSE Wall
- ☐ Other (explain)____________________________

Pier Type

- ☐ Mass
- ☐ Pile Bent
- ☐ Hammerhead
- ☐ Shaft
- ☐ Other (explain)____________________________

Pier Foundation Type

- ☐ H-Pile
- ☐ Pipe Pile
- ☐ Spread Footing
- ☐ Spread Footing on Bedrock
- ☐ Drilled Shaft
- ☐ Seal
- ☐ Rock Anchor
- ☐ Other (explain)____________________________

Buried Structure Type

- ☐ CIP Rigid Frame
- ☐ Precast Concrete Frame
- ☐ Precast Concrete Box
- ☐ Steel Structural Plate Pipe or Pipe Arch
- ☐ Steel Structural Plate Arch on Concrete Footings
- ☐ Aluminum Structural Plate Pipe, Pipe Arch, or Frame
- ☐ Aluminum Structural Plate Arch or Frame on Conc. Footings
- ☐ Other (explain)____________________________

Comments:

1.3.1.7 Bridge Information Form

The form preceding this section is completed by the Structural Designer as part of the PS&E package. It is available electronically as an Excel spreadsheet, and is used to establish a reliable database for tracking project features and preliminary estimate costs, and for adjusting costs in Engineer's Estimates.

1.3.1.8 Budgetary Information

In addition to the Engineer's Estimate, there are several documents that must be completed to ensure that the updated costs of the project are distributed throughout the MaineDOT. The Project Manager completes other budgetary forms, including the Project Cost Summary Form, Construction Authorization Form, and the portion of the PS&E form that pertains to costs. These forms can be found in the Project Management Guide.

1.3.2 Maintenance of Traffic

A Traffic Control Plan must be developed for every project. Responsibility for this plan is with either the Contractor, or MaineDOT, as determined at the PS&E stage. The complexity of the project may steer the Structural Designer toward keeping this responsibility within MaineDOT, to assure compliance with the conceptual design. Any traffic control plan must comply with the latest edition of the Manual of Uniform Traffic Control Devices (MUTCD).

1.3.3 Survey Layout

A DAB (describe alignment bearing) Report or similar geometric output file should be submitted by the Designer as part of the PS&E package. This file is used in conjunction with the horizontal alignment files to generate all necessary field layout information. For a more comprehensive description of required information, please refer to the "Bridge Plan Development and Estimating Guide."

Currently, MaineDOT provides Contractors with horizontal and vertical project control and quality assurance only. The Contractor is responsible for all remaining construction survey activities.

1.4 Design Check Guidelines

As a general rule, the design check of a structure or foundation will be assigned to a Structural Designer or a Geotechnical Designer, respectively (Design Checker). The check and/or review of the construction plans and the Engineer's

Estimate will be assigned to a Design Technician (Detail Checker or Reviewer). Design checks should be completed before any structural detailing is done whenever possible. Additional Structural/Geotechnical Designers and Design Technicians may be assigned to assist in the checking and review process for more complex projects or to facilitate project schedules. Occasionally, at the Team's discretion, the Design Checker and Detail Checker or Reviewer may be the same person.

There are six general areas where checking and/or review of a project should occur and these are:

- Preliminary Design Reports
- Geotechnical Design Reports (including Series 100 Reports)
- Hydrology/Hydraulics/Scour
- Final Structural and Approach Design of In-House Projects
- Final Structural and Approach Design of Consultant Projects
- Shop Drawings

The Structural or Geotechnical Designer (Designer) is responsible for a cost effective and efficient design in accordance with this "Bridge Design Guide" and the Preliminary Design Report (PDR). The Design Checker is responsible for assuring that this goal was met. The Designer is then responsible for communicating the design parameters and configuration to the Design Technician. The function of the Design Checker is not to re-design a project, but to perform the expected level of check or review as follows:

- *Independent Design Check:* Perform an independent structural or geotechnical analysis of designed components to assure that the design criteria are met. This level of design check is appropriate for structural and geotechnical components of new and rehabilitated structures, and horizontal and vertical geometry of approaches.
- *Design Review*: Use engineering judgment to evaluate the design of structural and geotechnical components without performing a structural analysis. This level of design review is appropriate for geotechnical reports (including Series 100 Reports), hydrology and hydraulics, consultant PDRs, consultant final designs, and structural notes.

PDRs are subject to the team process in which Coachpoint meetings and consultations with Team Members, municipalities, state and federal agencies, peers, and Functional Managers provide feedback and direction for the project. A completed PDR is reviewed and approved by the Engineer of Design for its design recommendations, and by the Assistant Program Manager for its budget, prior to the general distribution of the PDR for comments. The hydrology, hydraulics, and scour for a project should undergo a design review.

When a design is being performed by a new or inexperienced Structural Designer, the Design Checker should be an experienced Structural Designer. Inexperienced Structural Designers may be assigned as the Design Checker for designs done by experienced Structural Designers. All Geotechnical Reports should be checked and reviewed by experienced Geotechnical Designers only.

The Design Technician is responsible for developing good quality construction plans that will accurately communicate the Designer’s vision to the Construction team members and to the Contractor. The Detail Checker or Reviewer is responsible for assuring that this goal was met. The function of the Detail Checker or Reviewer is not to re-detail a project, but to perform the expected level of check or review as follows:

- *Significant Detail Check:* Verify significant details of major components and review completeness of plans (are there adequate sections, plan views, elevations, etc.). This level of detail check is appropriate for such items as approach plans, structural details of new and rehabilitated structures, foundation details, boring sheets, and estimated quantities.

- *Detail Review:* Use engineering judgment to evaluate the details without performing verification calculations, and review completeness of plans. This level of detail review is appropriate for such items as wearing surface projects, structural plate projects, reinforcement schedules, pay item lists, general notes, and consultant final plans.

The quality of a project begins with the Structural Designer, Geotechnical Designer, and the Design Technician. It is their responsibility to produce the preferred level of accuracy and completeness. They should not rely on the Project Checkers and/or Reviewers to fill in the missing pieces.

The Checkers and/or Reviewers should be aware of any commitments to town officials or other agencies to assure that they have been incorporated into the design of the project. The Design Checker should note all the changes that he/she feels are necessary for the Designer’s consideration. The Design Checker may also point out where the Designer could have used better judgment in design concepts, structural features, or structural economy. At times, a poor practice employed by the Designer may be allowed to stand in order to expedite the project. However, such poor practices, even if they are not of great consequence, should be pointed out to the Designer for his/her own benefit in order to prevent future repetition of that poor practice.

The Detail Checker should note all the changes that he/she feels are necessary for the Design Technician's consideration, if such changes may result in a significant cost reduction impact or if there is a risk of construction error. The Detail Checker should recommend a plan layout change only if there is a risk of construction error. If construction plans are poorly organized and difficult to decipher, then the Detail Checker should bring this to the Design Technician's attention for future reference. After the check/review process is completed, the Designer should inform the Detail Checkers of any additional changes made to the construction plans as a result of comments received from other programs, agencies, or the Engineer of Design.

When plans have been developed by new or inexperienced personnel, the Detail Checker or Reviewer should be an experienced Design Technician, Structural Designer, or Resident. The level and extent of detail check should be increased accordingly, due to the increased potential for omissions and errors. Inexperienced Design Technicians may be assigned as Detail Checker or Reviewer on plans developed by experienced Design Technicians.

If a dispute occurs, the disputants (whether they are the Design Checker and the Designer, or the Detail Checker and the Design Technician) should attempt to resolve the dispute themselves, consulting with their peers as the need arises. If an agreement cannot be reached even after consultation with their peers, then the case should be presented to an arbiter appointed by the Engineer of Design.

This same procedure applies if there is a disagreement between the Designer and the Design Technician. Past practice has been that the Designer has final say on the project's plans. Designers and Design Technicians should respect each other's professional skills and knowledge in their areas of expertise.

A 2% to 5%+ margin of error is acceptable for design overstress for either the superstructure or substructure design. A 10% to 15%+ margin of error is acceptable for design understress before a design reduction is recommended. These percentages depend greatly on the cost impacts and on the uncertainty of the design assumptions. For example, if the Structural Designer proposes to use #6 bars at 6" and the Design Checker finds that this is 20% overdesigned and that #5's and #6's alternating at 6" will probably work, the overdesign may be preferred for its simplicity in rebar detailing, ordering, and placement.

Margins of error for dimensions of significant details vary depending upon the structure component and type. For structural steel, the margin of error may be from 1/8" to 1/2". For camber dimensions, the margin may be from 1/8" to1/4". Blocking dimensions should be within 0.02 feet. A 1/4" to 1/2" margin of error is acceptable for cast-in-place concrete and a 1/8" to 1/4" margin of error is acceptable for precast, prestressed concrete. For cast-in-place concrete substructures, the nearest 1/2" is acceptable.

1.5 Small Bridge Initiative

A reduced project delivery process should be considered for any bridge project with a structure of 50 foot span or less.

These small bridge projects may not need a full hydrologic analysis, complete topographical field survey, right-of-way takings, utility adjustments, public meetings, subsurface investigations, or other activities typically used for larger projects. If a reduced process is considered, the project team should conduct a site review to determine the degree of effort and the scope of work. Discussions should also take place with abutting property owners and municipal officials.

1.5.1 Field Survey Considerations

Project characteristics that favor limited or no survey include:

- o Rural setting with few manmade features near the bridge
- o No permanent right-of-way acquisitions
- o In-kind structure replacement with very limited approach work
- o Acceptable existing roadway geometry
- o No sensitive environmental resources needing to be mapped
- o Lack of critical cross sectional issues

1.5.2 Right-of-Way Considerations

If practical, project limits and scope can be adjusted to require only work permits or construction easements.

1.5.3 Geotechnical Considerations

The Geotechnical Designer should assess the need for a geotechnical subsurface investigation. The Geotechnical Designer should collect previous subsurface data, field observations, performance data of the existing substructure, and typical soil characteristic tables to make a site-specific decision. In the event that enough information regarding the subsurface conditions exists, the Geotechnical Designer may choose to eliminate the subsurface investigation.

Even when the subsurface investigation is eliminated, design considerations (i.e., bearing capacity, settlement, frost protection, etc.) should be assessed by the Geotechnical Designer and made a part of the permanent record. When the subsurface investigation is eliminated from a project, it should be understood that this will result in the need for a more conservative design and the use of higher factors of safety. The use of higher factors of safety may, in the end, be more economical than performing an in-depth subsurface investigation.

1.5.4 Hydrologic Considerations

Project characteristics that favor limited or no formal analysis of hydrology and hydraulics are found in Section 2.3.3 Level of Analysis.

1.5.5 Minimization of Approach Work

Limits of approach work, approach roadway width, guardrail upgrades, and surface treatments should be consistent with the adjacent roadway. Relaxation of design standards should be considered to achieve this consistency. The project length should be kept to an absolute minimum.

In considering relaxing these standards, the Designer should check with the Regional Transportation Advisory Committee (RTAC) representative in the Bureau of Planning to be certain that the corridor is not likely to be upgraded in the near future.

1.5.6 Reduction of Structural Design Effort

Structure type should be determined from Table 1-1 whenever feasible, instead of performing cost comparisons of various alternates in the Preliminary Design Report. Structures that do not meet the criteria would need to be custom designed.

A substructure should be designed to minimize stream impacts whenever possible, in view of typical short in-stream work windows. Consider using longer spans by placing the abutment behind an aging abutment that can adequately support the embankment, or choosing a replacement structure that does not require in-stream work. Minimize necessary work in the stream by founding the abutment above frost, if minor movement can be tolerable, or by choosing low impact structure types, such as pile bents or drilled shafts.

Table 1-1 Type/Material Selection Guide for Small Bridge Projects

Structure Type

Span Range	Bedrock at Site	Structure Type Determination	
10 to 21 ft	Bedrock	Plate Arch or Frame	Go to Materials Determination
	No Bedrock or Easily Removed	Pipe, Pipe Arch, or Box	Go to Materials Determination
22 to 26 ft	Bedrock	Frame	Go to Materials Determination
	No Bedrock or Easily Removed	Box	Go to Materials Determination
26 to 50 ft	NA	Concrete Arch, Concrete Frame, or Concrete Voided Slab	

Structure Material

Water or Soil Reactivity			Maintenance of Traffic During Construction	Material Determination
Salt or Brackish Water?	Soil or Water pH	If Existing Pipe is Steel, Age?		
Yes	5 to 9	NA	Close Road	Aluminum
Yes	5 to 9	NA	Staged	Concrete
Yes	<5 or >9	NA	NA	Concrete
No	6 to 8	< 40 years	Close Road	Aluminum
No	6 to 8	< 40 years	Staged	Concrete
No	6 to 8	> 40 years	Close Road	Galvanized Steel
No	6 to 8	> 40 years	Staged	Concrete
No	5 to 9	NA	Close Road	Aluminum
No	5 to 9	NA	Staged	Concrete
No	<5 or >9	NA	NA	Concrete

1.5.7 Contracting Strategies

The following strategies should be considered to reduce construction costs:

- Grouping small projects for advertising can reduce costs. The projects should be located geographically near each other for efficiency of both MaineDOT personnel and the Contractor, and should be of similar scope. Projects from another Program sharing the same highway corridor or in the same general vicinity should also be constructed under one contract when feasible.

- Simplify project details to allow for faster construction, especially for projects with short project schedules. Examples include the use of integral abutments, elimination of bridge skews, use of prefabricated superstructure elements, using uniform details, etc.

- Time the bidding to allow enough time for the Contractor to plan their work. The advertisement of grouped projects should be far enough in advance of the construction season to allow as many Contractors to bid as possible.

- Consider a reduced plan or no plan project. The project should have a well-defined scope, such as replacing an existing pipe with another pipe or pipe arch. There would be no survey obtained, and the plans would include: a typical pipe or pipe arch sheet, a typical roadway cross-section, and typical guardrail end treatments. These plans would be on standard letter size sheets that are inserted into the contract proposal book. For these projects, sufficient right-of-way must be available or easily attainable to construct the project, and minimal environmental impacts must be anticipated.

1.6 Non-Vehicular Bridges

A multi-use bridge may be constructed for a combination of pedestrians, bicyclists, snowmobiles, or other users. For loading criteria, refer to Section 3.8 Non-Vehicular Bridges. Prefabricated pedestrian bridges must be designed by a registered Professional Engineer.

The owner and maintainer of the bridge should consider the following issues when developing the design:

- Width - For guidance on how wide a trail bridge should be, refer to AASHTO "Guide for the Development of Bicycle Facilities." A width less than 10 feet will prevent most vehicles from getting on to the bridge except for snowmobiles, ATV's, golf carts, and motorcycles. If the bridge will be plowed, additional width may be necessary.

- Vertical clearance - Vertical clearance is an issue with timber covered bridges or box type steel trusses. The minimum vertical clearance is 8 feet. Low vertical clearance will prevent heavier vehicles from using a bridge. A high vertical clearance of 14'-6" or more may be needed to accommodate snow grooming equipment, occasional maintenance equipment, or emergency vehicles.

- Emergency Vehicles – If emergency vehicles (ambulances, fire trucks, etc.) are expected, they should be accommodated. The bridge may be the only access to a remote area.

- o Inspection/Maintenance - How will the bridge be inspected and repaired? Refer to Section 2.9.6 Maintainability.

- o Bollards – Bollards may be used to control or limit access. Bollards are usually timber or steel posts spaced at about 5 foot spacing that prevent large vehicles from going onto a bridge. The spacing of the bollards can be reduced to 3 feet clear to prevent virtually all motorized vehicles from using the bridge. Removable bollards should be considered if emergency vehicles will occasionally use the bridge.

- o Rail - Bridges that may be used by snowmobiles should use at least a 54” bicycle height bridge rail. The use of a rub rail is highly recommended to prevent bicycle handlebars from catching on the bridge rail. The center of the rub rail should be 3’-6” above the riding surface.

The Structural Designer should also consider the use of security fencing, lighting, and attached utilities on the bridge. The load capacity of the bridge should be clearly posted on or near the bridge in accordance with MUTCD.

1.7 Aesthetics

1.7.1 General

Aesthetics involves more than just surface features such as color and texture. It includes the visual and perceptual effect made by the bridge as a total structure, as well as the effect made by its individual parts. Bridges affect their surroundings by virtue of their size, shape, line, color, and texture. All structures should be designed with consideration of site-specific features to create designs that provide function as well as a pleasing appearance. The key is to create a distinguished structure without spending excessive resources.

Bridges are usually viewed from one of two places, either from the roadway as a user, or from the side. For those bridges rarely seen from the side, aesthetic considerations are limited to the appearance of the rail, sidewalk, curb, and wearing surface. For other bridges, the view of the bridge from the side should be considered in the design. The nature of the surroundings may influence the aesthetic design choices, whether the location is urban, rural, industrial, or coastal.

1.7.2 Design Considerations

Consistency in the use of flares and tapers in bridge components will result in a more harmonic structure. For example, if a column is flared to be wider at the top, the fascia should also be sloped. A prismatic column may look better with a vertical fascia. Refer to Figure 1-1.

1.7.2.1 Superstructure

A bridge is primarily a horizontal structure that is supported by vertical members. Fewer piers will enhance the appearance by emphasizing the horizontal line. End spans that are shorter than middle spans often have structural as well as aesthetic advantages. A constant depth superstructure will appear more graceful than one with spans of different depths. Even more graceful is a haunched girder structure, especially if the haunch transition is long, up to 40% of the span length.

The end of the slab seen on the fascia will look better if it appears thinner. This can happen by creating deeper shadows through sloping the bottom of the fascia away from the viewer, or tapering the slab thickness toward the fascia, and by using an overhang of about 2/3 the depth of the girder. Refer to Figure 1-2 and Figure 1-3.

The rail may be the most visible aspect of the bridge to the traveling public. Spending money enhancing the rail system can go far to improve the appearance of the structure. Refer to Section 4.4.6 Aesthetics.

Ornamental lighting can enhance the aesthetics of a high profile bridge. Tall light poles can be located over piers to streamline the appearance.

1.7.2.2 Substructure

Most piers are classified as short, with the length (transverse) greater than the visible height. It is more difficult to enhance the appearance of a short pier than a tall pier. The vertical nature of a tall pier can be emphasized by minimizing the batter, and by minimizing the horizontal faces of the pier by using sloped faces. When a bridge has several piers with different heights, the pier shape should be one that can accommodate varying proportions and batters to create both short and tall piers that look good. Batters can be greater on a short pier without sacrificing appearance.

Hammerhead piers should be proportioned to balance the shaft length and height, as well as the length and depth of the cantilevered cap. Some starting proportions are shown in Figure 1-4. The Structural Designer should do a scale drawing of each pier to be sure the proportions look pleasing. A short cantilever looks better when the shaft batter is negative toward the ground, while a longer cantilever is needed when the batter is positive. Refer to Figure 1-5.

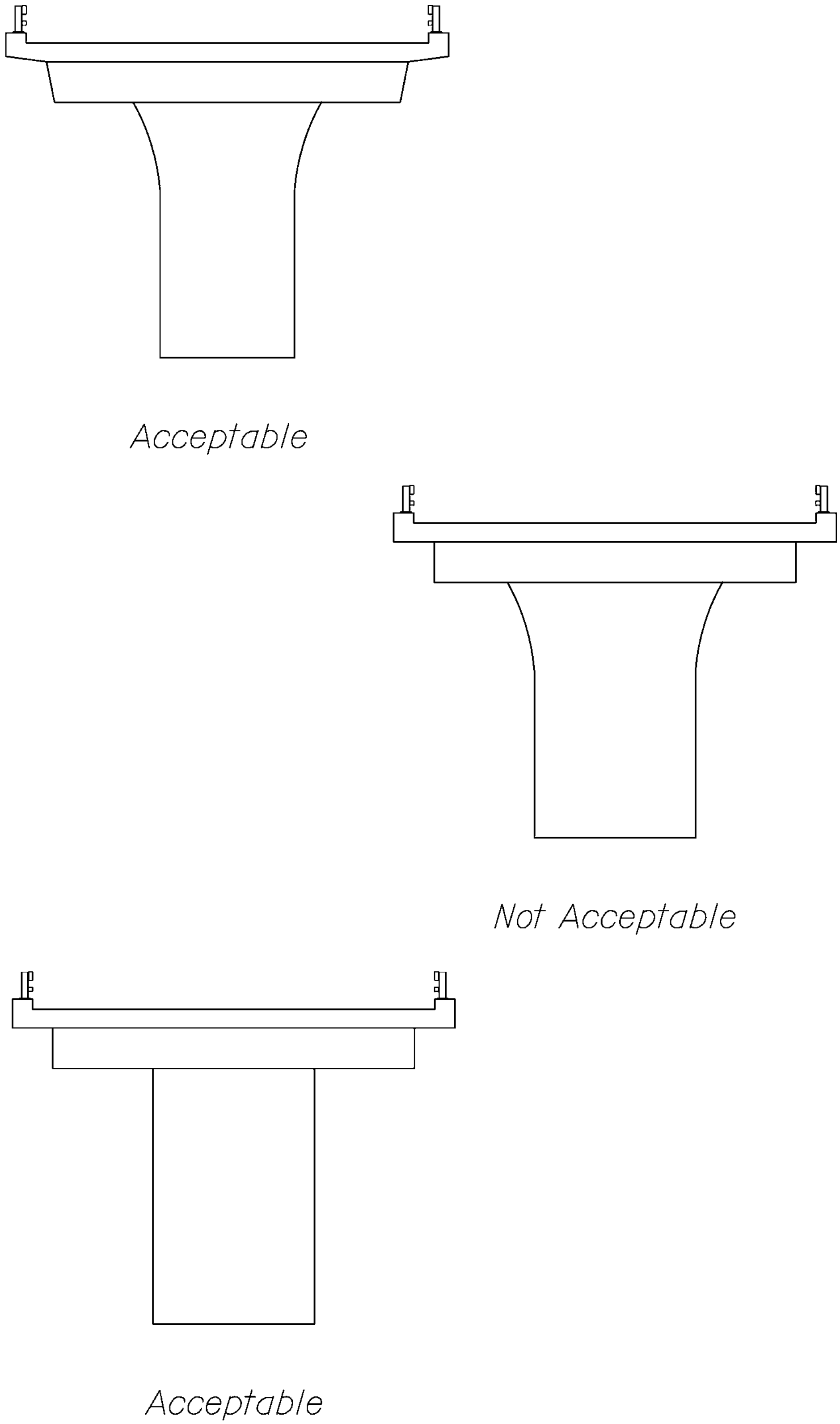
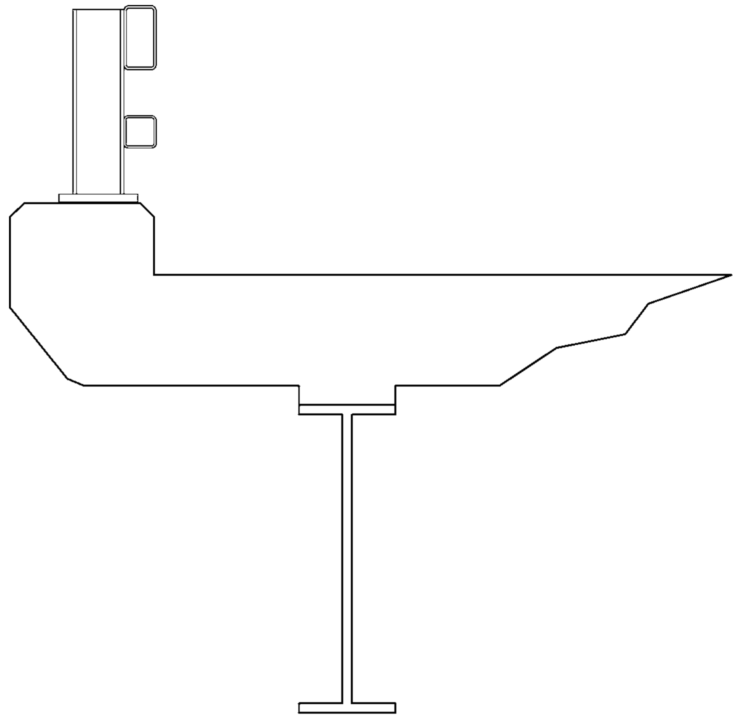


Figure 1-1 Consistent Use of Flares



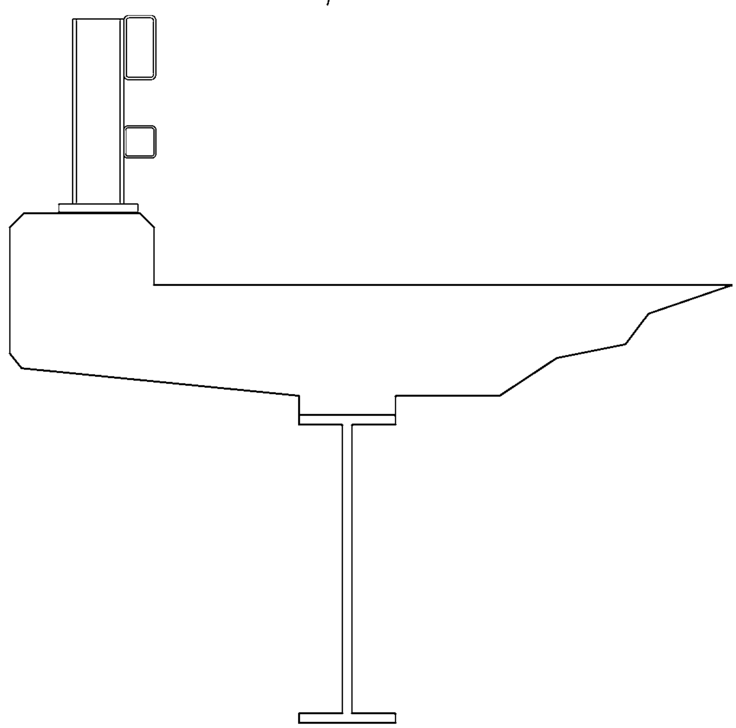


Figure 1-2 Methods to Thin Appearance of Fascia

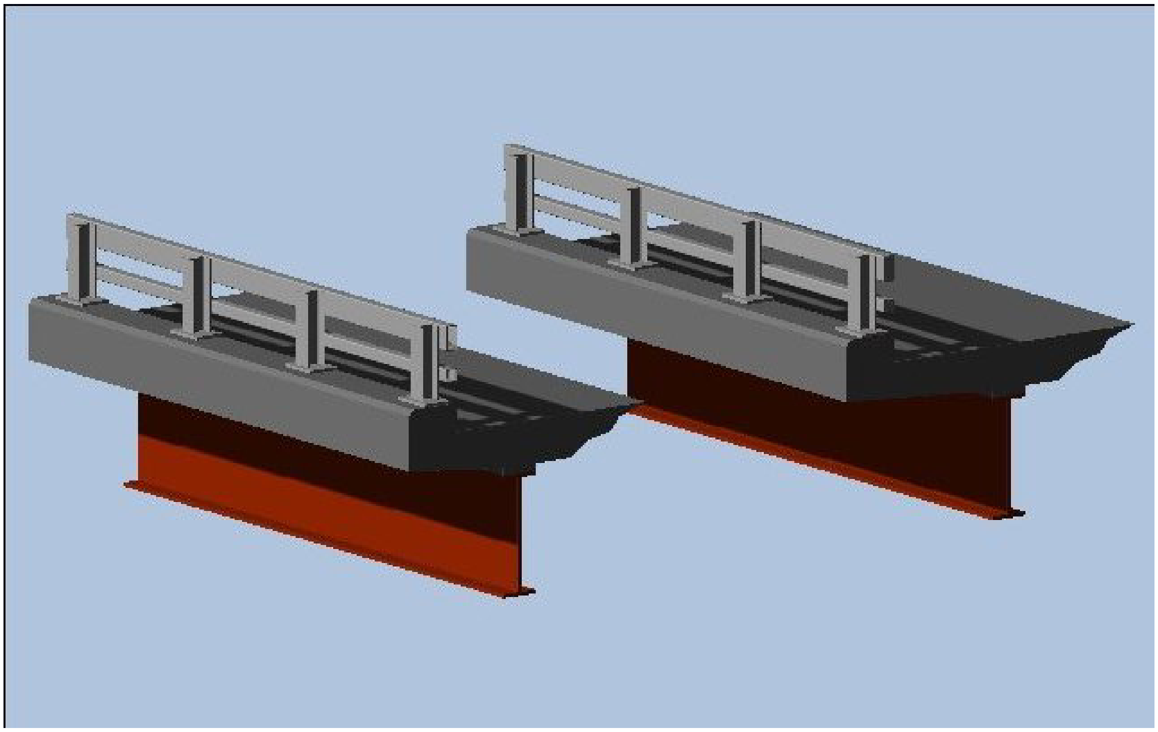


Figure 1-3 Effect of Overhang Length on Beam Shadow

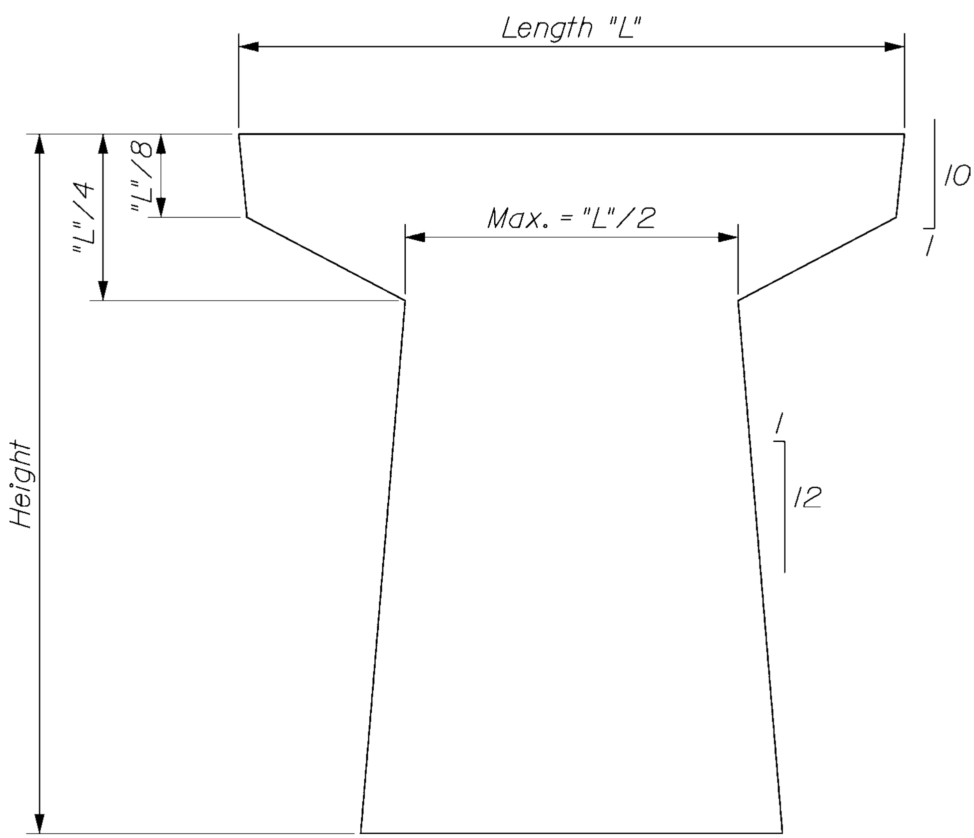


Figure 1-4 Hammerhead Pier Proportions

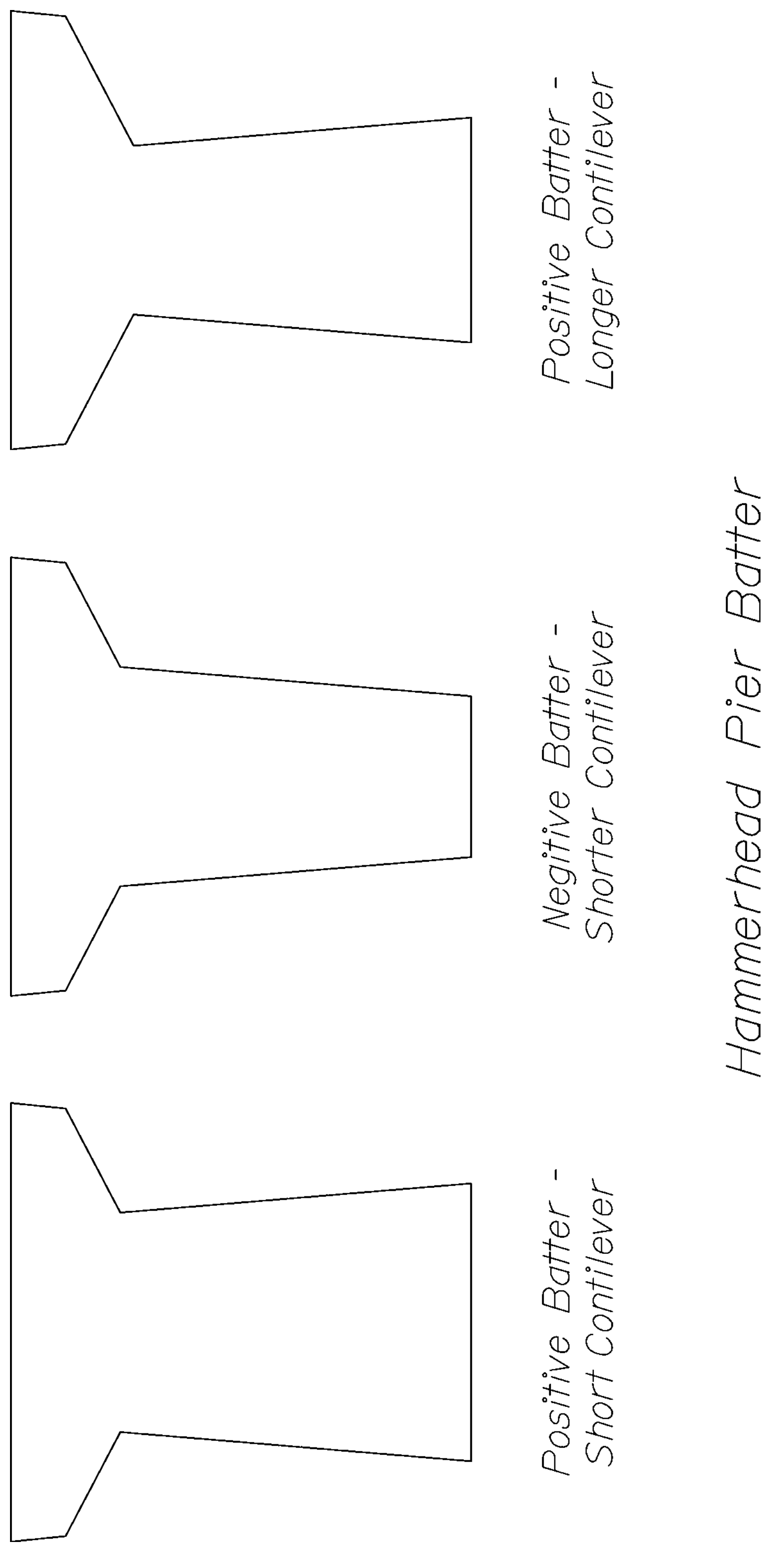


Figure 1-5 Variations of Cantilever Length and Batter

The relative pier width (longitudinal) to the fascia depth seen from the side also affects appearance. If the pier is too narrow, the bridge will appear unsupported and weak, while a wide pier will appear bulky. The apparent fascia depth includes the parapet rail height for a closed rail system, but does not include the rail height for an open rail system. Pier width should be between 25% and 50% of the fascia depth for a concrete barrier system. It should be between 50% and 67% of the fascia depth for an open rail system. Refer to Figure 1-6.

In general, slender columns are more graceful than wider columns. Columns will look more slender if the edge facing the viewer is partially in shadow. An octagonal column may look thinner than a round column, which looks thinner than a square column. Refer to Figure 1-7.

Form liners, acid washing techniques, or stone facing can be used to create surface texture on abutments, wingwalls, and piers. If the wall is viewed only at high speeds, the patterns used must be large enough to be visible. Pay special attention to corners and tops of walls when imitating stonework with form liners. Also consider having horizontal lines on return wings such as chamfers and construction joints follow the road grade when possible.

1.7.2.3 Color

In special situations, adding color to components of the bridge can be considered to enhance the fit into the surroundings. Coloring will increase maintenance costs, and may result in a poor appearance if maintenance is neglected. Concrete can be colored, but the cost is high, quality control is difficult, and it is often hard to match colors between batches. Concrete can also be stained, which presents its own appearance and durability concerns. Steel bridge rail can be color galvanized, as discussed in Section 4.4.6 Aesthetics, Bridge Rail, and other steel structures such as historic trusses can be painted as well.

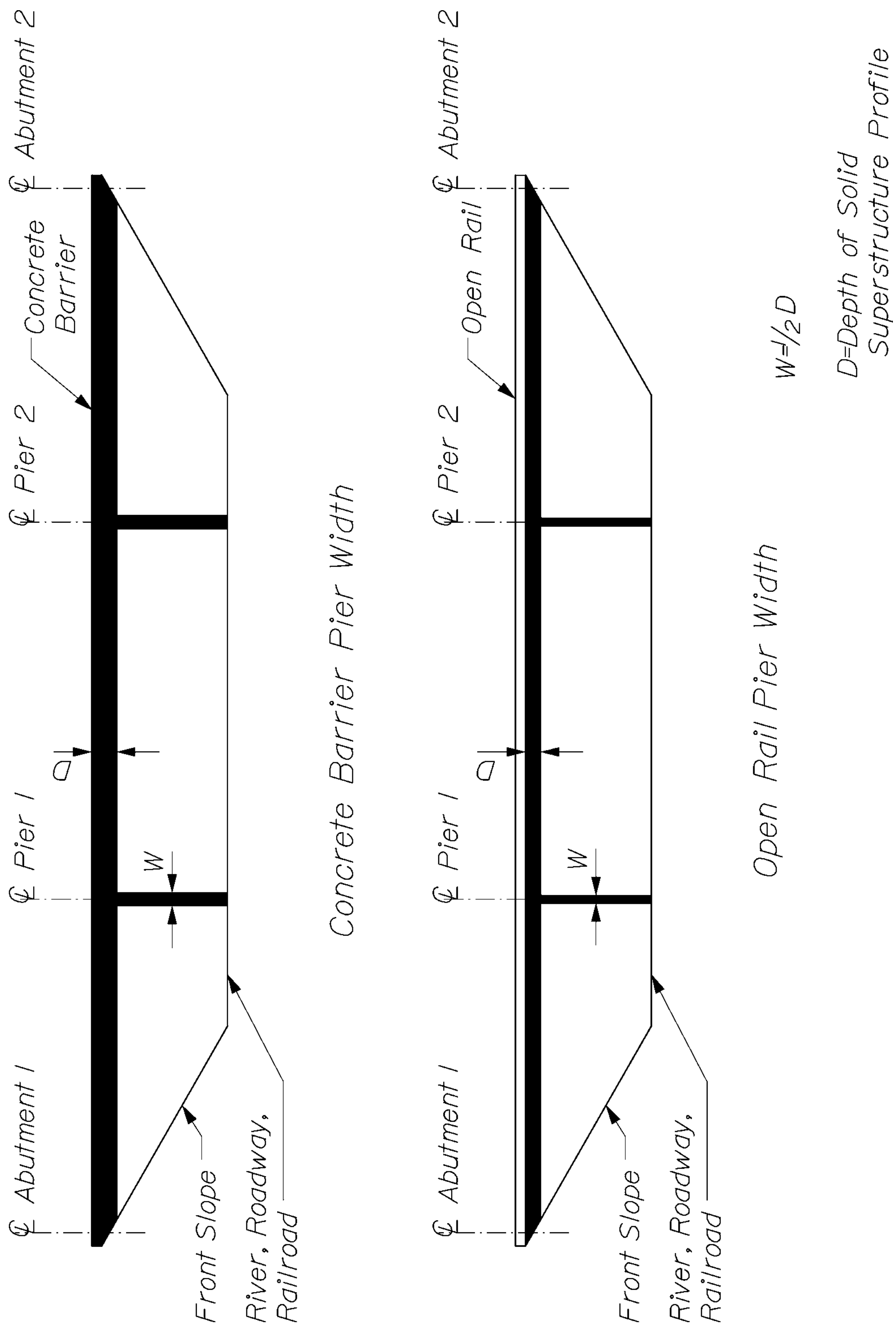


Figure 1-6 Ratio of Pier Width to Fascia Depth

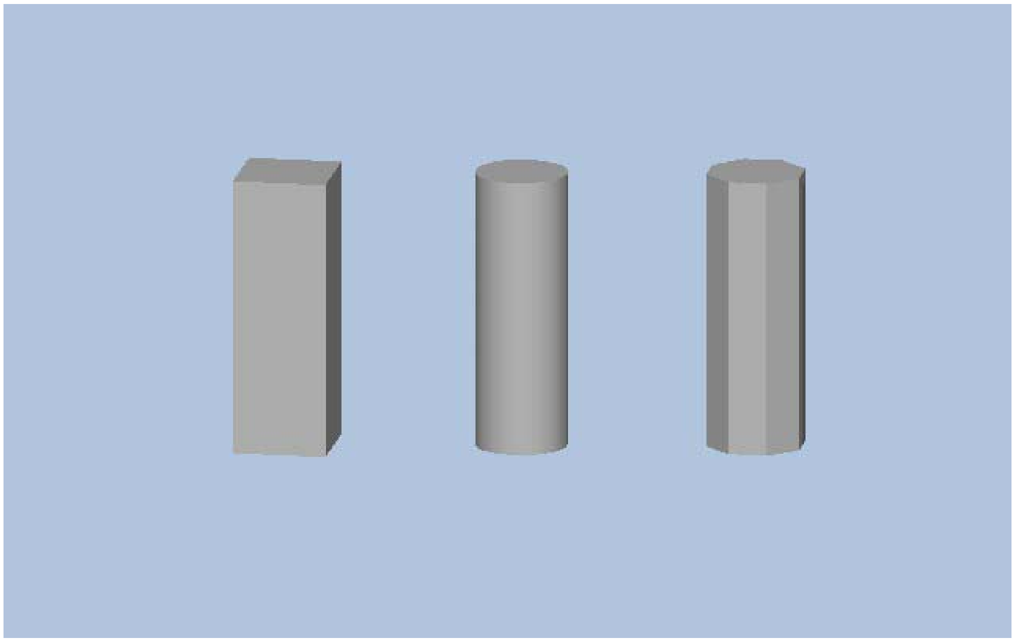


Figure 1-7 Effect of Column Shape on Shadows and Thin Appearance

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