

ENCE 717 BRIDGE ENGINEERING ABUTMENT/PIER DESIGN

C. C. Fu, Ph.D., P.E.
The BEST Center
University of Maryland
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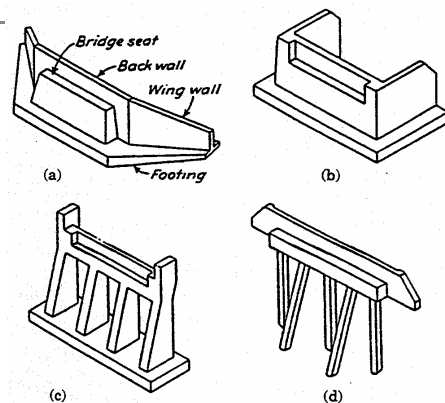
Function of Abutments

Abutments are used at the ends of bridges to retain the embankment and carry the vertical and horizontal forces from the superstructure. They could be designed as piers or retaining walls and they should be able to withstand against overturning and sliding. The footings should be designed to avoid differential settlement and excessive horizontal movements.



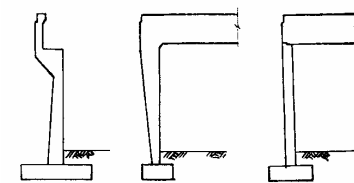
Abutment Types

- (a) Typical gravity abutment w/wing walls
- (b) U-abutment
- (c) Spill-through abutment
- (d) Pile bent abutment with stub wings



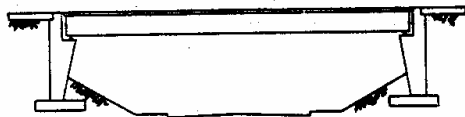
Full Height Abutment

A full height abutment is constructed at the lower level roadway and should support the entire embankment. This abutment is costly and is generally used in congested urban and metropolitan area where structure depth is critical.



Semi-stub Abutment

A **semi-stub abutment** is constructed somewhere between the top and bottom of an embankment and its height is between height of full and stub abutment.



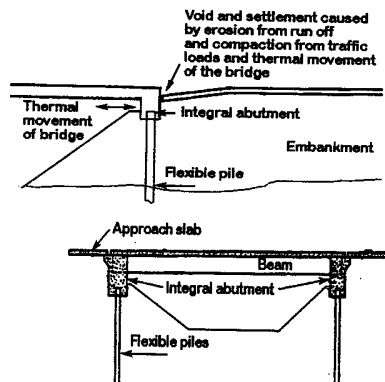
Stub Abutment

A **stub abutment** is built at the top of embankment slope and is considered as the best type of abutment for avoiding rough and settled approach pavements. A stub abutment is economical but gives a longer span length and a higher superstructure cost. However, the overall structure would be **less costly** than other alternate



Integral Abutment

Integral abutment is stub abutment on **single row of flexible piles** and **constructed without joints**. Integral abutments allow the expansion and contraction through movement at the abutments.

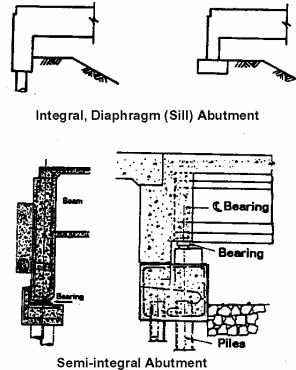


Benefit of Integral Abutment

- Cost saving by using less piling and simple design, eliminating joint, and less maintenance
- Maximum acceptable maximum range:
 - Steel : up to 200 – 300 ft
 - Concrete: 300 – 400 ft
 - Prestressed concrete: 300 – 450 ft
- Backfill at abutment should be free-draining material and compacted to 95%. Proper compaction is required to eliminate settlement of backfill. More attention should be given to backfilling including drainage details and potential use of geotextile to stabilize the backfill.
- Skew over 30 degree should not be used
- Integral abutment bridges are limited to pile supported abutments and drill shaft can not be used
- Longer than normal approach slab is required.

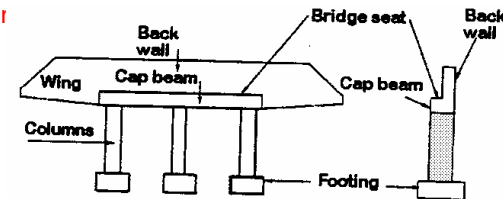
Semi-integral Abutment

Conventional stub abutment is fixed with in position with expansion and contraction movement of bridge superstructure. A **semi-integral bridge** can accommodate up to **400 feet** and **45 ° skew angle**.



Open/Spill-through Abutment

Open or Spill-through Abutment is used where an additional span will be added at a later date. It is essentially a pier functioning as an abutment. The main problem with this type of abutment are **compaction of embankment around the abutment, early settlement and erosion**



Pier Fundamentals

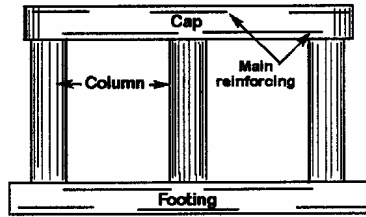
- Whenever possible **water crossing piers** should be aligned with the stream flow to avoid the creation of eddies and turbulence which can result in scour.
- **Two piers close to each shore line** may be more hydraulically efficient and economical to construct than one deep water pier
- When pier is located in **marine environments**, reinforcement should be corrosion protected and concrete should include corrosion inhibitors.
- To **offset abrasive action of water**, bridge pier should have HPC (High Performance Concrete) outer layers or form liners protection.

Pier Fundamentals (cont.)

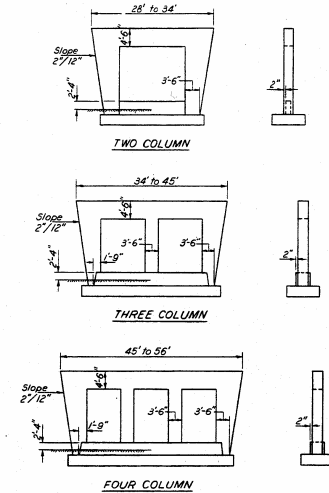
- It is preferred that the **pier shaft should be solid to a height** of 3 feet above navigable elevation or 2 feet above 100 year flood.
- The **upstream face of piers should be round or V shaped** to improve hydraulics. If ice and /or debris is problem, the upstream face should be battered 15 degree and armored with steel angle to a point 3 feet above design high water.
- The **wing walls on the upstream side should be aligned** to direction the flow through the bridge opening.
- In case where wing walls are at or near the water's edge, the **wing walls should be flared** to improve the hydraulic entrance condition.

Column Bent Pier

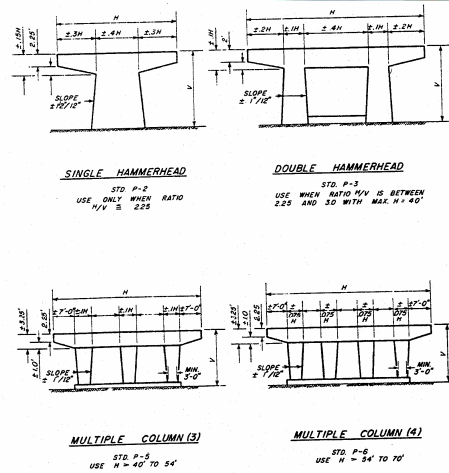
The **column bent pier** that consists of a pier cap with columns supporting an individual or a continuous footing is widely used on grade separation structures.



Typical Trapezoidal Piers for Grade Separation Structures

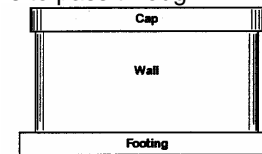


Typical Hammerhead Piers for Grade Separation Structures



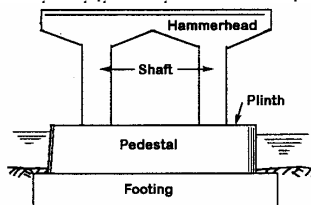
Wall Pier

A **wall pier** is used for most stream crossings to avoid collecting of debris and floating ices between columns. A wall type pier consisting of a single row of piles, especially H-piles, encased with concrete to form a wall provides more resistance to ice and debris and allows debris to pass through

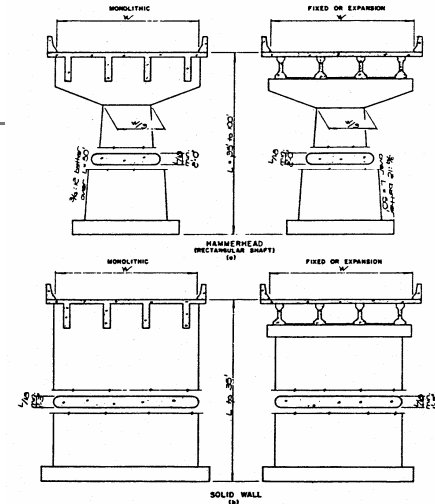


Hammerhead Pier

A **solid shaft pier** or **T pier** is used for major stream crossings where heavy loads, tall piers or sizeable ice and debris loads may occur. The hammerhead type T pier is generally cheaper than the solid wall pier because it requires fewer quantities of materials and a smaller cofferdam to c



Waterway Crossing Piers



Foundation Types

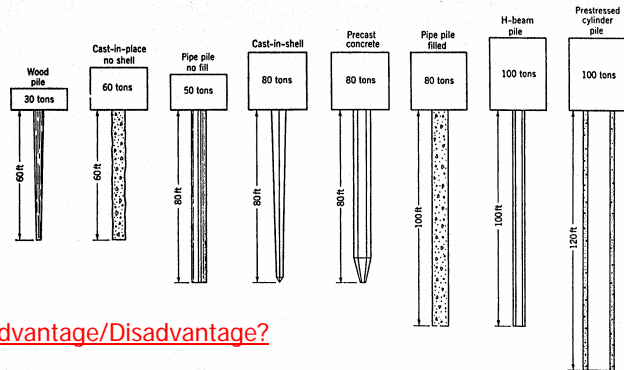
- **Spread Footings** (control bearing pressure, total settlement and differential settlement)
 1. Individual Footings
 2. Combined Footings
- **Driven Piles**
 1. Displacement piles (solid sections or hollow sections with a closed end)
 2. Non-displacement piles (less shaft friction, H-piles and open-ended sections)
- **Driven Shafts** (Referred to as drilled sub-piers or caissons)

Pile Installation Methods

- **Driven preformed piles**
 1. Impact methods
 2. Static installation
 3. Vibratory driving
- **Driven cast-in-situ piles**
- **Bored cast-in-situ piles**

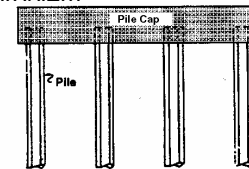


Summary of Frequently used Piles

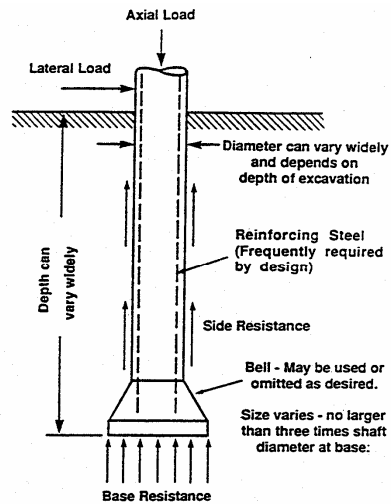


Pile Bent

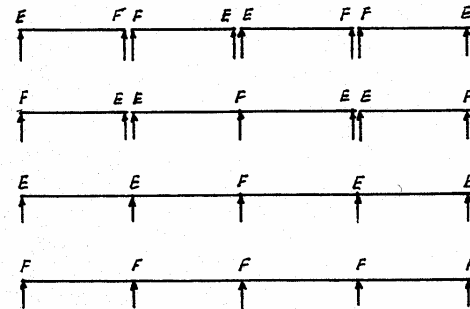
Pile bent piers consisting of a row of piles with a concrete cap encasing the pile tops are **the simplest and most economical type of pier**. They are used for stream crossings where the maximum height from the top of pier to stream bed is under 20 ft. (6 m) and there is no ice or debris problem.



Drilled Shaft (Drilled Subpier, Caisson)



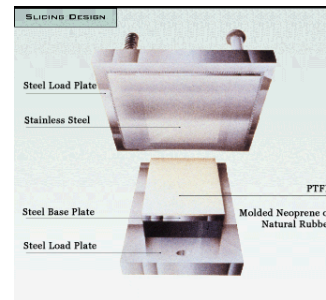
Possible Configurations for a Typical Four-span Highway Bridges



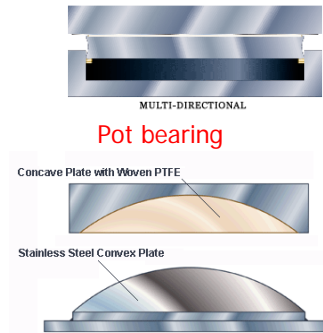
Bearings (recommended by steel industry)

- Use elastomeric if possible
 - Elastomeric -approximately \$225 ea
- Use pot bearing next
 - Pot Bearing -approximately \$800 ea
- Others
 - Spherical Bearing -approximately \$1200 ea
 - Bronze Rocker -approximately \$600 ea

Bearing Types



Elastomeric

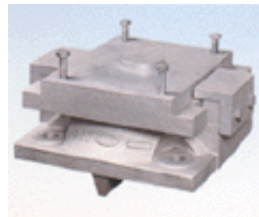


Spherical Bearing

Bearing Types (cont.)



Rocker



Sliding

Distribution of Longitudinal Forces to Fixed and Expansion Piers

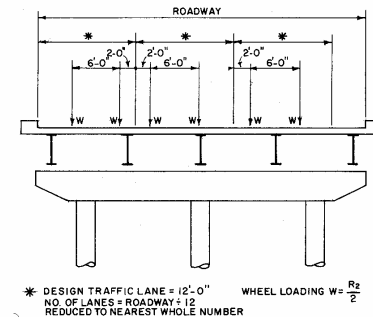
The following distribution modes of longitudinal forces are often assumed:

- Expansion bearings resist only thermal, while the fixed bearing resists all longitudinal forces associated with wind and traffic loads.
- The forces released from the expansion bearings due to live load vibration must be carried by the fixed pier.
- Expansion bearings carried loads to their friction capacity, computer as the dead load reaction multiplied by a friction coefficient. Any additional loads must be resisted at the fixed pier
- With massive, stiff abutments at the ends of a bridge, design intermediate piers for vertical loads only.

Loads resisted by the substructure

- Dead load from the superstructure
- Dead load of the substructure
- Live load and impact from the superstructure
- Wind loads on the super- and substructures
- Wind load on the live load
- Centrifugal force from the superstructure
- Longitudinal force from live load
- Dead load friction from bearings
- Earth pressure
- Stream flow pressure
- Ice pressure
- Earthquake forces
- Thermal and shrinkage forces
- Ship impact forces

Live Load Distribution



Live Load Distribution

- Live load reactions obtained from design of individual members of the superstructure should not be used for substructure design, resulting un-economic sections.
- For the calculation of the actual beam reactions on the pier, the maximum lane reaction can be applied within the design traffic lanes as wheel loads, and then distributed to the beams assuming the slab between beams to be simply supported.
- Multi-lane reduction shall be considered.

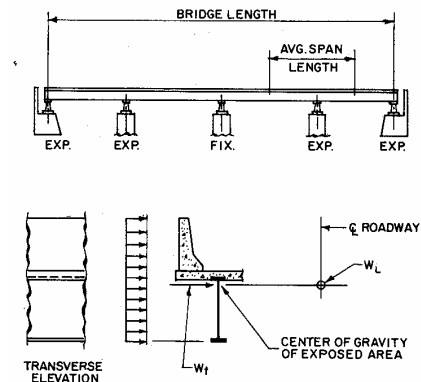
Transverse Loading: Wind Loads

a. Wind load on the superstructure

$W_{super,t} = (\text{Area of exterior beam, roadway slab and parapet per linear ft as seen in the transverse elevation}) \times$

(Average span length of two spans adjacent to the pier under consideration) \times

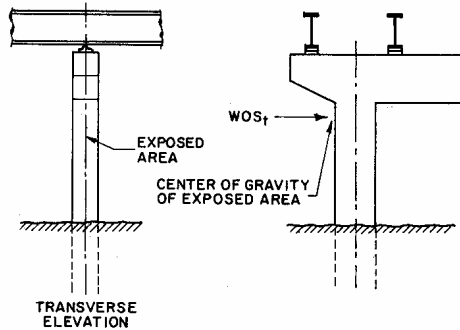
(Unit transverse wind load as specified in AASHTO LRFD 3.8.1.2.2)



Transverse Loading: Wind Loads

b. Wind load on the substructure

$WS_{sub,t}$ = (Area of exposed substructure as seen in the transverse elevation) x (Unit transverse wind load as specified in AASHTO LRFD 3.8.1.2.3) assumed base wind pressure of 0.04 ksf



Transverse Loading: Wind Loads

c. Wind load on moving live load

WL_t = (Average span length of two spans adjacent to the pier under consideration) x (Unit wind on a moving live load as specified in AASHTO LRFD 3.8.1.3) by an interruptible moving force of 0.1 klf acting normal to, and 6 ft above the roadway

Transverse Loading: Wind Loads

d. Wind overturning (upward) forces

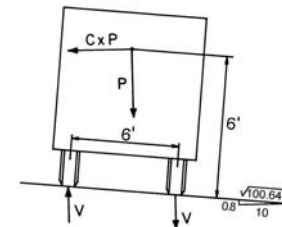
$WS_{overturn}$ = (The magnitude and application of this longitudinal line load is specified in AASHTO LRFD 3.8.2)

(A vertical upward wind force of 0.02 ksf) x (the width of the deck, including parapets and sidewalks) at the windward quarter-point of the deck.

Transverse Loading: Centrifugal Force

CE = (calculate and apply the horizontal radial force due to structure curvature as specified in AASHTO LRFD 3.6.3) at 6 ft above the roadway surface

$$C = 4/3 (v^2/gR)$$



Transverse Loading: Other Forces

Loads may include the influence of stream current (WA), floating or freezing ice (IC), drift, earth pressure (EH, ES, LS, DD), vessel collision (CV) and earthquake forces (EQ), or in the case of rigid frame bent piers, internal stresses due to temperature change and shrinkage forces (TU, TG, SH, CR, SE) in the appropriate group of loadings of AASHTO LRFD 3.9-3.14

Longitudinal Loading: Braking Force

$BR = \text{Max. of (25\% design truck or tandem, 5\% design truck or tandem+ lane) } \times$

$(\text{number of design traffic lanes loaded with one direction traffic}) \times$

$(\text{Reduction factor for lane loadings, AASHTO}) \text{ at 6 ft above the roadway surface}$

Longitudinal Loading: Wind Loads

a. Wind load on the superstructure

$WS_{\text{super,L}} = (\text{Area of the exterior beam; roadway slab and parapet per linear foot as seen in the transverse elevation}) \times (\text{Bridge length}) \times$

$(\text{Unit longitudinal wind load as specified in AASHTO LRFD 3.8.1.2.2})$

b. Wind load on the substructure

$WS_{\text{sub,L}} = (\text{Area of the exposed substructure as seen in the longitudinal elevation}) \times$

$(\text{Unit longitudinal wind load as specified in AASHTO LRFD 3.8.1.2.3})$

Longitudinal Loading: Wind Loads

c. Wind load on moving live load

$WL_L = (\text{Average span length of two spans adjacent to the pier under consideration}) \times$

$(\text{Unit wind on a moving live load as specified in AASHTO LRFD 3.8.1.3}) \text{ by the components of parallel force of an interruptable moving force of 0.1 klf acting at 6 ft above the roadway}$