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2016

Title: 3D substructure analysis and design

NAME Edgar De Los Santos / MIDAS IT – United States

Content

- What is Substructure
- Parts of the substructure
- MIDAS Modeling
- Midas GSD
- Midas Design+

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What is the Substructure?

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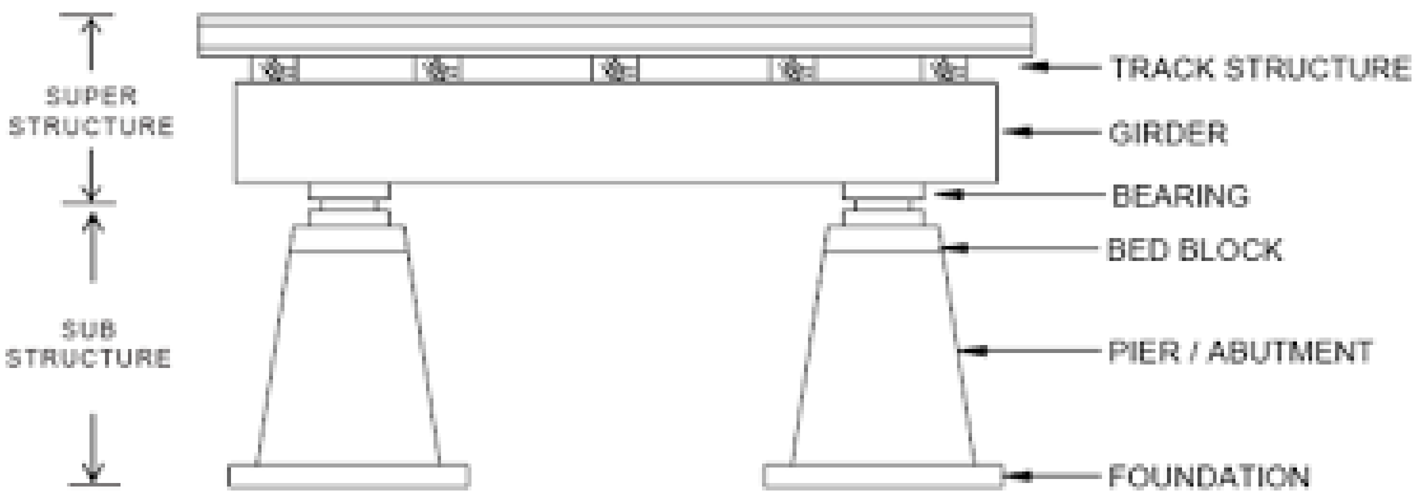
What is Substructure?

Is the part of the structure that is in charge of transmitting the load to the ground.
It is composed of:

-Bearings
-Piers/Abutments
-Foundation



Parts of the Substructure

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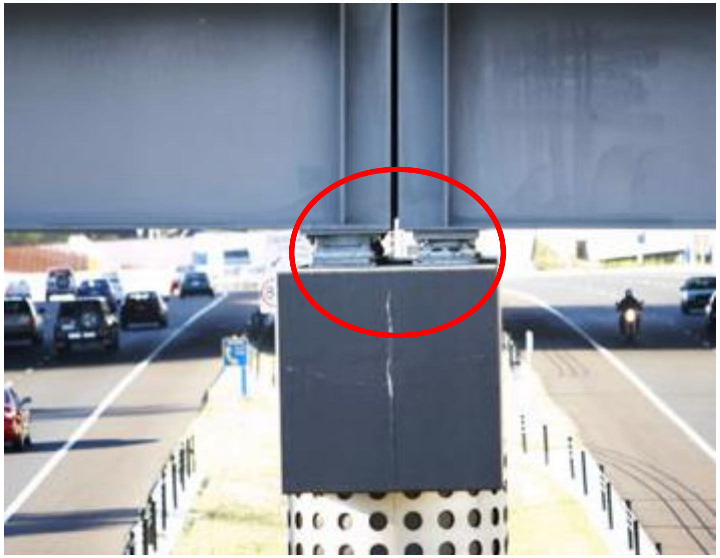
Bridge Bearings:

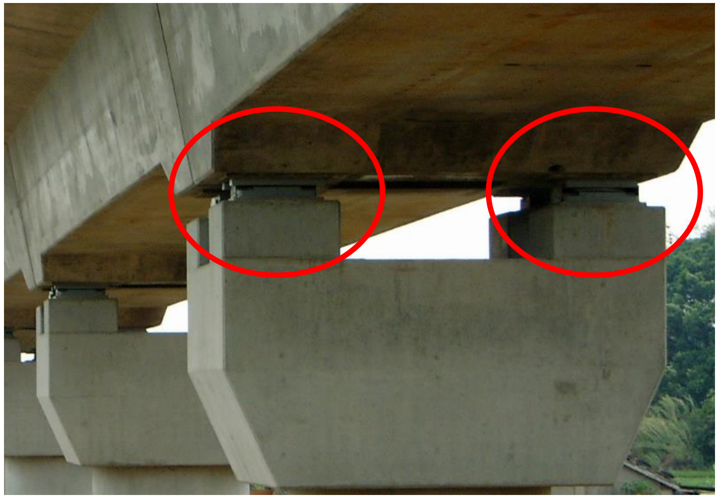
Functions of bridge bearings:

- Transfer forces from superstructure to Substructure
- Provide rotational &/or translational Restraints

To accommodate the deformations occurring due to:

- Thermal expansion/contraction
- Elastic deformation under live load
- Seismic forces
- Creep and shrinkage of concrete
- Settlement of supports
- Longitudinal forces - tractive/ braking
- Wind loads

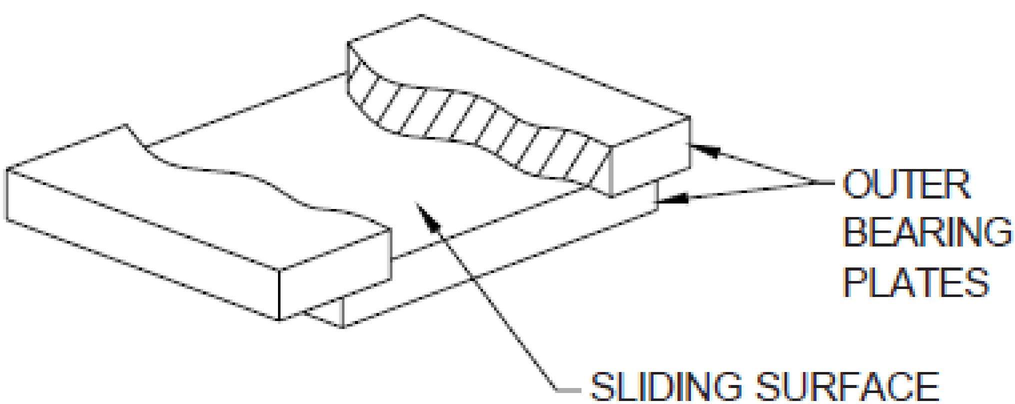


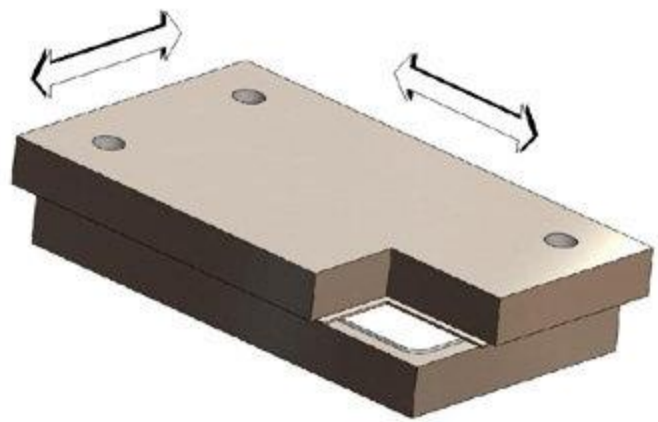


Bridge Bearing Types

- Sliding Bearings
- Rocker & Roller Bearings
- Knuckle Bearings (Pinned, Cylindrical, Spherical & Leaf)
- Elastomeric Bearings (plain & laminated)
- POT PTFE Bearings

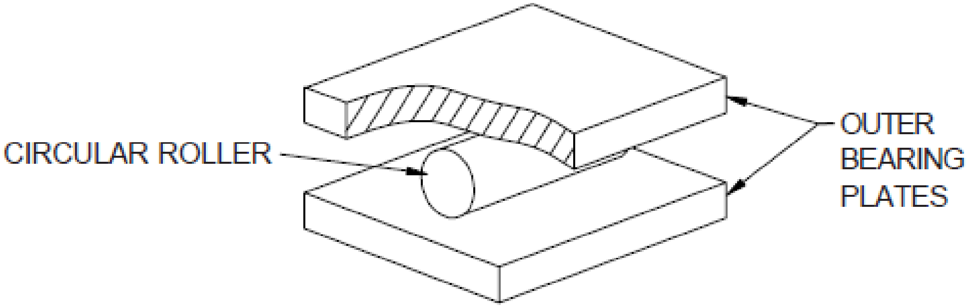
1. Sliding Bearings



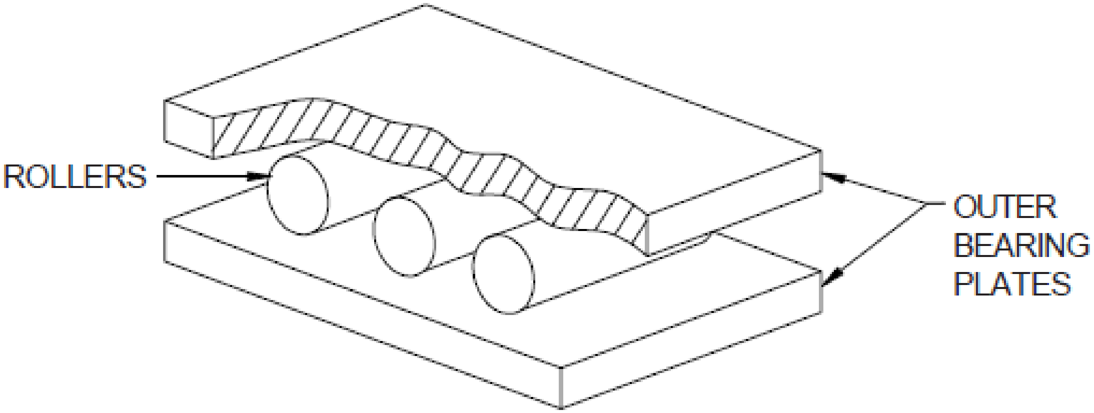


2.a. Roller Bearings

Single Roller Bearing

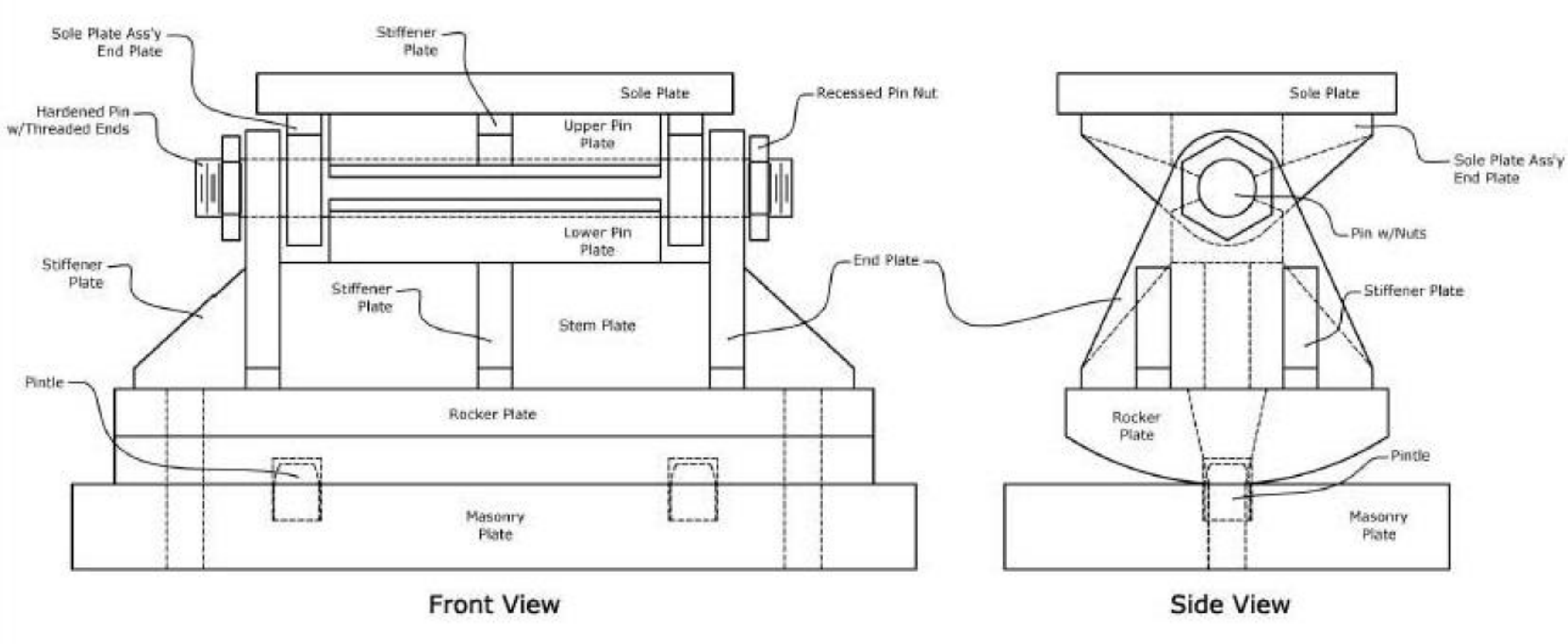


Multiple Roller Bearing



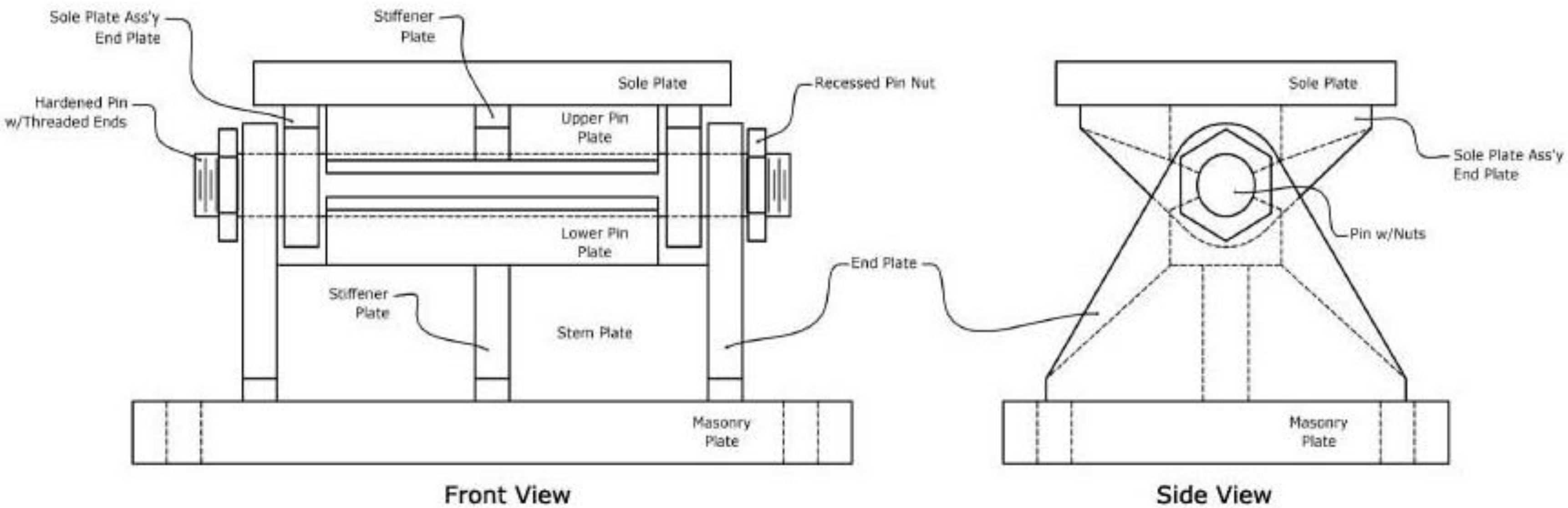
2.b. Rocker Bearings

Expansion Rocker Bearing (Pin Style)



2.b. Rocker Bearings

Fixed Rocker Bearing (Pin Style)



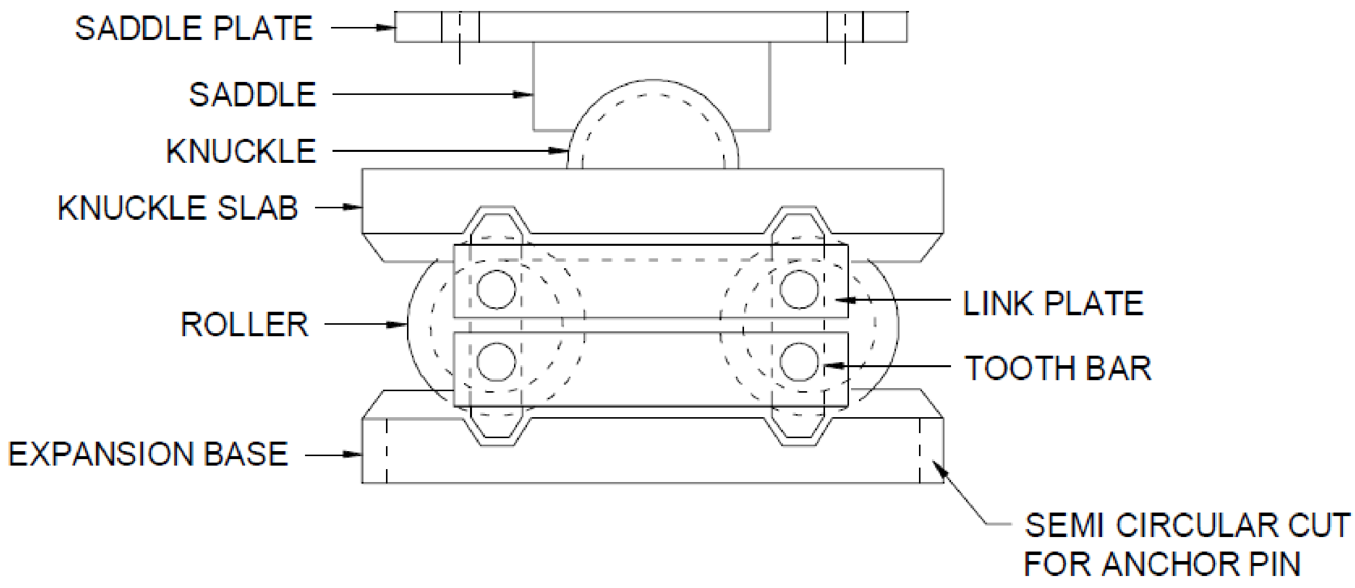
2.b. Rocker Bearings

Free Rocker Bearing

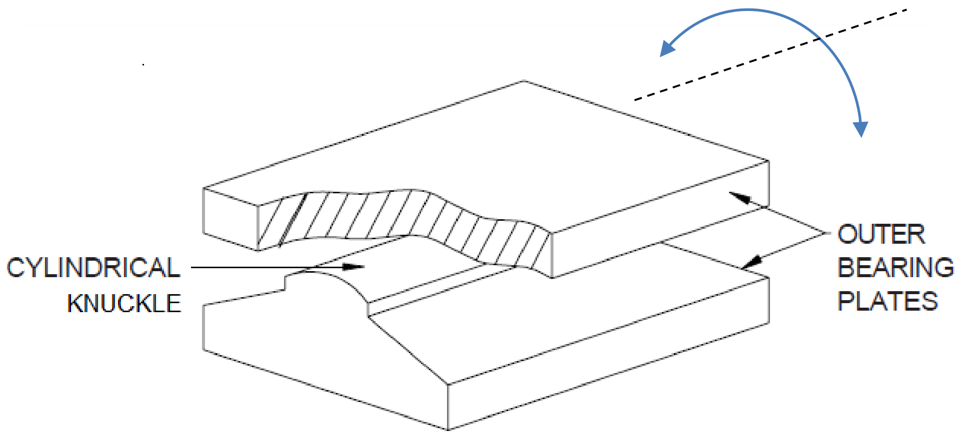
Fixed Rocker Bearing

3.a. Knuckle Pinned Bearing:

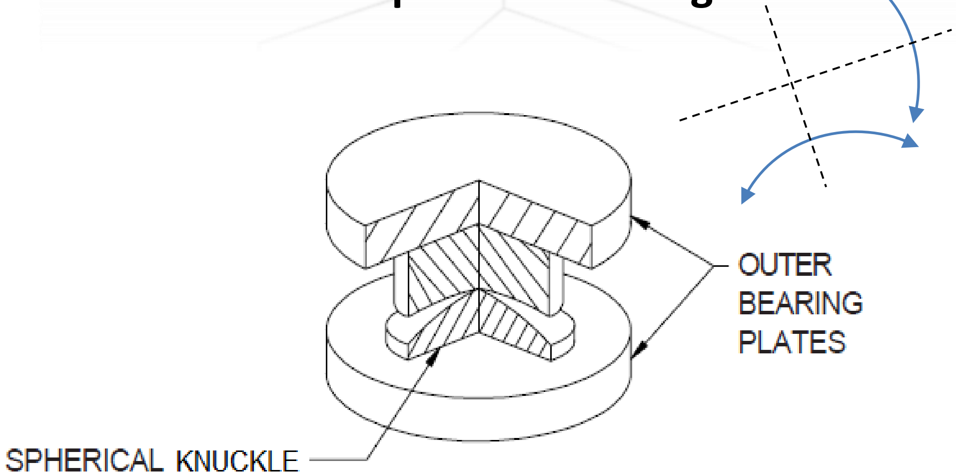
Combination of rocker and roller bearing



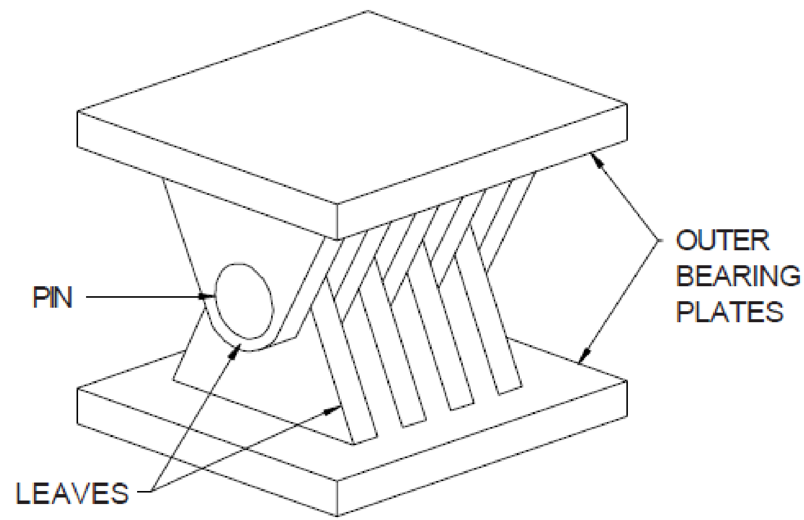
3.b. Knuckle cylindrical Bearing:



3.c. Knuckle spherical Bearing:



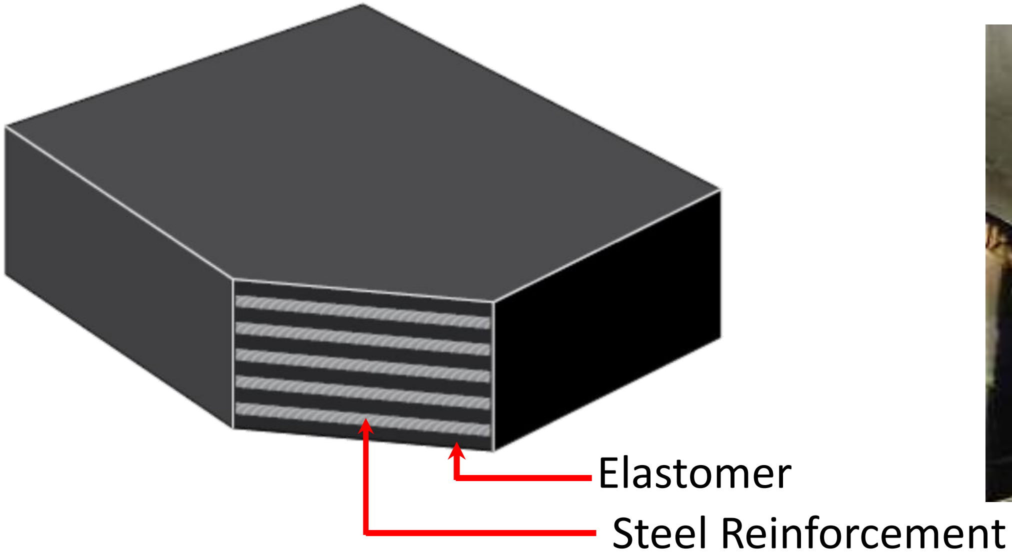
3.d. Knuckle leaf Bearing:



4. Elastomeric bearings:

- Plain elastomeric bearings
- Steel reinforced elastomeric bearings
- Fibre reinforced elastomeric bearings

Steel Reinforced Elastomeric Bearings



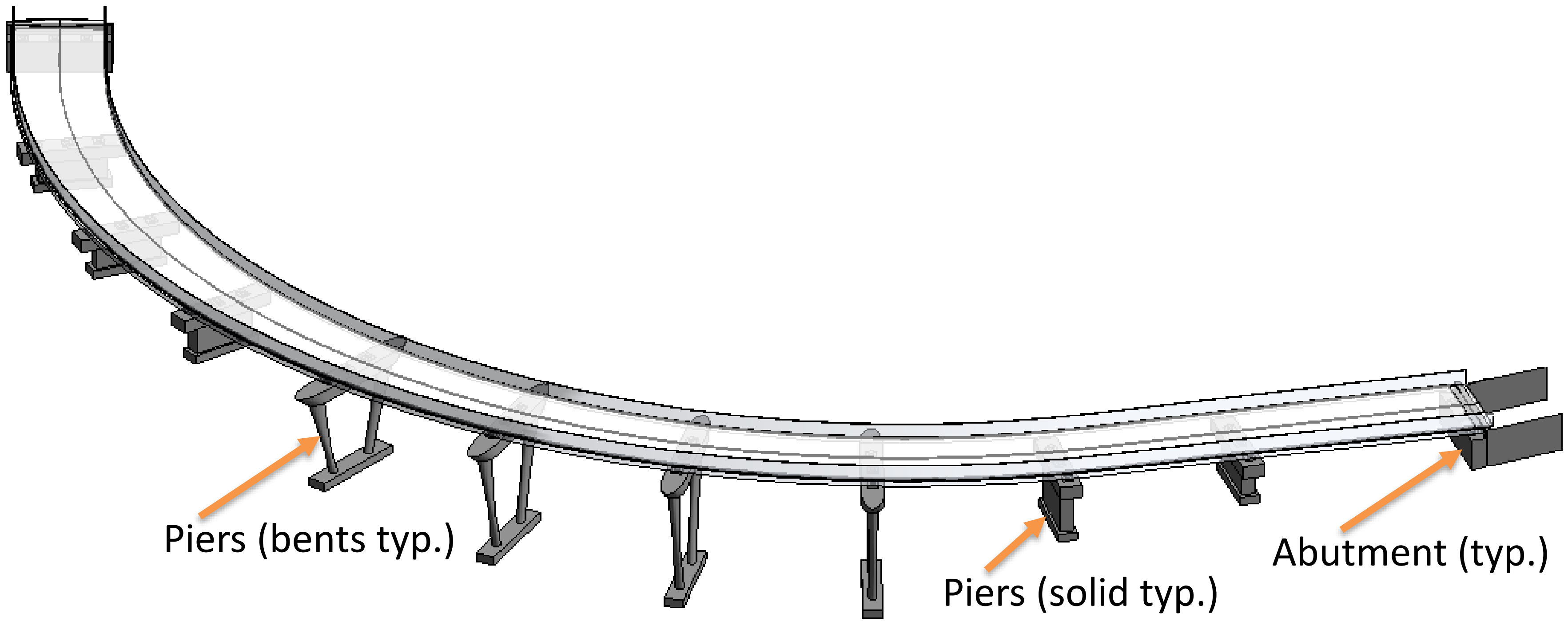
Piers & Abutments

an integral part of the load path between the superstructure and the foundation

Functions of Piers:

- To transfer the superstructure vertical loads to the foundation
- To resist all horizontal forces acting on the bridge

Abutments in addition to the above functions of piers are used at the ends of bridges to retain the embankment



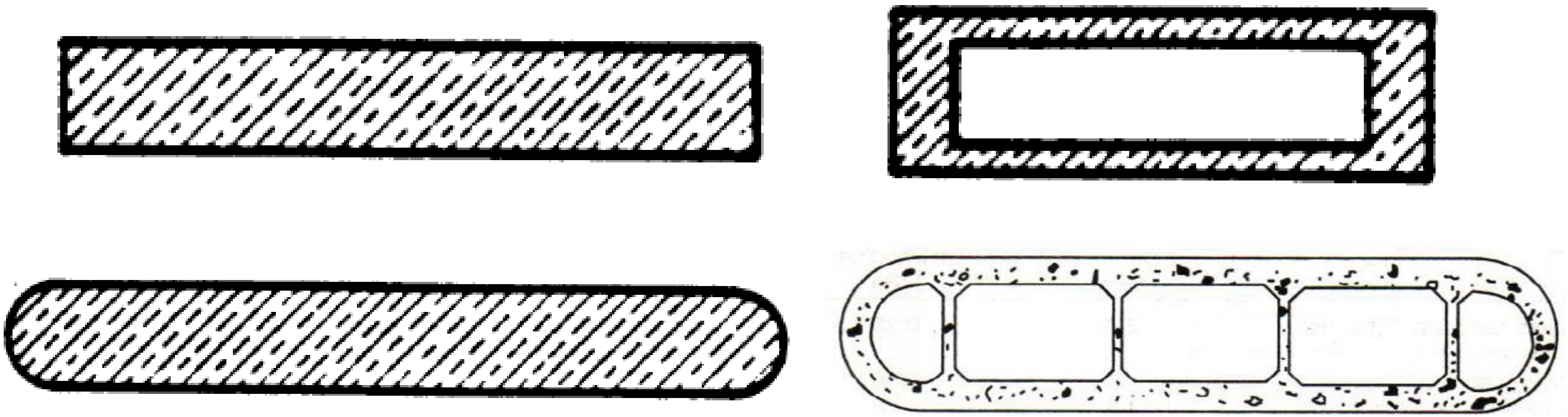
Piers

Classification based on connectivity with the superstructure

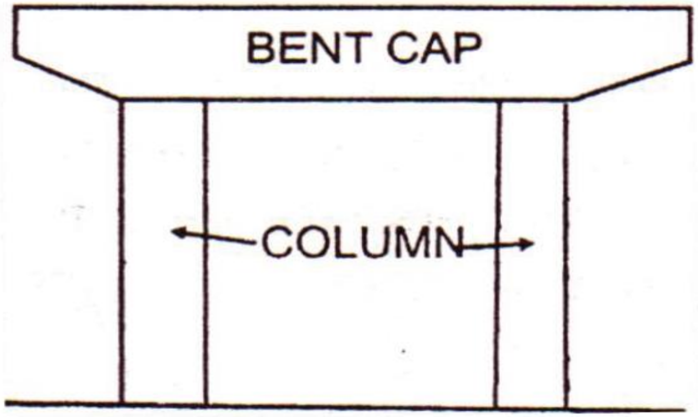
- Monolithic (integral)
- Cantilever

Classification based on sectional shape and framing configuration

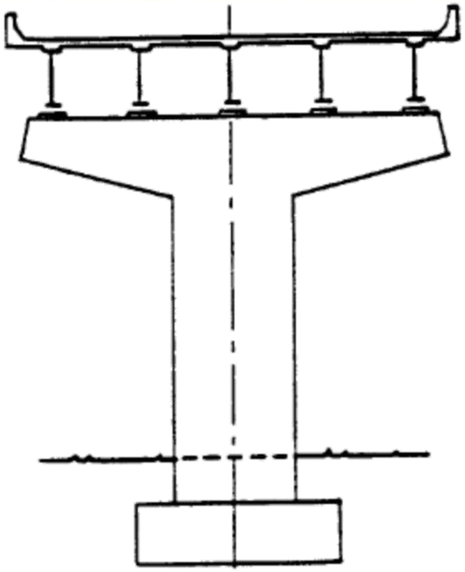
- Solid , Solid-hollow & Cellular type piers
- Trestle type pier (two or multiple column bent)
- Hammer-head type pier
- Framed type pier



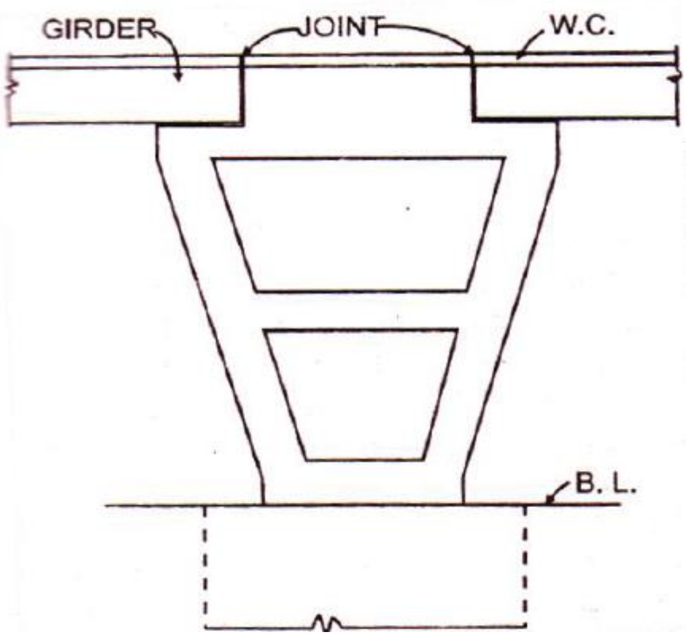
Solid , Solid-hollow & Cellular type piers



Trestle type pier



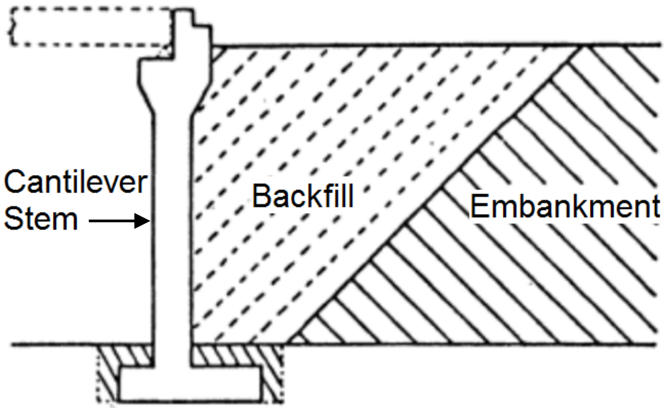
Hammer-head type pier



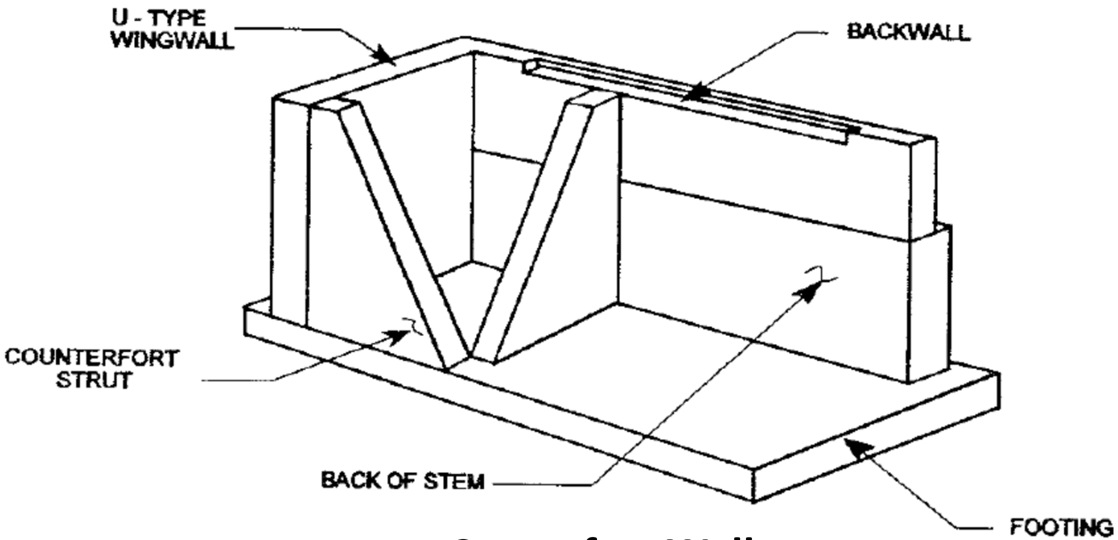
Framed type pier

Abutment Types

- Closed Cantilever (high) abutments
    - Wall type
    - Counterfort type
- Stub or perched abutments
- Pedestal or spill through abutments
- Integral abutments
    - With Piles
    - With open foundation



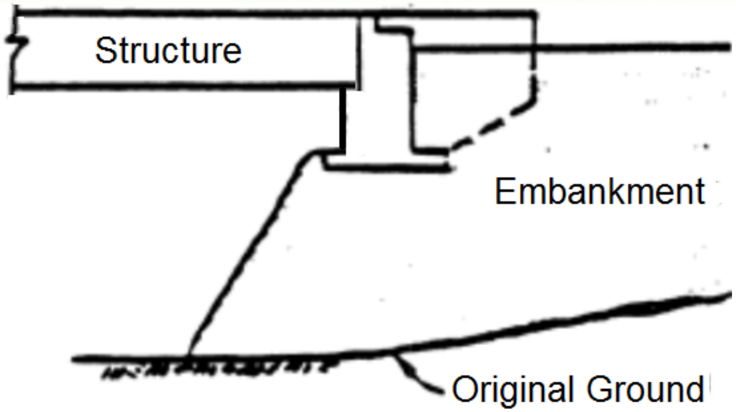
Wall type



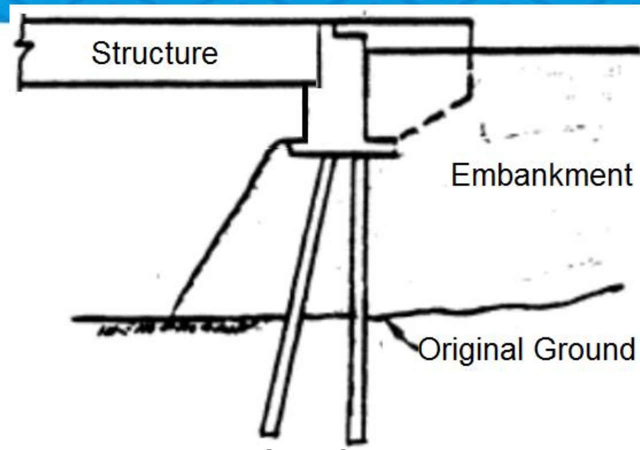
Conterfort Wall type

Cantilever Closed Abutments

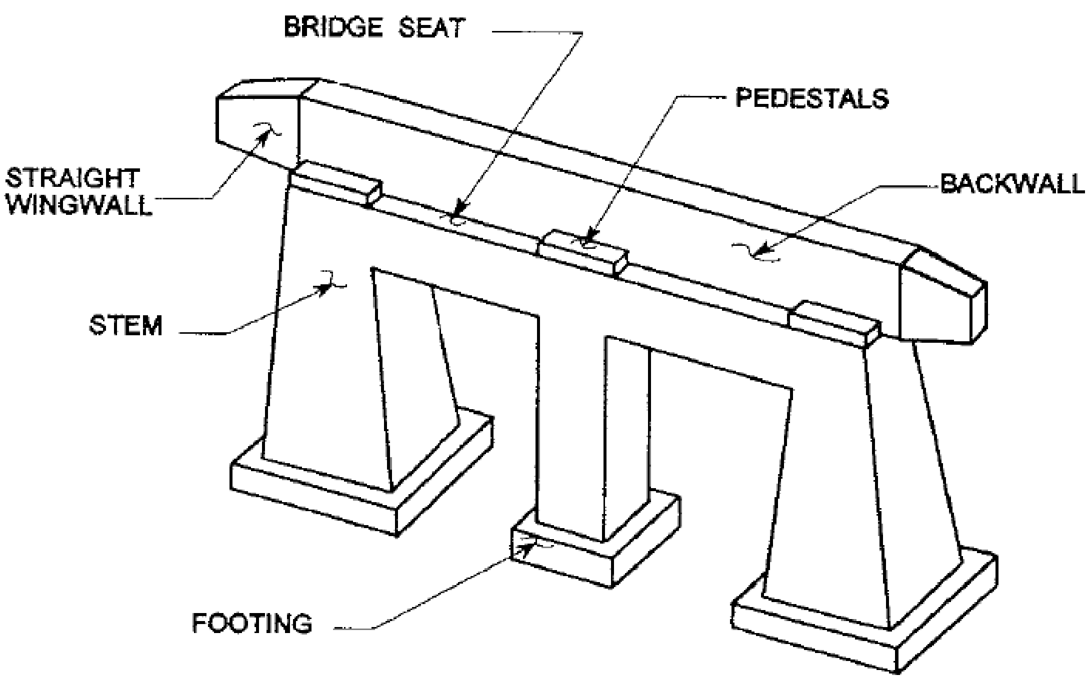
Stub Abutments

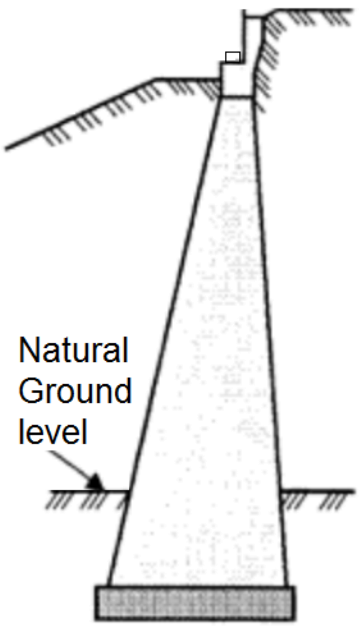


With Spread Footing



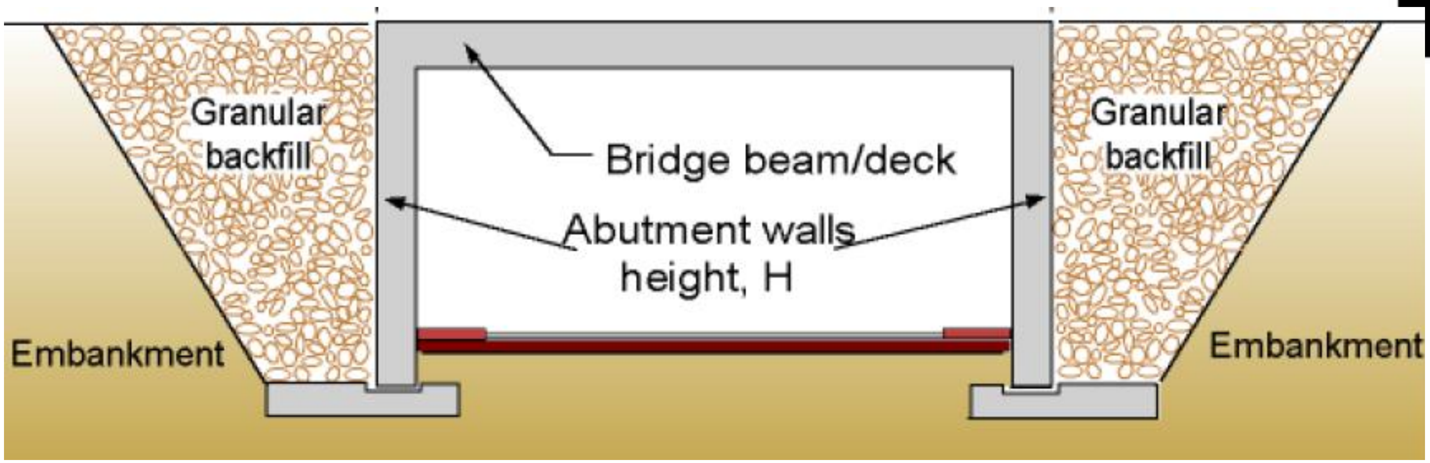
With Piles



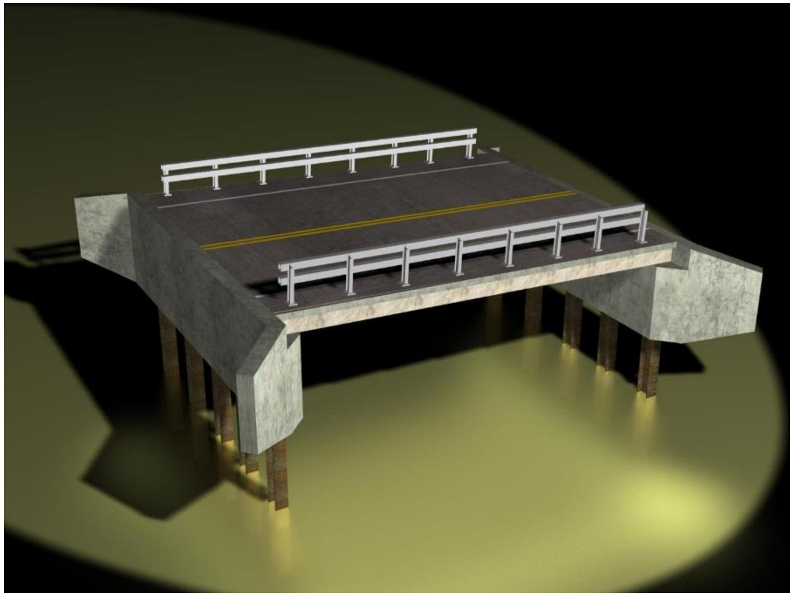


Cross section

Spill Through Abutment



Integral Abutment with Shallow Foundation



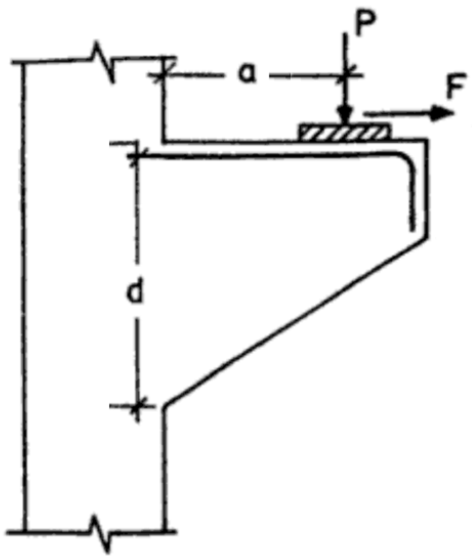
Integral Abutment with Pile foundation

Design of Piers

1. Design loads

- Dead loads
- Live loads and impact from the superstructure
- Wind loads on the structure and the live loads
- Centrifugal force from the superstructure
- Longitudinal force from live loads (braking and traction)
- Drag forces due to the friction at bearings
- Ice pressure
- Earthquake forces
- Thermal and shrinkage forces
- Forces due to settlement of foundations
- Vehicle Collision Loads

Pier-Cap Design → a/d Ratio
- <1 → Corbel
- >1 Cantilever



Design of Piers

2. Combined Axial and Bending Strength

Interaction Diagrams

For Pure Compression, the factored axial resistance is computed as

P= ΦPn = Φ 0.85 Po = Φ 0.85 [0.85 f'c(Ag - Ast)+ Ast fy] → for piers with spiral reinforcement
P= ΦPn = Φ 0.8 Po = Φ 0.8 [0.8 f'c(Ag - Ast)+ Ast fy] → for piers with tie reinforcement

For Pure Flexure, the factored flexural resistance is computed as

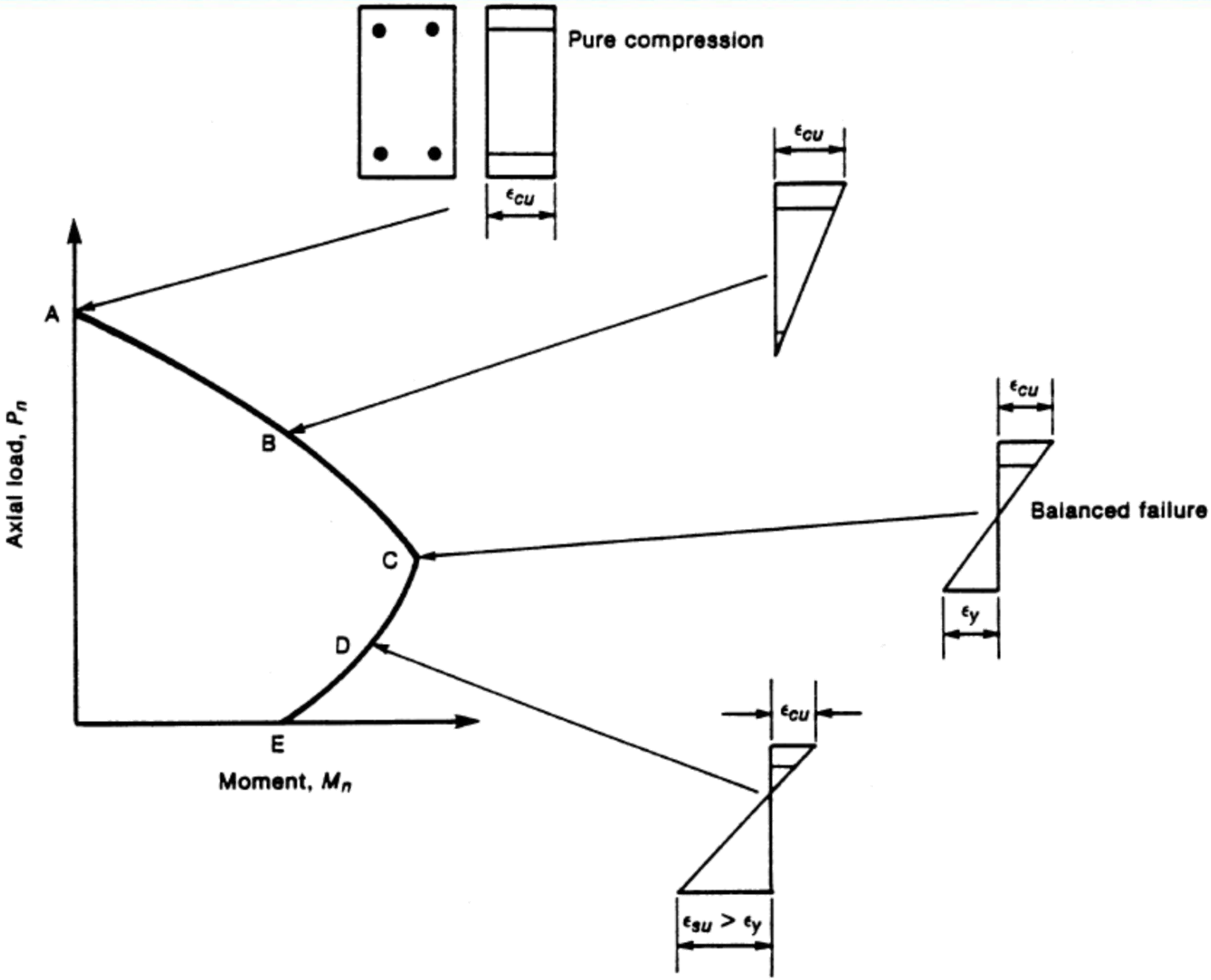
$$M_r = \Phi M_n = \Phi(A_s f_y\, d\,(1 - 0.6\rho \frac{f_y}{f'_c}))$$

For Biaxial bending, interaction check is carried out as

$$\frac{M_{ux}}{M_{rx}} + \frac{M_{uy}}{M_{ry}} \leq 1$$

Where,

M_{ux}, M_{uy} = factored applied moment about the x-axis, y-axis
M_{rx}, M_{ry} = uniaxial factored flexural resistance of a section about the x-axis and y-axis corresponding to the eccentricity produced by the applied factored axial load and moment, and


Pure compression
ϵ_{cu}
ϵ_{cu}
A
B
C
D
E
Axial load, P_n
Moment, M_n
ϵ_{cu}
Balanced failure
ϵ_y
ϵ_{cu}
$\epsilon_{su} > \epsilon_y$

Design of Piers

3. Shear Strength

The nominal shear strength provided by concrete subjected to flexure and axial compression should be computed by

$$V_n = V_c + V_s + V_p \leq 0.25\, f c'\, bvdv + Vp$$

where f c ' = concrete compressive strength
bv = effective web width
dv = effective shear depth taken as the distance, between tensile and compressive forces due to flexure, it should not be taken less than the greater of 0.9de or 0.72D

Here V_c = shear resistance due to concrete = $0.0316\, \beta \sqrt{fc}\, bvdv$

β = factor indicating ability of diagonally cracked concrete to transmit tension as specified in S5.8.3.4, taken as 2 for non-prestressed members

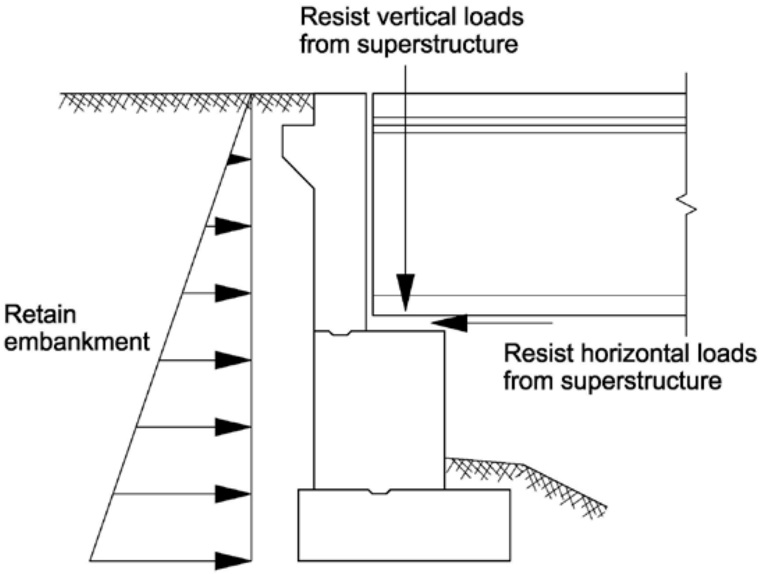
And V_s = shear resistance due to steel = $[A_v f_y d_v(\cot\theta + \cot\alpha)\sin\alpha]/s$

where:
s = spacing of stirrups
θ = angle of inclination of diagonal compressive stresses as determined in S5.8.3.4 (deg) = 45 deg for nonprestressed members
α = angle of inclination of transverse reinforcement to longitudinal axis (deg) = 90 deg for vertical stirrups
Av = area of shear reinforcement

Design of Abutment

Design loads

- Dead loads
- Live loads and impact from the superstructure
- Wind loads on the structure and the live loads
- Centrifugal force from the superstructure
- Longitudinal force from live loads (braking and traction)
- Drag forces due to the friction at bearings
- Ice pressure
- Earthquake forces
- Thermal and shrinkage forces
- Forces due to settlement of foundations
- Vehicle Collision Loads

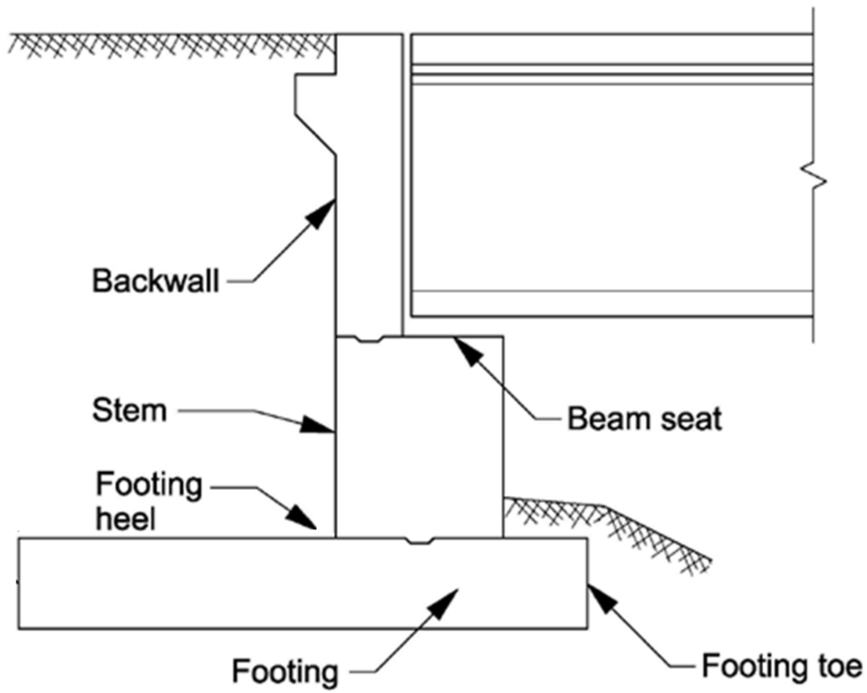


Design of a Cantilever Abutment with Shallow Footing

- The Abutment comprises of 3 components, heel, stem and toe.
- The dimensions of the footing are based on the base pressure check :
  - Forces due to lateral earth pressure.
  - Vertical and horizontal reactions from the superstructure.

$$\frac{P}{A} \pm \frac{M_L}{Z_L} \pm \frac{M_T}{Z_T}$$

  - In order to assure no tension at the bottom, the dimensions of footing are fixed based on the base pressure.



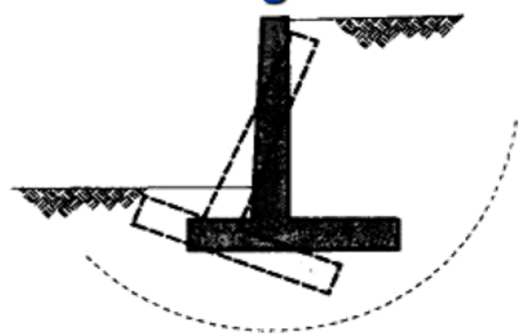
Stability Checks:

Sliding Failure
FOS >1.5

Overturning Failure
FOS > 2

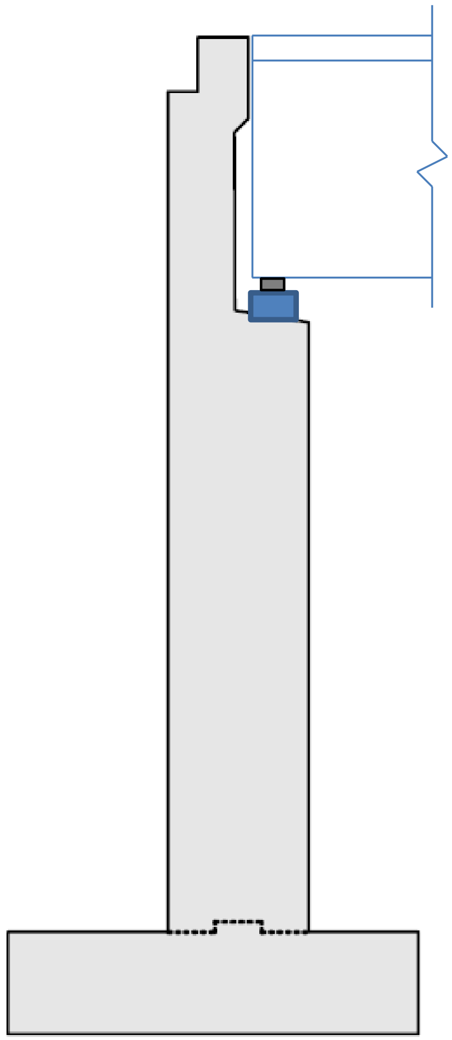
Bearing Failure

Deep-Seated
Sliding Failure



Stem Design → As a flexure member with shear check similar to piers

Design Loads Calculation for Abutment design



First, Preliminary dimensions of stem, toe and heel are selected and design loads are calculated.

1 : Computation of Dead Load Effects

a) Dead Load from Superstructure per unit length:

$$\frac{\text{Summation of Dead Load bearing Reactions from all bearings}}{\text{Length of Abutment}}$$

b) Dead load of backwall and Stem per unit length

c) Footing dead load of per unit length

d) Backfill Earth dead load of per unit length

e) Live Load effects

f) Temperature effects

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Pier Modeling

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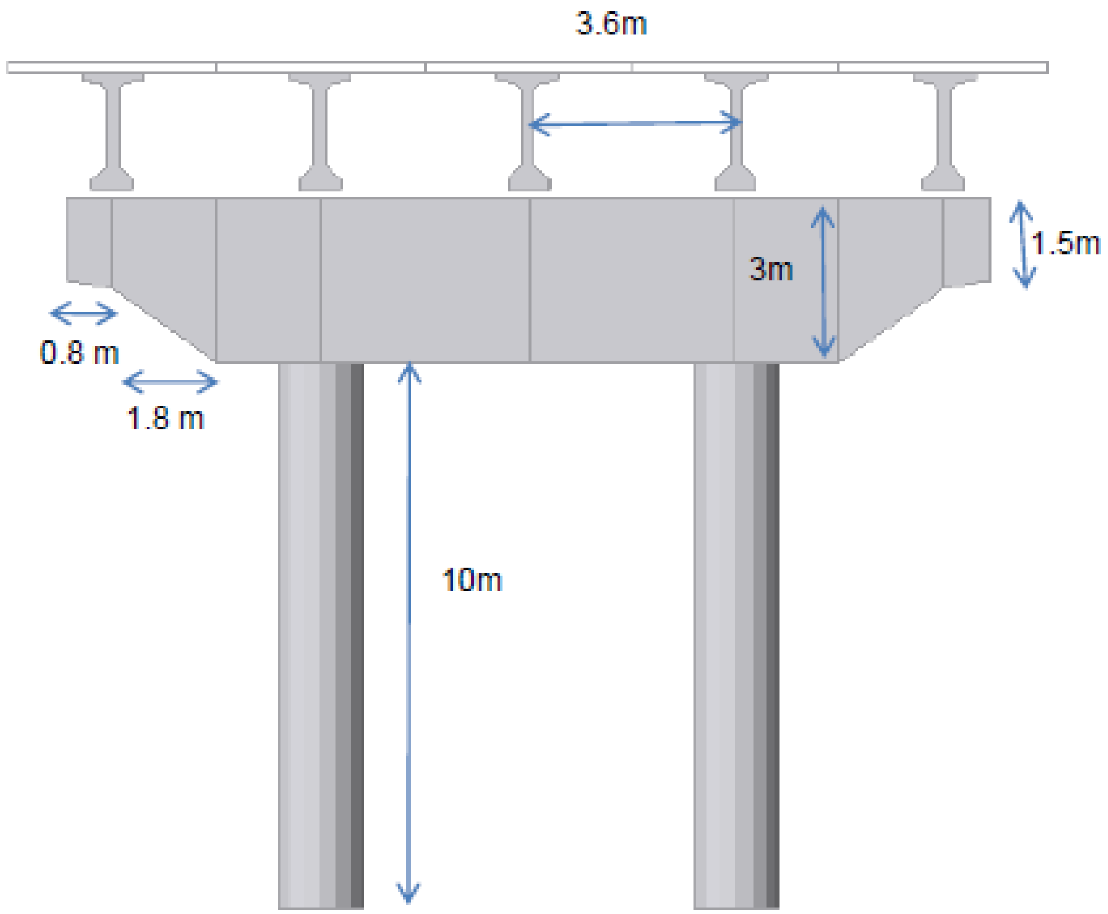
Pier modeling



Front View

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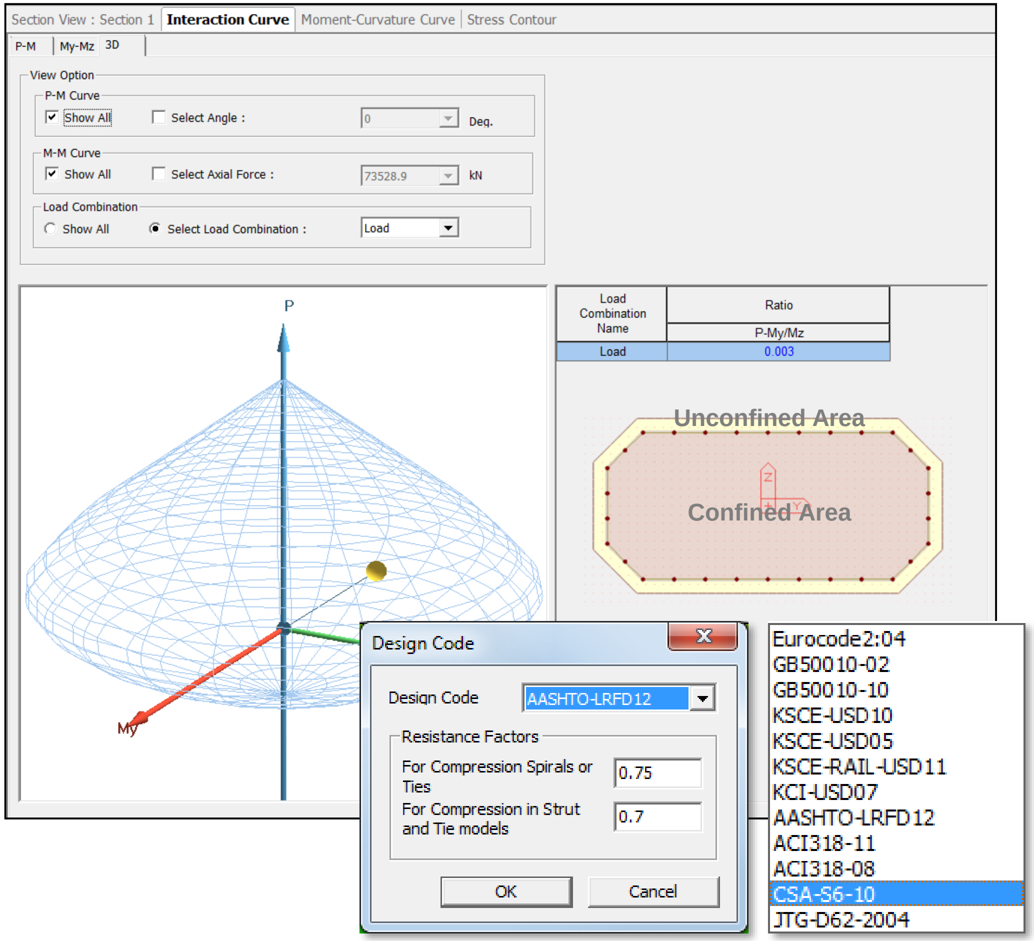
Pier Design Midas GSD

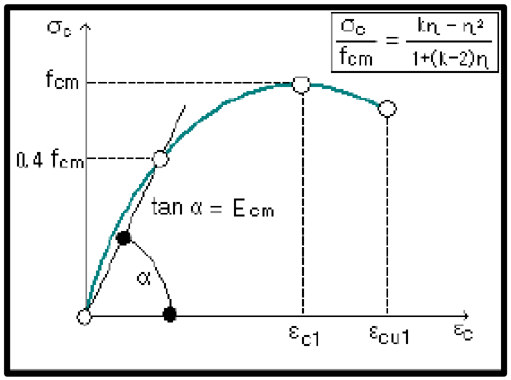
Pier modeling – Midas GSD

- Fiber Section for refined Dynamic Analysis
- Obtain PMM curve for Pier Design
- Check Pier Section for Cracking
- Obtain Moment Curvature Diagram

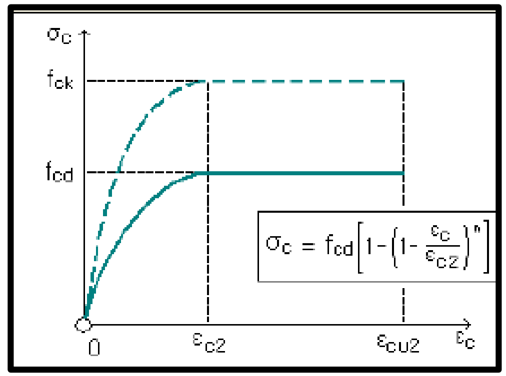


Pier modeling – Midas GSD

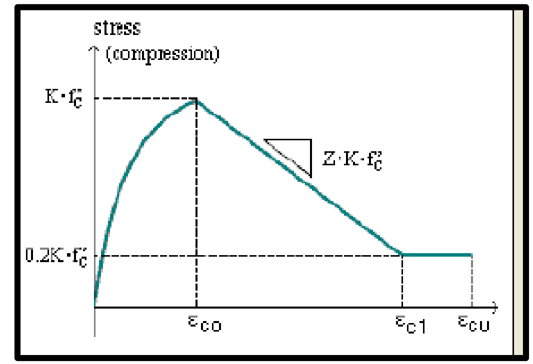
Concrete Nonlinear Properties



Parabolic stress-strain curve

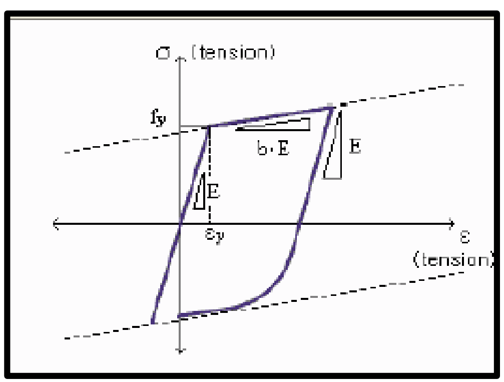


Parabola-rectangle

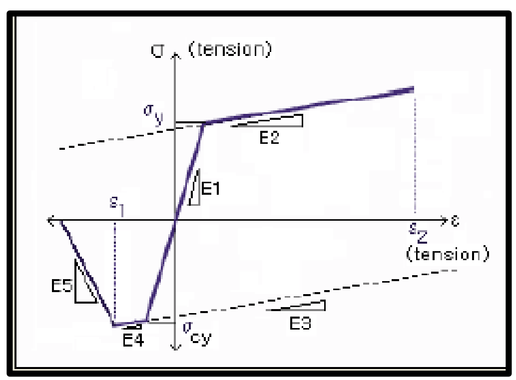


Kent & park model

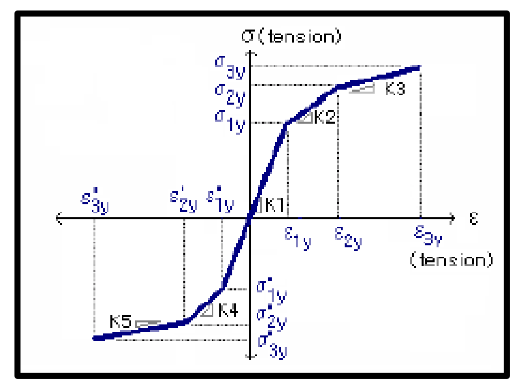
Steel Nonlinear Properties



Menegotto -Pinto



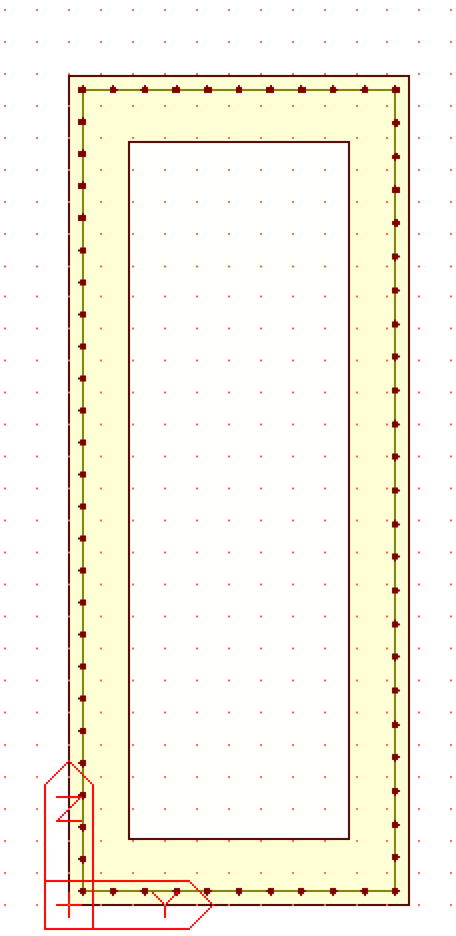
Asymmetric Bi-linear

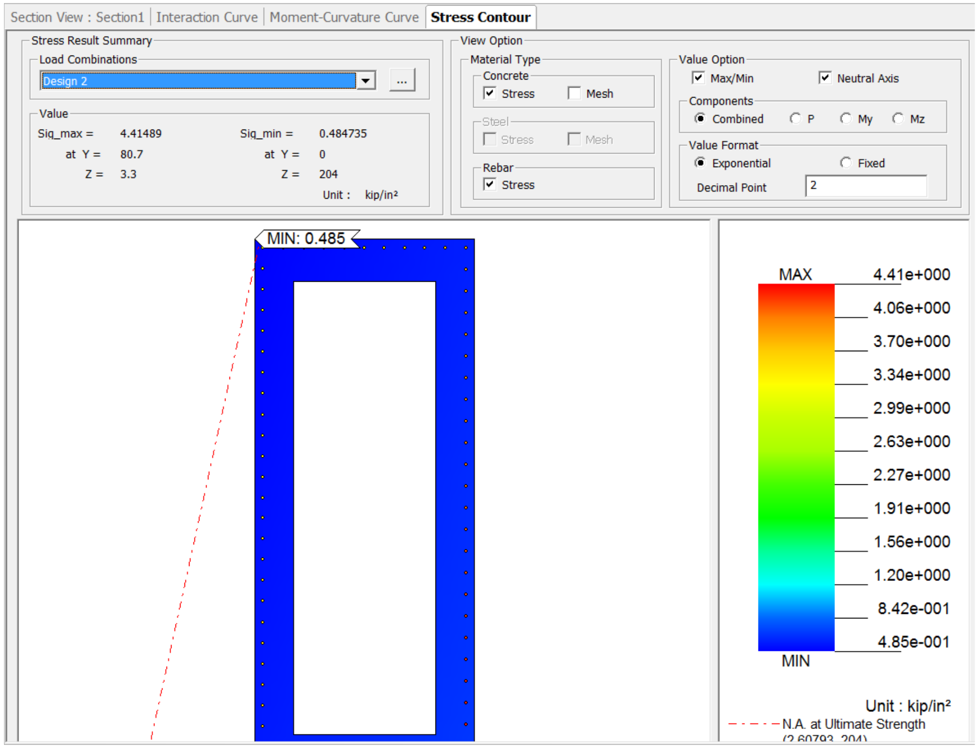


Tri-linear

Pier modeling – Midas GSD

Hollow Section





Bearing Modeling

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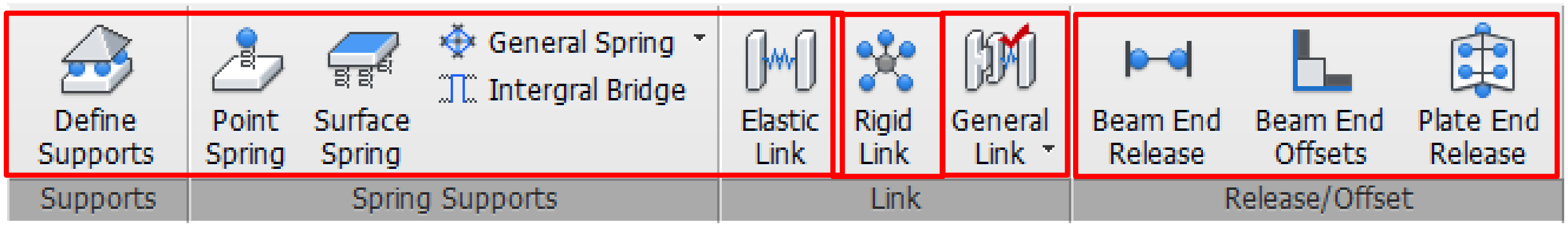
Boundary Conditions



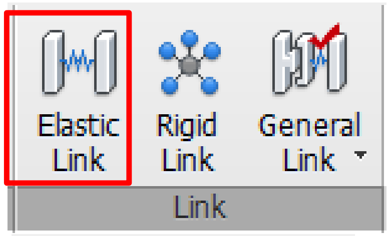
Nodal boundary conditions

- Constraint for degree of freedom (Supports)
- Elastic boundary element (Spring supports)
  - Point Spring Supports
  - Surface Spring Supports
  - General Spring Supports
- Elastic link element (Elastic Link)
- General Link element (General Link)
  - Element Type
  - Force Type

Element boundary conditions

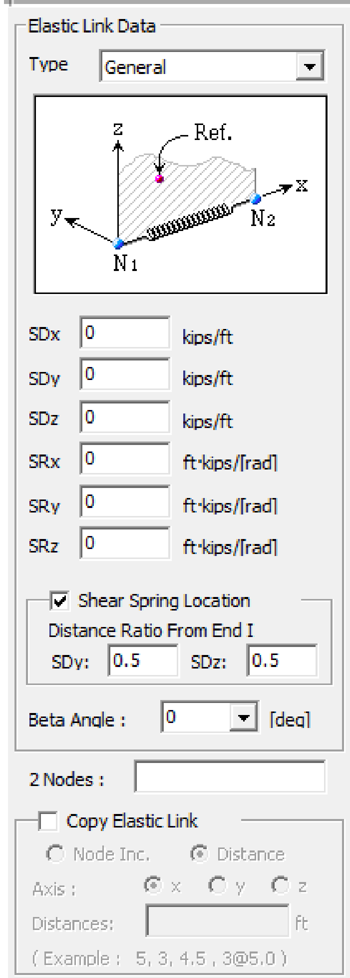
- Element End Release
  - Beam End Release
  - Plate End Release
- Rigid End Offset distance (Beam End Offset)
- Rigid Link

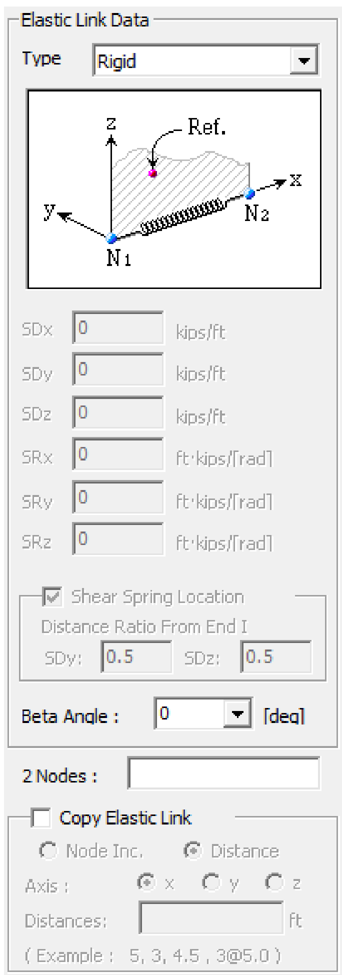
Boundary Conditions

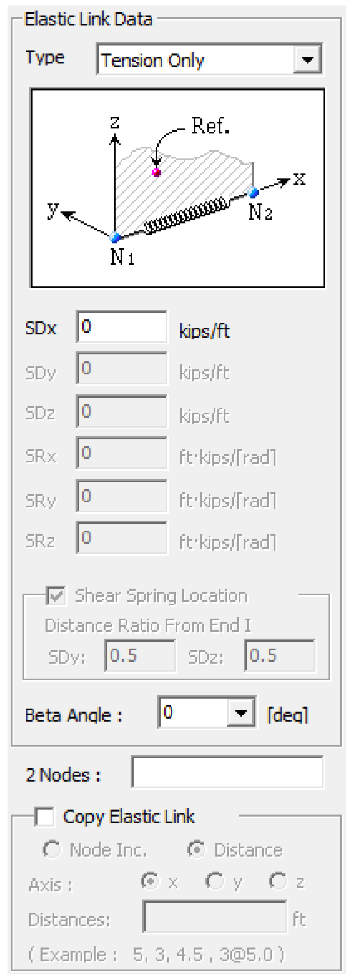


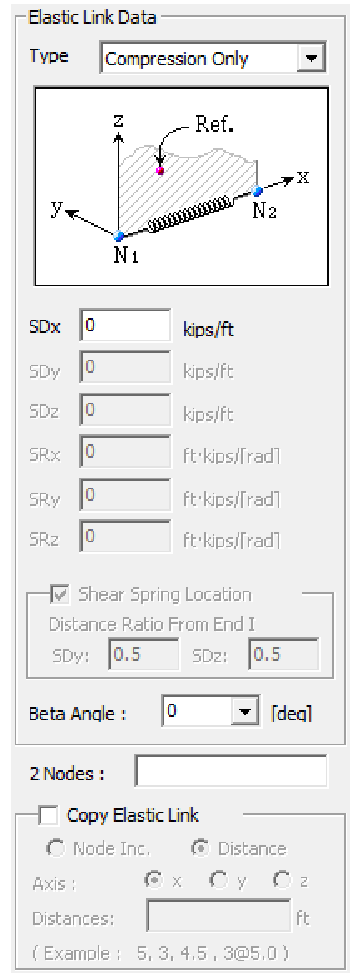
Usage

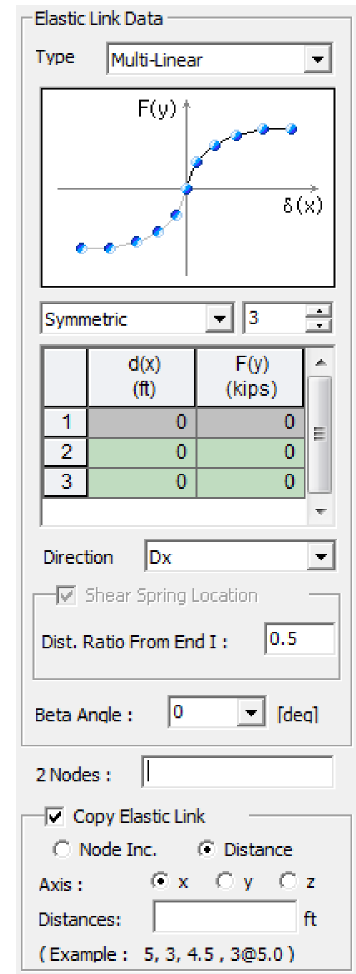
- Elastic bearings of a bridge structure, which separate the bridge deck from the piers.
- Compression-only Elastic link : the soil boundary conditions.
- Rigid Link : Connects two nodes with an “infinite” stiffness



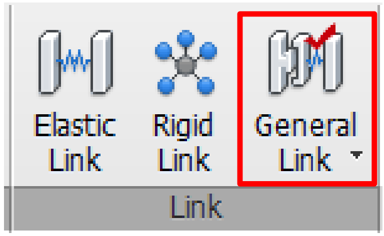






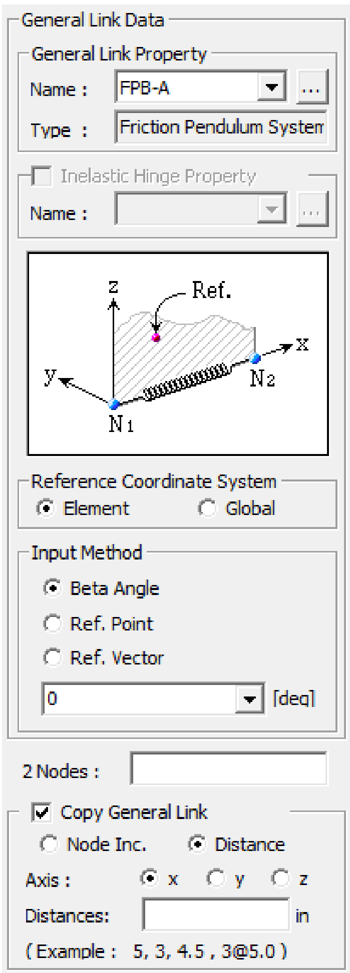


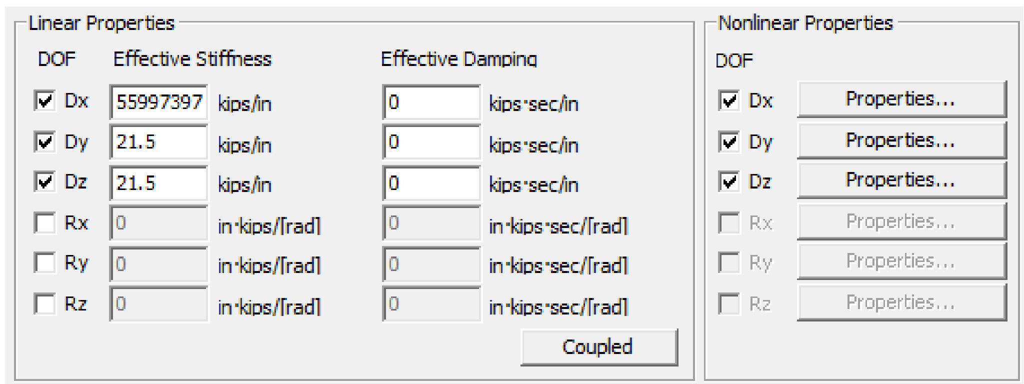
Boundary Conditions

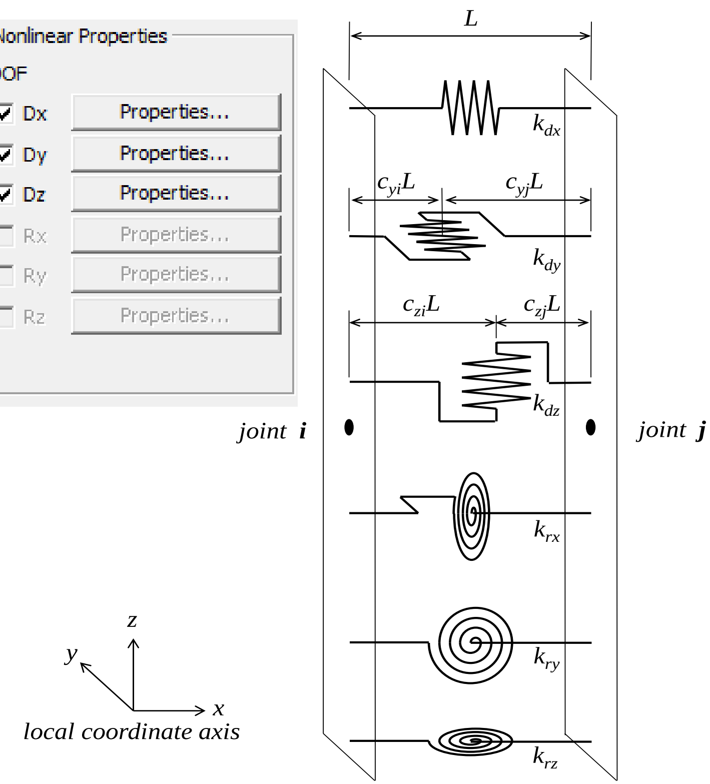


Usage

- Dampers, base isolators, compression-only element, tension-only element, plastic hinges, soil springs
- Used as linear and nonlinear elements
- Element type: Spring, Dashpot, Spring and Dashpot
- Force type: Viscoelastic Damper, Hysteretic System, Seismic isolators (Lead Rubber Bearing Isolator, Friction Pendulum System Isolator)







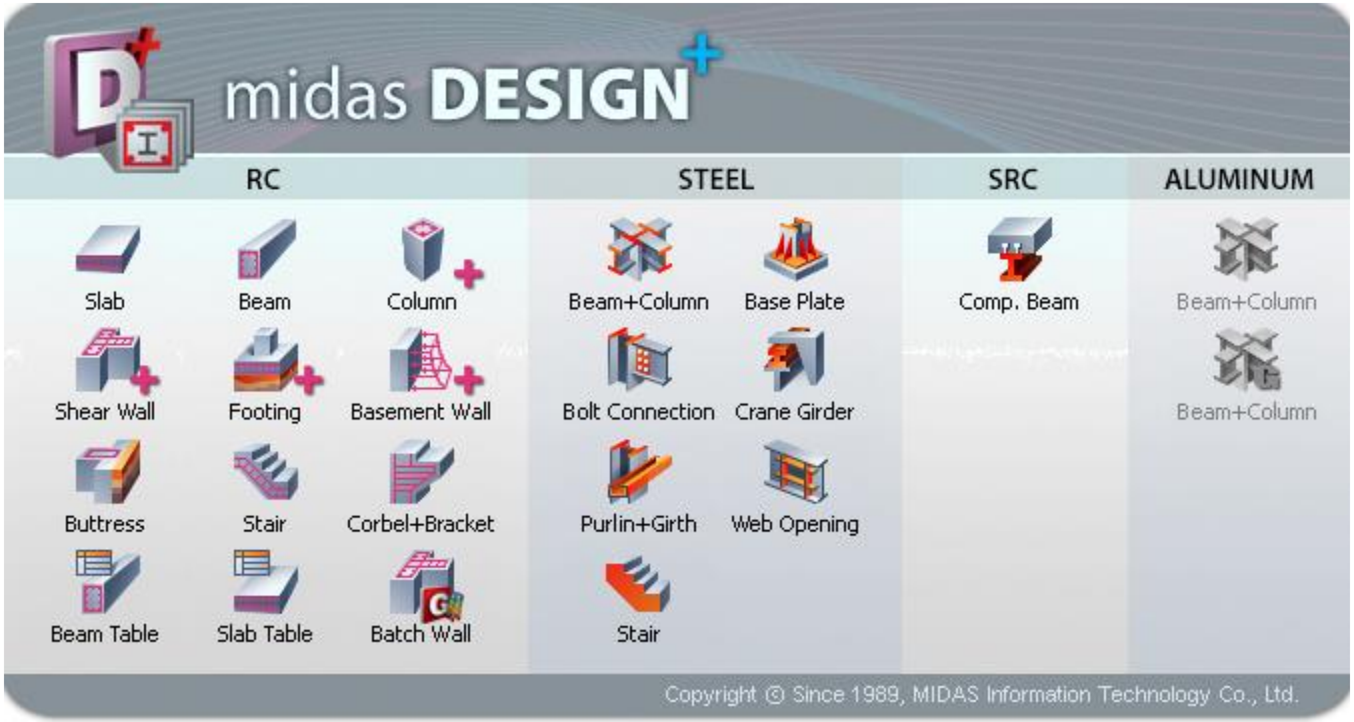
Isolated Footing

Midas Training Series

midas Civil

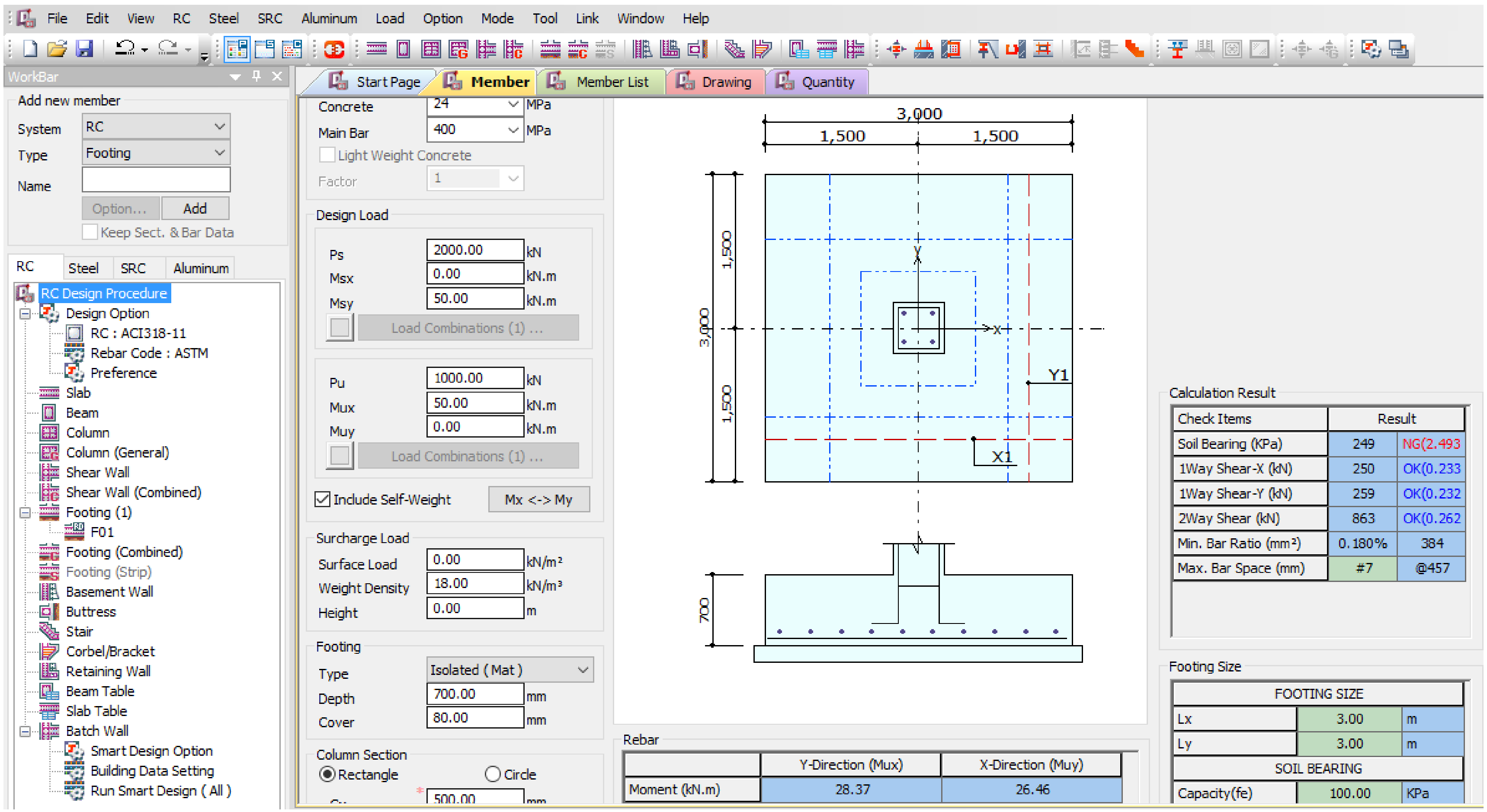
2016

Midas Design+ - Isolated Footing



Midas Training Series

Midas Design+ - Isolated Footing



MIDAS Technical Support

http://globalsupport.midasuser.com/

Thank you