United States Department of Agriculture

Reinforced Concrete Wall Design Basics

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Natural Resources
Conservation Service

Structural Concrete Design Requirements

- “American Concrete Institute Building Code Requirements for Structural Concrete (ACI 318)” which is referenced in NRCS Conservation Practice Standard 313 – Waste Storage Facility.

Typical Structural Concrete Wall Loadings

- Lateral Soil Backfill Loads (depends on soils type)
- Lateral Equipment Loads
- Vertical Wall Loads (structural slab or push-off ramp bearing on top of wall)
- Lateral Manure Loads

Structural Loadings

Common External Loadings

- ✓ Backfill pressure
- ✓ Equipment Loads

Common Internal Loadings

- ✓ Manure Fluid Pressure

Other Loadings to Consider

- ✓ Impact Loads
- ✓ Hydrostatic Pressure (Lateral and Uplift)
- ✓ Internal Ice Pressures (Lateral)
- ✓ Frost Pressure (Lateral and Uplift)

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STABILITY VS. STRENGTH DESIGN

- **STABILITY DESIGN**
  - ✓ OVERTURNING
  - ✓ SLIDING
  - ✓ BEARING PRESSURE

STABILITY DESIGN USES ACTUAL LOADS AND SAFETY FACTORS AND ASSUMES THE WALL AND FOOTING ARE INFINITELY STIFF

STABILITY VS. STRENGTH DESIGN

- **STRENGTH DESIGN**
  - ✓ BENDING
  - ✓ SHEAR
  - ✓ (TORSION)
  - ✓ (BUCKLING)

STRENGTH DESIGN USES:

- **LOAD FACTORS AND**
- **STRENGTH REDUCTION FACTORS**

RATHER THAN "SAFETY FACTORS"

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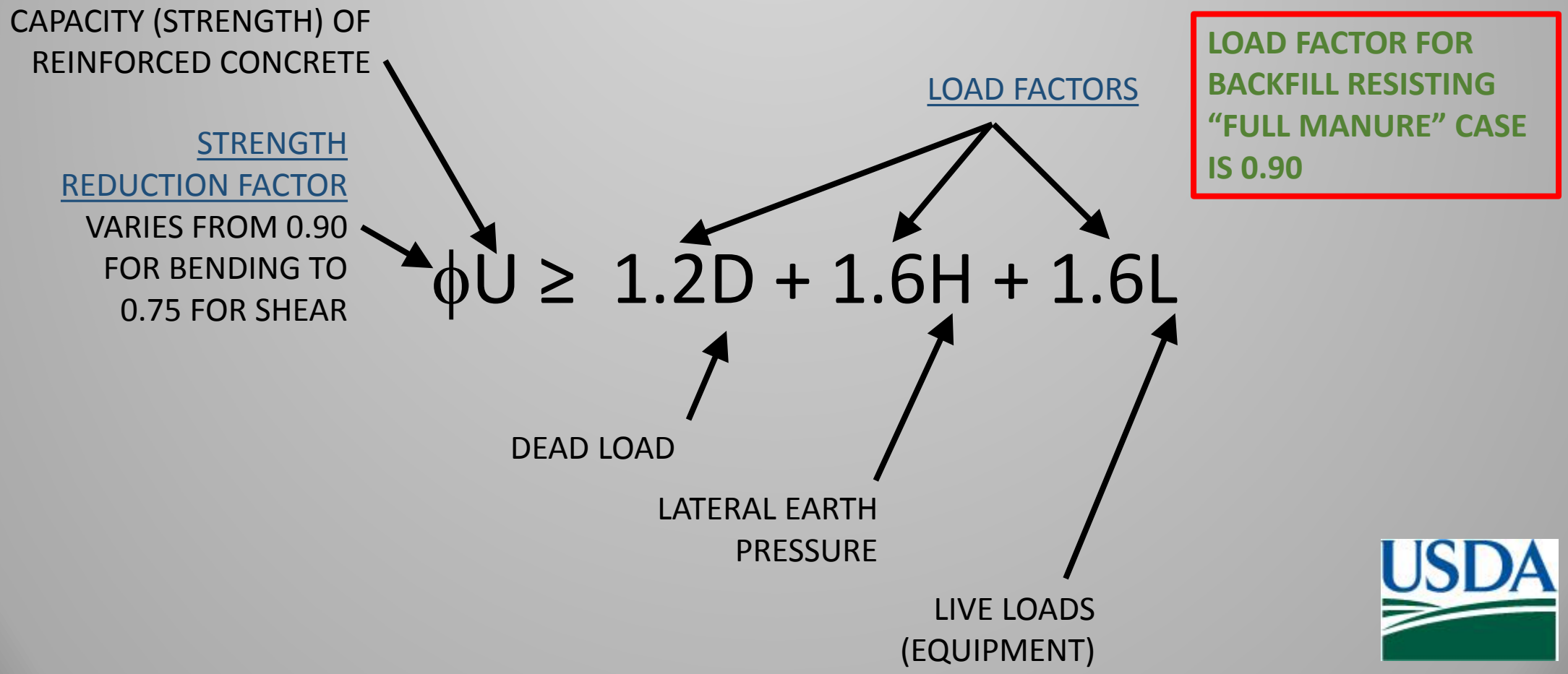
STRENGTH DESIGN

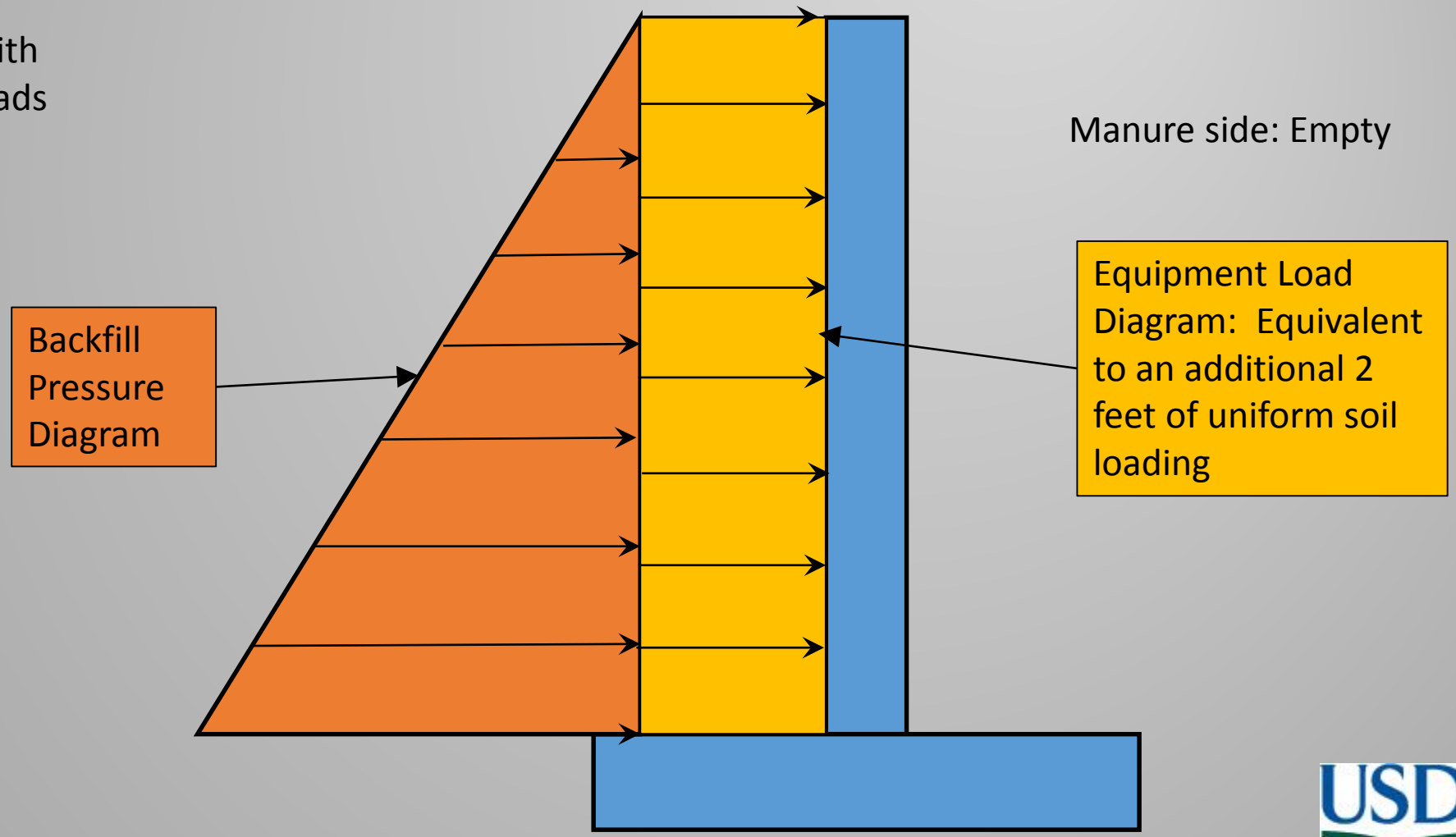
EXAMPLE OF ONE FACTORED LOAD COMBINATION



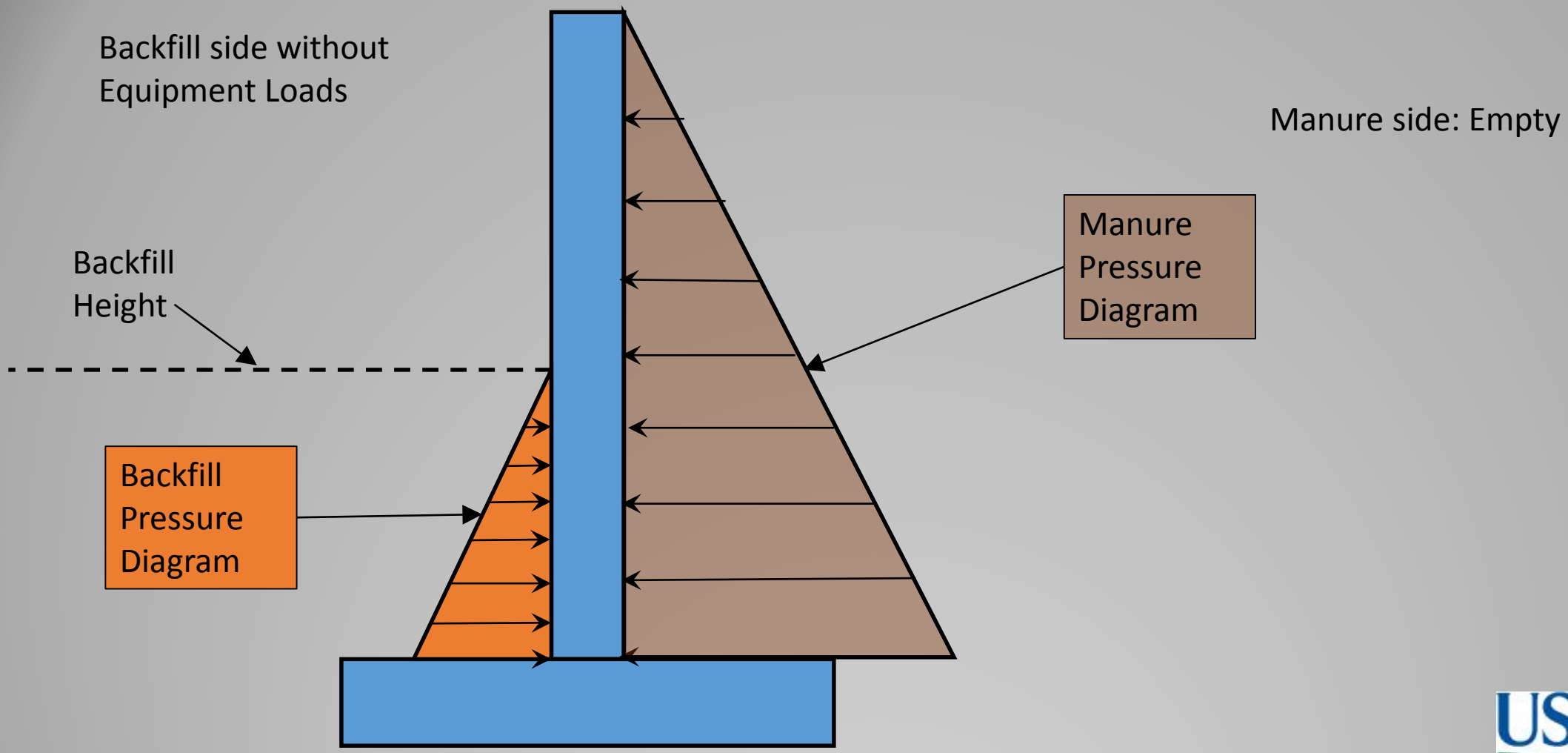
LOAD SCENARIO 1: MAXIMUM EXTERNAL LOADS AND EMPTY INSIDE

Backfill side with Equipment Loads

Manure side: Empty

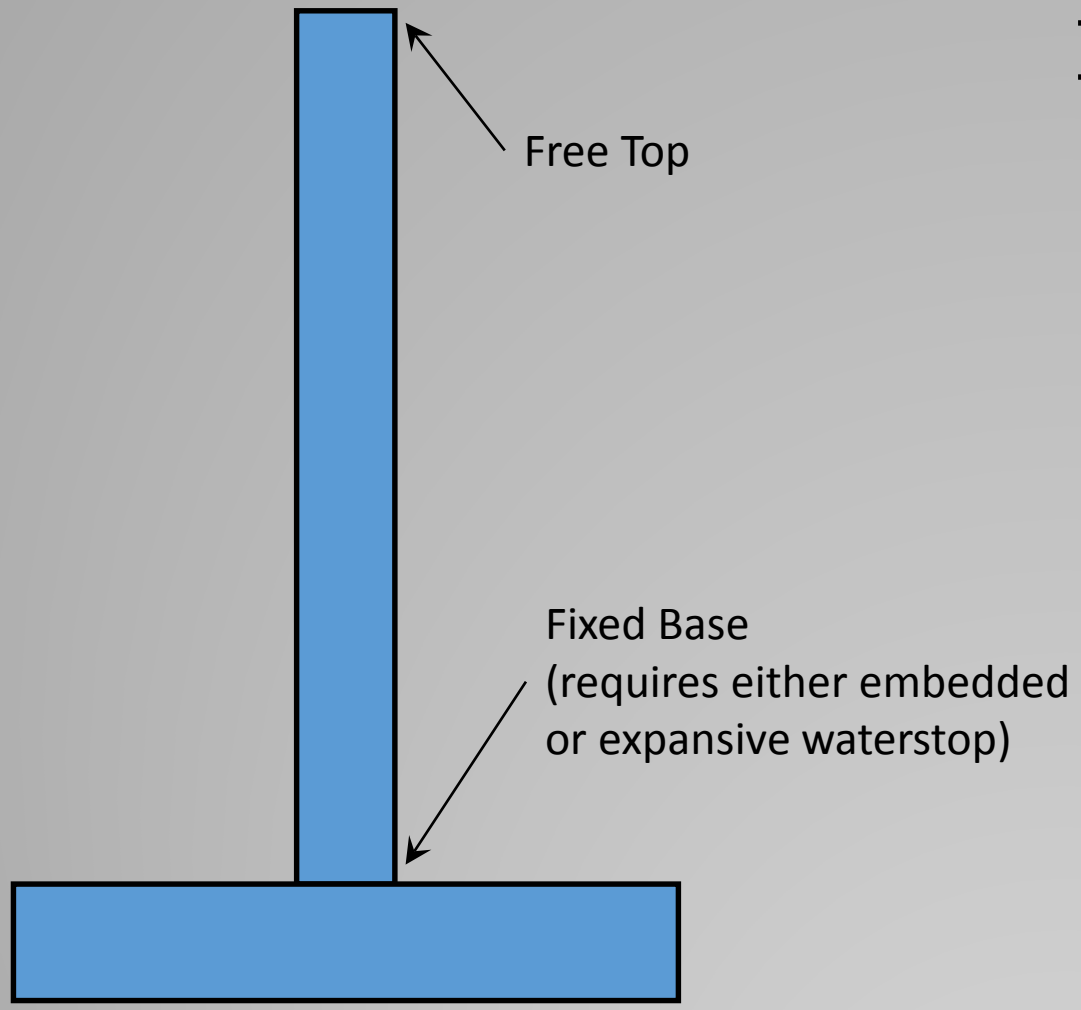


LOAD SCENARIO 2: FULL INSIDE WITH MINIMUM BACKFILL

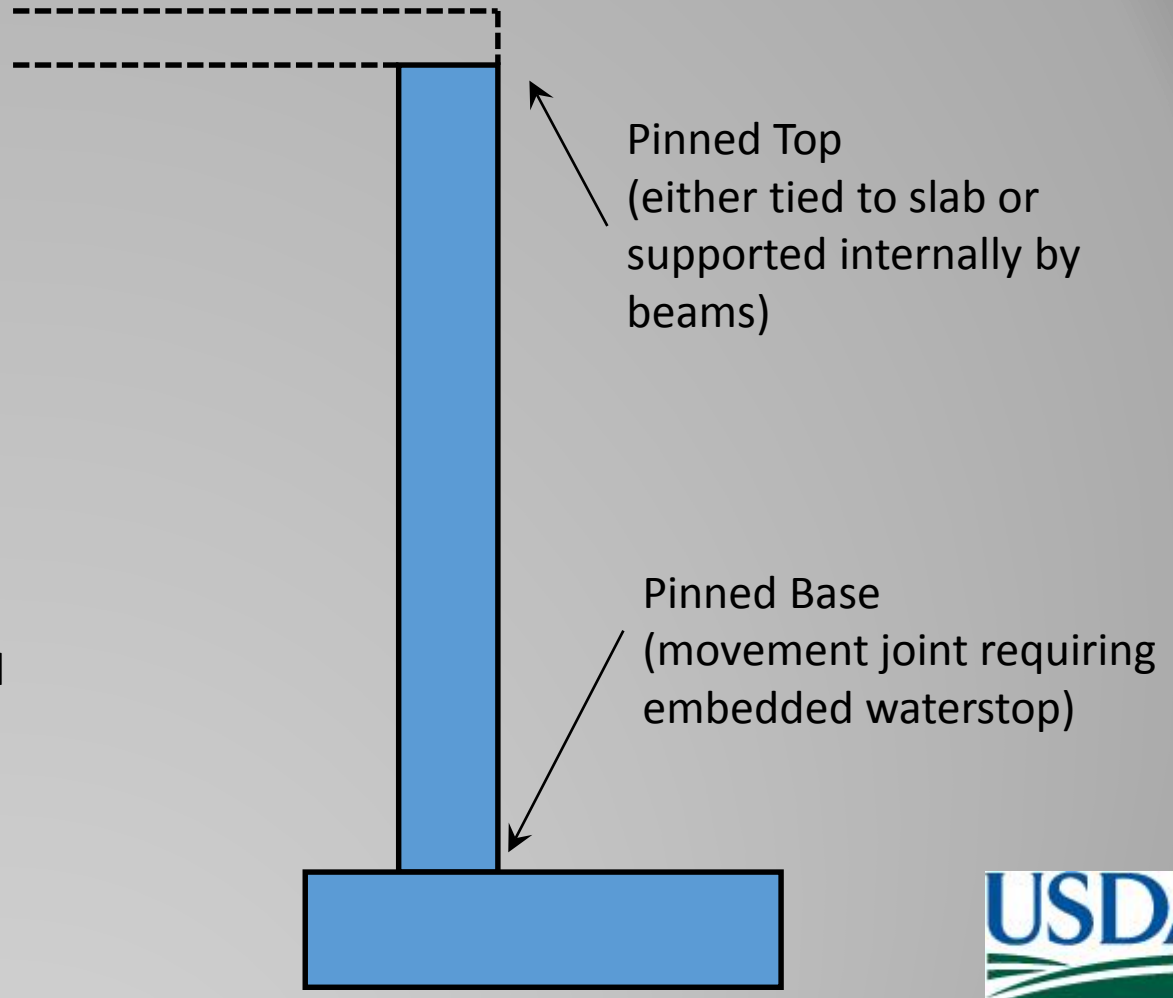


WALL SUPPORT

Cantilevered Wall



Simply Supported Wall
(740 Drawing Series Tanks)



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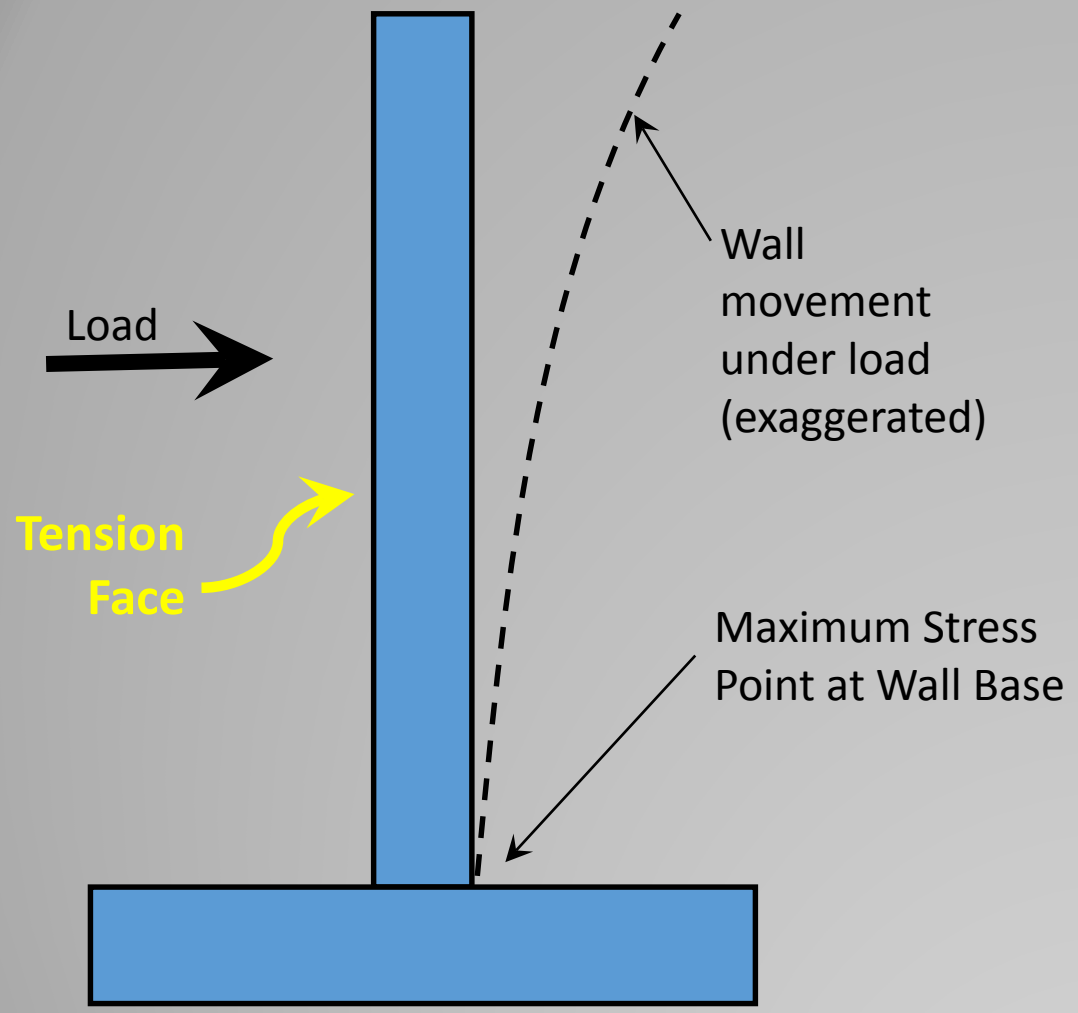
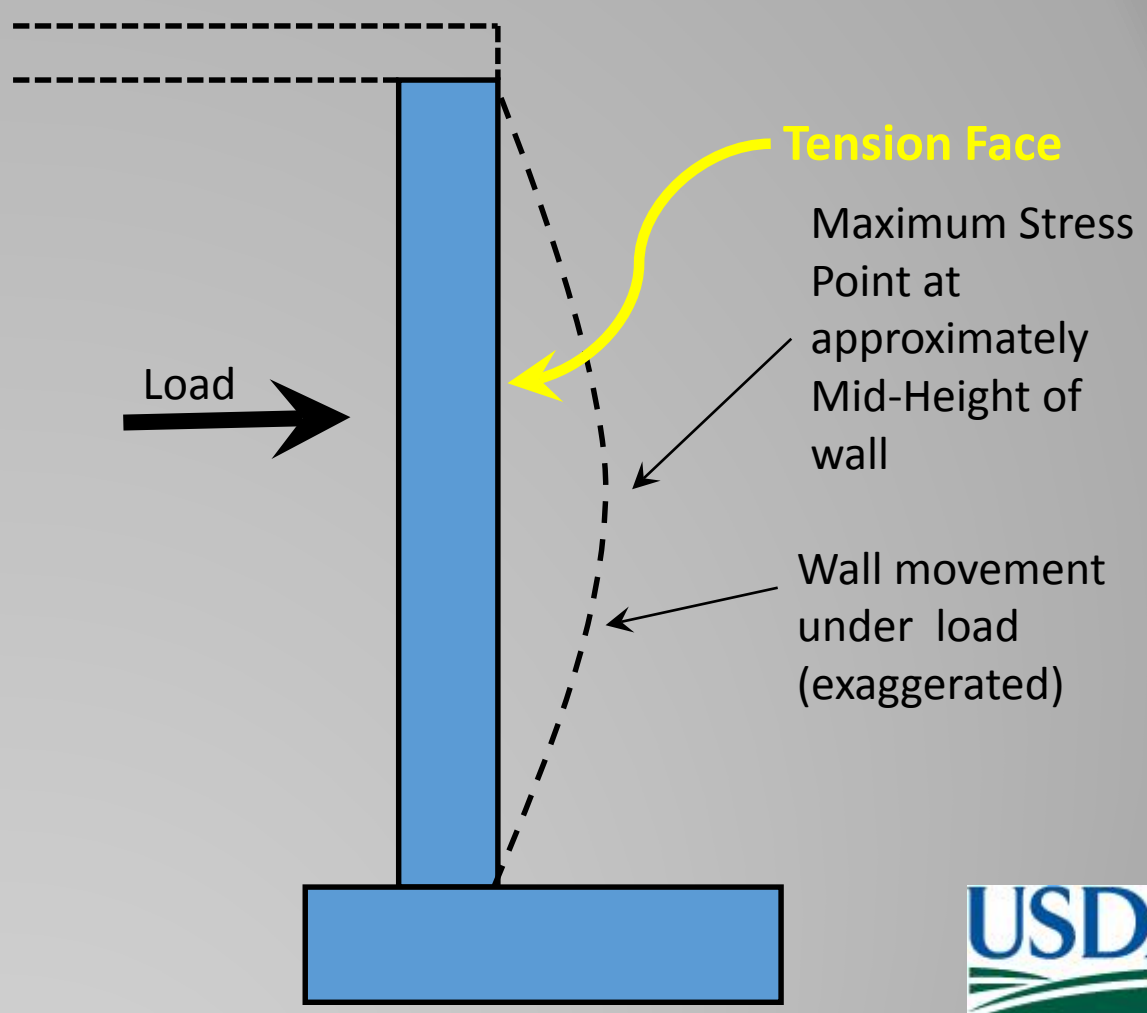
MAXIMUM BENDING STRESSES IN WALL STEM

Cantilevered Wall



Simply Supported Wall



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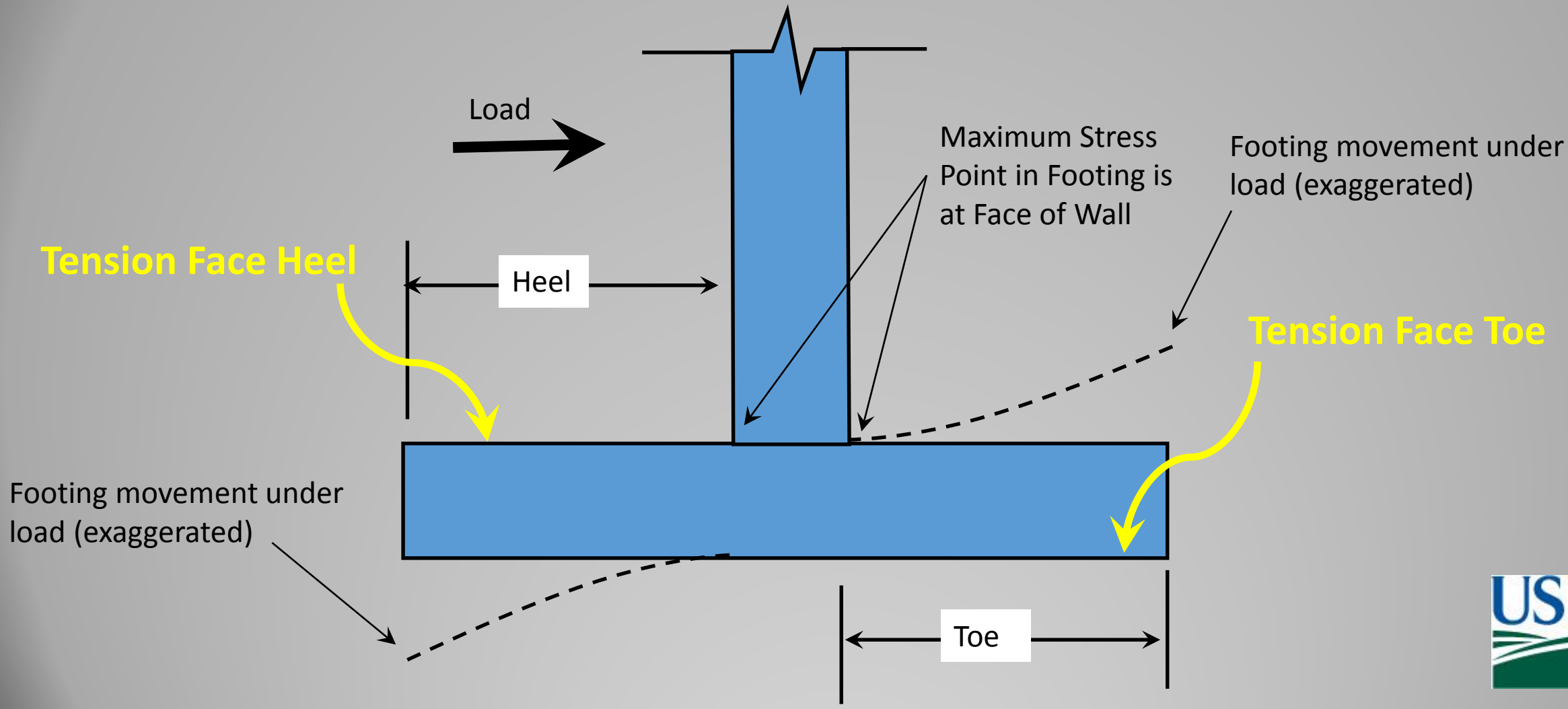
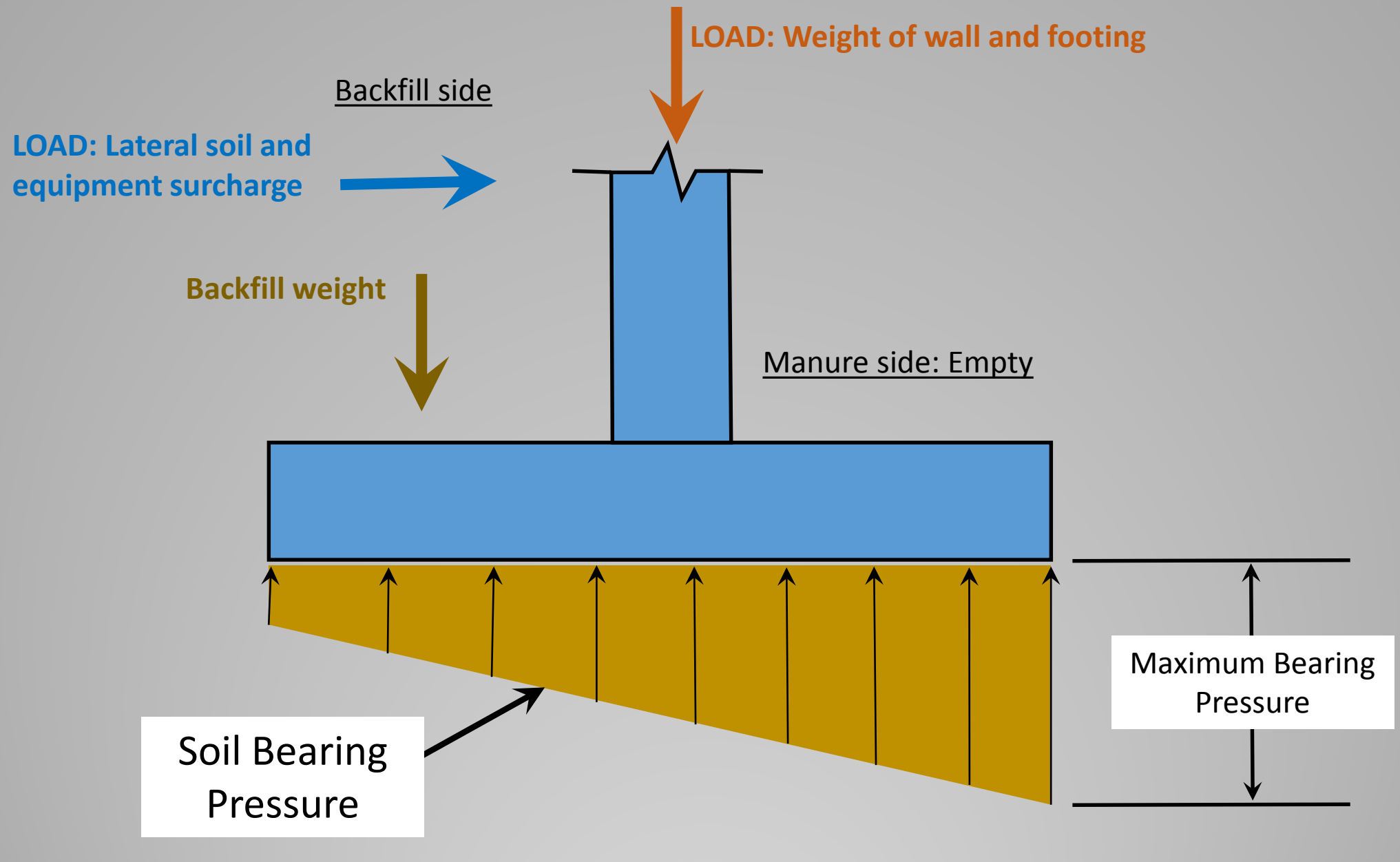
MAXIMUM BENDING STRESSES IN FOOTINGS

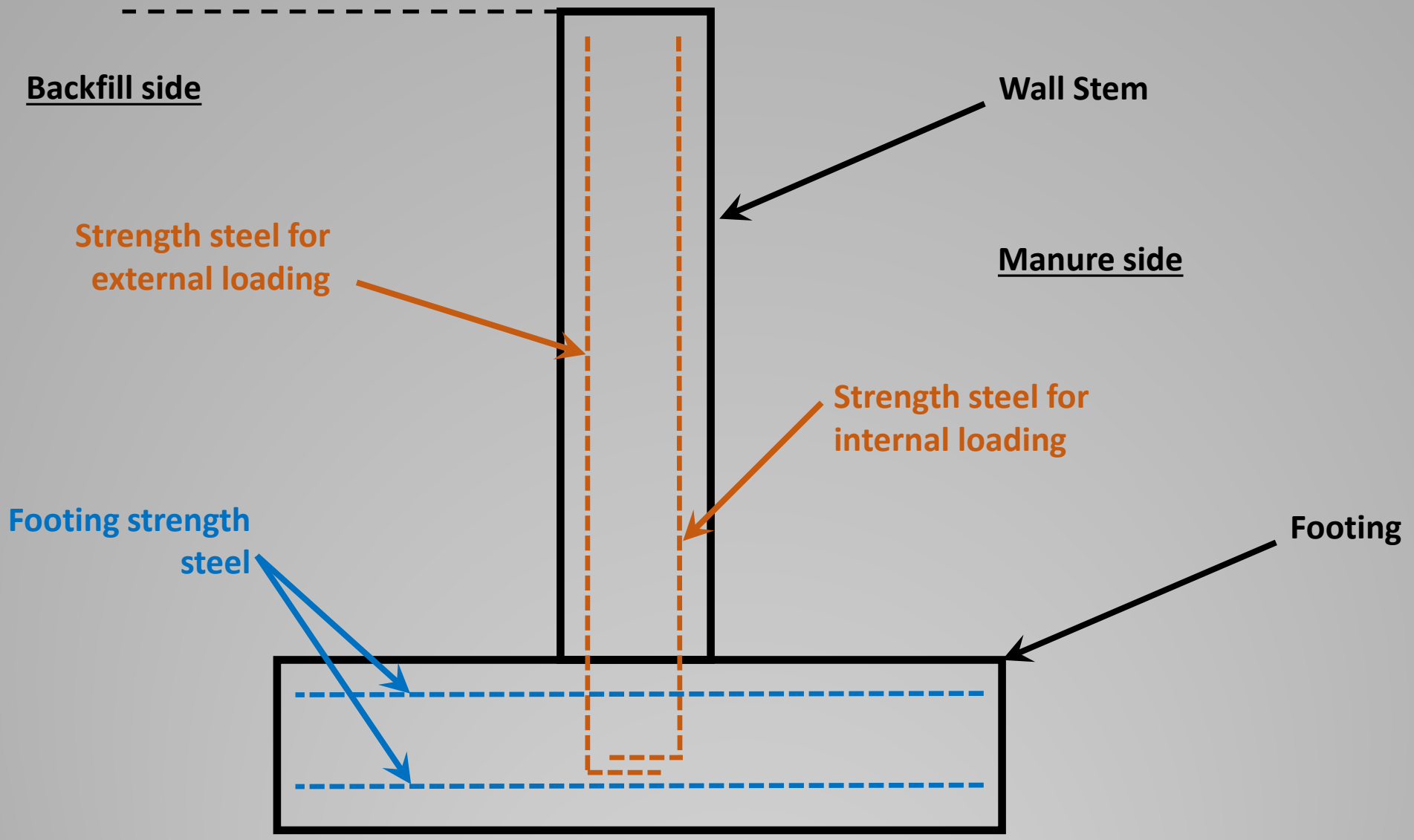
Cantilevered Wall
(Fixed Base)



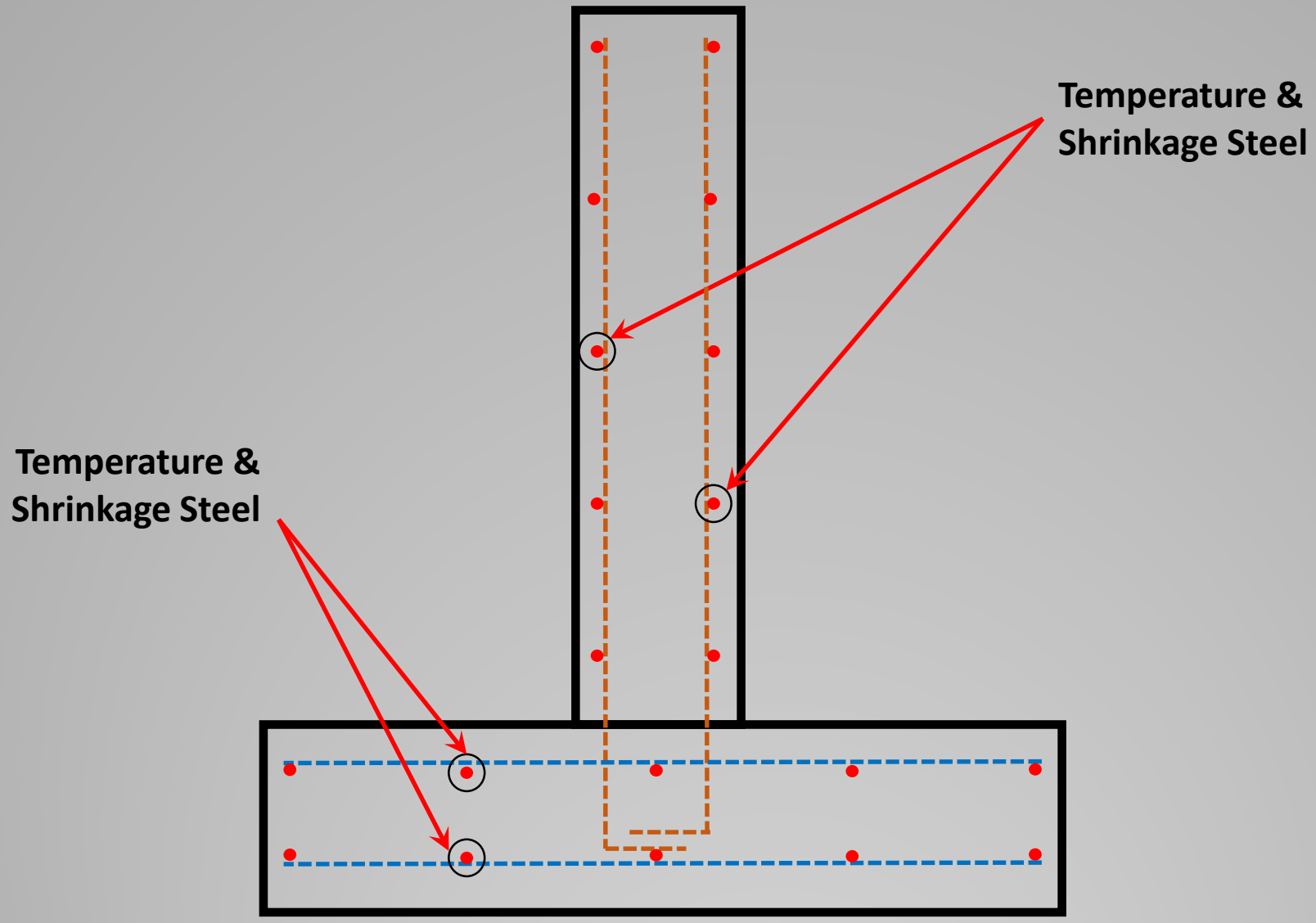
FOOTING BEARING PRESSURE



STRENGTH STEEL – CANTILEVERED "T" WALL



HORIZONTAL STEEL (Temperature and Shrinkage Steel)



STRENGTH OF REINFORCED CONCRETE SECTIONS

What Determines the Strength of a Reinforced Concrete Section (rebar and concrete acting together) ?

- 28 day compressive strength of concrete ($\mathbf{f'_c}$)
  3,500 or 4,000 psi minimum
- Grade of Rebar ($\mathbf{f_y}$)
  Usually Grade 60 (60,000 psi yield strength)
- Amount of rebar ($\mathbf{A_s}$)
  (size and spacing)
- Location of Rebar relative to compressive face of concrete (**d**)

Let's take a look at these in a little more detail and see what happens if the parameters for a particular design are not met

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STRENGTH OF REINFORCED CONCRETE SECTIONS

- ✓ 28 day compressive strength of concrete (f'_c)

  If the concrete strength requirements are not met:

  - Durability will be affected
  - Possibly failure under high loads, particularly in the long term when water (freeze-thaw) have deteriorated the sand/cement matrix of the concrete.

STRENGTH OF REINFORCED CONCRETE SECTIONS

- ✓ Grade of Rebar ($\mathbf{f_y}$)

The project calls for **Grade 60 and Grade 40 is used**:

Example: 10” thick wall
3500 psi concrete
2.5” clear to strength steel
#5@10

BENDING STRENGTH OF THE SECTION HAS BEEN REDUCED BY OVER 30%

STRENGTH OF REINFORCED CONCRETE SECTIONS

- ✓ Amount of rebar (A_s)

The project calls for **#5@10”** and **#5@12”** are used:

Example: 10” thick wall
3500 psi concrete
2.5” clear to strength steel
#5@12” rather than the designed #5@10”

BENDING STRENGTH OF THE SECTION HAS BEEN REDUCED BY ABOUT 16%

LET'S TRY THAT AGAIN A LITTLE DIFFERENTLY

- ✓ Amount of rebar (A_s)

The project calls for **#5@10"** and **#4@10"** are used:

Example: 10" thick wall
3500 psi concrete
2.5" clear to strength steel
#4@10" rather than the designed #5@ 10"

BENDING STRENGTH OF THE SECTION HAS BEEN REDUCED BY ABOUT 35%

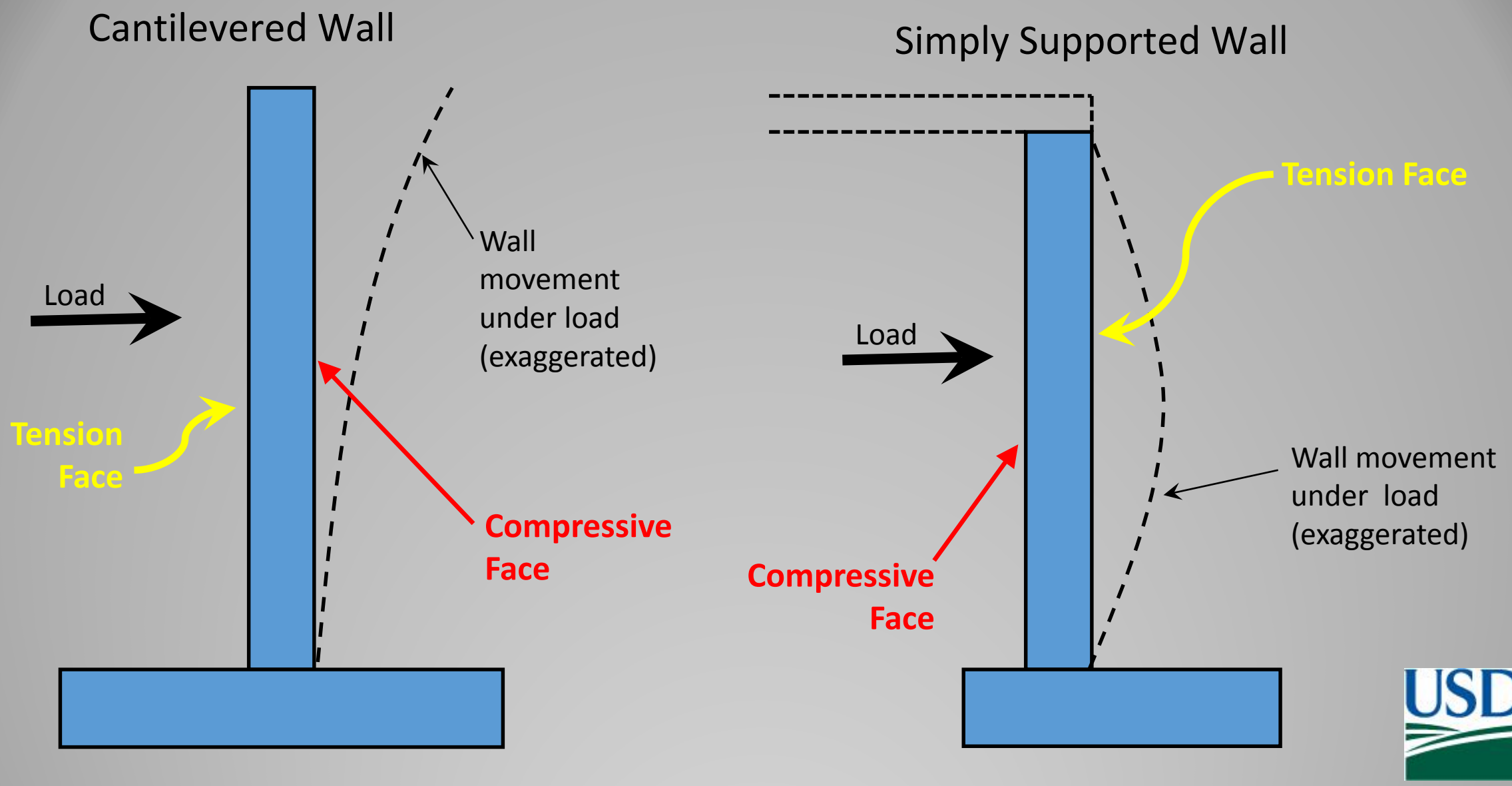
STRENGTH OF REINFORCED CONCRETE SECTIONS

- ✓ Location of Strength Rebar relative to compressive face of concrete (d)

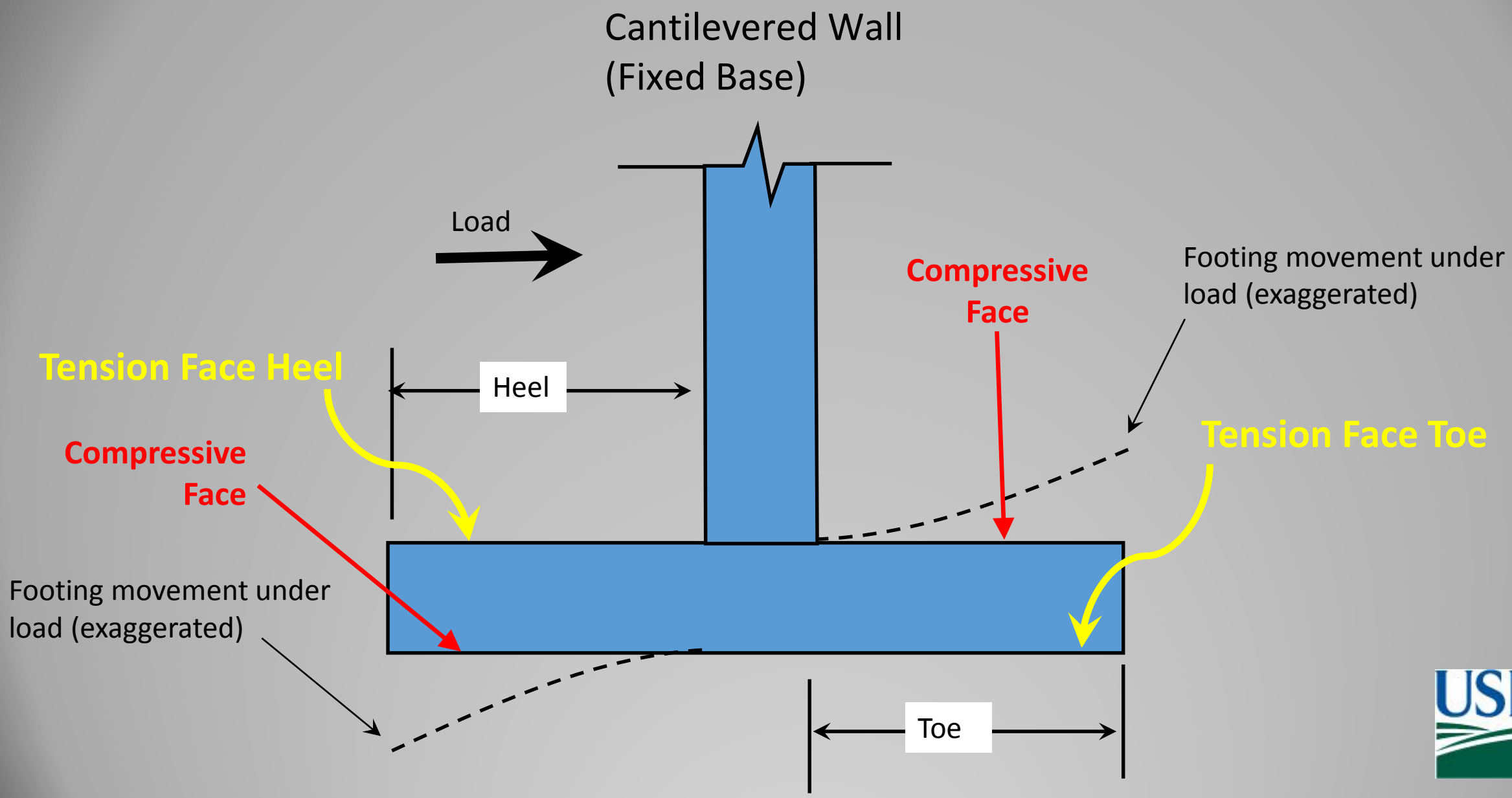
  What does “compressive face” mean?

  What does “strength rebar” mean?

COMPRESSIVE FACE & STRENGTH REBAR

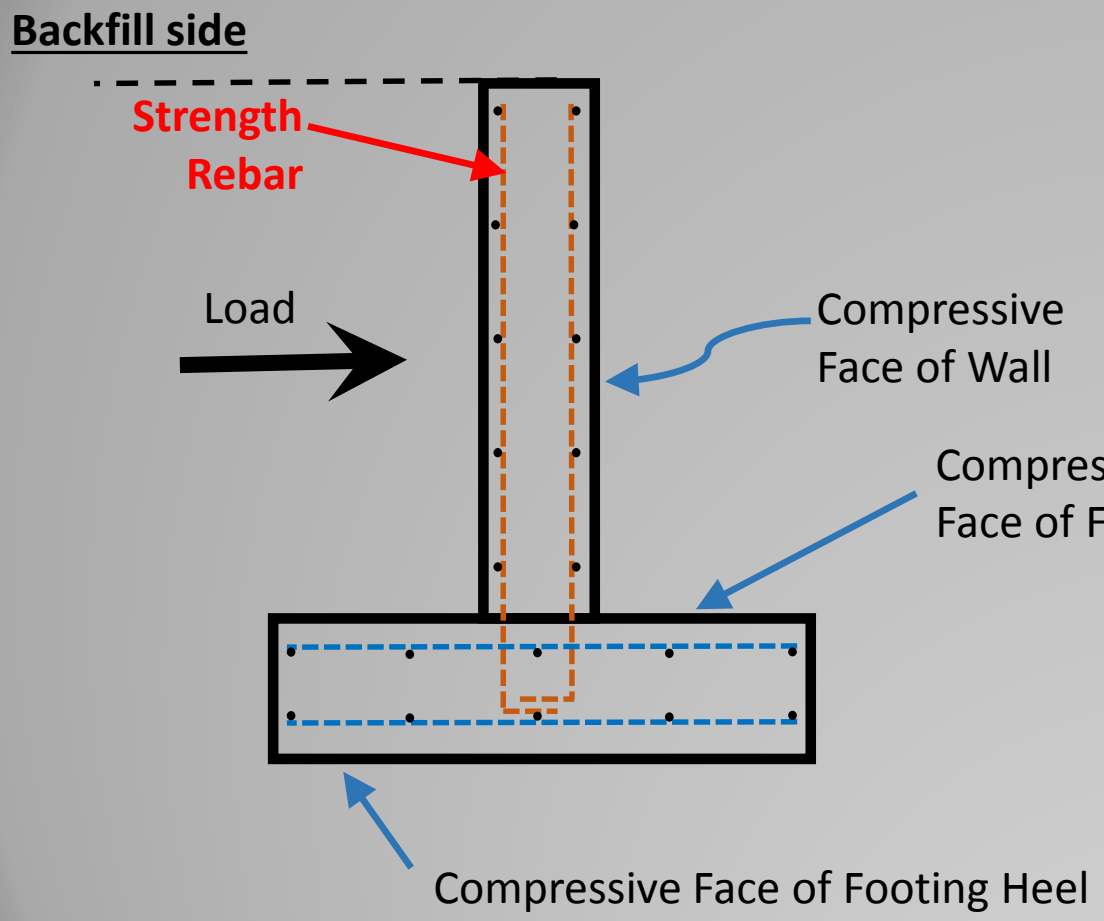


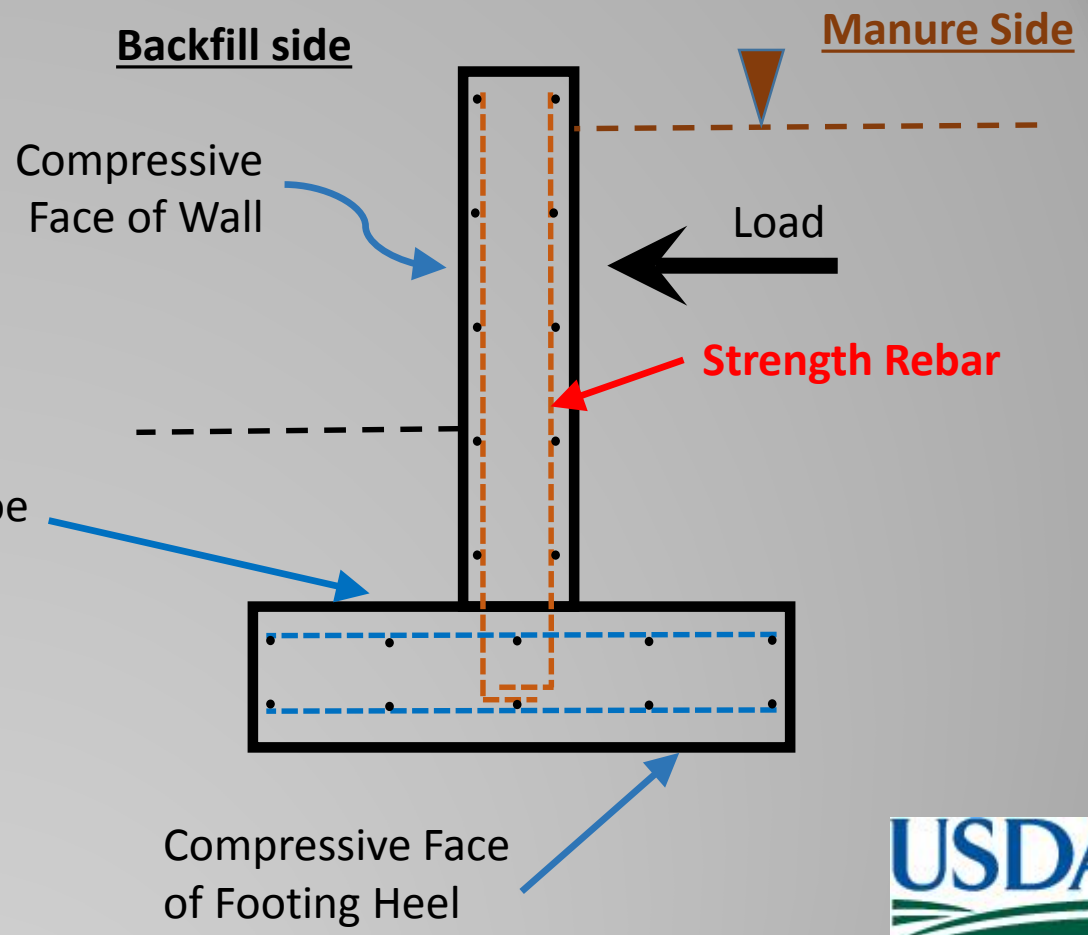
COMPRESSIVE FACE & STRENGTH REBAR



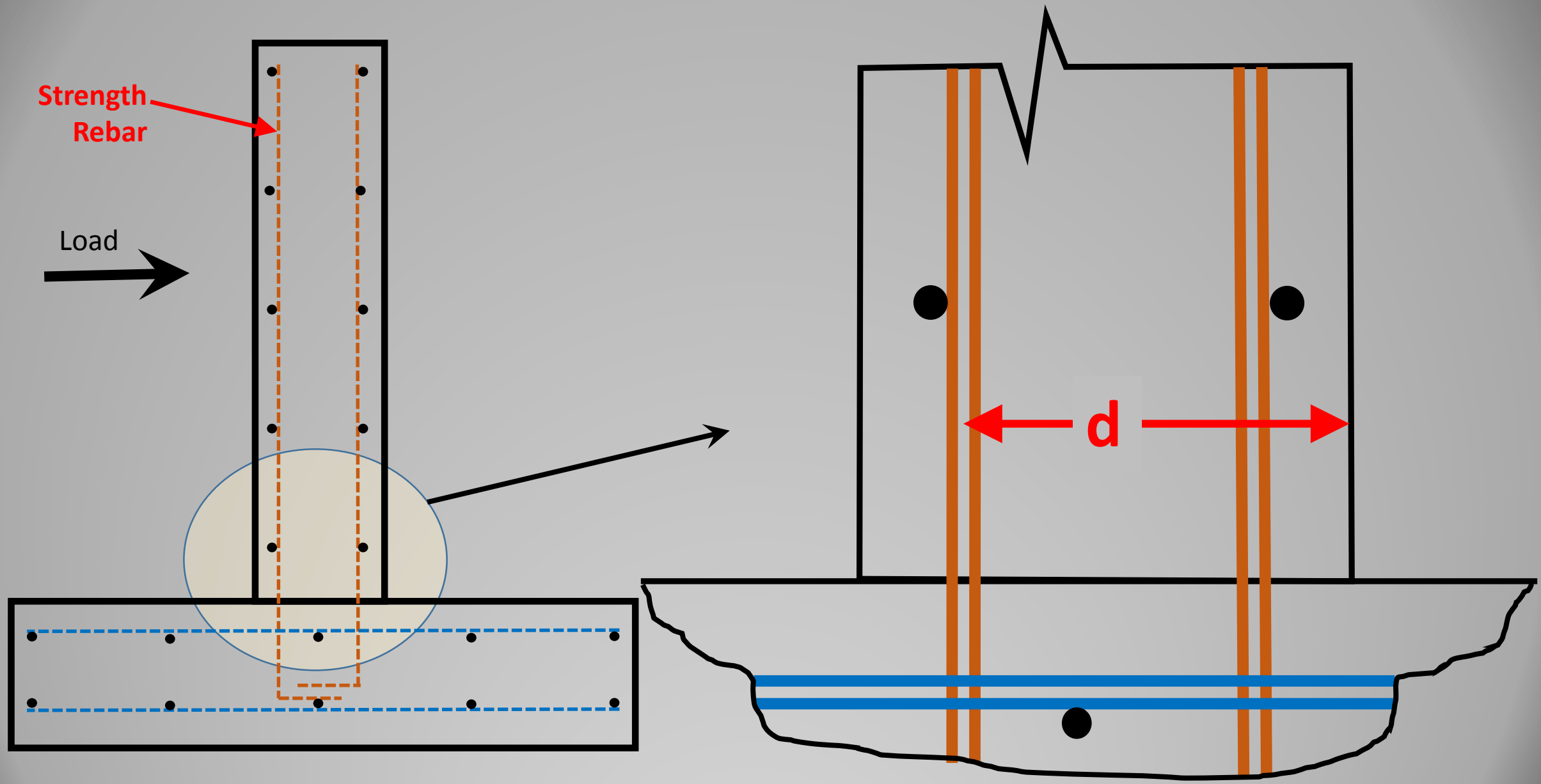
COMPRESSIVE FACE & STRENGTH REBAR

Cantilevered Wall



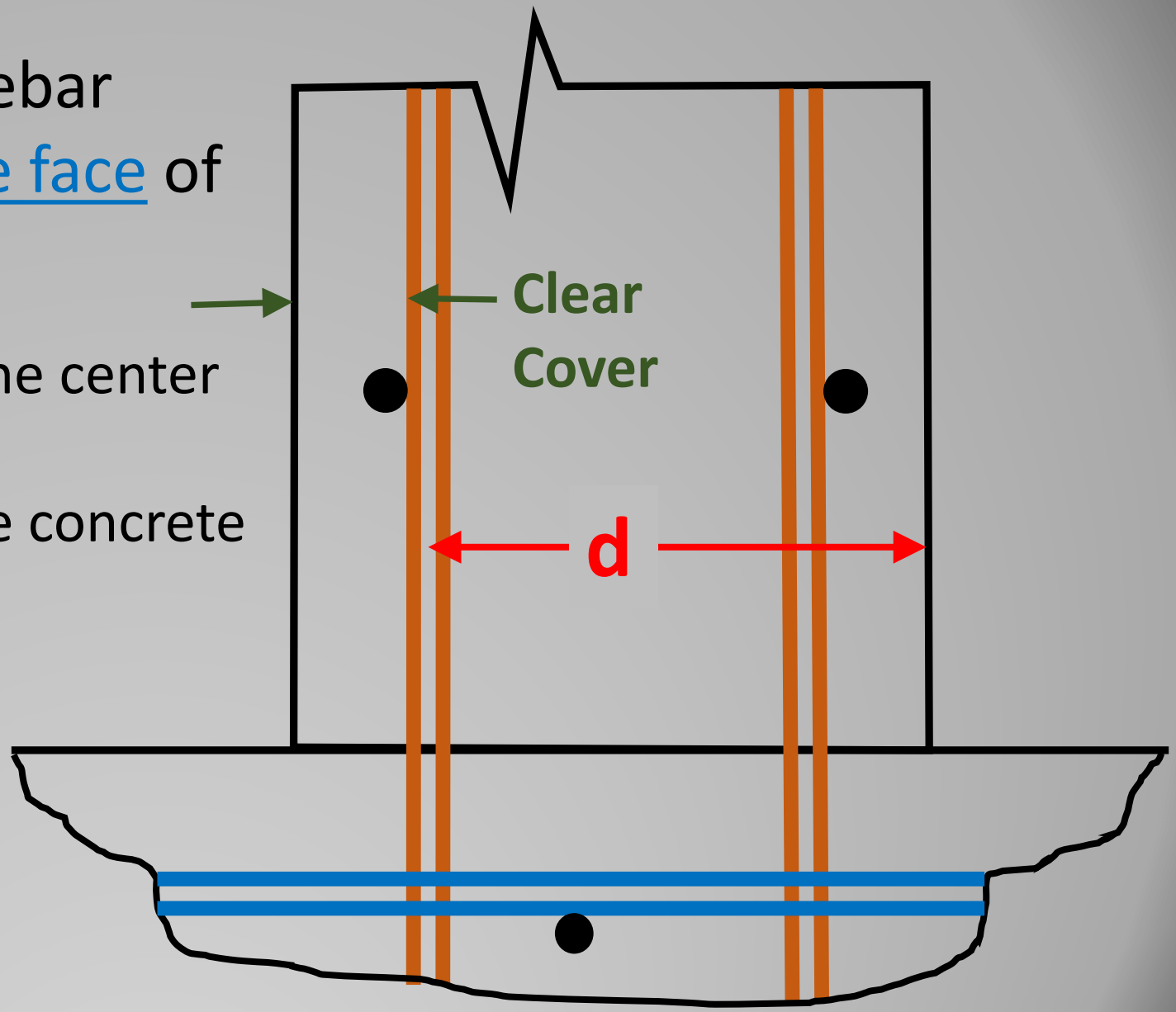


STRENGTH OF REINFORCED CONCRETE SECTIONS



STRENGTH OF REINFORCED CONCRETE SECTIONS

- ✓ Location of Strength Rebar relative to compressive face of concrete (d)
  - ➢ "d" is measured from the center of strength steel to the compression face of the concrete
  - ➢ "clear cover" is measured from the tension face of the concrete to the surface of the "strength" steel



STRENGTH OF REINFORCED CONCRETE SECTIONS

- ✓ Location of Strength Rebar relative to compressive face of concrete (d)

  The project calls for **clear cover of 2 inches** and the strength steel is installed with a **clear cover of 3 inches**:

  Example: 10” thick wall
  3500 psi concrete
  #5@10
  3” clear rather than the designed 2” clear

  BENDING STRENGTH OF THE SECTION HAS BEEN REDUCED BY ABOUT 15%

  SHEAR STRENGTH AT WALL BASE HAS BEEN REDUCED BY ABOUT 14%

SUMMARY
STRENGTH OF REINFORCED CONCRETE SECTIONS

- 28 day compressive strength of concrete ($\mathbf{f'_c}$)
  3,500 or 4,000 psi minimum
- Grade of Rebar ($\mathbf{f_y}$)
  Usually Grade 60 (60,000 psi yield strength)
- Amount of rebar ($\mathbf{A_s}$)
  (size and spacing)
- Location of Rebar relative to compressive face of concrete (**d**)

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New 8 Ft and 10 Ft Fixed Based (Cantilevered) wall designs:

- now posted on the Engineering pages of the Wisconsin NRCS Website
  - ✓ 8-ft walls x 10 inches thick
  - ✓ 8-ft walls x 12 inches thick
  - ✓ 10-ft walls x 12 inches thick
- Also, new joint drawings posted
  - ✓ Slab to slab joints
  - ✓ Wall to footing joints
  - ✓ Wall to wall joints

http://www.nrcs.usda.gov/wps/portal/nrcs/detail/wi/technical/engineering/?cid=nrcs142p2_025429

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Questions / Comments?

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