# Foundation Considerations for Manufactured Homes and Appurtenant Structures


## Presented by Kenneth Kinder

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ENGINEERING, PLANNING, & ENVIRONMENTAL CONSULTING SINCE 1958

# Presenter

## Kenneth W. Kinder, PE, CFM

- WV Professional Engineer and Certified Floodplain Manager
- 20 years of engineering experience

### Technical Expertise

- Civil Engineering
- Hydraulic Modeling
- Floodplain Permitting
- Hydrology and Hydraulics
- Flood Damage Assessments
- FEMA Hazard Grant Mitigation Program (HMGP)
- LOMAs, CLOMRs, LOMRs
- Construction Administration, Oversight, and Management
- Site Inspections
- Dam Inspections
- Erosion and Sedimentation Control

# About GAI


- Founded: 1958 in Pittsburgh, PA
- 27 Locations across 12 states
- Charleston and Bridgeport, WV
- Intrastate EMR – 0.68
- Engineering News-Record:
  - Top 500 Design Firms, 2006-2020 (No. 102)


**Markets we serve:**

- Energy
- Real Estate
- Education
- Industrial
- Transportation
- Municipal
- Healthcare
- Water

# About GAI

## Engineering | Civil

**Municipal Engineering**
- Sanitary sewer design
- Water main design
- Feasibility studies, reports, and estimates
- General development coordination
- Mapping
- Development reviews
- Capital improvement program development

**Construction Related Services**
- Pre-construction meetings
- Contract administration
- Construction observation
- Materials testing
- Record drawings
- Soil compaction testing
- Concrete sampling
- Footing testing

**Stormwater Management**
- Comprehensive stormwater management plans
- Detention / retention facilities
- Stormwater conveyance
- Stormwater utility development
- Ordinance development
- Water quality analysis and design
- Environmental permits

**57 Engineering Excellence Awards**

**Floodplain Management**
- Elevation certificates
- HEC-RAS hydraulic analyses
- Hazard mitigation assistance
- Letters of Map Change (LOMAs, LOMRs, LOMR-Fs)
- FEMA Grand Application Assistance
- Floodplain Zoning and Administration

**Geotechnical Engineering**
- Soil borings and testing
- Foundation design
- Stability analyses
- Retaining wall design
- Pavement design

Roads/bridges
Streetscapes
ADA compliant design
Park and trail design

**Survey Services**
- Preliminary/final platting
- Boundary survey
- ALTA survey
- Construction staking and layout
- Topographic and utility surveys
- Elevation certificates

**Civil/Site Engineering Services**
- Site geometry, demolition, and grading plans
- Water and sewer design
- Utility assessment, rehabilitation, and design
- Erosion and sediment control plans and permitting
- Soil-structure interaction investigations
- Stream and wetland permitting and mitigation
- Landscape Architecture

# Outline

- Siting and Permitting
- Foundation Considerations
- Other Structures

# Siting and Permitting

- Floodplain Ordinance
  - Installer must have a WV Manufactured Home Installer's License
  - Freeboard (to the lowest floor, ductwork, and utilities)
  - Permanent skirting must have flood vents
    - Minimum of 2
    - 1 $in^2$ per SF
    - Allow automatic entry and exit of floodwater

# Siting and Permitting

- Floodplain Ordinance (cont'd.)

b. Elevation shall be on reinforced piers on a permanent foundation or other foundation elements of at least equivalent strength engineered for use in a flood hazard area. Installation designs incorporating dry stacked block piers shall not be used in special flood hazard areas.

c. All manufactured homes shall be securely anchored to an adequately anchored foundation system in compliance with the requirements of 42 West Virginia Code of State Regulations, Series 19, Sections 10A and 10B as authorized by West Virginia Code § 21-9-1 et seq. The anchoring shall be adequate to resist flotation, collapse, or lateral movement. Methods of anchoring may include but are not limited to the over-the-top and frame ties, attached to permanent foundation elements. Ground anchors may **not** be adequate to satisfy flood specific anchoring requirements. This requirement is in addition to applicable State and Local anchoring requirements for resisting wind forces.

# Siting and Permitting

- Floodplain Ordinance (cont'd.)
  - Any additions to a manufactured home shall be similarly anchored and vented.
  - The installer must inspect, and certify in writing that the manufactured home was installed to the standards of the ordinance.

# Siting and Permitting

- Floodplain Ordinance (cont'd.)
  - Structures should be constructed with the longitudinal axis parallel to the direction of flow.
  - Structures should be placed approximately on the same flood-flow lines as those of adjoining structures.

# Siting and Permitting

# Siting and Permitting

- Floodplain Ordinance (cont'd.)
  - Flood Protection Setback
    - Stay out of floodway. (Zone AE)
    - 2X the width of channel (TOB to TOB), or 50 feet, whichever is less. (Zone A)

# Siting and Permitting

# Definition

- Anchoring
  - All structures…shall be firmly anchored…to prevent flotation, collapse, and lateral movement….

# Definition

- What is a manufactured home?
  - "…a structure, transportable in one or more sections…and which is built on a permanent chassis and designed to be used as a dwelling with or without a **permanent** foundation when connected to the required utilities." (24 CFR 3280.2 and 24 CFR 3285.5)

# Failure Modes

- Buoyancy
- Lateral Movement
- Pier Collapse
- Erosion and Scour
- Wind Forces

# Bouyancy

A mobile home can float with 6” of water or less!!
(could be considerably less with moving water)

# Typical Foundation Systems

- Piers w/ ground anchors
- Piers w/ fasteners
- Perimeter wall foundations
- Proprietary systems

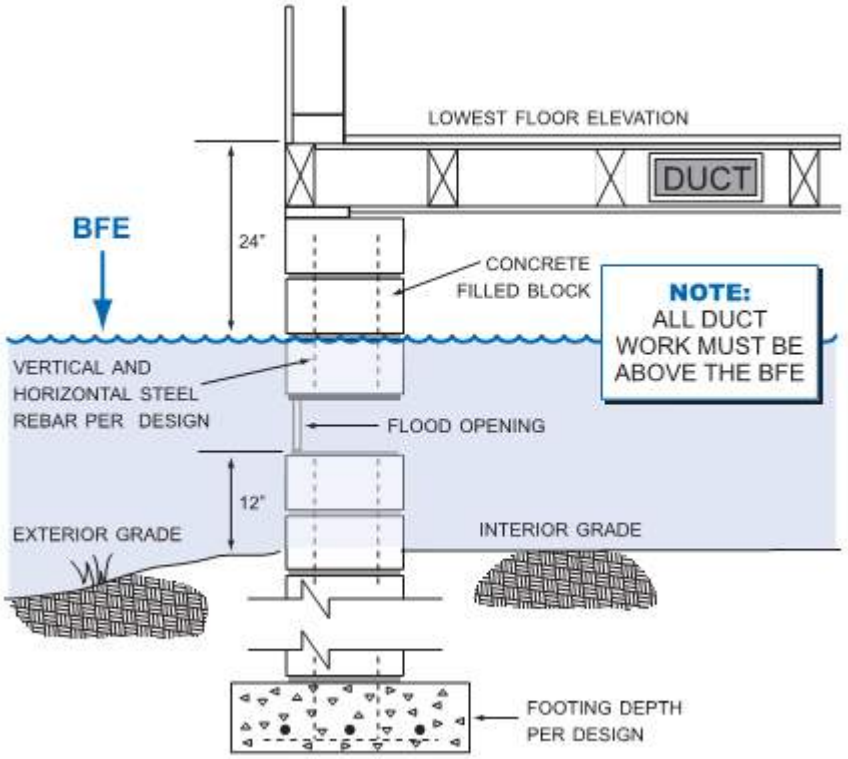
# National Flood Insurance Program (NFIP)

- Regulated under the NFIP
- Generally, must meet the same criteria as stick-built homes
- New manufactured home parks must meet the same basic requirements as other subdivision proposals

# National Flood Insurance Program (NFIP)

- Elevation Requirements:
  - "Must be elevated and anchored to resist flotation, collapse, or lateral movement. Methods of anchoring may include…the use of over-the-top frame ties to ground anchors." [44 CFR 60.3(b)(8)]
  - Zone A – elevated at a minimum of 3 feet or higher from the HAG
  - Zone AE – elevated to or above the BFE (with Freeboard)
  - For added protection, place bottom of steel frame above DFE to reduce the potential for flood damage

# National Flood Insurance Program (NFIP)



# National Flood Insurance Program (NFIP)

- Anchoring Requirements – system of ties, anchors, and anchoring equipment that will withstand flood and wind forces
- Must be constructed with flood resistant materials
- Utilities and mechanical equipment must be protected
  - Elevated or waterproofed

# National Flood Insurance Program (NFIP)

- Enclosed Areas:
  - Walls are subject to hydrostatic and hydrodynamic forces
  - People tend to convert enclosures into areas that sustain damage (add mechanical equipment, etc.)
  - Must be designed to equalize hydrostatic forces
  - Allowed uses:
    - Parking
    - Building access
    - Storage
  - Non-conversion agreement

# Hazard Analysis and Risk Assessment

- Determine what hazards exist and what the risk level is
  - Flooding
  - Dam failure
  - Land subsidence
  - Land slides
  - Seismic hazards
  - Severe wind
  - Others…

# Hazard Analysis and Risk Assessment

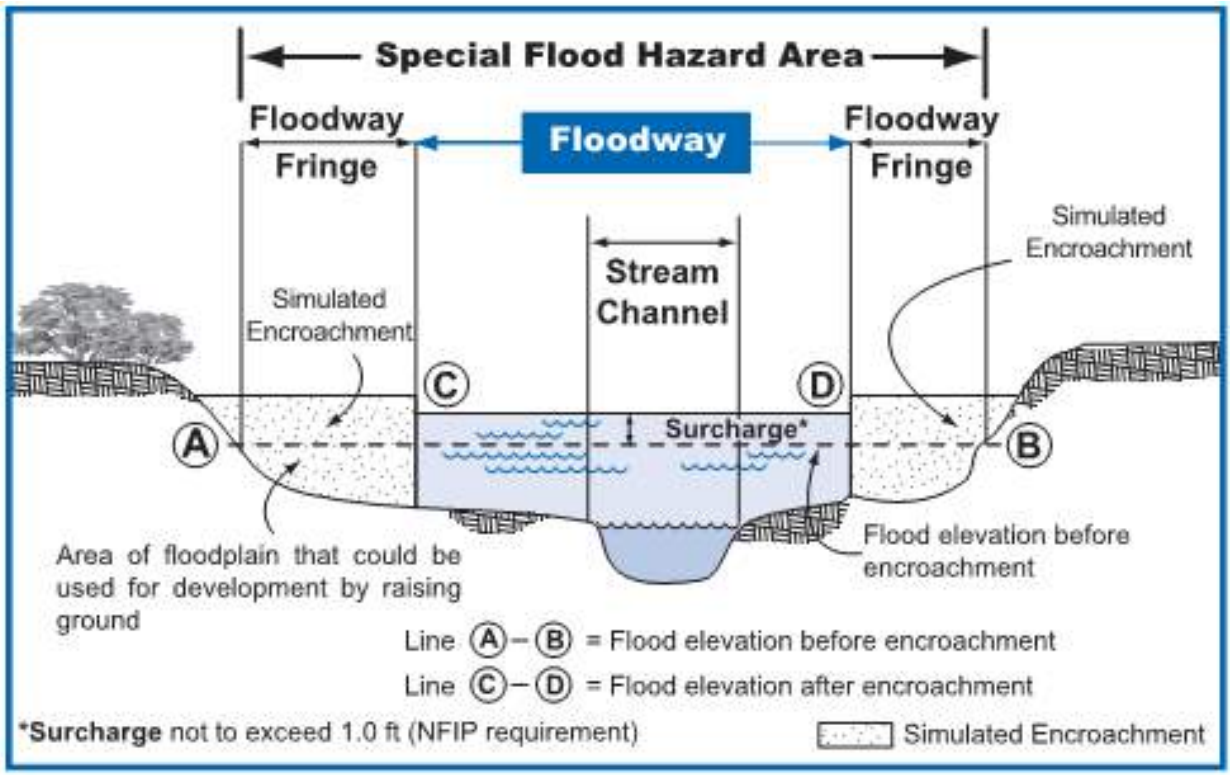
## Flooding Hazards

| Flood Hazard | Associated Flood Hazard Areas or Property Characteristics |
|---|---|
| Long duration flooding | • Large water bodies (rivers, bays)<br>• Water bodies with slow drainage (lakes, ponds) |
| Inadequate storm drainage | • Flat or poorly graded land<br>• Land located directly adjacent to a flood source |
| Impact forces | • Coastal areas subject to wave action flooding<br>• Riverine flooding areas subject to high velocity flooding |
| High velocity flows | • Coastal areas subject to wave action<br>• Steeply-sloped riverine flooding areas or areas otherwise subject to high velocity flood flows |
| Erosion | • Coastal areas subject to wave action<br>• Steeply-sloped riverine areas with high velocity flood flows or areas otherwise subject to high velocity flood flows |
| Sediment deposition | • Coastal overwash areas |
| Movable stream beds | • Dynamic river systems |
| Flood depth | • Areas adjacent to the flood source<br>• Areas with poor capacity for drainage |

# Protecting Properties in Flood-Prone Areas

- Locate the structure outside of SFHA if possible
- Locate the structure in an area less susceptible to "destructive" flooding
- Generally, the farther a structure is from the flood source, the better (reduced flood depths and velocities)
- Consider too: Floodwaters can limit access to and from a home during AND after a flood event
- Stay outside of the floodway!!!

# Protecting Properties in Flood-Prone Areas



# Poll Question No. 1

# Foundation Design Considerations

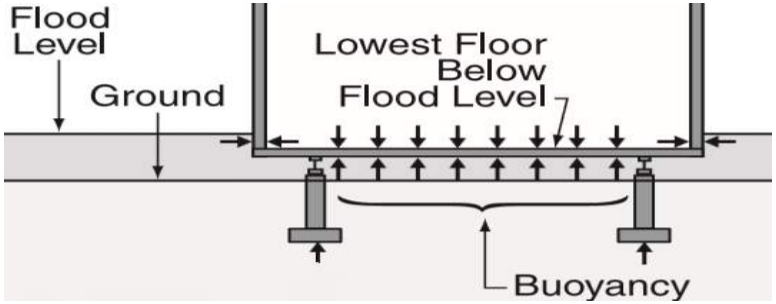
- Flood Data – Determined from FIRM, FIS Reports, WV Flood Tool
- Flood Characteristics
  - **Frequency** (5-year, 10-year, 100-year, etc.) – how often can a flood occur
  - **Duration** – how long will it take floodwaters to recede
  - **Rate of Rise** – how rapidly will water depths increase. This affects warning times and hydrostatic force equalization times (a fast rise may create buoyant forces)

# Foundation Design Considerations

- **Design Flood Elevation** (DFE) – the elevation to which development in the floodplain is built
  - DFE = BFE + Freeboard
- **Flood Depth** – the difference between the water surface elevation and the ground surface
- **Advisory Flood Heights**

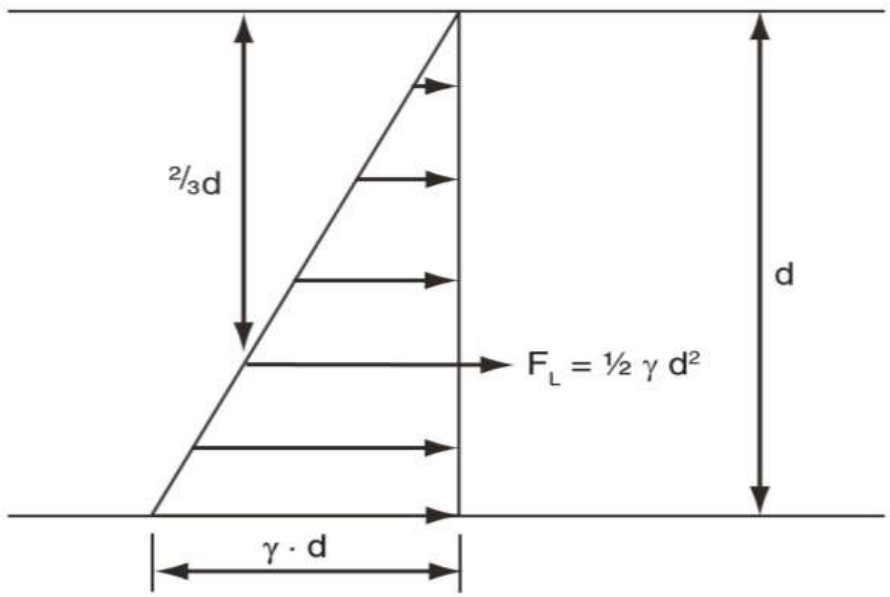
# Foundation Design Considerations

- **Hydrostatic Forces** – forces exerted by surrounding water
  - Static forces
    - Act perpendicular to the surface they are applied (i.e. lateral forces on walls, vertical forces on floors)
  - Buoyant forces = weight of water displaced
  - $F_{bouy} = \gamma \times V_{ol}$



# Foundation Design Considerations

- **Lateral Forces** – create a triangular loading on vertical surfaces
- $F_L = 1/2\gamma \times d2$



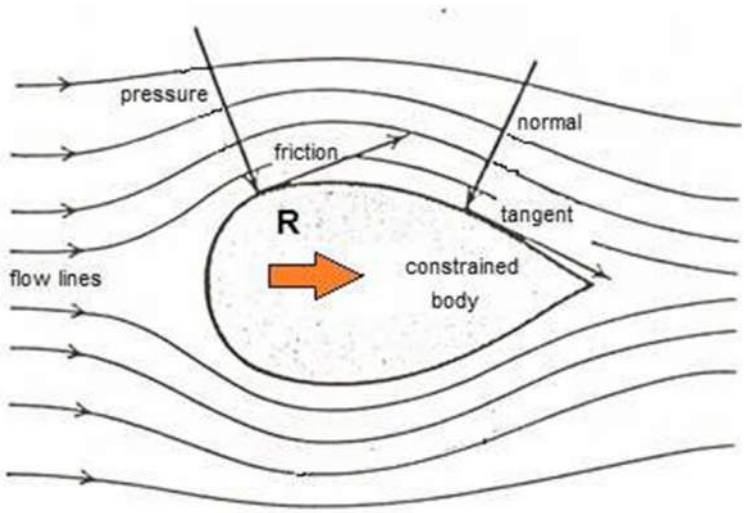
# Foundation Design Considerations

- Hydrostatic Force Notes
  - Hydrostatic forces can lift (or push) inadequately anchored homes off their foundations
  - Flood depths of **4-5 inches** above the lowest floor can float a manufactured home!!
  - Walls and floors are not typically designed to resist hydrostatic forces

Smart Vent

# Foundation Design Considerations

- **Hydrodynamic Forces** – forces exerted by moving floodwaters
  - Magnitude depends on velocity, floodwater depth, and a drag coefficient
  - Can cause sliding failure or overturning
  - $F_d = (C_d \times A \times \gamma \times V_2)/2g$
    - Cd is a function of pier/footing shape

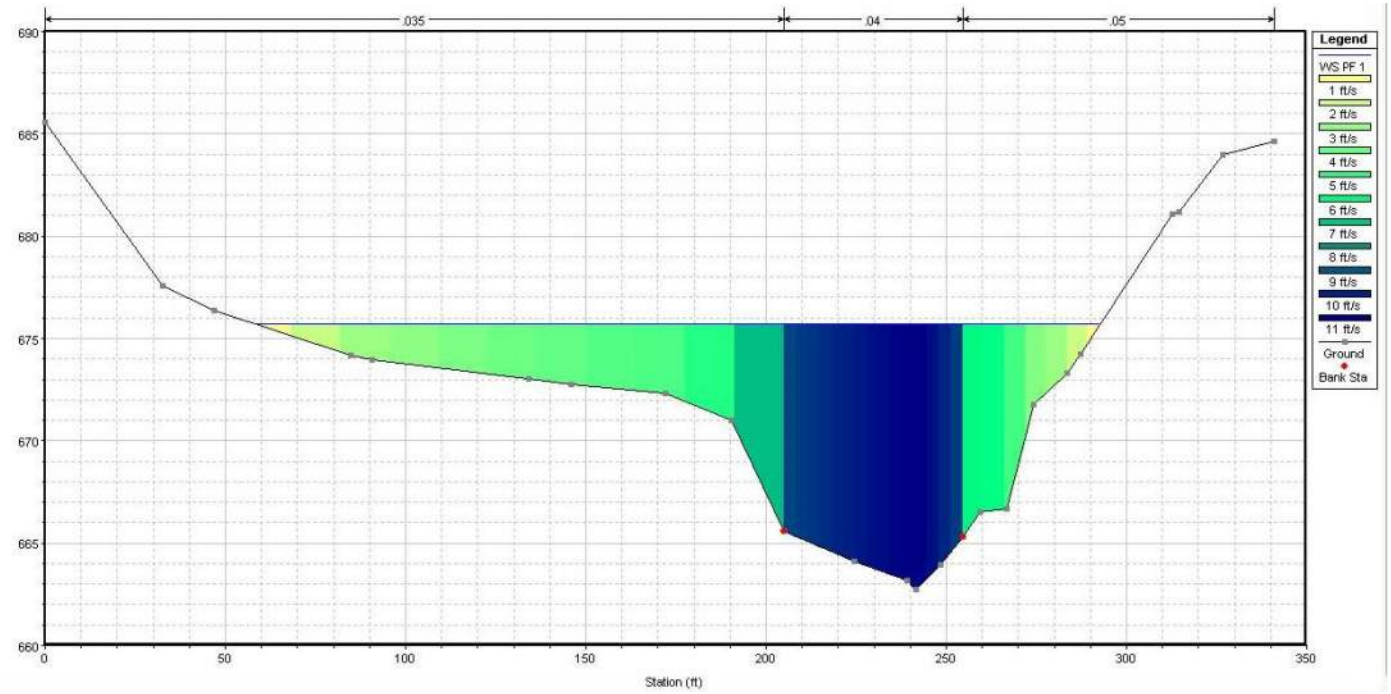


# Foundation Design Considerations`

- **Velocity**
  - Varies throughout the cross section
  - Generally decreases with flow depth and effects of surface roughness
  - FIS Floodway Data Table lists average velocities

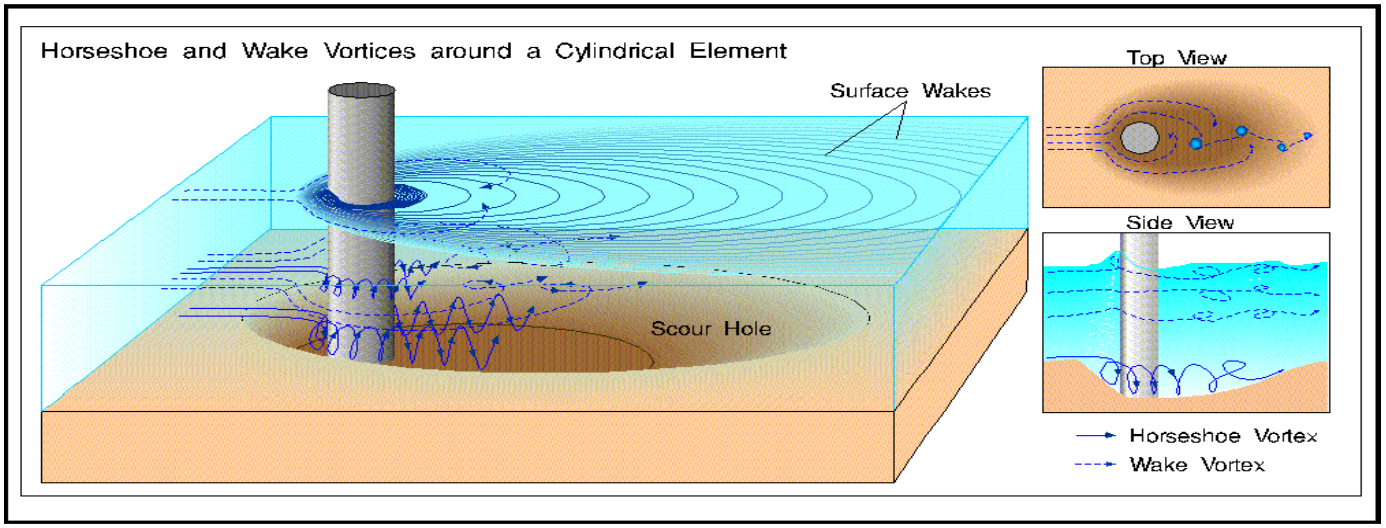
| FLOODING SOURCE | | FLOODWAY | | | BASE FLOOD WATER SURFACE ELEVATION (FEET NAVD) | | | |
|---|---|---|---|---|---|---|---|---|
| CROSS SECTION | DISTANCE[1] | WIDTH (FEET) | SECTION AREA (SQUARE FEET) | MEAN VELOCITY (FEET PER SECOND) | REGULATORY | WITHOUT FLOODWAY | WITH FLOODWAY | INCREASE |
| Big Sandy Creek | | | | | | | | |
| A | 100 | 143 | 3,026 | 6.6 | 629.2 | 619.0[2] | 620.0 | 1.0 |
| B | 805 | 222 | 4,207 | 4.8 | 629.2 | 619.9[2] | 620.8 | 0.9 |

# Foundation Design Considerations



# Foundation Design Considerations

- **Erosion and Scour**
  - Erosion - loss of soil from the ground surface
  - Scour – loss of soil from beneath and around objects



# Foundation Design Considerations

- **Scour (cont'd)**
  - Scour depth is a function of foundation shape, velocity, and soil particle size
  - Coarse grained (non-cohesive) soils – scour quickly
  - Fine grained (cohesive) soils – scour slower, but to the same depth
  - Scour mitigation
    - Place footing below ultimate scour depth
    - Install riprap around foundations

# Foundation Design Considerations

- **Other factors**
  - Debris impact
  - Wind
  - Earthquakes
  - Lateral earth pressure
  - Roof live loads
  - Consider load combinations!!

# Soils

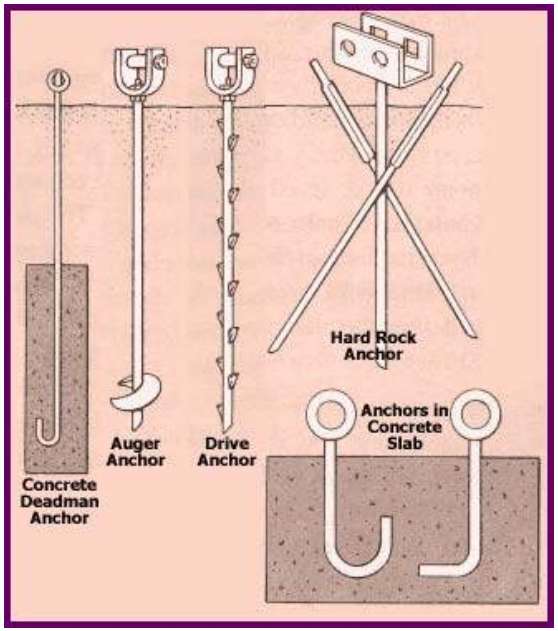
- **Bearing Capacity** – soil's ability to support load without catastrophic failure
- Determined through:
  - Soil surveys (preliminary design only)
  - Subsurface investigation (drilling)
  - Field measurement (penetrometer)

# Soils

- **Flood Duration and Frequency** - Soil strength is a function of moisture content
  - Granular soils:
    - Submerged weight is about half of non-submerged
    - Bearing capacity can be reduced by half
  - Cohesive soils:
    - Soil particles bound by electrochemical bonds
    - MC can increase the distance between bonds, decreasing cohesion, decreasing strength

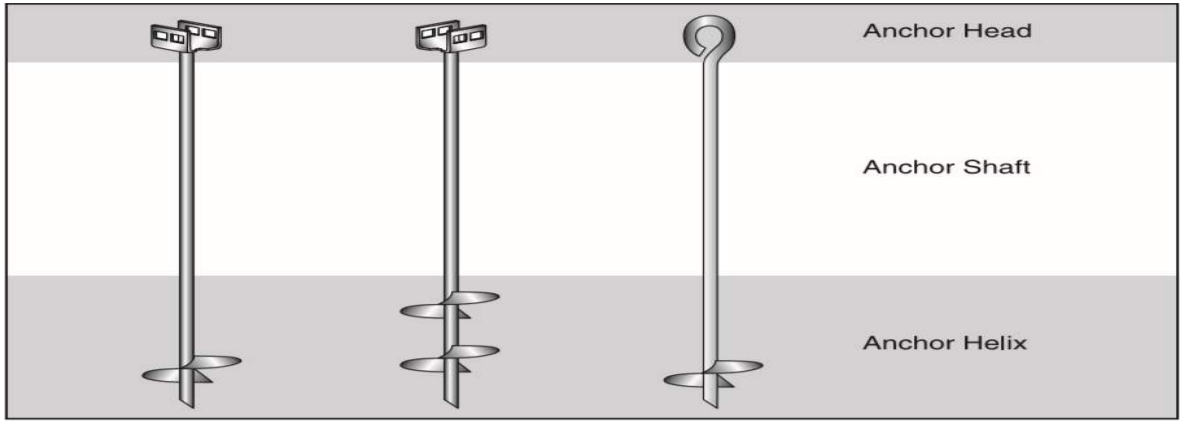
# Ground Anchors

- Pros
  - Resist flotation, collapse, lateral movement
  - Widely used
  - Economical and readily available
  - Installed with lightweight equipment
- Cons
  - Movement (2-3 inches is acceptable)
  - Lateral movement can cause toppling
  - Vertical movement can displace piers
  - Should be inspected and retightened as needed



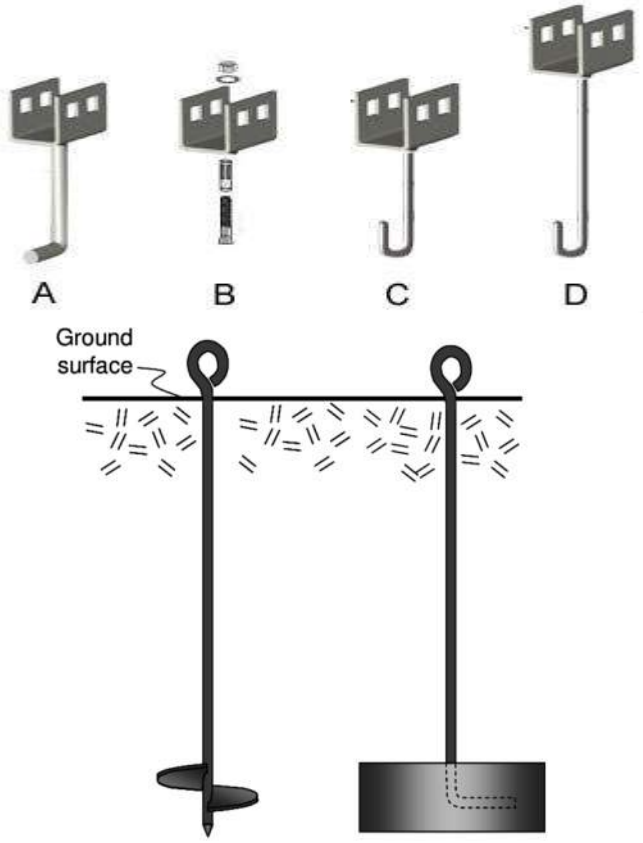
# Types of Ground Anchors

- **Helical Earth Anchors**
  - Contains a head secured to a metal shaft
  - Augered (screwed) into the ground
  - One or more helixes



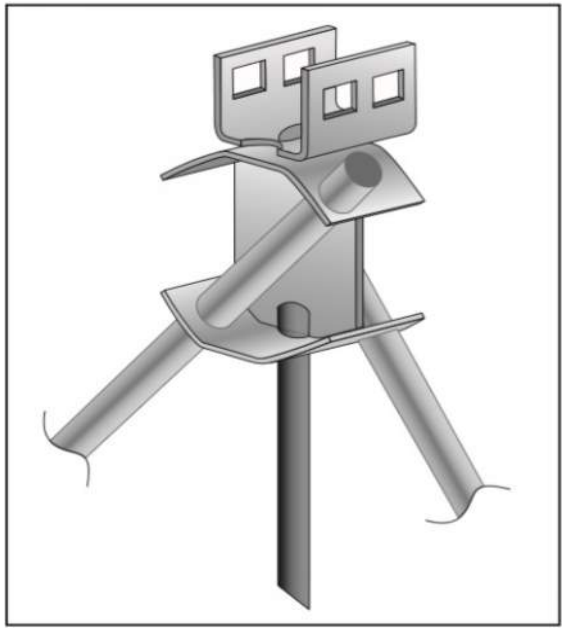
# Types of Ground Anchors

- **Concrete Anchors**
  - Uses dead weight or combination of dead weight and soil uplift resistance
  - Connection to concrete (anchor bolts) is critical! (adequate embedment)



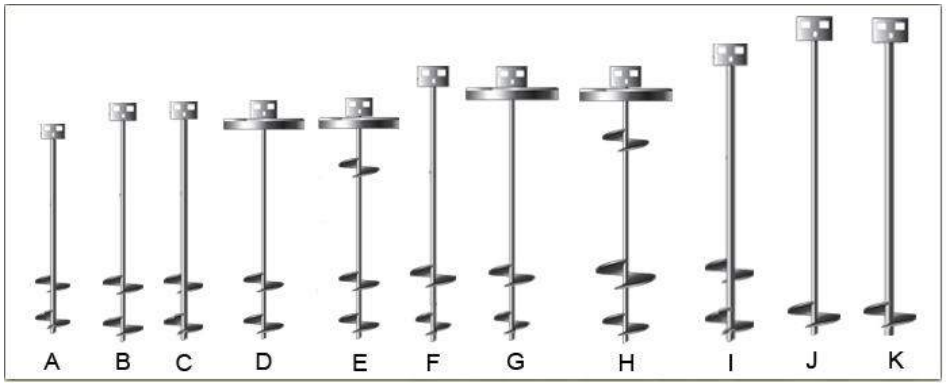
# Types of Ground Anchors

- **Cross Drive Anchors**
  - Contains a head secured to a metal shaft
  - Metal pins are driven into the ground to form an “X”



# Anchor Selection

- **Stiff/firm soils** – short anchors with small helixes
- **Weak soils** – longer anchors or anchors with more or larger helixes
- Based on torque probe test

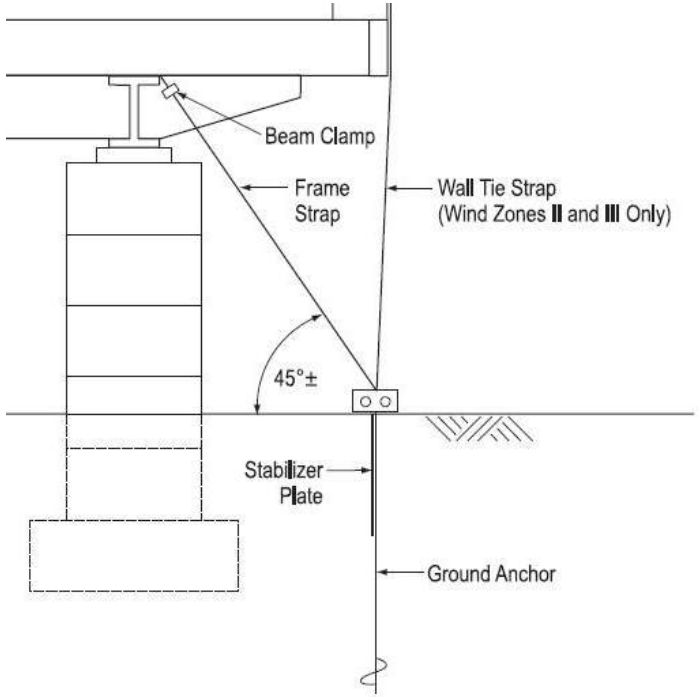


# Anchor Installation

- **Machine installation** – Portable equipment rotates and advances the anchors
- **Hand installation** – holes are excavated, anchors are placed, soil is backfilled and compacted
  - Disturbs more soil, reduces load capacity
  - Load capacity is a function of compacted backfill
  - Not recommended in poor soils

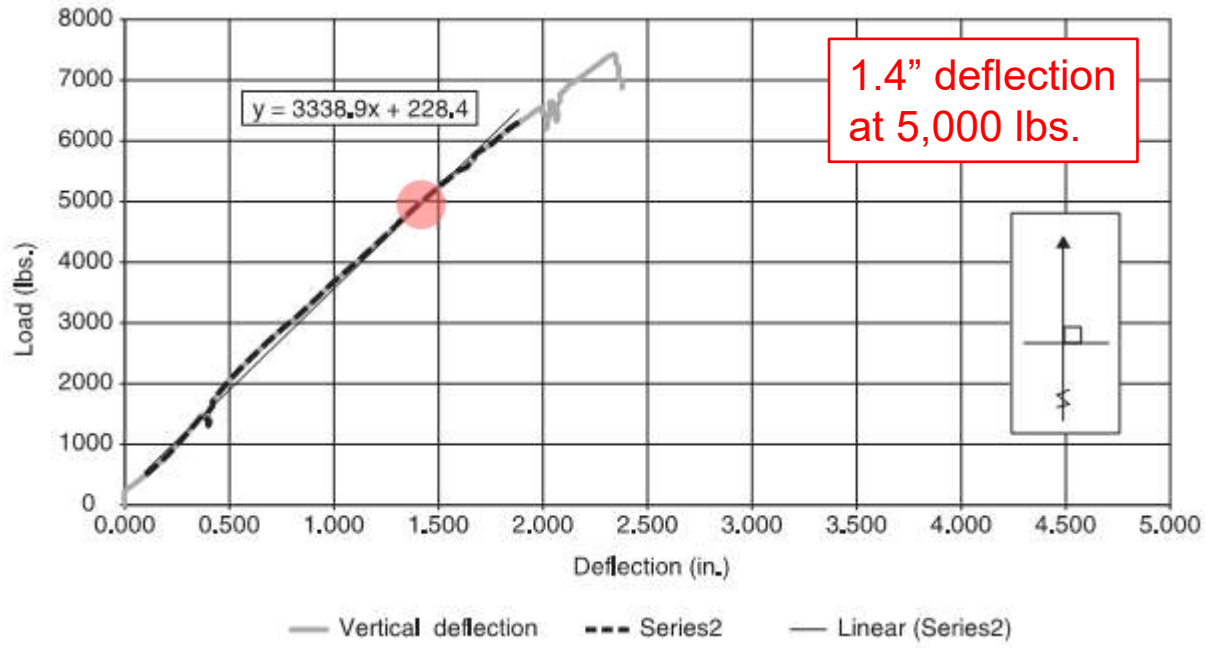
# Anchor Installation

- Installed vertically or inclined slightly to facilitate installation (5-15 deg.)
- Stabilizer plates can be used along the shaft
- Wall tie straps are required in high wind zones



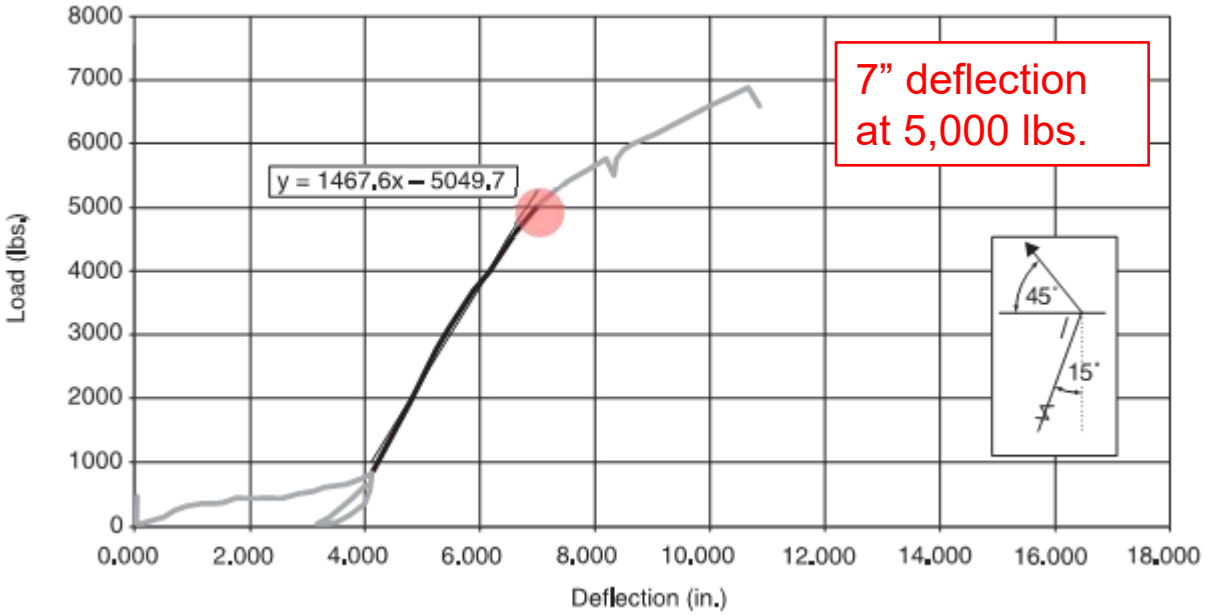
# Anchor Performance

- **Axially Loaded** – capacity is a function of the shear stresses along the soil failure plane (typically a symmetrical cone from the helix plate)



# Anchor Performance

- **Non-axially Loaded** – capacity is a function of passive soil resistance of the surrounding soil.



# Anchor Performance

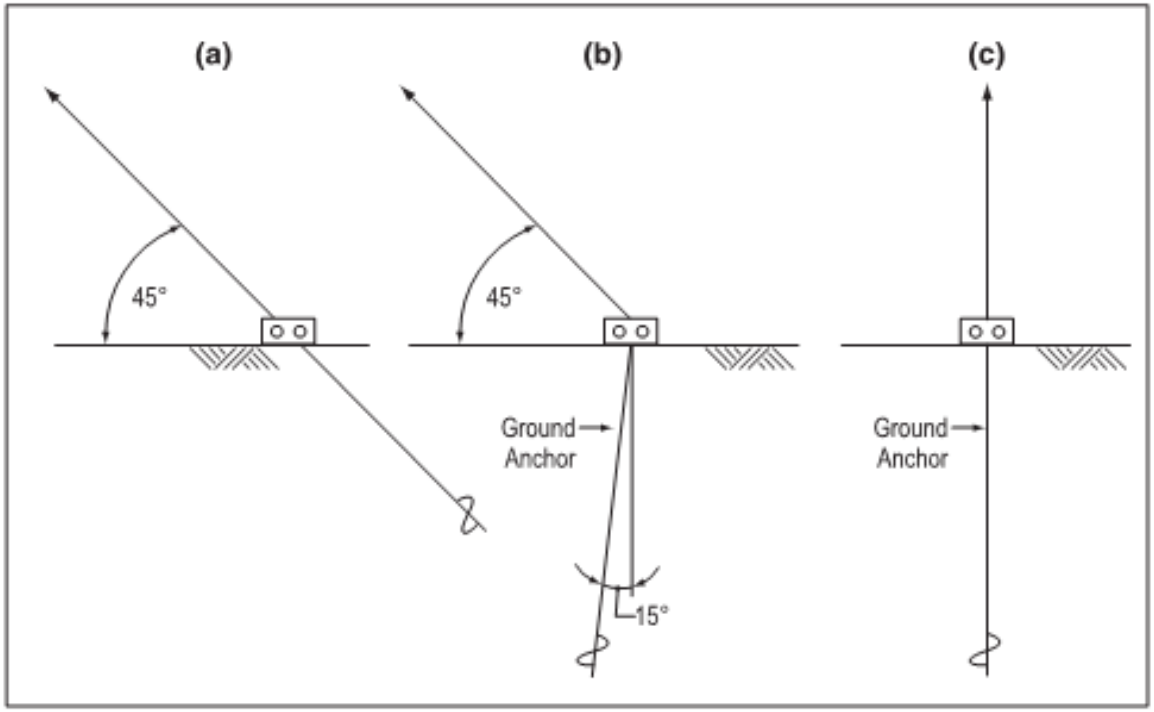



Figure 7-9. Three graphics showing the anchor configurations described in Tables 7-2 and 7-3. From left to right, they are (a) ground anchor installed at 45 degrees and loaded axially, (b) ground anchor installed at 15 degrees from vertical and loaded 45 degrees from horizontal, and (c) ground anchor installed vertically and loaded axially.

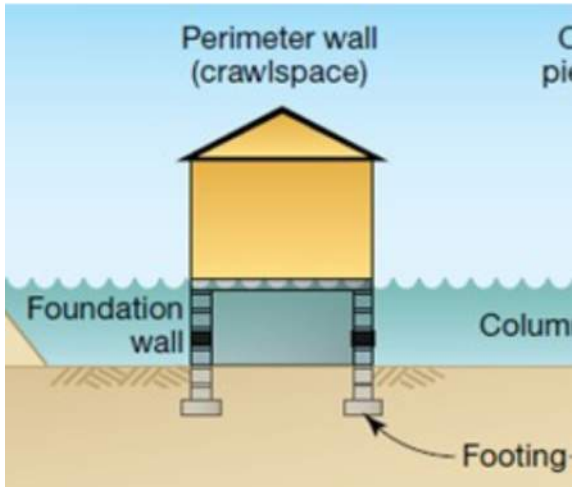
# Poll Question No. 2

# Foundation Systems - Introduction

- Support the weight of the home
- Resist loads from wind, snow, floodwaters, seismic, passive earth, etc.
- Elevate the home to prevent loss from floodwaters
- Classified as **enclosed** or **open**

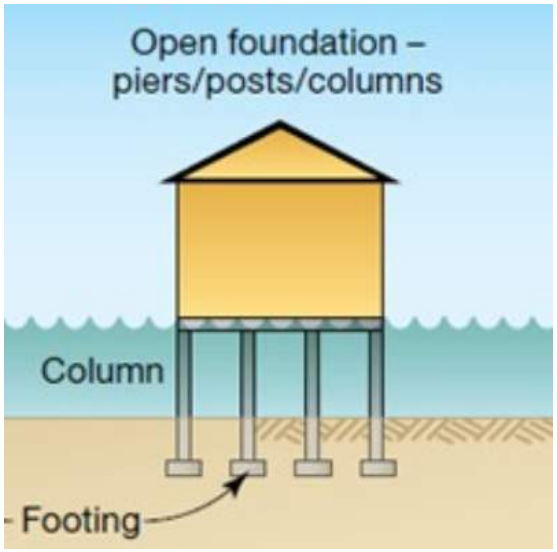
# Foundation Systems - Enclosed

- Perimeter foundation walls on continuous footings (does not include non-structural skirting)
- Must comply with NFIP requirements
  - Must contain at least 2 appropriately sized flood vents
  - Must be used solely for parking or storage
- Should not be used where high velocities are expected
- Not permitted in V Zones
- Should include adequate reinforcement to resist unbalanced hydrostatic and hydrodynamic loading (fast rising flood levels)



# Foundation Systems - Open

- Involves elevating the structure on piers, posts, or piles
- Required in coastal areas
- Recommended in riverine systems subjected to high velocities, significant water depth or erosion
- More resistant to moving floodwaters and waves (less exposed surface area)
- Some have breakaway walls
  - Nonstructural skirting
  - Designed and constructed to fail under flood loading

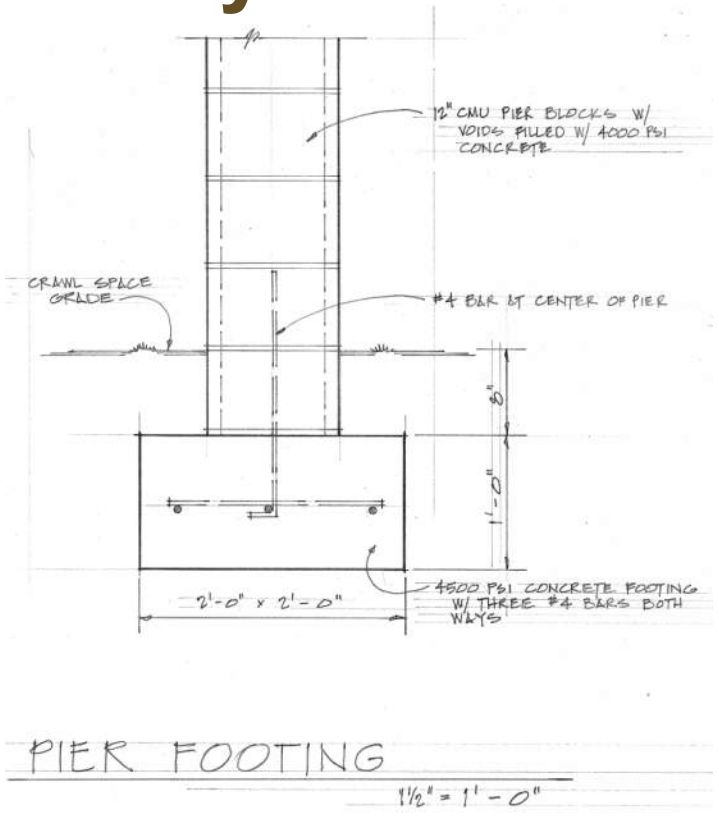


# Foundation Systems – Pier Systems

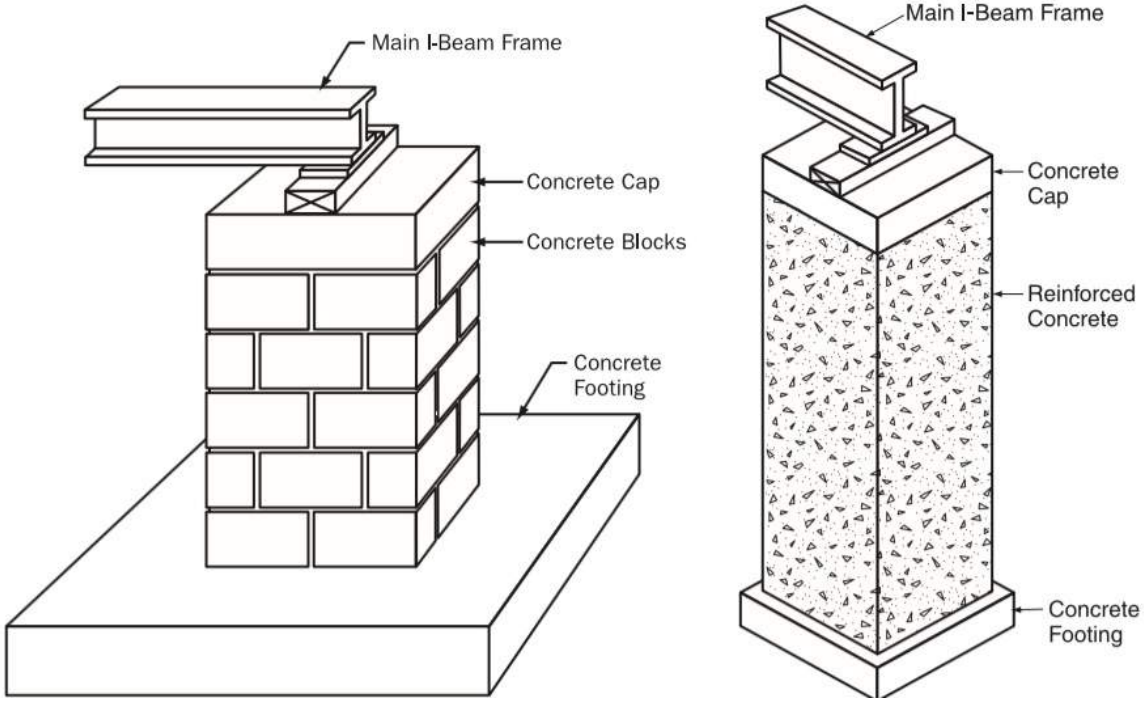
- Type of **open foundation**
- Most commonly used foundation system for manufactured homes
- Two general styles: **reinforced** and **unreinforced**

# Foundation Systems – Pier Systems

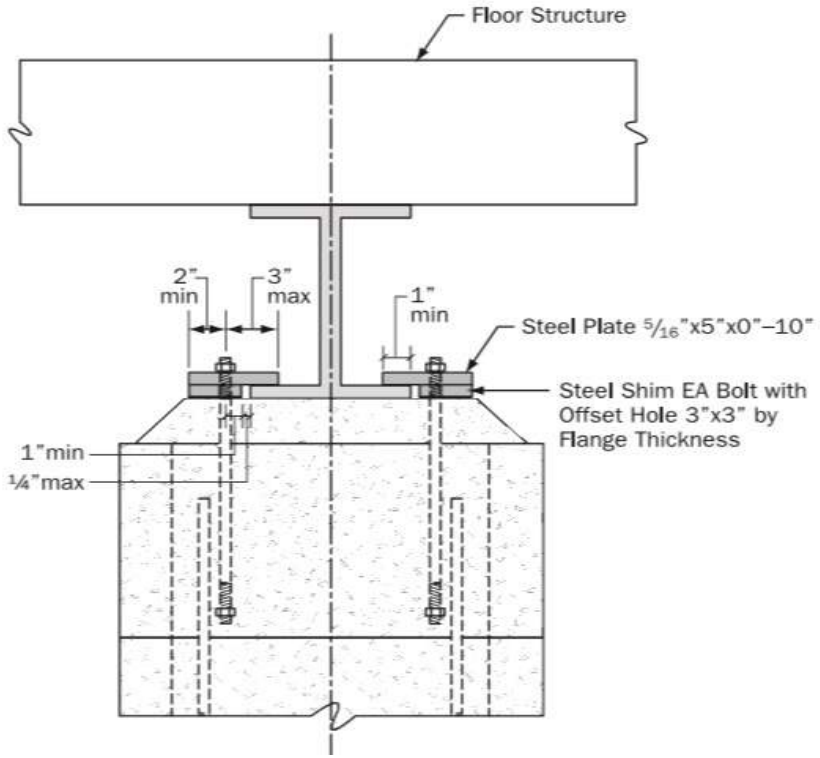
- **Reinforced pier foundations** – pier and footings resist all loads
  - **Reinforced** masonry blocks or **reinforced** concrete
  - Footings must be installed below scour depth
  - Piers must be firmly attached to the footings
  - Manufactured home frame must be securely attached to the piers



# Foundation Systems – Pier Systems



# Foundation Systems – Pier Systems



# Foundation Systems – Pier Systems

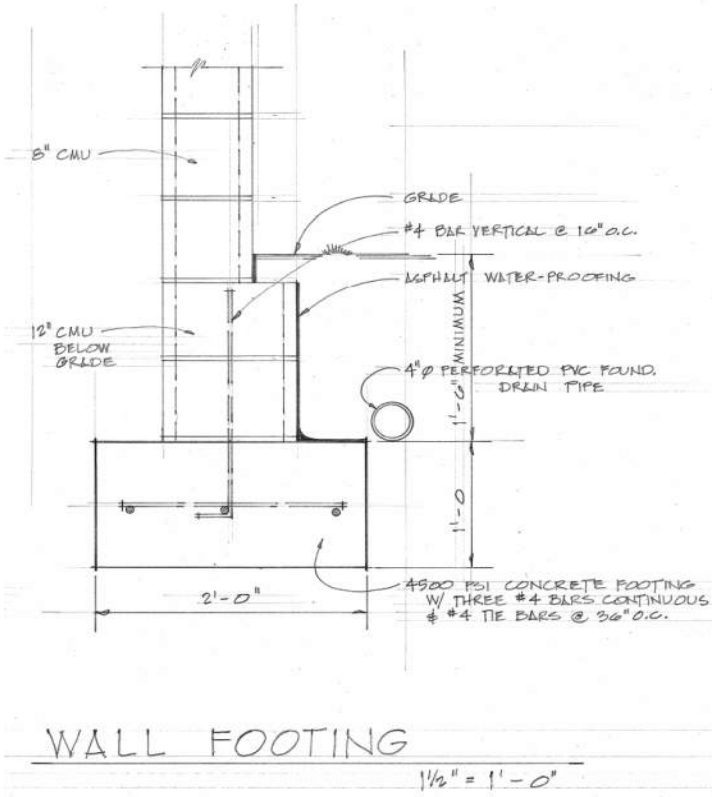
- **Unreinforced pier foundations**
  - **Unreinforced** masonry blocks (not backfilled w/ grout)
  - Must include ground anchors and frame straps for lateral stability
  - Blocks can be “dry-stacked” at flow velocities < 1 fps

# Foundation Systems – Pile Systems

- Uses driven piles
- Can withstand high wind, high flow velocities and waves
- Typically used in coastal areas

# Foundation Systems – Footings

- Installed below grade
- Transfer loads from the home to the ground
- Support gravity loads as well as uplift loads
- Should be installed below the frost depth AND expected scour depth
- Footing size is a function of soil bearing capacity



# Recommended Design Process

## 1. Determine Design Criteria

- HUD's Model Manufactured Home Installation Standards
- International Residential Code (IRC)
- ASCE 7 – Minimum Design Loads for Buildings and Other Structures
- ASCE 24-05 – Flood Resistant Design and Construction
- NFIP
  - "adequately anchored to prevent flotation, collapse, or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy". [44 CFR 60.3(a)(i)]

# Recommended Design Process

## 2. Select Design Methodology and Assess Load Combinations

- Two predominant methodologies
  - Allowable Stress Design (ASD)
  - Strength Design/Load and Resistance Factor Design (LRFD)
- Determine load combinations (hydrostatic, hydrodynamic, wind, debris impact, etc.)
- Consider failure modes
  - Uplift
  - Sliding
  - Overturning

# Recommended Design Process

3. **Select Foundation Type and Material**
4. **Determine Forces at Connections and Foundation Components**
   - Connections between foundation and home's steel frame
   - Connections through the foundation
   - Connections from the foundation to the footing
   - Adequacy of the footing and surrounding soil

# Recommended Design Process

5. **Specify Connections Along with Component Dimensions**
   - Size and number of bolts, nails or straps
   - Size and spacing of piers, amount of reinforcement, etc.
6. **Note All Design Assumptions and Details on Drawings**
   - All assumptions, calculations, and details should be clearly documented
   - This ensures that floodplain managers and installers understand the design

# Recreational Vehicles

- A recreational vehicle or trailer located in the regulated floodplain must:
  - Meet the elevation and anchoring requirements for manufactured homes; OR
  - Be on the site for fewer than 180 consecutive days; OR
  - Be fully licensed and ready for highway use (i.e. on its wheels or jacking system, attached to the site only by quick disconnect type utilities, and with no permanently attached additions).

# Appurtenant Structures

- A structure on the same parcel of property as the principal structure and the use of which is incidental and used for storage only to the use of the principal structure. (This does not include a gas or liquid storage tank).

# Appurtenant Structures

- Built on-site by owner
- Built on-site by others
- Trailer mounted
- Can be built or delivered very quickly

# Appurtenant Structures

- Site Plan
- Elevation Certificate
  - Flood Resistant Materials
  - Flood Vents
- Non-conversion agreement

# Appurtenant Structures

- Structures shall be no more than 800 square feet in size and valued at less than $10,000.
- Floors shall be at or above grade on at least one side.
- Structures shall be located, oriented and constructed to minimize flood damage.
- Structures shall be designed and adequately anchored to prevent flotation, collapse, or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy.

# Tiny Homes

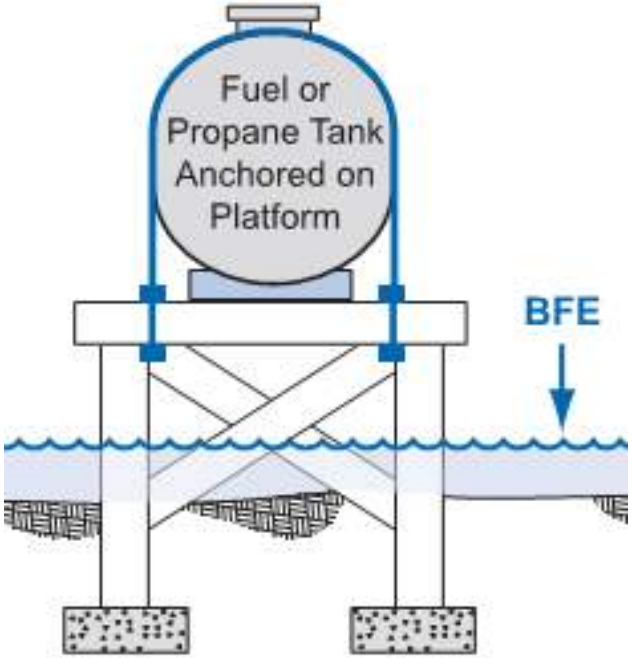
- Built on-site
- Trailer mounted
- Built by volunteer forces
- Can be built in a weekend, or less

# Propane Tanks

"All air ducts, large pipes, swimming pools and storage tanks located at or below the Base Flood Elevation shall be firmly anchored to resist flotation."

# Propane Tanks

- FEMA P-312(*Homeowner's Guide to Retrofitting*) Chapter 9.0 – "Protecting Service Equipment"
- Elevated above DFE
- Anchored to concrete pad
- Ground anchors with straps



# Poll Question No. 3

# Q&A

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