"Foundation Considerations for Manufactured Homes"

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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

Typical Foundation Systems

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

National Flood Insurance Program (NFIP)

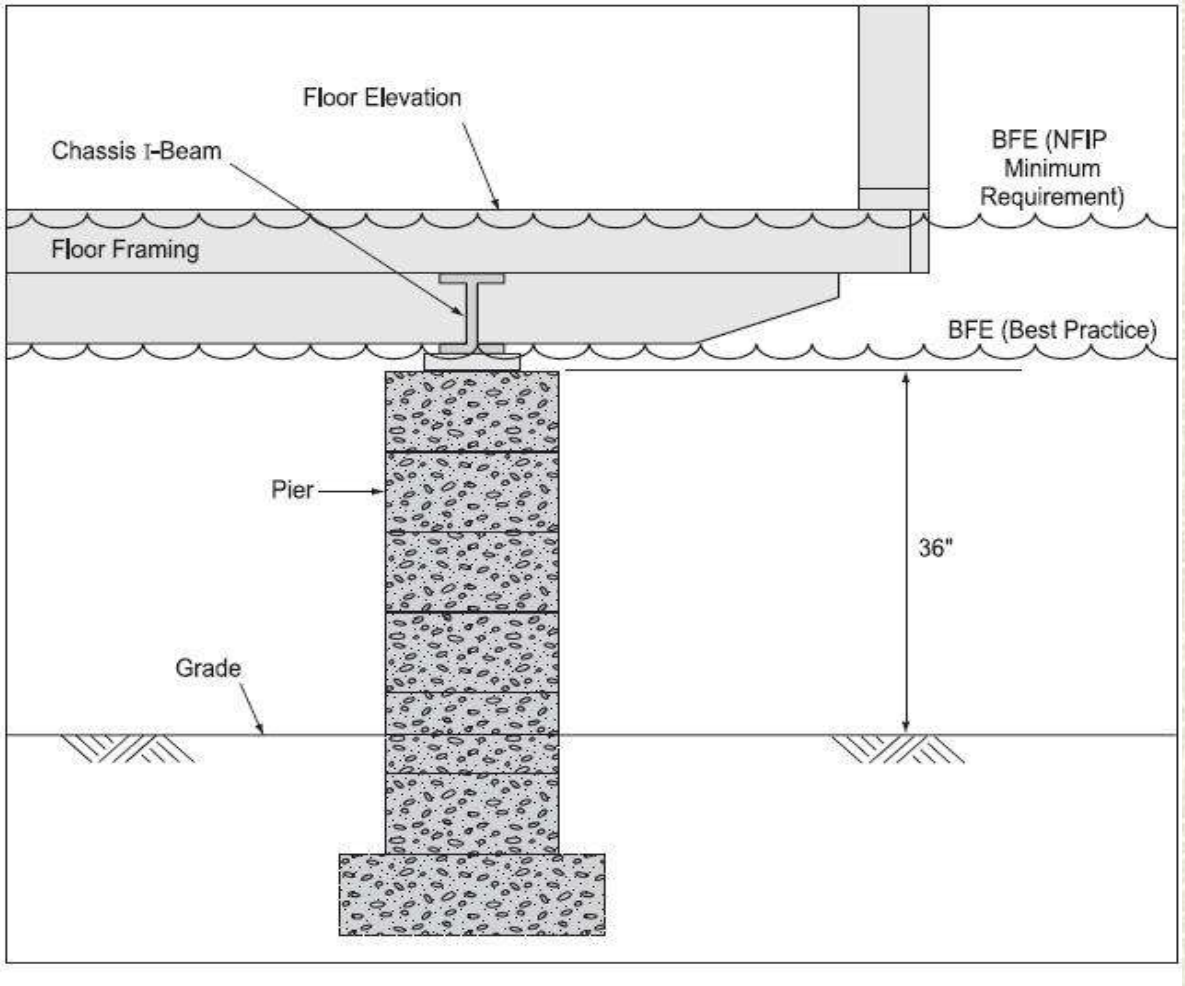
- Regulated under the NFIP
- Generally, must meet the same criteria as stick-built homes
- New manufactured home parks must meet the same basic requirements as other subdivision proposals

NATIONAL
FLOOD
INSURANCE
PROGRAM

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
  - For added protection, place **bottom** of steel frame above BFE to reduce the potential for flood damage (insert figure 3-3)

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

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…..

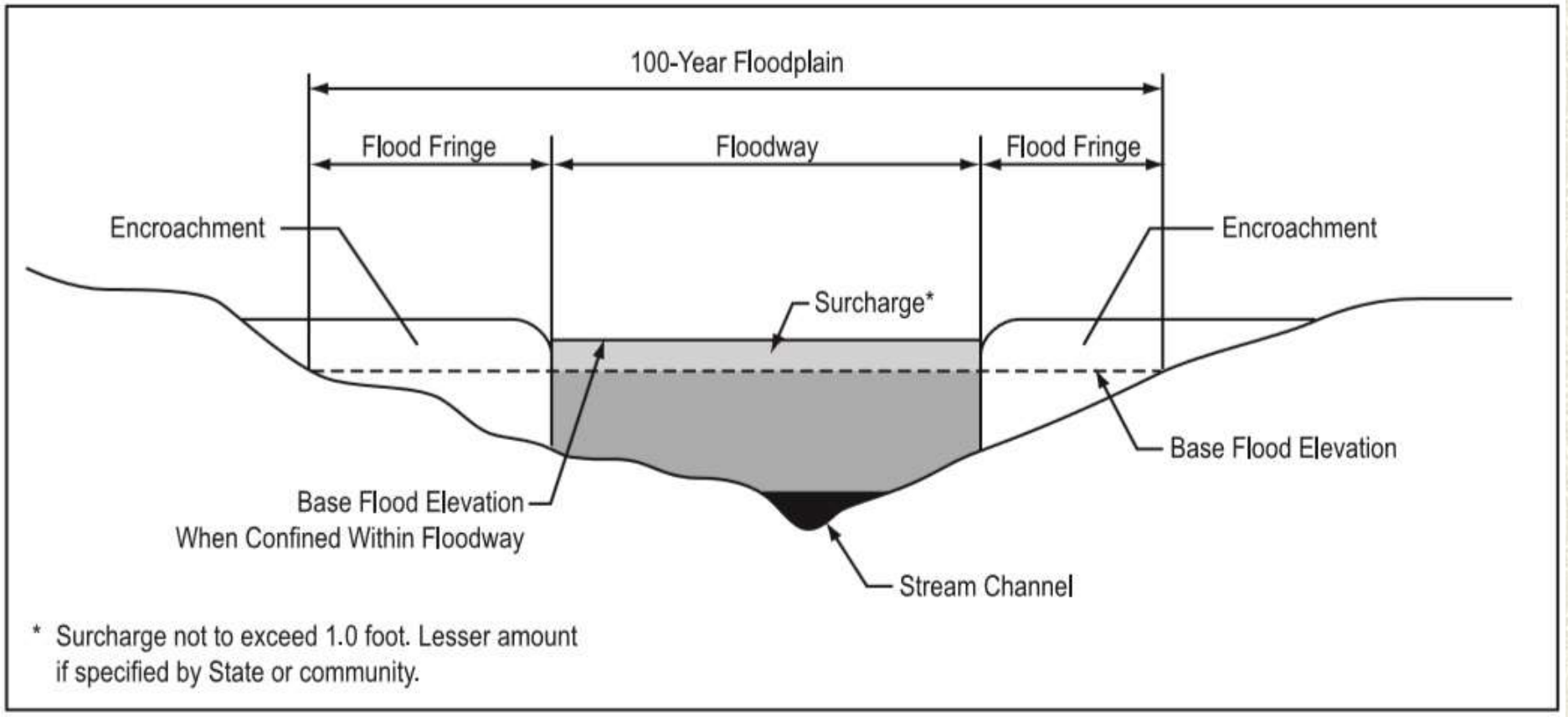
Flood Hazards

Flood Hazard	Associated Flood Hazard Areas or Property Characteristics
Long duration flooding	• Large water bodies (rivers, bays) • Water bodies with slow drainage (lakes, ponds)
Inadequate storm drainage	• Flat or poorly graded land • Land located directly adjacent to a flood source
Impact forces	• Coastal areas subject to wave action flooding • Riverine flooding areas subject to high velocity flooding
High velocity flows	• Coastal areas subject to wave action • Steeply-sloped riverine flooding areas or areas otherwise subject to high velocity flood flows
Erosion	• Coastal areas subject to wave action • 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 • 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



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)

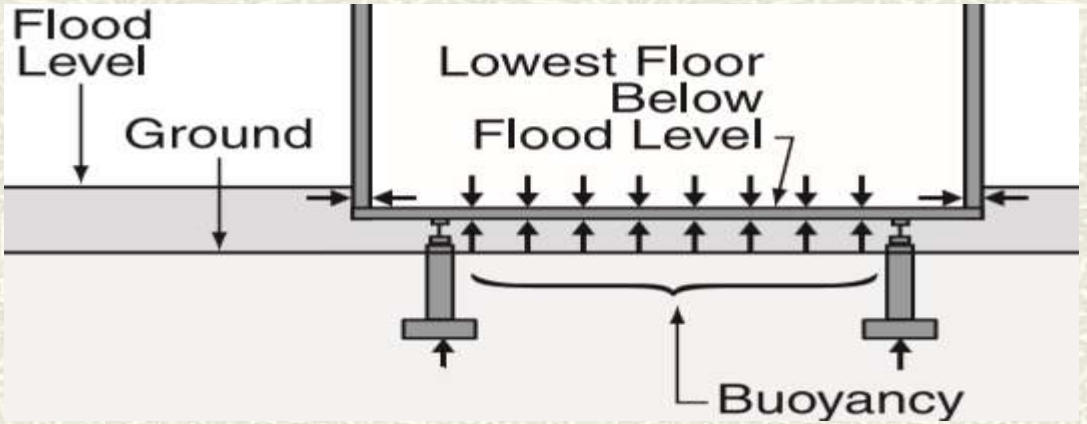
Design Considerations

- **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***

Design Considerations

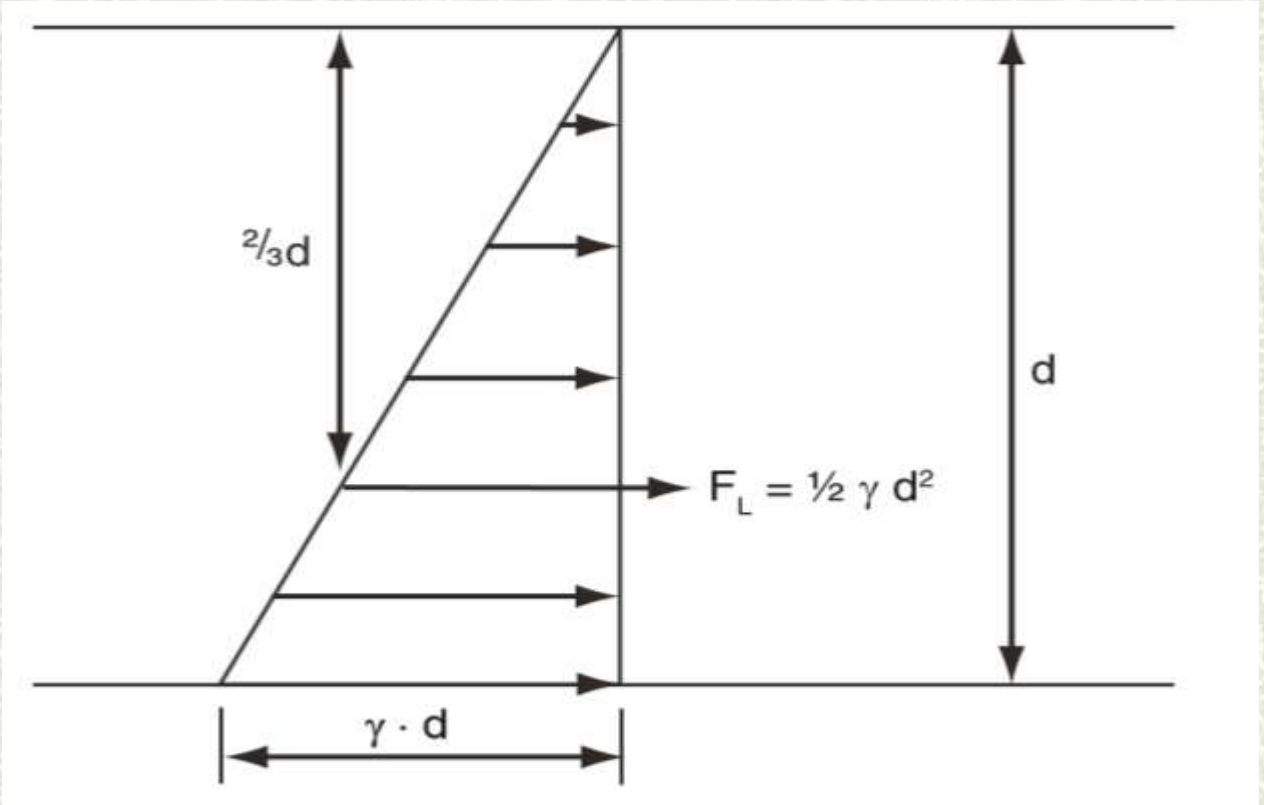
- **Hydrostatic Forces** – forces exerted by surrounding water
  - Static forces
    - Act perpendicular to the surface they are applied (i.e. lateral forces on walls, vertical forces on floors)
  - Buoyant forces = weight of water displaced

$$F_{bouy} = \gamma \times V_{ol}$$



Design Considerations

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



Design Considerations

- Hydrostatic Force Notes
  - Hydrostatic forces can lift 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

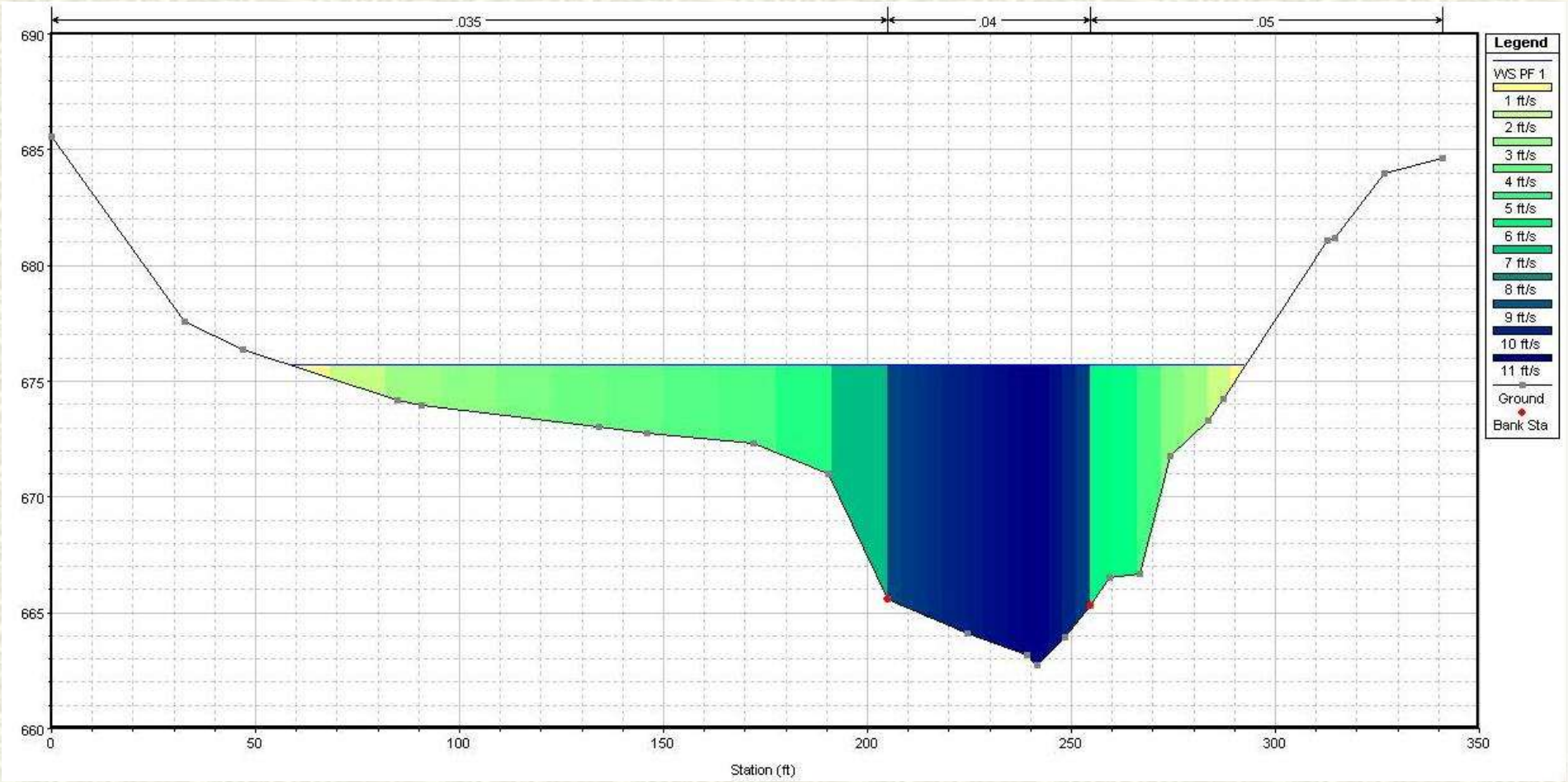
Design Considerations

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

Design Considerations

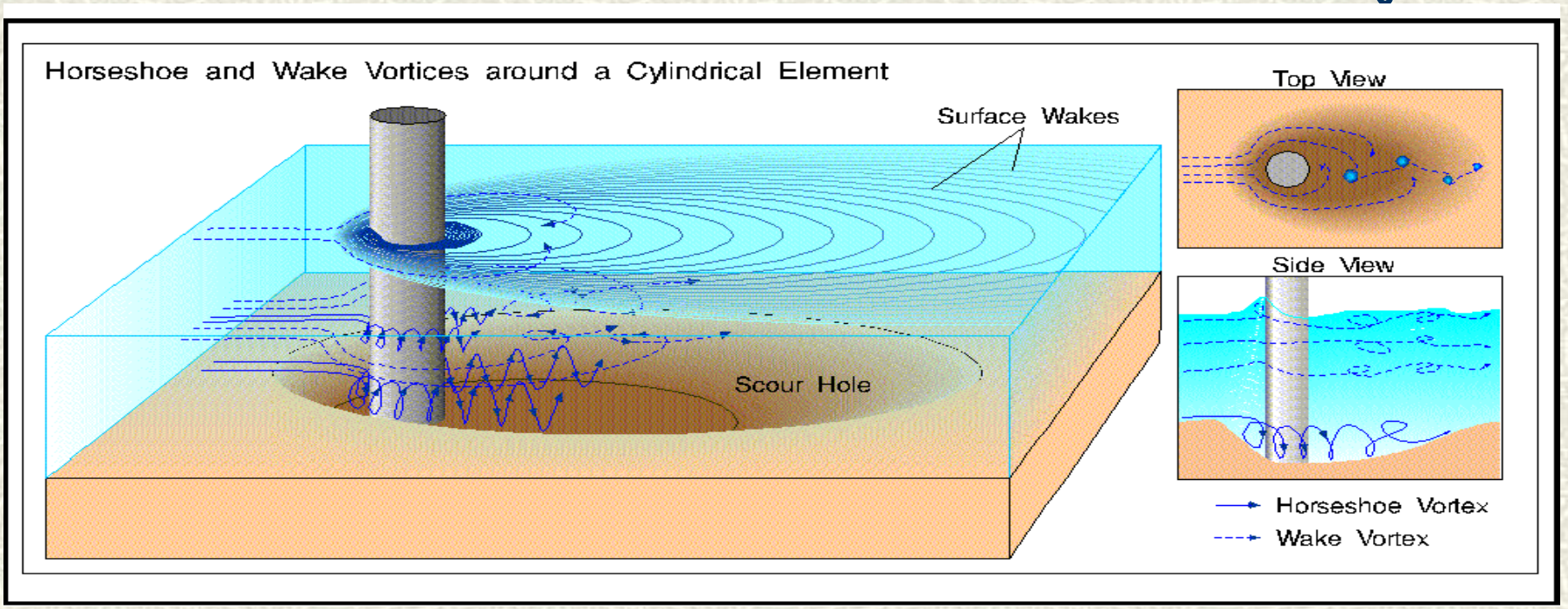
- **Velocity**
  - Varies throughout the cross section
  - Generally decreases with flow depth and effects of surface roughness
  - FIS Floodway Data Table lists average velocities

Design Considerations



Design Considerations

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



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

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

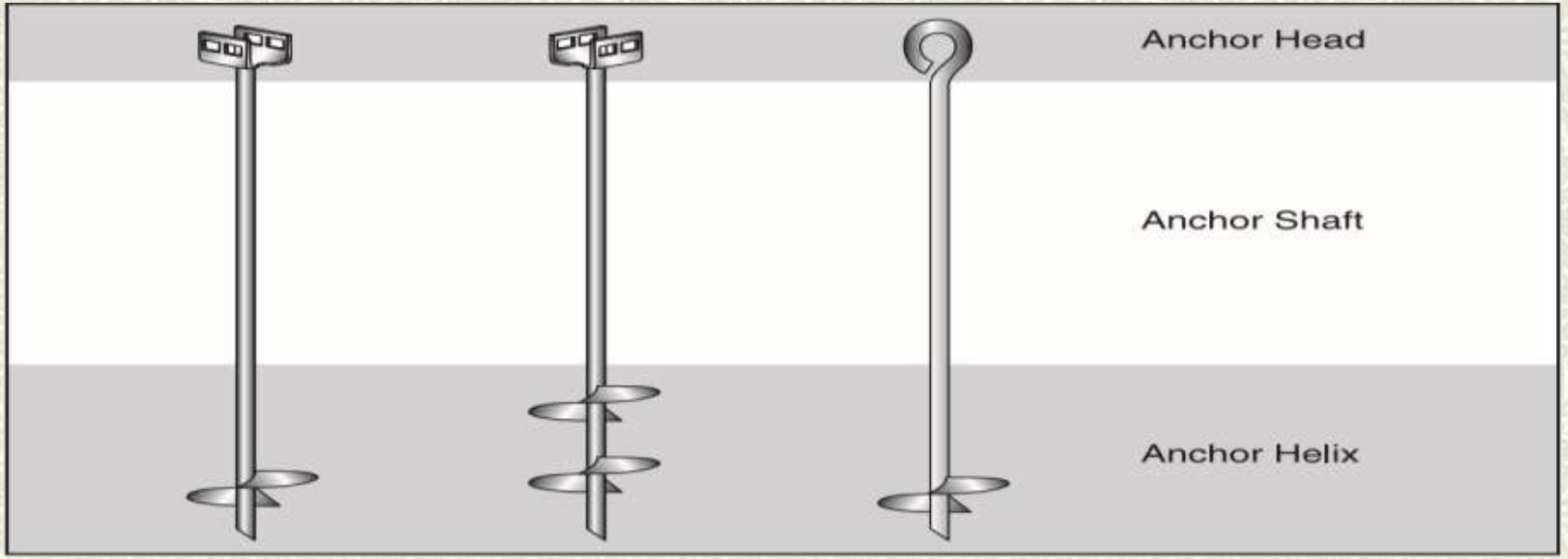
- Pros
  - Resist flotation, collapse, lateral movement
  - Widely used
  - Economical and readily available
  - Installed with lightweight equipment

- 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

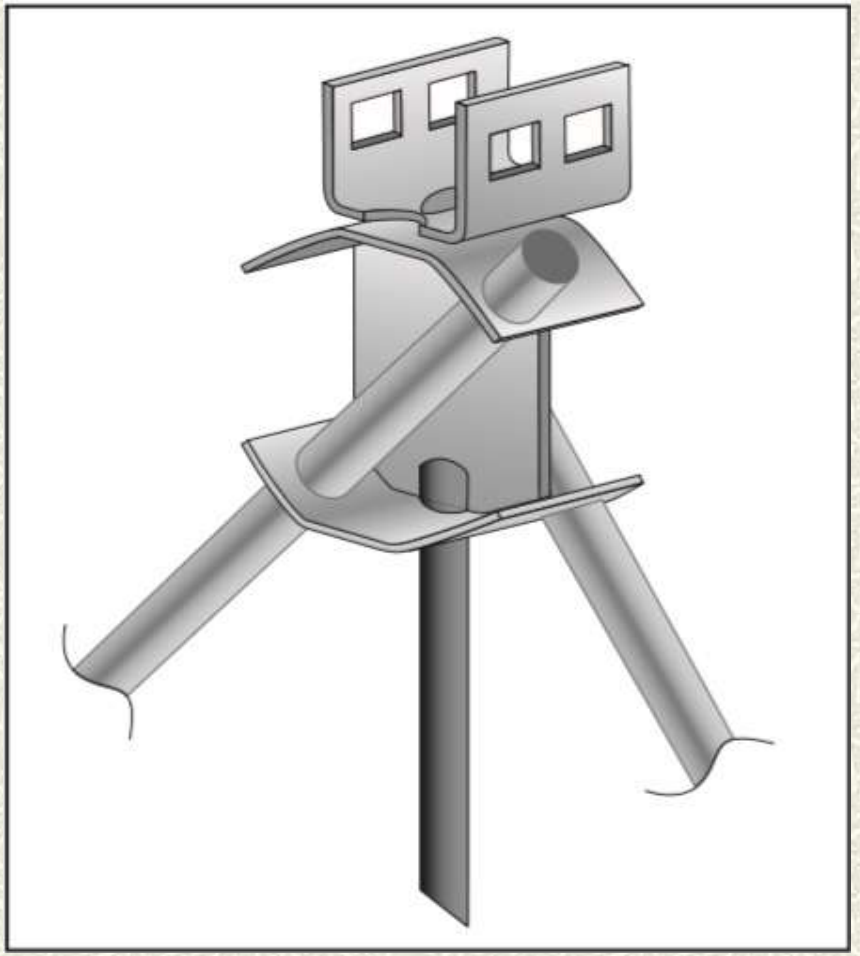
-Uses dead weight or combination of dead weight and soil uplift resistance

-Connection to concrete (anchor bolts) is critical! (adequate embedment)

Types of Ground Anchors

Cross Drive Anchors

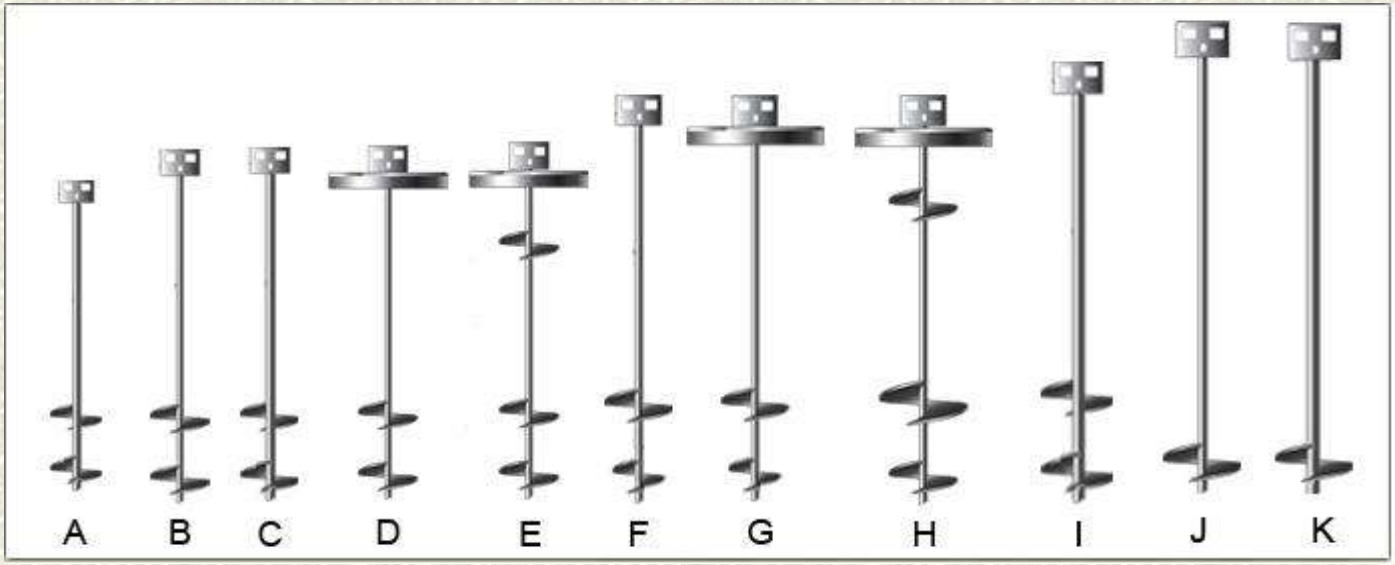
-Contains a head secured to a metal shaft
-Metal pins are driven into the ground to form an "X"



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



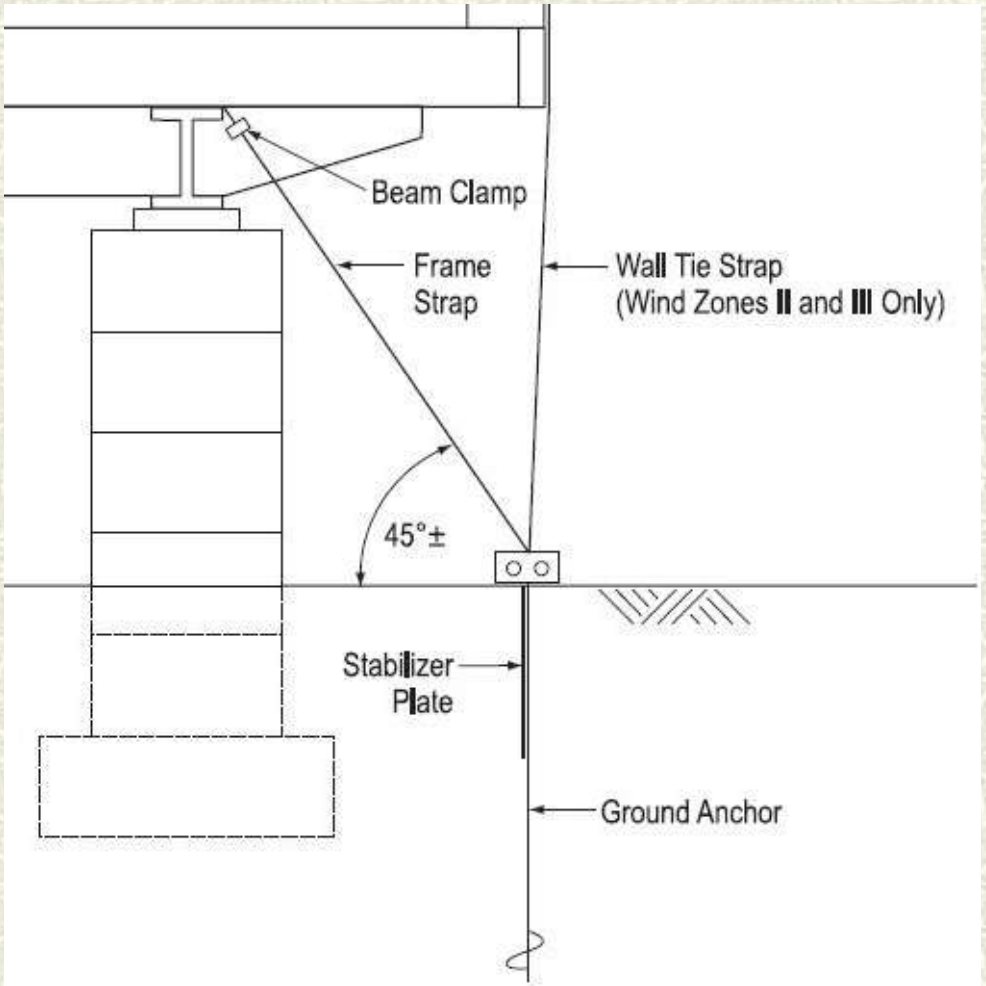
Anchor Installation

- **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 (cont'd.)

- 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



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

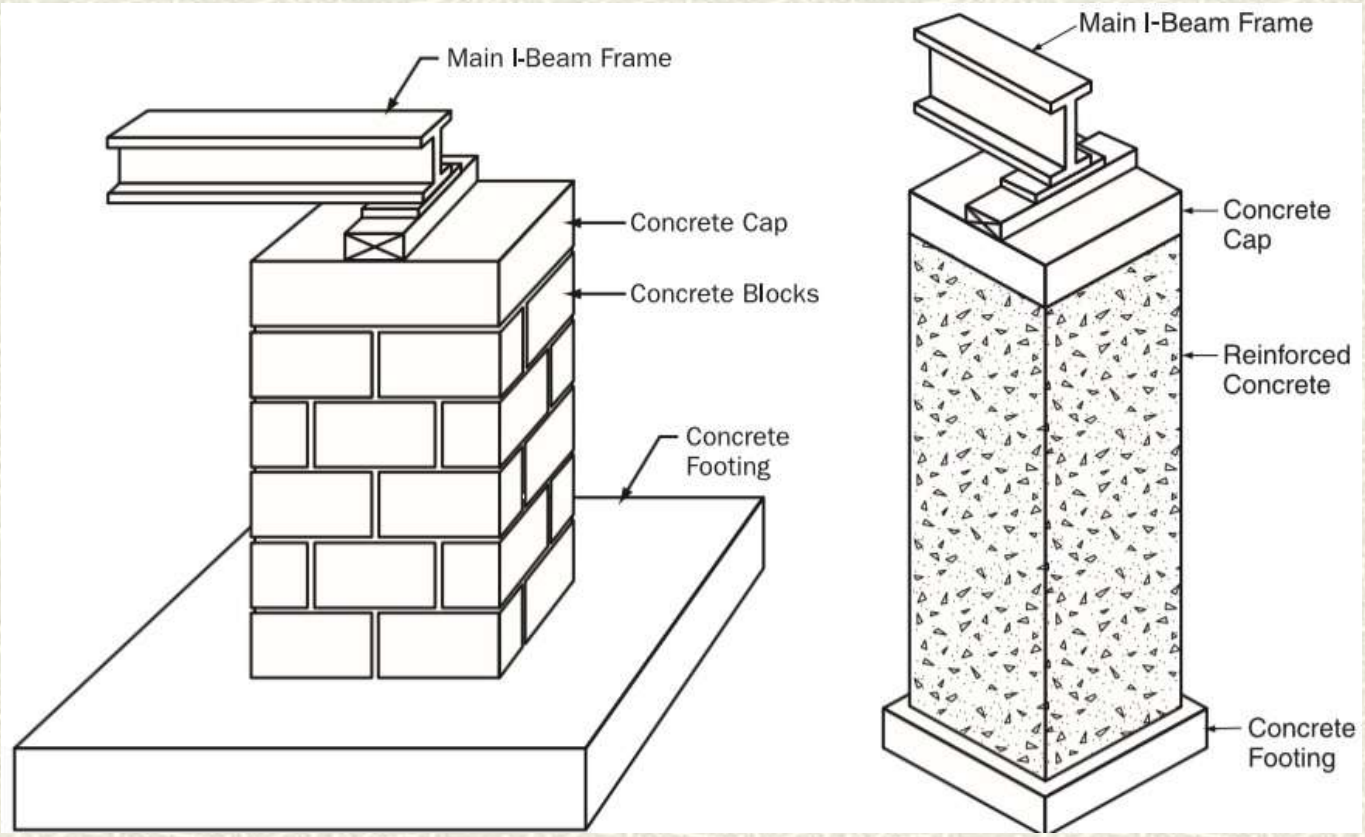
- Type of **open foundation**
- Most commonly used foundation system for manufactured homes
- Two general styles: **reinforced** and **unreinforced**

Foundation Systems – Pier Systems

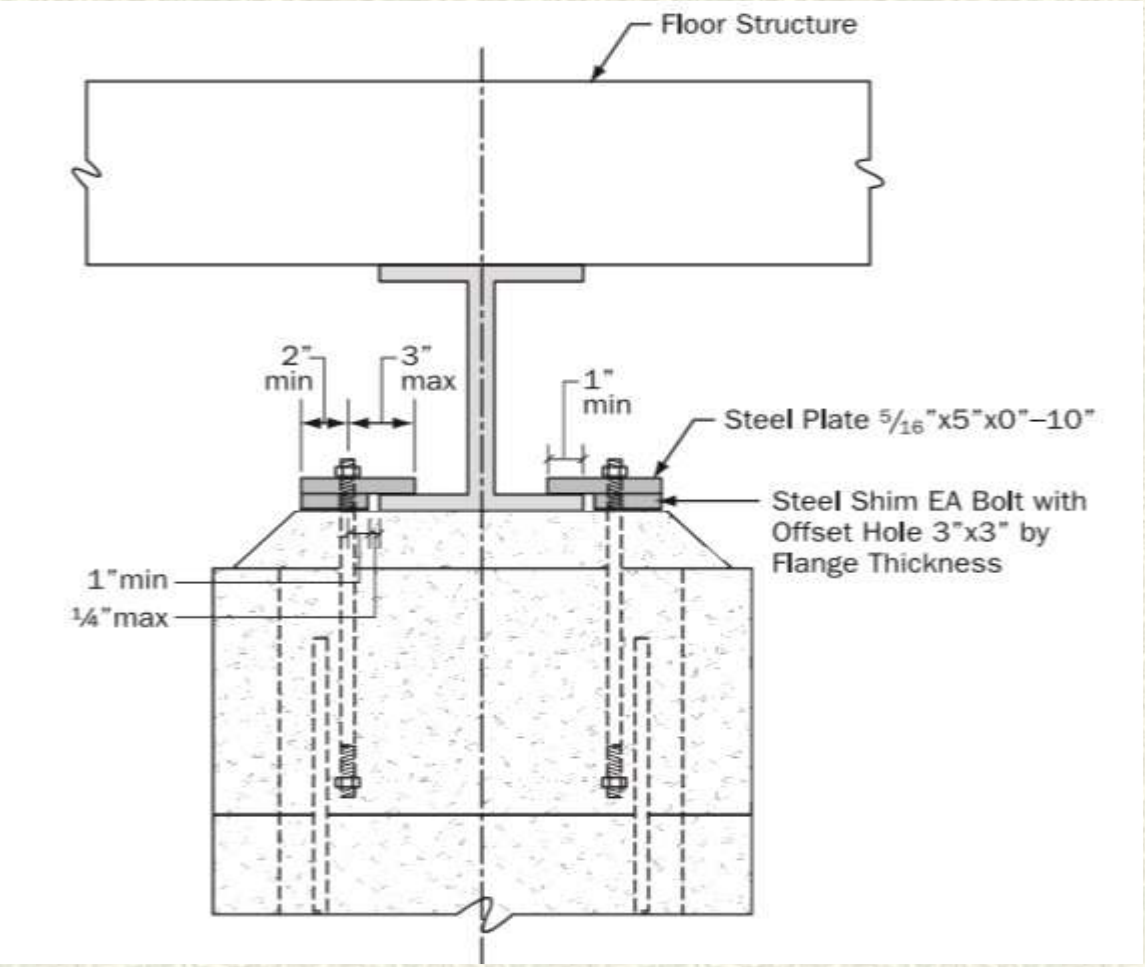
Reinforced pier foundations – pier and footings resist all loads

- **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*
- 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

QUESTIONS ???

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