“Foundation Considerations for Manufactured Homes”

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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
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)
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- 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
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

<table>
<thead>
<tr>
<th>Flood Hazard</th>
<th>Associated Flood Hazard Areas or Property Characteristics</th>
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| 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

* Surcharge not to exceed 1.0 foot. Lesser amount if specified by State or community.
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
  - $\text{DFE} = \text{BFE} + \text{Freeboard}$
- **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
    \[ F_{\text{bouy}} = \gamma \times V_{ol} \]
Design Considerations

- Lateral Forces - create a triangular loading on vertical surfaces

- $F_L = \frac{1}{2} \gamma \times d^2$
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
  - \[ F_d = \frac{(C_d \times A \times \gamma \times V^2)}{2g} \]
    - \( C_d \) 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)
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

Floor Structure

Steel Plate \( \frac{5}{16}'' \times 5'' \times 0'' \) to 10''

Steel Shim EA Bolt with Offset Hole 3'' x 3'' by Flange Thickness

1'' min

\( \frac{1}{4}'' \) max
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
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)]
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**
   o Size and number of bolts, nails or straps
   o Size and spacing of piers, amount of reinforcement, etc.

6. **Note All Design Assumptions and Details on Drawings**
   o All assumptions, calculations, and details should be clearly documented
   o This ensures that floodplain managers and installers understand the design
QUESTIONS ???

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