SEBA Professional Services, LLC
Management Consultants and Financial Advisors

Manufactured Home Foundations in Freezing Climates

An Assessment of Design and Installation Practices For Manufactured Homes in Climates with Seasonally Frozen Ground

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For

The U.S. Department of Housing and Urban Development,
Office of Manufactured Housing Programs
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EXECUTIVE SUMMARY

The primary purpose of this report is to provide guidance on the installation of “frost-protected shallow foundations” (FPSF) and “frost-free foundations” (FFF) for new manufactured homes in frost-susceptible climates. There are important issues with current frost-protected foundation designs that must be considered and addressed when installing a new manufactured home within any state where soil is susceptible to frost heave. The detailed findings on reviewed designs are provided in the Engineering Assessment Report located in Appendix A.

The primary requirements for consideration in any frost-protected foundation, include:

- clarity of technical requirements,
- definite criteria for determining soil frost susceptibility and soil moisture sub-surface drainage conditions, and
- guidance on water table depth to determine if the site is suitably well drained.

Additionally, it is necessary to provide guidance on appropriate site-specific adjustments of details such as depth of non-frost-susceptible soil, fill layers and the layout of sub-surface drainage. Clarification and accuracy of roles during the site testing and installation process also plays an important part in ensuring that frost-protected foundation designs are acceptable. Most reviewed designs failed one or more of these requirements.

Per these requirements, each organization involved in the process of foundation design, approval, and installation has responsibilities that must be met. These responsibilities are described in more detail later in the report.

- For manufacturers, this includes ensuring designs comply fully with 24 Code of Federal Regulations (CFR) 3285, Model Manufactured Home Installation Standards (HUD Code) and applicable provisions of SEI/ASCE 32-01 (ASCE 32). Installation instructions that rely exclusively on surface drainage must be terminated or immediately revised and all instructions should inform installers that prior to beginning the installation, a site-specific soil test is required to determine soil frost susceptibility.

- Retailers must provide consumers with a copy of the consumer disclosure and verify that the installations are performed only by licensed installers. Additionally, retailers must notify HUD of any new manufactured home sales within or into a HUD-administered state.

- Design professionals and Design Approval Primary Inspection Agencies (DAPIAs) must comply with all aspects of the HUD Code as provided in 24 CFR 3285 as well as the ACSE 32 standard. Designs that rely on surface drainage exclusively or do not specify the means of assessing frost susceptibility of soils and their sub-surface drainage characteristics must be disapproved. Additionally, design and installation responsibilities may not be delegated to local regulatory authorities.

- Installers, if installing a new home on a site that has conditions not covered in the manufacturer's installation instructions or the engineered foundation plan, should bring the site conditions to the engineer of record or any licensed architect or engineer. Once the plan is updated to address site conditions and sealed, it should be sent to the manufacturer and its DAPIA for approval as well as the Local Authority Having Jurisdiction (LAHJ). Installers should not use any design that has them take on the responsibility of assessing frost susceptibility and sub-surface drainage conditions without proper soil analysis.

- Regulatory officials and inspectors should categorically reject installation plans that require them to take on any aspect of design responsibility. If a site is claimed to have soil that is not frost susceptible or soil that is well-drained, evidence must be provided. Installation plans should be available on-site during inspections. If these plans are not available, the home cannot pass inspection. In areas where no set local frost depth is determined, the depths corresponding with the Air Freezing Index (Figure 1) should be used. Installation rules in both states and local municipalities should be compared to the ASCE 32 standard and HUD Code to ensure conformity.

INTRODUCTION

Engineered Foundations Designs (EFD) including frost-protected shallow foundations (FPSF) and "frost-free foundation" (FFF) variant as implemented for some manufactured housing installations, have great appeal and potential in freezing climates as a cost-effective means of installing manufactured homes on seasonally-frozen ground. Understandably, their use has been promoted and increased in recent years as a means for reducing manufactured housing installation costs when compared to using conventional or proprietary foundation support systems in freezing climates. However, some key factors important to their long-term and consistent success require special considerations that are often neglected, particularly for FFF designs and installations. These factors include appropriately engineered installation details, site investigation practices, and verification procedures to ensure that important design conditions are actually being achieved in practice.

PURPOSE

Given the concern described above, this report was developed for the purpose of clarifying requirements and providing practical guidance for the manufactured housing industry when designing or setting foundations for a manufactured home in locations with freezing climates with seasonal ground freezing. This guidance is intended for first-time installations, not replacement installs when current foundations exist on site.

FINDINGS

In support of this report's purpose, a selection of representative FFF designs in current use were reviewed for consistency with the HUD code, the SEI/ASCE 32-01 (ASCE 32) standard titled *Design and*

Construction of Frost Protected Shallow Foundations, and generally accepted engineering practice. These reviews and additional technical information (including terminology and technical references) are included in an engineering assessment report located in Appendix A. Thus, Appendix A provides the technical basis for the guidance and recommendations included herein. FPSF designs were also reviewed, however, fewer issues were identified than were found with the FFF variants.

A summary of key findings from the engineering assessment in Appendix A is as follows:

- One reviewed FFF design demonstrated an appropriate application of the HUD code and ASCE 32 standard's technical requirements for frost protection of foundations. Thus, it is possible to develop a compliant FFF design.
- All other reviewed FFF designs contained a number of flaws or non-conformances, including:
    - A lack of clarity of technical requirements in manufacturer installation instructions, details, and notes
    - Missing or vague criteria for identification and measurement of soil frost susceptibility
    - Missing or vague guidance for determining soil moisture, sub-surface drainage conditions, and water table depth in relation to determining if the site is "well drained" and suitable for an FFF installation.
    - Missing guidance to direct appropriate site specific adjustments of important installation details (e.g., depth of non-frost-susceptible soil or fill layers and lay-out of sub-surface drainage when required).
- All of the FFF installation designs reviewed showed a pattern of confused roles and responsibilities, often assigning design decisions and site engineering evaluations to local regulatory officials who are typically neither qualified nor trained in foundation engineering or soil mechanics and engineering. Furthermore, they are not charged for such responsibilities because it may pose a conflict of interest (i.e., enforcers making design and construction decisions or judgments on matters they will be enforcing) and a potential conflict with state engineering practice laws (i.e., conducting engineering or design activities for which they are not licensed). Consequently, this practice can lead to an incorrect selection of the proper foundation and drainage system for the site.

Consequently, most of the reviewed FFF designs were found to be not in conformance with the HUD Code and the ASCE 32 reference standard for frost-protection of shallow foundations. In addition, one state's installation rules were reviewed and provisions related to FFF design and installations were found to be similarly non-compliant. Thus, a need exists to clarify requirements and provide guidance for proper and compliant applications of FFF designs as an alternative to a conventional (frost depth) footing or a conventional FPSF design using insulation to protect against ground freezing per the ASCE 32 standard.

RECOMMENDATIONS

Recommendations to resolve the problems with FFF designs all relate to technical and procedural conformance issues identified in the previous section. These issues necessarily involve designers, DAPIAs, manufacturers, installers, and regulatory authorities. The most important factor in reducing problems is a properly designed installation instruction giving appropriate direction and details for

installers to implement and regulatory officials to verify and inspect. Because this over-arching concern is applicable to all methods of installation related to foundation frost-protection, specific recommendations and guidance for various design and installation options are provided in the next section.

Recommendations for Manufacturers

Manufacturers should require that design professionals who submit plans to them for approval, as required by 24 CFR Part 3285.2 (c) (1) (ii), develop foundation frost-protection installation methods that comply with applicable provisions of the HUD Code and ASCE 32. To ensure consistent and effective conformance, options with detailed guidance for compliant designs are provided in the next section and should be followed. These directions should also be incorporated into their Manufacturer Installation Instruction manual as required by 24 CFR Part 3285.2 (c)(2).

- Current FFF installation instructions that rely exclusively on surface drainage as a means of foundation frost-protection should be terminated or immediately revised in accordance with the previous recommendation.

- Manufacturer installation instructions for FFF designs need to indicate that, prior to commencement of installation, a site-specific soil test is required in order to determine if the site soil is non-frost-susceptible and that the soil is "well-drained" with a water table depth consistently and sufficiently below the frost line. Specific requirements are presented in the installation practices section of this paper.

- Manufacturer installation instructions should indicate that a ground water assessment needs to be done prior to commencement of installation. If there appears to be a situation where the ground water is within 2 feet of the bottom of the foundation then an engineered design must be used.

- Manufacturer's installation instructions need to identify what steps need to be taken to confirm that the site is non-frost-susceptible. If a soil test is not done to prove that the soil is non-frost susceptible, then the site must be assumed to be frost susceptible and must be developed accordingly, as such tests must be done prior to commencement of installation.

To facilitate installations in locations subject to freezing, manufacturer instructions should have at least one example of an acceptable foundation system for frost and non-frost susceptible soil conditions for use in freezing climate locations. These designs must have a design professional's seal, and if not previously part of the manufacturer's instructions, be approved by the manufacturer and its Design Approval Primary Inspection Agency (DAPIA). These plans can be a supplement to the manual and should also be available as an electronic PDF.

It is recommended that manufacturers make an updated copy of their manufactures installation instructions with the supplements available in electronic format as part of the sale process. This will

greatly decrease mistakes made in installing the foundations before the owners and installers have a copy of the manufactures instruction manual.

Retailers-and Park Owners

Retailers and park owners operating as retailers must provide buyers with a copy of the required consumer disclosure which indicates that new manufactured homes must be installed by licensed installers and must verify and employ only installers that have the proper licenses and training to install manufactured homes within the state of each home's installation.

It is also recommended that an electronic copy of the manufacturer's instruction manual and foundation details be available at the time of the sale to purchasers to evaluate any foundation options before the home is delivered and before installation begins.

In HUD Administered Installation States, retailers and park owners acting as retailers must notify HUD of the certification and location of each home installation (HUD 306 form) and each installation must be inspected by a qualified inspector (see 24 CFR § 3286.511(a)) and the acceptability of the inspection verified on a HUD approved inspection form (HUD 309 form).

Recommendations for Design Professionals and DAPIAs

Foundation frost-protection methods used for installation designs must comply with the HUD Code and the ASCE 32 standard. To ensure consistent and effective conformance, options with detailed guidance for development of compliant designs and for DAPIA review and approval are provided in the next section, Conformance Options for New Designs and Future Installation Practices.

FFF installation designs that rely exclusively on surface drainage as a means of foundation frost-protection are not acceptable. Any existing installation designs of this type should be removed for use and revised by the engineer of record and DAPIA approval withdrawn.

FFF installation designs that do not specify appropriate means of assessing the frost-susceptibility of soils and their sub-surface drainage characteristics on a site-specific basis need to be removed from use and DAPIA approval withdrawn.

FFF installation designs that assign design responsibilities to local regulatory authorities, such as assessing site drainage, water table depth, or soil frost-susceptibility are also not acceptable and need to be disapproved.

Recommendations for Installers

When installing a new home on a site that has conditions not covered in the manufacturer's instruction manual provided by the manufacturer, or the engineered foundation plan, the special site conditions should be brought to the attention of the engineer of record. If there is no engineer of record, a licensed engineer or licensed architect should be retained to evaluate the conditions and then design a plan to

install the home. Once this plan is finalized and sealed, it must be sent to the manufacturer and its DAPIA for approval per 24 CFR Part 3285.2(c)(1)(ii). The plan should also be submitted to the Local Authority Having Jurisdiction (LAHJ) for approval if applicable. Refer to the next section for guidance on compliant installation instructions and installation practices.

Manufactured homes must not be installed using FFF installation plans that rely exclusively on surface drainage as a means of frost protection.

Installers should never initiate a FFF installation where the instructions requires them to take on design responsibility of assessing soil frost-susceptibility and sub-surface drainage conditions without proper soil testing and analysis. Instead, installers should verify that appropriate soil testing and site assessment for use of a FFF design has been completed prior to initiating an installation. Refer to the next section for guidance.

Prior to installation of an engineered system that is not included in the manufacturer's installation instructions, installers need to verify that the installation plan is stamped by an engineer of record as well as approved by the manufacturer and its DAPIA. A LAHJ may require that the plans be reviewed and sealed by an engineer or architect that is licensed in the state where the installation is occurring.

Recommendations for Local Regulatory Officials and Inspectors

Regulatory officials and inspectors should reject installation plans that require them to execute a design responsibility such as assessing the subsurface drainage, water table depth, or frost-susceptibility of soils on a given site. Freezing-climate installation plans that rely exclusively on surface drainage as a means of frost protection should not be approved by local regulatory officials.

Where a site is claimed to have non-frost-susceptible soils or soils that are "well-drained" as a basis for setting foundation pads or footings above the design frost depth, evidence should be required including soils tests and site sub-surface drainage and groundwater investigation by a qualified laboratory or professional. Single site soil samples can be taken by a HUD Licensed Manufactured Home Installer in HUD administered states with the soil tests done by an accredited lab.

Regulatory officials should assure that the approved installation plans and the manufacturer installation instructions are on site and available during inspections. If approved installation plans are not available and on site during inspections, the home cannot pass inspection.

Local regulatory officials should consider permitting design frost depths to be determined in accordance with Option #1 in the next section. In areas where no set local frost depth is determined, the frost depths from the Air Freezing index (see Figure 1 and Table 1) should be used.

State and local installation rules should be reviewed and corrected as necessary to ensure conformity with the ASCE 32 standard and the HUD code 24 CFR, Part 3285.312(b).

OPTIONS FOR NEW DESIGNS AND FUTURE INSTALLATION PRACTICES

OPTION #1: Checklist for Conventional Footings in Freezing Climates
HUD Code, 24 CFR Part 3285.312(b)(1)

- Obtain the local-design frost depth for footings from one of the following:
  - The local authority having jurisdiction (LAHJ),
  - Use Table 1 with the site's Air-Freezing Index (AFI) from Figure 1[1], or
  - Consult with a registered professional engineer, registered architect, or registered geologist.

- When using Table 1 and Figure 1 to determine frost depth for footings, the depth of interior pier footings complying with footnote (b) of Table 1 may be taken as one-half the depth required in Table 1 with approval of the LAHJ.

- Based on the required frost depth for footings, dig the footing to the frost depth.

- Check the soil bearing at depth of the footing with a torque probe, pocket penetrometer or other suitable testing device.

- Based on the tested soil bearing value, properly size the footing according to the manufacturer's installation instructions or use Table to 24 CFR Part 3285.312 in the HUD Code.

- Place footing pads and construct piers or supports at locations specified in accordance with the manufacturer's installation instructions.

- Backfill as needed and grade the site as required for drainage:
  - Crown the finish grade at the centerline of the foundation
  - Slope grade a minimum of ½-inch per foot for a minimum distance of 10 feet away from the home perimeter.

[1] A list of AFI values for various states and counties can be found in the 2015 International Residential Code (IRC), Table R403.3(2), published by the International Code Council, Inc., and used as the model building code for most states.

TABLE 1. DESIGN FROST DEPTH FOR FOOTINGS[a]

AIR-FREEZING INDEX [See Figure 4]	MINIMUM DEPTH[b] (inches)
≤ 50	3
250	9
350	12
500	16
1000	24
1500	32
2000	40
2500	45
3000	52
3500	57
4000	62
4250	65

a. These design frost depths are intended to be used for protection of building foundations against frost heave and are not applicable to site or street utilities or other non-building applications.

b. These design frost depths for footings shall be permitted to be halved for footings interior to the building perimeter and located within an enclosed space. Where skirting is used to enclose the space, the skirting shall be insulated to a minimum R-5 (1000 to

2500 AFI) or R-10 (>2500 AFI) and vents shall be capable of automatically closing at outdoor temperatures below 40 deg F (which necessitates use of a ground vapor barrier).

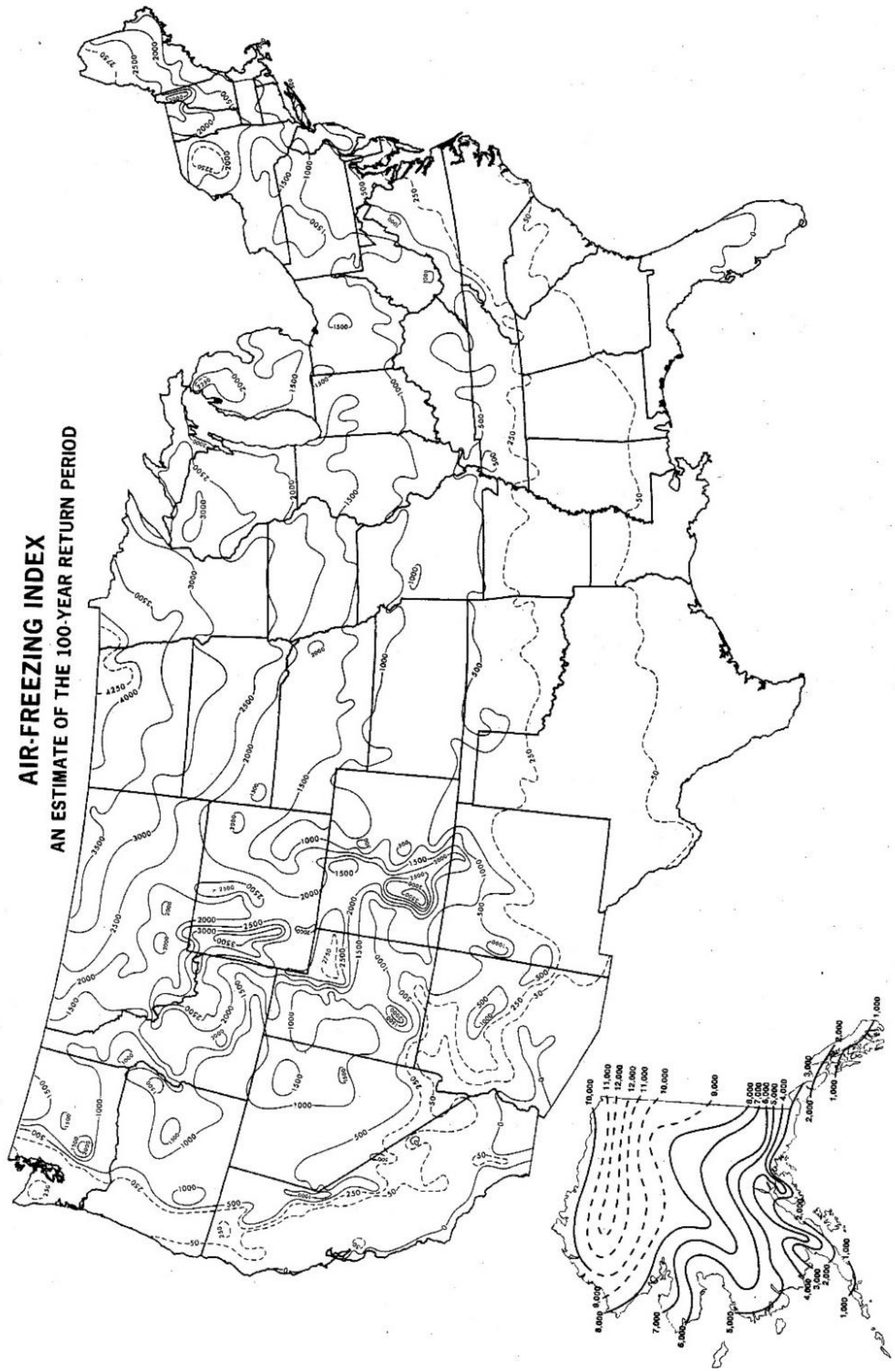

Figure 1. U.S. Air Freezing Index Map (based on Steurer, 1989 and Steurer and Crandell, 1995)

OPTION #2: Checklist for Monolithic Slab Systems in Freezing Climates ("Frost Free Footing")
HUD Code, 24CFR Part 3285.312(b)(2)

Pre-Installation Preparations:

- Before initiating installation, verify that the installation instructions are designed (sealed) by a registered professional engineer or registered architect, approved by the manufacturer and its DAPIA. The LAHJ can require that the plans also be reviewed and sealed by an engineer or architect in the state where the installation is to occur.

- Verify that the LAHJ has accepted and approved the foundation and installation plan and all applicable permits are obtained. An approved installation design needs to comply with one of the following conformance options for the proposed installation design as permitted in the HUD Code:

    - Complies with SEI/ASCE 32 standard by use of non-frost-susceptible fills or existing soils (adequately tested and verified as such as defined in SEI/ASCE 32) and that such fills or soils extend to the local frost depth with provision for adequate surface drainage and, in addition, subgrade drainage where underlying soils are poorly drained and/or the water table is within two feet of the design frost depth.

    - Complies with accepted engineering practice to prevent the effects of frost heave in a manner equivalent to the SEI/ASCE 32 standard. Equivalent alternative accepted engineering practices include: (1) the specification of an alternative criteria for testing the frost susceptibility of soils (e.g., different fines content allowances based on substantiating data), and (2) different frost depth determination based on thermal modeling of the climatic, soil, and foundation conditions.

    NOTE: Reliance solely on surface drainage to prevent frost heave without verification of non-frost-susceptible fill materials or existing non-frost susceptible soils to frost depth does not comply with the SEI/ASCE 32 standard or HUD Code's allowance for "acceptable engineering practice to prevent the effects of frost heave."

- For designs that rely on well-drained sites and use of existing soils to frost depth that are non-frost susceptible, verify the following before initiating installation:

    - The non-frost-susceptible condition of existing soils above the frost depth (and below the base of the proposed slab) have been tested in accordance with ASTM D442 and determined to have a fines mass content of less than 6% passing a #200 sieve for the specific installation site or the development as a whole. A soils report should be provided by the engineer or soil lab of record for verification.

- Alternatively, conduct or contract such testing as follows:

    - Obtain a minimum of two soil samples per installation site (one at each end of the foundation area) and from any borrow materials on site used as fill. A materials report from a quarry may be used when material is supplied from a licensed quarry.

    - When conducting borings for soil samples, take a minimum of one pint (plastic bag full) of soil from depths of one foot and at the locally prescribed frost depth or as determined from Table 1, Design Frost Depth for Footings. Continue each boring to two feet below the locally-prescribed frost depth (as measured from the proposed finish grade) to determine if the water table is present.

    - Deliver or send the soil samples to a soils lab for particle size testing per ASTM D442.

    - If the soils lab report indicates greater than 6% fines by mass passing a #200 sieve then the soil at the site is frost susceptible and either footing to frost depth or one of the alternative foundation options (see Appendix C) for frost susceptible soil conditions must be used.

- The water table condition of the site has been assessed by the engineer of record and documentation provided of the water table being at least two feet below the local frost depth. Alternatively, make this determination using soil borings as described above.

- If the water table is higher than two feet below the local frost depth, a network of drainage pipes sloped to drain to daylight must be placed at the base of non-frost-susceptible fill (e.g., clean gravel or crush rock) placed to a depth equal to the local frost depth.

- Alternatively, a site specific foundation design can be prepared and sealed by a professional engineer or registered architect and approved the manufacturer and it's DAPIA.

- Save documentation of all of the above and provide to the LAHJ for verification.

- For designs that rely on well-drained sites and use of fill materials to frost depth that are non-frost susceptible, verify the following before initiating installation:

    - The slab base and foundation fill materials are specified by the engineer of record as non-frost susceptible such as clean gravel or crushed rock or other suitable material with no more than 6% fines by mass passing a #200 sieve per ASTM D442 test method. Order subgrade materials accordingly and in an amount required to fill from the frost depth to the slab base for the entire extent of the slab plus any over dig.

- The water table condition of the site has been assessed by the engineer of record and documentation provided of the water table being at least two feet below the local frost depth. Alternatively, make this determination using soil borings as described above.

    - If the water table is higher than two feet below the local frost depth, a network of drainage pipe sloped to drain to daylight must be placed at the base of non-frost-susceptible fill (e.g., clean gravel or crush rock) placed to a depth equal to the local frost depth.

- Save documentation of all of the above and provide to the LAHJ for verification.

Installation Phase:

- Excavate slab area to frost depth or only to the bottom of the slab's non-frost-susceptible base layer if existing soils have been determined to be non-frost susceptible down to frost depth during the pre-installation preparation phase (see above).

- Place foundation drains sloped to drain to daylight at the bottom of the non-frost-susceptible base or fill material layer.

- Place the non-frost-susceptible fill and base materials, compacting as required by the manufacturer's installation instructions and the engineer of record. Do not initiate fill placement where compaction requirements and methods are not specified. Obtain compaction requirements, as needed, from the engineer of record. The minimum requirement is 90% compaction per 24 CFR Part 3285.201 although an engineer or LAHJ may require a higher number based on the fill material used.

- Construct the reinforced monolithic slab in accordance with the manufacturer's installation instructions or according to the manufacturer and DAPIA approved plans.

- Backfill as needed and grade the site as required for drainage:
  - Slope grade a minimum of ½-inch per foot for a minimum distance of 10 feet away from the home perimeter.

NOTE: The above procedures also apply to designs where a monolithic slab is not used and pier footing pads are placed directly on non-frost-susceptible fill materials (e.g., clean gravel or crushed rock).

OPTION #3: Checklist for Insulated Foundations (Frost-Protected Shallow Foundation)
HUD Code, 24 CFR Part 3285.312(b)(3)

Pre-Installation Preparations:

- Before initiating installation, verify that the installation instructions are designed (sealed) by a registered professional engineer or registered architect, approved by the manufacturer and its DAPIA. A LAHJ may also require the plans to be reviewed and sealed by a licensed engineer or architect in the state where the installation is to occur.

- Also, verify that the plans have approved the installation design as complying with one of the following basis for the proposed installation design as permitted in the HUD Code:

    - Complies with SEI/ASCE 32 standard by use of properly-specified insulation materials and sized in accordance with the local climate and located around the perimeter of the foundation (including insulated skirting with vents capable of closing at temperatures below 40 degrees) or the entire foundation pad is

insulated where there is no skirting or the skirting is un-insulated or the skirting has non-closing vents. Non-frost-susceptible base materials are used at a minimum thickness required by SEI/ASCE 32, and insulation materials are protected against damage in accordance with SEI/ASCE 32.

- Complies with accepted engineering practice to prevent the effects of frost heave in a manner equivalent to the insulation provisions in the SEI/ASCE 32 standard. Equivalent alternative accepted engineering practices include: (1) the specification of an alternative insulation amounts based on dynamic thermal modeling of the climatic, soil, and foundation conditions specific to the site, and (2) alternative insulation materials or types with data substantiating long-term R-values in below-grade applications.

- NOTE: Designs which place insulation materials in a discontinuous fashion, such that exposed slab edges or other types of thermal bridging occurs, do not meet the requirements of the SEI/ASCE 32 standard or the HUD Code provisions that allow the use of "acceptable engineering practice to prevent the effects of frost heave."

- Order foundation insulation materials as specified in the installation instruction and verify the correct type is received. Commonly accepted insulation materials include Extruded Polystyrene (XPS) and Expanded Polystyrene (EPS) of various "types" in accordance with ASTM C578.

- Insulation material conformance with the specified type should be verified by product labels or a certification from the insulation manufacturer. Materials commonly stocked in supply stores may not be the correct "type" even though it may be the correct "kind" (e.g., XPS or EPS).

  NOTE: There is no need to determine the frost susceptibility of underlying soils to frost depth in the insulated foundation design approach when the provisions of SEI/ASCE 32 are satisfied.

<u>Installation Phase:</u>

- Excavate the foundation area to the correct shallow foundation depth as indicated in the manufacturer's installation instructions or by the engineer of record (generally the foundation depth need not exceed 12" to 16" below finish grade).

- Place specified non-frost-susceptible base material and provide drainage pipes around the perimeter, at a minimum of 4 inches (within the base material layer) as required by the installation instructions. Pipes need to be day-lighted or have a mechanical means of draining the water (see detail in Appendix C).

- Sequence the foundation slab or pad construction and insulation placement in accordance with the design approach indicated on the manufacturer's installation instructions. Where sub-slab insulation is required this will need to be placed before slab construction. Perimeter insulation may be placed after slab construction (see detail in Appendix C).

- After construction of the slab and supports and placement of the home, construct the insulated skirting with automatically closing vents as required by the manufacturer's installation instructions. Where the foundation slab is entirely insulated with horizontal below ground insulation (the design does not rely on perimeter insulation only), no skirting is required. (See detail in Appendix C).

- Place wing insulation (extending outward horizontally underground from the perimeter of the foundation) as required by the installation instructions. Depending on the design approach and climate severity, wing insulation may or may not be required.

- Provide protection of any exposed exterior insulation or within 10 inches of the finish grade surface. (see detail in Appendix C)

- Backfill as needed and grade the site as required for drainage:
    - Slope grade a minimum of ½-inch per foot for a minimum distance of 10 feet away from the home perimeter.

CONCLUSION

A detailed review of several systems outlined in the report below indicate that many FFF designs and practices are not conforming to the requirements outlined in 24 CFR part 3285.312 and SEI/ASCE 32.01. This non-conformance is largely due to lack of consistency in design approaches, insufficient or nonexistent instructions in Manufacturers Installation Instructions related to FFF designs, the lack of understanding of best practices for installation site analysis and foundation installation, and an overreliance on localities that often do not possess officials with specialized knowledge of FFF designs and requirements. These shortcomings can be improved by establishing consistent, well-documented best practices and supplemental guidelines for the use of FFF designs.

APPENDIX A – ENGINEERING ASSESSMENT REPORT

Foundation Design for Manufactured Homes in Freezing Climates

An Assessment of Design and Installation Practices For Manufactured Homes in Climates with Seasonally Frozen Ground

FINAL REPORT

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INTRODUCTION

Foundation systems that do not require standard footings to below the frost line have great appeal and potential in colder climates as a cost-effective means of installing manufactured homes on seasonally-frozen ground. Understandably, their use has been promoted and increased in recent years as a means for manufactured housing installation using conventional or proprietary foundation support systems in colder-climates. However, key factors important to their long-term success require special consideration. These factors include appropriately engineered installation details, site investigation practices, and verification procedures to ensure that important design conditions are actually being achieved in practice.

For the purpose of this report, frost-free foundations (FFF) are distinguished in practice from a frost-protected shallow foundation (FPSF) even though both methods are based on the same design and construction standard, ASCE 32-01, *Design and Construction of Frost-Protected Shallow Foundations* (ASCE 32). The FFF relies exclusively on the presence of non-frost-susceptible subgrade materials (soil or fill) on a well-drained site. The FPSF relies exclusively on the use of foundation and below-ground insulation to protect the soil under the foundation (assumed frost-susceptible) from freezing, although a nominal amount of drainage is still required as a matter of good practice to provide a suitable environment for acceptable below-grade insulation materials and to also satisfy building code or HUD code requirements for foundation and site surface drainage.

Theoretically, frost protection can be achieved by removing any one of the three conditions required to support the occurrence of frost heave: (1) moist ground or a moisture source at depth below ground, (2) freezing temperatures within the ground, and (3) presence of fine-grained, frost-susceptible soils or fill materials. However, this should not be taken to imply that by simply removing any one of these factors an equally reliable design is achieved or that there are not important differences in execution to ensure an equivalent and consistent performance outcome. In short, differences in the proper execution of the different methods of frost protection affect the level of reliability achieved in practice.

For example, using the FPSF method, attention must be paid to proper specification and installation of foundation insulation in accordance with ASCE 32-01. Similarly, using the FFF method, care must be

taken to properly specify and confirm the non-frost-susceptibility of foundation sub-grade soils or fill materials. In both cases, but for different purposes and reasons or consequences, adequate drainage is required. In particular, the ASCE 32 standard requires in Section 4.2 that FFF designs, which rely primarily on subgrade non-frost-susceptibility rather than protection against freezing temperatures, must address the following criteria:

(1) "placed on a layer of well-drained undisturbed ground or fill material",
(2) the ground or fill material "is not susceptible to frost", and
(3) the non-frost-susceptible ground or fill layer must extend to the "design frost depth".

The proper execution of the above criteria require a proper understanding of:

1) The meaning of "well-drained" and how to confirm and provide this characteristic
2) The meaning of "not susceptible to frost" and how to confirm the presence of or provide this characteristic in relation to site soils or fill materials
3) The meaning of "design frost depth" and, again, how to confirm or characterize it for a given site.

The above items define important design considerations in ASCE 32 and also establish a standard of care that other alternative methods must meet with at least an equivalent level of performance and reliability. These same design concepts and principles apply to FFF designs as currently used in the manufactured housing industry. Thus, this report has involved the review of a number of contemporary FFF designs and installation practices. Consequently, a number of inconsistencies and problems have been identified in the execution of the above concepts for conformance with the HUD Code and, specifically, its reference to the ASCE 32-01 standard. To assist in resolving these problems, this report examines the meaning and intentions of the above terms and criteria. Finally, recommendations are made where considered necessary and meaningful to ensure the proper and cost-effective execution of FFF designs for installation of manufactured housing units in cold climates with seasonal ground freezing.

IMPORTANT TERMS AND THEIR MEANING

Well-drained

The term "well-drained" in reference to FFF designs is not defined in the ASCE 32-01 standard. Therefore, its application in regard to frost-heave mitigation or prevention must rely on accepted engineering practice. Well-drained encompasses both surface drainage and sub-surface moisture conditions of a soil which are affected by site topography and also local climate among other factors such as sub-surface water flows. Merely, assessing site surface drainage without assessing ground water conditions at depth or vice-versa is inadequate. In addition, assessing these conditions at a point in time (without considering climate factors and soil moisture conditions that vary seasonally and over longer periods of time) also can lead to an inadequate or incomplete assessment. The term "well-drained" must also align with the intended application. For example, a common agricultural definition of a "well-drained soil" is as follows (http://agebb.missouri.edu/agforest/archives/v10n2/gh14.htm):

> "Well-drained soil is that which allows water to percolate through it reasonably quickly and not pool…
>
> Deep, loamy soil and sloping sites tend to be well drained. Soil high in clay content, depressions, or sites with high water tables, underlying rock or 'hard pans' (a layer of soil impervious to water) tend to not be well drained. A test that is often recommended is to dig a hole 12 by 12 inches square and about 12 to 18 inches deep. Fill it with water and let it drain. Then do it again, but this time clock how long it takes to drain. In well-drained soil the water level will go down at a rate of about 1 inch an hour. A faster rate, such as in sandy soil, may signal potentially dry site conditions; a slower rate is a caution that you either need to provide drainage …"

However, the above definition is inadequate and incomplete for an engineering application related to protection of building foundations from frost heave risk. For example, should the soil infiltration rate be measured at the design frost depth? Can an installer reliably conduct a soil boring to identify the water table (or absence thereof) when the water table may vary seasonally or annually? At what infiltration rate should use of subsoil drainage be triggered to prevent accumulation of water in non-frost-susceptible soil or fill layers placed above the frost line. Clearly, more information is needed to properly differentiate between "well-drained conditions" and those that are not so "well-drained" from the perspective of mitigating risk of frost heave or thaw-weakening of soils supporting building foundations. Furthermore, the "well-drained" criteria may need to be more stringent for conditions where existing soils are marginally frost susceptible (or worse) as oppose to conditions where a clearly non-frost-susceptible fill material is used to frost depth (e.g., less than 6% by mass passing a #200 sieve as determined by site samples or certification from the quarry/supplier). The vulnerability of a building foundation to and consequences of foundation differential movement due to a given level of frost-heave or thaw weakening hazard should also be considered, although common practice is aimed at minimizing the hazard to avoid uncertain long-term damage and serviceability problems.

Where soils are potentially frost-susceptible (and must be used for bearing within the frost depth or "active freezing zone" layer of the soil because there are no alternatives such as use of a deeper foundation or non-frost-susceptible fill material), the following description represents an accepted engineering practice for creating a "well-drained" condition intended to protect against excessive frost heave (e.g., control it, but not necessarily eliminate it):

> "…it is imperative to provide the best drainage possible. In more moderate regions where frost does not penetrate as deeply, this may include the careful installation of underdrains to allow water…to escape. Barriers to restrict capillary moisture flow…from below [the frost depth] may also be considered. These may be layers of course grained material or geotextile layers. The purpose is to break the capillary action of fine grained soil…so that moisture [below the frost depth] cannot "wick" to the freezing front…." (McFadden and Bennett, 1991, pp.340-342).

For natural soils, the above practice requires a means of establishing the absence of a water table in close proximity to the design frost depth and that the soil materials within the frost depth are adequately drained, using sub-drainage or ensuring the ability for infiltration below the frost depth. The accepted foundation engineering practice for protection against frost-heave does not merely rely on surface drainage when structures are supported on the "active freezing zone" of a frost-susceptible soil or fill.

Non-Frost-Susceptible

In reference to soil or fill materials, the phrase "not susceptible to frost" or "non-frost-susceptible" is usually taken to mean the soil is granular (e.g., coarse grained) and lacks a sufficient amount of fines (e.g., very fine sand, silt, and clay) to support development of ice lenses in the soil which results in varying degrees of frost heave or thaw-weakening potential depending on a number of factors. Very clayey soils, however, can suppress frost heave potential due to the inability of tightly held soil moisture to migrate by capillary action to the freezing front in the soil to form ice lenses. But, these soils are still considered frost susceptible from the standpoint of thaw-weakening effects.

While varying degrees of sophistication are available to assess the frost-susceptibility of soil (Chamberlain, 1981), methods commonly used rely on an assessment of the grain size distribution of the soil. The most simple of these methods provides a limit on the percentage of a soil mass below a certain particle size, although the percentage may vary from 3% to more than 10% (Chamberlain, 1981). In the ASCE 32 standard (Section 4.2), a non-frost-susceptible soil is defined as follows:

> "Undisturbed granular soils or fill material with less than 6% of mass passing a #200 (0.074 mm) mesh sieve in accordance with ASTM D442."

Other approved materials also are permitted, but with the understanding that the approval is based on geotechnical evidence and analysis as is generally required for alternative means and methods of design and construction. For example, foundation applications that are more sensitive to differential soil movement (due to heave or thaw-weakening) may require a more stringent criteria whereas those that are less sensitive may justify use of a less stringent criteria. But, in both cases, a criteria is applied based on engineering analysis and evidence. The above "6% by mass" criteria is considered appropriate for general foundation applications and is the referenced basis for judging frost-susceptibility of soils in the HUD Code for manufactured housing foundations.

Finally, the ASCE 32 standard requires that "Classification of frost susceptibility of soil shall be determined by a soils or geotechnical engineer, unless otherwise approved." Again, it is clear that, while alternatives are permitted, there is a requirement for evidence that a given soil or fill material on a given site is not susceptible to frost. For example, a contractor or technician may sample materials, have them assessed by a soils lab per ASTM D442 as required by ASCE 32. The soils lab report serves as a basis for approval (i.e., evidence consistent with the requirements and intent of ASCE 32 when an FFF design is pursued). Also, a qualified geotechnical engineer may determine that use of a different method to assess soil frost susceptibility is more favorable (and at least equivalent), again based on evidence.

Design Frost Depth

The term "design frost depth" refers to a depth into ground that frost is expected to reach under a given severity of winter freezing conditions and other factors (such as soil type and ground cover or lack thereof). Generally, design frost depths have been established in an ad-hoc fashion from locality to locality. Consequently, requirements may vary based on different perspectives or experiences that are not always consistent with the physics of frost penetration into ground. For example, some localities in warmer climates may require greater frost depths than those in colder climates. In general, there is no

consistent consideration of the soil type or ground cover. But, experience represented in local building codes is the common source relied upon in the building industry for locally-prescribed frost depths.

To address variation in local design frost depth requirements (where they are available) and provide a more uniform and risk-consistent basis for design frost depth determinations, an alternative procedure for determining the local design frost depth is provided later in the recommendations section of this report. The approach has been prepared as a proposal for future consideration by the ASCE 32 committee. It is based on research and modeling conducted by the NOAA Northeast Climate Data Center (Cornell University) for the U.S. Department of Housing and Urban Development (HUD, 2001). The following chart (Figure 1) provides the basis of the procedure and demonstrates its relationship to variations in locally prescribed (presumptive) frost depths and modeled frost depths. The design frost depths determined by the modeled approach (noted in Figure 1 as “2yr Bare x Safety Factor 2”) are calibrated to agree with local design frost depths used in more severe climates where experience with frost damage and freezing conditions are more consequential and experience may be considered more robust. It is notable that in warmer climate zones there is a clear tendency for locally-defined frost depths to overstate actual design frost depths which signals a lack of risk-consistency in locally-defined frost depths. Thus, use of risk-consistent frost depths will tend to economize foundation construction in moderately cold climates with seasonal ground freezing.

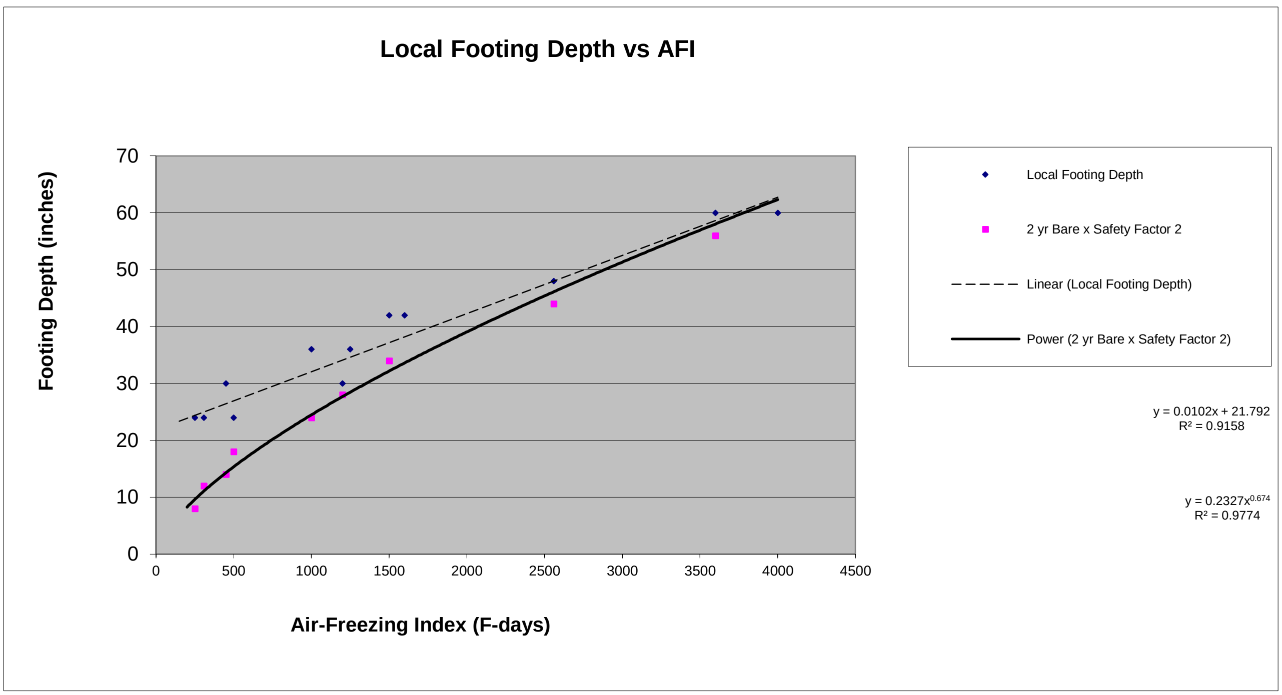

Figure 1. Comparison of Modeled and Locally-Defined Frost Depths for Building Foundations

SEBA Professional Services, LLC
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REVIEW OF EXISTING FFF DESIGNS & DATA

As mentioned, several FFF designs currently used in several US states were provided for review and assessment. From those designs, four representative examples were selected for assessment in this report.

<u>Example #1: FFF Design A (crushed stone pad on subgrade)</u>

Figure 2 illustrates this FFF design as implemented by a DAPIA-approved engineered detail included in the manufacturer's installation manual.

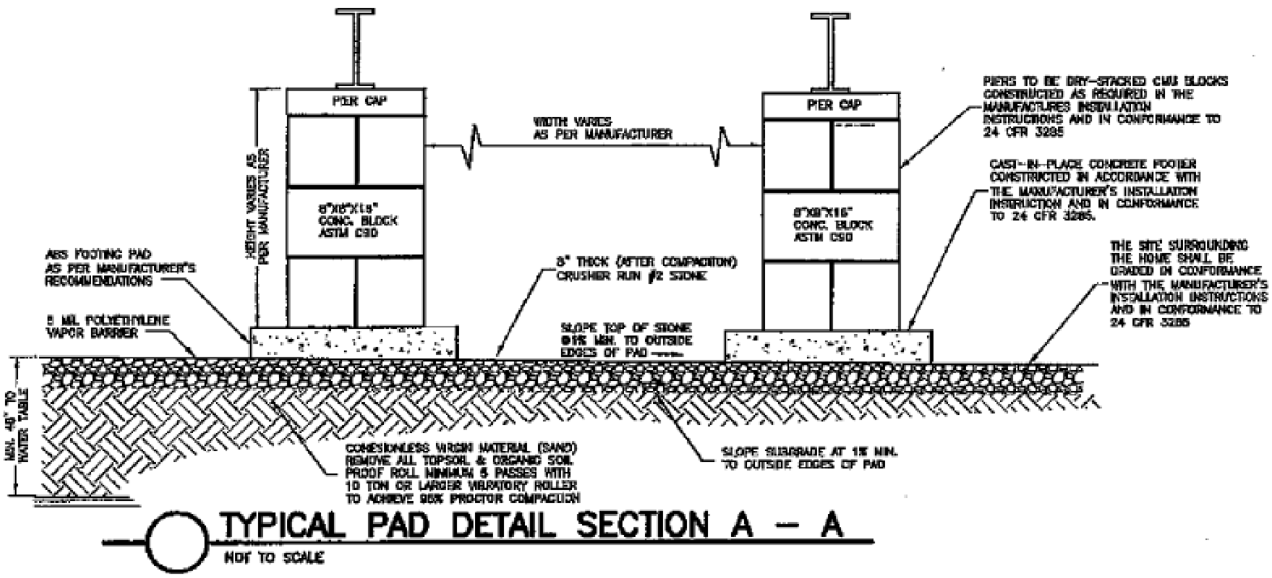

Figure 2. Installation detail for Example#1 (FFF using crushed stone pad on subgrade)

This design represents a reasonable application of the FFF technical requirements in accordance with Section 4.2 of the ASCE 32 standard. For example, it appropriately defines non-frost-susceptible material and requires it to be well-drained and to extend below the required frost depth. However, it places the burden on the local authorities for determining frost-susceptibility for each site application of the design, while at the same time requiring engineering verification (see "DESIGN NOTES" below). The reverse process is more appropriate (i.e., the engineer determines and the authority verifies). This may cause some unintended confusion as to roles and responsibilities which may be entirely missed by installers and those responsible for enforcement. Local authorities have an inspection and verification role, not a construction management or design decision-making role. To do otherwise creates a conflict of interest due to a lack of appropriate separation of roles and responsibilities.

Thus, it may be unlikely that the design is being implemented and enforced consistently in conformance with the technical requirements otherwise reasonably indicated on the installation documents (unless the engineer of record is actually contracted to visit each site or development to conduct the required determinations). Further, the requirement for testing is found in notes within the manufacturer

installation instructions as being at the discretion of the local code official, when the ASCE 32 standard clearly requires testing or an equivalent means of determination. Such judgments should originate with and be the responsibility of the design professional not a local authority or installers. The notes also do not specify a means of determining water table depth. It also does not specify any action other than notifying the engineer before continuing work when groundwater is encountered (thus implying that a ground water assessment is the responsibility of the installer, not the engineer of record and that construction can proceed after the engineer is simply notified). But, this too conflicts with other notes regarding roles and responsibilities.

To exemplify these concerns (i.e., confused or conflicted roles and responsibilities as noted above), the following notes are excerpted verbatim from the reviewed installation plan:

> "DESIGN NOTES:
> The gravel slab foundation design applies only to sites that contain all of the following soil conditions:
> 1. Well drained granular soils that are not susceptible to frost heave.
> 2. No groundwater to a depth of at least 4 feet below the bottom of the proposed slab.
> 3. Soils with a safe bearing capacity of 2,000 psf or greater.
> 4. Soil conditions at each lot shall be verified by design engineer prior to construction.
>
> …
>
> The slab design does not incorporate insulation around and/or under the proposed slab. The foundation shall be enclosed with skirting in accordance with manufacturer's installation instructions and in conformance to 24 CFR 3285.
>
> …
>
> Foundation shall be placed on non-frost susceptible layers of well-drained, undisturbed ground or fill materials that extend below the required frost depth. The non-frost susceptible material shall be approved by the local authority having jurisdiction. When required by the local authority having jurisdiction, the material shall be tested in accordance with ASTM D422 and found to have less than 6% of mass passing #200 mesh sieve to be considered non-frost susceptible. Soil conditions shall be verified by a soils or geotechnical engineer to verify the soil conditions are not susceptible to frost heave.
>
> …
>
> During construction if soil conditions other than well drained soils or groundwater is encountered at a depth of less than 4 feet, the contractor shall notify the design engineer prior to continuing construction. "

This FFF design also includes a detail (Figure 2) which requires the subgrade to be cohesion less (sand) extending to a minimum depth of 48 inches and compacted with a 10 ton or larger vibratory roller. The water table is required to be at least 48 inches below finish grade together with surface grading required to meet the HUD code. Thus, the detail seems reasonably consistent with the technical intent of the design notes, despite confusion regarding important installation process considerations related to roles and responsibilities as mentioned above. However, the indicated "cohesion less (sand)" subgrade material could be moderately frost susceptible if it is a very fine sand (e.g., approaching silt-size particles). Thus, the Design Notes and plan detail should be clarified that the "6% of mass passing #200 sieve" also applies to the vaguely described cohesion-less sand material in the installation detail.

It should be noted that the 8"thick crusher run #2 stone course above the non-frost-susceptible layer may include more than 6% fines and according to ASCE 32 could be considered to be frost-susceptible. However, for materials with large aggregate, the amount of fines can be increased somewhat and still

provide adequate protection against frost action. Furthermore, the 8" layer is located above what is intended to be a well-drained, non-frost-susceptible subgrade. In such a case, this sub-drainage will keep the 8" layer reasonably dry, particularly where located below the manufactured housing unit and protected from rainfall and runoff. Thus, the critical component of this design is assuring that the subgrade is indeed non-frost-susceptible and well-drained as called out on the plans consistent with the ASCE 32 standard.

Example #2: FFF Design B (directly on soil)

This FFF design appears to be based in large part on a report for the Systems Building Research Alliance (SBRA/Hayman, 2010). A typical installation detail is shown in Figure 3.

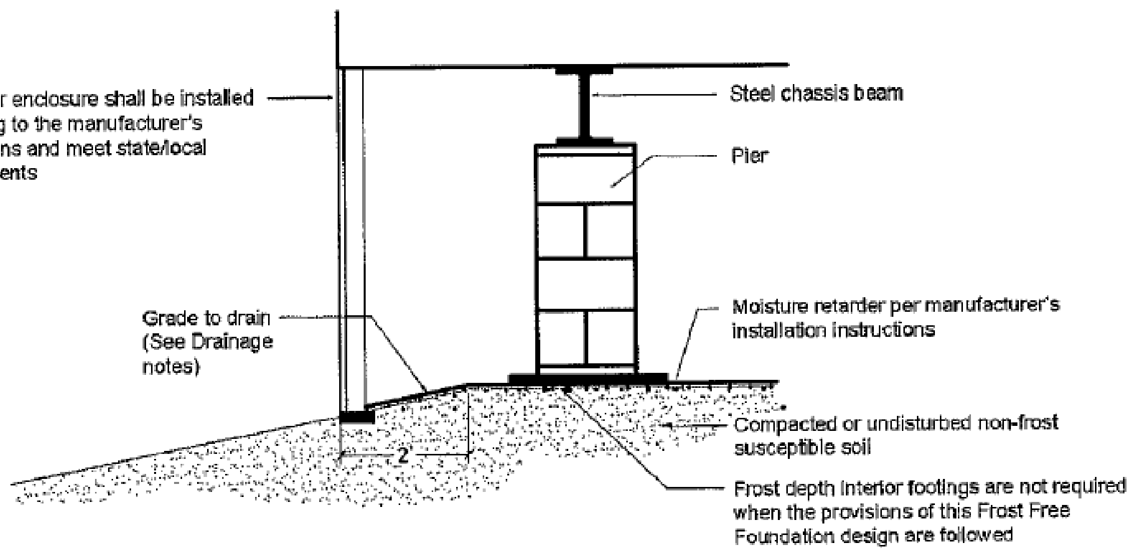

Figure 3. FFF installation detail for Example #2 (FFF with piers directly on soil) based on SBRA/Hayman (2010) report.

This design has a distinct difference from Example #1 and the ASCE 32 provisions: it relies exclusively on ensuring that "the soil beneath the manufactured home stays dry thereby preventing frost heave." The report by SBRA/Hayman (2010) mistakenly claims that "Soil type is not relevant using the Frost Free Foundation design. Soil tests are not necessary." For reasons discussed below, it is the opinion of this author, having served on the ASCE 32 committee and its task group on development of the non-frost-susceptible soil criteria, that these statements are not representative of the intent of the ASCE 32 standard or equivalent alternative procedures for ensuring the intent is met. (Refer to the earlier discussion on the meaning of key terms and clauses in the ASCE 32 standard.)

The SBRA/Hayman report claims that soil tests are a "potentially expensive and time consuming process" without providing documentation. In addition, undocumented quotes and other undocumented sources or anecdotal forms of experience (that are not repeatable or verifiable or fully

explained) are mentioned in the report. For example, a partial quote on page 6-7 of the report is extracted from the Unified Facilities Criteria (UFC, 2004) for roadway design and is apparently mistaken to mean that no soils analysis or other consideration is required under "special conditions". It is then asserted that manufactured homes create these special conditions.

To the contrary, the cited UFC document states elsewhere that only four material groups (gravel, crush stone, crush rock, and sand) can be considered as "generally suitable for base course and sub-base course materials" with respect to frost heave or thaw-weakening potential. The quote as contained and edited in the SBRA/Hayman (2010) report also leaves out important caveats related to the required justification for re-classifying the frost-susceptibility status of a material under "special conditions". The complete discussion in the Unified Facilities Criteria document is as follows:

> *d. Special conditions.* Under special conditions the frost group classification adopted for design may be permitted to differ from that obtained by application of the above frost group definitions. This will, however, he subject to the specific approval of HQUSACE (CEMP-ET) or the appropriate Air Force Major Command if the difference is not greater than one frost group number and if complete justification for the variation is presented. Such justification may take into account special conditions of subgrade moisture or soil uniformity, in addition to soil gradation and plasticity, and should include data on performance of existing pavements near those proposed to be constructed.

Clearly, there is substantial evidence and justification required on a case-by-case basis as well as approval by authorities familiar with the subject matter. The requirements also indicate the form of evidence required, including data to demonstrate soil gradation and plasticity, subgrade moisture conditions, and soil uniformity. It also includes supplemental data on performance of existing pavements near those proposed to be constructed. Thus, a complete analysis of the site conditions as well as consideration of neighboring conditions (experience) is required. The SBRA/Hayman report and design does not contain such procedural requirements or data requirements for a given site. It does not indicate how to ascertain moisture conditions below grade, the need to test for soil gradation and plasticity, or other equivalent technical or procedural matters mentioned in the full quote above.

Simply protecting the soil from direct rainfall over the small footprint of a manufactured home may do little to address moisture conditions at depth below the ground surface or the degree of frost-susceptibility of the subgrade should moisture be present at depth. Despite these omissions, the SBRA/Hayman (2010) report concludes that the FFF provides "superior under home water control capabilities". Also, important differences from road design are not address such as roads being designed for a much lesser life expectancy than buildings (i.e., design return periods for frost heave or freezing events are typically less than 30 years as commonly represented by using the average of the three worst years in a period of thirty years or the worst year in a short period of 10 years).

In addition, the SBRA/Hayman (2010) report references various sources of experience, mostly from the standpoint of attempting to prove a negative by making the assumption that an absence of complaints

means an absence of problems. While this is relevant information, it is very weak data unless properly evaluated and interpreted in context. For example, what are the variations in soil type and particle size at the sites represented by the generalized experience claim. What were the winter Air-Freezing indices observed during the period of record associated with the experience statement as needed to ascertain potential "sampling error" problems? For example, a cursory review of national average heating degree day data for years 1994-2004 (the same period of record for one quoted source of anecdotal evidence) indicates below average national winter conditions in 8 of the 11 years (with 3 of the years exceeding the average by a relatively small amount – certainly not reflective of design conditions). A more detailed association of climate data in relation to the ad-hoc experience reported is needed to make a reasoned scientific analysis and engineering interpretation of the claimed experience and its relevance to design conditions. This must also be weighed against the common foundation construction practice represented by the generalized experience claim (e.g., what depth or variation of depth were the footings actually placed at?). In other words, is the reported experience actually relevant to the FFF design as presented in the SBRA/Hayman (2010) report?

Reference is also made to reduced frost depths for footings located underneath and within an enclosed area beneath the manufactured home foundation. However, this allowance may be more appropriately associated with prevention of or suppression of freezing temperatures, not the supposed absence of sufficient soil moisture to prevent frost heave. A similar practice has been recognized and used for many years in Anchorage, AK for site built construction by differentiating between "cold" and "warm" footings (with different footing frost depths used for each condition). Thus, the stated experience in the SBRA/Hayman (2010) report, while valid when understood in context, is not justification for reliance on merely keeping the ground surface dry in the immediate vicinity of a footing as an appropriate or complete means to prevent frost heave and broadly avoid adequate frost protection measures or footing depths in general for all climates and conditions that may be experienced.

This experience also is not based on the use of FFF foundation designs and could be considered as irrelevant on that basis alone. The experience suggested in at least one place (i.e., Kentucky) was associated with footings at a frost depth of 24 inches at the perimeter and 12 inches within the enclosed portions of the foundation. Similar experience was noted in West Virginia. It is no surprise that this has worked well as demonstrated in Table 1 and Figure 4 presented later in this report. But, it is not directly relevant to the FFF design presented in the SBRA/Hayman (2010) report. Instead, it is more appropriately taken as support for the adequacy of conventional methods of foundation installation (e.g., placing footings at frost depth, including reduced frost depths in enclosed areas underneath the building).

The SBRA/Hayman (2010) report does appropriately recognize that "the possibility of ground water level overlapping the frost depth does need to be addressed…If the ground water depth is determined to be above the local frost depth, the Frost Free Foundation design cannot be used." (ibid. p.8). However, the means of establishing that the ground water table is below the frost depth during the winter season and is misappropriated to "the local authority having jurisdiction". As stated in the review of Example #1, this determination is a matter of design or construction management for individual sites; local authorities are supposed to have the role of only inspection and verification, not making decisions about and executing the practice of design. This confusion of roles and responsibilities presents a conflict of interest among regulators and perhaps also infringes on state laws regarding the practice of engineering. In addition, merely keeping the water table depth at the local frost depth does not control

frost-susceptibility in soils that are particularly frost-susceptible because water is "wicked" from the ground water source up to the freezing front in the soil. This is the mechanism by which frost heave occurs. Thus, for some soil conditions, the water table depth may need to be well below the local design frost depth to prevent frost heave.

Finally the proposed SBRA/Hayman (2010) FFF design focuses only on the following two criteria related to risk of frost heave or thaw weakening (ibid., p.9):

- Site – the design only requires that surface drainage minimally comply with HUD Code, 24 CFR Part 3285.203.
- Footings – frost depth footings are not required (can essentially locate footings at finish grade with no depth)

The first item neglects any means of establishing depth of ground water. It also fails to determine if the soil profile (at least to frost depth) is well drained. It also neglects the requirement that non-frost-susceptible soils be used in accordance with the HUD Code (24 CFR Part 3285.312(b)) and the ASCE 32 Standard. Reliance on surface drainage alone without site-specific soil drainage or water table analysis and soil particle size analysis is not consistent with accepted engineering practice for building foundations and also does not provide an equivalently reliable alternative to the methods and requirements specified in the ASCE 32 standard or the HUD Code.

The second item is not really a criteria for frost-protection, but is actually and exemption from frost protection based on the first item. Placing the footings with 0 (zero) frost depth presumes perfection in the control of frost heave risk merely by keeping the ground surface in the immediate vicinity of the footing free from direct rainfall (i.e., located underneath the housing unit) and providing for surface drainage. This is an unrealistic and unconventional presumption and, at best, may result in highly uncertain and unreliable performance. Therefore, the HUD/CODE CONFORMANCE section of the SBRA/Hayman (2010) report significantly overstates the degree of conformance or equivalency of the proposed FFF design. If a dry soil criteria is used alone for frost protection, then the level of protection against a wetted soil condition (at least to frost depth) must far exceed the level of criteria and verification specified in the FFF design by SBRA/Hayman (2010). Consequently the design criteria presented in the SBRA/Hayman (2010) report and the associated model installation plan are largely incomplete or inadequate.

For example, the installation detail based on the SBRA/Hayman (2010) report reveals the following (see Figure 3):

1. It leaves discretion for the means and methods of establishing the water table depth to the local authority. This is a design decision going beyond the role of regulatory authorities, creating a conflict of interest in their role and the practice of design and installation. The plans should specify a means of determining water table depth following accepted engineering practice and require that it be at or well below the frost depth if merely a "point-in-time" investigation is done by others than a geotechnical engineer or experienced professional.
2. It provides no means of determining or verifying the use of non-frost susceptible soil as required in the detail (but which is indicated as being unimportant in SBRA/Hayman (2010)). Such a practice is important and such inconsistencies unnecessarily confuse the issue. Specifications

and a means of determining and verifying important design criteria should be provided on installation details (see also the discussion on Example #1 which included appropriate specifications but misappropriated or confused roles and responsibilities related to design, installation, and enforcement).

3. The design does not require the use of a below foundation drainage system and gives no indication under what sub-grade conditions one may be required to maintain a "well-drained" condition.

Example #3 – FFF Design C ("Floating Slab")

Example #3 is a variant of the FFF design approach that utilizes a "floating slab" concept as shown in Figure 4 (other similar FFF variants include a "floating strip footing" approach). Interestingly, this "floating slab" installation detail was certified by an engineer and DAPIA-approved in one state, but is included in the manufacturer's installation manual for another state.

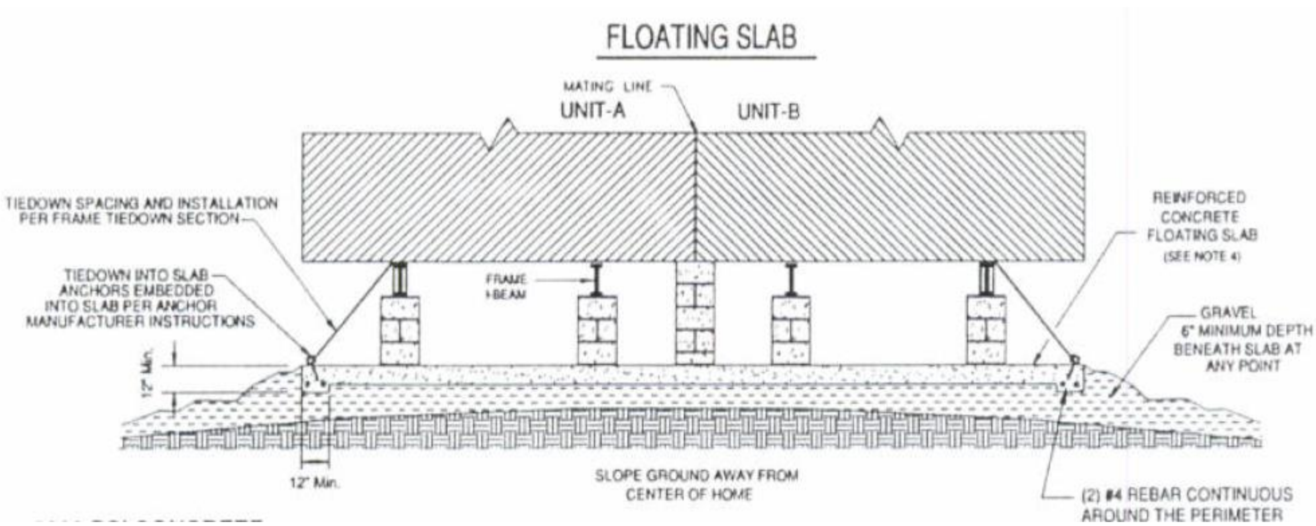

Figure 4. Installation detail for Example #3 ("Floating Slab" FFF)

Relevant notes accompanying the installation detail shown in Figure 4 are as follows:

NOTES :

1. SITE ONLY ON WELL DRAINED SOIL WITH AVERAGE MOISTURE CONTENT LESS THAN 25% TO FROST DEPTH.
2. THESE SOIL PREPARATION CONDITIONS ARE ADEQUATE FOR FOOTINGS INSTALLED ABOVE FROST LINE AND FOR FLOATING SLAB SYSTEMS WHEN INSTALLED WITH GRAVEL BACKFILL PROVIDED THE SOIL BENEATH THE GRAVEL IS WELL DRAINED WITH MINIMAL MOISTURE CONTENT.
3. FINAL DETERMINATION OF THE APPROPRIATE APPLICATION OF THE FOOTING ABOVE THE FROST LINE OR FLOATING SLAB, IS BY THE LOCAL AUTHORITY HAVING JURISDICTION FAMILIAR WITH ACTUAL SOIL CONDITIONS. BASED UPON ACTUAL SOIL CONDITIONS, DETERMINATION OF THE PROPER FOOTING DESIGN ILLUSTRATED ABOVE CAN BE MADE.

The following observations relate to concerns with the above-described "floating slab" FFF design:

1. Note #1 requires use on sites with "well drained soil with an average moisture content less than 25% to frost depth". The means of determining the average moisture content to frost depth is not specified. Is this an average at a given point in time or an average including seasonal variation? Is the moisture content volumetric or by mass? Does 25% average moisture content provide adequate frost protection for all frost-susceptible soil types? For example, soil may approach saturation at a volumetric moisture content of 25% or be saturated at a gravimetric moisture content of 20%. Furthermore, if soil moisture content is measured to a frost depth of say 4 feet, the top two feet may be relatively dry, but the bottom two feet wet; yet the average moisture content may meet the stated criteria (even though the overall moisture condition of the soil would promote frost heave in a frost susceptible soil – a risky soil condition which is not prohibited by this design). Clearly, the specification is incomplete and vague. Yet, this criteria is presented as the main "pass/fail" criteria for acceptance of a site for use of the "floating slab" FFF design.
2. Note #2 is significantly more vague and unenforceable referring to a requirement that "soil beneath the gravel is well drained with minimal moisture content". How is well drained determined in relation to frost-heave potential? What is a "minimal" moisture content?
3. Note #3 presents what is a common and inappropriate deferral of design decisions and site evaluation requirements to the "local authority having jurisdiction", thus, relying on the local enforcement authority to execute the practice of design to produce the evidence needed for enforcement (presenting a conflict of interest). It also requires the local authority to be "familiar with actual soil conditions". What are these soil conditions? Is the local authority supposed to measure moisture contents to confirm conformance with Note #1? Are there other conditions that need to be assessed?

Even if the above noted problems were resolved, the design still relies exclusively on keeping a potentially frost-susceptible soil adequately dry to the frost depth as the sole means of frost-protection. As mentioned in other reviewed examples of FFF designs, this design approach is not compliant with the provisions of the ASCE 32 standard or the HUD code. These standards require the use of non-frost-susceptible fill materials to frost depth and the provision of adequate drainage. With the above incomplete and vague design controls and confused roles and responsibilities as to the execution of design and verification of site conditions, this approach should not be considered as an equivalently reliable alternative means of frost protection.

<u>Example #4 – FFF Design D (Monolithic Slab)</u>

This FFF design is similar to that addressed in Examples #2 and #3. While purported to be used in a northeastern state, the design is certified by a registered engineer in a central mid-western state and was DAPIA approved. An example installation detail for this design is shown in Figure 5.

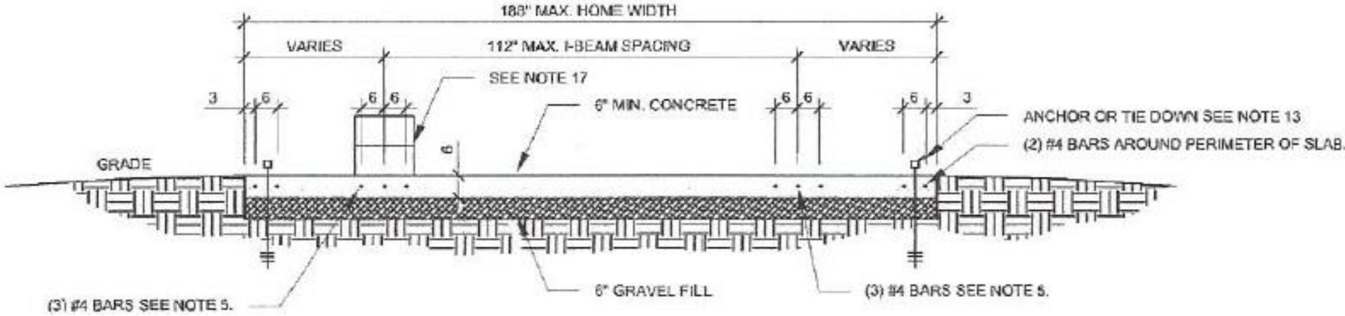

Figure 5. FFF installation detail for Example #4 (Monolithic Slab FFF)

Relevant "GENERAL NOTES" associated with the above installation detail are as follows:

7. THE SLAB FOUNDATION DESIGN IS SUSCEPTIBLE TO FROST HEAVE AND SHOULD NOT BE PLACED ON EXPANSIVE SOILS. CONSULT LOCAL JURISDICTION.
8. SLAB DEPTH NOTED SERVES ONLY AS A MINIMUM, THE BASE OF THE SLAB AND ITS GRAVEL FILL BASE MUST BE BELOW THE FROST LINE. CONSULT LOCAL JURISDICTION FOR THE FROST LINE DEPTH.
9. ADEQUATE DRAINAGE MUST BE PROVIDED UNDER THE SLAB TO THE PERIMETER OF THE SLAB. CONSULT LOCAL BUILDING CODE FOR REQUIREMENTS.

The above-described design raises concerns similar to those addressed in Examples #2 and #3. First, general note #7 does seem to admit that the design is susceptible to frost heave. However, it states that it should not be placed on expansive soils. While it is true it should not be placed on expansive clay soils, this is a different design matter than frost heave. Instead, the note should state that it should not be placed on frost-susceptible soils. Even so, the necessary criteria for evaluation of the frost-susceptibility of soils is not provided. Yet, this is presented as the critical "pass/fail" criteria for use of the design on a given site.

Second, general note #8 does seem to clarify that a gravel base must be below the frost line. Yet, the gravel base is not specified as to the amount of fines that can be tolerated. Is the intention to use clean (washed) gravel or bank run? Furthermore, the detail implies a shallow depth is intended (or may be interpreted) since the frost-depth is not shown to coincide with the depth of the gravel fill. Without careful installation and enforcement, the design intention may be overlooked or not be properly executed in the field.

Finally, note #9 indicates that drainage must be provided under the slab, but the drainage design is not defined or indicated on the detail other than to say that water is to be drained "to the perimeter of the slab". This may actually cause water to be concentrated at the edges of the slab where differential frost heave would be promoted. It also does not clarify where the drainage system is to be placed (e.g., at the bottom of the gravel layer) and that drainage water should be discharged to daylight well away from the perimeter of the slab foundation. The building code is referenced for detailed requirements, but building code foundation drainage requirements generally are not intended to address this application (e.g., drainage of fills and subgrades to prevent frost heave). The design should show a drainage plan for cases where the sub-grade is not well-drained (e.g. water table not below the frost depth or a soil layer at depth with a low infiltration rate).

<u>Other Considerations</u>

Skirting – Other considerations include installation of skirting. Where founded at a shallow depth, significant frost-heave may raise the skirting by as much as several inches, causing the building to be jacked and distorted since frost heave rarely occurs uniformly. Thus, provisions for skirting frost protection must also be considered (e.g., drainage and depth of non-frost-susceptible fill, use of a footing to frost depth as common to permanent wood foundations, or use of insulation to protect the ground against freezing). Some designs have used insulation for this purpose, but have not placed it in accordance with the ASCE 32 standard – leaving significant thermal bridges that may negate or diminish the function of the insulation. For example, see Figure 3.38 and others in the "Guide to Foundation and Support Systems for Manufactured Homes" prepared by SBRA for HUD.[2] In addition, for an FPSF design using a raised foundation (i.e., crawlspace) the enclosed area must be unvented (at least during winter months) and insulated around the perimeter (skirting) to prevent the potential for increased frost depth in the shaded ground underlying a raised foundation (PHRC, 2014).

Proprietary Foundations – Various proprietary foundation systems are commonly used to support and anchor manufactured housing units. These systems in general rely on the same means for frost protection as conventional foundations or piers. Thus, the findings and recommendations of this report apply equally to proprietary types of foundation supports that may use shallow footings or footing pads. Frost-heave does not distinguish between foundation types. If any shallow, uninsulated footing is on frost-susceptible soil with an adequate source of moisture from the surface or ground moisture from below (even if the surface appears dry) and experiences freezing temperatures within the ground, it will experience frost heave and/or thaw-weakening.

Local Regulations – One state's installation standards were provided for review in relation to the topic of this report. In New Hampshire's installation standards for manufactured housing (Chapter 600, Section 603.08), the following requirements are stated in regard to footings:

> (b) Every pier shall be supported by a footing of the following type:
> - (1) A pad which shall be a monolithic concrete slab…and complies with the following:
>   - a. Fill shall extend a minimum of 3 inches up the side of the slab;
>   - b. Top soil and all organic soils shall be removed under the slab area;
>   - c. A minimum of 12 to 14 inches of sand or gravel compacted; and
>   - d. Shall be at minimum as set forth in Figure 600-3; or
> - (2) Below frost footing, which shall be designed by a New Hampshire licensed professional engineer.

The above-mentioned "Figure 600-3" below is a detail of a FFF foundation slab similar to the "floating slab" design evaluated in Example #3 (and also similar to examples #2 and #4). There is no provision to ensure that the sub-grade is well drained or that non-frost-susceptible soils or fill are used to the frost depth. Also, it is extremely odd that the above provision allows the FFF approach (Item (1)) to be used with no engineering or site verification, yet a conventional footing design to frost depth (Item (2)) is required to be designed by a New Hampshire licensed professional engineer. The regulation appears to be significantly misguided in regard to which foundation approach should require an engineering design

[2] It should be noted that this guide, while containing much practical information, also contains many cases of incomplete information or questionable advice that can lead to poor practices for frost protection. HUD should consider withdrawing this document until such a time that the deficiencies can be remedied. The copy reviewed was noted as a Draft dated March 27, 2002.

and site investigation. Other state installation rules should be investigated for similar technical irregularities and corrected as needed to bring them into conformity with the HUD code (24 CFR Part 3285.312(b)).

CONCLUSIONS

The following conclusions summarize the key findings of this report:

1. Several problems with execution of the FFF design approach were identified in reviewed installation details. These problems include:
    a. Lack of enforceable or consistently actionable criteria related to important design factors governing the applicability of the FFF design and installation method for a particular site or development.
    b. Commonly confused assignments of roles and responsibilities for determining site conditions and suitability of a FFF design for a given site. In particular, matters of design in determining the suitability of a site are often deferred to local authorities which are not charged with a responsibility to practice design. Their role should be limited to enforcement and verification of evidence demonstrating conformance.
    c. Installation details for FFF designs often lack criteria for measuring the frost-susceptibility of soils or fill materials which is a critical aspect of the design and an important source of data for verification by local authorities.
    d. Requirements for determining soil moisture criteria and/or minimum water table depth are often vague and unenforceable.
    e. Similarly, means of measuring and confirming a "well-drained" soil condition generally are not defined or adequately specified. Suitable sub-drainage strategies for conditions that are not well-drained are generally not specified such that installers and inspectors can perform their duties consistently and in accordance with the design intent.
2. Because of the above problems, most of the reviewed FFF designs should not be considered compliant with the ASCE 32 standard or provisions in the HUD Code related to frost-protection of manufactured home foundations, including conventional and proprietary foundation systems that are placed at shallow depth (above the frost line) using the FFF concept.
3. It appears that at least some state installation rules also may be contributing to or propagating the above problems with FFF designs. The one example reviewed in this study was for New Hampshire. Therefore, state and local installation rules should be reviewed and corrected as necessary to ensure conformity with the ASCE 32 standard and the HUD code (24 CFR Part 3285.312(b)).
4. In at least one reviewed case (Example #1), a reasonably compliant implementation of an FFF design was achieved with only the exception of proper definition and assignment of roles and responsibilities in the assessment of site conditions (see 1.b. above). This demonstrates that the FFF design approach (and similarly FPSF designs) are capable of being executed properly, despite several examples where they are not. Consistency and conformance can be improved with supplemental guidelines for development and execution of FFF and FPSF foundation designs

including minimum design requirements, installation practices, and enforcement procedures. Recommendations toward this end are provided in the next section of this report.

RECOMMENDATIONS FOR DESIGN AND INSTALLATION

Refer to the section titled “CONFORMANCE OPTIONS FOR NEW DESIGNS AND FUTURE INSTALLATION PRACTICES” on page 7 of the main body of the report.

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APPENDIX B – GLOSSARY

Term	Definition
DAPIA	Design Approval Primary Inspection Agency
IPIA	Inspection Primary Inspection Agency
LAHJ	Local Authority Having Jurisdiction
Fill	Material that is used to level a building site
Non-frost susceptible soil/ fill	Existing soils that are not subject to the effects of frost; they can be identified as granular soils or fill material with less than 6% of mass passing a #200 (0.074 mm) mesh sieve in accordance with ASTM D442 tests
Frost susceptible soil	Silty soils that can retain water; these soils or fill contain more than 6% by mass of their material as passed through a #200 (0.074 mm) mesh sieve in accordance with ASTM D442 tests
Frost-susceptible climate	A climate which is susceptible to seasonal ground freezing
Frost Protected Shallow Foundations	A construction method that uses below-ground insulation and drainage to raise the frost line of soil to a level that allows relatively short and shallow foundations via preventing the soil beneath the home from freezing
Frost Heave	The raising of ground height due to ice crystallization action within the soil or other material beneath the home
Design Frost Depth	A depth into ground that frost is expected to reach under a given severity of winter freezing conditions and other factors as determined by local authorities or the Air Freezing Index
Frost Free Foundations (FFF)	1. A foundation that relies exclusively on the presence of non-frost-susceptible subgrade materials such as soil or fill on a well-drained site.

	2. The name of a foundation system designed by Paul Hayman
Monolithic slab	A foundation system constructed as one single concrete pour that consists of a concrete slab with thickened portions of the slab under load bearing walls and all perimeter edges that take the place of footers
Well-drained soil	Soil (or other applicable material) which allows water to percolate through it reasonably quickly and not pool
Water Table	Depths at which groundwater collects and pools under ground
Drainage	The natural or artificial removal of surface and sub-surface water from an area
Surface drainage	Drainage performed exclusively on the ground surface by shaping the grade to shed water
Subsurface drainage	Drainage performed beneath the surface of the ground to remove water

APPENDIX C - CONFORMING DESIGNS AND PRACTICES FOR INSTALLING MANUFACTURED HOMES IN LOCATIONS SUBJECT TO FREEZING TEMPERATURES

APPENDIX C - CONFORMING DESIGNS AND PRACTICES FOR INSTALLING MANUFACTURED HOMES IN LOCATIONS SUBJECT TO FREEZING TEMPERATURES

Appendix C includes examples of foundation systems that can be used to set manufactured homes in locations that are subject to freezing temperatures. When designing a foundation system and analyzing its potential use, significant consideration should be given to longevity, cost and access. The main objective should be to provide a foundation system that will last the life of the home while also being as cost effective as possible.

Options for sites that have Non-Frost Susceptible Soil

In locations with non-frost susceptible soil, one (1) of the three (3) below options can be used for installing the foundation.

1. Place pier footings per the Manufacturers Installation Manual with pads and in accordance with 24 CFR part 3285.312.
2. Pour runners with a minimum thickness of 6 inches in accordance with 24 CFR part 3285.312.
3. Pour slabs with a minimum of 6 inches of concrete.

Options for sites where soil is untested or known as Frost Susceptible

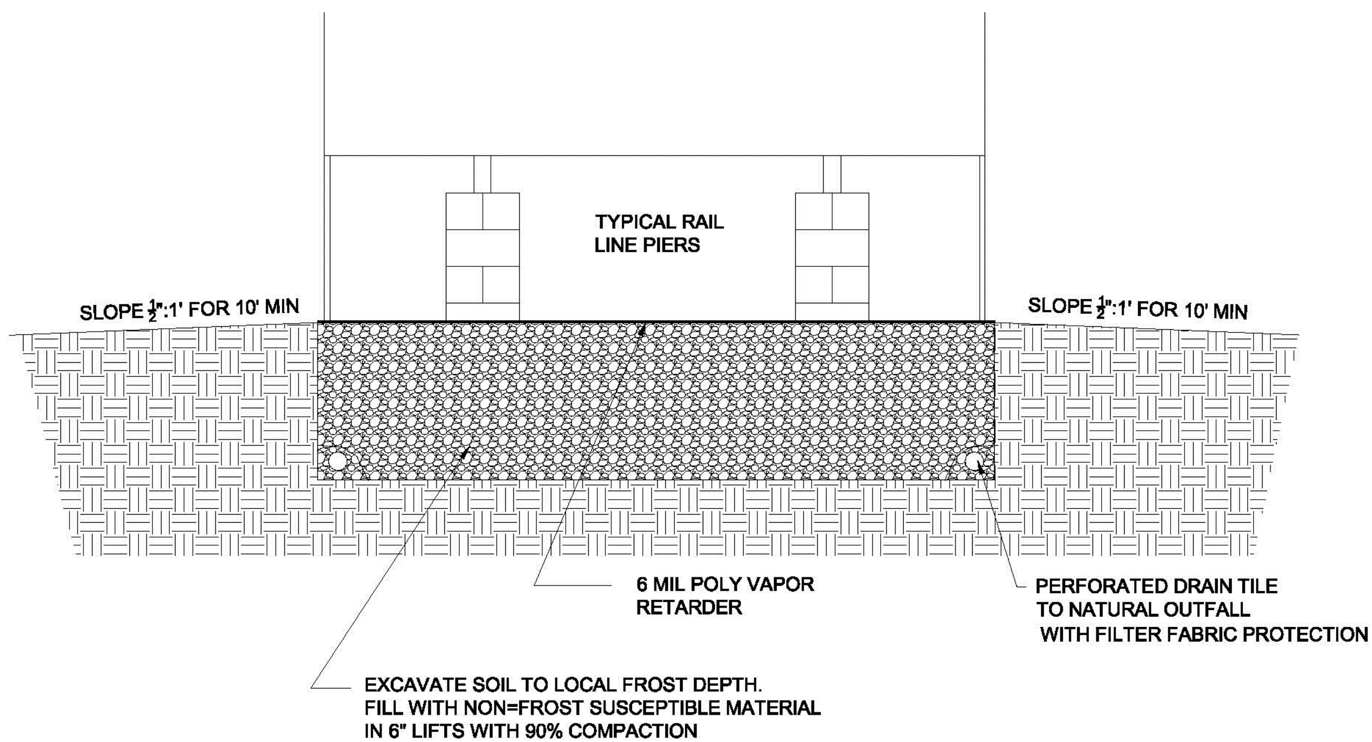
In areas with frost susceptible soil, or the soil type is unknown, the below process can be used to create a non-frost susceptible pad. These steps are required prior to beginning the foundation installation.

1. Cut the area of house pad to the frost depth as determined by the Local Authority Having Jurisdiction (LAHJ) or that of the Air Freezing Index (AFI). (see Cut and Fill to Make Pad details)
2. At the base level, install a drainage pipe to day light or install a mechanical means of de-watering below the frost depth. (see Cut and Fill to Make Pad details)
3. Fill cut area with non-frost susceptible free draining fill in 6 inch lifts. Compact each lift to a minimum of 90% of its relative density. Fill material must have at least a 1500 PSF bearing capacity.
4. Ensure the water table is at least two (2) feet below the frost depth at the site.

This process should be used to create a non-frost susceptible pad for a cut and fill process or filling low areas. Cut and fill is applicable when frost susceptible soil is replaced with non-frost susceptible fill on a flat site. Filling low areas or hilly areas to make a uniformly flat site may also be done with this method. In both cases organic material must be removed before fill is placed and/or added at the installation site.

Below are examples of the above described methods for creating non-frost susceptible pads prior to setting the home.

CUT AND FILL TO MAKE PAD



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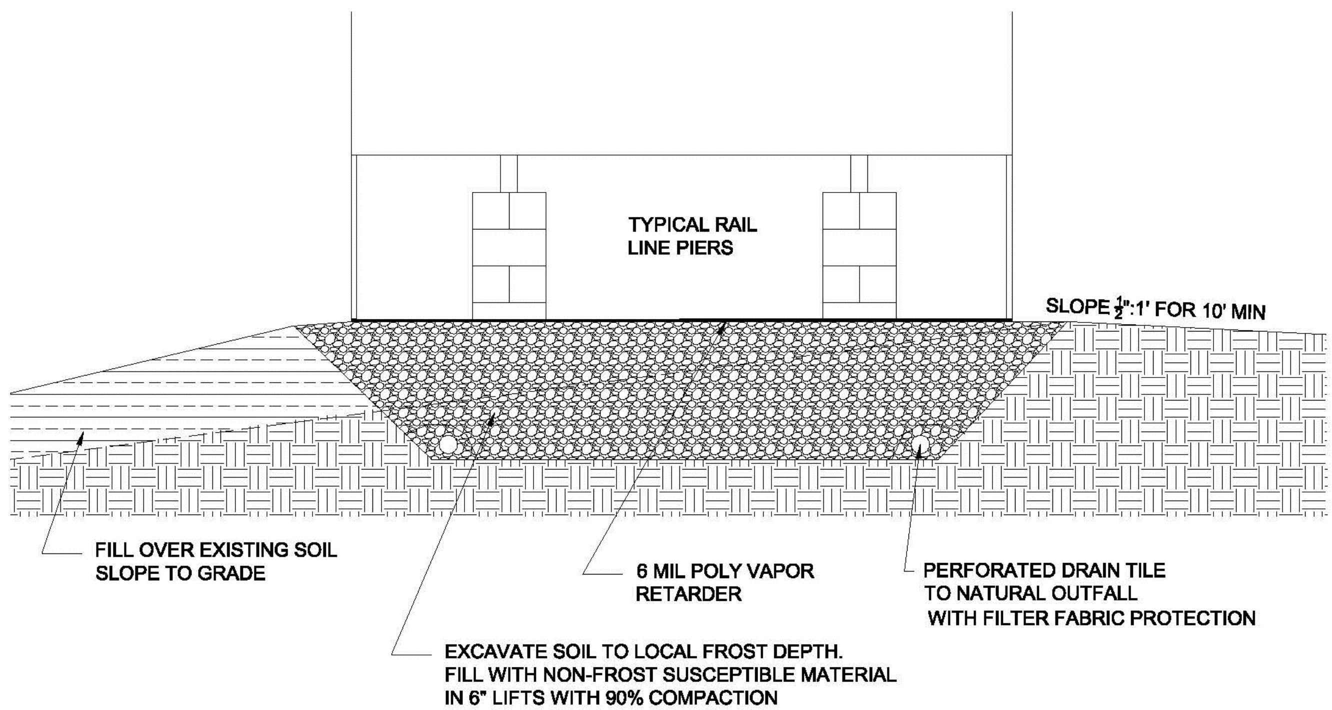
FILL EXISTING GRADE FOR PAD - SINGLE



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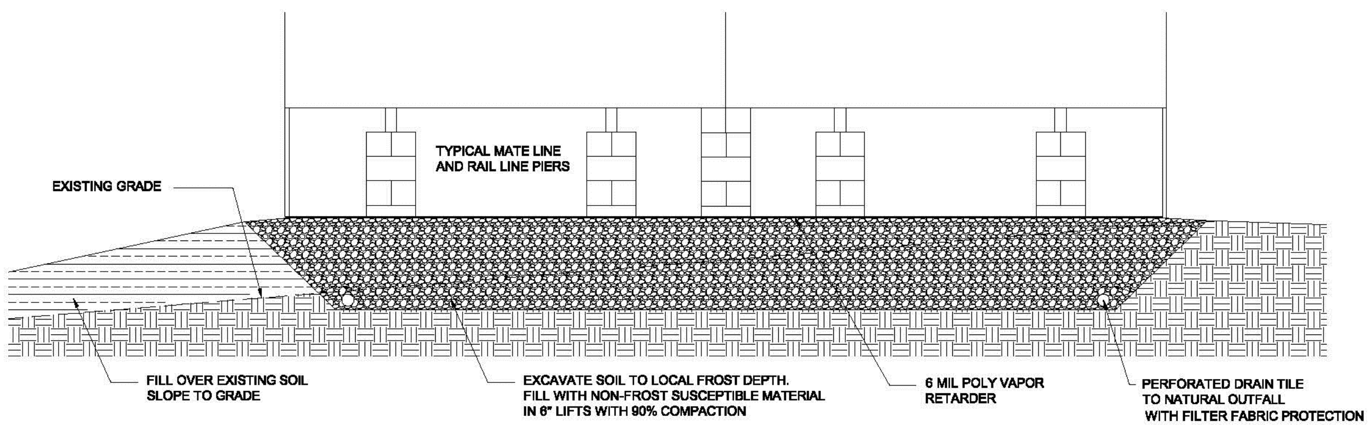
FILL EXISTING GRADE FOR PAD - DOUBLE



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The below steps and design can be used to install a monolithic slab with no insulation.

1. Remove all organic material from the pad site.
2. Place 4 inches of stone with 2 drain pipes to day light or provide a mechanical drain.
3. Form and pour the slab with tied #4 rebar as in diagram.
4. For best results the slab should have at least 1 inch center crown for drainage.
5. Grade around the perimeter of the slab so that there is at least ½ inch of fall for the first 10 feet. In areas that are too tight to achieve this, swales and surface drains can be used.

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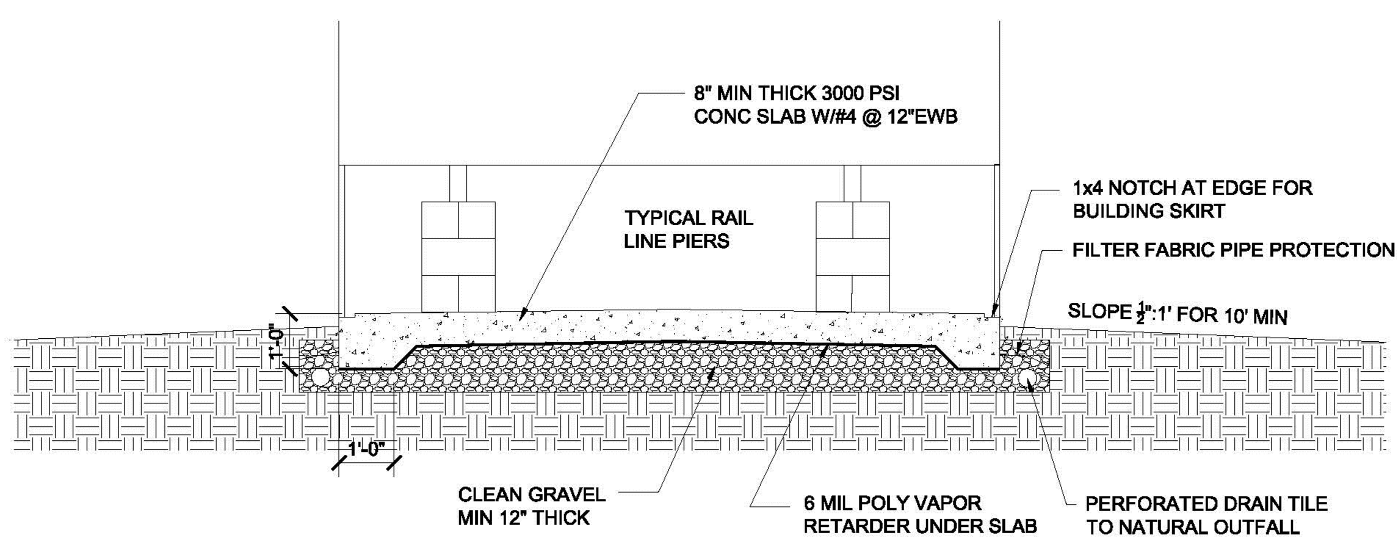
MONOLITHIC SLAB ALL SOIL - SINGLE



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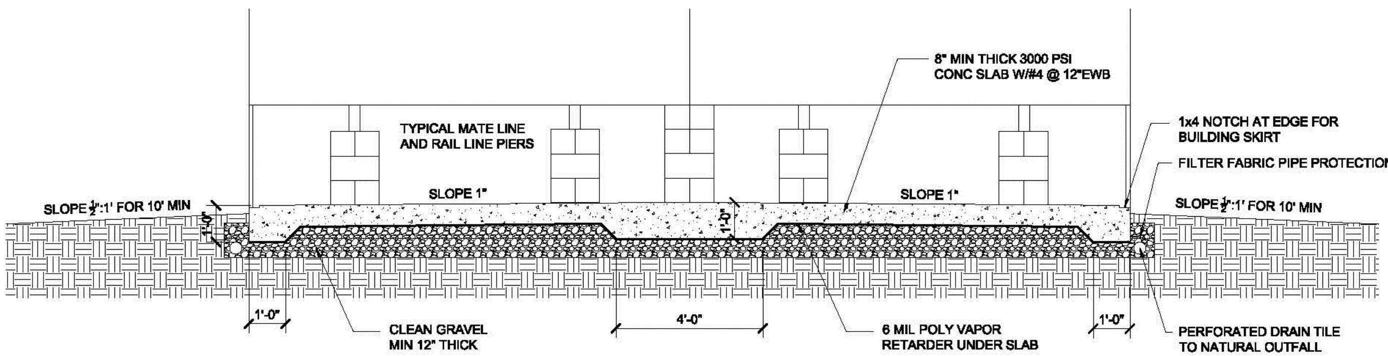
MONOLITHIC SLAB ALL SOIL - DOUBLE



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Examples of designs that are currently used in frost susceptible climates that utilize insulation to make a frost protected foundation systems.

Clayton Homes provided permission to include its plans SU-ADD 107.2, SU-ADD 107.3, and SU-ADD 107.4 to SU-ADD 107.6 in this Appendix. These systems have been approved for use in the state of New York, are designed by an engineer/architect and are approved by the Manufacturer and its DAPIA pursuant to 24 CFR Part 3285.2. The plans use AFI to determine the local frost depth requirements. This allows one plan to cover the entire state by referencing the localities' AFI, allowing for proper adjustments to current home designs. Future use of AFI will guarantee a plan to be applicable to the entire United States and thus increase usability. Several companies are currently working on similar plans and intend to have their products available on a national level. It is estimated that these plans will be available by the first quarter of 2017.

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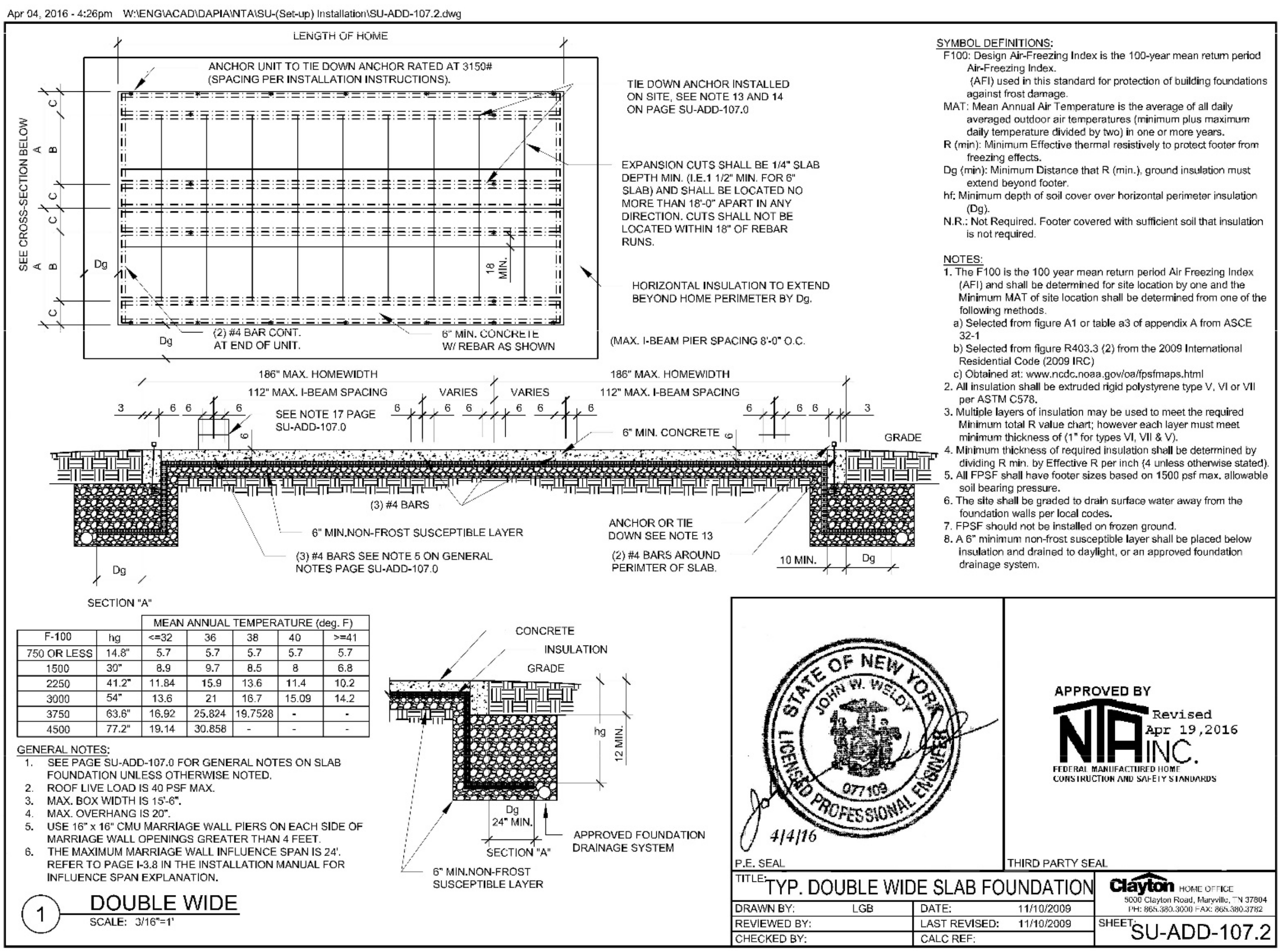
New York Frost Protected Foundation Design (SU-ADD 107.2)

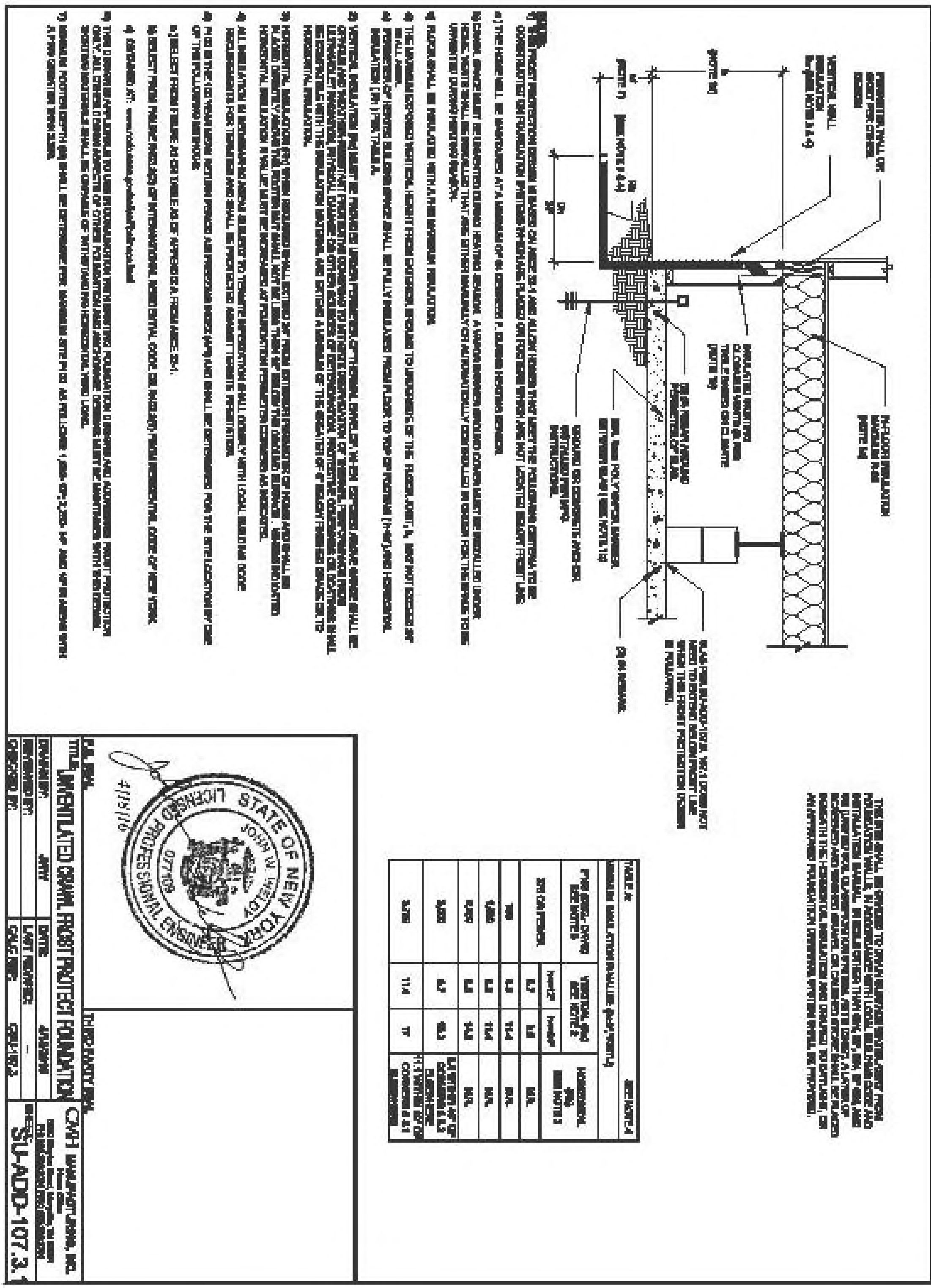
This plan shows how to use insulation under the slab to create a frost protected foundation system.



		MEAN ANNUAL TEMPERATURE (deg. F)				
F-100	hg	<=32	36	38	40	>=41
750 OR LESS	14.8"	5.7	5.7	5.7	5.7	5.7
1500	30"	8.9	9.7	8.5	8	6.8
2250	41.2"	11.84	15.9	13.6	11.4	10.2
3000	54"	13.6	21	16.7	15.09	14.2
3750	63.6"	16.92	25.824	19.7528	-	-
4500	77.2"	19.14	30.858	-	-	-

New York Frost Protected Foundation Design (SU-ADD 107.3)

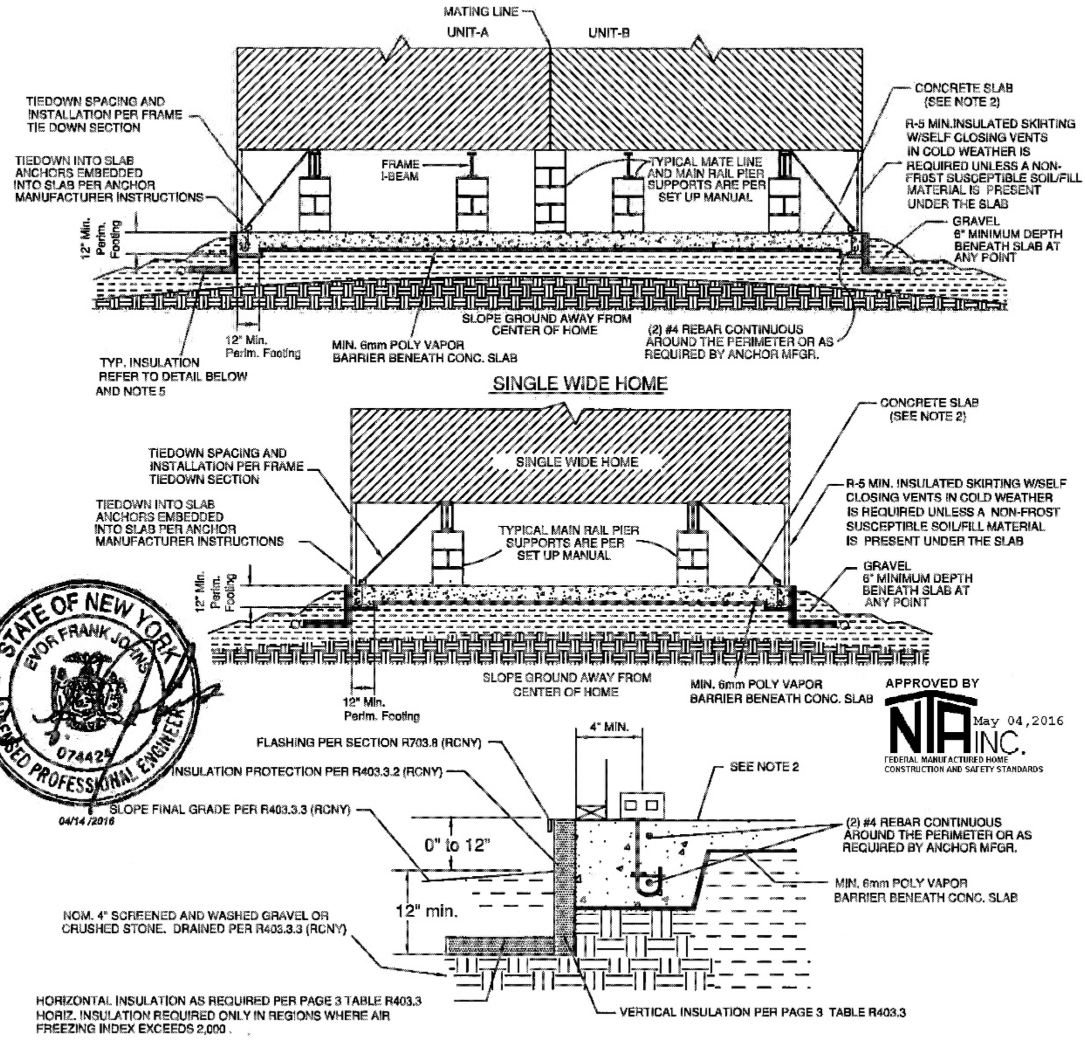
This plan shows how to use insulated skirting to provide a frost protected foundation system.



New York Slab Design – Insulated Skirting (SU-ADD 107.4 to SU-ADD 107.6)

CLAYTON HOMES ADDENDUM TO HUD INSTALLATION MANUAL

(NEW YORK STATE SLAB-ON-GROUND REQUIREMENTS USING INSULATED SKIRTING OPTION)



NOTES :

1. SITE ONLY ON WELL DRAINED SOIL WITH AVERAGE MOISTURE CONTENT LESS THAN 25% TO FROST DEPTH. SOIL CONDITIONS AS INDICATED ARE ADEQUATE FOR SLAB INSTALLED ABOVE FROST LINE.
2. THE THICKNESS OF THE SLAB IS SET AT 6" FOR AN ASSUMED 2000 PSF SOIL BEARING CAPACITY. FOR 1000 PSF MIN SOIL BEARING CAPACITY, USE 8" THICK CONCRETE SLAB. CONCRETE COMPRESSIVE STRENGTH: 3500 PSI MIN.
3. ALL INSULATION SHALL BE EXTRUDED POLYSTYRENE TYPE V, VI, OR VII PER ASTM C578.
4. INSULATION FOR SLAB IS NOT REQUIRED IF PLACED ON A LAYER OF WELL DRAINED, UNDISTURBED GROUND OR FILL THAT IS NOT SUSCEPTIBLE TO FROST. CLASSIFICATION OF FROST SUSCEPTIBILITY OF SOIL SHALL BE DETERMINED BY A SOILS OR GEOLOGICAL ENGINEER UNLESS OTHERWISE APPROVED. THE DETERMINATION PROVIDED TO THE LAHJ BY THE SOILS ENGINEER SHALL INCLUDE DATA THAT DESCRIBES THE SOIL CONDITIONS TO A MINIMUM DEPTH THAT INCLUDES THE FROST DEPTH.
5. REFER TO PAGE 3 FOR TABLE R403.3 (RCNY) SPECIFYING REQUIRED INSULATION LENGTH AND R-VALUES AND TABLE R-403.3(1) (RCNY) FOR AIR FREEZING INDEX VALUES PER GEOGRAPHIC LOCATION.
6. REFER TO INSTALLATION INSTRUCTIONS FOR ANCHOR TIE DOWN REQUIREMENTS AND SPACING. REFER TO ANCHOR MANUFACTURER INSTALLATION INSTRCUTIONS FOR ALL OTHER REQUIREMNTS.

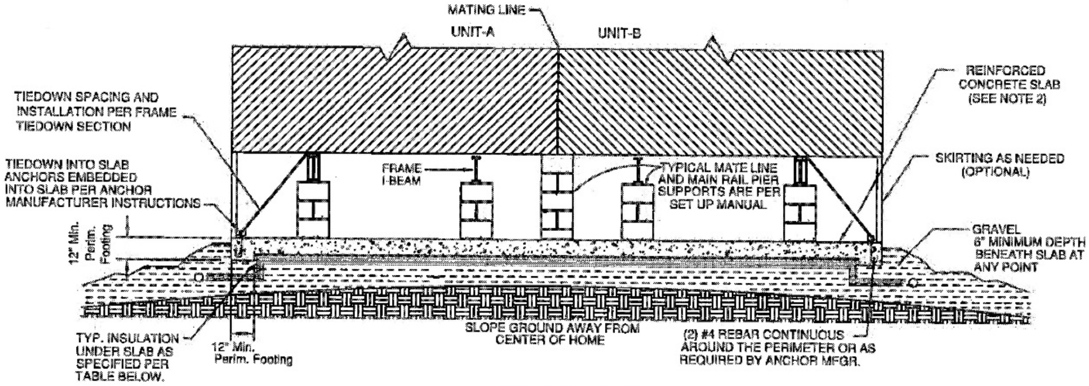
PAGE 1

SU-ADD-107.4 (NY Slab Design- Insulated Skirting)

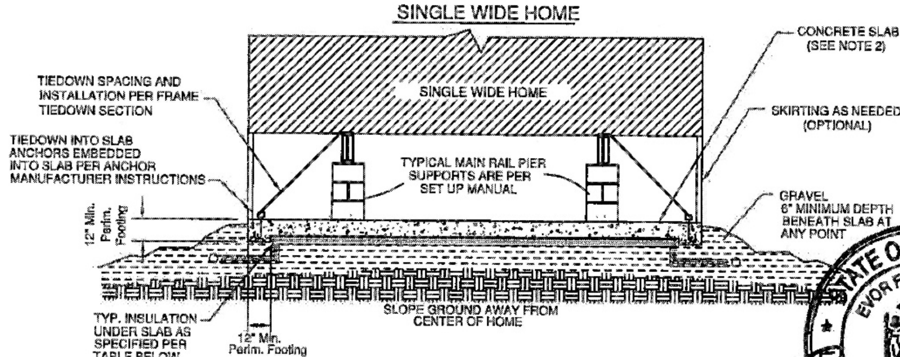
Clayton home building group 4/4/16

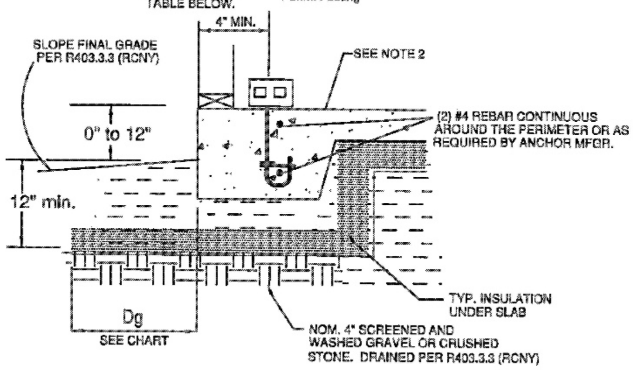
CLAYTON HOMES ADDENDUM TO HUD INSTALLATION MANUAL

(NEW YORK STATE SLAB-ON-GROUND REQUIREMENTS USING INSULATED SLAB OPTION)



SINGLE WIDE HOME





CONTINUOUS SLAB INSULATION REQUIREMENTS (PER TABLE 8 OF SEI/ASCE 32-01)

AIR FREEZING INDEX (See page A-19.3)	Dg	REQUIRED R-VALUE * Assumes Mean Annual Temp. ≥ 41° F
750 OR LESS	30"	5.5
1500	49"	6.5
2260	63"	8.9
3000	79"	13.9

* INSULATION IS REDUCED BY 0.3 FOR R-VALUE OF 6" MINIMUM CONCRETE SLAB

STATE OF NEW YORK — EVOR FRANK JOHNS — 074424 — LICENSED PROFESSIONAL ENGINEER — 04/14/2016

APPROVED BY NTA INC. May 04,2016
FEDERAL MANUFACTURED HOME CONSTRUCTION AND SAFETY STANDARDS

NOTES :

1. SITE ONLY ON WELL DRAINED SOIL WITH AVERAGE MOISTURE CONTENT LESS THAN 25% TO FROST DEPTH. SOIL CONDITIONS AS INDICATED ARE ADEQUATE FOR SLAB INSTALLED ABOVE FROST LINE.
2. THE THICKNESS OF THE SLAB IS SET AT 6" FOR AN ASSUMED 2000 PSF SOIL BEARING CAPACITY. FOR 1000 PSF MIN SOIL BEARING CAPACITY, USE 8" THICK CONCRETE SLAB. CONCRETE COMPRESSIVE STRENGTH: 3500 PSI MIN.
3. ALL INSULATION SHALL BE EXTRUDED POLYSTYRENE TYPE V, VI, OR VII PER ASTM C578.
4. INSULATION FOR SLAB IS NOT REQUIRED IF PLACED ON A LAYER OF WELL DRAINED, UNDISTURBED GROUND OR FILL THAT IS NOT SUSCEPTIBLE TO FROST. CLASSIFICATION OF FROST SUSCEPTIBILITY OF SOIL SHALL BE DETERMINED BY A SOILS OR GEOLOGICAL ENGINEER UNLESS OTHERWISE APPROVED. THE DETERMINATION PROVIDED TO THE LAHJ BY THE SOILS ENGINEER SHALL INCLUDE DATA THAT DESCRIBES THE SOIL CONDITIONS TO A MINIMUM DEPTH THAT INCLUDES THE FROST DEPTH.
5. REFER TO INSTALLATION INSTRUCTIONS FOR ANCHOR TIE DOWN REQUIREMENTS AND SPACING. REFER TO ANCHOR MANUFACTURER INSTALLATION INSTRCUTIONS FOR ALL OTHER REQUIREMNTS.

TABLE R403.3
MINIMUM INSULATION REQUIREMENTS FOR FROST-PROTECTED FOOTINGS IN HEATED BUILDINGS[a]

AIR FREEZING INDEX (°F-days)[b]	VERTICAL INSULATION R-VALUE[c, d]	HORIZONTAL INSULATION R-VALUE[c, e]		HORIZONTAL INSULATION DIMENSIONS PER FIGURE R403.3(1) (inches)		
		Along walls	At corners	A	B	C
1,500 or less	4.5	Not required	Not required	Not required	Not required	Not required
2,000	5.6	Not required	Not required	Not required	Not required	Not required
2,500	6.7	1.7	4.9	12	24	40
3,000	7.8	6.5	8.6	12	24	40
3,500	9.0	8.0	11.2	24	30	60
4,000	10.1	10.5	13.1	24	36	60

a. Insulation requirements are for protection against frost damage in heated buildings. Greater values may be required to meet energy conservation standards. Interpolation between values is permissible.

b. See Table R403.3.1 for Air Freezing Index values.

c. Insulation materials shall provide the stated minimum *R*-values under long-term exposure to moist, below-ground conditions in freezing climates. The following *R*-values shall be used to determine insulation thicknesses required for this application: Type II expanded polystyrene-2.4*R* per inch; Type IV extruded polystyrene-4.5*R* per inch; Type VI extruded polystyrene-4.5*R* per inch; Type IX expanded polystyrene-3.2*R* per inch; Type X extruded polystyrene-4.5*R* per inch.

d. Vertical insulation shall be expanded polystyrene insulation or extruded polystyrene insulation.

e. Horizontal insulation shall be extruded polystyrene insulation.

TABLE R403.3(1)
AIR FREEZING INDEX (BASE 32° FAHRENHEIT) RETURN PERIOD OF 100 YEAR (99% PROBABILITY)

Station Name	Station Number	Air Freezing Index	Station Name	Station Number	Air Freezing Index
ALBANY WSO	300042	1350	LIBERTY	304731	1515
ALCOVE DAM	300063	1451	LITTLE FALLS CITY RES	304791	1586
ALFRED	300085	1499	LITTLE VALLEY	304808	1540
ALLEGANY STATE PARK	300093	1494	LOCKPORT 2 NE	304844	1147
ANGELICA	300183	1421	LOWVILLE	304912	1768
BAINBRIDGE	300360	1349	MILLBROOK	305334	1246
BATAVIA	300443	1310	MINEOLA	305377	496
BOONVILLE 2 SSW	300785	1963	MOHONK LAKE	305426	1109
BRIDGEHAMPTON	300889	510	MOUNT MORRIS 2 W	305597	1355
BROCKPORT 2 NW	300937	1195	NEW YORK CNTRL PK WSO	305801	440
CANANDAIGUA 3 S	301152	1185	NY WESTERLEIGH STAT IS	305821	521
CANTON 4 SE	301185	2124	NORWICH 1 NE	306085	1679
CARMEL 1 SW	301207	1093	OGDENSBURG 3 NE	306164	2038
CHASM FALLS	301387	1952	OSWEGO EAST	306314	1164
CHAZY	301401	1997	PATCHOGUE 2 N	306441	599
COOPERSTOWN	301752	1454	PENN YAN 2 SW	306510	1075
CORTLAND	301799	1396	PERU 2 WSW	306538	1733
DANNEMORA	301966	1794	PORT JERVIS	306774	990
DANSVILLE	301974	1230	POUGHKEEPSIE FAA AP	306820	1160
DOBBS FERRY	302129	576	RIVERHEAD RESEARCH	307134	510
ELIZABETHTOWN	302554	2078	ROCHESTER WSO	307167	1199
ELMIRA	302610	1361	SALEM	307405	1706
FRANKLINVILLE	303025	1715	SCARSDALE	307497	618
FREDONIA	303033	1143	SETAUKET	307633	452
GENEVA RESEARCH FARM	303184	1297	SODUS CENTER	307842	1248
GLENHAM	303259	985	SPENCER 3 W	308088	1514
GLENS FALLS FAA AP	303294	1688	STILLWATER RESERVOIR	308248	2483
GLOVERSVILLE	303319	1500	SYRACUSE WSO	308383	1213
GOUVERNEUR	303346	1877	TUPPER LAKE SUNMOUNT	308631	2372
GRAFTON	303360	1516	UTICA FAA AP	308737	1545
HEMLOCK	303773	1436	WANAKENA RANGER SCHOOL	308944	2192
INDIAN LAKE 2 SW	304102	2317	WATERTOWN	309000	1701
ITHACA CORNELL UNIV.	304174	1367	WESTFIELD 3 SW	309189	1247
LAKE PLACID CLUB	304555	2318	WEST POINT	309292	899
LAWRENCEVILLE	304647	1956	WHITEHALL	309389	1594