SECTION 9B
HUD

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9B.1 INTRODUCTION

The U.S. Department of Housing and Urban Development (HUD) covers the United States with numerous field offices (Figure 9.B.1). One or more of these offices may be located in each state. The various HUD field offices apply, monitor, or oversee the varied HUD programs, pursuant to Congress's allocation of funds, through appropriate HUD Handbooks and procedures.

The United States Congress has mandated that HUD create conditions for every family to have decent and affordable housing. Numerous HUD programs[1] and activities may, in part, involve new or rehabilitation design and construction of several types of foundation systems for varied types of structures and projects. The current and future long-term stability of any new or rehabilitated foundation system, in any HUD program area, is critical to the economic interest of the American taxpayer and necessary to assure occupant safety.

Several HUD programs discussed in this section that are involved with foundation design, construction, repair, or rehabilitation include single-family (SF) homes, multifamily (MF) projects (new or rehabilitated), existing SF properties/MF projects, policy development and research, HUD's Technical Suitability of Products Program, affordable housing (via lower-cost foundations), and manufactured housing (mobile homes).

The views presented in the HUD part of this handbook are those of the author as an individual and do not necessarily represent the views of HUD.

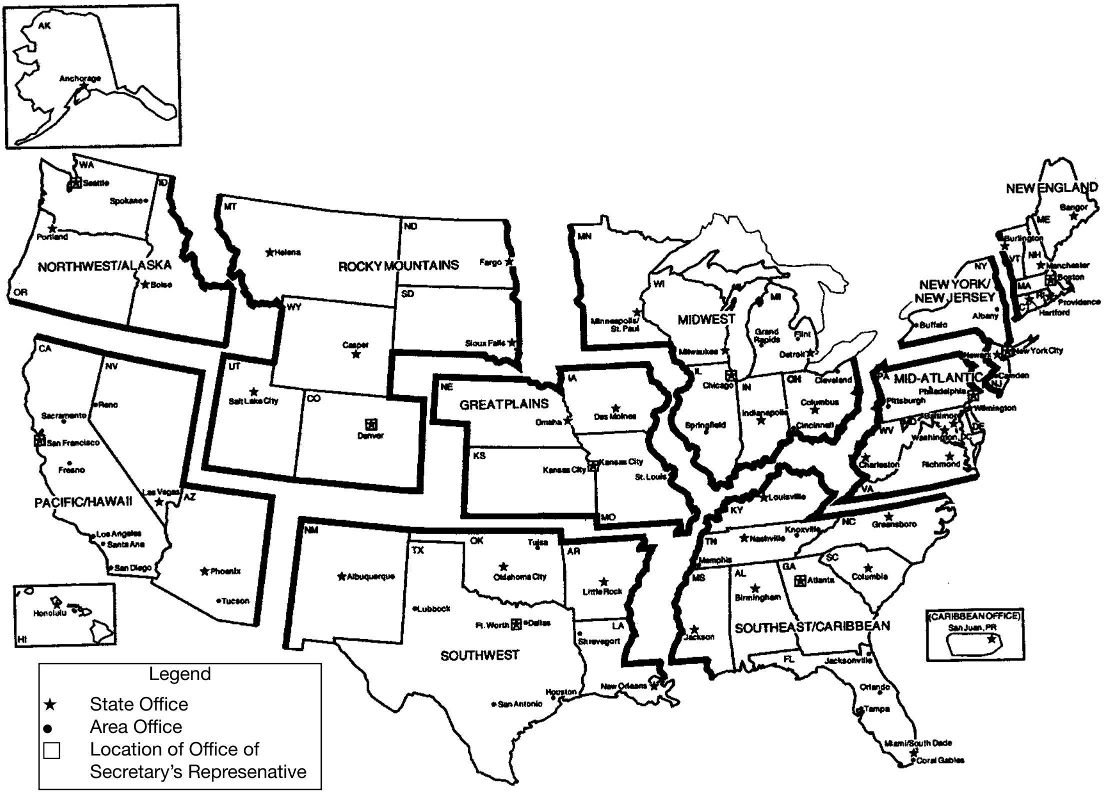


FIGURE 9B.1 HUD field offices.

9B.2 SCOPE

Numerous HUD programs assist borrowers in acquiring SF homes or are used for developing MF projects[1]. Such homes and projects are planned, located, and constructed to serve the present and predictable needs of tenants and to encourage owners in the maintenance and preservation of their investment. HUD may provide mortgage insurance for a loan obtained from a financial institution to purchase an SF property or finance an MF project. Acceptable risk to HUD's insurance fund (mortgage insurance) can be defined where a mortgage is secured by a property or project that meets the requirements of HUD's Minimum Property Standards (MPS)[2]. The strength of an owner's desire to retain ownership will depend largely upon continuing satisfaction with a property or project. Dissatisfaction arising from any cause, including foundation-related problems, lessens motivating interest in ownership and increases mortgage risk.

HUD relies on local codes or national model codes, in addition to standards listed in HUD's MPS for Housing,[2] as the basis for defining acceptable foundation standards and foundation design and construction practices. National model codes include the Council of American Building Officials (CABO) One and Two Family Dwelling Code, the Uniform Building Code (UBC), the Building Officials and Code Administrators (BOCA) Basic/National Building Code, and the Standard Building Code (SBC). HUD typically requires that foundation design and construction, as well as reports or repair methods related to foundations, be designed and completed by qualified professionals, that is, licensed architects, engineers, or contractors. Certifications from qualified professionals may also be required by HUD as a condition of mortgage reinsurance. Usually, completed foundation construction carries a one-year workmanship and materials warranty. For any foundation-related repairs, corrections should be permanent in nature and commensurate with the value and type of property or project.

HUD SF properties or MF projects are involved in nearly the full range of foundation types, design, construction, inspections, and rehabilitation that have been covered in this handbook. HUD SF and MF areas involving foundations are further discussed in the sections that follow and cover new (proposed) construction, rehabilitation construction, or existing construction.

9B.2.1 Single-Family Units

SF units can be detached, semidetached, duplex, or row houses, either site-built or fully or partially factory manufactured. For example purposes, this section deals with typical site-built, detached SF homes covered by FHA mortgage insurance.

9B.2.1.1 New (Proposed) SF Construction

New (proposed) construction of SF units must comply with HUD's MPS for One and Two-Family Dwellings (Appendix K of Reference 2). HUD currently utilizes, wherever possible, acceptable state or local codes as a portion of its MPS for any particular property.

Should no acceptable state or local code be available in an area, HUD will utilize the CABO One and Two Family Dwelling Code. HUD field offices maintain lists of jurisdictions and their appropriate codes, which HUD utilizes as part of its MPS. HUD enforces and interprets codes for its own purposes and not for any local entity.

The CABO code, or any other acceptable state or local code, will address foundation systems. Any foundation system section of a code used by HUD as part of its MPS must address foundation depths, footings, and foundation materials criteria. Such codes also typically reference acceptable engineering practices and standards relative to foundations constructed of varying types of materials and methods, such as brick, masonry, treated wood, and concrete. HUD also defines acceptable material standards and engineering practices related to foundations (Appendices C, E, and F of Reference 2).

HUD SF processing procedures for new proposed construction are defined in HUD Handbook 4145.1 REV-2.[3] These procedures define exhibits that must be submitted for each unit. These exhibits include a separate foundation plan and technical reports and other exhibits when the mortgage risk could be affected by unstable soil or other differential ground movement. Such reports or exhibits might include, but are not limited to, an engineer's report on soil exploration and testing along with special foundation designs for conditions found.

At times, HUD may receive complaints from homeowners relative to foundation problems. If the property is covered by one of the typical 10-year structural warranty policies offered by various entities, HUD will rely on said warranty company as the first avenue of resolution (Appendix 10 of Reference 3). If no assistance is available from one of these warranty companies, HUD does have a process available to assist homeowners in correcting structural defects.[4] Under Section 518(a) of the National Housing Act, HUD can assist in the repair of structural defects reported within the first four years of the issuance of mortgage insurance. Problems with foundations can possibly qualify for assistance if deemed to be the builder's responsibility and the builder refuses to repair or rectify the situation. HUD may contract for repairs, reimburse the homeowner for completed repairs, or buy back the property from the homeowner.

9B.2.1.2 Rehabilitation of SF Construction

HUD promotes and facilitates the restoration and preservation of the nation's existing SF housing stock. One avenue provided by HUD in which a property can be acquired and rehabilitated is via

Section 203(k) of the National Housing Act. There is a minimum $5000 requirement for the cost estimate of eligible rehabilitation or improvement items. As in other SF mortgage insurance programs, a Section 203(k) mortgage is funded by a HUD approved lender, and the mortgage is insured by HUD.

The procedures of the 203(k) program are detailed in HUD Handbook 4240.4 REV-2.[5] Under this program, one of the architectural exhibits required by HUD to be submitted is an inspection report from a qualified architectural, engineering or home inspection service defining the adequacy or required upgrading of existing systems, such as heating, plumbing, and foundation. Homes that have been demolished, or will be razed as part of the rehabilitation work, are eligible, provided the existing foundation system is not affected and will still be used. The complete foundation system must remain in place. A report from a licensed structural engineer is required stating that the existing foundation is structurally sound and capable of supporting the proposed dwelling construction.

Other foundation structural alterations and reconstruction, if necessary, could also be covered under a 203(k) mortgage in the form of foundation rehabilitation. A guidebook produced by HUD[6] addresses SF foundation rehabilitation areas that could qualify as eligible rehabilitation items under a Section 203(k) mortgage. The guidebook covers topics from the design and engineering of rehabilitated foundation systems to shoring and repair, waterproofing, crack repair, drainage, and insulation. New foundation elements for new additions could also qualify as eligible items under a Section 203(k) mortgage. Any new foundation construction must conform with local or state codes and HUD's MPS (Appendix K of Reference 2). HUD Handbook 4905.1 REV-1,[7] which addresses acceptable conditions of existing units, applies in part to this program when defective conditions, including foundation problems, must be rectified (see Section 9B.2.1.3 for further discussion).

9B.2.1.3 Existing SF Construction

HUD requirements for the quality of existing SF properties, including technical acceptability, are defined in HUD Handbook 4905.1 REV-1.[7] Existing SF units with defective conditions are unacceptable for involvement in normal HUD program areas. Such conditions include defective construction, evidence of continuing settlement, or other conditions impairing the structural soundness of the dwelling. Such defective conditions shall render the property unacceptable until the defects or conditions have been remedied and the probability of further damage eliminated. Also, properties shall be free of hazards that may adversely affect the structural soundness of the improvements.

HUD's treatment of existing properties is also outlined in HUD Handbook 4150.1 REV-1.[8] HUD technical personnel, either HUD staff or fee staff (architects, engineers, construction analysts, and so on), are usually not involved in an inspection of an existing SF property for determining acceptability, unless specifically requested. Usually, a HUD approved fee appraiser will determine the value of a property for FHA mortgage insurance purposes. In addition to providing an estimate of value, the appraiser inspects the property for any visible deficiencies that may affect the health and safety of the occupants or the continued marketability of the property. HUD makes no warranties as to the value or condition of the house. Therefore, the borrower must determine that the price of the property is reasonable and that its condition is acceptable. The borrower is also urged to hire a home inspection service to check out a property for adequacy.

The condition of existing building improvements is examined at the time of appraisal to determine whether repairs, alterations, or additions are necessary. When examination of existing construction reveals noncompliance with the general acceptability criteria defined in HUD Handbook 4905.1 REV-1,[7] the appraiser must define an appropriate specific correction of the deficiency, if correction is feasible. A typical condition requiring repair, which would be noted by the appraiser, might involve visible foundation damage or damage related to foundation problems. Usually, the appraiser may either define the required repairs, or, more commonly, the appraiser will request an inspection by a licensed or registered structural engineer defining the cause and cure of any foundation-related problem. Any cures defined by the structural engineer may also be required to be inspected and cleared by the same structural engineer as to adequacy of completion.

9B.2.2 Multifamily Projects

MF projects can involve buildings designed and used for normal MF occupancy, including both unsubsidized and subsidized insured housing. Buildings with five or more living units are typically involved.

9B.2.2.1 New (Proposed) MF Construction

MF projects involved in HUD programs[1] cover a wide range of foundations and structures (single story, stick-built to multistory, high-rise concrete). Such structures typically must comply with HUD's MPS for Housing,[2] along with a partially or fully acceptable state or local building code. If no partially or fully acceptable state or local code is in force or acceptable, a recognized model code must be utilized (such as UBC, BOCA, or SBC). HUD field offices maintain lists of jurisdictions with typically utilized or accepted codes for MF HUD project development. HUD enforces and interprets codes for its own purposes and not for any local entity.

Any acceptable state or local code, as well as any recognized model code, covers foundation systems. Foundation system code sections must cover soil tests, foundation depths, footings, foundation materials criteria, piles (materials, allowable stresses, design) and excavations. Codes also will reference acceptable engineering practices and standards relative to foundations which are constructed of varying types of materials and methods (brick, masonry, treated wood, concrete, and so on). HUD also provides similar or additional listings of foundation-related acceptable material standards and engineering practices (Appendices C, E, and F of Reference 2).

HUD requires that reliable subsurface exploration information be available (soils reports, test boring logs, test pit data, soil bearing values, geotechnical study, and so on).[9] Usually soils reports will recommend foundation types along with design parameters for HUD MF projects. Also, HUD requires MF project structural foundation plans to be stamped by a registered architect or professional engineer.[9]

9B.2.2.2 Rehabilitation of MF Construction

MF-type dwelling structures have always been, and probably will continue to be for the foreseeable future, a major source of housing for lower and moderate-income families. Over the years, because of economic conditions and higher operating costs, many of these dwelling units have been neglected, and some are seriously deteriorated. Typical HUD procedures for MF rehabilitation are defined in HUD Handbook 4460.1 REV-1 (refer to Chapter 4 of Reference 9).

A building should undergo a preliminary examination in order to clarify whether or not it is generally suitable for rehabilitation. After said preliminary examination, HUD may require an engineering report to examine major building components, such as the foundation system, to define any upgrading or replacement to assure structural soundness.

The services of a state licensed or registered engineer will be required by HUD when the design and construction of an MF rehabilitation project necessitates plans and specifications to properly define the scope and concept of the rehabilitation if structural changes are necessary or an addition is proposed to an existing building. Rehabilitation must comply with applicable local codes and ordinances. All new construction or additions that enlarge existing buildings must meet applicable codes and HUD's MPS for new construction. (Refer to Section 9B.2.2.1 and Reference 2). Typical types of foundation repairs or new foundation elements involved have been covered in this handbook.

Examples of HUD MF projects, involving foundation rehabilitation are briefly summarized as follows[10]:

1. Minerva Place Apartments (St. Louis, MO/FHA #085-25-339) Constructed in 1942 as a two-story YMCA with a swimming pool, it was converted to a 56-unit apartment complex with a new third floor added. A subsurface soil investigation, which determined the soil bearing capacity, required installation of new larger footings.

2. Douglas Manor Apartments (Webster Groves,MO/FHA #085-35-350) Constructed in 1945 as a two-story public elementary school with classrooms and gymnasium, it was converted to a 41-unit apartment building. The critical element in the structure was found to be the allowable soil bearing under existing column spread footings. Soil analysis indicated that the shear strengths of the soil were low and erratic, and the allowable bearing capacity would be less than the load applied to the soil due to the installation of additional floors. Therefore the 12 columns supporting the gymnasium were shored so that the spreadfootings could be underpinned and enlarged for an allowable soil pressure of 2700 lb/ft^2 (13,200 kg/m^2).
3. Patterson Place (Bismarck, ND/Proj. #094-35040-LD-SR-L8) Constructed in 1910 as a six-story hotel with approximately 100 rooms, over the years (around the 1930s) four more floors were added to extend the structure to a 10-story height. The proposed rehabilitation consisted of converting the hotel into 117 apartments for the elderly. Because of the addition of four more floors, the foundation and columns became underdesigned. To reduce the loads on column footing pads, the rehabilitation required the removal of 2 to 4 in (0.8 to 1.6 cm) thick concrete floor toppings, nonbearing concrete partitions, and heavy plastered ceilings. Steel stud drywall partition walls were installed, and overloaded columns from the basement to the fifth floor were upgraded.

9B.2.2.3 Existing MF Construction

HUD offices nationwide are involved with a large inventory of varying types of existing MF structures (wood frame, reinforced concrete, steel, and so on) originally constructed under various HUD programs [such as 221(d)(4) insured apartments, 202 elderly, or public housing].[1] At any time, an MF structure might develop a foundation problem necessitating action. Such foundation problems may surface during an inspection by HUD staff, or, they may be reported by project personnel or by tenants themselves. A report from a registered or licensed structural engineer, defining causes and cures, may be requested. Any rehabilitation (cure) or retrofit of foundation elements could be accomplished under various HUD programs, depending on the type of MF project.

As an example, a project known as Jackson Heights Elderly Highrise (Proj. #SD-045-001W), constructed in 1978 in Rapid City, SD, started to exhibit stress conditions on several interior wall surfaces in 1984/85 (cracked drywall, door frame racking, and so on). A structural engineer and a soils consultant were employed to define causes and cures. The structure was six stories in height, consisted of 106 units, and was constructed of standard concrete columns bearing on isolated concrete footing pads. A drastic change in the moisture content of a subsurface bearing strata layer caused an approximate 2 in (5 cm) differential settlement between adjacent reinforced concrete columns and pads spaced from 17 ft to 20 ft (5.2 to 6.1 m) apart. 12 isolated concrete pad footings of one wing were stabilized via compaction grouting. An experienced contractor completed the necessary repairs. For a discussion of compaction grouting, see Section 6B.

9B.3 POLICY DEVELOPMENT AND RESEARCH

To carry out presidential and congressional mandates in the areas of housing, community development, and fair housing efficiently and effectively, HUD is structured so that research, economic and policy analyses, and program evaluations are the responsibility of the Assistant Secretary for Policy Development and Research (PD&R) in Washington, DC. All research activities are centralized in PD&R. The research data HUD uses in policy development are made available to interested parties such as state and local governments, financial institutions, builders, developers, universities, and colleges.

The research program of PD&R has focused, in part, on granting research contracts to various groups to investigate and report on hazards to housing (expansive soils, lead-based paint, radon gas, and so on). Relative to foundation systems, work carried out under research contracts is usually based on developments in applied structural and geotechnical theory. Cooperative efforts of research institutions (colleges, universities, and so on), contractors, practicing engineers, and others involved in such research contracts have produced a better understanding of the factors that contribute to foundation performance. Through HUD's PD&R efforts, a guidebook was produced as a rehabilitation guide for SF foundations.[6] (Refer to Section 9B.2.1.2). Examples of HUD funded research involving foundation systems includes a study of remedial measures for houses damaged by expansive clay,[11] as well as a study of experimental residential foundation designs for use on expansive clay soils.[12]

9B.3.1 Remedial Measures for Houses Damaged by Expansive Clay

One such research contract investigated certain remedial techniques that could be used to restore house foundations damaged by expansive clay soils.[11] All techniques were directed towards stabilizing a mass of soil beneath house floor slabs to a depth of 5 ft (1.5 m) or more. The 10 houses included in the investigation were HUD-owned properties identified by the HUD Dallas Office, and all were severely distressed by vertical movement and volume change of the soil. Data acquisition continued over approximately 2 years, or four seasonal climatic cycles.

The remedial techniques included lime slurry pressure injection, a subsurface irrigation system, and three types of moisture migration barriers (granular, recycled rubber, and lean concrete). The lime slurry injection process, utilized around the foundation perimeters to stabilize the soil mass and inhibit moisture migration, was very costly and not very effective. The subsurface irrigation system was not completely effective, due to additional climatic effects and difficulty in keeping the mechanical components of the system active. All three of the moisture migration barriers (granular, recycled rubber, and lean concrete) appeared to be viable techniques when accompanied by increasing the foundation soil moisture 2 to 3% above the plastic limit. These barriers, approximately 5 ft (1.5 m) deep and the width of trenching equipment, isolated a mass of soil beneath the floor slab and caused the slab and soil to interact as a layered system. Assuming that a stable equilibrium condition is realized after water infusion, cosmetic repairs could be effected both inside and outside the damaged structure and the foundation restored to a usable condition.

9B.3.2 Experimental Residential Foundation Designs on Expansive Clay Soils

Preventive measures, applied at the time of construction, were also studied under a research contract.[12] These have also been discussed in Section 7C. The study involved 11 experimental homes, each with a different type of foundation system, constructed over expansive clay soils in Grand Prairie, TX. The performance of the homes was monitored over a 3 year period, or six seasonal cycles. Foundation systems utilized various reinforced concrete, posttensioning, moisture barrier stabilization techniques, and subsurface irrigation systems.

The typical reinforced concrete systems (BRAB waffle slab design) performed adequately, yet exhibited a prohibitively high cost. Posttensioned systems exhibited reasonably effective performance (See Section 9B.5.4 and References 13–15 for further discussion). Active subsurface irrigation systems proved not to be justified because of indeterminate effects of interruptions of water service, tampering with controls, and concerns for the longevity and durability of any buried pipe. Perimeter passive vertical moisture barrier stabilization techniques were deemed viable, provided the soils encompassed by any barrier were preswelled and moisture was contained. A futher discussion of the prolonged behavior of all 11 expirmental homes was published by Robert Wade Brown in *Design and Repair of Residential Foundations,* McGraw-Hill, New York, 1990.

9B.4 TECHNICAL SUITABILITY OF PRODUCTS PROGRAM

Section 521 of the National Housing Act of 1965 directs HUD to adopt a uniform procedure for the acceptance of materials and products to be used under HUD housing programs. To comply with this mandate, HUD developed the Technical Suitability of Products Program for review and acceptance of building systems, components, products, and materials. The objectives of this program are the acceptance of new and innovative building materials and systems, and to encourage improvements in, and development of, technological advances in home building.

The program and processing procedures are outlined in HUD Handbook 4950.1 REV-3.[16] Under this program, one such type of acceptance document that can be issued by HUD is a structural engineering bulletin (SEB). An SEB can be issued to accept complex components that have structural features not addressed by, or not in compliance with, HUD requirements for new construction. A floor, wall, or roof system can be covered by an SEB issued by HUD headquarters.

Wall systems can, in part, cover foundation systems. An example is SEB #1117, issued to Superior Walls of America, Ltd., for their precast concrete stud wall panels utilized in SF home basement construction. The wall panels, in themselves, are designed to act as a reinforced concrete monolithic concrete panel with a footing (Figure 9B.2). Over 10,000 Superior Walls foundations have been installed throughout the northeastern United States. The precast reinforced concrete insulated foundation basement wall panels can be used for dwellings up to 2½ stories (plus basement). Wall panels can be precast in 4 ft (1.2 m), 8 ft (2.4 m), and 10 ft (3 m) heights and up to 20 ft (6 m) wide. The panels consist of reinforced concrete exterior skins, interior studs, and interior insulation. Minimum concrete strength is 5000 psi (34.5 MPa).

The concrete exterior skins are 1¾ in (4.5 cm) thick, monolithic with 10½ in (26.7 cm) top ledger and bottom footing reinforced with 2 #3 horizontal bars. The reinforced concrete interior studs are 2¼ in (5.7 cm) by 6¾ in (17.1 cm) with a #4 vertical bar. Studs are spaced 24 in (60 cm)

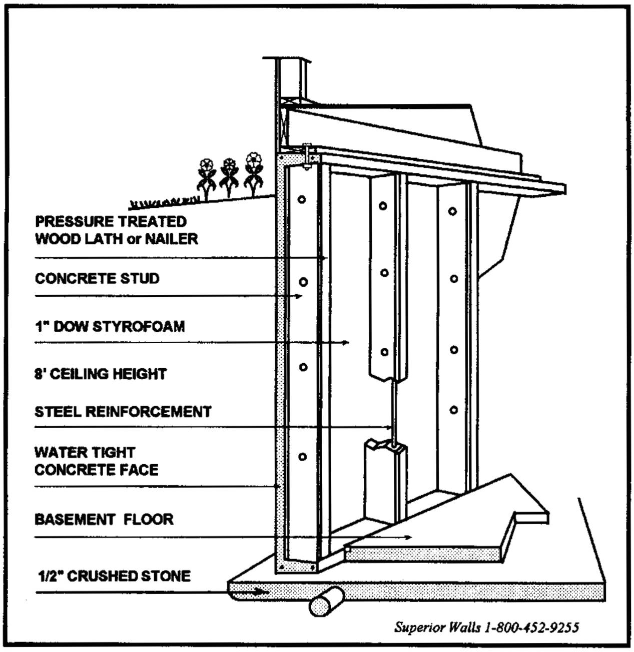


FIGURE 9B.2 Superior Wall and Foundation System.

center to center and are mechanically anchored to the concrete skin, top ledger, and bottom footing. Treated wood nailers are attached to the interior face of the studs. Basement foundation wall panels have a maximum allowable load (earth pressure) of 60 lb/ft^3 (960 kg/m^3) equivalent fluid pressure and a maximum allowable vertical load (building structure plus live loads) of 4200 lb/lin ft (6250 kg/m).

9B.5 LOWER-COST FOUNDATIONS

Homes that are safe, durable, marketable, and affordable must be provided to meet national housing goals. In January, 1982, HUD announced the formation of the Joint Venture for Affordable Housing (JVAH) as a public–private partnership to reduce housing costs. Over the years, several HUD JVAH demonstration projects have utilized lower-cost structural foundation systems to assist in reducing housing costs.[17,18] Lower-cost foundation systems used in the JVAH effort, as well as other cost-saving foundation systems, are discussed in this section.

9B.5.1 Concrete Footings, Foundation Walls, and Slabs

Footing widths could be reduced if accurate soils data were utilized rather than providing local practice minimum widths. Footing reinforcing can be deleted for footings placed on undisturbed stable soil. Reinforcement in foundation walls is usually not required in nonexpansive soil and in areas of low seismic risk. Under stable base conditions, concrete slab floors do not require typical welded-wire fabric (WWF), concrete slab thickness can be reduced to 2½″ (6 cm), and concrete slab strength can also be reduced to 2000 psi (13.8 MPa). Highly expansive soils may necessitate specialized construction.

9B.5.2 Frost-Protected Shallow Foundations (FPSF)

Perimeter insulation is added along with a shallow foundation system in lieu of a full-frost-depth foundation (Figure 9B.3).[19] Insulation dimensioning is according to design guides of the Norwegian Building Research Institute along with some extrapolation and adjustment for U.S. energy code minima. Corner insulation is typically extrawide due to three-dimensional heat loss. Cost savings have been projected from $1239 to $2875 for insulated shallow foundation systems versus full-frost-depth foundations used in several areas of the country [1612 ft^2 (150 m^2) home, block and concrete foundations].[19]

More recent demonstrations of FPSF technology were completed in 1994 by the National Association of Home Builders (NAHB)/National Research Center (NRC) for HUD.[20] Five FPSF demonstration homes were constructed, monitored, and evaluated for foundation performance and construction costs. One home each was constructed in Vermont, Iowa, and Alaska, with two built in North Dakota; they were built according to European FPSF design guidelines and a proposed simplified design method for adoption by the major model building codes.[21] This demonstration concluded that the homes performed well and that houses and other structures may be built on shallow, slab-on-grade foundations in cold climates when properly insulated to protect against frost heave. Cost savings to a home buyer could range from approximately 1 to 4% of the cost of a conventional slab-on-grade home and even greater when compared to basement construction.

9B.5.3 Permanent Wood Foundation (PWF)

The PWF system (Figure 9B.4),[22] previously identified as the AWWF (All-Weather Wood Foundation), is basically a below-grade stud wall built of pressure-preservative-treated lumber and Ameri-

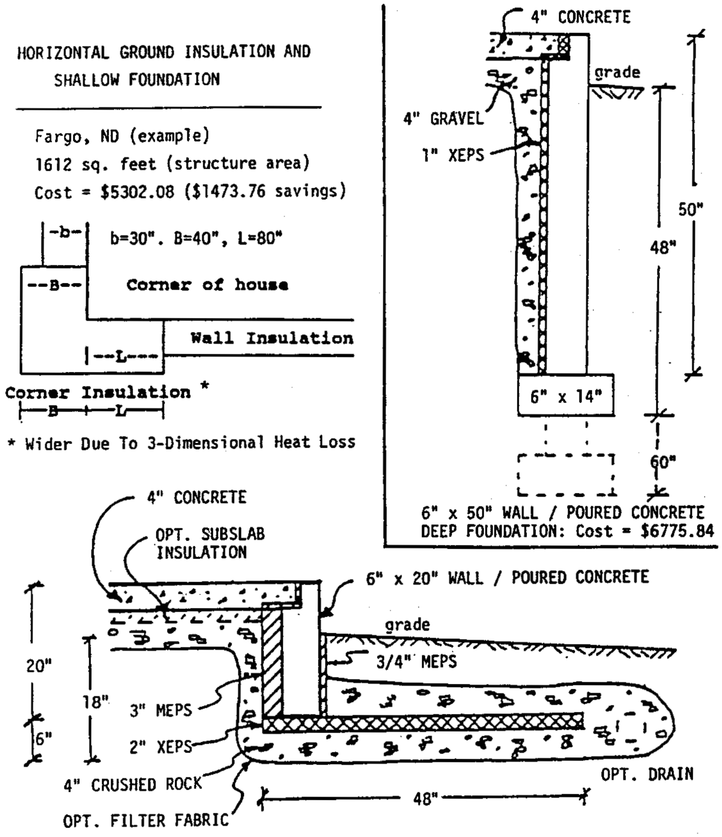


FIGURE 9B.3 Frost-protected shallow foundation and full-frost-depth foundation.

can Plywood Association (APA) trademarked plywood. Basic advantages of the PWF are installation in nearly any weather condition, speed of construction, ease of interior finishing, and versatility. HUD JVAH demonstration projects in Tulsa, OK, and Fairbanks, AK, utilized the PWF system, and cost savings amounted to $1470 and $1035 per unit, respectively.[18] The PWF system is also identified in HUD's rehab guide for foundations[6] as a possible replacement option for damaged sections of existing SF foundation walls.

9B.5.4 Posttensioned Slab-on-Grade

Certain foundation configurations are designed to be relatively insensitive to the fluctuations in soil moisture and the consequent variations in supporting soil volume. Typical foundations depend on stable supporting soil. The use of posttensioned slabs-on-ground is most often specified in locations with highly expansive soils or in other situations where the foundation-supporting material provides uncertain or variable supporting qualities.[13,14]

The system can be utilized for sites with highly expansive or compressible soils where the use of conventional foundations might require extensive site soil modifications (soil removal and replace-

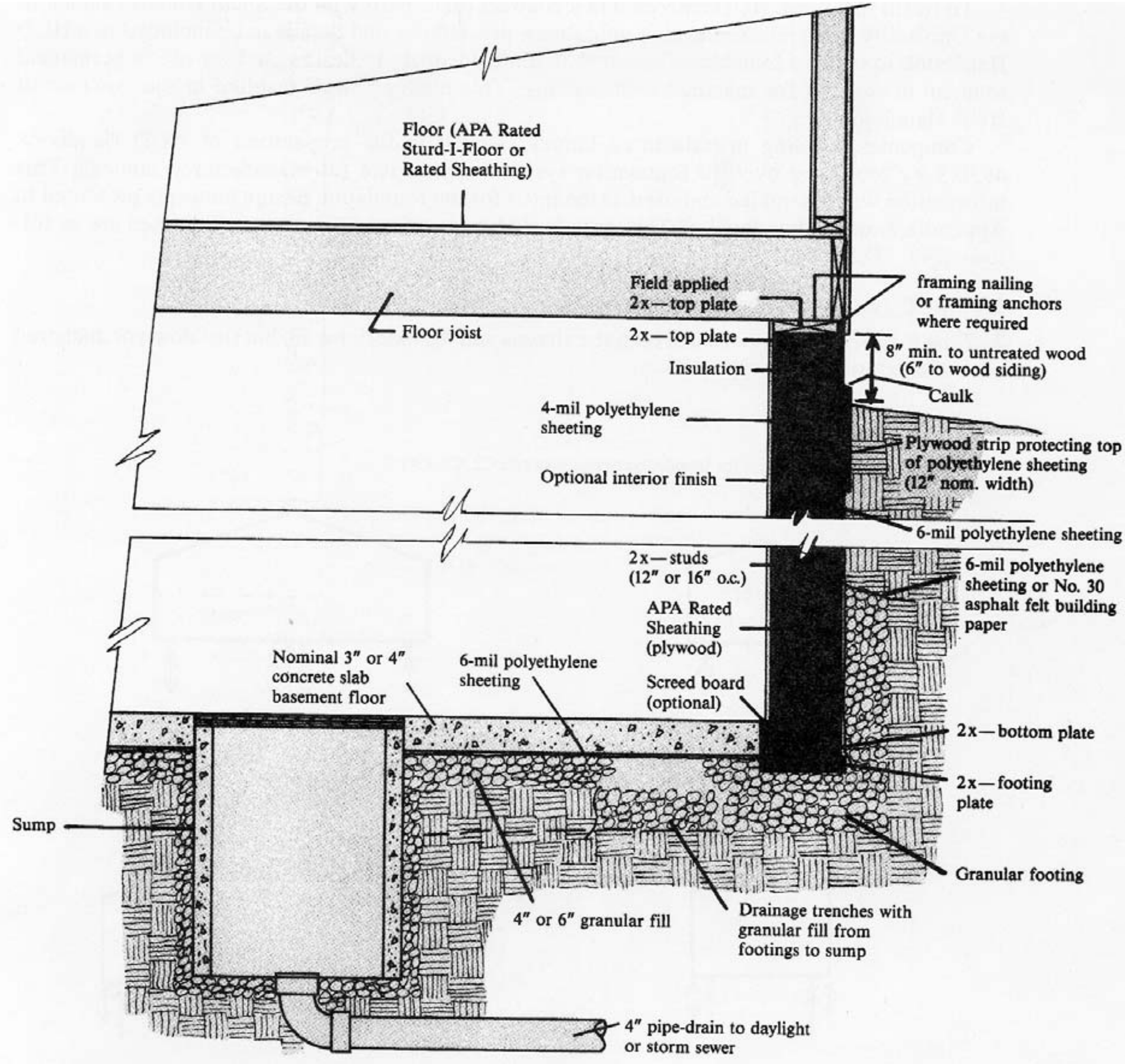


FIGURE 9B.4 Permanent Wood Foundation (PWF) system.

ment). More extensive deep foundation systems otherwise might be required. Costs vary with site soil conditions and building configurations. Part 4 further discusses this type of foundation system.

In 1990, some HUD concerns were expressed relative to these types of systems and their utilization in Texas for units involving FHA mortgage insurance.[15] However, HUD concerns could be acceptably mitigated with assured certifications as to defining proper soil design parameters, following current design procedures, and providing for adequate supervision over construction.[15]

9B.6 MANUFACTURED HOUSING (MOBILE HOME) FOUNDATIONS

In 1983, HUD extended eligibility for typical FHA SF mortgage insurance to manufactured homes constructed in conformance with the Manufactured Home Construction and Safety Standards (MHCSS), when permanently attached to a site-built foundation. Neither HUD's MPS nor the Manual of Acceptable Practices (MAP) adequately covered special requirements for permanent foundations for manufactured housing. Due to this inadequacy, HUD headquarters realized an urgent need to furnish HUD field offices with technical guidance concerning acceptance of permanent site-built foundations for manufactured housing if they are to be covered by typical 30-year FHA SF mortgage insurance.

To fulfill this need, HUD entered into a contract with the Small Homes Council of the University of Illinois to develop guidelines, procedures, and details to be included in a HUD Handbook to contain foundation concepts that are adequate in design, and for use in permanent foundation systems for manufactured housing. This contract work resulted in the 1989 issuance of HUD Handbook 4930.3, Permanent Foundations Guide for Manufactured Housing.

In 1996, the Building Research Council of the School of Architecture at the University of Illinois at Urbana/Champaign, under contract with HUD, updated and revised the 1989 version of HUD Handbook 4930.3.[23] Whereas wind alone governed the information on overturning and sliding in the 1989 handbook, stringent seismic criteria made it necessary to review both wind and seismic forces to determine which should control the foundation design. To account for this significant issue, the tables in the handbook were modified to include seismic data and to highlight those values controlled by seismic considerations.[23]

The foundation design concepts, presented in Appendix A of the Handbook,[23] were condensed from over 40 systems submitted by the manufactured housing industry. The three basic types of foundation systems, for single-section and multisection units, are defined as follows (Figures 9B.5 and 9B.6):

1. Type C: Support and vertical anchorage occurs at equally spaced joints along the chassis beam lines only.
2. Type E: Support occurs at the exterior longitudinal foundation walls as well as at equally spaced points along the chassis beam lines. Vertical anchorage occurs continuously along the exterior longitudinal foundation walls for single-section or multisection units (two ties), or a combination of vertical anchorage can occur continuously along the exterior longitudinal foundation walls and along the equally spaced pier locations along interior chassis beams (four ties).
3. Type I: Support occurs at the exterior longitudinal foundation walls as well as at equally spaced piers along the chassis beam lines, just as for type E, for single-section or multisection units. Vertical anchorage occurs at the equally spaced piers along the chassis beam lines only for single-section or multisection units (two ties or four ties).

Type C1 and E1 systems are depicted in Figures 9B.7 and 9B.8. Once the system is defined, Appendix B of the Handbook[23] presents foundation design load tables for use in determining foundation anchorage and footing sizes for all foundation types. Seismic, wind, and snow loads were computed based on ASCE 7-93, Minimum Design Loads for Buildings and Other Structures. Minimum wind and minimum roof live loads were based on Appendix K of HUD's MPS.[2] Normal ranges of allowable footing bearing pressures are also defined in the Handbook.[23] Foundation capacity tables are presented in Appendix C of the Handbook[23] to determine the sizes and spacing of anchors, required size and depth of footings, and necessary reinforcement. Horizontal and vertical anchorage and withdrawal resistance capacities are defined for foundation systems of reinforced concrete, grouted masonry, isolated piers, and all-weather wood systems (on concrete or gravel) (Figures 9B.9 through 9B.13).

The Handbook is a logically organized easy-to-use reference for the permanent foundation

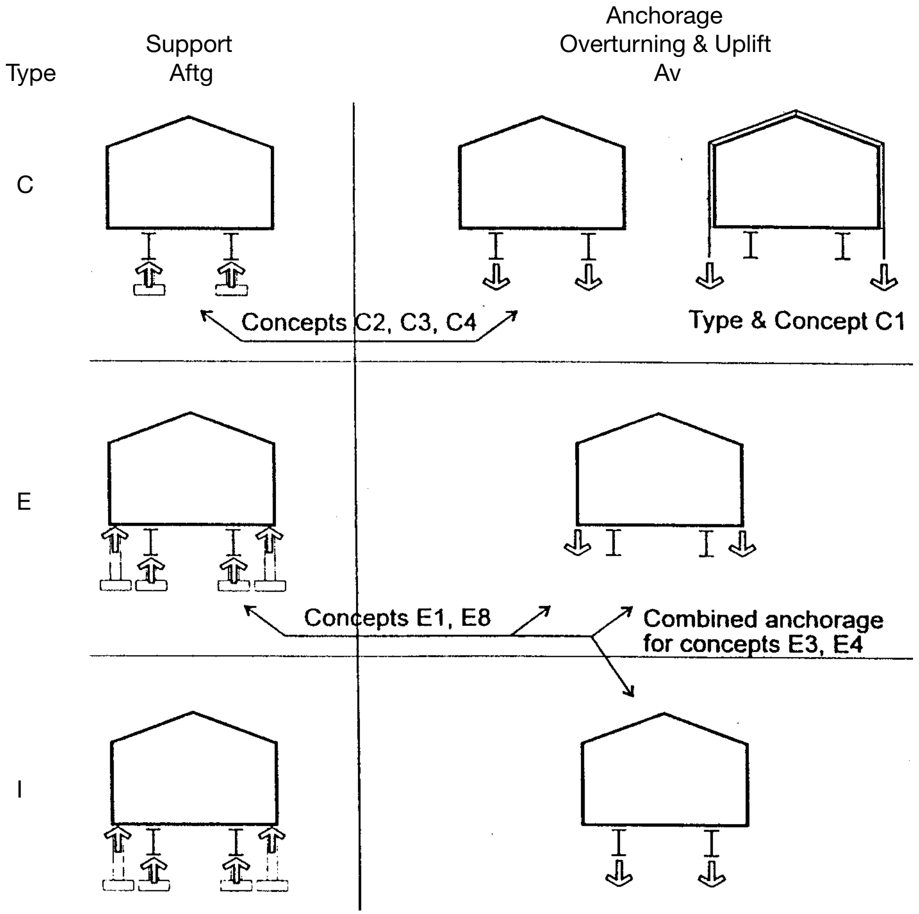


FIGURE 9B.5 Foundation design concepts: single-section units.

process and for the design of anchorages that will assure adequate structural performance for manufactured homes. Companion computer software, and a guide for same,[24] is also available.

9B.7 CONCLUSION

The previous sections have described several HUD program areas involved with foundation design, construction, repair, and rehabilitation. Numerous types of foundation systems and repair techniques are and have been utilized in various HUD program areas. HUD typically relies on foundation design and construction procedures defined in national model codes, acceptable state and local codes, or defined in its MPS for Housing. Policy development and research activities have been sponsored by HUD to study remedial measures for damaged foundations as well as acceptable foundation systems for use over expansive clay soils. HUD's Technical Suitability of Products Program is an avenue that has been used by sponsors to obtain a review and acceptance of foundation-related

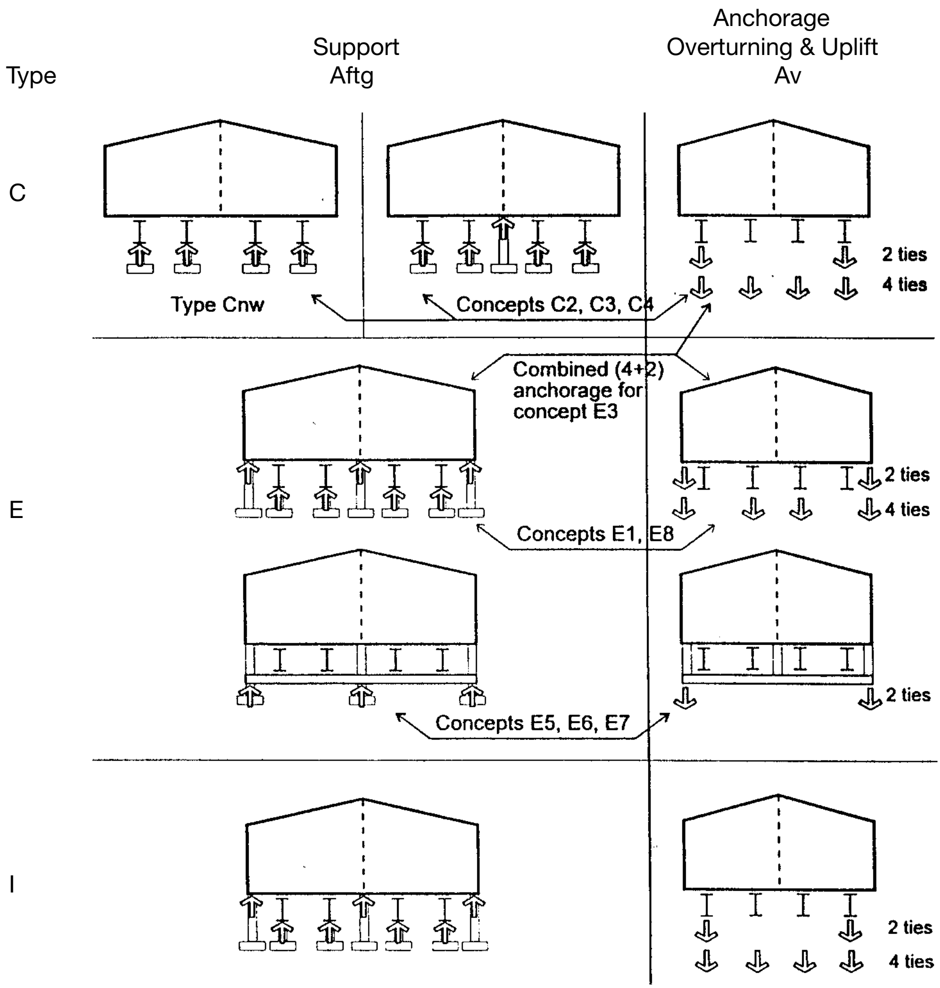


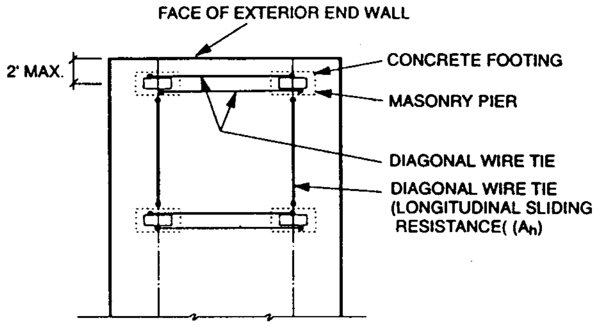
FIGURE 9B.6 Foundation design concepts: multisection units.

housing components or systems. Various types of economically built foundation systems have been shown to contribute to affordable housing in demonstration projects developed either under HUD's Joint Venture for Affordable Housing (JVAH) or under other HUD sponsored efforts. Manufactured housing (mobile home) foundations, considered permanent in nature, have been defined by HUD through cooperative efforts of the industry and the University of Illinois.

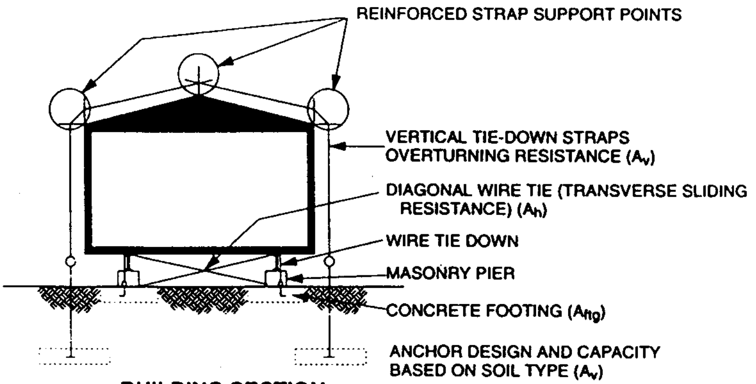
It has not been possible in the course of these brief sections to cover all the types of HUD program areas that may involve foundation design and construction. Omitted, for example, are discussions of public and Indian housing projects, community planning and development grants, and HUD-held properties or projects. However, in such omitted program areas, similar procedures are utilized and are based on the use of acceptable foundation standards, complying with building codes, involving qualified design professionals, and utilizing experienced contractors. Key goals are to assure structural integrity and longevity, occupant safety, durability, protection of HUD's mortgage insurance fund, and the efficient and economical use of Congressionally allocated funds.

FOUNDATION TYPE Reinforced masonry piers w/ wire tie downs and diagonal tie	SYSTEM NUMBER
SUPERSTRUCTURE TYPE Chassis supported single-wide	C1

SINGLE-WIDE



FOUNDATION PLAN



BUILDING SECTION

NOTE: TYPICAL STEEL TIE-DOWN STRAP: 1/32" × 1-1/4"
MINIMUM BREAKING TENSION STRENGTH = 4750 LB (ULTIMATE LOAD)
(ASTM D3953-83) OR
FEDERAL QQ-S-781G

FIGURE 9B.7 Type C1 foundation type.

FOUNDATION TYPE **Reinforced perimeter wall, unreinforced piers at chassis**	SYSTEM NUMBER
SUPERSTRUCTURE TYPE **Exterior anchored, chassis supported single- and multi-wide**	**E1**

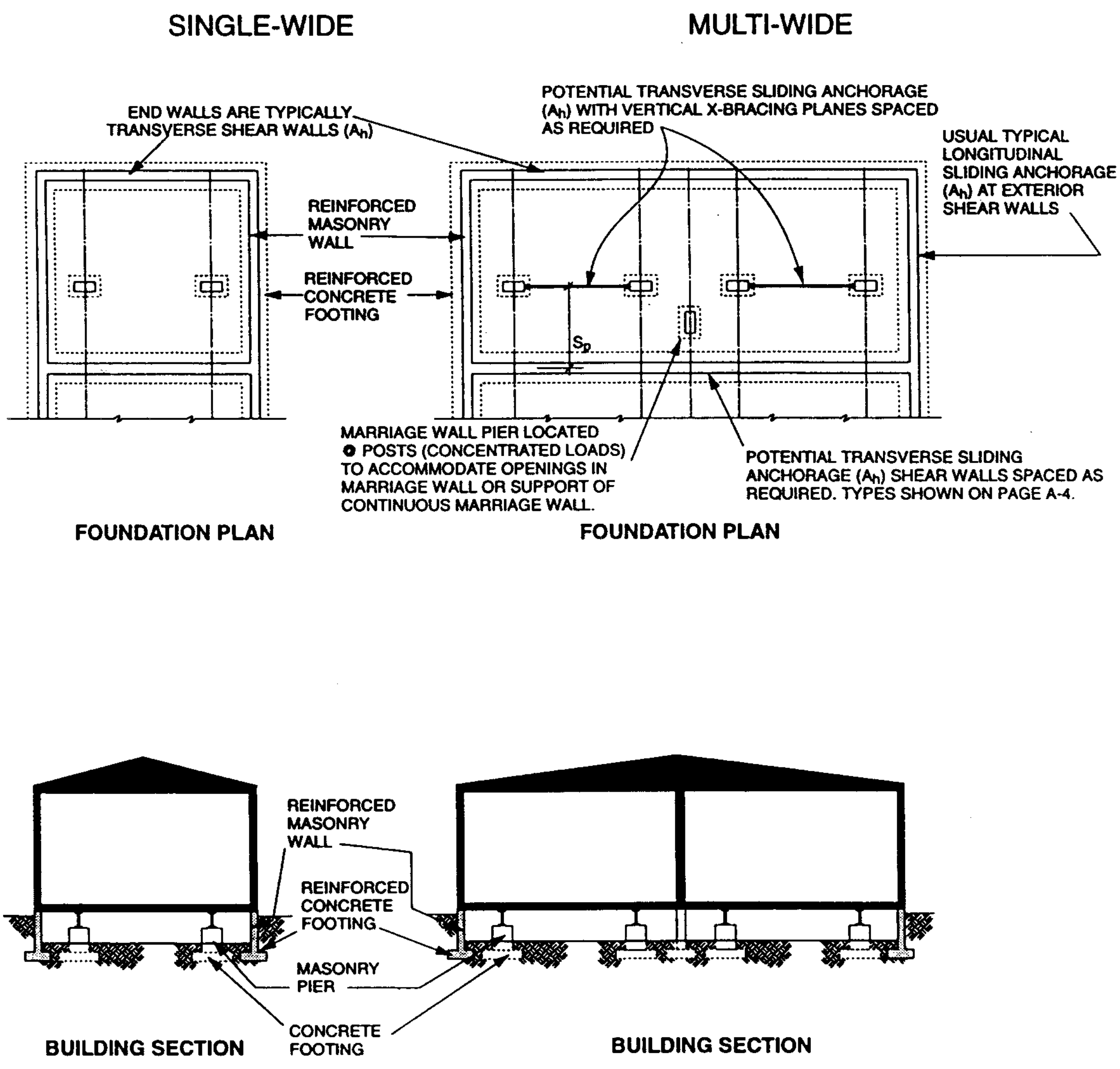
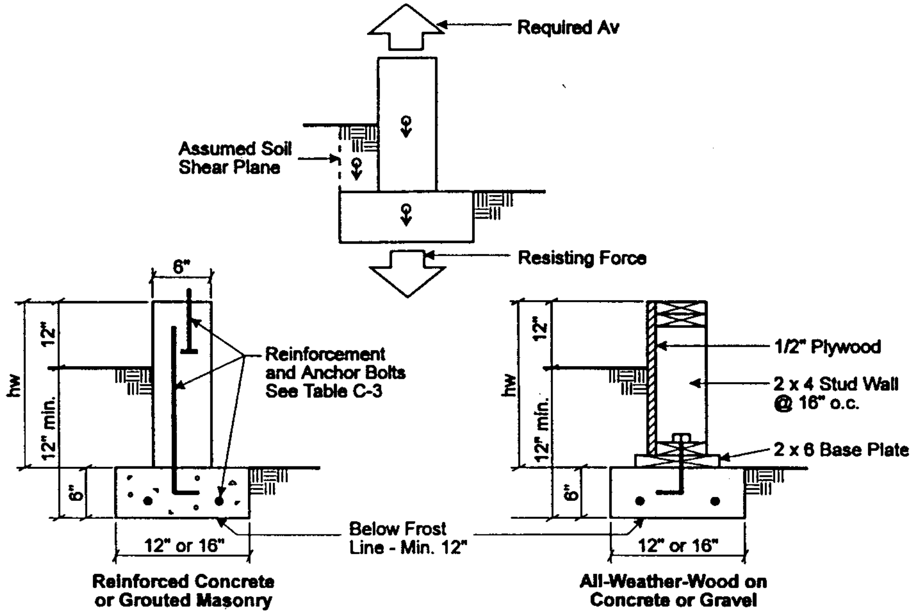


FIGURE 9B.8 Type E1 foundation type.

Table C-1
Withdrawal Resistance[1]
Longitudinal Continuous Foundations[2, 3]
(In pounds per linear foot of wall)



hw	Reinforced Concrete		Masonry- Fully Grouted 6" CMU		Masonry- Grouted @ 48" o.c.		All-Weather Wood w/ Conc. Footing	
	Footing Width		Footing Width		Footing Width		Footing Width	
	12"	16"	12"	16"	12"	16"	12"	16"
2'-0"	255	300	231	276	195	240	126	171
2'-8"	325	383	293	351	245	303	154	212
3'-4"	395	466	355	426	295	366	182	254
4'-0"	465	550	417	502	345	430	211	296
4'-8"	535	633	479	577	395	493	240	337

[1] Potential resistance to withdrawal is the maximum uplift resistance which can be provided by the foundations shown. It is computed by adding the weights of building materials and soil over the top of the footing, plus the footing weight. To fully develop this potential, adequate connections to the footing and superstructure must be provided. Material weights used: concrete (nlwt) = 150 psf; 6"solid grouted CMU = 63 psf; 6" CMU grouted @ 48"o.c. = 45psf; grout wt assumed = 140 pcf; CMU units nlwt; wood = 35 pcf; soil = 120 pcf.

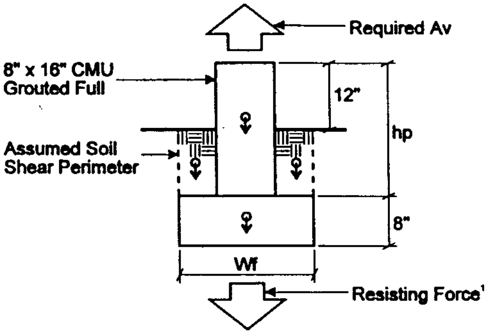
[2] Foundations must be designed for bearing pressure, gravity loads, and uplift loads in addition to meeting the anchorage requirements tabulated in the Foundation Design Tables.

[3] Values shown in this table could be increased by widening the footing, provided the system is designed for the increased load, or by a more detailed analysis of the shearing strength of the soil overburden.

FIGURE 9B.9 Withdrawal resistance.[23]

Table C-2
Withdrawal[1] Resistance For Piers[2, 3]
(In pounds per pier)

Hp Depth	Width of Square Footing: Wf			
	1'-0"[4]	2'-0"	3'-0"	4'-0"[4]
2'-0"	279	997	2097	3755
2'-8"	361	1322	2824	5049
3'-4"	442	1643	3541	6325
4'-0"	525	1967	4267	7617
4'-8"	607	2292	4994	8911



[1] Potential resistance to withdrawal is the maximum uplift resistance which can be provided by the foundations shown. It is computed by adding the weights of building materials and soil over the top of the footing, plus the footing weight. To fully develop this potential, adequate connections to the footing and superstructure must be provided. Material weights used: concrete (nlwt) = 150 psf; nlwt 8"CMU = 84 psf grouted solid; grout (nlwt) = 140 pcf; soil = 120 pcf.

[2] Foundations must be designed for lateral soil pressure, bearing pressure, gravity loads, and uplift loads, in addition to meeting the anchorage requirements tabulated in the Foundation Design Tables. The bottom of the footing must also be below the maximum depth of frost penetration.

[3] Values shown in this table could be increased by widening the footing, providing the wall system is designed for the increased load, or by a more detailed analysis of the shear strength of the soil overburden.

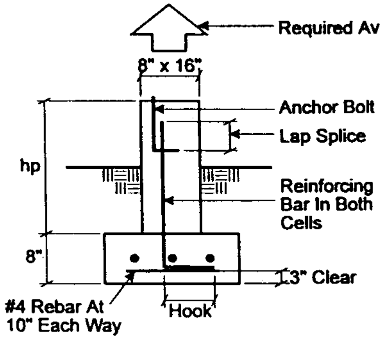
[4] Assumes 8" x 8" pier for the 1'-0" square footing, and 16" x 16" pier for the 4'-0" square footing.

Table C-3
Vertical Anchor Capacity For Piers[1, 2]
(In pounds)

Anchor Bolt Dia.	Capacity Per Number Of Bolts	
	1	2
1/2"	4240	8480
5/8"	6620	13240

Table C-3A

Anchor Bolt Dia.	Vertical Rebar	Minimum Lap Splice	Rebar Hook
1/2"	# 4	16"	6"
5/8"	# 5	20"	7"

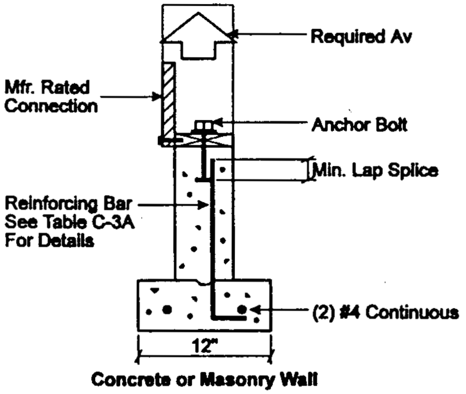


[1] The vertical anchor capacity is based upon the working capacity of ASTM A-36 rod stock anchor bolts in 2500 psi concrete or grout. To fully develop this capacity, anchor bolts must be properly lapped with the pier's vertical reinforcement.

[2] The capacity is based on f_c = 2500 psi; F_y = 36,000 psi.

FIGURE 9B.10 Withdrawal resistance and anchor capacity.[23]

Table C-4A
Vertical Anchor Capacity For Longitudinal Foundation Wall[1]
(In pounds per linear foot of wall)



Vertical Capacity[5] lbs./ft.		Required Anchorage[2, 3]		
Standard Washer	Over-Sized Washer	Anchor Bolt	Rebar[4]	Spacing[5]
146	239	1/2"	# 4	6'-0"max.
164	270	↓	↓	5'-4"
187	307	↓	↓	4'-8"
218	359	↓	↓	4'-0"
262	431	↓	↓	3'-4"
327	538	↓	↓	2'-8"
437	718	↓	↓	2'-0"

[1] Compare with required Av for Type E units.
[2] Values are based on vertical capacity per foot of wall.
[3] Assuming 1 1/2" thick sill plate, 3/4" edge distance for wood or composite nailer plates or 20 diameter end distance for plywood sheathing; APA rated, properly seasoned wood; Group III woods, not permanently loaded, and a 25% length of bearing factor increase.
[4] It is assumed that a reinforcing bar of the same diameter and spacing as the anchor is adequately embedded in the footing and lapped with the anchor.
[5] Spacing and capacity is based on allowable compression of wood perpendicular to grain for F_c = 565 psi and washer as define below:

Standard washer: 1 3/8" O.D. and 0.5625" I.D. washer (for 1/2" ϕ bolt)
Over-sized washer: 1 3/4" O.D. and 0.6875" I.D. washer (for 5/8" ϕ bolt) placed under the standard washer.

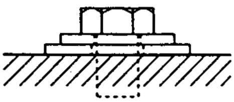
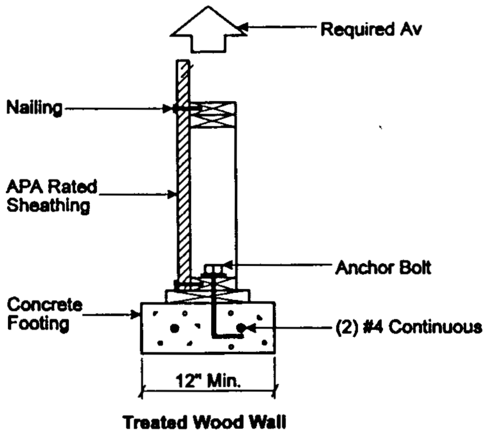


FIGURE 9B.11 Vertical anchor capacity for concrete or masonry wall.[23]

Table C-4B
Vertical Anchor Capacity For Longitudinal Foundation Wall[1,2]
(In pounds per linear foot of wall)



Vertical Capacity lbs./ft. Standard Washer	Required Nailing[4,5] (Edge Spacing, in.)	Min. Plywood Thickness	Required Anchorage[2,3]	
			Anchor Bolt Diameter	Bolt Spacing[6]
146	6d @ 6" o.c.	3/8"	1/2"	6'-0"max.
164	↓	↓	↓	5'-4"
187				4'-8"
218	8d @ 6" o.c.			4'-0"
262	8d @ 4" o.c.			3'-4"
327	8d @ 4" o.c.	15/32"		2'-8"
437	10d @ 2 1/2" o.c.	↓		2'-0"
***				

*** For required Av greater than 437 lbs./ft., consider using a different foundation material or utilize an engineered design with a higher capacity.

[1] Compare with required Av for Type E units.
[2] In the case of a treated wood foundation wall, the wood wall and its connections must be designed to transfer the anchor load to a concrete footing. This table does not apply to treated wood foundation walls on gravel bases.
[3] Values are based on vertical capacity per foot of wall.
[4] Assuming 1 1/2" thick sill plate, 3/4" edge distance for wood or composite nailer plates or 20 diameter end distance for plywood sheathing; APA rated, properly seasoned wood; Group III woods, not permanently loaded, and a 25% length of bearing factor increase.
[5] Nailing schedule in this table is intended to secure the superstructure to the foundation only, and not to provide required edge fastening for plywood siding or sheathing.
[6] Spacing and capacity is based on allowable compression of wood perpendicular to grain for F_c = 565 psi and standard washer = 1 3/8" O.D. and 9/16" I.D. washer (for 1/2" ϕ bolt).

FIGURE 9B.12 Vertical anchor capacity for treated wood wall.[23]

Table C-5A
Horizontal Anchor Capacity For Transverse or Longitudinal Shear Walls[1]
(In pounds per foot of wall)

Concrete or Masonry

Horizontal Capacity[2] lbs./ft.	Required Anchorage[5]		
	Anchor Bolt[4]	Rebar	Spacing[6]
300	1/2"	#4	72" o.c. max.
600			36" o.c.
675			32" o.c.
900			24" o.c.
1350			16" o.c.
1800			12" o.c.
***			
See Table C-3A For Rebar Details			

*** For required Ah greater than 1800 lbs./ft., consider using an engineered design with a higher capacity.

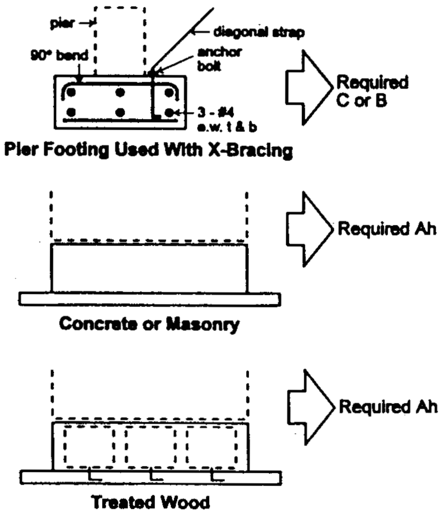


Table C-5B

Treated Wood

Horizontal Capacity[2] lbs./ft.	Required Nailing[3,4] (Edge Spacing, in.)	Min. Plywood[4] Nailer Thickness	Required Anchorage	
			Anchor Bolt Diameter	Bolt Spacing[7]
300	8d @ 4" o.c.	7/16"	1/2"	4'-0" max.
360	8d @ 4" o.c.	15/32"		3'-4"
449	10d @ 4" o.c.	15/32"		2'-8"
600	10d @ 3" o.c.	19/32"		2'-0"

1 Compare capacity with required Ah in transverse or longitudinal direction.
2 Values are based on horizontal load per foot of wall. Select Ah for pier spacing of 4 feet for use with this table.
3 Assuming 1 1/2" thick sill plate, 3/4" edge distance for wood or composite nailer plates or 20 diameter end distance for plywood sheathing; APA rated, properly seasoned wood; Group III woods, not permanently loaded.
4 Nailing schedule in this table is intended to secure the superstructure to the foundation only, and not to provide required edge fastening for plywood siding or sheathing.
5 It is assumed that a reinforcing bar of the same diameter as the anchor is adequately embedded in the footing and lapped with the anchor. In the case of a treated wood foundation wall, the wood wall and its connections must be designed to transfer the anchor load to a concrete footing. This table does not apply to treated wood foundation walls on gravel bases.
6 Spacing based on bearing capacity of bolt against concrete/grout.
7 Spacing based on capacity of anchor bolt in bearing against the wood plate. (see also #5.)

FIGURE 9B.13 Horizontal anchor capacity.[23]

Some important programs, projects, or properties may regrettably have gone unmentioned because they have not come to the attention of the author. Nevertheless, it is hoped that the preceding review, which has attempted to emphasize several HUD programs, projects, and property types, will provide an informative guide as to how HUD handles the critical housing subject of foundations. For more detailed information on HUD programs, including available publications or handbooks, contact the HUD field office in your area.

9B.8 ACKNOWLEDGMENTS

Grateful acknowledgment should be expressed to many colleagues, especially to the limited nationwide staff of HUD technical professionals (architects, engineers, and construction analysts) who strive to assure that properties and projects involved in HUD program areas have adequately designed and constructed foundations. A special acknowledgment is also expressed to G. Robert Fuller (Retired, HUD Headquarters), Kenneth L. Crandall (Retired, HUD headquarters), and Robert Wade Brown, whose helpful suggestions and cooperation have contributed significantly to the preparation of this section.

9B.9 REFERENCES

1. U.S. Department of Housing and Urban Development (HUD), Programs of HUD," HUD-214-PA(18), Washington, DC, May 1992.
2. U.S. Department of Housing and Urban Development (HUD), "Minimum Property Standards for Housing," HUD Handbook 4910.1, Washington, DC, 1994.
3. U.S. Department of Housing and Urban Development (HUD), "Architectural Processing and Inspections For Home Mortgage Insurance," HUD Handbook 4145.1 REV-2, Washington, DC, Feb. 1992.
4. U.S. Department of Housing and Urban Development (HUD), The Construction Complaints and Section 518(a) and (b) Handbook," HUD Handbook 4070.1 REV-2, Washington, DC, Aug. 1981.
5. U.S. Department of Housing and Urban Development (HUD), "203(k) Handbook-Rehabilitation Home Mortgage Insurance," HUD Handbook 4240.4 REV-2, Washington, DC, Dec. 1991.
6. U.S. Department of Housing and Urban Development (HUD), "The Rehab Guide Volume 1: Foundations," Washington, DC, June 1997.
7. U.S. Department of Housing and Urban Development (HUD), "Requirements for Existing One to Four Family Units," HUD Handbook 4905.1 REV-1, Washington, DC, Aug. 1991.
8. U.S. Department of Housing and Urban Development (HUD), "Valuation Analysis for Home Mortgage Insurance," HUD Handbook 4150.1 REV-1, Washington, DC, Feb. 1990.
9. U.S. Department of Housing and Urban Development (HUD), "Architectural Analysis and Inspections For Project Mortgage Insurance," HUD Handbook 4460.1 REV-2, Washington, DC, Dec. 1995.
10. G. R. Fuller and S. Asar, "Structural Evaluation and Rehabilitation of Multistory Residential Buildings," presented at ASCE Spring Convention, May 1983.
11. A. Poor, "Remedial Measures for Houses Damaged by Expansive Clay," UTA, for HUD Contract H-2240R, HUD-PDR-415-2, Apr. 1979.
12. A. Poor, "Experimental Residential Foundation Designs on Expansive Clay Soils. Data Supplement," UTA, for HUD Contract H-2240R, Dec. 1979.
13. Post-Tensioning Institute (PTI), "Design and Construction of Post-Tensioned Slabs-On-Ground," PTI, Phoenix, Ariz., 1980.
14. Post-Tensioning Institute (PTI), "Tentative Recommendations For Prestressed Slabs-On-Ground Used On Expansive Or Compressible Soil," PTI, Phoenix, Ariz., Sept. 1975.
15. R. J. Sazinski, "HUD Concerns: Post-Tensioned Foundations in Texas." In Proceedings 7th International Conference on Expansive Soils, Dallas, TX, Aug. 1992.
16. U.S. Department of Housing and Urban Development (HUD), "Technical Suitability of Products Program Processing Procedures," HUD Handbook 4950.1 REV-3, Washington, DC, Aug. 1997.
17. R. J. Sazinski, "Lower Cost Structural Techniques For Housing." In Proceedings ASCE Specialty Conference on Affordable Housing, Miami, FL, Dec. 1989.

18. U.S. Department of Housing and Urban Development (HUD), Affordable Housing, Challenge and Response, vol. II: Affordable Residential Construction; a Guide for Home Builders," HUD-1128-PDR(vol. 2), prepared for HUD by National Association of Home Builders (NAHB)/National Research Center (NRC), Upper Marlboro, MD, July 1987.
19. R.A. Morris, "Frost-Protected Shallow Foundations: Current State-of-the Art and Potential Application in the U.S.," prepared for the Society of the Plastics Industry by NAHB National Research Center (NAHB/NRC Proj. 2070), Upper Marlboro, MD, Aug. 1988.
20. U.S. Department of Housing and Urban Development (HUD), "Frost-Protected Shallow Foundations, Phase II-Final Report," prepared for HUD by National association of Home Builders (NAHB)/National Research Center (NRC), Upper Marlboro, MD, June 1994.
21. NAHB Research Center, "Design Guide for Frost-Protected Shallow Foundations," prepared for HUD, Washington, DC, 1994.
22. Southern Forest Products Association (SFPA), Southern Pine Council, "Permanent Wood Foundations, Design and Construction Guide," SFPA #400, Kenner, LA, 1998.
23. U.S. Department of Housing and Urban Development (HUD),"Permanent Foundations Guide for Manufactured Housing," HUD Handbook 4930.3, Washington, DC, Dec. 1996.
24. U.S. Department of Housing and Urban Development (HUD), "Permanent Foundations Guide for Manufactured Housing—Software User's Guide," Washington, DC, Dec. 1996.