Research and Analysis for Manufactured Housing Foundations

Reports:

3a: Non-Conventional Foundation and Stabilization Systems

and

3b: Analysis of General Design Principles and Evaluation of Sound Engineering Judgement

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Description: Research and Analysis for Manufactured Housing Foundations

Report Scope: **Task 3a – Identification of Non-Conventional Foundation and Stabilization Systems**
Task 3b – Analysis of General Design Principles and Evaluation of Sound Engineering Judgment

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I. OVERVIEW OF TASK REQUIREMENTS

Three key objectives define the purpose of Tasks 3a and 3b:

1. Review current alternatives for conventional foundation systems, and
2. Identify and compare new alternatives based on industry research that could be adapted for use in manufactured housing foundation systems.
3. Verify analysis, testing methods and design approaches used by manufacturers for design and State approval purposes.

Activities to achieve these objectives, as detailed in the project work plan, are represented in this interim report. The report is organized as follows:

I. Overview of Task Requirements
II. Methodology for Analysis
III. Detailed Review and Analysis of Non-Proprietary and Proprietary Systems

II. METHODOLOGY FOR ANALYSIS

Systems were identified based on reference material available and company websites, supplemented by information gathered by telephone from the manufacturers whenever possible. Systems were grouped into categories, beginning with non-proprietary crawl space, slab, and basement systems. Proprietary systems were grouped together by type, beginning with unique designs. Systems were comparatively evaluated with regard to the following parameters:

1. Earthquake protection (type and extent)
2. Resistance to wind loading and combined flood and wind loading
3. Climate
4. Soils and drainage
5. Accommodation to sloping ground

6. Aesthetics
7. Availability of materials
8. Need for specialized set-up crews
9. Durability, longevity, and maintenance
10. Retrofit applications and limitations
11. Code compliance
12. Cost

Important Issues Referenced in the Discussion of Individual Systems

System design issues and potential modes of failure are discussed here and referenced by letter in the discussion of each identified system, where applicable.

A. Unitary floor systems

At least one proprietary floor system (Lindsay Floor System, used by New Era Homes) has been devised to transfer floor loads from the chassis beams to a perimeter beam or truss. Simpler systems have been devised by a number of manufacturers. One type uses the principle of the queen-post truss. Outriggers are strengthened and provided with a bearing pad that transfers loads to the stem wall or basement wall. A steel tie-bar or channel is welded between chassis beams in line with the outriggers. The top chord is provided by the floor joists, which must be firmly attached to the rest of the system in order for the truss to function. Finally, the chassis beams act at the queen posts, and also act as purlins to transfer loads to the trusses.

A more recent design replaces the chassis beams with channel frames outboard of the floor system. Deeper joists are required to span the full width of the home section, and steel cross-members of some kind are needed onto which the undercarriage shackles are mounted. If tire wells are provided above the floor, the road clearance can be reduced relative to a conventional floor section. A perimeter steel frame allows a welded attachment to the foundation if steel plates are cast into the top of the foundation wall.

B. Perimeter support

It is commonly believed in the industry that continuous support of the perimeter of a HUD-Code home is not allowed. In one design, for example, a load bearing stem wall is installed (to resist backfill loads), but is held ¼” below the floor system (except at load points designated by the manufacturer for support at openings and concentrated loads). The theory is that the stem wall will then will provide support only if it becomes overloaded.

Relieving the critical negative moment in the floor joists that occurs above the chassis beams can only decrease loads on the joists. Deflections won’t change because the floor is not being jacked up by the stem wall. Movement caused by periodic snow loads will cease when the loads are directly supported by the stem wall.

C. Moment load on chassis beams

Several systems intend to develop resistance to lateral loading by creating a “moment connection” between the top of the support and the chassis beam. The theory is that if the support is firmly clamped to the lower flange of the beam, and has a broad base that is also firmly clamped to the post, the post will neither slide nor tip, and thus will resist the lateral loading. This technique depends for its effectiveness on two factors that are not under the control of the system’s designer: how the lower flange of the beam is welded to the web (in factory-fabricated beams, often used in the past to save the cost of standard rolled sections, a thin flange is spot welded at intervals to a thin-gauge corrugated web); and the load on the support (if there is little load, the post will slide under lateral load instead of tipping).

D. Uplift resistance using concrete

Many designs use the mass of poured concrete footings to resist wind, flood or seismic uplift. The amount of concrete used per lineal foot depends on assumptions about the width and height of the building. If a mass concrete is used to resist wind, flood or seismic uplift, sufficient reinforcing must be provided to keep the mass together during its resistance. Concrete depth and reinforcing must be sufficient to prevent pull-out of embedded anchors when they are used in conjunction with tie-down straps.

E. Unformed footings

Some designs are based on trench footings. These are widely used in the Midwest and perhaps other areas. One constraint is that resteel must be set in 3" to prevent exposure at irregularities in the sidewalls. In cases where a footing must step down to stay below the frost line (as when the grade is dropping), it may be desirable to use a rubble trench to lower the bottom of the footings, or even to fill the trench with concrete, rather than stepping the footings and having to make an excavation wide enough to allow workers to construct the wall in the trench. This may or may not be allowed by the local building official.

F. Site water control

No foundation can work properly if water from the roof and surrounding surface is not directed away from the foundations. HUD-Code homes typically do not have gutters and leaders, and often have short or non-existent overhangs. In these cases, the accumulation of water along the foundation and under the home is almost a given unless the ground under and around the home is decisively graded away from the foundations.

The Shallow Frost-Protected Foundation concept (hereinafter SFPF) was developed by the NAHB for site-built homes. Some efforts have been made to adapt the SFPF system to manufactured homes, but no standard details have been developed. Typical details show exterior insulation extending from grade to 18" or 24" below grade, then outward at a slope for about 24". When this design is used, an ideal solution for water protection of the foundations is to cover the underground portion of the vertical insulation and underground "apron" with black 6-mil poly. It ideally would be clamped to the foundation so that water could not flow down behind it. It will act as a sort of roof below grade, and in most cases will keep the footings dry. Even without a SFPF, such a poly apron can be installed to protect the foundations. This system is especially important around basements.

G. Freeze lift

The common term "frost heaving" reflects a limited view of how freezing water can affect a foundation. Frost heaving occurs where there are no horizontal constraints on the growth of a lens of ice. A familiar example is the frost heaves that create humps in highways. These form when a channel of water runs freely under the road. As the frost level descends to the level of the water, it begins to freeze the water. The heat of fusion liberated during freezing suspends the descent of the frost line, creating a growing lens of ice that heaves the road up. This can occur if water under a foundation can be refreshed by new flowing water, as might happen at the water table; hence the requirement that footings be below the local "frost line."

However, a much more common form of freeze lift occurs when ice is constrained horizontally by the foundation. Again, the process requires a continuing source of water: the expansion from one-time freezing can be accommodated by the pores in the soil. Pressed against the foundation wall, the lens can lift the foundation as it grows. The typical preventive measure against this mode of failure is heating from an uninsulated basement or crawl space that stays warm.

Failures occur when the basement or crawl space is insulated, or where the crawl space or slab is unheated, as in a garage. One common example of this mode of failure is a diagonal crack in the garage floor across the corner. This problem also can arise at a slab under a home if ventilation is sufficient to drive the space between the home and the slab below freezing. This might occur in very cold areas, but in Connecticut, according to Jensen, code-required ventilation is not enough to counteract the heat lost through the belly board (through the extensive cold bridges formed where the insulation is squeezed under the chassis beams), and the space under the home doesn't freeze.

SFPF designs avoid this problem because even if a lens forms outside the insulation, it cannot get a grip on the wall through the insulation. However, if the remaining exposed stem wall (which may approach 18" high to accommodate the required ventilation openings – see H) is not insulated, this may compromise the protection offered by the exterior below-grade insulation. Insulation above grade is a problem, because it may obscure termite passages, and needs some sort of covering, the selection and application of which can be problematic (see discussion under J).

H. Crawl space inspection

Closed crawl spaces must be regularly visited and inspected for water, mold buildup, termites, tie-down strap adjustment, pier leveling, and repairs. Some designs do not provide adequate access, or suggest that access be cut through the home's floor, which will likely be structurally unsafe and invalidate the warranty. Designs with full concrete slab crawl space floors are ideal for encouraging regular access.

J. Crawl space ventilation

It has been found that crawl space ventilation is the major source of wet crawl spaces, and a minor industry has arisen to seal them after inspection, in cold climates. Also, ventilation is almost completely ineffective in removing moisture from a closed crawl space.

Based on contemporary research, site building codes are offering options for closed crawl spaces, but this option is not currently available under the HUD Code. If the floor of the crawl space is a concrete slab, or is covered with a durable moisture barrier, a crawl space will stay dry under most circumstances. 6-mil poly works but tears readily; 10 mil fiberglass-reinforced poly is much better. In cold climates, the only way to keep the crawl space dry is to seal it up. As soon as the dewpoint rises above ground temperature, which occurs in the spring in cold-humid climates and during most of the summer in northern maritime climates, water will condense on hard surfaces in the crawl space, and will saturate wood, creating mold and rusting fasteners.

In addition, openings into the crawl space located right at grade function as scuppers, directing ground water into the crawl space. If vent openings are used, their bottoms should be at least 6-8" above grade.

K. Termite control

Some designs show termite shields at the top frost walls. These do not stop termites, but only force them to build tunnels around the shield. These are then visible for removal if inspected regularly. Shields are not effective if joints are not sealed, as termites can and will tunnel horizontally through a loose joint. Also, termites can climb interior piers as readily as frost walls, and again, regular inspection is necessary. If the exterior wall is insulated above grade, be sure some bare wall is left, or a removable band of insulation provided, to allow inspection for termite tunnels.

L. Obstacles to retrofit

Many homes are improved by the addition of permanent non-structural skirting (stucco, brick, various proprietary systems) and add-on structures such as garages, sunrooms, decks and porches. These structures make it difficult to apply many of the wind bracing and earthquake bracing systems described below, particularly those involving structural stem walls. Such accessory structures would also make the addition of auger anchors around the home's perimeter impractical.

Some of the proprietary system described below, particularly those that involve bracing struts and do not require poured footings, could be retrofit under any home that has the required access to the crawl space.

III. DETAILED REVIEW AND ANALYSIS

A. NON-PROPRIETARY SYSTEMS

Non-proprietary systems identified are categorized into 3 groups:

- Crawl Space Systems
- Slab Systems
- Basements Systems

CRAWL SPACE SYSTEMS

Description

Crawl space systems are characterized by continuous footings under the perimeter of the building, on which a stem wall is built. In some systems, the wall acts primarily as a retaining wall, allowing the grade outside to be raised, eliminating the elevated first floor that marks the home as HUD-Code. In other cases, the stem wall is also load-bearing interior footings can be conventional piers, isolated poured concrete footings similar to those used in a conventional home, or a grid of interconnected footings. A continuous slab thickened at the edges and at concentrated loads is also possible. This use of a structural slab is included in this section; the section on slab designs will cover slabs without structural stem walls.

Lateral loads are either taken out through the stem wall or through conventional ties anchored to the concrete footing system (or a combination). Uplift loads are counteracted by the mass of the stem wall and footings.

Design Considerations

1. Earthquake protection (type and extent)

A continuous stem wall can, if properly designed, resist earthquake loads. It must be securely attached to the footings and the floor of the home with fasteners designed to resist the appropriate loads, and must be designed with the required reinforcement or shear capacity to carry the shear loads. Obviously in these cases the wall must support the perimeter of the home (A,B)

2. **Resistance to wind and combined flood and wind loading**

See comments under Earthquake Protection above for wind loads in Zone I. Wind loads in Zones two and three may require additional resistance using strap ties secured to embedded anchors.

Flood loading can be accommodated by stem walls with required flood vents, and without backfill (that is, the floor of the crawl space must be at or above the exterior grade).

3. **Climate**

A skirting of buried insulation, following the principles for designing SFPF's, will reduce the required depth of perimeter footings (however, see G and J).

Another approach to frost protection is to use a rubble footing. In this design, a trench is dug to an elevation somewhat below the frost line, a perimeter drain is placed on 4" of stone, and the trench filled with stone to within a foot of the top. A grade beam is then poured on the stone. Ideally, the trench is lined with filter fabric.

4. **Soils and drainage**

While some installers claim that a grid of footings will act like an integral system of grade-beams that allow the foundation to float on unstable clay soils, this is unlikely. A typical floating slab is post-tensioned to provide the integrity needed to act as a unit. If surface or ground water cannot be controlled to prevent alternate wetting and drying of expansive soils, an engineered foundation design is necessary. Collapsing boxes placed under poured concrete footings may prevent local heaving of the soil from cracking the foundation – consult an engineer familiar with the problem.

Drainage is relatively simple for sites where additional earth is piled up to raise the perimeter grade. In these cases, a conventional footing drain can be placed before backfilling, and run to daylight, drywell, or sump. When the crawl space is recessed below prevailing grade, drainage is both essential and problematic. On dead flat lots, the crawl space floor may need to be sloped to a sump, which is pumped automatically to a sewer or drywell. Directing roof and surface water away from the home is an essential measure (F).

If the soils do not collapse at the walls of the trench, the footings can be trenched instead of formed above grade (E).

5. **Accommodation to sloping ground**

Crawl space designs work well on sloping ground when the slope is less than about 3 feet. The bottom of the stem wall footing must stay below the frost line. Steps should be in modules of the blocks used in the stem wall and piers (4" or 8"). (E)

6. **Aesthetics**

Stem wall designs that are entirely or partially backfilled can create an appearance exactly like that of a modular or site-built home. Block or CMU walls can be left unfinished, stuccoed, or painted. If insulation extends above grade, it can be finished with stucco. (In areas with termite problems, see K.)

Stem wall systems with on-grade crawl spaces can be made attractive, to resemble older homes with high foundations. Also, in flood plains, all the homes are likely to be on high foundations.

7. Availability of materials

Stem walls can be made of CMU, concrete or treated wood (following the requirements for pressure-treated wood foundations. The only material for which there is no substitute is concrete. Where ready-mix material is not available, concrete can be site mixed.

8. Need for specialized set-up crews

The skills required are similar to those required for a conventional foundation. In particular, it is typically necessary to match the foundation closely to the home's footprint. For retrofit installations, this is obviously the only way possible. For new construction, even well-regarded companies occasionally make homes that are under- or over-sized, or that end up slightly skewed. In these cases, it is ideal to set the home and then build the stem walls to suit the home. Obviously the footings must be wide enough to accommodate variations in the location of the walls above. This approach also allows the home to be driven into position rather than craned in or roller set.

Many systems, however, assume that the stem walls are constructed while the home is awaiting delivery. In these cases, one wall can be omitted to allow a drive-in set, or the home is set by crane or rollers.

9. Durability, longevity, and maintenance

Concrete or CMU stem walls and footings maximize durability and minimize maintenance, assuming water problems are resolved. However, as in site-built or modular housing, the control of site water is crucial for durability and maintenance (F). The longevity of pressure-treated wood is debated, and certainly depends on the pressure under which the wood was treated. 60 psi is the minimum acceptable and higher values are desirable.

10. Retrofit applications and limitations

It is feasible to build a stem wall under a home in place, although excavation for the perimeter footing may have to be done by hand, which would raise the cost. Excavating for footings under the home is not feasible, as it would require digging with very restricted vertical clearance. Structural stem walls and interior footings are probably not feasible in homes with add-on structures (L). Constructing pressure-treated stem walls might be possible behind an add-on structure, with considerable effort.

11. Code compliance

Crawl space systems are varied in their designs and must be approved individually, typically in the jurisdictions where the inventor of the system works. Systems are often developed by retailers for their own use, and the retailer will apply for approval by the authority having jurisdiction. This would typically be the local building official, except in California where it would be the state agency that regulates the installation of manufactured homes.

12. Cost

These systems vary in cost, but generally cost substantially more than conventional skirting and tie-downs and substantially less than basements.

SLAB SYSTEMS

Description

The slab designs to be discussed here are restricted to those that do not have a structural perimeter stem wall. One common use of slab systems is to create a durable and easily maintained pad in a manufactured home park. Kris Jensen has considerable experience with slabs, and reports that they are very trouble-free. In some states, the slab can "float" on top of a bed of crushed stone, while in others a perimeter frost wall is required. Jensen has had no trouble with floating slabs in central Connecticut, and has found that even with ventilated vinyl skirting (J), the crawl space almost never freezes (G). He crowns the slabs to provide positive drainage from the center (F), and includes embedded tie-down anchors. A full slab provides a clean and visually uncluttered crawl space floor that encourages access for maintenance (H), and also creates an excellent continuous moisture barrier.

"Ribbon" slabs are provided only where needed to support the loads, (D) typically leaving out several feet of slab between the chassis beams to save cost. While technically feasible, this design loses the advantage of the clean access and moisture barrier created by a continuous slab. This design would not be practical in any jurisdiction that requires frost walls.

Any form of skirting, including semi-permanent proprietary systems, can be used with a slab design. If the skirting is insulated and the slab is built according to SFPF principles, the crawl space will stay warm. This could be a cost savings in jurisdictions where frost walls are required, and would help maintain a warm floor in the home, while saving heating energy.

A slab coupled with a structural perimeter stem wall is covered under crawl spaces, above.

Design Considerations

1. Earthquake protection (type and extent)

Properly sized, a slab with embedded tie-down anchors should provide adequate restraint for a home in an earthquake prone area (D).

2. Resistance to wind and combined flood and wind loading

Properly sized, a slab with embedded tie-down anchors should provide adequate restraint for a home against wind loading (D). With properly designed flood vents in the skirting, or breakaway skirting, or no skirting at all, a slab design should be compatible with requirements for homes in flood plains. However, the edges of the slab may need to be deepened to prevent scouring that would undermine the slab.

3. Climate

As mentioned above, an uninsulated slab on a well-drained stone base does not seem to have problems with freeze lift as far north as central Connecticut. Prevention of corner cracking from freeze lift likely depends on the depth of the slab edge and the amount of reinforcing along the edge. In colder areas than central Connecticut, insulated skirting and SFPF insulation around the slab edges may be required to insure that no freezing plane occurs under the slab, and therefore that the movement of ground water under the slab will not cause frost heaving. This is especially important for sites with underlying rock and for low-lying sites with poor drainage (F). Water typically flows on the surface of underlying rock, and the elevation of the rock under the slab is typically not known and likely to be highly variable.

4. Soils and drainage

The discussion above under Climate covers soils and drainage in cold climates. Adopting standards similar to those used for site-built slabs on grade should resolve any problems with soils and drainage. If poly is used under the slab to prevent wetting of the slab from underground moisture, the poly should be directly under the slab and not under a "blotter layer" of sand or gravel. This in turn requires relatively dry concrete, as over-watered concrete will not dry promptly over a layer of poly.

The slab must be deep enough at the anchor locations to provide proper embedment for embedded anchors (D).

5. Accommodation to sloping ground

A slab cannot accommodate sloping ground. A sloping site must be graded to form level terraces for the slab. However, no site should be dead flat (F).

6. Aesthetics

Except in cases where a structural stem wall is used (covered under Non-Proprietary Crawl Space Designs), a slab foundation looks exactly like a conventional foundation with an elevated floor and some form of skirting. If the slab extends beyond the edges of the home's floor (as it would do in a park pad sized for a larger home), it would be visible around the perimeter. This could be an aesthetic advantage, as it facilitates the maintenance of a neat edge to grass or other ground covering that occurs at the site.

7. Availability of materials

Concrete, formwork, resteel, resteel supports, and embedded anchors are all commonly available in most areas. If ready-mixed concrete is not available, concrete could be site mixed, as long as care is taken to insure a proper bond between successive pours.

8. Need for specialized set-up crews

A slab set is very straightforward, as each section of the home can be driven directly onto the slab and then moved into position using standard methods.

9. Durability, longevity, and maintenance

A slab, if protected from frost heave and freeze lift at the edges will provide a highly durable, very low-maintenance base for the foundation system.

10. Retrofit applications and limitations

If a home is already firmly in place and difficult to move (especially if it has solid skirting and/or peripheral add-on structures), it is not feasible to build a slab under it. However, a home that is easily moved could be set aside while a slab is poured, and reset on the slab.

11. Code compliance

Except in California, where a special jurisdiction handles HUD-Code installations, the slab would have to be approved by the same agency that approves site-built home slabs.

12. Cost

A slab is more expensive that a conventional set, but might be the lowest cost way to achieve secure, low-maintenance wind or seismic resistance.

BASEMENT SYSTEMS

Description

Basement designs share many design issues with crawl space designs, but have specific problems and opportunities of their own. Basements provide useful living space, can be ventilated with user-operated windows and doors, and are much more expensive than homes without basement systems. A home's perimeter must be sealed to the top of the basement wall, which for practical purposes results in an edge-bearing structure (B).

Supporting a home along the chassis beams, practical in a crawl space, becomes problematic in a basement, because the resulting forest of columns adds considerable cost and obstructs the use of the basement for living space. Instead, two basic approaches are used: transverse steel beams span from midline supports to the perimeter walls, supporting the chassis beams; or the home is built with a unitary or integrated floor system (A).

To use the basement for living space, a source of heating is needed. If this is to be provided by the home's furnace, the added load must be accounted for in the home's design. If the basement is used as a garage, the garage must be separated from the home above by a layer of gypsum board that provides the required fire protection. In either case, the utility runs must be planned to work with the dropped ceiling. Utilities drops also must miss cross beams, and sloping runs must be coordinated with the elevation of cross-beams. Pre-planning is essential for a successful basement set.

Another requirement that must be accommodated in the home's design and construction is an interior staircase. In homes with conventional chassis beams, (which cannot legally be cut), the stair is typically located outboard of the beams, creating a long straight-run stair. Integrated floor systems can be designed to accommodate other stair configurations. Perimeter-support designs that depend on reinforced outriggers present additional obstacles to stair location. The option of an external stairway is seldom acceptable to the owner.

Some jurisdictions require that basement foundation walls be laterally supported at the top by the home's floor system. Whether specifically required or not, a laterally supporting connection is structurally essential unless the wall is designed as a retaining wall. This should not be a structural problem for the home, but may require some modifications to the perimeter floor details. If a laterally supporting connection is not made, the wall is free to arch inward, which could crack the wall and damage or break the tie between the home and the wall, compromising wind and earthquake performance.

Design Considerations

1. Earthquake protection (type and extent)

Providing the connections between the home and the top of the foundation walls are properly engineered (see above), a basement creates an adequate anchor for the home in an earthquake.

2. Resistance to wind and combined flood and wind loading

Again providing the connections between the home and the top of the foundation walls are properly engineered, a basement creates an excellent anchor for the home against wind loads. Basements are not feasible in a flood plain, because the basement is considered the first floor of the home, which must be elevated above the 100 year flood level.

3. Climate

Basements are widely used in colder climates, and seldom used in warmer ones. There is a tradition of basement construction throughout the Midwest and down the east coast, well below the serious snow belt. A frost line of 3 feet or more requires considerable excavation. To pour a slab then requires compacting backfill along the inside of the frost walls, which if not done properly will lead to slab cracking.

Insulation can be on the exterior, possibly using an underground skirt of insulation combined with a waterproof skirt, as described above. As with insulated crawl spaces, code officials in areas with subterranean termite infestation typically will not allow insulation above grade, leaving a portion of the foundation unprotected. Removable insulated panels can solve this problem (K).

Many homeowners sooner or later wish to finish a basement. The traditional method (an insulated stud wall inboard of the concrete, finished with gypsum board) has been shown to foster mold growth between the wall and the foundation. There are proprietary systems (Owens Corning makes one) that perform well but are somewhat costly. Rigid insulation adhered directly to the wall and supporting gypsum board has been shown to be a mold-resistant solution that also provides foundation insulation. Note, however, that this results in a cold foundation wall. If water collects next to the wall in the freezing zone, freeze lift can occur, creating structural damage (G).

Pressure-treated wood foundations have the advantage that they can be constructed in freezing weather, after a level bed of drained crushed stone is provided at the base in lieu of footings. In addition, there are precast concrete basement wall systems that can be installed in cold weather.

4. Soils and drainage

The foundation walls needs to be kept dry. As discussed under Non-Proprietary Crawl Space Systems, an "apron" of poly or other water-resistant membrane secured to the wall at grade and extending outward under the ground for 2 or 3 feet is usually an effective way to keep surface water from descending next to the wall. If rigid insulation is used under the membrane, a SFPF is created. Because many HUD-Code homes lack gutters, special effort is needed to insure that the grade slopes away from the home. This may involve re-compacting the backfill next to the wall after a year of settlement.

In expansive soils, it is impractical to create a floating foundation because of the difficulty of post-tensioning the basement floor. In the Denver area where basements are very common, the foundations are typically a grid of pilings or caissons connected by grade beams. An expansion space is created under the grade beams, foundation walls and basement slab by pouring them on collapsible boxes.

A basement should never be built lower than the worst-case high water table. Establishing its elevation is difficult in areas with underlying ledge, where spring thaws can temporarily fill up elevated underground "pockets" in the ledge, or flow near the surface in areas that are dry the rest of the year. To avoid litigation or expensive remediation, ground water levels should be measured during the spring, and local experts should be consulted for advice.

In ordinary (non-expansive but poorly draining) clay soils, a basement excavation becomes an "underground swimming pool" into which surface water will freely flow through the backfill (which is usually gravel or other pervious material). The footing drains must be relied on to drain the excavation. The drains must either empty by gravity or be pumped to a sewer or drywall. However, to keep the drains working, it is very desirable to prevent most water from descending to footing drain level, as large flows will saturate the ground next to the basement walls, and ultimately will silt up the drains. The plastic "apron" described above is an ideal solution, creating an underground roof over the excavated area around the basement. The apron should completely span the excavation.

5. Accommodation to sloping ground

Basements are ideally suited to accommodate sloping ground. The low point of the basement floor can be set near grade, creating a highly desirable walk-out condition (this may expose more foundation wall than desired at the high point – see discussion under Aesthetics, below).

The footings cannot be allowed to rise above the required frost depth. To prevent this, the bottom of the footings must drop as the grade drops. This can be done in several ways: the footing can be poured deeper, at the expense of more concrete; the wall can step down to follow the footing; or if allowed by the local code official, a rubble foundation can be added below the footings as needed (E). The future grade should be plotted before dampproofing is applied to the wall so it will not be visible above grade.

If the walk-out condition is on the side or front, a basement garage can be created under the home. Be aware, however, that the ceiling of the garage must create a one-hour separation between the garage and the home (see Discussion, above).

6. Aesthetics

Basements used on a level site can create the "low-profile" look desired by most homeowners. Alternatively, if grade adjacent to the wall is allowed to vary on a sloping site, a walk-out condition can be created, as described above. This must be balanced against the appearance of the exposed basement, which can be painted or stuccoed, but sometimes is marred by an overrun of dampproofing (see Soils and Drainage, above). Another solution is to hold the face of the basement wall back relative to the house walls (which is a good idea in any case), and allow the house cladding to extend over the face of the wall. Aligning the cladding may not be possible if the home section above is out of square. Extending the cladding is the solution of choice for treated wood foundations.

7. Availability of materials

Concrete, CMU's, reinforcing and accessories are readily available. Formwork is typically owned by a specialty contractor who builds the wall, but can be rented. It is typically not cost-effective to build the forms from scratch, except when the wall must be higher than the standard 8 foot forms, as is usually the case when the chassis beams are carried on transverse beams. Pressure-treated wood walls are a possible and economical choice as long as the treatment is done at a sufficiently high pressure: 60 psi is minimum, and higher pressures are desirable. Unfortunately, wood treated to these pressures are hard to find.

8. Need for specialized set-up crews

Basements require skilled erection to insure that the walls align with, or are slightly set back from, the perimeter of the home sections. As basement walls cannot be built after the home is set up, unlike crawl space stem walls, it is essential to know the exact dimensions of the home sections before constructing the wall. This may require measuring the home sections after construction, unless the company has sufficient quality control procedures to guarantee square and true floor sections.

For poured concrete walls, contractors experienced in forming and pouring concrete can do the work faster and more accurately than can amateurs, with much less likelihood of a form "blowouts," inadequately vibrated concrete, visible pour joints, and other errors that commonly occur in pouring high walls. CMU walls, although commonly used and less expensive than concrete, are more prone to leakage, inward bulging from water-related soil conditions, and other problems. CMU walls should be properly reinforced.

9. Durability, longevity, and maintenance

Concrete basement walls should last indefinitely, if properly built. It must be supported at the top by the home's floor system and at the bottom by the basement slab, and should be protected from surface and ground water accumulations outside the wall. It must also be properly reinforced.

CMU walls are more problematic, but if properly reinforced and supported top and bottom, should last indefinitely. CMU walls are more vulnerable to water infiltration and damage than are concrete walls.

Pressure-treated wood foundations have been found to be successful and long-lived by some builders, but have always seemed impermanent relative to masonry. Besides proper construction and restraint top and bottom, the key variable is likely to be the pressure at which the treatment chemicals are applied. Also, abandoning arsenic-based chemicals has made treatment less effective. Borates work well as long as the wood stays dry.

10. Retrofit applications and limitations

Basements are not suitable for retrofit, in the sense of adding a basement under an existing home. Homes that are relatively mobile can be moved and replaced on a basement, but this is effectively a new installation.

11. Code compliance

Except in California, where a special jurisdiction handles HUD-Code installations, the basement would have to be approved by the same agency that approves site-built home basements.

12. Cost

Basements are the most expensive type of foundation, but provide valuable living space at a relatively low cost per square foot.

B. PROPRIETARY SYSTEMS

Systems identified as proprietary systems are classified in the following categories:

- Vertical corrugated steel stem wall systems
- Lateral strut and deadman anchor systems
- Systems with steel piers anchored to mass concrete footings
- Tension cross-braced systems
- Piers anchored to chassis beams with compression cross-bracing

<u>VERTICAL CORRUGATED STEEL STEM WALL SYSTEM</u> (Unique design)

AnchorPanel Foundation System (Fast Track Foundation System)

Manufacturer

ANCHORPANEL PERIMETER FOUNDATION SYSTEM
32149 Forest Lane
Fort Bragg, CA 95437
800-789-9694, 707-961-1891
www.anchorpanel.com

Description

A trench is dug directly under the perimeter of an in place structure (or floor structure of building under construction) for the desired footing (below frost line)(E). Corrugated galvanized steel panels (polymer coated or protected on site as needed) are suspended into the trench, fastened at the top to the underside of the floor rim members through a channel that is factory-attached to the top of each panel (B). Bottoms of panels are field-cut to length, then bent 90 degrees to form a 3" wide key. Two #4 rebars are placed, then bottom of panel (including key) and rebars are cast into the footing. Concrete is pumped into the outside of the footing (can be poured if both sides of the trench are accessible). Deep trenches need only be filled to footing depth. Details for various applications are available from the manufacturer (A).

Design Considerations

1. Earthquake protection (type and extent)

Excellent shear resistance, approved for two-story retrofits in Zone 4. Attachment to structure should be consistent with shear requirements. Top anchorage is critical in transferring vertical and shear loads from the home into the foundation. Manufacturer provides the necessary engineering, either through pre-approval of standard designs by regulatory agencies, or directly for special cases (A).

2. Resistance to wind and combined flood and wind loading

High shear and uplift resistance allows system to meet wind load requirements of most codes. Manufacturer provides the necessary engineering, either through pre-approval of standard designs by regulatory agencies, or directly for special cases.

System meets the requirements of FEMA 85 for combined wind and flood loads, when provided with required flood vents. System is ideally suited for raising homes damaged by hurricane flooding (3 feet elevation typically required).

3. Climate

Because the footing trench can be dug to frost line, the system should protect against freezing uplift in any climate. In cold climates (>5,000 dd approximately), if interior footings are below frost level, system should not experience frost heave (but see G). If interior footings are at or near ground level, panels should be insulated from 24" below grade up to 6" below wood framing, closeable vents installed, and panel joints sealed to prevent freezing interior footings via wind-driven cold air.

Vents are located in the manufacturer's layout drawing for the project. Panels are cut 12" short and supplied without the top channel. A special "vent liner" is supplied (a 3-sided channel assembly) into which the vent panel is screwed. The manufacturer promises a vent screen assembly at some point. If that is not available, various venting arrangements are described in the installation instructions.

4. Soils and Drainage

Footings are installed into undisturbed ground, so normal regulations about conditions and inspections of the footing trench apply. Since most existing manufactured homes and mobile homes have few or no gutters, there is always the potential for water to saturate the ground outside the foundations. Unlike a pier foundation, which allows water to enter the crawl space (and flood it, if the floor is recessed), AnchorPanel acts as an effective dam to water entry (panel joints are adhesive bonded and sealed). As with any foundation, grading should drain surface water away from the foundation wall (F).

The system acts as an effective grade beam, and will greatly stiffen the outside walls and allow them to span over areas of unstable soil. In ordinary soils, this feature should improve the stability of the home. In homes with individual piers built on expansive clay or other unstable soil, the results of adding AnchorPanel perimeter walls may be difficult to predict. Contact the manufacturer for information about experience with homes in similar situations.

5. Accommodation to sloping ground

System excels in accommodating sloping sites. Panels can work as tested up to 6 feet high, and are wind and earthquake resistant at higher dimensions (engineering provided by the manufacturer). Customers measure the required heights at corners and midpoints of walls, and manufacturer prepares a computerized layout. From this layout, panels are square-cut to length in 4" increments. The cuts in the corrugations required for bending the tabs are factory cut 4" from the bottom of the panels, and customer bends the tabs over, either using a special tool provided by the company, or blocks of wood as leverage. Footings are poured deep enough to cover the steps in the bottom of the panels. Customer can trim panels and cut new slots in case of mis-measurement.

6. Aesthetics

FHA and state approvals require that the panels be entirely coated on the outside with "tar" (asphalt emulsion) or stucco, typically sprayed on. Panels can support cladding of many varieties. Interior grade can be recessed up to 3 feet to reduce the visible height of skirting. As the system grows in popularity, details for various cladding will become available.

7. Availability of materials

Panels are currently manufactured in central California (Fresno) and Arizona. Shipping within California is listed as typically "in the $200's." New plants are opening soon in Texas, Oklahoma, Louisiana, Mississippi, and Alabama, as the panels are ideal for raising homes above a 3' flood level, a common need in areas hit by recent hurricanes. Future plants are projected in the Southeast. Concrete, rebars, coatings, ventilation panels and hardware are locally provided by the installer.

8. Need for specialized set-up crews

None needed; there is excellent support from the manufacturer, and the system concept is straightforward. However, this is not a job for a beginner, as it requires care in keeping the panels plumb and in line during concreting, as well as care and thought in turning corners and spacing panels. Installer should be familiar with grout-pumped concrete, although concrete can be placed by hand (preferably installing from both sides of the panels). No Spanish language versions are listed on the website, but verbal Spanish language support is available from the manufacturer, and written instructions and videos in Spanish are likely in the near future.

9. Durability, longevity, and maintenance

Unlike standard galvanizing (G60, which means 0.30 oz/sq.ft. each side), or that required by the HUD-Code for tie-down straps (G30 or 0.15 oz/sq.ft each side), this product is protected by G140 to G210 (0.70 to 1.05 oz/sq.ft. each side), which provides exceptional durability. Cut edges are either protected by the upper support channel, buried in the footing, or coated with sealant. As noted elsewhere, despite the heavy galvanizing, FHA and state approvals require that the panels be coated outside and inside where in contact with soil, with asphalt or stucco. Approvals also do not allow the system to be used in high-corrosion areas subject to salt spray.

10. Retrofit applications and limitations

As noted above, this product is well suited for retrofit applications (but see L).

11. Code compliance

The system has been tested for shear resistance by ICC (ICBO) testing per ASTM E-72. FHA, California, Texas, and Arizona have approved the system as meeting the requirements of HUD's "Permanent Foundation Guide for Manufactured Housing" of September, 1996. This is somewhat surprising, as that document specifically has "X'd" out a system design with a perimeter stem wall and individual interior piers that are not founded on poured concrete footings. The AnchorPanel installation drawings show this configuration, allowing the system to work with any interior pier design that meets the requirements of the home manufacturer.

Individual installers could use poured footings, but this would raise the system's cost substantially. Furthermore, properly designed piers with cast-in-place footings (such as the SureSafe System) can provide needed wind and earthquake resistance without the need for a perimeter bracing wall.

The AnchorPanel system also can meet the requirements of FEMA-85 for simultaneous high wind loads (Zone III) and flooding, within a flood zones and within certain other limits. To meet these requirements, top fasteners must be closer together, the interior piers must be placed on precast or poured-in-place concrete footings, and footings near the perimeter must be keyed to the perimeter footing. Flood vents are also required.

12. Cost

This system is obviously more costly than most pier and tie-down designs, but it provides substantial additional benefits. When compared with other semi-permanent skirting systems, it should be comparable on an overall cost basis.

LATERAL STRUT AND DEADMAN ANCHOR SYSTEM (Unique design)

Rigid Foundation Anchoring System (using a "Deadman anchor and "Strong Arm" telescoping strut)

Manufacturer

JM PRODUCTS INC.
680 County Road, 1025 East
Toledo, OH 62468
(217) 849-3172 / (217) 843-2326
(Fax) (217) 849-3225
E-Mail: jmproducts@rr1.net
No website

Description

This lateral strut bracing system substitutes an earth anchor for the support and pad base used on the three steel combined support and bracing systems described herein. As a result, the system shares many of the disadvantages of conventional earth anchors. The materials used seem to be heavy gauge and robust, and the earth anchor is of the driven toggle anchor type, rather than a conventional earth auger. It can be used in any soil type, including coral, except sands or gravelly sands without fines, in which is cannot get a grip.

At the foot of the anchor, which is approximately four feet long, a spade-shaped anchor foot is welded to the 7/8" diameter shaft. Hinged to the foot is the toggling plate that acts as the deadpan when the anchor is partially withdrawn. The shaft has a threaded head, onto which a jackhammer bit is threaded. Anchors are driven in by jackhammer at angles between vertical and 15 degrees tilt. At the top of the anchor is a heavy stabilizer plate to which is welded a tube through which the shaft runs, holding the plate close to the shaft; and a "compression cap," several inches in both dimensions with two down-turned edges. After driving, a tension head is substituted for the jackhammer bit. When screwed, the head can withdraw the anchor by 4" to set the toggle. Once the anchor is set, the telescoping tube, the smaller of which appears to be at least 1-1/2" in dimension, is secured to the U-shaped tension head and to a clamp at the top of the chassis beam so that it does not exert a torsion force on the side of the beam (C).

There is no provision for exerting a lateral force to set the stabilizer. In principle, pre-tensioning could be accomplished by securing a strap tie between opposite anchors and tightening the tie. It is not clear that fittings are available to actually do this easily, although it would make sense to add appropriate fittings to the system for this purpose. Note that with or without pre-tensioning, the maximum deflection condition in the direction of lateral force will cause the opposite Strong Arm strut to push the stabilizer plate back to and beyond its original position. Over time, this could loosen the soil around the plate, resulting in successively increased deflections under load; and during an earthquake, might cause excessive deflection. This condition needs to be tested for.

A typical installation locates four systems near the corners of the home, to provide symmetrical uplift support and to place the anchors at the perimeter where they can be driven. If the home is placed on a concrete slab and the tension head is securely anchored to a slab, the Strong Arm struts should provide excellent lateral and uplift support to the home.

Design Considerations

1. Earthquake protection (type and extent)

Based on tests performed by a third party laboratory, performed in poor soils to meet the HUD-Code failure limits of 3" horizontal and 2" vertical maximum deflection, calculations indicate that the system meets Seismic Zone 4 requirements. However, the system cannot provide rigid lateral support, as lateral deflection must occur before the stabilizer plates will set and resist lateral loading (see comments above). No testing was done to check the behavior of the system when subjected to the rapidly reversing lateral loading that will occur during an earthquake. This objection does not apply to an installation secured to a concrete slab.

2. Resistance to wind and combined flood and wind loading

Because it includes a tie-down, the system resists both lateral loads and uplift. For higher wind zones, the current HUD Code requires additional perimeter ties. As noted under Earthquake Protection, the system cannot resist significant lateral loads until deflection has occurred to set the stabilizer plates. Unlike tie-down straps, which can exert the required lateral pre-tensioning to the anchor, there is no obvious way to pre-tension the anchor using the struts (see above). This objection does not apply to systems secured to a concrete slab.

The anchoring system should resist lateral movement and flotation in a flood zone. Testing is needed to check anchor behavior in saturated soils. Again, this is not an issue with an installation on a concrete slab.

3. Climate

The toggle plate ends up approximately 40 inches underground. Although the basis for the requirement is not clear, the HUD Code requires that ground anchors reach below the frost line. In areas with a frost line lower than 40", insulated skirting and a SFPF would be required in order to use this system (G). In highly corrosive environments, lateral adjustment of the struts might become impossible due to corrosion.

4. Soils and drainage

All earth anchor systems share similar disadvantages: potentially large deflections, uncertain behavior in saturated soil, and uncertain performance on an individual basis. The latter disadvantage is especially relevant to toggle-type anchors, because the toggle may not open if restrained by underground rocks. Presumably this problem will be evident if strong and increasing resistance is not encountered when tightening the tension head. Failure requires that the anchor be withdrawn and re-driven.

5. Accommodation to sloping ground

As with any earth-anchor based system, only a limited range of pier heights can be accommodated. Height is limited by the adjustment range of the Strong Arm strut and by the need to keep the strut angle within a limited range.

6. Aesthetics

Earth-anchor based systems are intended primarily for use in conventional sets on a level pad with skirting. If the Deadman anchors are set far enough inboard, some types of skirting that retain earth might be used to approach a low-profile set.

7. Availability of materials

The system seems readily available, but on-line ordering is not available.

8. Need for specialized set-up crews

The crew needs to be familiar with this type of anchor, and with the operation of a jackhammer.

9. Durability, longevity, and maintenance

Corrosion failure of the earth anchor is probably the most likely mode of failure, and in this respect, this system's durability is no different from that of any heavy-gauge earth anchor system that is not galvanized. Another likely weak point is the clip that secures the Strong Arm to the chassis beam.

10. Retrofit applications and limitations

Retrofit limitations are the same as those for any earth anchor system: it is costly, or sometimes impossible, to apply this system to retrofit homes with substantial add-on structures, or with semi-permanent skirting (L).

11. Code compliance

Limited third-party testing has been done, resulting in approval from several states. Other states require approval by the home's manufacturer (many of which have approved the system).

12. Cost

The cost should compare favorably with conventional ground anchor and strap tie systems.

SYSTEMS WITH STEEL PIERS ANCHORED TO MASS CONCRETE FOOTINGS
(2 systems)

"Big Foot" and "Big Red" foundation systems

Manufacturer:

R. D. BAKER FOUNDATIONS INC.
13420 Bunker Hill Dr
Willis Texas 77318
(888)-231-3330

Description:

Both systems are based on steel posts anchored to a mass concrete base. Big Foot is the heavier of the two, having four tapered flanges in a star configuration welded to a base plate with four bolted anchor connections, designed to transfer the moment generated by lateral forces into a mass footing. Big Red is a lighter post with four spreading feet welded to the bottom of the pipe shaft. Lateral forces are carried directly to the concrete footings through lateral and longitudinal struts. At the top, the posts are attached with bolted clips to the bottom flange of the chassis beams (C).

Both posts consist of a 1-1/4" Schedule 40 pipe within which is welded a nut to receive a threaded 3/4" rod. In the Big Foot design, a collar is welded to the top of the four flanged legs to hold the pipe, which is the upper part of the post. The threaded rod is welded to the post base, and vertical adjustment is made by rotating the upper pipe. Once set, the collar bolts are tightened. The collar is about 4 inches high, to transfer moment from the base into the post. In the Big Red design, the pipe is welded to the feet at the base, and the threaded rod is rotated to provide vertical adjustment. The longitudinal and lateral struts are of the same threaded-rod-inside-a-pipe configuration as the posts, and unlike other strut designs, attaches to the bottom flange of the chassis beams. It is likely that this design will fail (from lateral buckling) at a lower compressive stress than struts made of a tube inside a tube. It is notable that the standard design shown on the web includes more struts than are required by the tube-in-tube systems.

The complete system really is a delivery system. Pre-engineered designs for cast-in-place concrete footings are installed by a licensed dealer-installer for a published price. The Big Foot footing is 1 foot deep and 2 feet by 3 feet horizontally, with mesh reinforcing. A variety of strip and slab footing designs are designed for the Big Red system, which uses lateral struts (E).

Design Considerations

1. Earthquake protection (type and extent)

Properly engineered, the system should resist Zone 4 earthquake loads, subject to the caveat described in (C).

2. Resistance to wind and combined flood and wind loading

Subject to the caveat described in (C), either system can be designed for any wind load condition. In flood zones, the system can be set on footings deep enough to prevent scouring; and the system resists uplift.

3. **Climate**

The manufacturer's instructions require the footings to extend below the frost line. In other respects, the system is climate-neutral.

4. **Soils and drainage**

Because the system relies on mass footings to resist lateral and uplift movement, it should work in any soil.

5. **Accommodation to sloping ground**

Three heights of Big Foot bases are available, which coupled with the adjustability of the posts provides a range of heights, from approximately one foot to approximately three feet. Obviously, there is a limit to the post's height based on its moment-carrying capacity. Vertical adjustment of the Big Red system appears to be somewhat more limited, but roughly comparable.

6. **Aesthetics**

The system, being hidden, is aesthetically neutral.

7. **Availability of materials**

The system is available in all 50 states.

8. **Need for specialized set-up crews**

The system is installed only by licensed dealer-installers. The website advertises dealers.

9. **Durability, longevity, and maintenance**

The steel parts appear to be painted and not heavily galvanized. Except in highly corrosive environments (close to salt water), the systems should remain adjustable and durable indefinitely. Salt corrosion will severely limit the system's life unless all parts are heavily galvanized.

10. **Retrofit applications and limitations**

For conditions where the installer can construct poured-in-place footings, either system will work in a retrofit situation. In most cases, only the Big Foot system can be used, because the Big Red system requires full-width footings that would be difficult to pour under an existing home.

11. **Code compliance**

The company provides engineering services with engineering backup that should meet the requirements of any state.

12. **Cost**

The cost is listed on the website as $2,500 to $3,000 per home, plus $800 for an FHA Lenders Compliance Package.

SureSafe® Foundation

Manufacturer

SURESAFE® INDUSTRIES
1257 Simpson Way
Escondido, CA 92029
800-322-1999
Contact: Art Angelo
www.suresafe.com

Description

The SureSafe Foundation system replaces conventional piers and tie-downs. A SureSafe pier is clamped at the top to the lower flange of the chassis beams (C), or to the home's wood structure, suspended with its base 5" to 8" off the ground, then embedded within a mass of concrete that is poured on site into a geotextile bag tied to the pier. Conceptually, the clamping head transfers loads from the home's structure into the piers, and the mass of the concrete, conforming to the ground under it, transfers lateral and uplift loads into the ground. Each concrete mass weighs about 475 pounds.

Adjustable nuts in the clamping head, pier lengths varying from 8" to 36" in 4" increments, and variable distance between bottom of the pier and the ground between 5" and 7" together allow the distance between grade and the chassis beam to range continuously between 15" and 47". Three sizes of bag create 30", 36" and 42" square footings containing 5.5 cf, 8 cf, and 11 cf of concrete respectively. To support more than one pier or to form a continuous perimeter footing (typically used only for modular edge-bearing homes) continuous geotextile fabric tubes are used. For a multiple pier, a tube is cut to length and slit open to receive the piers and allow concrete entry. Ends are blocked with plywood forms.

At the perimeter of a manufactured or mobile home, 8" wide by 12" deep footings are poured, either continuous to support perimeter bearing loads, or discontinuous to support bearing points on either side of doors or wide openings. A saddle-shaped clamping head transfers loads into individually cut steel tube posts the rest on the concrete, very much like miniature adjustable basement support piers.

The system is built to conform with the Permanent Foundation Guide for Manufactured Housing, September, 1996. The manufacturer strongly feels that the requirement in the Guide for footings to be reinforced concrete poured on site is an essential step in restoring lender confidence in manufactured housing.

Design Considerations

1. Earthquake protection (type and extent)

Typically, elevated lateral wind loads will exceed the lateral loads generated in an earthquake, for typical manufactured or mobile homes. As this system can meet any wind load simply by increasing the number of supports, it clearly can function as an earthquake protection system. If additional lateral sliding resistance is needed, a "keyway" can easily be excavated in the ground under the footing.

2. Resistance to wind and combined flood and wind loading

As noted above, the number of supports determines the wind loading resistance. It should be possible to support the chassis against any wind load that can be resisted by the superstructure.

Flood loading depends in part on the design of the skirting, which is not specified in any detail, and on the behavior of the footings with respect to scouring. The manufacturer does not make any claims about the system's flood resistance. The system should resist buoyancy uplift loads.

3. Climate

The system, which relies on surface-bearing piers, must also rely on some system of perimeter enclosure in colder climates. Because perimeter supports in this system are separated posts, typically at irregular spacing, the skirting must be a self-supporting system. The installation details indicate insulated skirting schematically, and do not address what it is made of, how it is attached to the home, how vents and access panels are cut in, or how termites are blocked from using the insulation as a route up into the framing. Also, for frost resistance below grade the system relies on a SFPF. The manufacturer owes the installer and customer carefully worked out details or references to cladding systems developed by other companies.

4. Soils and drainage

Installation diagrams do not show a recessed installation, in part because it does not include skirting within the system. There is no difference between the soil and drainage requirements for the SureSafe system and those for a normal set, for example on a park pad.

5. Accommodation to sloping ground

The system has limited ability to accommodate sloping ground (about 26" inches of height adjustment available). It excels in adjusting to irregularities directly under the piers, because the fabric-enclosed concrete conforms exactly to the underlying soil.

6. Aesthetics

Because the system does not specify the design of the perimeter skirting or the possibility of a recessed crawl space, it has no direct impact on aesthetics one way or another. The detail provided for a modular (wall-bearing) setup could be used for a HUD-Code home. This detail, however, is unspecific about the exterior finish, and is extremely unusual in requiring a continuous steel girt channel between posts, as well as installing plywood below grade. See comments above under "climate."

7. Availability of materials

Bags and stands are available from franchised dealers in Arizona and California, or directly from the factory in California. The company is currently extending its production capacity by adding licensed fabricators, especially in the Gulf States and Florida. Concrete and #4 rebars are the only other materials required. Note that the perimeter enclosure is not part of the system except indirectly in frost-prone areas (see comments under "climate" above).

8. Need for specialized set-up crews

The system is very simple and can be accomplished by any set-up crew. Note that the perimeter enclosure is not part of the system. Each home is engineered by the manufacturer based on a description provided by the customer or setup contractor. Each home is individually engineered conforming to the manufacturer's requirements for approval by the state or (when state codes do not meet HUD standards) by HUD. The company's engineers are licensed in 32 states, and will be licensed in all states by the end of 2006.

9. Durability, longevity, and maintenance

Compared with auger-based tie-down systems, the SureSafe piers and footings are far less likely to need periodic leveling, and do not need major adjustment after being stressed, as do augers. In some cases, the company provides yearly inspection for 5 years, and an inspection is recommended after major wind or earthquake events. The stands are galvanized to at least G-60 standards and are welded to aircraft standards.

10. Retrofit applications and limitations

The system can easily be used to replace conventional piers in order to provide required resistance to wind and earthquake loading. A major advantage of the system is its applicability to retrofitting any home that is set on piers, including those with permanent skirting, add-on rooms, decks or porches that make the use of auger-based tie-downs impractical or impossible. Unlike typical formed concrete footings, the bag form makes installation under the home simple with pumped concrete.

11. Code compliance

The manufacturer includes the following quote in the literature on their website: 'WARNING: There is no blanket approval for foundations and no such thing as FHA or HUD approved. Compliant foundations require engineering that is designed to the site condition and the homes**.'** What this means is that the system is able to meet standard HUD Code calculation requirements for resisting wind loads, applying these on a case by case basis. The company updates its listing in the California-approved ERBS (Earthquake Resistant Bracing Systems) list.

12. Cost

As of mid-2006, a HUD-Compliant foundation for a double-wide home in California on a normal site runs about $6,700. This price is highly variable depending on location. For example, a home in a high-snow load area, where 30 yards of concrete were required, ran $16,000.

<u>TENSION CROSS-BRACED SYSTEMS</u> (2 systems included)

Vector Dynamics Foundation System

Manufacturer

TIE DOWN ENGINEERING INC.
5901 Wheaton Drive
Atlanta, Georgia 30336
(404) 344-0000
(Fax) 404-349-0401
www.tiedown.com

Description

This is a well-tested and engineered system that attempts to provide wind load protection using conventional pier setups with the least amount of additional material. In concept, two adjacent piers (across the marriage wall in a double-wide home) are tied together to create a rigid truss. The home's floor system provides the top compression member, and a pressure treated 4x4 acts as the bottom chord, with strap diagonals that run over the top of the chassis beams. This system has the advantage that it does not rely on attachment to the bottom flange of the chassis beams, which are sometimes not built to resist torsional loads (C). To provide additional "dig-in" resistance against sliding, the block piers rest on a galvanized steel plate with bent-down flanges. Piers are conventional dry-set stacked CMU's with wood bearing members supporting the chassis beams. The system has versions to accommodate steel piers and sets on concrete slabs, concrete strips, and concrete footings. A version adds shallow multiple rod anchors for Florida soil conditions where conventional auger anchors do not work.

The system can resist Zone I wind loads without tie-downs with pier-height limits of 24" for single-section homes, 38" for double-wide homes 24' wide or less, and 46" for double-wide homes 26' wide and over. For other cases, an anchor is needed at each side of the home at each Vector Dynamics assembly used. For Zone II and Zone III, more assemblies are required, along with tie-downs under each vertical strap on the home. Longitudinal resistance is provided by steel struts connecting the steel base plate to the chassis beam.

Given its limited applicability, the system has been completely engineered with versions for nearly every condition, and has been approved in all 50 states. One test done in 2001 involved supporting a standard double-wide home and subjecting the home to the prop wash from a C-130, simulating 80-90 mph winds with gusts to 105 mph. In another test, trucks with dynamometer-equipped straps pulled on the "leeward" side of a home to simulate lateral loads equivalent to 120 mph winds. The system passed both sets of tests.

Design Considerations

1. **Earthquake protection (type and extent)**

   Although any system that protects the home against Zone I winds should meet the standards for earthquake protection, this system is not on the current list of California approved ERBS, and is not advertised as an ERBS.

2. **Resistance to wind and combined flood and wind loading**

   As the system does not include skirting, it is incomplete with regard to the issues addressed by FEMA 85, which is concerned with the effect of skirting resistance and scouring on the home's support.

3. **Climate**

   The system is designed to convert conventional piers into wind-resistant assemblies, and so is vulnerable to any of the problems relating to climate and soils that conventional piers encounter. If used in freezing climates, some sort of insulated perimeter enclosure must be provided; or the system must be set on a concrete slab that in turn is prevented from freezing.

4. **Soils and drainage**

   See comments under item 3.

5. **Accommodation to sloping ground**

   The system will accommodate a 26" slope across the home, with a 50" maximum height on the down side.

6. **Aesthetics**

   As the system does not address the skirting or backfilling, it is aesthetically neutral.

7. **Availability of materials**

   The materials needed (except the CMU and wood components) are all made to high standards by Tie Down Engineering.

8. **Need for specialized set-up crews**

The system is simple, and involves the use of familiar elements such as conventional piers and tie-down straps.

9. **Durability, longevity, and maintenance**

Using galvanized base plates and straps (G60, 0.30 ounces/SF on each side), the system is as durable as the conventional components of a support system.

10. **Retrofit applications and limitations**

Retrofitting homes should be straightforward. For Zone I, only 6 piers would have to be removed, set on "dig-in" base plates, and replaced. The other components could then be added with no difficulty. For higher wind zones, more piers would need replacing, and tie-downs added if they are not present. Thus, retrofit would be impossible for homes with permanent skirting or extensive add-on rooms, decks, etc. that would prevent the use of auger anchoring equipment.

11. **Code compliance**

If placed on concrete footings and coupled with an approved skirting system that protected the piers from frost heave, the system would contribute to a permanent foundation. The system has been approved in all 50 states.

12. **Cost**

The system is somewhat cumbersome and probably is more costly than more recent designs using struts for bracing. However, it may also be more effective – subject to further testing.

Storm Anchor

Anchor Post

Manufacturer

THE ANCHOR POST COMPANY
1150 Hungryneck Blvd., Suite C-346
Mr. Pleasant, SC 29464
843-200-3573

Description

The Storm Anchor and Anchor Post systems are adjustable steel support and bracing systems. They both rely on massive concrete footings or grade beams to transfer lateral and uplift loads into the ground, and do not address perimeter closure of the crawl space.

The systems are identical below the top fitting. Nesting vertical steel pipes (a 2 1/2" pipe inside a 2 7/8" pipe) with spaced holes topped with a treaded rod for fine vertical adjustment form the vertical members. Special fittings secure diagonal wires to the tops and bottoms of adjacent posts for lateral bracing. The base is anchored to concrete footings.

The Storm Anchor is designed with a top fitting to clamp onto the lower flange of a chassis beam (C), while the Anchor Post has an adjustable saddle for attachment to a main support beam in conventionally framed floor systems (adjustable from 4-1/2" wide to 7-1/2" wide). Both systems are intended to provide all the vertical support needed for a home. Because Anchor Post is used at the perimeter of modular and site-built homes, it could well be used to support a perimeter-bearing HUD-Code floor system, and would then provide an attachment point for skirting (although the company should be consulted about the effect of horizontal wind and flood loads on the stability of the posts).

Design Considerations

1. **Earthquake protection (type and extent)**

   See discussion under paragraph 2.

2. **Resistance to wind and combined flood and wind loading**

   The system has been tested for vertical and lateral loads, and can be engineered to transfer loads between the home's structural frame and concrete footings, for any wind and earthquake zone. This is an important point because the system's integrity depends on a properly designed footing or grade beam system. Also, the Storm Anchor design assumes a conventional chassis beam (C).

3. **Climate**

   Both systems are climate-neutral. The footings and skirting must be designed to meet climate parameters.

4. **Soils and drainage**

   Both systems are neutral with regard to soils and drainage, which are dealt with during the design of footings and skirting.

5. **Accommodation to sloping ground**

   The vertical posts are adjustable from approximately 27" to approximately 51". Any additional height variation would have to be taken up by elevated footings that were designed to resist overturning.

6. **Aesthetics**

   The systems will have no impact on the appearance of the home once hidden behind skirting.

7. **Availability of materials**

   The system is manufactured in South Carolina, and is available through certified installers.

8. **Need for specialized set-up crews**

   Installers must be certified, but the system is simple to construct. However, engineering and construction of the foundations may involve more than routine resteel installation.

9. **Durability, longevity, and maintenance**

   No information is available. It is not clear whether the posts and fittings are galvanized or merely shop painted (the pictures suggest the latter). As the units are entirely under the home, shop painting should provide many years of service. If shop painted, units near salt water are likely to corrode within a few years, reducing their carrying capacity and their adjustment capability.

10. **Retrofit applications and limitations**

    These units are not well-suited for retrofit applications, as reinforced footings are necessary to provide anchorage for the system's posts. They may be suitable for use on a slab, at least for Zone I and Zone II winds and earthquake loads, but the system should be engineered.

11. **Code compliance**

    The system has been tested by SBCCI as meeting several model codes.

12. Cost

Much of the system's cost will be in providing adequate reinforced footings to resist the loads that the posts and ties are capable of transferring from the home to the footings; and providing skirting. Overall, the system will be of moderate cost.

PIERS ANCHORED TO CHASSIS BEAMS WITH COMPRESSION CROSS-BRACING

(Five systems included)

Xi and Xi2 Systems

Manufacturer

TIE DOWN ENGINEERING INC.
5901 Wheaton Drive
Atlanta, Georgia 30336
(404) 344-0000
(Fax) 404-349-0401
www.tiedown.com

Description

The Xi systems are very simple: a 1-1/2" tube nesting into a 1-3/4" tube forms a strut that runs laterally from the base of one pier to the top of the chassis beam above an adjacent pier; or longitudinally, from the base of a pier to the bottom flange of the chassis beam supported by that pier (C does not apply to longitudinal loads). The system can be quickly installed, and larger loads can be supported by multiplying the number of struts. The struts work by pressing down on the pier base, the pressure increasing as the load increases. Working only in compression, struts must be in pairs to resist load from either side. The lateral struts have no tie-down function, but rely on the weight of the home to resist overturning, in Wind Zone I. In higher wind zones, tie-downs will be necessary.

The pier base may be poured concrete (required for flood resistance), or a 3-foot square formed galvanized steel Xi pad, similar to that used in the Vector Dynamics system. This pad has down turned ears at the corners that dig into the earth to resist the lateral loads applied by the struts.

An adjustable steel pier support in an X configuration (with a vertical support pipe from the center of the X to the chassis beam above) that provides longitudinal bracing is available in approximately one-, two-, and three-foot heights (this seems to distinguish the Xi system from the Xi2, which is designed for conventional piers and separate longitudinal struts). Lateral struts are either five feet or six feet long, while longitudinal struts for the Xi2 system are available ranging from 30" to 65", to accommodate a range of CMU pier heights.

Design Considerations

1. Earthquake protection (type and extent)

It is likely that some versions of the system can resist earthquake loads satisfactorily. Lateral struts would need to be carefully arranged to avoid creating torsional reactions in resisting lateral earthquake loads (which may come from any direction); and concrete footings would be needed instead of the metal "dig-in" plates. Vertical acceleration in an earthquake may partly or fully counteract the downward force from the struts onto a Xi metal plate footing, which would then fail to "dig in" and therefore fail to transfer the lateral loads from the struts to the ground.

2. **Resistance to wind and combined flood and wind loading**

The system has been tested to resist Zone I winds, and the manufacturer's literature claims the ability to resist higher winds, presumably with more struts and added conventional tie-down anchors. [It should be noted that the test described on the website was flawed. Based on incorrect logic, only a one psf uplift was applied to the test home. The intent seems to have been to simulate a home weighing 1 psf less than the required uplift load of 9 psf. If so the test should have applied 1 psf more than the actual weight of the home, which was 28 psf: in other words, 29 psf. At a minimum, 9 psf should have been applied. However, few or no homes have a dead weight at low as 8 psf. By contrast, most single-wide homes cannot resist Zone I wind loads without some sort of tie-down.]

Only systems with concrete footings poured deep enough to avoid scour can be used to resist floods. No resistance to buoyancy is claimed by the system.

3. **Climate**

System configurations with the metal pier pads are intended for pier locations that are protected from frost and water (F, G). Systems with poured concrete footings can resist any depth of frost if the pier footings are designed for that depth. Otherwise, the system is climate-neutral. The metal parts are galvanized to G-60 standards (twice the G-30 required by the existing HUD Code).

4. **Soils and drainage**

As in the discussion under Climate, above, the choice of a footing is the only variable that is impacted by soil type or drainage. The manufacturer claims that the system can work properly in any soil type; but this is predicated on the existing HUD-Code limits on movement of 3" horizontally and 2" vertically. In tests carried to failure under simulated wind loads in excess of Zone I velocities (by a steady pull from cables), the metal pan footers only moved

5. **Accommodation to sloping ground**

The Xi2 metal support piers range in height from one foot to three feet, and the lateral and longitudinal struts are sized to accommodate this range of height. The system does not work for greater heights.

6. **Aesthetics**

As with any internal support and bracing system, the Xi and Xi2 systems have no aesthetic impact.

7. **Availability of materials**

Tie-Down Engineering has a complete catalog of parts and can fill orders anywhere in the U.S.

8. **Need for specialized set-up crew**s

The system is simple enough to be installed in a short time by any installer with some experience who can read and follow installation instructions.

9. **Durability, longevity, and maintenance**

Because the parts are galvanized to a good standard, longevity even in moderately corrosive environments is likely to be good. However, even galvanized parts will become coated with corrosion in highly salty environments, making future adjustment difficult or impossible.

10. Retrofit applications and limitations

Systems utilizing the Xi metal pads are ideal for retrofit installations, as they can be installed under any home with an accessible crawl space. Note however that retrofitting in wind Zones II and III will require tie-downs, which may be difficult or impossible to add, depending on whether the perimeter of the home is accessible and not hidden by add-on structures.

11. Code compliance

The Xi system has been stamped by Radco engineers as meeting the standards in 32 states.

12. Cost

As with other metal bracing and support systems, the system is a small part of the overall cost of supporting the home. Only two sets of struts are claimed by the manufacturer to resist Zone I wind loads, and if so, the system is comparable in cost to conventional auger anchors and tie-downs.

All Steel Foundation System Model #1100

Manufacturer

OLIVER TECHNOLOGIES INC.
P.O Box 9
Hohenwald, TN 38462
931-796-4555
Fax: 931-796-8811
www.olivertechnologies.com

Description

As this system and the next are very similar to the Xi system described above, it makes sense to discuss them relative to that system, noting the differences and similarities.

The most important difference is that most components are lighter than the Xi system (and presumably less expensive). The lateral tubes are 1-1/4" inside 1-1/2", as opposed to 1-1/2" inside 1-3/4" for the Xi system. The combined support pier and longitudinal brace is a light-weight "V" shape rather than the more robust "X" shape with added vertical strut, as in the Xi system. This means that it relies for its vertical support on how tightly the tops of the V are clamped to the bottom flange of the chassis beam – a detail vulnerable to installer error and the loosening of fasteners over time. The 3-foot square metal pad has simple down-turned edges, rather than the distinct ears of the Xi system that are likely to bite into the soil more effectively (this needs to be confirmed by testing, however).

Much less information is available on the website about the system. There is no information about the level of galvanizing (or even if the product is galvanized – it is assumed to be based on other references, but the level is not known); and in general, no details or installation instructions are available on the web. Systems advertised for Zones II and III seem not to be available on order from the website. The system is claimed to be approved in 14 states, but unlike the Xi system, the approvals are not shown on the website. Finally, although it seems to have been tested by some veteran industry engineers, no test data is shown or claimed.

This system is unlikely to exceed the Xi and Xi2 systems in performance, and some aspects are likely to result in lower relative performance. However, it must be proved by testing and analysis that the added strength of the Tie-Down Systems is needed. In general, rigorous and well-controlled testing is essential to prove the effectiveness of all these systems.

LLBS Longitudinal and Lateral Bracing System

Manufacturer

MINUTE MAN PRODUCTS, INC.
305 West King Street
East Flat Rock, NC 28726
Phone: (800) 438-7277 / (828) 692-0256
Fax: (828) 692-0258
www.minutemanproducts.com

Description

This system will be compared with the Tie-Down Engineering Xi and Xi2 systems.

The size of the lateral tubes is not stated: they appear to be 1-1/4" inside 1-1/2", as opposed to 1-1/2" inside 1-3/4" for the Xi system. The combined support pier and longitudinal brace consists of sturdy longitudinal struts with vertical support provided by a standard pyramidal metal pier. The 3-foot square metal pad has turned-up edges that do not try to bite into the soil. The relative performance of these pad designs needs to be tested. The components are galvanized and are described as "sturdy" by the manufacturer.

Although little information is available on the website (details are being added, but are not yet available), a catalog is available by mail-order. A map of the U.S. provides links to various states, many of which list approved systems. No third-party testing is claimed.

This system is unlikely to exceed the Xi and Xi2 systems in performance, and some aspects may possibly result in lower relative performance. It is not certain that the added strength of the Tie-Down Systems is needed; rigorous and well-controlled testing is essential to prove the effectiveness of these systems.

Primary Support Column (PSC) System

Perimeter Support Wall (PSW) System

Manufacturer

FOUNDATIONWORKS INC.
7600-B Boeing Dr.
Greensboro, NC, 27409
Tel: (336) 544-0559
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Email: http://foundationworksinc.com

Description

FoundationWorks provides two systems: Primary Support Column (PSC), which is a substitute for a conventional pier; and Perimeter Support Wall (PSW), a concrete skirting system (B). Pairs of PSC's can be tied together transversely and longitudinally with 1-1/2" x 1/8" gauge steel tubes provided by the factory.

The PSC System consists of nested schedule 40 pipes held by a steel pin. The lower pipe is 4" in diameter (compared with other systems using 1-1/4" to 1-3/4" tubes, this system is extremely robust), with a 3-1/2" diameter upper tube telescoping inside. A 3/8" welded base plate on the lower pipe section bolts to a reinforced precast lightweight concrete 24" x 38" base with a pyramidal shape varying from 4" at the center to 1" at the edge. Bolts are 6-1/4" apart. The lower pipe section can be obtained in four heights, allowing a height from the ground to the underside of the chassis ranging from 13" to 35" (higher posts require longitudinal and lateral cross-bracing). The top pipe section is welded to a plate with a welded nut that supports a threaded rod, which is welded to the clamping plate that attaches to the lower flange of the chassis beam (or, with added site-drilled holes, to a channel beam)(see C). An adjustable nut on the rod allows 3" of vertical adjustment. Steel struts anchored to the concrete base and to the chassis beam provide longitudinal bracing.

The PSW system consists of factory-cast panels of very light-weight concrete (about 67 pcf) 1.5" thick, 27" high and 48" long. These are supported by slotted precast concrete block "shoes" that are set on gravel. At perimeter support locations, triangular angle frames sit on the inside flange of the blocks and support lengths of 4x6 set into a steel saddle (there is a height adjustment similar to that on the PSC's). The 4x6's in turn support two joists rather than the edge framing, because the skirting wall occupies the dimension of the edge beam. The top of the skirting is set into a support channel secured to the edge framing. Then, presumably to close off air leaks, the panel is wedged up tight to the floor system, using plastic wedges driven under the panels through a special transverse slot cast into the base supports for that purpose. The base supports are then anchored to the ground with two rebars, through an angle hole provided for the purpose.

The tests of the lateral load capacity of the piers (on the order of 4,000 pounds) were made with a simultaneous vertical load of 6,000 pounds. While this tests certain aspects of the piers' load carrying capacity, it does not test the behavior of the piers in a typical installation recommended by the manufacturer. The system is designed to have piers placed at 22' centers longitudinally, with (typically) two conventional intermediate posts between (actual spacing as recommended by the home's manufacturer). The expected dead load in this case could be as low as 1,000 pounds. However, a Zone I lateral wind load will transfer dead load to the lee-side piers. With the moment-resisting connections at top and bottom of the piers, they would dig in and resist sliding.

In any case, the home's installation instruction indicate that the system only protects the home in Wind Zone I, and even then it requires four longitudinal auger-anchor tie downs for a single-wide section. For higher wind zones, 1-1/2" steel tube struts are provided by the factory, presumably to custom length, as they are not telescoping. PSC piers have attachments at top and bottom to receive flat tabs at the ends of the struts. Struts are also required in an "X" configuration between piers for piers between 35" high and 52" high. No Zone II or Zone III configurations are shown on the website.

Design Considerations

1. Earthquake protection (type and extent)

Most HUD-Code homes that are properly tied-down to resist HUD-Code Zone I wind loads will also meet Zone 4 earthquake standards. Constraints on the roof pitch, exterior wall height, and others apply to this generalization. Because the PSC system allows a home to meet Zone I wind standards, it will also meet Zone 4 earthquake standards.

2. Resistance to wind and combined flood and wind loading

As noted in the Description, above, the system is designed to meet only Zone I wind loads. There is no mention in the literature of meeting FEMA 85 standards for combined flood and wind loading. One requirement would be heavier poured concrete footings to prevent scour and anchor the home from buoyancy forces.

3. **Climate**

The perimeter system provides a backing for the application of rigid insulation. In a typical installation shown, the outside panels are backfilled 17", leaving 10" exposed. For insulation, the detail shows rigid insulation beginning 5" below grade and continuing out from the home underground (note that this leaves the top 15" of the panels uninsulated). Reference is made to standard SFPF requirements, and vents are required to be closed up during the winter. This is likely to be in violation of the Consensus standards being developed for HUD-Code installations, which prohibit closeable vents. However, the system of insulation shown probably provides sufficient insulation to count as a SFPF system for relatively mild climates. Additional insulation is likely to be needed in climates with more than 6,000 degree-days of heating (G).

4. **Soils and drainage**

The system is designed for well-drained sites (F). Proper grading away from the foundations is required. In the event of water buildup against the skirting, water can easily run under the walls and enter the crawl space. A moisture barrier is required under the home; the installation video shows it being cut away for the footing instead of the footing being placed on top of the barrier, which would be preferable, to prevent the footing from becoming wet.

5. **Accommodation to sloping ground**

The basic system provides limited accommodation to sloping ground (22" of variation max), but higher piers can be used with lateral and longitudinal cross-bracing. The PSW system can accommodate the same range of heights (27" x 48" panels weight about 80 pounds).

6. **Aesthetics**

The concrete panels of the PSW system if left exposed look quite like a conventional foundation. They can also be coated with appropriate finishes. The PSC piers have no impact on aesthetics, as they replace conventional piers.

7. **Availability of materials**

Concrete panels and steel posts are shipped from the factory. Currently, there is a factory in Cottage Grove, Oregon and another in Greensboro, North Carolina. Because of the weight of the components, shipping costs will have a noticeable impact on the overall cost.

8. **Need for specialized set-up crews**

Installers must be licensed by the company.

9. **Durability, longevity, and maintenance**

The extra lightweight concrete wall panels (about 75 pcf) used in the perimeter panels may not be suitable for below-grade use in freezing climate. A bituminous sealer may be advisable, but is not mentioned by the installer. The posts are required by the installation details to have a technical coating, which presumably is applied at the factory.

10. **Retrofit applications and limitations**

The system works equally well for retrofits and new construction.

11. **Code compliance**

There is no information on the company website about approvals or code compliance (there is a link, but it is not active). The company claims that the system has been approved as a permanent foundation for "many government financed programs."

12. Cost

The PSC supports are likely to be substantially more expensive than those of other brands, which have much less metal in them. Further testing is needed to see under what circumstances the added strength is required.

Quake-Mate Earthquake Resistant Bracing System (ERBS)

Manufacturer

MERRIMAN'S INCORPORATED
987 Calimesa Boulevard
Calimesa CA 92320
800-339-6077
909-795-5301
Fax: 909-795-8344
Email: http://www.merrimansinc.com/contactinformation/

Description

As this system is very similar to the FoundationWorks Primary Support Column (PSC), only the differences between the systems will be discussed.

The QuakeMate pier consists of an approximately 2" vertical tube welded to an approximately 20" x 20" x 3/16" steel base, which in turn is screwed to a plywood pad treated at 60 psi. From each corner of the steel base, an approximately 1-3/4" steel tube braces the central tube. A smaller tube telescopes inside the lower tube. A nut is welded to the upper tube to receive a 1-1/4" diameter threaded rod for fine adjustments (compare with 3/4" rod in other systems).

The system is designed specifically as an ERBS. For longitudinal bracing, the base is modified to receive pairs of heavy diagonal tubes that are secured to the underside of the chassis beam above. Like the PSC column, these are intended to substitute for conventional piers, and will not be effective if installer error results in a loose connection to the beam. Lateral bracing is accomplished with adjustable tubular struts.

The system should be comparable in cost to the PSC system, and will add noticeably to the overall cost of installation. It should be an effective retrofit solution.