Soil-Structure Interaction Seminar of 1996

Ramada Hotel NW
12801 NW Freeway
Houston, Texas
July 25, 1996

SPONSORED BY THE:
FOUNDATION PERFORMANCE COMMITTEE

SOILS-STRUCTURE INTERACTION
1996 SEMINAR

Thank you for attending our 1996 Seminar. Your personal Evaluation of our program is requested so that we can continue to improve it.

Your Profession:

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___ Builder
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How did you hear about the seminar?

___ Direct mail flier
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How do your rate the seminar?

(E) - Excellent, (VS) - Very Satisfactory, (S) - Satisfactory, (F) - Fair, (P) - Poor

___ Seminar Overall
___ Speakers Overall
___ Subject matter Overall

___ Facilities
___ Visual Aids
___ Proceedings Manual

__ Y __ N Was material presented suitable for you background, experience?
__ Y __ N Did you get what you came for?
__ Y __ N Will you attend again next year? (Notify me at address below.)
__ Y __ N Would you like to attend our monthly Committee meetings?

Most valuable part of this seminar was: ______________________________

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Needing most improvement was: ______________________________

Eliminate:____

Any Other Comments:______________________________________

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1996 SOILS-STRUCTURE INTERACTION SEMINAR

INTRODUCTION

FOUNDATION PERFORMANCE COMMITTEE

The Foundation Performance Committee was founded in 1991 initially through the efforts of David Eastwood. The work of the Committee was then continued through the participation of individuals who were involved with the design, construction, inspection and repair of residential and other forms of light construction. Meetings were held on a regular basis and subcommittees were formed to investigate such issues as deflection criteria, foundation failure criteria, the use of void cartons, etc. As a result of these activities, those of us who have participated have gained in knowledge and experience as well as having gained valuable communication interfaces with our contemporaries. In 1994, we were able to conduct our second seminar on the subject of soils-structure interaction.

Perhaps our most outstanding achievement, however, occurred this year when we became incorporated as a non-profit corporation known as the Foundation Performance Committee. The objectives of this Corporation, as stated in the by-laws, includes the following:

a) To serve the public by advancing the skill and the art of engineering analysis, investigation, and consultation in the design, construction, and repair of light structural foundations; primarily for residential buildings.
b) To engage in research through the conduct of seminars and the publication of technical papers, books, and articles on the science of residential design, construction, and repair of light foundations.
c) To maintain a library of information on the science of design, construction, and repair of light foundations.
d) To establish criteria for the preparation of specifications, geotechnical testing, design analysis, construction techniques, quality control, performance criteria, investigation and failure analysis, and repair techniques for light foundations; for the benefit of the public.
e) To elevate the standards and ethical concepts of those engaged in the light foundation industry.
f) To cooperate and share with other related professions engaged in related services information on the science of residential design, construction, and repair of light foundations

A slate of officers was elected which included Jack Deal as President, David Eastwood as Vice-President, Richard Peverley as Secretary/Treasurer, and Joe Edwards as Parliamentarian. Application forms have been mailed to some individuals who have participated in our past activities. Application forms will be available at this seminar for any others who may wish to join our organization. We hope the funds we obtain from the membership fee will help to maintain this organization, to sponsor future seminars, and to hopefully sponsor some needed research.

Our first official meeting of the Committee will be at the end of this seminar. Our first order of business will be to elect a new President because Jack Deal has resigned. Jack is leaving the Houston area and we will all miss him. We owe Jack our gratitude for the work he did in keeping this Committee going. Other business will also be conducted.

SOIL-STRUCTURE INTERACTION SEMINAR
SPONSORED BY THE FOUNDATION PERFORMANCE COMMITTEE

The purpose of the seminar is to develop a more consistent foundation design and construction procedures for residential and light commercial projects in the Gulf-Coast area. In addition, our experts will define what constitutes foundation failure and will develop a failure criteria. In this seminar, we get all of the design and construction team members together to develop a more uniform design, construction and quality control procedure. This is becoming more and more important in light of the significant number of foundation failures and potential litigation and exposure of the design and construction professionals.

PROGRAM AGENDA

- Foundation Performance Committee - History:
  Dick Peverley, P.E. - Peverley Engineering, Inc. (5 minutes)
- Introduction
  David A. Eastwood, P.E. - Geotech Engineering and Testing, Inc. (5 minutes)
- Guidelines for Geotechnical Design, Construction Quality Control, for Residential and Light Commercial Projects in the Houston Area
  David A. Eastwood, P.E. - Geotech Engineering and Testing, Inc. (85 minutes)
- Break (10 minutes)
- State-of-Practice of Foundation Design
  Tract Homes - Lowell Brumley, P.E. - TSG Consultants, Inc. (20 minutes)
  Custom Homes - Michael Skoller, P.E. - National Structural Engineering, Inc. (20 minutes)
- Future of Post-Tensioned Slabs on Ground
  Russel Price, P.E. - Suncoast Post-Tension Corporation (15 minutes)
- Break (10 minutes)
- Recommended Quality Control and Inspection
  Jack Spivey - J. Spivey and Associates, Inc. (25 minutes)
- Causes of Foundation Distress - Committee Report
  Brad Crane - Shepard Crane & Associates, Inc. (20 minutes)
- Foundation Distress Evaulation - Committee Report
  Richard Peverley, P.E. - Peverley Enigneering, Inc. (20 minutes)
- Foundation Distress Evaluation - Committe Report
  Don Lenert, P.E. - Lenert Engineering, Inc. (20 minutes)
- Break (10 minutes)
- Foundation Repair Techniques
  James Dutton - Du-West Foundation Repair (20 minutes)
- Builder's Point-of-View
  Jim Miller - Kickerillo Custom Homes (20 minutes)
- Government Agency Point-of-View
  Joseph A. Edwards - Former City of Bellaire Building Official (20 minutes)
- Deceptive Trade Practice Act
  James Moriarty - Attorney at Law (20 minutes)
- Break (10 minutes)
- Panel Discussion (60 minutes)

The seminar will be held at the Ramada Hotel Northwest located at 12801 Northwest Freeway at Pinemont, Houston, Texas 77040 (corner of 290 and Pinemont) in the Austin Ballroom from 12:30 p.m. to 7:15 p.m. on July 25, 1996. RSVP to Geotech Engineering and Testing, Inc., Ms. Vicky Bonds (713) 699-4000 before July 19, 1996. The registration fee is $75 if registered before July 19, 1996. If registered after this date, the fee will be $99. This fee includes course notes, beverages, and desserts. This fee is Non-Refundable. Please make your check payable to Geotech Engineering and Testing, Inc., Dept. Seminar, 800 Victoria Drive, Houston, Texas 77022-2908. Please feel free to distribute this seminar information to your colleagues and clients.

GEOTECHNICAL GUIDELINES

FOR

DESIGN, CONSTRUCTION, MATERIALS AND

MAINTENANCE OF

RESIDENTIAL PROJECTS IN THE HOUSTON AREA

By

David A. Eastwood, P.E.
Geotech Engineering and Testing, Inc.

Presented at the

Soils-Structure Interaction Seminar

July 1996

BIOGRAPHY

David A. Eastwood, P.E.

David Eastwood is the President of Geotech Engineering and Testing, Inc. Mr. Eastwood has practiced consulting engineering for about 18 years serving in key technical, project management, and administrative roles on both domestic and international assignments. His experience in these functions include a wide range of project types and large capital investments ranging from residential, industrial to commercial buildings. Geotech Engineering and Testing, Inc. has been a leader in providing soils and foundation engineering services to the Houston area builders, developers, architects, and designers. Mr. Eastwood has conducted soils and foundation explorations and foundation distress studies for a wide variety of projects including a large number of residences, subdivisions, apartment buildings, shopping centers, and office buildings. Mr. Eastwood received his Bachelor and Masters of Science in Civil Engineering from the University of Houston with specialization in soils engineering. Mr. Eastwood has attended Continuing Education Seminars at Rice, Prinston, University of Maryland and University of Houston. He has several publications on design and construction of foundations on expansive soils. Mr. Eastwood is a member of PTI, GHBA, AIA, ASTM, TSPE, TIBD, ACME, and ASCE. Mr. Eastwood is the Chairman of the geotechnical committee of Post-Tensioning Institute Slab-On-Grade Committee.

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TABLE OF CONTENTS

ILLUSTRATIONS

INTRODUCTION

The variable subsoil conditions in the Gulf Coast area has resulted in very special design requirements for residential and light commercial foundations. The subsurface conditions should be carefully considered when a subdivision or a residence is to be built. Proper planning from the stand point of environmental conditions, subsidence, faulting, soil conditions, design, construction, materials, quality control and maintenance program should be considered prior to any development.

The purpose of this document is to recommend the scope of geotechnical work to develop soils and foundation data for a proper and most economical design and construction of foundations in the Houston area. It is our opinion that portions of these studies should be performed prior to developing the subdivision or buying the lots in order to minimize potential future soils and foundation problems. These problems may arise from the presence of hazardous waste, faulting, poorly compacted fill, soft soil conditions, expansive soils, perched water table, presence of sand and silts, tree roots, etc. This guideline is divided into six segments, including Pre-Development Studies, design, construction, materials, quality control, maintenance program and foundation stabilization. Our recommendations are presented from a geotechnical stand point only and should be complemented by a structural engineer.

PRE-DEVELOPMENT STUDIES

Environmental Site Reconnaissance Study

Environmental site assessment studies are recommended on the tracts of land for subdivision or commercial developments. A study like this is generally not required for a single lot in an established subdivision or an in-fill lot in the city. This type of study is used to evaluate the potential risk of environmental contamination that is on or used to be on a project site prior to development. The study is divided into phases, Phases I through III.

The scope of Phase I includes a preliminary site reconnaissance, including: (a) document search, (b) site walk through, (c) review of aerial photographs, (d) historical ownership report, (e) regulatory data review and (f) a report of observations and recommendations.

In the event that the results of the Phase I study indicates the potential for the presence of contaminants, a Phase II study is performed. The scope of Phase II study may include: (a) soil and groundwater sampling, (b) chemical testing and analysis, (c) site reconnaissance, (d) contact with state and federal regulatory personnel, and (e) reporting.

A Phase III study involves implementing the recommendations given in the Phase II study; including remediation and monitoring.

Subsidence

Potential subsidence problems should be considered when developing subdivisions in the coastal areas, such as Clear Lake, Seabrook, Baytown, etc. Also, other parts of Houston, subject to groundwater removal are also subject to subsidence. This type of study is generally not needed for a single lot in an established subdivision or an in fill lot in the city.

Subsidence is the sinking of the land surface caused by the withdrawal of groundwater. The land elevation lost to subsidence is generally permanent and irreversible. In the Harris-Galveston region of Texas, subsidence poses the greatest threat in the coastal areas susceptible to flooding due to high tides, heavy rainfall and hurricane storm surge. Because of low elevation, any additional subsidence in the coastal areas results in a significant increase in potential tidal flooding or permanent inundation.

The rate of land subsidence in Harris County has been reduced significantly due to changes in water development from the surface water instead of groundwater.

A review of recent subsidence data available from Harris County Subsidence District indicates that the subsidence in areas such as Pasadena, Southwest Houston, etc. have slowed down significantly. However, the subsidence rate in the Addick Area (West, Northwest Houston) is about one-inch per year.

Geologic Faulting

Many faults have been observed within the Gulf Coast Region of Texas. In general, faults are caused by groundwater and oil removal from the underlying surface. Faults originate several thousand feet below the ground surface and can often cause displacement of the ground surface, causing broken pavement and damage to residential and commercial structures.

Faults are studied in several phases. A Phase I fault study will include the first step in identification of faulting. The scope of a Phase I investigation includes the following elements:

1. Literature Review. This includes a search for, and study of, published data on surface faults in the area of the site.

2. Remote Sensing Study. Aerial photographs, infra-red imagery, where available, should be studied.

3. Field Reconnaissance. This includes a visit to the study area and vicinity by a qualified engineer to examine the area for physical evidence of a possible fault or faults. Physical evidence includes, but is not limited to, (a) natural topographic scarps, (b) soil layer displacements that may be recognized in ditches, creek banks and trenches, (c) breaks in pavements, (d) distress in existing buildings, and (e) vertical offsets in fences.

Once a residence is built on an active fault, the foundation for the residence will be subject to a continual movement and subsequent distress. Foundation stabilization of structures built on active faults can be difficult, but possible. A study of geologic faulting is recommended prior to development of any subdivision in the Gulf-coast area.

GENERAL SOILS AND GROUNDWATER

Geology

The Houston area is located on the Gulf of Mexico Coastal Plain, which is underlain largely by overconsolidated clays, clay shales and poorly cemented sands to a depth of several miles. Nearly all soil of the area consists of clay, associated with moderate amounts of sand. Some of the formations in the Houston area consist of Beaumont, Lissie, and Bentley.

The Beaumont formation has significant amounts of expansive clays, resulting in shrink/swell potential. Desiccation of this formation also produces a network of fissures and slickensides in the clay that is potential plains of weakness. The Beaumont formation generally occurs in South, Southwest, East, and Central Houston. The Lissie and Bentley formations generally occur in North and part of West Houston. These formations consist of generally sands and sandy clays. These soils are generally low to moderate in plasticity with low to moderate shrink/swell potential.

General Soils Conditions

Variable soil conditions occur in the Houston area. These soils are different in texture, plasticity, compressibility, and strength. It is very important that foundations for residential and light commercial structures be designed for subsoil conditions that exists at the specific lot in order to minimize potential foundation and structural distress. Details of general subsoil conditions at various parts of the Houston area are described below. These descriptions are very general. Significant variations from these descriptions can occur. The General soil conditions are as follows:

Location	Soil Conditions
Northwest and Northeast Houston, including Kingwood, The Woodlands, Cypresswood, Copperfield, Atascocita area, Fairfield, Worthom, and Oaks of Devonshire	Generally sandy surficial soils occur in these areas. The sands are generally loose and are underlain by relatively impermeable clays and sandy clays. This condition promotes perched water table formation which results in the loss of bearing capacity of the shallow foundations such as a conventionally-reinforced slab or post-tensioned slabs. This condition also may cause subsequent foundation settlement and distress.

South, Southwest, Southeast, and part of West Houston including, Kirbywoods, parts of the South Shore Harbour, Kelliwood Gardens, Clear Lake area, New territory, Greatwood, First Colony, Brightwater, Vicksburg, Pecan Grove, Woods Edge, Cinco Ranch, and Lake Olympia.	Generally highly plastic clays, and sandy clays are present in these areas. These clays can experience significant shrink and swell movements. The foundations must be designed for this condition. Parts of Cinco Ranch has a surficial layer of sands, underlain by expansive clays. The foundations these soils should be designed, assuming a perched water table condition.
Central Houston, including Bellaire, Tanglewood, West University, River Oaks.	Highly expansive clays, drilled footings are the preferred foundations system. Soft soils are observed in some lots. The soils in the River Oaks area are generally moderately expansive.
Memorial area, Heights, spring Branch, Hunter's Creek, Bunker Hill, Piney Point, Hedwig Village.	Moderately expansive sandy clays, clays, and sands. Special foundations must be used for structures near ravines. Look for faults.
Other Locations:	
(a) Weston Lakes, Oyster Creek.	Very sandy soils in some areas, variable soil conditions. Slab-at-Grade is a typical foundation; sometimes piers. Shallow water table at Oyster Creek. Highly expansive soils in parts of Weston Lakes.
(b) Sugar Mill, Sugar Creek, Plantation Colony, Quail Valley, Sweetwater.	Highly expansive clays on top of loose silts and sands. Variable soil conditions. A floating slab is a typical foundation. Piers can also be used at some locations. Soft in some lots. Shallow water table.

Water Level Measurements

The groundwater levels in the Gulf Coast area vary significantly. The groundwater depth in the Houston area generally ranges from 8- to 30-feet. Fluctuations in groundwater level generally occurs as a function of seasonal rainfall variation, temperature, groundwater withdrawal, and construction activities that may alter the surface and drainage characteristics of the site.

The groundwater measurements are usually evaluated by the use of a tape measure and weight at the end of the tape at the completion of drilling and sampling.

An accurate evaluation of the hydrostatic water table in the relatively impermeable clays and low permeability silt/sands requires long term observation of monitoring wells and/or piezometers. It should be noted that it is not possible to accurately predict the pressure and/or level of groundwater that might occur based upon short-term site exploration. The installation of piezometers/monitor wells is beyond the scope of a typical residential geotechnical reports. We recommend that the groundwater level be verified just before construction if any excavations such as construction of drilled footings/underground utilities, etc. are planned.

The geotechnical engineer must be immediately notified if a noticeable change in groundwater occurs from the one mentioned in the same report. The geotechnical engineer should then evaluate the affect of any groundwater changes on the design and construction of the facilities.

Some of the groundwater problem areas in Houston include Southside Place, parts of Sugar land, etc. One should not confuse the perched water table with the groundwater table. A perched water table occurs when bad drainage exists in areas with a sand or silt layer, about two- to four-foot thick, underlain by impermeable clays and sandy clays. During the wet season, water can pond on the clays and create a perched water table. The surficial sands/silts become extremely soft, wet and may lose their load carrying capacity.

DESIGN

Foundations and Risks

Many lightly loaded foundations are designed and constructed on the basis of economics, risks, soil type, foundation shape and structural loading. Many times, due to economic considerations, higher risks are accepted in foundation design. Most of the time, the foundation types are selected by the owner/builder, etc. It should be noted that some levels of risk is associated with all types of foundations and there is no such thing as a zero risk foundation. All of these foundations must be stiffened in the areas where expansive soils are present and trees have been removed prior to construction. The following are the foundation types typically used in the area with increasing levels of risk and decreasing levels of cost:

FOUNDATION TYPE	REMARKS
Structural Slab with Piers	This type of foundation (which also includes a pier and beam foundation with a crawl space) is considered to be a minimum risk foundation. A minimum crawl space of six-inches or larger is required. Using this foundation, the floor slabs are not in contact with the subgrade soils. This type of foundation is particularly suited for the areas where expansive soils are present and where trees have been removed prior to construction. The drilled footings must be placed below the potential active zone to minimize potential drilled footing upheaval due to expansive clays. In the areas where non-expansive soils are present, spread footings can be used instead of drilled footings.
Slab-On-Fill Foundation Supported on Piers	This foundation system is also suited for the area where expansive soils are present. This system has some risks with respect to foundation distress and movements, where expansive soils are present. However, if positive drainage and vegetation control are provided, this type of foundation should perform satisfactorily. The fill thickness is evaluated such that once it is combined with environmental conditions (positive drainage, vegetation control) the potential vertical rise will be minimum. The structural loads can also be supported on spread footings if expansive soils are not present.
Floating (Stiffened) Slab Supported on Piers. The Slab can either be Conventionally-Reinforced or Post-Tensioned	The risk on this type of foundation system can be reduced sizably if it is built and maintained with positive drainage and vegetation control. Due to presence of piers, the slab can move up if expansive soils are present, but not down. In this case, the steel from the drilled piers should not be dowelled into the grade beams. The structural loads can also be supported on spread footings if expansive soils are not present.
Floating Slab Foundation (Conventionally-Reinforced or Post-Tensioned Slab)	The risk on this type of foundation can be reduced significantly if it is built and maintained with positive drainage and vegetation control. No piers are used in this type of foundation. Many of the lightly-loaded structures in the state of Texas are built on this type of foundation and are performing satisfactorily. In the areas where trees have been removed prior to construction and where expansive clays exists, these foundations must be significantly stiffened to minimize the potential differential movements as a result of subsoil heave due to tree removal.

The above recommendations, with respect to the best foundation types and risks, are very general. The best type of foundation may vary as a function of structural loading, house geometry, and soil types. For example, in some cases, a floating slab foundation may perform better than a drilled footing type foundation.

Foundation Types

Residential structures in the Houston area are supported on drilled footings, post-tensioned slabs, or conventionally reinforced slabs. In general, properly designed post-tensioned slabs or conventionally-reinforced slabs perform satisfactory on most subsoils. Drilled footings may provide a superior foundation system when large slabs, significant offsets or differential loading occurs on the foundations.

The selection of foundation is a function of economics and the level of the risk that the client wants to take. For example, a structural slab foundation is not used for a track home that costs about $100,000. This type of foundation is used for houses that cost usually much more expensive. In general, floating slab type foundations are used with houses with price ranges of less than $200,000 or when subsoil conditions dictates to use this type of foundation.

Geotechnical Foundation Design Criteria

Foundations for a residential structure should satisfy two independent design criteria. First, the maximum design pressure exerted at the foundation base should not exceed the allowable net bearing pressure based on an adequate factor of safety with respect to soil shear strength. Secondly, the magnitude of total and differential settlements (and shrink and swell) under sustained loads must be such that the structure is not damaged or its intended use impaired.

It should be noted that properly designed and constructed foundation may still experience distress from improperly prepared bearing soils and/or expansive soils which will undergo volume change when correct drainage is not established or an incorrectly controlled water source becomes available.

The design of foundations should be performed by an experienced structural engineer using a soils report from an experienced soils engineer. The structural engineer must use a lot/site specific soils report for the foundation design. The structural engineer should not use general subdivision soils reports written for underground utilities and paving for the slab design. Furthermore, he should not design slabs with disclaimers, requiring future soils reports to verify his design. The designers or architects should not provide clients with foundation design drawings with generic foundations details. All of the foundation drawings should be site and structure specific and sealed by a professional structural engineer.

Recommended Scope of Geotechnical Studies

Soil testing must be performed on residential lots before a foundation design can be developed. The recommended number of borings should be determined by a geotechnical engineer. The number of borings and the depths are a function of the size of the structure, foundation loading, site features, and soil conditions. As a general rule, a minimum of one boring for every five lots should be performed for subdivision lots. This boring program assumes that a conventionally-reinforced slab or a post-tensioned slab type foundation is going to be used. Furthermore, many lots will be tested at the same time so that a general soils stratigraphy can be developed for the entire subdivision. In the event that a drilled footing foundation is to be used, a minimum of one boring per lot is recommended. In the case of variable subsoil conditions, two or more borings per lot should be performed. A minimum of two borings is recommended for custom homes or a single in-fill lot. A minimum boring depth of 15-feet is recommended for the design of post-tensioned or conventially-reinforced slabs. The boring depths for the design of drilled footing foundations should be at least 15-feet deep. In the event that the lot is wooded and expansive soils are suspected, the boring depth (if drilled footings are to be used) should be increased to 25-ft. On the wooded lots, when the presence of expansive soils are suspected the borings should be drilled near the trees, if possible. Root fibers should be obtained to estimate the active zone depth. The active zone depth is defined as the depth within which seasonal changes in moisture content/soil suction can occur. In general, the depth of active zone is about two-feet below the lowest root fiber depth.

The borings for the residential lots should be performed after the streets are cut and fill soils have been placed and compacted on the lots. This will enable the geotechnical engineer to identify the fill soils that have been placed on the lots. All fill soils should have been tested for compaction during the placement on the lots. A minimum of one density test for every 2500 square feet per lift must be performed once a subdivision is being developed. Fill soils may consist of clays, silty clays, and sandy clays. Sands and silts should not be used as fill materials. Typical structural fill in the Houston area consists of silty clays and sandy clays (not sands) with liquid limits less than 40 and plasticity index between 10 and 20. The fill soils should be placed in lifts not exceeding eight-inches and compacted to 95 percent of the maximum dry density (ASTM D698-91). On-site soils with the exception of sands can also be used as structural fill under floating slab foundations. A floating slab foundation is defined as a conventionally-reinforced slab and a post-tensioned slab.

In the case of a subdivision development, the developer should perform only the borings for the streets and underground utilities. The borings for the lots should wait until all fill soils from street and underground utility excavations are placed and compacted on the lots. In general, the geotechnical testing of the soils for the lots should be the builders responsibility. We recommend that all of the foundations in the subdivision be engineered by a registered professional engineer specializing in residential foundation design.

In the areas where no fill will be placed on the lots prior to site development, the borings on the lots can be performed at the same time as the time as the borings for streets. The soils data from the street and underground borings should never be used for the slab design. This is due to potential in variability in the soil conditions, including soils stratigraphy, compressibility, strength, and swell potential.

Soil borings must be performed prior to foundations underpinning for distressed structures. This is to evaluate the subsoil properties below the bottom of the drilled footings. The depth of drilled footings for foundation underpinning should be determined by a geotechnical engineer. Unfortunately, this is not always followed, and many "so called" foundation repair jobs are performed incorrectly, causing significant financial loss for the client.

In the event of building additions, a minimum of one boring is recommended on residential additions of less than 1,000 square feet. A minimum of two borings is recommended for additions greater than 1,000 square feet.

In general, a scope of typical geotechnical exploration does not include the evaluation of fill compaction. These studies should have been performed at the time of fill placement.

In the areas where highly expansive soils are present, the drilled footings should be founded in a strong soil stratum below the zero movement line. This depth is defined as the depth below which no upward movements occur. It is possible to found a drilled footing below the zero movement line and within the active zone depth. The active zone is defined as the zone within which seasonal changes in subsoil moisture can occur. This is shown on Plate 1. Drilled footings in the area with deep active zones, where trees are present, and subsoils are expansive can be as much as 18-feet deep. The depth of drilled footings should also be determined such that the uplift along the pier shafts be resisted by the presence of bells or shaft skin friction below the zero movement line. The depth of the active zone should be verified by a geotechnical exploration. The evaluation of active zone depths and zero movement line should be performed using the techniques provided in the 1996 Post-Tensioning Institute Slab-on-Grade Design Manual. Drilled footings founded at shallower depths may experience uplift due to expansive soils. In the areas where non-expansive soils are present, the footing depth can be as low as eight-feet.

The grade beams for a floating slab foundation should penetrate the clay soils a minimum of 12-inches. The grade beam penetrations for a floating slab foundation into the surficial sands should be at least 18-inches to develop the required bearing capacity. A minimum grade beam width of 12-inches is recommended in sands and silts.

In the event that a floating slab (post-tensioned slab or a conventionally-reinforced slab) is constructed in sands or silts, the geotechnical engineer must specify bearing capacity, assuming saturated subsoil conditions. This results in bearing capacities in the range of 600- to 900 psf in a typical sand or silt soils in the Houston area. Higher bearing capacity values can be used if the sands/silts do not get saturated during the life of the residence. This assumption is generally unrealistic due to the presence of sprinkler systems, negative drainage, and cyclic rainfall in the Houston area.

Design parameters for a post-tensioned slab on expansive clays must carefully evaluated by a geotechnical engineer. It should be noted that the 1996 post-tensioned slab design manual does not directly model the poor drainage, the effect of the trees, and the depth of the active zone. The geotechnical engineer must modify the design parameter presented in the manual to come up with the proper design parameter. It should be noted that it is currently very difficult (to impossible) to design economical floating slab foundations on expansive soils on wooded lots where trees are to be removed prior to slab construction.

Floor Slabs

The floor slabs for foundations supported on drilled footings may consist of (a) structural slabs with crawl space, (b) slab-on-fill or (c) slab-on-grade.

Residential Structures Constructed near the Bayous

Many large residential structures are being build near the bayous. Portions of the slopes on the bayous are very steep with slopes steeper than 3(h):1(v). The foundations for residences near the bayous must be provided by the use of deep drilled footings/piling. The geotechnical boring depths should be at least twice the depth of the bayou.

Any foundation which falls within the hazard zone which extends from the toe of the slope, extending backward on a 4(h):1(v) slope to the existing grade should be supported on deep foundations. Foundations outside the hazard zone may be supported on shallow piers. The floor slabs in the hazard zone should consist of a structural slab. The floor slabs outside the hazard zone may consist of slab-on -fill or slab-on-grade. No skin friction should be used for piers within the hazard zone from the surface to the toe of the slope elevation.

We recommend the stability of bayou slopes be evaluated using a slope-stability analyses, using computer solutions. The house should be placed on top of the slope and the stability of the slope for global stability should be evaluated. The slopes should then be flattened and covered with erosion protection to minimize potential sloughing and erosion problems.

CONSTRUCTION

Site Preparation

Our recommendations on site preparation are summarized below:

1. In general, remove all vegetation, tree roots, organic topsoil, existing foundations, paved areas and any undesirable materials from the construction area. Tree trunks under the floor slabs should be removed to a root size of less than 0.5-inches. We recommend that the stripping depth be evaluated at the time of construction by a soil technician.

2. Any on-site fill soils, encountered in the structure and pavement areas during construction, must have records of successful compaction tests signed by a registered professional engineer that confirms the use of the fill and record of construction and earthwork testing. These tests must have been performed on all the lifts for the entire thickness of the fill. In the event that no compaction test results are available, the fill soils must be removed, processed and recompacted in accordance with our site preparation recommendations. Excavation should extend at least two-feet beyond the structure and pavement area. Alternatively, the existing fill soils should be tested comprehensively to evaluate the degree of compaction in the fill soils.

3. The subgrade areas should then be proofrolled with a loaded dump truck, scraper, or similar pneumatic-tired equipment. The proofrolling serves to compact surficial soils and to detect any soft or loose zones. Any soils deflecting excessively under moving loads should be undercut to firm soils and recompacted. The proofrolling operations should be observed by an experienced geotechnician.

4. Scarify the subgrade, add moisture, or dry if necessary, and recompact to 95% of the maximum dry density as determined by ASTM D 698-91 (Standard Proctor). The moisture content at the time of compaction of subgrade soils should be within -1 to +3% of the proctor optimum value. We recommend that the degree of compaction and moisture in the subgrade soils be verified by field density tests at the time of construction. We recommend a minimum of four field density tests per lift or one every 2500 square feet of floor slab areas, whichever is greater.

5. Structural fill beneath the building area may consist of off-site inorganic silty clays or sandy clays with a liquid limit of less than 40 and a plasticity index between 10 and 20. In the event that a floating slab foundation system is used, on-site soils (with the exception of sands or silts), free of organics, can be used as structural fill. Other types of structural fill available locally, and acceptable to the geotechnical engineer, can also be used.

   These soils should be placed in loose lifts not exceeding eight-inches in thickness and compacted to 95 percent of the maximum dry density determined by ASTM D 698-91 (Standard Proctor). The moisture content of the fill at the time of compaction should be within ±2% of the optimum value. We recommend that the degree of compaction and moisture in the fill soils be verified by field density tests at the time of construction. We recommend that the frequency of density testing be as stated in Item 4.

6. The backfill soils in the trench/underground utility areas should consist of select structural fill, compacted as described in Item 4. In the event of compaction difficulties, the trenches should be backfilled with cement-stabilized sand or other materials approved by the Geotechnical Engineer. Due to high permeability of sands and potential surface water intrusion, bank sands should not be used as backfill material in the trench/underground utility areas.

7. In cut areas, the soils should be excavated to grade and the surface soils proofrolled and scarified to a minimum depth of six-inches and recompacted to the previously mentioned density and moisture content.

8. The subgrade and fill moisture content and density must be maintained until paving or floor slabs are completed. We recommend that these parameters be verified by field moisture and density tests at the time of construction.

9. In the areas where expansive soils are present, rough grade the site with structural fill soils to insure positive drainage. Due to their high permeability of sands, sands should not be used for site grading where expansive soils are present.

10. We recommend that the site and soil conditions used in the structural design of the foundation be verified by the engineer's site visit after all of the earthwork and site preparation has been completed and prior to the concrete placement.

Other Construction Considerations

1. Grade beam excavations should be free of all loose materials. The bottom of the excavations should be dry and hard.

2. Surficial subgrade soils in the floor slab areas should be compacted to a minimum of 95% of Standard Proctor Density (ASTM D 698-91). This should be confirmed by conducting a minimum of four field density tests per slab, per lift.

3. Minimum concrete strength should be 3,000 psi with a maximum slump of 5-inch. Concrete workability can be improved by adding air to the concrete mix and the use of a concrete vibrator. The concrete slump and strength should be verified by slump tests and concrete cylinders.

4. The Visqueen, placed under the floor slabs, should be properly stretched to maximize soil-slab interaction.

5. In the areas where expansive soils are present, the backfill soils for the underground utilities under the floor slabs should consist of select fill and not sands or silts. The cohesionless backfill can act as a pathway for surface water to get under the foundation and resulting in subsoil swelling. In the event that a floating slab is used, on-site soils (not sands or silts), free of organics, can be used as structural fill.

6. Tree stumps should not be left under the slabs. This may result in future settlement and termite infestation.

MATERIALS

The use of proper materials is crucial to the performance of a foundation system. Some of the relevant material issues is as follows:

- Inadequate concrete strength.

- Reinforcement, steel grade.

- o Improperly manufactured post-tensioned materials.
- o The geotechnical technician must check the earthwork testing, concrete pier, installation, and concrete placement.

QUALITY CONTROL

General

Construction monitoring and quality control tests should be planned to verify materials and placement in accordance with the project design documents and specifications. Earthwork observations on the house pad, pad thickness measurements, drilled footing installation monitoring, and concrete placement monitoring should be performed. Details of each of these items is described in the following paragraphs.

Earthwork Observations

The subgrade and fill soils under the floor slabs should be compacted to about 95 percent of maximum dry density (ASTM D 698-91). Furthermore, the fill soils should be non-expansive. Atterberg limit tests should be performed on the fill soils, obtained from the borrow pit, to evaluate the suitability of these soils for use as structural fill and their shrink/swell potential. Expansive soils, of course, should not be used as structural fill. In the event that a floating slab foundation is used, on-site soils with the exception of sands/silts can be used as structural fill.

Field density tests should be conducted on the subgrade soils and any borrow fill materials in the floor slab and pavement areas. In the areas where expansive soils are present, about 18- to 36-inches of structural fill is placed under the floor slab areas. Laboratory proctor tests will also be performed on the on-site soils as well as off-site borrow fill materials to evaluate the moisture-density relationship of these soils.

Fill Thickness Verification

Fill soils may have to be placed on the lots to raise the lot or to provide a buffer zone in between the on-site expansive soils and the floor slabs. We recommend that the required thickness of the fill be verified after the completion of the building pad. This task can be accomplished by drilling two borings to a depth of two-feet in the building pad area, examining and testing the soils to verify the fill thickness.

Drilled Footing Observations

In the event that the structure is supported by drilled footings, we recommend that the installation of the footings be observed by a geotechnical technician.

The technician will conduct hand penetrometer tests on the soil cuttings to estimate the bearing capacity of the soil at each footing location. He will make changes to the foundation depth and dimensions if obstacles or soft soils are encountered. Therefore, minimizing costly construction delays. In addition, the technician must verify the bell size by a bell measurement tool. One set of concrete cylinders (four cylinders) will be made for each 50 yards of pour. Two cylinders will be broken at seven days, and two cylinders at 28 days.

Concrete Placement Monitoring

The concrete sampling and testing in the floor slab and placement areas will be conducted in accordance with ASTM standards. A technician will monitor batching and placing of the concrete. At least four concrete cylinders should be made for each 50 yards floor slab pour. Two concrete cylinders are tested at seven days and two cylinders at 28 days.

HOMEOWNER MAINTENANCE PROGRAM

Introduction

Performance of residential structures depends not only on the proper design and construction, but also on the proper foundation maintenance program. Many residential foundations have experienced major foundation problems as a result of owner's neglect or alterations to the initial design, drainage, or landscaping. This has resulted in considerable financial loss to the homeowners, builders, and designers in the form of repairs and litigation.

A properly designed and constructed foundation may still experience distress from vegetation and expansive soil which will undergo volume change when correct drainage is not established or incorrectly controlled water source becomes available.

The purpose of this document is to present recommendations for maintenance of properly designed and constructed residential projects in Houston. It is recommended that the builder submit this document to his/her client at the time that the owner receives delivery of the house.

Drainage

The initial builder/developer site grading (positive drainage) should be maintained during the useful life of the residence. In general, a civil engineer develops a drainage plan for the whole subdivision. Drainage sewers or other discharge channels are designed to accommodate the water runoff. These paths should be kept clear of debris such as leaves, gravel, and trash.

In the areas where expansive soils are present, positive drainage should be provided away from the foundations. Changes in moisture content of expansive soils are the cause of both swelling and shrinking. Positive drainage should also be maintained in the areas where sandy soils are present.

Positive drainage is extremely important in minimizing soil-related foundation problems.

The homeowners berm the flowerbed areas, creating a dam between the berm and the foundation, preventing the surface water from draining away from the structure. This condition may be visually appealing, but can cause significant foundation damage as a result of negative drainage.

The most commonly used technique for grading is a positive drainage away from the structure to promote rapid runoff and to avoid collecting ponded water near the structure which could migrate down the soil/foundation interface. This slope should be about 3 to 5 percent within 10-feet of the foundation.

Should the owner change the drainage pattern, he should develop positive drainage by backfilling near the grade beams with fill compacted to 90 percent of the maximum dry density as determined by ASTM D 698-91 (standard proctor). This level of compaction is required to minimize subgrade settlements near the foundations and the subsequent ponding of the surface water. The fill soils should consist of silty clays and sandy clays with liquid limits less than 40 and plasticity index (PI) between 10 and 20. Bank sand or top soils are not a select fill. The use of Bank sand or top soils to improve drainage away from a house is discouraged; because, sands are very permeable. In the event that sands are used to improve drainage away from the structure, one should make sure the clay soils below the sands have a positive slope (3 - 5 Percent) away form the structure, since the clay soils control the drainage away from the house. The on-site soils (not sand or silts), free of organics, can be used as structural fill.

The author has seen many projects with an apparent positive drainage; however, since the drainage was established with sands on top of the expansive soils the drainage was not effective.

Depressions or water catch basin areas should be filled with compacted soil (sandy clays or silty clays not bank sand) to have a positive slope from the structure, or drains should be provided to promote runoff from the water catch basin areas. Six to twelve inches of compacted, impervious, nonswelling soil placed on the site prior to construction of the foundation can improve the necessary grade and contribute additional uniform surcharge pressure to reduce uneven swelling of underlying expansive soil.

Pets (dogs, etc.) sometimes excavate next to the exterior grade beams and created depressions and low spots in order to stay cool during the hot season. This condition will result in ponding of the surface water in the excavations next to the foundation and subsequent foundation movements. These movements can be in the form of uplift in the area with expansive soils and settlement in the areas with sandy soils. It is recommended as a part of the foundation maintenance program, the owner backfills all excavations created by pets next to the foundation with compacted clay fill.

Grading and drainage should be provided for structures constructed on slopes, particularly for slopes greater than nine percent, to rapidly drain off water from the cut areas and to avoid ponding of water in cuts or on the uphill side of the structure. This drainage will also minimize seepage through backfills into adjacent basement walls.

Subsurface drains may be used to control a rising water table, groundwater and underground streams, and surface water penetrating through pervious or fissured and highly permeable soil. Drains can help control the water table in the expansive soils. Furthermore, since drains cannot stop the migration of moisture through expansive soil beneath foundations, they will not prevent long-term swelling. Moisture barriers can be placed near the foundations to minimize moisture migration under the foundations. The moisture barriers should be at least five-feet deep in order to be effective.

Area drains can be used around the house to minimize ponding of the surface water next to the foundations. The area drains should be checked periodically to assure that they are not clogged.

The drains should be provided with outlets or sumps to collect water and pumps to expel water if gravity drainage away from the foundation is not feasible. Sumps should be located well away from the structure. Drainage should be adequate to prevent any water from remaining in the drain (i.e., a slope of at least 1/8 inch per foot of drain or 1 percent should be provided).

Positive drainage should be established underneath structural slabs with crawl space. This area should also be properly vented. Absence of positive drainage may result in surface water ponding and moisture migration through the slab. This may result in wood floor warping and tile unsticking. Furthermore, The crawl space area should be properly vented.

It is recommended that at least six-inches of clearing be developed between the grade and the wall siding. This will minimize surface water entry between the foundation and the wall material, in turn minimizing wood decay.

Poor drainage at residential projects in North and West Houston can result in saturation of the surficial sands and development of a perched water table. The sands, once saturated, can lose their load carrying capacity. This can result in foundation settlements and bearing capacity failures. Foundations in these areas should be designed assuming saturated subsoil conditions.

In general, roof drainage systems, such as gutters or rain dispenser devices, are recommended all around the roof line when gutters and downspouts should be unobstructed by leaves and tree limbs. In the area where expansive soils are present, the gutters should be connected to flexible pipe extensions so that the roof water is drained at least 10-feet away from the foundations. Preferably the pipes should direct the water to the storm sewers. In the areas where sandy soils are present, the gutters should drain the roof water at least five-feet away from the foundations.

If a roof drainage system is not installed, rain-water will drip over the eaves and fall next to the foundations resulting in subgrade soil erosion, and creating depression in the soil mass, which may allow the water to seep directly under the foundation and floor slabs.

The home owner must pay special attention to leaky pools and plumbing. In the event that the water bill goes up suddenly without any apparent reason, the owner should check for a plumbing leak.

The introduction of water to expansive soils can cause significant subsoil movements. The introduction of water to sandy soils can result in reduction in soil bearing capacity and subsequent settlement. The home owner should also be aware of water coming from the air conditioning drain lines. The amount of water from the condensating air conditioning drain lines can be significant and can result in localized swelling in the soils, resulting in foundation distress.

Landscaping

General. A house with the proper foundation, and drainage can still experience distress if the homeowner does not properly landscape and maintain his property. One of the most critical aspects of landscaping is the continual maintenance of properly designed slopes.

Installing flower beds or shrubs next to the foundation and keeping the area flooded will result in a net increase in soil expansion in the expansive soil areas. The expansion will occur at the foundation perimeter. It is recommended that initial landscaping be done on all sides, and that drainage away from the foundation should be provided and maintained. Partial landscaping on one side of the house may result in swelling on the landscaping side of the house and resulting differential swell of foundation and structural distress in a form of brick cracking, windows/door sticking, and slab cracking.

Landscaping in areas where sandy, non-expansive soils are present, with flowers and shrubs should not pose a major problem next to the foundations. This condition assumes that the foundations are designed for saturated soil conditions. Major foundation problems can occur if the planter areas are saturated as the foundations are not designed for saturated (perched water table) conditions. The problems can occur in a form of foundation settlement, brick cracking, etc.

Sprinkler Systems. Sprinkler systems can be used in the areas where expansive soils are present, provided the sprinkler system is placed all around the house to provide a uniform moisture condition throughout the year.

The use of a sprinkler system in parts of Houston where sandy soils are present should not pose any problems, provided the foundations are designed for saturated subsoil conditions with positive drainage away from the structure.

The excavations for the sprinkler system lines, in the areas where expansive soils are present, should be backfilled with impermeable clays. Bank sands or top soil should not be used as backfill. These soils should be properly compacted to minimize water flow into the excavation trench and seeping under the foundations, resulting in foundation and structural distress.

The sprinkler system must be checked for leakage at least once a month. Significant foundation movements can occur if the expansive soils under the foundations are exposed to a source of free water.

The homeowner should also be aware of damage that leaking plumbing or underground utilities can cause, if they are allowed to continue leaking and providing the expansive soils with the source of water.

Effect of Trees. The presence of trees near a residence is considered to be a potential contributing factor to the foundation distress. Our experience shows that the presence or removal of large trees in close proximity to residential structures can cause foundation distress. This problem is aggravated by cyclic wet and dry seasons in the area. Foundation damage of residential structures caused by the adjacent trees indicates that foundation movements of as much as 3- to 7-inches can be experienced in close proximity to residential foundations.

This condition will be more severe in the periods of extreme drought. Sometimes the root system of trees such as willow, elm, or oak can physically move foundations and walls and cause considerable structural damage. Root barriers can be installed near the exterior grade beams to a minimum depth of 36-inches, if trees are left in place in close proximity to foundations. It is recommended that trees not be planted closer than half the canopy diameter of the mature tree, typically 20-feet from foundations. Any trees in closer proximity should be thoroughly soaked at least twice a week during hot summer months, and once a week in periods of low rainfall. More frequent tree watering may be required.

Tree roots tend to desiccate the soils. In the event that the tree has been removed prior to house construction, subsoil swelling can occur for several years. Studies have shown that for certain types of trees this process can last as much as 20 years in the areas where highly expansive clays are present. In this case the foundation for the house should be designed for the anticipated maximum heave.

Furthermore, the drilled footings, if used, must be placed below the zone of influence of tree roots. In the event that a floating slab foundation is used, we recommend the slab be stiffened to resist the subsoil movements due to the presence of trees. In addition, the area within the tree root zone may have to be chemically stabilized to reduce the potential movements. Alternatively, the site should be left alone for several years so that the moisture regime in the desiccated areas of the soils (where tree roots used to be) become equal/stabilize to the surrounding subsoil moisture conditions.

Tree removal can be safe provided the tree is no older than any part of the house, since the subsequent heave can only return the foundation to its original level. In most cases there is no advantage to a staged reduction in the size of the tree and the tree should be completely removed at the earliest opportunity. The areas where expansive soils exist and where the tree is older than the house, or there are more recent extensions to the house, it is not advisable to remove the tree because the danger of inducing damaging heave; unless the foundation is designed for the total computed expected heave.

In general, in the areas where non-expansive soils are present, no foundation heave will occur as a result of the tree removal.

In the areas where too much heave can occur with tree removal, some kind of pruning, such as crown thinning, crown reduction or pollarding should be considered. Pollarding, in which most of the branches are removed and the height of the main trunk is reduced, is often mistakenly specified, because most published advice links the height of the tree to the likelihood of damage. In fact the leaf area is the important factor. Crown thinning or crown reduction, in which some branches are removed or shortened, is therefore generally preferable to pollarding. The pruning should be done in such a way as to minimize the future growth of the tree, without leaving it vulnerable to disease (as pollarding often does) while maintaining its shape. This should be done only by a reputable tree surgeon or qualified contractor working under the instructions of an arboriculturist.

You may find there is opposition to the removal or reduction of an offending tree; for example, it may belong to a neighbor or the local authority, or have a Tree Preservation Order on it. In such cases there are other techniques that can be used from within your own property.

One option is root pruning, which is usually performed by excavating a trench between the tree and the damaged property deep enough to cut most of the roots. The trench should not be so close to the tree that it jeopardizes its stability. In time, the tree will grow new roots to replace those that are cut; however, in the short term there will be some recovery as the degree of desiccation in the soil under the foundations reduces.

Where the damage has only appeared in a period of dry weather, a return to normal weather pattern may prevent further damage occurring. Permission from the local authority is required before pruning the roots of a tree with preservation order on it.

Root barriers are a variant of root pruning. However, instead of simply filling the trench with soil after cutting the roots, the trench is either filled with concrete or lined with an impermeable layer to form a "permanent" barrier to the roots. Whether the barrier will be truly permanent is questionable, because the roots may be able to grow round or under the trench. However, the barrier should at least increase the time it takes for the roots to grow back.

Foundations/Flat Works

Every homeowner should conduct a yearly observation of foundations and flat works and perform any maintenance necessary to improve drainage and minimize infiltrations of water from rain and lawn watering. This is important especially during the first six years of a newly built home because this is usually the time of the most severe adjustment between the new construction and its environment. We recommend that all of the separations in the flat work and paving joints be immediately backfilled with joint sealer to minimize surface water intrusion and subsequent shrink/swell.

Some cracking may occur in the foundations. For example, most concrete slabs can develop hairline cracks. This does not mean that the foundation has failed. All cracks should be cleaned up of debris as soon as possible. The cracks should be backfilled with high-strength epoxy glue or similar materials. If a foundation experiences significant separations, movements, cracking, the owner must contact the builder and the engineer to find out the reason(s) for the foundation distress and develop remedial measures to minimize foundation problems.

FOUNDATION STABILIZATION

General

Several methods of foundation stabilization are presented here. These recommendations include foundation underpinning, using drilled footings or pressed piling, moisture barriers, moisture stabilization, and chemical stabilization. Some of these methods are being used in the Houston area. A description of each method is summarized in the following sections of this document.

Foundation Underpinning

Foundation Underpinning, using drilled footings or pressed piling has been used in the Houston area for a number of years. The construction of a drilled footing consists of drilling a shaft, about 12-inches in diameter (or larger) constructed underneath the grade beam. The shaft is generally extended to depths ranging from 8 to 12-feet below existing grade. The bottom of the shaft is then reamed with an underreaming tool. The hole is then backfilled with steel, concrete, and the grade beams are jacked to a level position and shimmied to level the foundation system.

In a case of pressed piling, precast concrete piers are driven into the soils. These pier attain there bearing capacity based on the end bearing and the skin friction. In general, the precast concrete units are about 12-inches in height, six-inches in diameter and jacked into the soil. It is important the precast pier foundations are driven below the zero movement line to resist the uplift loads as a result of underlying expansive soils. Some of these jacked piles may consist of perma-piles, ultra piles, cable lock piles, etc.

The use of drilled footings/pressed piles should be determined by a geotechnical/structural engineer. Each one of these foundation systems have their pluses and minuses. Neither of these foundations can resist upward movement of the slabs. In general, they only limit the downward movement of the slabs. The pressed piles may not resist uplift loads as a result of skin friction of expansive soil if they are not connected with a cable or reinforcement. Therefore, if the units are not properly connected, they will not provide any tensile load transfer. The construction of each method should be monitored by an experienced geotechnical/structural engineer.

Helical piles which consist of Helical auger drilled into the soils provide a good method for underpinning, especially in the areas where sand, silts, shallow water table or caving clays are present. The helical piles are drilled into the soils until the desired resistance to resist the compressive loads are achieved. The augers are then fitted with a bracket and jacked against the grade beams to lift and to level the foundations.

Interior foundations may be required to level the interior of the residence. This can be accomplished by installing interior piers, tunneling under foundations and using pressed piling, or the use of polyurethane materials injected at strategic locations under the slab. The use of tunneling to install interior piers may introduce additional problems, such as inadequate compaction of backfill soils under the slab. However, the author has never encountered such a problem with pressed piling.

Partial underpinning is used in the areas where maximum distress is occurring under a slab. The use of full underpinning which includes placement of piers/pressed piling underneath all foundations is not necessarily a better method of stabilizing foundations. Many foundations are performing satisfactorily with partial underpinning. In the event that foundation underpinning is used, the home owners should put into place a foundation maintenance program to prevent additional foundation distress as a result of changes in subsoil moisture content.

Moisture Stabilization

Moisture Stabilization can be an effective method of stabilizing subsoil shrink swell movements in the ares where expansive soils are present. This method of stabilization is not effective in the areas where sands are present such as north of Harris County in areas such as Kingwood, Fairfield and The Woodlands. This method could be effective in the areas of highly expansive soils such as Tanglewood, Bellaire, West University, River Oaks, South Houston, and Southwest Houston. The method uses a porous pipe that is placed around the perimeter of the foundation and is connected to a water pressure system. A timer turns the water on and off depending on the subsoil moisture conditions, the moisture conditions around the perimeter of the house are monitored by moisture sensors. In general, the purpose of the system is to stabilize the moisture content around the slab to a uniform condition; therefore, minimizing the extremes of shrink and swelling problems. As it was mentioned earlier, the use of this method can result in major problems in the areas where sandy soils are present.

Moisture Barriers

Moisture barriers can be used to isolate subsoil moisture variations in the areas where expansive soils are present. This can be as a result of surface water, groundwater, and tree root systems. In general, a moisture barrier may consist of an impermeable filter fabric, placed just outside the grade beams to depths ranging from five- to seven-feet. The moisture barriers can be horizontal or vertical. A horizontal moisture may consist of a sidewalk attached the exterior grade beams. The waterproofing between the moisture barrier and the exterior grade beams are very important. The connection should be completely sealed so that surface water can not penetrate under the horizontal moisture barrier. In general, it may take several years for the moisture barriers to effectively stabilize the moisture content underneath the floor slabs. A minimum vertical moisture barrier depth of five-feet is recommended.

Chemical Stabilization

This method of foundation stabilization has not been used in the Houston area routinely; however, it has been used for many projects in Dallas and San Antonio areas. The purpose of chemical stabilization is to chemically alter the properties of expansive soils; thus, making it non-expansive. In a chemical stabilization technique, the chemicals which may consist of lime or other chemicals are injected into the soil to a depth of about 7-feet around the perimeter of the structure. The chemical stabilization may (a) chemically alter the soil properties, and (b) provide a moisture barrier around the foundation. In general, this type of stabilization is effective when the chemicals are in intimately mixed with the soil. This can occur in soils that exhibit fissured cracks and secondary structures. This method of stabilization is not effective in the areas where soils do not experience significant cracking.

Regardless of what method of foundation stabilization is used, the homeowner maintenance with respect to proper drainage and landscaping is extremely important for success of any method.

RECOMMENDED QUALIFICATIONS FOR THE GEOTECHNICAL ENGINEER

We recommend that the geotechnical engineer should have the following qualifications:

- Engineer must have several years experience in the same geographical area where the work will take place (i.e. proven designs in a given area).

- A Professional Engineer (P.E.) designation with a geotechnical engineering background should be required. A civil engineer with a master's degree or higher is preferred. The civil engineer must have a geotechnical engineering specialty.

- The geotechnical engineering firm must have a A2LA Laboratory certification in geotechnical engineering.

- The firm must have professional liability insurance with errors and omissions.

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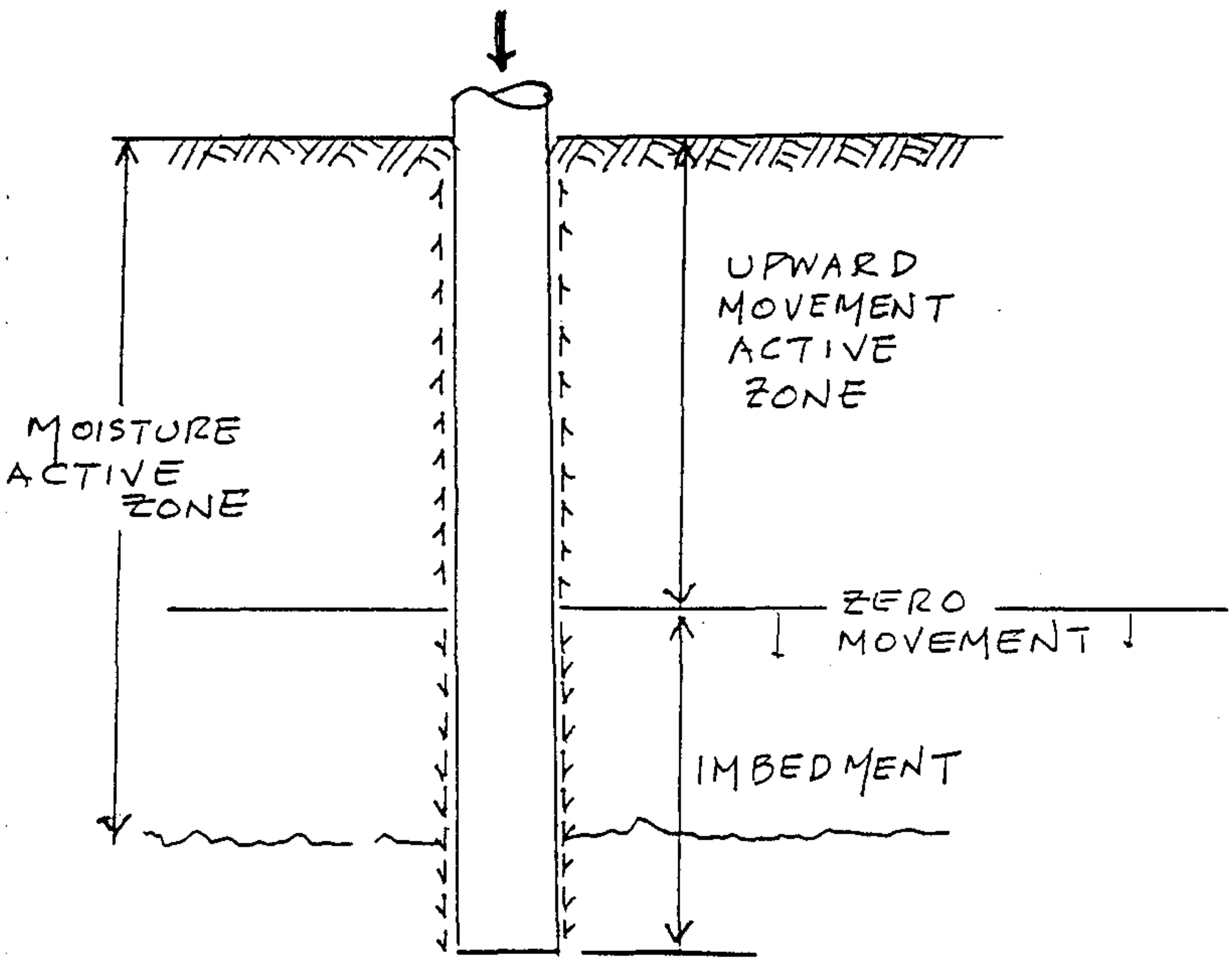
DESIGN CONDITIONS: UPLIFT



From Dr. Lytton

FOUNDATION DESIGNS FOR TRACT HOMES

By Lowell Brumley, P.E.

INTRODUCTION:

By definition, the term "tract" is used to reference a stretch, extent, area, or a definite region of the anatomical parts of the body, a particular time period, an extent of water or an extent of land. When used in conjunction with residential construction, a tract home is generally considered a residence which is built in a newly developed subdivision or area where a reasonably large number of new homes are being built by one or two builders. These builders use a series or group of house plans from which they will construct the homes. The same plans generally are built repetitively, until the subdivision, section, or housing tract is completely developed. This type of construction was generally developed to allow the builder to reduce and control costs and thereby provide affordable housing for a greater number of people.

HISTORY:

Originally a large majority of affordable homes were constructed with pier and beam foundation systems. In a typical home, the piers would consist of short small concrete piles which extended 2 to 6 feet into the ground, or many times a series of flat concrete block pads were placed on the existing grade, and the house would rest on concrete or hadite blocks stacked vertically above the pads.

The first floor structure would then be constructed with a series of wooden girders, beams, and floor joists. This type of system was generally installed by rule of thumb (what worked before should work again), and the relative success of the home built, related directly to the builder's general experience.

More specifically, in Texas, in the early 1900's, frame dwellings were constructed on bois d' arc posts embedded in the ground; it was an accepted fact that these homes would move around, and a sticking door or a rip in the wall paper were accepted occurences. This type of flexible framing system was used extensively in expansive soil areas prior to 1915.

During the 1920's small homes with brick veneer exteriors gained a foothold and soon became a standard. By the 1930's brick veneer buildings had spread across the country and, in areas where expansive soils were present, cracking in the walls became prevalent. Generally, these cracks were blamed on bad construction without any regard to the soils. The role of soil movement was not yet recognized as a major contributing factor.

In the early 1930's residential construction came to a stand still as the Depression rolled across the country. In the late 1930's home construction increased, with brick veneer construction continuing to gain in popularity. However, once again no real improvements were made to prevent problems in expansive soils, as the problems encountered in the 1920's had long since passed from memory.

The 1940's brought about the use of slab-on-ground construction, as builders discovered that a concrete slab placed on the ground could be built more cheaply than a "crawlspace" foundation. This type of construction spread in the 1940's, slowed during World War II and came back strongly after the War. The construction and design of these foundations evolved more by trial and error than any theoretical design approach. Millions of houses, funded with V.A. and F.H.A. loans, were built with this rule of thumb type construction, until in the 1950's, the failure rate of these homes warranted the government's attention. The Building Research Advisory Board (BRAB) of the National Research Council was asked to study the problem and find a solution. After a few interim recommendations, the BRAB Report No. 33 was published in 1968. This report was the first widely accepted publication to give definitive design guidelines for residential construction. It quickly became the standard for residential design and remained so until the mid 1980's.

Four major contributions can be derived from the BRAB report:

1) Four basic slab types were defined:

   A. "Unreinforced" which is a Type I.

   B. "Lightly reinforced" against curing shrinkage and temperature cracks, which is a Type II.

   C. "Reinforced and stiffened" which is a Type III.

   D. "Structural" (which is not supported by the ground), which is a Type IV.

2) The need for extensive research was mandated. One of the programs which sprang from this mandate included the studies performed in the 1970's at the University of Texas at Arlington. During this study, several foundation design types were used to construct several residences, and these homes were analyzed over a period of years.

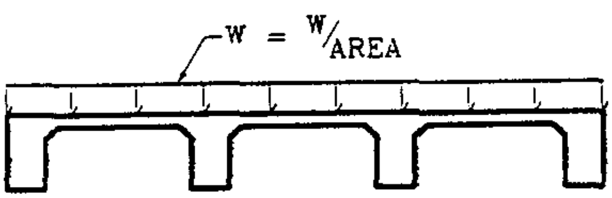
3) Recognition that the soil, slab, and super structure must all be considered in a single interacting relationship was finally brought to the forefront.

4) A rational design approach was presented, which could be used

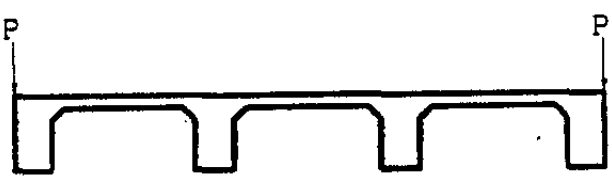
with relative ease to derive design values, while research and development were being continued.

In the 1960's, and 1970's home building experienced an incredible expansion as low energy prices and high demand for housing combined. Expansion in the Texas markets was exceptionally high, fueled by the fact that housing prices in Texas were well below the national average for major cities. During this period, new materials, construction techniques, and concepts were introduced into home building. Many of these were introduced without considering their lack of any history of performance or any proper research. Their use was predicated more on the phrase "is it cheaper" than "will it work better". The name of the game was "economy" and by the late 1970's, the quality of materials and workmanship had reached a point where large numbers of homes were not performing adequately. However, several good things were generated in the midst of this expansive construction boom. Among these were The Federal Housing Administration's 79g requirements for residential construction, and two new design procedures, for slab-on-grade design: These were "The Design of Slab on Ground Foundations", by the Wire Reinforcement Institute and Concrete Reinforcing Steel Institute, 1981 Edition, and "The Design and

Interestingly, in the development of rational design approaches, one or more of these load conditions is neglected depending on which procedure is being used. For instance, the BRAB Design Procedure virtually ignores the effects of concentrated loads and uses a large uniform load which consists of the toal building weight, divided by the square feet of slab area (the thought being that this is justified by the simplified design procedures and equations used). On the other hand, when calculating the stress conditions for flexure, shear and deflections of a foundation, the PTI Design Procedure totally ignores the uniform loads placed on the slab and considers only the perimeter concentrated loads.



'BRAB' DESIGN LOAD



'PTI' DESIGN LOAD

DESIGN CRITERIA

The design formulas used in both procedures generally include:

1. Load Criteria from the upper structure.
2. The overall Length of the slab or a portion thereof.
3. The relative stiffness of the slab and beam system.
4. Soil parameters such as clay content and plasticity.
5. Climatic conditions.

However the following equations show just how differently the same problem can be viewed, over the course of just a few short years.

Basic Design Equations Derived for BRAB Procedure (1968)

$$150 \text{ lbs/ft}^2 \leq \overline{w} \leq 200 \text{ lbs/ft}^2$$

while $S_b \leq 16$ ft. The effective soil reaction then is

$$q = \frac{\overline{w} S_b (1 - C)}{C}$$

The maximum shear

$$V_{max} = \frac{\overline{w} S_b L}{2}$$

where L is the actual length of the slab.

The maximum moment

$$M_{max} = 1.5 \overline{w} S_b L_{eff}^2 (1 - C)$$

where L_{eff} is the length L or 40 ft. whichever is least. The assumption is that lengths of over 40 feet do not contribute to increased moment or increased deflection.

Basic Design Equations for PTI Procedure - (1982)

A.2.1 Center Lift Design

A. Moment in the Long Direction

$$M_\ell = A_o \left[B(e_m)^{1.238} + C \right]$$

where

$$A_o = \frac{1}{727} \left[L^{0.013} (S)^{0.306} (d)^{0.688} (P)^{0.534} (y_m)^{0.193} \right]$$

and for

$$0 \leq e_m \leq 5 \quad B = 1 \quad C = 0$$

$$5 < e_m \quad B = \left(\frac{y_m - 1}{3} \right) \leq 1.0 \quad C = \left[8 - \left(\frac{P - 613}{255} \right) \right] \left(\frac{4 - y_m}{3} \right) \geq 0$$

B. Moment in the Short Direction

$$M_s = \left(\frac{58 + e_m}{60} \right) M_\ell$$

C. Shear in the Short Direction

$$V_s = \frac{1}{1350} \left[(L)^{0.19} (S)^{0.45} (d)^{0.20} (P)^{0.54} (y_m)^{0.04} (e_m)^{0.97} \right]$$

D. Shear in the Long Direction

$$V_\ell = \frac{1}{1940} \left[(L)^{0.09} (S)^{0.71} (d)^{0.43} (P)^{0.44} (y_m)^{0.16} (e_m)^{0.93} \right]$$

E. Differential Deflection

$$\beta = \frac{1}{12} \sqrt[4]{\frac{E_c I}{E_s}}$$

$$\Delta_o = \left[\frac{(y_m L)^{0.205} (S)^{1.059} (P)^{0.523} (e_m)^{1.296}}{380 (d)^{1.214}} \right]$$

$$\Delta_c = e \sqrt{\frac{6400}{\beta L}}$$

$$\Delta = \Delta_o \left[\frac{100 - \Delta_c}{100} \right]$$

A.2.2 Edge Lift Design

A. Moment in the Long Direction

$$M_\ell = \left[\frac{(S)^{0.10} (d e_m)^{0.78} (y_m)^{0.66}}{7.2 (L)^{0.0065} (P)^{0.04}} \right]$$

B. Moment in the Short Direction

$$M_s = (d)^{0.35} \left[\frac{19 + e_m}{57.75} \right] M_\ell$$

C. Shear (Both Directions)

$$V = \left[\frac{(L)^{0.07} (d)^{0.40} (P)^{0.03} (e_m)^{0.16} (y_m)^{0.67}}{3.0 (S)^{0.015}} \right]$$

D. Differential Deflection

$$\Delta = \left[\frac{(L)^{0.35} (S)^{0.88} (e_m)^{0.74} (y_m)^{0.76}}{15.90 (d)^{0.85} (P)^{0.01}} \right]$$

A.2.3 Design for Compressible Soils

A. Moment in the Long Direction

$$M_{cs\ell} = \left(\frac{\delta}{\Delta_{ns\ell}} \right)^{0.50} M_{ns\ell}$$

where

$$M_{ns\ell} = \left[\frac{(d)^{1.35} (S)^{0.36}}{80 (L)^{0.12} (P)^{0.10}} \right]$$

$$\Delta_{ns\ell} = \left[\frac{(L)^{1.28} (S)^{0.80}}{133 (d)^{0.28} (P)^{0.62}} \right]$$

δ = Expected settlement, in inches, due to the total load expressed as a uniform load; reported by the Geotechnical Engineer.

B. Moment in the Short Direction

$$M_{cs_s} = \left(\frac{970 - d}{880} \right) M_{cs\ell}$$

C. Shear in the Long Direction

$$V_{cs\ell} = \left(\frac{\delta}{\Delta_{ns\ell}} \right)^{0.30} V_{ns\ell}$$

where

$$V_{ns\ell} = \left[\frac{(d)^{0.90} (PS)^{0.30}}{550 (L)^{0.10}} \right]$$

D. Shear in the Short Direction

$$V_{cs_s} = \left(\frac{116 - d}{94} \right) V_{cs\ell}$$

E. Differential Deflection

$$\Delta_{cs} = \delta \exp(Z)$$

where

Δ_{cs} = Expected Differential Deflection, in Inches

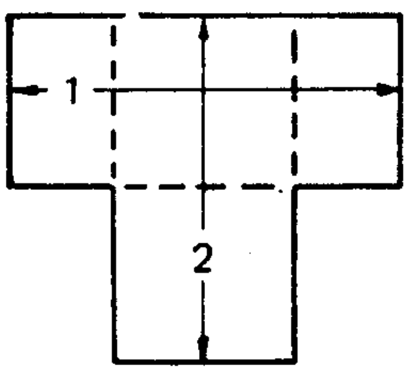
Z = $1.78 - 0.103(d) - 1.65 \times 10^{-3} (P) + 3.95 \times 10^{-7} (P^2)$

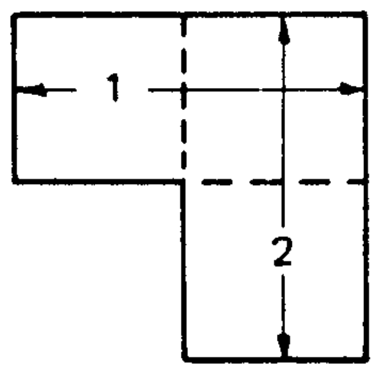
$\exp(Z)$ = Natural base e raised to the exponent Z, i.e. e^Z

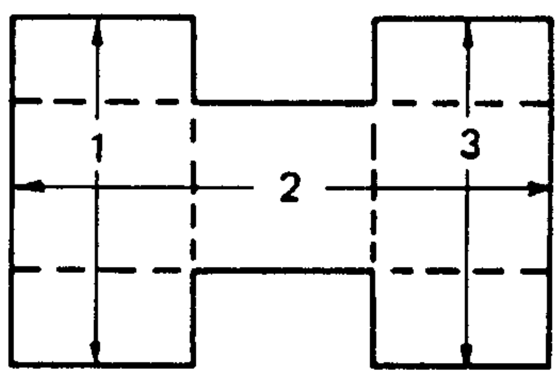
The additional complexity of the PTI Procedure is based on the larger number of interacting variables being considered. Both the BRAB and PTI procedures were empirically generated (i.e. the design formulas have been generated from observed data and computer generated models), and it has been our experience that as long as you stay within the rational boundaries of both, the designs based either procedure generally work well, as long as they are properly implemented.

SLAB CONFIGURATION:

In all rational design approaches used today, the foundation footprint is designed as a series of overlapping rectangular sections.



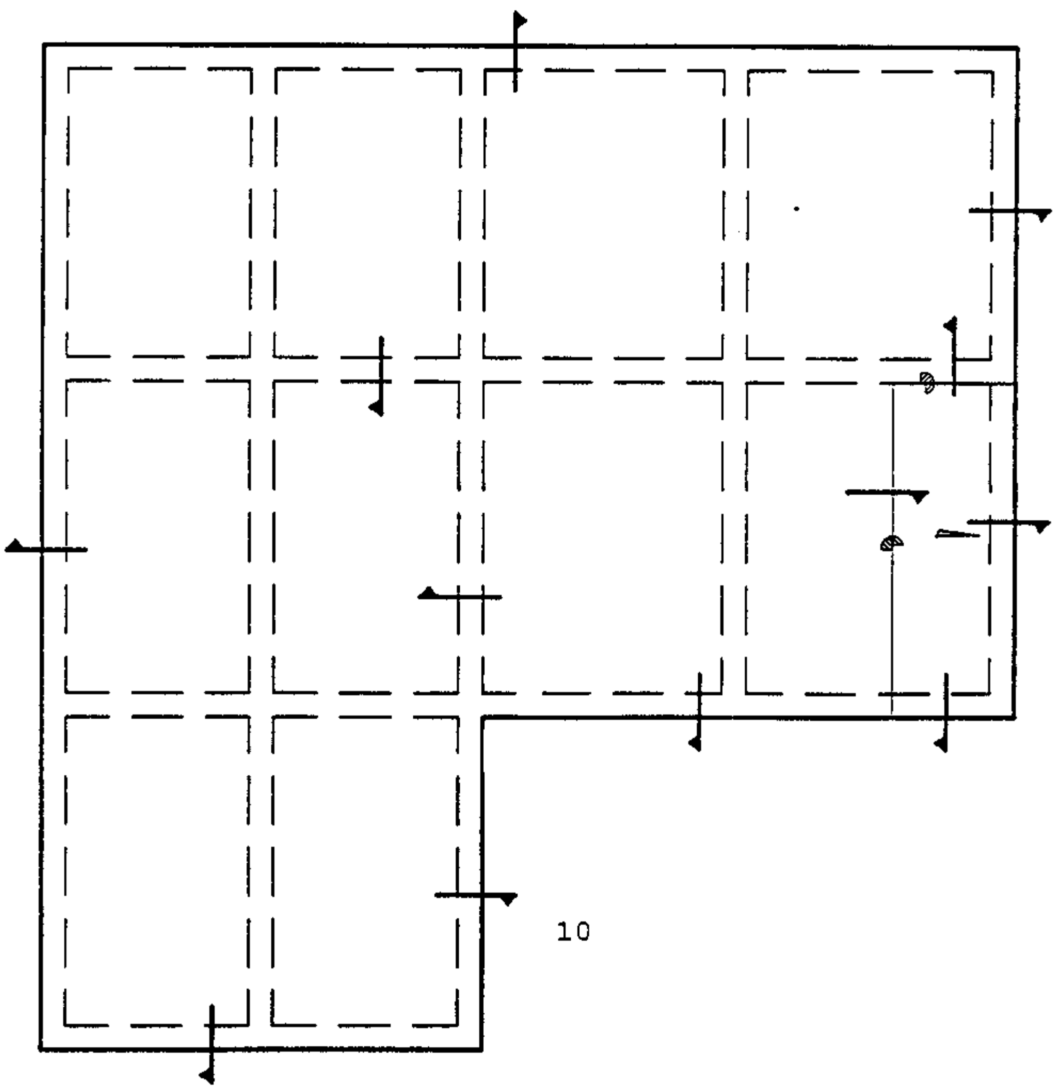




Each of these rectangles is designed separately with their own number of beams and reinforcement, and then the overlapping areas are merged, and the more conservative design is used for the areas of overlap. In this way, a good, solid, conservative foundation design should be achieved.

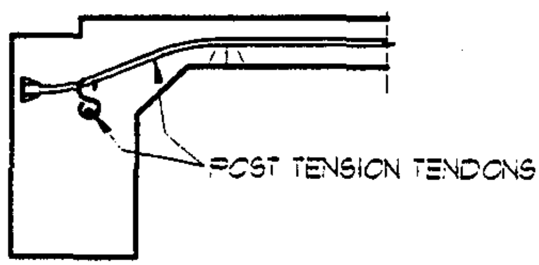
Foundation Configuration and types of reinforcing systems used for tract home construction:

A general foundation configuration layout is shown below. The dashed lines indicate the location of interior and exterior stiffening beams.



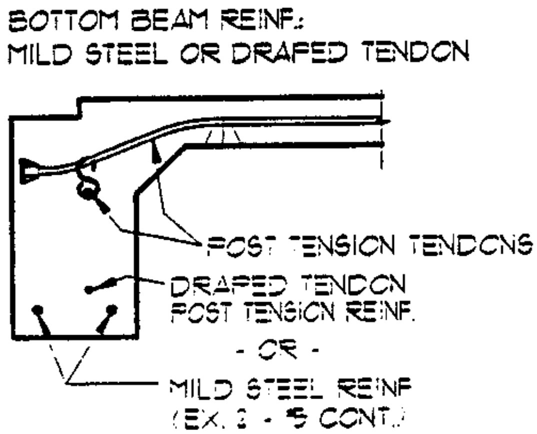
Several various reinforcing systems have been designed and used for slab on grade foundations:

Type A: Post Tension Reinforced:



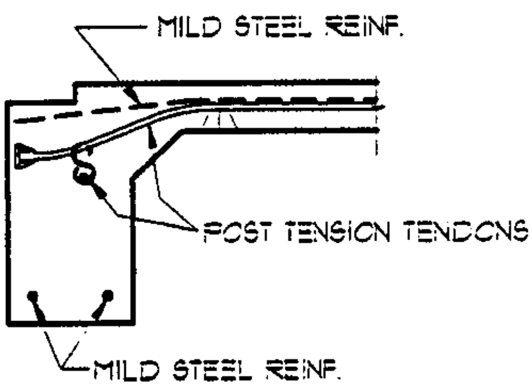
This type of reinforcing system assumes a solid monolithic concrete slab will be placed and compressed. It should be placed such that the soils will induce only moderate edge lift conditions (which the tensile strength of the concrete can handle), so that eventually the long term center heave or down warping condition will control.

Type B: Post-Tension Reinforced with Bottom Beam Reinforcement:



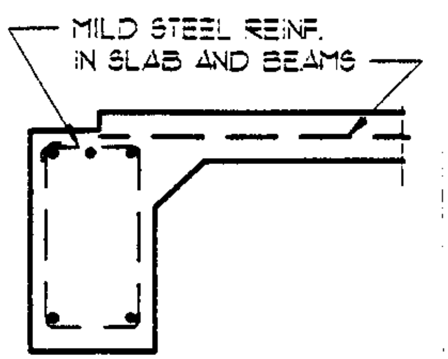
This system assumes a solid monolithic section will be placed on soils which will induce not only long term center heave but which are variable enough that a cracked section may occur at the base of the beams, if they are unreinforced.

Type C: Post Tension with Additional Steel for Crack Control:



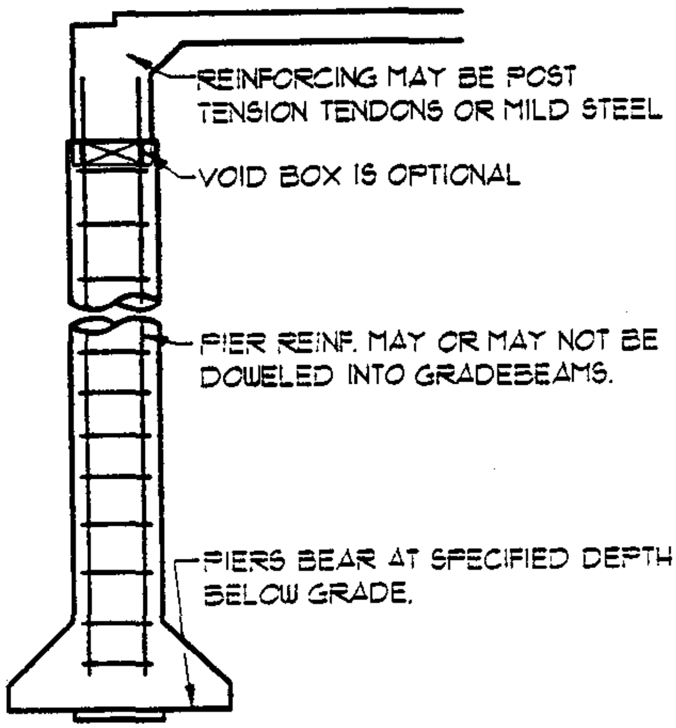
This system allows a monolithic design approach to be used, however it assumes that a cracked condition inevitably will occur. It allows for both substantial cupping and down warping stresses (center heave, edge lift and settlement), as well as a number of construction variables.

TYPE D: Conventionally Reinforced Slab on Grade:



This foundation essentially performs much the same as a Type C, however, costs generally are greater.

Type E: Slab on Grade on Piers:



This type of system is still very much affected by expansive bearing soils, as the piers only prevent downward movement of the foundation. (They will not prevent the soil from lifting up on the slab!!!) This is a good choice where large settlements are of concern.

In the Texas market, the majority of tract homes we see being constructed today use Type B and Type C foundation systems. The use of these two types appears to be predicated on several items:

1. Post tensioning is the standard reinforcing system used by volume builders.

2. Due to the vast number of foundations placed in the past 20 years a good deal of experience has been gained with these systems.
3. Economy can still be achieved even though the end product user (the buyer) is more quality demanding.
4. The builder has become more aware of his long term obligations as the useful service life of a home has steadily increased.

These two foundation types are relatively tolerant of a great number of the inherent unknowns found in building homes on expansive soils. Also by incurring only modest cost increases, they can be adapted to the differing climatic and terrain conditions found in Texas. They give you an excellent return on money spent, when viewing overall construction costs, follow up customer service costs, and long term repair costs. While no foundation system is perfect, the success rate of these design types is very high.

WHAT SLAB ON GRADE FOUNDATIONS CAN AND CANNOT DO:

Slab on Grade Foundations Can:

1. Carry the imposed loads of the upper structure.
2. Prevent excessive flexural bending in the foundation thereby limiting problems in the upper structure and finish materials.

3. Prevent differential settlement across a vertical plane of both the slab and upper framing system.
4. If properly installed and maintained, perform well for the serviceable life of the structure.

Slab on Grade Foundations Cannot:

1. Prevent the soils from causing the foundation and house to slope. This is a soil stability problem and should be addressed as such.
2. Prevent a detached garage from moving horizontally or vertically with respect to the house foundation or upper structure. These are two separate structures and foundation systems, and must be addressed as such.
3. Withstand the cumulative effects of improper installation. (i.e. improper pad and lot preparation, shallow beam placement, improper reinforcement, bad drainage, etc.).
4. Withstand the effects of a long term plumbing leak.
5. Withstand long term, the effects of improper maintenance (i.e. bad drainage, lack of watering or improper watering).
6. And finally, a slab-on-ground foundation cannot satisfy a home buyer which expects a perfect, maintenance free house.

FINAL COMMENTS:

The foundation design and construction procedures for residential tract construction have evolved and improved greatly over the last 20 years and, in our estimation, will continue to improve as new research and products come forward. One of the reasons for the increased success we have had, is due to the interactive and coordinated efforts of the soils engineer, the design engineer and the builder, in communicating, comparing notes, and educating each other. In this way, we have been able to more properly define the areas of responsibility for all parties involved, including those of the buyer. Ultimately the buyer must be educated about the product he is buying and the inherent responsibilities of ownership. Our job, as an industry, is to give him a quality product to start with.

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1. ASCE 76 Design and Construction of Light Foundations on Expansive Clay Soils.
2. "Comments on Foundations" by Authur R. Poor, PHd, P.E.
3. Interim Criteria for Slab on Ground Concrete Foundations For Residential Construction TR-1-75 by Ernest L. Buckley, P.E, PHd and H.F. Ball, P.E.
4. Design and Construction of Post-Tensioned Slabs-on-Ground - Post Tensioning Institute, 1982 Edition.
5. BRAB Report No. 33 Recommendations, 1968.

STATE-OF-PRACTICE OF FOUNDATION DESIGN FOR CUSTOM HOMES

by

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President November 1992 - Present
National Structural Engineering, Inc.

Structural Engineering consulting for the residential, commercial and light industrial industries. This includes framing and foundation designs and drawings and follow-up field construction reviews. Typical projects include:

- Over 1000 residences in Houston and throughout the country
- Churches, temples and schools
- Foundations for cranes, tanks and industrial equipment
- Restaurants, office buildings and other miscellaneous commercial buildings

Partner June 1989 - November 1992
Structuneering Inc.

Structural Engineering consulting for the residential and low rise commercial industries. This included framing and foundation designs and follow-up field inspections. Rigid frame/metal building design for the commercial industry.

Chief Engineer & General Manager October 1985- May 1989
Commercial Carports, Incorporated

Structural design of steel and combination wood/steel covered parking facilities and open sided buildings.

Project Engineer January 1985- September 1985
IMI Engineering Company

Contract designed and managed turnkey onshore and offshore workover and drilling rig packages.

Project Engineer/Sales (part-time) January 1984-January 1985
Vulcan Foundation Repair

Inspection and repair recommendations of residences and commercial buildings with foundation problems.

Staff Engineer December 1981-December 1984
Welltech, Incorporated

Designed and managed the fabrication of projects involving the structural, mechanical and hydraulic drilling and workover systems.

Project Engineer November 1979-November 1981
National Steel Products Company/ Stran Steel

Structural design of metal buildings and grain storage facilities.

EDUCATION

University of Houston	M.B.A.	December 1984
Carnegie-Mellon University	B.S. Civil Engineering	May 1976

Registered Professional Engineer in the State of Texas and approximately forty additional states including the National Council of Engineering Examiners.

PROFESSIONAL AFFILIATIONS

American Society of Civil Engineers
Post Tensioning Institute
American Concrete Institute
Brick Institute of America
National Concrete Masonry Association
Concrete Reinforcing Steel Institute
American Plywood Association
Foundation Performance Committee

STATE-OF-PRACTICE OF FOUNDATION DESIGN FOR CUSTOM HOMES

A. INTRODUCTION

Most of the soils in Houston and surrounding areas are expansive. The shrinking and swelling of expansive soils is analogous to a sponge. When it gets wet it expands and when it dry outs it shrinks. The soils that are closest to the surface are affected the most by the seasonal moisture changes such as droughts and rains. If the soils that a foundation sit on shrink and swell, then the foundation may move down and up, respectively. The deeper the piers or grade beams are below the surface the less the foundation should be affected by the seasonal moisture changes. Expansive soils are defined as those with a plasticity index above 20 (Liquid Limit less the Plastic Limit equals the plasticity index or PI). In some areas of Houston the PI can exceed 70. Please note that all foundations may move, regardless of the foundation type used.

A site and geotechnical investigative report should be obtained in all situations. The end client must be made aware of the risks involved in doing a foundation without a site and geotechnical investigative report, but invariably the liability will fall to the structural engineer.

Every foundation should be designed for a specific site. The structural engineer should be made aware of the site conditions such as faults, old pools and septic tanks, vegetation and slope by the geotechnical investigative report, the architect and/or builder. In addition, the site should be visited by the structural engineer if adverse conditions are known to exist (for example, sloped sites). In designing a house on a sloped site the structural engineer should have a slope stability analysis from the geotechnical engineer determining pier depth, retaining wall requirements, etc. If there is an active fault on the site, special design techniques must be used such as cantilevering above ground from one side of the fault over to the other.

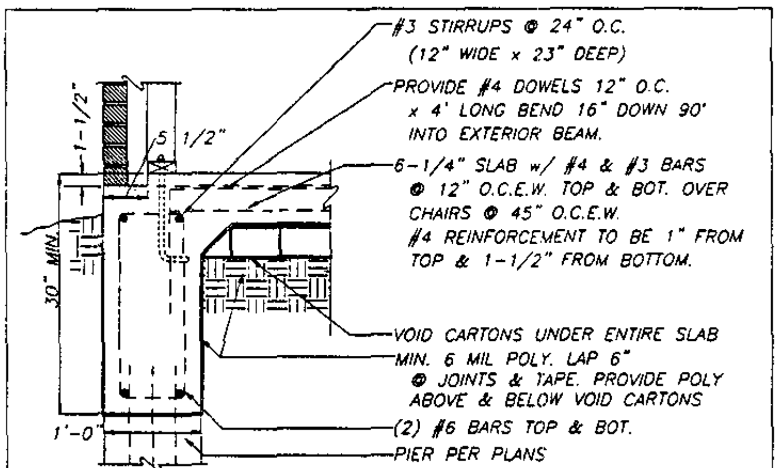
Tree removal on a site with expansive soils need special consideration because of the potential for upheaval. Everyone involved in the project, especially the end client, should be aware of the risks.

Everyone involved in the design and building process should be aware of the various foundation types and the inherent risks in each. The risks versus costs should be discussed with the end client, as they should be involved in the decision making process wherever possible. For example, a floating post-tensioned or "waffle" slab on grade may move more than a slab with piers, however, it costs much less. The structural engineer must be familiar with the various design methods of each of the foundation types he designs.

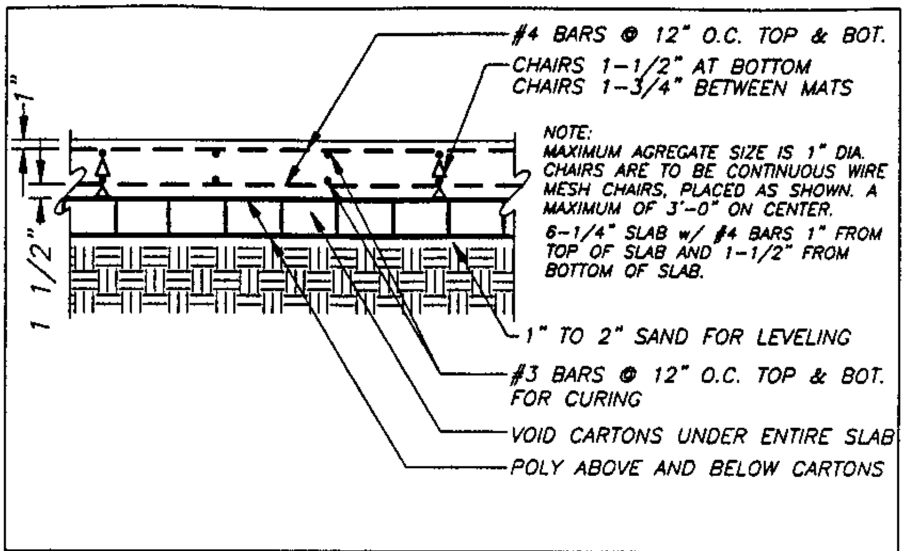
B. THE FOLLOWING ARE VARIOUS TYPES OF FOUNDATIONS THAT CAN BE USED IN CONJUNCTION WITH EXPANSIVE SOILS. THE FOUNDATIONS ARE LISTED IN ORDER FROM LEAST POTENTIAL MOVEMENT/RISK TO MOST POTENTIAL MOVEMENT/RISK:

1) **Structural slab or crawl space**: Minimizing movement is what a structural slab or crawl space foundation achieves. The slab or floor is designed so it does not come into contact with the expansive soils that change moisture content and volume due to seasonal rains and droughts. The structural slab has cardboard void cartons separating it from the surface soils. The void cartons range from 4" to 8" deep depending on the expansiveness of the soils. The more expansive the soil (the higher the Plasticity Index) the deeper the void carton. The slab is called a "structural slab" because it is designed to span between grade beams as in a parking garage. The grade beams are supported by drilled under-reamed piers founded below the active moisture zone at a depth of 9'0" to 20'0" below natural grade. The depth is a function of how expansive the soils are, the strength of the soils and the location of trees and sands. The expansive soils at this depth maintain a constant moisture content not affected by the seasonal moisture changes and, thereby, should not move up and down like the soils near the surface. According to geotechnical engineers the "structural slab" is usually the best type of foundation to be used in conjunction with expansive soils because these foundations minimize upheaval and settlement.

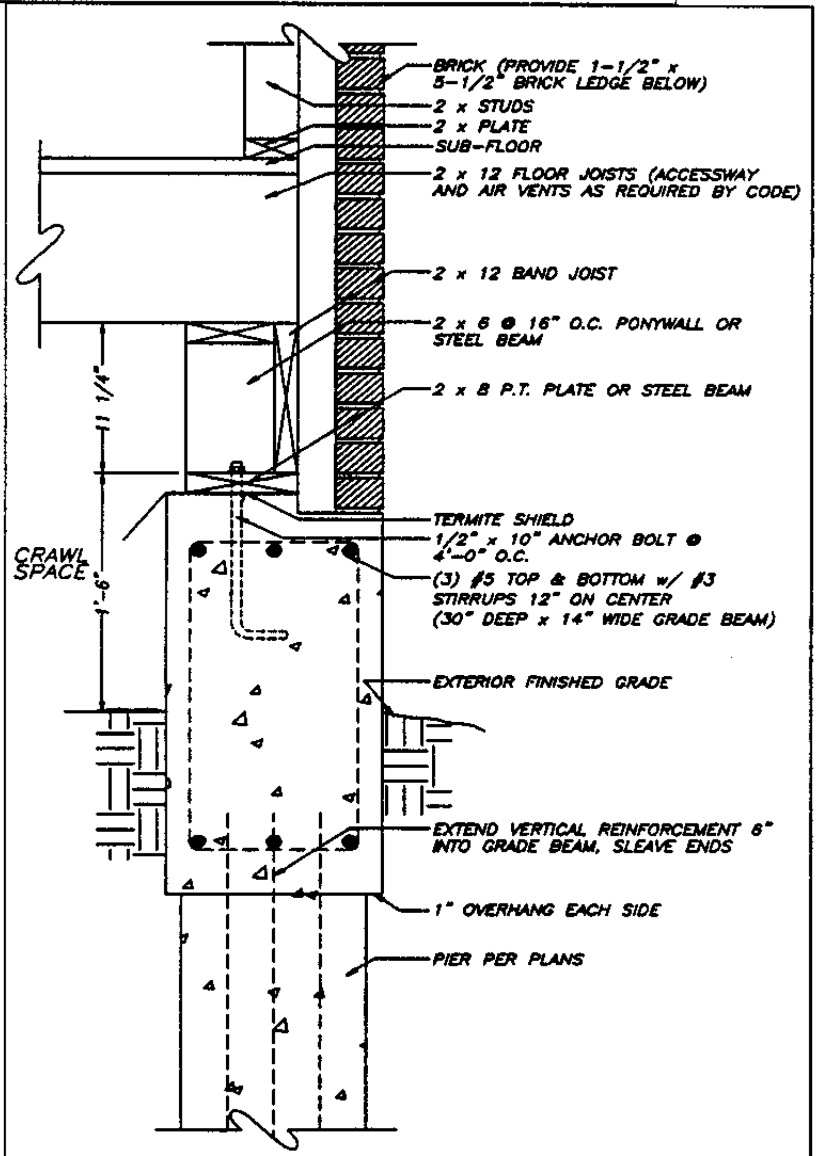
   Following is a typical exterior grade beam detail for a structural slab; a cross section through a structural slab; and a typical exterior grade beam detail for a crawl space foundation:



STRUCTURAL SLAB EXTERIOR GRADE BEAM DETAIL



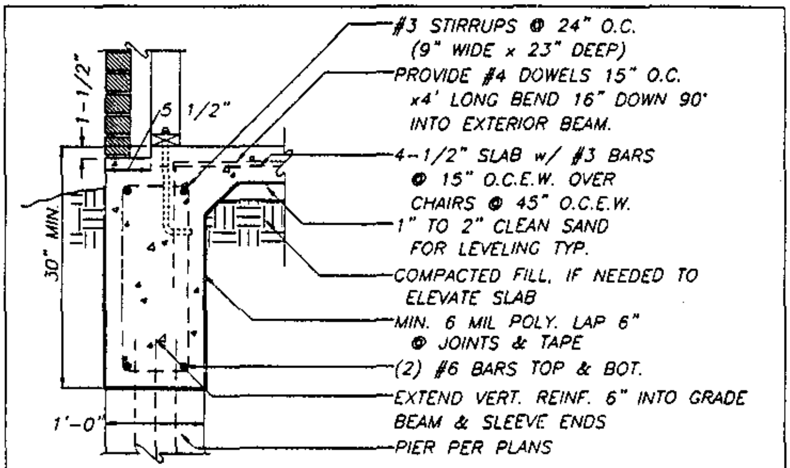
STRUCTURAL SLAB SECTION



CRAWL SPACE PERIMETER FOOTING

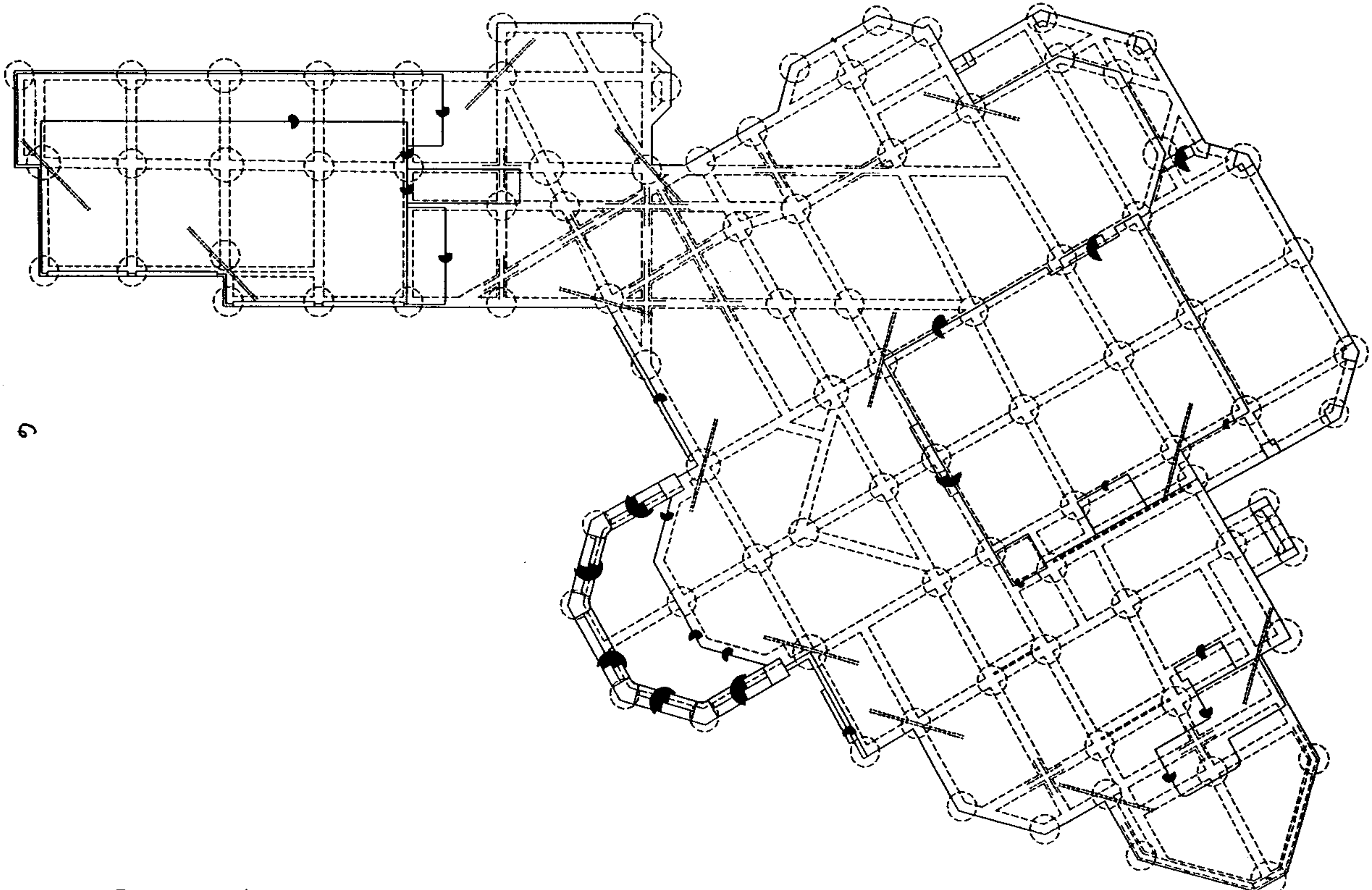
2) **Slab-on-fill with drilled piers:** The slab portion of the foundation sits on and is supported by non-expansive structural compacted fill (sandy clays with a PI between 8 and 20) which acts as a buffer zone between the expansive soils and the slab. This fill reduces the potential movement of the foundation. For example: soils with a PI of 60 and three feet of select structural fill (PI below 20) will have an *effective* PI of 48. The foundation should be designed as a "waffle" slab (beams forming a grid-like pattern), using the *effective* PI, to reduce the potential upward movement (upheaval). With higher PI soils the grade beams should be deeper and/or closer together. The piers are usually not tied to the grade beams with a "waffle" slab design. Piers are used to minimize downward movement (settlement).

Following is a typical exterior grade beam detail for a slab-on-fill with drilled piers:



EXTERIOR GRADE BEAM FOR SLAB-ON-FILL WITH PIERS

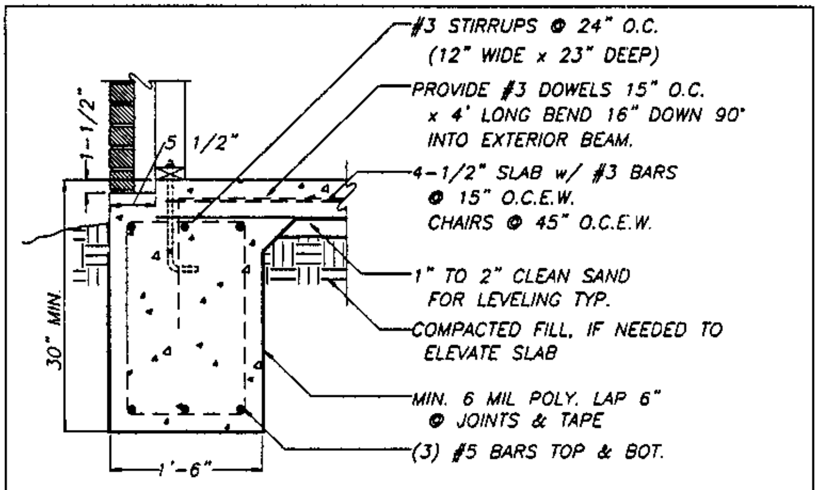
Continuity of grade beams should bear special consideration in soils with expansive soils, even in foundations with piers. Using continuous footings in a grid-like fashion (i.e. a "waffle" slab) will help to reduce differential movement. Even slabs with angled sections or bay windows can be designed with continuous grade beams to supply some extra rigidity when movement occurs. Please see the following page for an example of a complicated foundation utilizing continuity:



Complicated Slab-on-Fill with Drilled Piers

3) **"Waffle" or post-tensioned floating foundations:** This is the most common type of foundation used in the Houston area. The entire slab is supported by the surface soils which are susceptible to the seasonal moisture fluctuations and movement. The foundation is designed as a "waffle" slab (beams forming a grid-like pattern). Although the foundation will move, differential deflection should be minimal. The subgrade and any other fill used to elevate the slab must be compacted to 95% compaction.

   a) The "conventional" floating or "waffle" slabs are reinforced with steel rebar. These slabs can be designed per the "Design of Slab-on-Ground Foundations" developed by Walter L. Snowden, as specified in the 1994 UBC and 1988 City of Houston Code. If the fill used to elevate the slab is not compacted, the foundation can be designed as a structural slab between grade beams. A typical exterior grade beam detail for a "waffle" slab is shown below:



EXTERIOR GRADE BEAM FOR FLOATING WAFFLE SLAB

   b) The post-tensioned floating slabs are reinforced with post-tensioned cables. These foundations must be designed according to the "Design and Construction of Post-Tensioned Slabs-on-Ground" by the Post-Tensioning Institute.

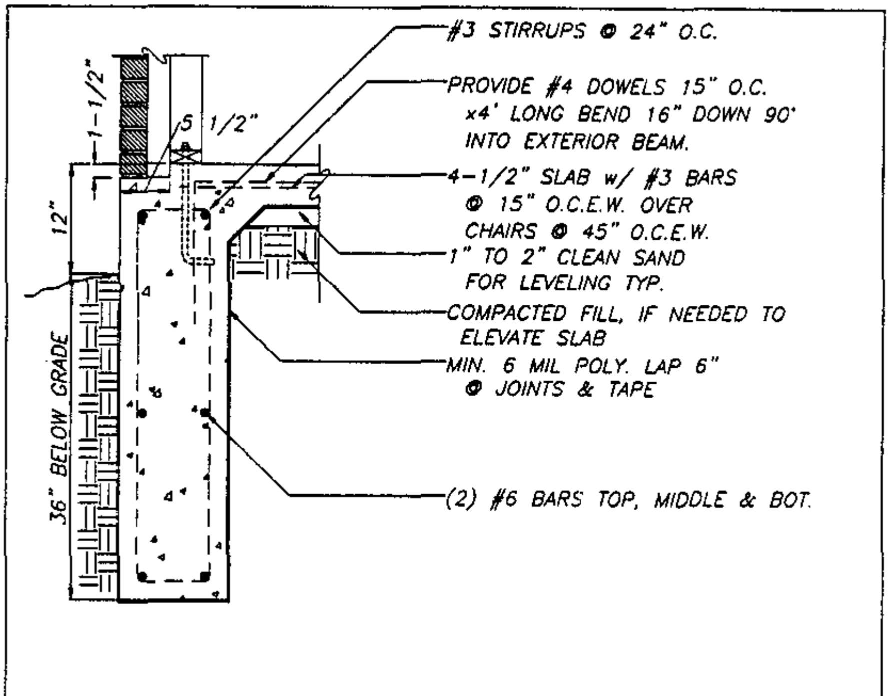
- Please note that all foundations, with the possible exception of a structural slab with deep piers, will **not** resist upheaval that occurs when trees die or are removed.

- Please note that all foundations may move when there is a plumbing leak or poor drainage.

- All concrete foundations crack. It is imperative that the homeowner be aware that some cracking, such as curing cracks, are normal.

C. ITEMS THAT WILL AID IN REDUCING MOVEMENT AND CRACKING IN FOUNDATIONS:

1) Deeper exterior grade beams below final grade will help to reduce moisture changes under the foundation. This will reduce the volume changes in the soils. A typical deep exterior grade beam is shown below:

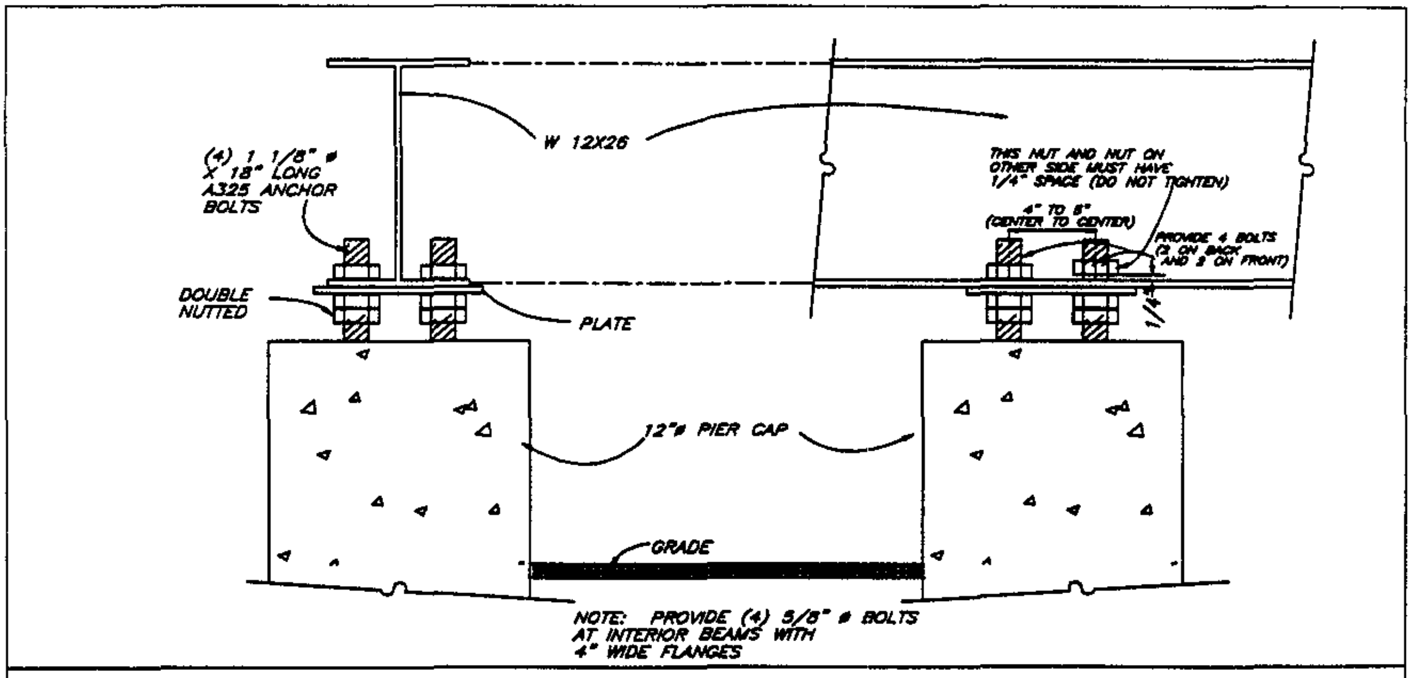


DEEP EXTERIOR GRADE BEAM FOR FLOATING WAFFLE SLAB

2) Provide stiffer slabs
   a) Provide grade beams that are closer together or have more steel
   b) Provide deeper grade beams
   c) Provide a thicker slab with more reinforcement
3) To reduce (not eliminate) temperature cracking in the slab
   a) Use a double mat of slab reinforcement
   b) Add fiber reinforcing to the mix
   c) Use rebar reinforcement instead of welded wire mesh. If welded wire mesh must be used, use a size that is stiff enough to be supported on chairs without much deflection.
4) Compact the subgrade, after scarifying the surface, for all types of foundations partially or fully supported on grade. The subgrade and all additional fill must be tested and approved for compaction by the geotechnical lab.
5) Use deeper piers and a structural slab if there are trees on the site where the foundation is to be installed. Have the Geotechnical lab do borings to 25' and check the depth of root fibers.
6) Remove all the expansive soils to a depth below the active moisture zone and replace with non-expansive structural compacted fill. This method is usually cost prohibitive.

D. OTHER COMMENTS AND SUGGESTIONS

1) Do not use void cartons under the grade beams. It is a channel for water and the use of void cartons may exacerbate upheaval rather than minimize it. Water can travel down the sides of the piers and/or migrate into the soils under the slab, especially when there is bad drainage. Use void cartons under the slab portion of the foundation rather the beam portion of the foundation since the slab comprises about 90% of the foundation in contact with the expansive soils.
2) Use (2) # 6 bars top and bottom in the grade beams instead of (3) # 5 bars top and bottom. When (3) # 5 bars top and bottom are used in a 12" wide beam, and are spliced, there is no room for 1 1/2" concrete aggregate to fit between the bars. Also, since grade beams are typically under load bearing walls and walls sometimes have a plumbing pipe extending from the wall into the grade beam, it would be impossible to have the center reinforcing bar be continuous when using (3) # 5 bars top and bottom. Please note that the total cost (labor plus material) for using (2) # 6 bars top and bottom in the grade beams will be less than that of using (3) # 5 bars top and bottom.
3) Finally, accept that fact that the soils are going to move and make the entire residence adjustable. This can be achieved by using steel beams supported by anchor bolts embedded into drilled piers. The elevation of the steel beam can be adjusted by jacking against the pier caps. Please see the detail below:



ADJUSTABLE FOUNDATION

BIOGRAPHY

Jack Spivey is president of J. SPIVEY & ASSOCIATES, INC., a real estate inspection firm serving the greater Houston area. Mr. Spivey is a Licensed Real Estate Inspector and has been in business since 1987. Prior to that, he was employed for nine years, as Vice President of MFI Associates, an engineering firm which primarily provided foundation design and inspection services to tract and multi family builders, in Houston, Dallas-Ft Worth and San Antonio. He was previously employed as the Division Manager for Slab on Grade Foundations with the Prescon Corporation. Prescon was one of the earliest post tension companies in the United States and was extremely influential in the design and implementation of post tension slab on grade foundations. Mr. Spivey was involved in the introduction of these foundations in early days of "tract building" in the Houston area. His firm J. Spivey & Associates, Inc. currently provides field inspection services for a number of tract builders in the Houston area, as well as inspection and foundation repair design. His firm currently employs some twelve field inspectors as well as a Structural Engineer. Mr. Spivey is a 1970 graduate of the University of Texas at Austin.

INTRODUCTION

"If you'r not going to do it right then just don't do it."

PLATT THOMPSON PE, 1994

Those words by Platt Thompson fairly well sum up the basis of this section of the program. The area of quality control and inspection pertains to doing it right so that you don't have problems. The type of problems which result from poor construction and planning are extremely costly and can certainly reduce or eliminate any hope of profit in home building. Taking this into account the focus of this section of the program is how to do it right the first time.

It is my opinion that the construction of the typical slab on grade foundation is the most complex and demanding element of the entire structure. No other element in the house has as many, and as varied a combination of materials and trades as the foundation. Building a foundation typically involves the supply and coordination of some thirteen trades and services, and five different material suppliers. All this must be done in the correct sequence, with each trade and supplier meshing together to get the foundation make-up to the point that the concrete is ready for placement. The superintendent is much like a symphony conductor waiting for the final movement when the concrete trucks roll up on the job. He has carefully built the supporting structure according the "score" supplied by engineers and architects, he has coordinated all the movements of trades and suppliers and the final moment of truth is at hand. The material that is now to be dealt with is amazingly plastic when it arrives on his job and will be extremely hard in a very short period of time. Therefore, it is essential that everything which he is about to cover with concrete be correct. It is considerably easier to fix a problem with the sheetrock or wall paper than it is to repair a foundation problem. The final movement then involves placing a very heavy plastic substance inside the forms and then curing it correctly. Once the concrete is placed the crescendos begin to fade and the final resolution of form removal and clean-up, stressing, grouting, fine grading and landscaping begins. Each of these is critical to ultimate success of foundation and each contains its own subtle set of problems. It should be remembered that it may be a long time before the fat lady sings, and that aria may be very costly. So it is essential that you make sure that the construction of the foundation is completed according to the plans and specifications and that good construction practice is followed.

As noted by Dick Peverly there are some 117 firms listed under the heading of " Foundation Repair " in the Houston phone book. Each of these firms is dependent upon some type of foundation failure to stay in business. Foundation failures due to poor construction constitute definite percentage of the repair companies market, and it could be posited that all foundation failures are due to some sort of construction problem. However, it is my opinion that a greater percentage of problems are related to site and design than actual construction. It should also be noted that according to Dick Peverly the incidences of failure due to serious construction errors most often occur in the first three to five years of the foundations life. This means that if it is not constructed correctly the homeowner will be made aware of it early and responsibilty for repair will probably fall on the builder. Consequently the need for quality control and inspection will always be part of foundation construction.

In an effort to implement quality control and eliminate foundation failure due to construction the following guidelines are recommended. These are broken into five separate categories related to the sequence of construction. These guidelines are not all inclusive and generally relate to the typical slab on grade construction found in the Houston area.

SITE

A. The initial stage of construction begins with the site and its preparation. Though the site is a minor part of the actual construction it is hugely important to the long term performance of the foundation. The site is the environment that the foundation must exist in and it cannot be ignored or taken lightly. Therefore, the following recommendations are made regarding site considerations.

B. It is essential that a study of the existing soil conditions at the site be made. This means a soil test. Without this data the structural engineer cannot accurately determine the design parameters for the foundation.

C. Attention should be given to preparation of the site. To accomplish this the following should be addressed.

1. The site of the foundation should be scraped of vegetation and any organic materials.

2. Any fill used on the site should be added according to the instructions provided in the soil report. This normally means in six inch lifts with adequate compaction. The lifts require compaction tests and any deviation from the soils engineer's specifications should be reported to and approved by the engineer.

3. Attention should be given to the ability of the site to drain properly. To this end a plan for drainage should be part of the construction documents.

4. Attention should be given to trees with any proximity to the foundation or any other naturally occurring problems at the site such as ditches, creeks or extreme grade changes.

FOUNDATION MAKE UP

A. The construction of the foundation should begin with a set of plans specifically designed for the soil conditions found at the site.

B. Once construction begins the following items must be taken into account.

1. If piers are part of the design they should be positioned according to the plans. They should be drilled to a size and depth specified by the soils engineer, the shafts should be clean and the bells should be inspected prior to concrete placement.

2. The forms should be secure, particularly in areas in which there are extreme grade changes.

3. Fill material should be graded and compacted and its moisture content should be checked.

4. Slab thickness should be measured to assure uniformity.

5. Grade beams should be fully sized and should extend into undisturbed soil or compacted fill. Beams should be clean of water or any debris.

6. Plumbing should be secure, tested for leaks, and should not eliminate appreciable areas of the beam section.

7. The moisture barrier should be secured by taped joints, and the penetrations created by plumbing should be covered by mastic. The barrier should lay smoothly over the slab section and should lay smoothly in the beam configuration.

8. Reinforcing steel should be checked for grade, size, and location. The reinforcing steel should be securely positioned in the beams or the slab, and it should have adequate clearance for concrete placement. If mesh is used it should be chaired securely and proper clearance should be assured.

9. Post tension tendons should be placed according to the plans and specifications. They should be secured in the beams and slab areas to assure that they donot move during concrete placement. This includes the use of 20d nails, adequate chairs; all tied, "s" hooks; crimped, and all intersections tied. Any draped tendons should conform to the plan profile and should be secured in the beam.

CONCRETE PLACEMENT

A. The site should be secured for placement. It should be determined whether you can get trucks to the forms, or whether it is necessary to use a pump truck. It should also be determined that whether the concrete supplier can provide a steady supply of material.

B. The weather should be taken into consideration. Will it rain, will you have adequate curing temperatures, is it too cold or too hot.

C. Once the concrete arrives at the site the following considerations must be taken into account.

1. The concrete placement should be completed within a reasonable amount of time to assure uniformity of materials and adequate curing.

2. The concrete strength should not be weakened by the addition of too much water at the site. A slump test is recommended.

3. Concrete additives should be used with care. Additives such as retarders should be used only with good control of the process and according to the manufacturers specifications.

4. Extenders such as flyash should be identified by the supplier and should be used with care. The excessive addition of water can reduce the strength of the material dramatically. Also exteme weather conditions can impede the curing process when flyash is used. Only class "C" flyash is recommended and then never more than 20% of the total cement portion of the mix.

5. Good compaction around reinforcing is necessary, also maintaining the position of the reinforcing during placement is all important.

6. Adequate time for correct compaction and curing should be observed. Curing conditions should be controlled if at all possible.

STRESSING

A. The stressing operation should not take place until the concrete has reached an acceptable strength, typically seven days.

B. Partial stressing is advisable with long tendons such as apartment buildings or in extremely hot curing weather.

C. Stressing operations should take the following into account.

1. Forms should be stripped and adequate clearance for stressing equipment should be provided.

2. Wedges should be installed free of any debris that may hamper proper seating.

3. A recently calibrated guage should be used.

4. Tendon elongations should be measured.

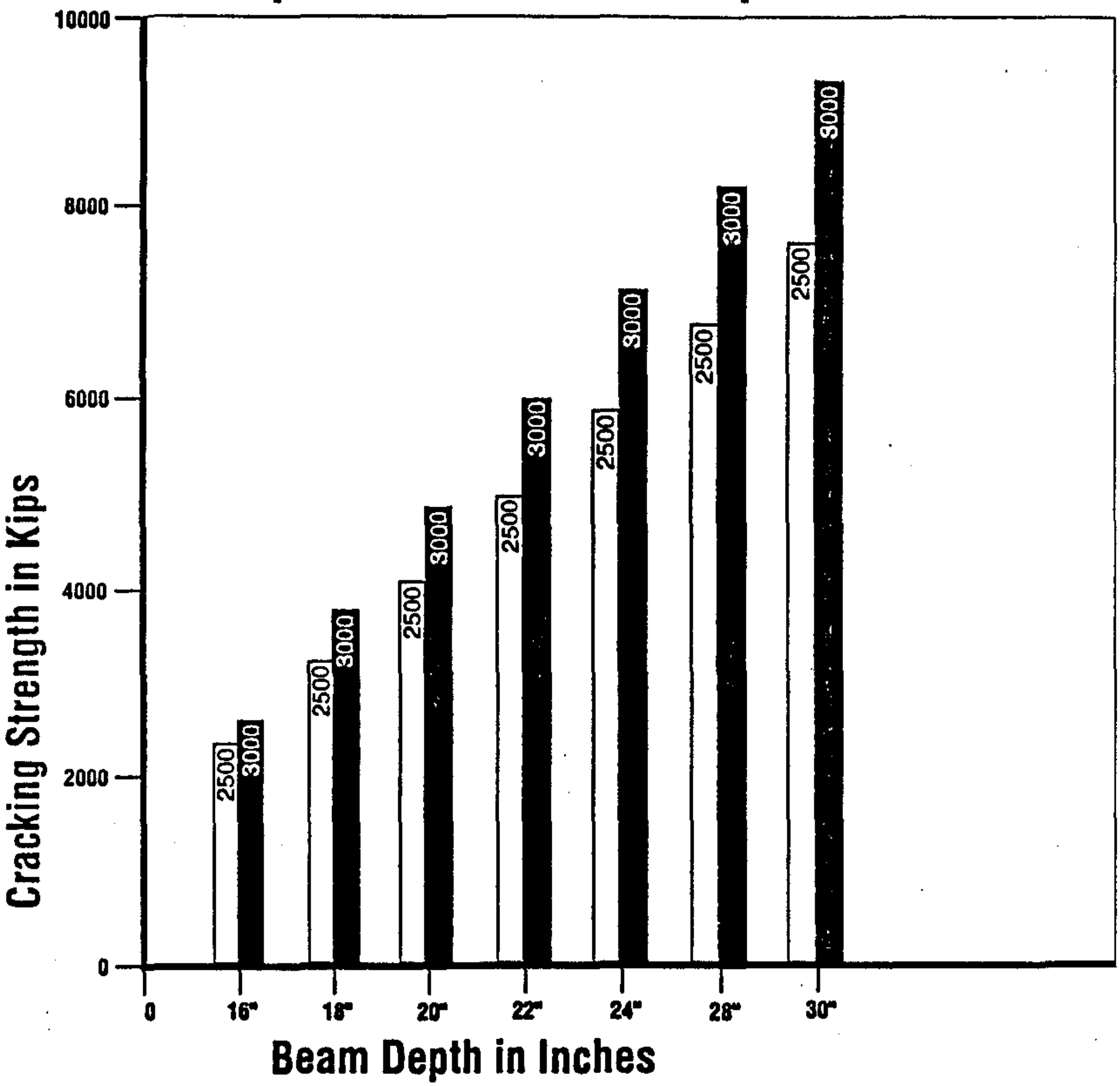
5. Following the stressing operation the tendon ends should be cut off inside the pocket former hole and hole should be grouted using a none shrink grout.

FINAL GRADING & LANDSCAPING

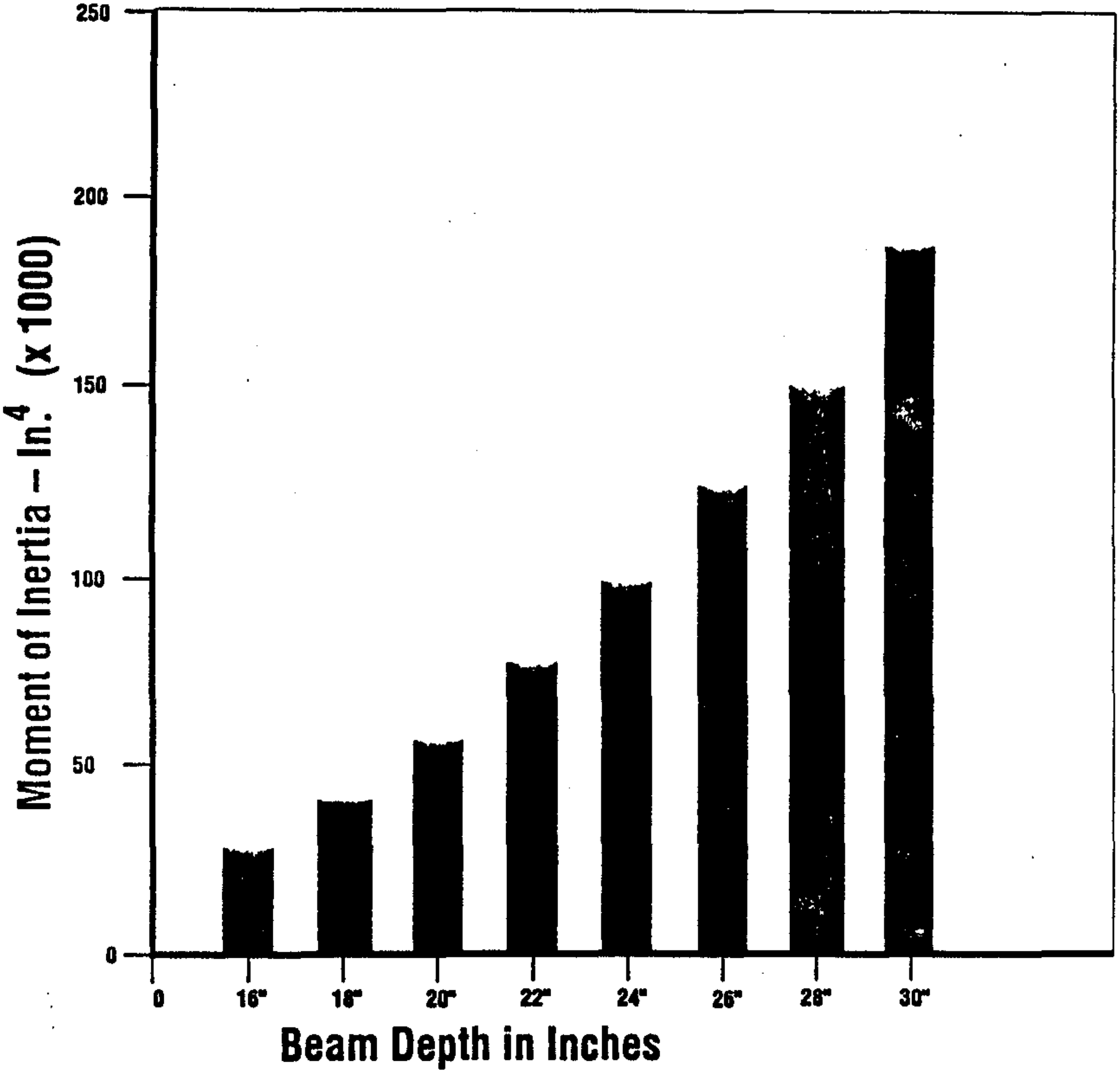
A. The final grading of the yard should be set up to positively drain rainwater away from the foundation. Placement of guttering and downspouts should take this into consideration.

B. The placement of landscaping, trees, shrubs, watering systems etc. should take the foundations environment into consideration.

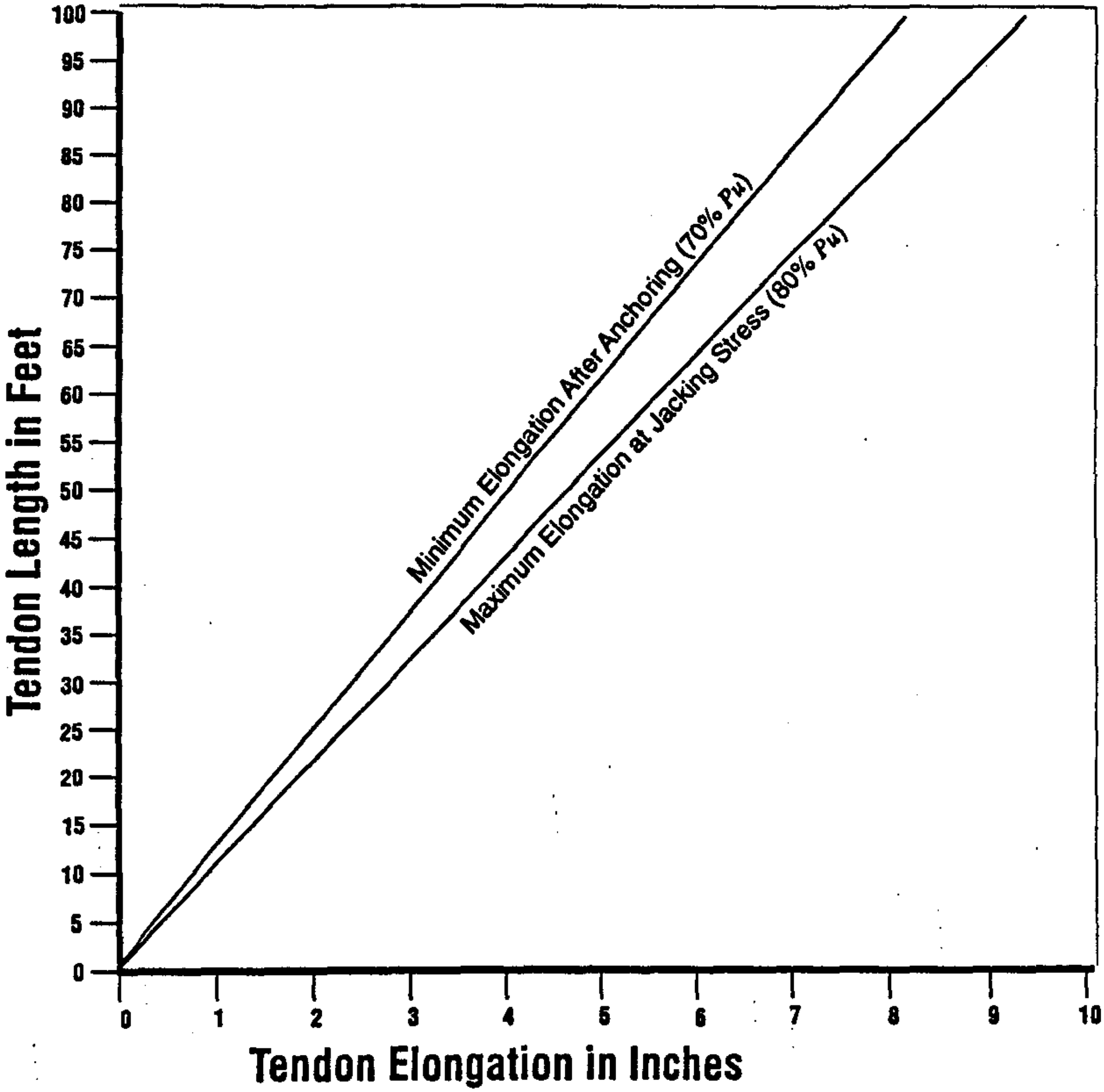
Cracking Strength
2500 psi Concrete vs. 3000psi Concrete



Moment of Inertia Capacity Resistance to Deflection



Tendon Elongation vs. Tendon Length for 270K - 7 Wire Stress-Relieved Strand



J. Spivey & Associates, Inc.

Licensed Real Estate Inspectors

1706 Seamist
Suite 510
Houston, Texas 77008

861-6880
861-1865 Fax

FOUNDATION MAKE-UP REPORT

Builder ____________ Subdivision ____________ Date ____

Address ______________________ Lot____ Blk.____ Sec. ____

Plan No. ________ Supt. ____________ Time of insp __________

Check if ok   If not explain below

SITE

Subdivision lot ____ Other ______
Explain ______________
Fill on site ____ Compacted______
Will lot drain yes ____ no _____

SLAB

_____ 4" Thickness
How measured ______________
Fill material ______________
_____ Level and compacted

BEAMS

_____ Proper depth _________ in.
 Actual depth _________ in.
_____ Proper width _________ in.
 Actual width _________ in.
_____ Beams bear 6" into undisturbed soil or fill
_____ Clean of soil & debris
_____ Water _____ Depth _____ in.
 Will water drain _________
_____ Is plumbing obstructing the beam ______________

MOISTURE BARRIER

_____ 6 mil. Lapped and taped
_____ Seated in bottom of beams
_____ Mastic applied at plumbing

FORMS

_____ Are forms secure
_____ Are floats installed
_____ Is garage closed in

TENDONS

_____ Size 1/2" Other _______
_____ Installation (6'-0 Max. spacing) Other _______
_____ 20 d nails used
_____ Cathead clamps installed
_____ All intersections tied
_____ Dead ends 3/4" clearance
_____ Beam tendons (hand tight)
_____ "S" hooks crimped
_____ Supported at intersections
_____ Double tendons draped
_____ Supported by bricks___#3s___
_____ Chairs (ample,all tied)
_____ Sheathing (tape breaks and 4" from dead and live ends)

SUPERVISION

_____ Was supertintendent on the site during the inspection ?
_____ Were needed changes understood
_____ Were they left at site
 Where ____________

REINFORCING STEEL

_____ Mesh (2" from top of slab, _______ gauge)
_____ All seams lapped 6" _____ All edges 2" from the form
_____ Rebar Grade _____ 3" bottom coverage____, 2" top & sides ___
 splices lapped 30 diameters____ corner bars installed _____)
_____ Exterior beams ____________________stirrups _____
_____ Interior beams ____________________stirrups ______
_____ Diagonals / 2 #_____ x 5'-0" at major re-entrant corners

IS THE FOUNDATION READY FOR CONCRETE PLACEMENT YES____ NO ____

NEEDED CHANGES : ______________________________

____
____
____
____
____

____________________ ____________________
Inspector's signature Superintendent's signature

J. Spivey
& Associates, Inc.
Licensed Real Estate
Inspectors
1706 Seamist
Suite 510
Houston, Texas 77008
861-6880
861-1865 Fax

CONCRETE PLACEMENT REPORT

Builder ________________ Subdivision ______________ Date _____

Address _________________________ Lot____ Blk._____ Sec ______

Plan No. ________ Supt. ______________ Concrete Co. ___________

Check if ok If not explain below

SITE
Subdivision lot ___ Other ______
Explain ______________________
Are there obstructions at the site which would prevent access for concrete trucks ______________

FORMS
Are forms secure ___________
Are floats installed _________
Is there adequate clearance at the floats ________________

WEATHER
Start time ____________ estimated finish time ______________
Weather conditions ____

CONCRETE
Batch plant location ______________________________________
Delivered by truck___ Was it pumped yes __ no ___
Mix: _______________ psi _____________ psi Pump Mix
Sack mix : 4½ __ 5__ 5½ __ other___ Strength Mix __________
Additives:_______________________________ "No Calcium Chloride"
Fly Ash: no more than 20% Type C Yes___No ____
Slump as ordered _____ inches, as delivered _____ inches
Was concrete consolidated by: vibrator _____ other __________

If water is added at the jobsite show amounts over ten gallons

Truck #	Gals added	Placement Location	Slump

Draw a diagram of the slab showing the locations of each load designated by the truck number

ADDITIONAL COMMENTS ______________________________________

_____________________ Inspector's signature

_____________________ Superintendent's signature

J. Spivey & Associates, Inc.

1706 Seamist
Suite 510
Houston, Texas 77008

861-6880
861-1865 Fax

STRESS INSPECTION

SITE

Builder ________________ Subdivision ________________ Date _____

Address __________________________ Lot ____ Blk ____ Sec _____

Superintendent _________________ Post Tension Co. _____________

Concrete Placement Date __________ Stress date __________

Check if ok / if not explain below

_____ Were the tendons painted at the edge of the slab ?
_____ Were the wedges placed in a vertical position ?
_____ Were the wedges seated ?
_____ Was there evidence of gripper marks on the tendons ?
_____ Were the elongation measurements correct with regard to the length of the tendon ?
_____ Was there any evidence of disruptions to the slab from the stressing operation? Specifically blow-outs at corners or at garage entrys. If so explain below.

SKETCH Draw a simple sketch of the foundation configuration noting the tendon locations and any problem which you have observed.

_____ If the foundation appears to be stressed correctly check here. Then place a piece of BLUE surveyors tape on a tendon end closest to the street.
_____ If problems exist with the stressing check here. List the problems in the ADDITIONAL COMMENTS below and tie a piece of YELLOW surveyors tape on the tendon nearest the street and on the problem area.

ADDITIONAL COMMENTS

____

____

____

(use back if necessary)

________________________ ________________________

Inspectors signature Superintendents signature

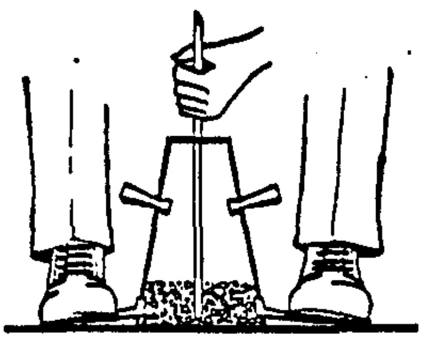
CONCRETE SLUMP TEST

Purpose of test: *To determine the consistency of fresh concrete and to check its uniformity from batch to batch. This test is based on ASTM C 143: Standard Method of Test for Slump of Portland Cement Concrete.*

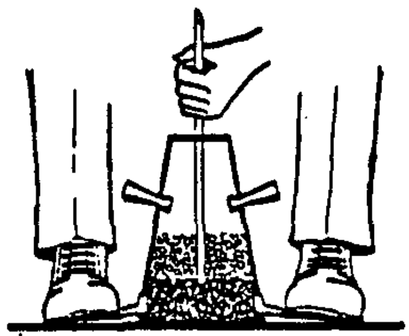
Take two or more representative samples—at regularly spaced intervals—from the middle of the mixer discharge; do not take samples from beginning or end of discharge. Obtain samples within 15 minutes or less. *Important:* Slump test must be made within 5 minutes after taking samples.

Combine samples in a wheelbarrow or appropriate container and remix before making test.

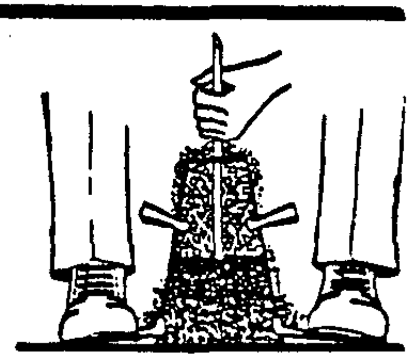
Dampen slump cone with water an place it on a flat, level, smooth, mois non-absorbent, firm surface.



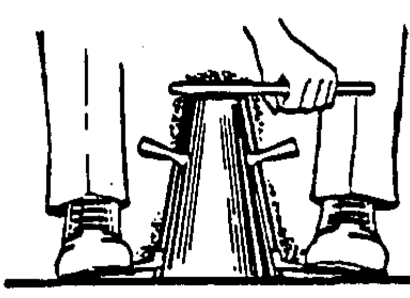
1. Stand on two foot pieces of cone to hold it firmly in place during Steps 1 through 4. Fill cone mold 1/3 full by olume (2-1/2" high) with the concrete sample and rod it with 25 strokes using a round, bullet-nosed steel rod of 5/8" diameter x 24" long. Distribute rodding strokes evenly over entire cross section of the concrete by using approximately half the strokes near the perimeter (outer edge) and then progressing spirally toward the center.



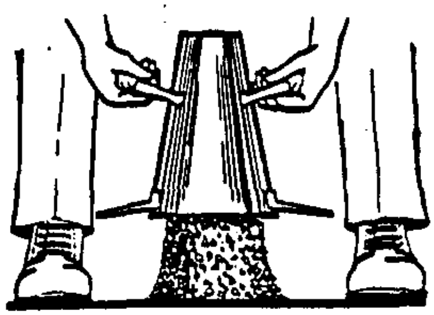
2. Fill cone 2/3 full by volume (6" or half the height) and again rod 25 times with rod just penetrating into, but not through, the first layer. Distribute strokes evenly as described in Step 1.



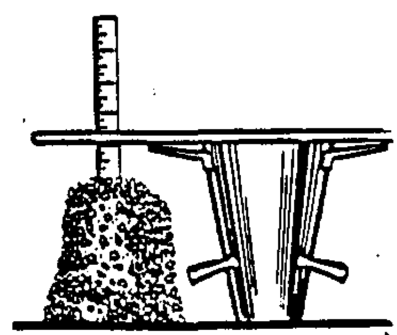
3. Fill cone to overflowing and again r 25 times with rod just penetrating into b not through the second layer. Aga distribute strokes evenly.



4. Strike off excess concrete from top of cone with the steel rod, so that the cone is exactly level full. Clean the overflow away from the base of the cone mold.



5. Immediately after completion of Step 4, the operation of raising the mold shall be performed in 5 to 10 sec. by a steady upward lift with no lateral or torsional motion being imparted to the concrete. The entire operation from the start of the filling through removal of the mold shall be carried out without interruption and shall be completed within an elapsed time of 2-1/2 minutes.



6. Place the steel rod horizontally ac the inverted mold, so the rod extends c the slumped concrete. Immediately mea the distance from bottom of the steel ro the original center of the top of specimen. This distance, to the neares inch, is the slump of the concrete.

CAUSES FOR FOUNDATION DISTRESS

COMMITTE REPORT

BY

BRAD CRANE, P.E.

SHEPARD CRANE & ASSOCIATES, INC.

REASONS FOR FOUNDATION DISTRESS

General

Foundations may experience distress as a result of one or a combination of many factors. It is frequently difficult to pin point the exact cause of foundation distress because more than one factor may be involved. The factors which may cause foundation distress are:

False Foundation Movement
Lack of Maintenance
Improper Construction
Inadequate Information and Design

False Foundation Movement

False foundation movement is not really movement, although some acceptable variations in elevation may have occurred, but rather is some cosmetic conditions which develop. It generally occurs in the early years of the structure and the cosmetic indicators include some molding separations, some tile and sheetrock cracks, nail pops, and some brick cracks. These items are frequently covered in the one year warranty because they may be caused by drying/shrinking of the wood structure, the veneers and the trim after completing construction and dehumidifying the residence. The brick cracks are frequently expansion/contraction cracks caused by temperature variations in excessively long walls or short intersecting walls.

Lack of Proper Maintenance

Maintenance is the process of controlling the environment and condition of a structure so that it may perform its intended function properly. Since it is the responsibility of the owner, all owners/residents must understand the effect of moisture variation in expansive clays and the influence of water, landscaping, trees, drainage, sand, downspouts, gutters, sprinklers and remodels on the foundation. Improper control of these items will influence the foundation and may cause differential movements which may become excessive, resulting in foundation distress.

Improper Construction

Construction techniques vary from builder to builder and all builders generally desire to building a good product but they supervise many trades and people, all of whom will affect foundation performance. A partial list on construction problems is as follows:

- The failure to follow recommendations of the soils engineer with regard to compacted fill and the scraping of organic matter from the lot.

- The lack of attention of the site conditions related to good drainage and moisture maintenance. These include large trees, their root systems, and ditches or creeks with a close proximity to the foundation.

- The improper installation of drilled footings. These include, failure to follow the engineers recommendations with regard to depth, bell sizing, reinforcing and spacing.

- The grade beams are undersized or do not extend into the specified stratum of undisturbed soil.

- The slab section does not reach the specified thickness, or is placed over unstable fill or voids.

- Improper reinforcing steel placement, specifically ungraded reinforcing, lack of attention to "continuous" reinforcing, the lack of chairs under welded wire fabric, and the failure to place the fabric in the correct position in the slab.

- The lack of adequate post-tensioned reinforcing due to improper installation of tendons. This includes tendons unsecured during the concrete placement, resulting in tendons on the bottom of the slab or grade beams.

- The lack of attention to concrete placement procedures including adding to much water to the mix.

- Improper stressing of post-tensioning materials, the failure to have measured elongations reviewed by an engineer, and improper grouting procedures for post-tensioned slabs.

- The lack of attention to correct final grading of the lot and the installation of landscaping.

<u>Inadequate Information and Design</u>

Foundation distress can occur if the foundation, structure or veneers are poorly designed. The following factors which may cause inadequate design are as follows:

- A faulty geotechnical report which may consist of the following:

a) Inadequate site condition description
b) Incorrect bearing capacity values and/or improper grade beam embedment
c) Footing depth
d) Inadequate PTI or BRAB parameters
e) Absence of recommendations on foundation maintenance
f) Inadequate testing of soil characteristics
g) Incorrectly estimated movement values
h) Inadequate information regarding perched water table
i) Borings drilled in the wrong locations

- Unfamiliarity with proper design methods in regards to Post-Tensioned slab design, Conventional slab design, and Structural slab design.

- Excessive pier spacing or undersized piers.

- Foundation design without soils report.

- Continuity of grade beams/waffle slab for Post-Tensioned and Slab-on-Grade Systems or for slabs on fill with piers when the PIs are high.

- Misapplication of design to site conditions which includes sloped sites, sites on active faults and using the wrong type of foundation for soil conditions.

- Eccentric loading of slabs, specially post-tensioned slabs which includes support of concentrated loads.

- Drops and raises in foundation.

- Inadequate information with regards to drainage, slope, existing trees, future trees and vegetation prior to foundation design.

Conclusions

In general, one or several of the items discussed may be responsible for foundation distress. In order to determine the cause of distress in any foundation the items as mentioned must be reviewed and evaluated to properly identify the problem areas.

FOUNDATION DISTRESS MEASUREMENT AND EVALUATION

RICHARD W. PEVERLEY
Peverley Engineering, Inc.

Abstract

There has been a general lack of consistency in the methods generally used to inspect residential foundations along with the reporting of the data, there from. The purpose of this paper, therefore, is to explore methods of assessing the performance of a residential foundation from the process of the inspection through the presentation of the results. Methods of collecting data, procedures for analyzing such data and techniques for data presentation are discussed. This paper contains recommendations for the gathering of the data which will be the basis of determining if a foundation failure has occurred, as is currently being assessed by the Foundation Deflection Subcommittee for the Foundation Performance Committee. The initial results of this work will be discussed in one of the papers to be presented following this one.

INTRODUCTION

The state-of-art in the conduct of quality control inspections has, in many industries, achieved a comparatively high state of sophistication and reliability. The process has become sufficiently complex that at least one state (California) provides for Professional Engineering Registration in the discipline of Quality Engineering. An essential element of this process is that it be rigidly controlled through sets of standards with recognized pass-fail criteria combined and procedures for the presentation of the inspection results. The American Concrete Institute, as an example, has issued a set of standards for the inspection of concrete placement. To the best of our knowledge, no such formal standards or procedures exist for the inspection of foundation performance for residential buildings and other types of light construction. This deficiency has been recognized by the Foundation Performance Committee and, as a result, a sub-committee was assigned to investigate this part of the foundation industry and to make recommendations to the Committee with regard to the preparations of standards for assessing if a foundation failure has occurred.

The purpose of this paper is to discuss methods of acquiring and presenting the data that will be needed so that such assessments can be made and uniformly understood throughout the industry. This paper is based on procedures and processes that are currently available and often used when conducting a foundation inspection of this type; albeit, not well documented in the past. The objective of this paper is to explore standards by which the identification and assessment of foundation performance can be uniformly judged in the future.

THE PURPOSE OF CONDUCTING FOUNDATION PERFORMANCE ASSESSMENTS

Residential foundations are generally examined for one of the following three purposes:

- o <u>Real Estate Transactions</u>: The purpose of such inspections is to provide a potential buyer of a residential property with an opinion regarding the current condition of the foundation along with an analysis of its current state compared to other residential buildings of similar age, type of construction, and similar location. The condition of residential foundations generally falls into one of the three following categories: (1) very good, (2) very bad, or (3) somewhere in between. Unfortunately, a significant majority of the foundation conditions fall within the third category. Thus, the objective of such an inspection is to simply provide information to the potential buyer so that an informed decision can be made with regard to whether or not to purchase the property and, if so, at what price. Thus, there is, in reality, no absolute pass/fail criteria which applies in this type of inspection. The individual conducting such an examination most often must fall back on what, in his knowledge and experience, is a comparison to what is perhaps the most nebulous of all criteria - acceptable community standards.

Presented at the 1996 Foundation Performance Committee Symposium, Houston, Texas, July 25, 1996

- Owner Consultation: The significance of foundation problems has received an increasing amount of publicity in the recent past. As a result, a majority of homeowners in this general area have become concerned when negative phenomena, such as cracks, distortions, etc. appear and seek the advise of an expert with regard not only to the seriousness of the damage but also with regard to any remedies that may be required. One of the major differences between this, and a real estate inspection, is the need to be as specific as one can be, considering the inherent limitations to any diagnoses that may be produced. For example, any inspection and diagnoses of a foundation problem, which includes a recommendation for foundation repair, that fails to note the presence of a large oak tree growing near the foundation in an expansive soil must, in our opinion, be considered to be deficient. Also, the presence of sloping floors in an older building, where the owner has no current intent to sell, may not be as significant as it would be if the purpose of the examination was to provide information to a potential buyer or to a jury.

- Forensic Examination: The word forensic, as used in this application, implies that the results are to be used in conjunction with legal matters. An expert conducting a forensic examination has one, and only one, objective in such a task and that is to be a trier of fact and not to act as an advocate for either party in a legal matter. On this basis, the examination of the foundation and its attached structure for this purpose is, by far, the most detailed and the examiner must obtain all of the data that can be acquired within the budget limitations assigned by the client. Any results of the examination must be accurate and pointed. The diagnoses must be based upon the evidence which has been made available and which has been analyzed on the basis of existing engineering principals. The data acquired during such an examination should be so well documented and so clear in its presentation that it will withstand cross-examination to the point that its accuracy will stand alone.

INSPECTION METHODS

The following is a discussion of those examination methods which may be employed during the inspection of a residential foundation. Included in this discussion will be are analysis of the viability of each method. Initially, the presentation will be made with regard to the examination method alone however; its applicability to one of the three types of inspections will be discussed later in this section of the paper. The processes are described:

Initial Examination: The first part of this inspection process involves the visual examination of the residential building. The first thing an examiner should do is to make a cursory tour of the property both inside and outside of the building. The purpose of such an examination is to be able to formulate a more detailed plan for the remainder of the investigation. The negative phenomena (cracks, distortions, separations, etc.) should be examined to determine their extent and a phenomena plan can be prepared. Such a plan can be put to writing or simply be mentally planned out by the examiner.

Preparation of the Sketch of the Building Plan: The next step in the procedure should be the preparation a drawing or a sketch of the building plan. Where applicable, the plan may be of the residential building alone or it may include appropriate features in the yard, such as out-buildings, patios, driveways, sidewalks, trees, drainage ditches, and/or swails and berms. The building plan may be a sketch with limited proportionality or a detailed drawing based upon measured distances. An example of one such sketch is shown in Figure 1. One of the most significant things on any drawing is the relative location of the trees to the foundation. In our experience, it is prudent to make the drawing to some scale rather to do it on a free-hand basis since proportionality can become an important factor.

Phenomena Plan: Having the drawing in possession, a phenomena plan can then be prepared. This plan must be prepared in such a manner as to give the reader an understanding of the relationship between the deflections that currently exist in this foundation and the damage that has occurred. The phenomena plan can best be illustrated in a hypothetical example, such as is contained in Figure 2. In this example, the damage is limited to the degree that it can be illustrated on a comparatively simple diagram. In some cases, the number of defects may become so great that any attempt to find any correlation may be futile.

Measuring the Relative Flatness of the Foundation: The next step in the procedure should be determination of the sloping conditions that exist on the interior floors of the building since they should, in most cases, provide a direct indication of the deflection, or the tilting, that has occurred in the foundation. Any difference between deflections and tilting will be discussed in more detail later in this paper. One method of conducting such an analysis is to put a spirit level on the surface of the floor then indicate, on the building plan, the direction of the slope. Some spirit levels even have graduated scales on the bubble tube such that the slope, in turns of inches per foot or inches per the length of the level, can be read. We do not have an example of how such a drawing would look using this procedure because it is never employed by the author. I do not believe that such a procedure has any real benefit, other than possibly to provide an overall indication that some type slope exists in a building and the direction that the slope has taken.

In our experience, there are two measurement devices which have been used in some degree of success in providing foundation slope data; these are water levels or laser levels. Each will be discussed in the following paragraphs.

A water level is a slang name for manometer. Manometry is a technique that has been around for a very long time. The manometer, as it is used in this application, is based upon the principle that water will seek its own level; i.e. the surface of the water will be parallel to the surface of the earth. There are two basic types of manometers that are used; i.e., the U-tube manometer and the Bulb manometer. Both are shown in the Figure 3. Either of these devices will provide satisfactory results. The choice of which device to use depends on which one is more convenient to the user. There is currently on the market, a bulb type of manometer that is equipped with a pressure transducer and sufficient electronics such that relative height differences can be automatically exhibited for readout.

A typical procedure for the use of a manometer is as follows. An arbitrary reference point is established some place in the residential building. One end of the manometer is placed on a reference point while the other end is moved to various locations around the room for the purpose of measuring relative heights in selected points. The choice of reference point is totally arbitrary. It is often convenient to place the reference point someplace on the interior of the building and/or at a location where floor heights of difference thickness come together. The selection of a reference point, if properly done, can eliminate the possibility of having turning points and/or having to compensate for differences in floor covering heights. Once the data have been acquired the measurements can than be annotated on the plan drawing of the residential building.

Another device which has been used frequently in this type of work is a laser level. This device generally consists of a rotating light mounted on a tripod in such a manner that the head of the tripod can be leveled. Once the laser light is set up at some location, one can move a measuring stick from point to point through out the line-of-site of the laser device and read the differences between points off of a scale. Compensation can be made for variations in floor height covering by taking a reading off of the top of the thicker covering and one off of the adjacent floor. The amount of difference between the two would then become an adjustment for the remaining measurements that are taken. Where it is desirable to take readings that are not in the line-of-site with the laser source, it will need to be moved. The operational procedures for acquiring these data are somewhat similar to those used when making the survey with a water level.

In terms of accuracy, both devices are approximately the same. Some inspectors use architectural scales in making their measurements while others use engineering scales. The accuracy of either scale is approximately the same. One may argue that when the scale is divided into increments as small as $^1/_{16}$", the data are more accurate than when the scale is divided into increments of 1/10"; however, there are other factors that contribute to the accuracy of the measurements taken. First, the height of the meniscus at the top of the water column is often at least 1/16" to 1/8" in height and any attempt to read the column height somewhere in that range would, in our opinion, be an exercise in futility. Second, floor coverings, such as carpeting or tile, have thickness variations well over 1/16". Further, if one were to move the measurement device as short of a distance of one foot away, it would not be unusual to find a variation of somewhere between 1/16" and 1/10. Also, each time it is necessary to make a turning point, as is often required when using a laser level, the accumulated reading error can double. Finally, the analysis of these data generally involve making assumptions that would negate any benefits that might be accrued in improving the overall accuracy of such measurement systems. In our experience one can produce an accuracy of ± 0.1" in any one set of measurements than a repeatability of ± 0.2" between sets of measurements made at some locations in the same building, but at different times. It has also been our experience that such data are more than sufficiently accurate for an adequate analysis to be made.

Data Presentation: Data must be presented in such a manner that it can be equally understood by the client as well as other professionals. This can obviously be a difficult task in some cases. We have found that presenting the data in raw numerical form, in contour form, and in cross-sectional form can often achieve these results. We have utilized data taken from an actual residential building to illustrate how this can be done.

- Figure 4 shows the raw measurement data taken during the first inspection of the property. The measurements are shown on an engineering scale in inches and tenths of an inch. From these data, one can ascertain that there is a definite downward slope of the floors toward the right-hand wall as well as on the interior of the building.

- Figure 5 shows the contours of equal height that were drawn using the data from figure 4. These contours lines display the trend in the building towards a downward slope from the left hand side towards the right.

- Figure 6 shows, as a matter of interest, an isometric drawing which displays the surface of the foundation in a different way. The drawing was made the following manner. The outline of the building was drawn in an isometric plane. The plane was then divided into intervals of ten feet in either direction. From the contour drawing, the contour heights were read at the intersection between the horizontal and the vertical interval line and were vertically plotted using a different scale, as shown in Figure 6. The purpose of such a drawing is to convey the surface of the plane in a 3-D perspective.

- Figure 2 has already shown the phenomena plan for this building, in terms of description and location. A presentation of this type is somewhat preferable to a detailed listing since it tends to convey a better understanding of the relationship of the damage to its location in the building.

Structural Examination Testing: There are some occasions where structural testing is required to determine the cause of failure and/or provide the data necessary to specify repairs. The following are typical of the type of tests that can be conducted:

- Soils testing requires soil borings and the analysis of data to include, but not necessarily limited to type classification, Atterburg limits determination, soil strengths, moisture content, potential vertical rise, root depth, and the presence of perched water table conditions.

- Excavations can be made along the side of the foundation grade beams for the purpose of determining the depth and width of the grade beam as well as soil conditions along the side and under the grade beam.

- If the foundation is supported on drilled pier, excavations can be made along the side of the piers down to their bottom, for the primary purpose of determining pier depth, bell diameter, and pier-to-beam connection.

- Concrete cores can be extracted from the foundation slab and tested to determine concrete strength and the presence/location of reinforcement. A minimum of 3 cores will be required. The cores must be tested in accordance with ASTM C-42. The acceptability of the results must be analyzed in accordance with ACI-318. In addition, soil samples should be extracted through the core holes and the soil under the foundation examined for type, foreign material, and bedding sand.

Such tests are, of course, comparatively expensive and generally can only be justified in conjunction with a forensic examination.

Preparation and Publication of the Analysis Report: Now that all of the data have been acquired, it is time to put the results into writing so they can be used to the benefit of the client and the affected general public, as well. Although all parts are of equal importance, we must emphasize the absolute need for any investigator to give the proper attention to this vital part of the investigative process. A poorly prepared report can totally negate the results of an otherwise thorough investigation. Unfortunately, some engineering schools do not, or have not, placed enough emphasis on report writing. Hard as it is for some engineers to admit they have any weakness in any of their skills, we can not over emphasize the importance of obtaining professional assistance if it is required.

The report must be clear, concise, complete, and technically accurate. The report must be understandable to one of your contemporaries, as well as your client, who may not have the benefit of a technical background. Although some reports are specifically written to be used in a court of law, every author of a foundation investigation report must recognize that any report he prepares may end up in front of a jury after it has been torn asunder by an opposing attorney. As an engineer, we must also realize that any report we write may be reviewed by the Board who will probably be more critical than anyone else. A suggested minimum format for such reports is shown in Table 1, below.

TABLE 1
SUGGESTED REPORT FORMAT

	Transmittal Letter	Establishes the report as an entity and identifies its distribution.
	Report Summary	Provides the author with an opportunity to emphasize the important points and for those who do not wish to read the entire report.
	Table of Contents	An essential organizational tool for any report.
1	Introduction	What is the purpose of the report and what are the limitations in the investigation process that could affect the outcome.
2	Project Description	Describe the project & identify the configuration of the structure.
3	Investigation Results	Describe in detail the type of investigation conducted and the results thereof.
4	Data Analysis	What is the meaning of the data results and what are its limitations.
5	Conclusions	What is the conclusions that can be derived from the investigation and what should be done.
6	Certification	For a PE, a certification statement is required. A Professional Engineering Seal is mandatory.
7	References	All references must be listed.
	Illustrations	All drawings and sketches must be included.
	Appendices	This is a good place for detailed technical data/discussions in which only another engineer or an attorney may be interested.

CONCLUSIONS AND RECOMMENDATIONS

The foregoing investigation elements have been provided on a generic basis. Obviously, there are some parts of these elements that will not apply in all cases while others will. We have attempted to separate these elements into their recommended applications in Table 2, below.

The importance of consistency, detail, and good english in the acquisition, analysis, and presentation of foundation inspection data can not be over-emphasized. In this paper, we have attempted to recommend a set of standards to be used in this task. There are some areas which may not be consistent between investigators. For example, one investigator may choose to acquire more data than would another. One may argue that the more data, the better the examination while the other may argue that too much data can clutter the results. In realty, the amount of data required is at the choice of the investigator who is the ultimate individual who is responsible for the results. So long as the results of the investigation are accurately, and completely, presented, the results will be sufficient that they can be read and appreciated by not only the investigators contemporaries but the investigators clients as well.

TABLE 2
FOUNDATION INSPECTION METHODS

INSPECTION METHODS	INSPECTION TYPE		
	REAL ESTATE	HOME OWNER	FORENSIC
Preliminary Walk-thru Examination	X	X	X
Preparation of the Building Plan Sketch	X	X	X
Complete the Building Phenomena Plan	O	O	X
Measure the Relative Flatness of the Slab	X	X	X
Preparation of the Data Presentation	X	X	X
Conduct Structural Examination Tests	O	O	X
Preparation & Publication of Analysis Report	X	X	X

X Recommended
O Optional

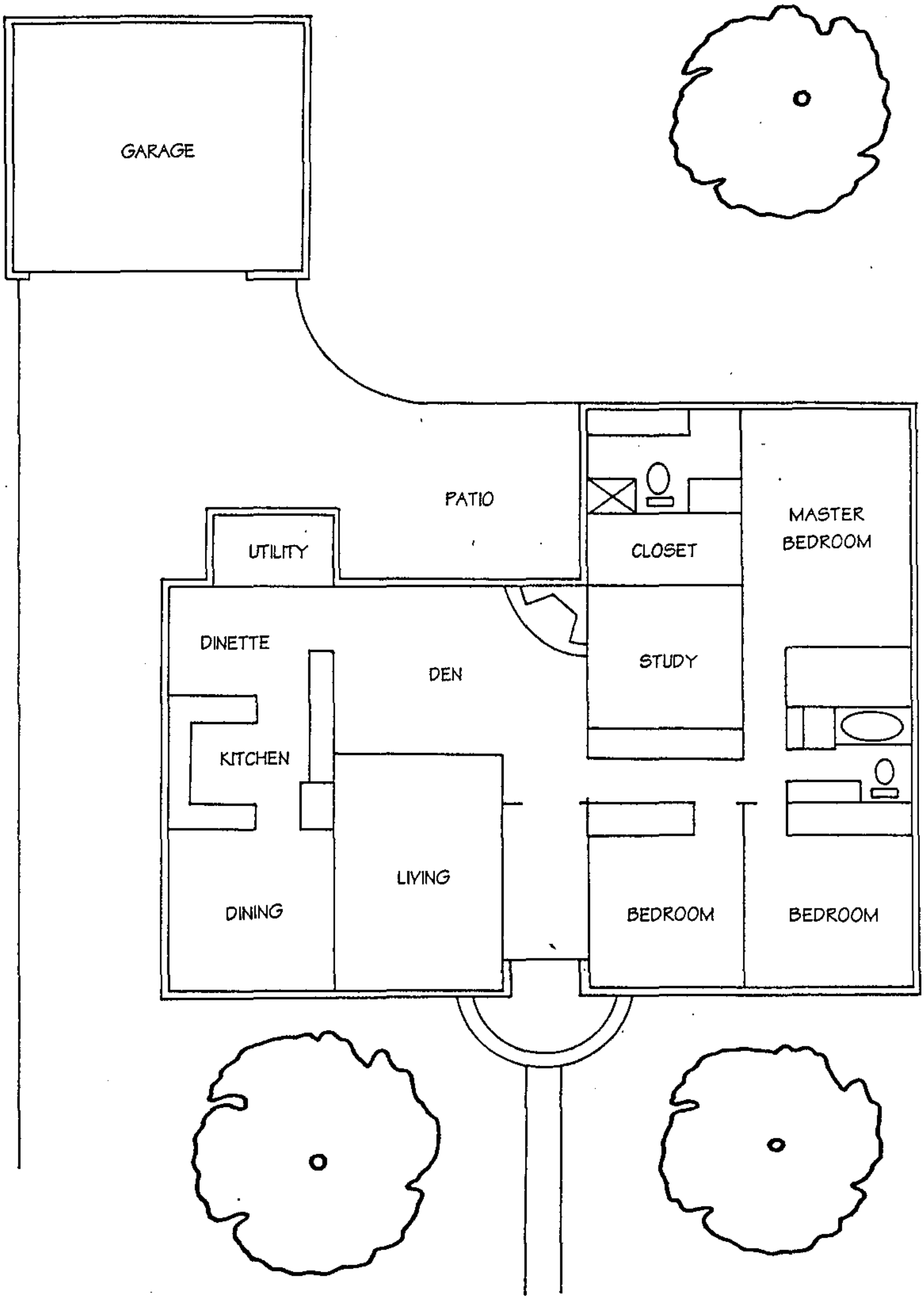
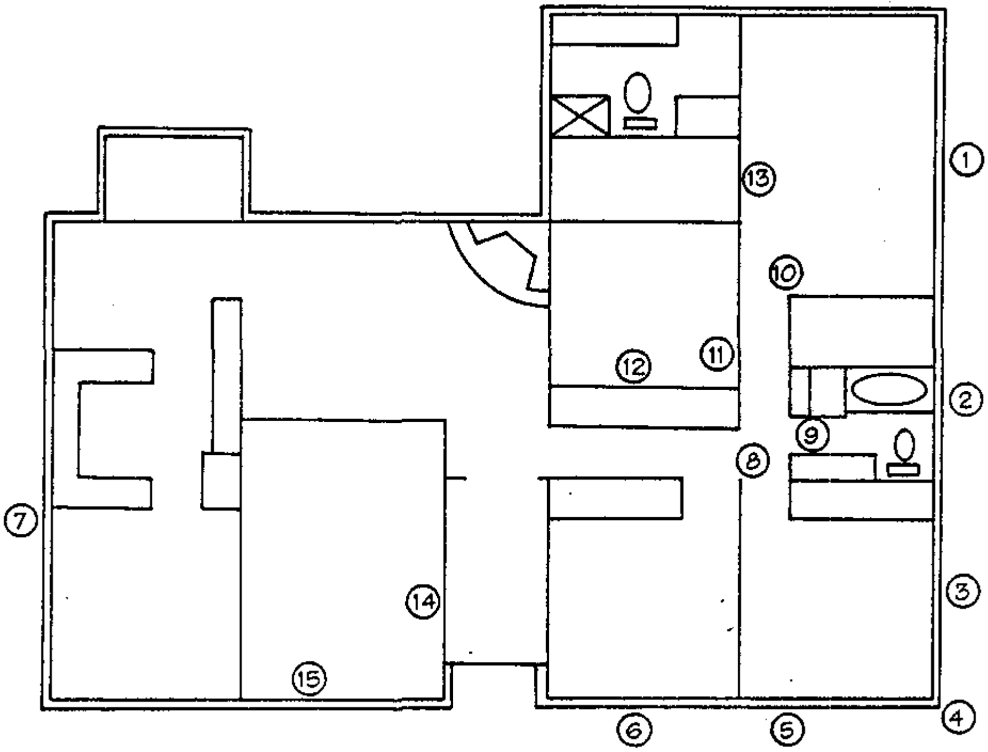


FIGURE 1. A TYPICAL SKETCH OF A RESIDENCE AND PLOT PLAN

FIGURE 2. RESIDENCE OUTLINE SHOWING THE PHENOMEN PLAN



DEFECTS OBSERVED

1. WINDOW/BRICK SEPARATION OF 1/4". BRICK CRACK 1/8" DOWN FROM LOWER LEFT WINDOW CORNER.
2. WINDOW/BRICK SEPARATION OF ½". BRICK CRACK 1/4" DOWN FROM LOWER LEFT WINDOW CORNER.
3. WINDOW/BRICK SEPARATION OF 3/8". BRICK CRACK 1/4" DOWN FROM LOWER RIGHT WINDOW CORNER.
4. FACIA SEPARATION @ CORNER.
5. BRICK CRACK 3/8" DOWN FROM LOWER LEFT CORNER OF WINDOW.
6. BRICK CRACK 1/8" DOWN FROM LOWER LEFT CORNER OF WINDOW.
7. HAIRLINE BRICK CRACKS @ LOWER WINDOW CORNERS.
8. CRACKS @ BOTH DOOR CORNERS. FRAMES NOT SQUARE. TOPS SLOPE DOWN TOWARDS EAST WALL. DOORS BIND.
9. BATHROOM DOOR WILL NOT CLOSE.
10. DOOR FRAME NOT SQUARE. TOPE SLOPES DOWN TO EAST. DOOR DOES NOT LATCH.
11. ENTRY DOOR FRAME NOT SQUARE. TOP SLOPES DOWN TO SOUTH.
12. CLOSET DOOR FRAME SLIGHTLY OUT-OF-SQUARE. SLOPES DOWN TOWARD EAST.
13. CLOSET DOOR FRAME SLIGHTLY OUT-OF-SQUARE.
14. HAIRLINE DIAGONAL CRACK UP FROM UPPER RIGHT CORNER OF DOOR FRAME.
15. HAIRLINE CRACK UP FROM UPPER LEFT WINDOW CORNER.

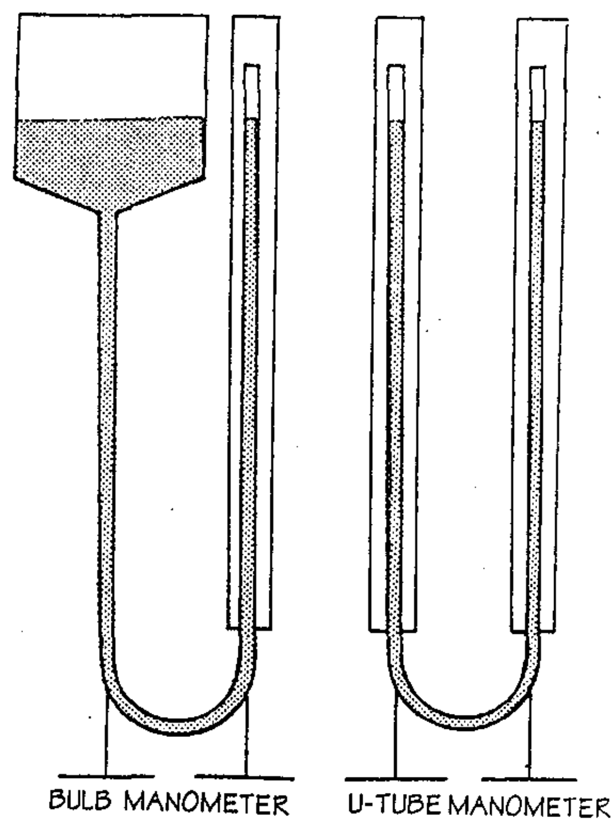


FIGURE 3. A SCHEMATIC SKETCH OF A MANOMETER USED AS A WATER LEVEL.

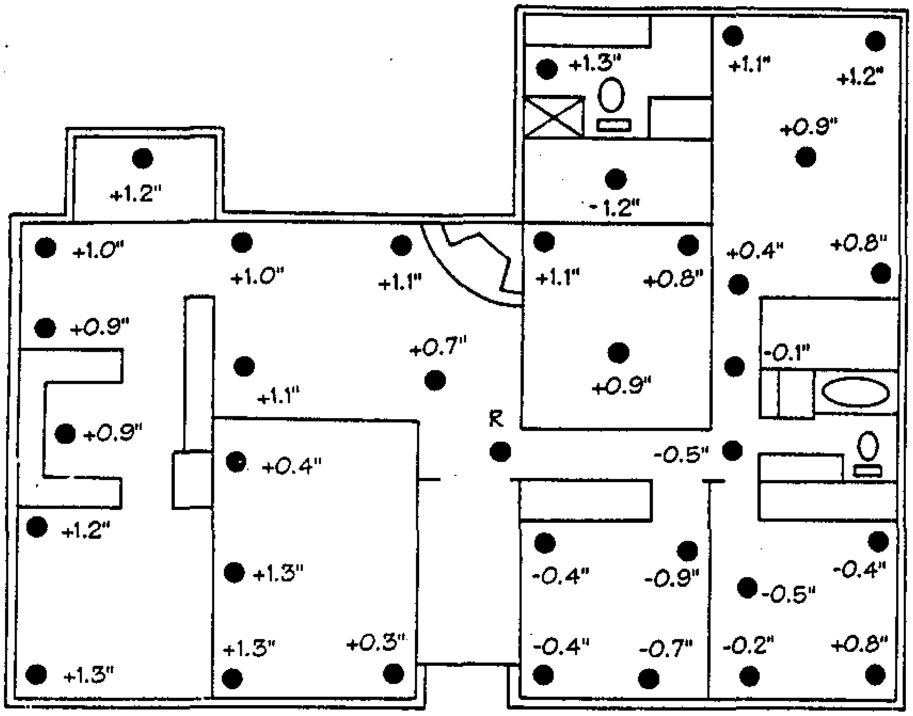


FIGURE 4. AN EXAMPLE OF A RESIDENCE PLAN SHOWING RELATIVE MEASURED HEIGHTS.

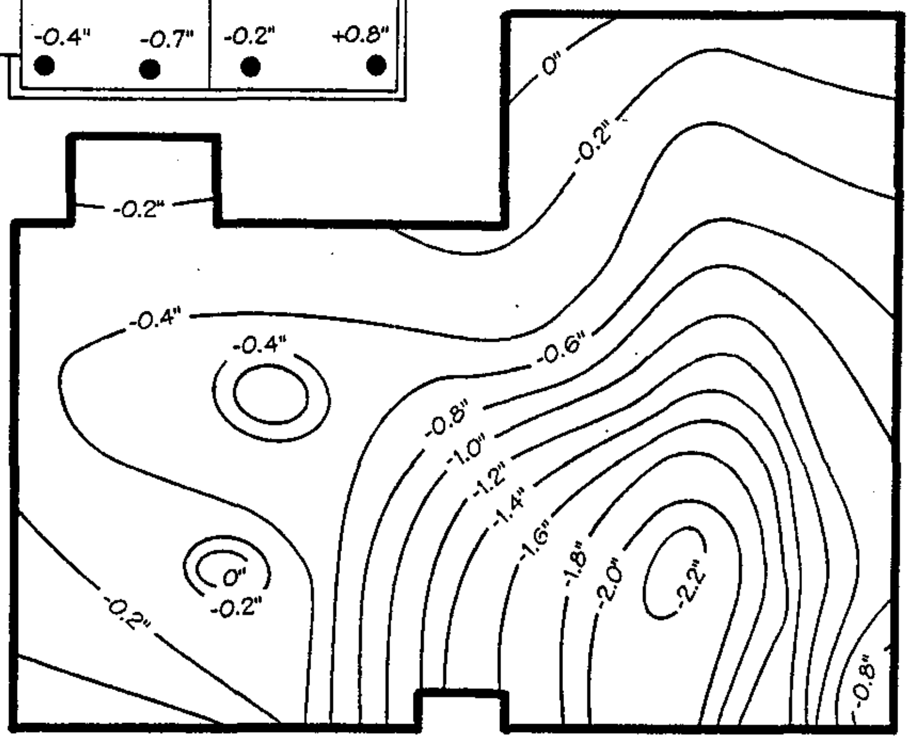


FIGURE 5. AN EXAMPLE OF A RESIDENCE PLAN SHOWING CONTOURS OF EQUAL HEIGHTS MADE FROM THE MEASUREMENTS SHOWN IN FIGURE 4.

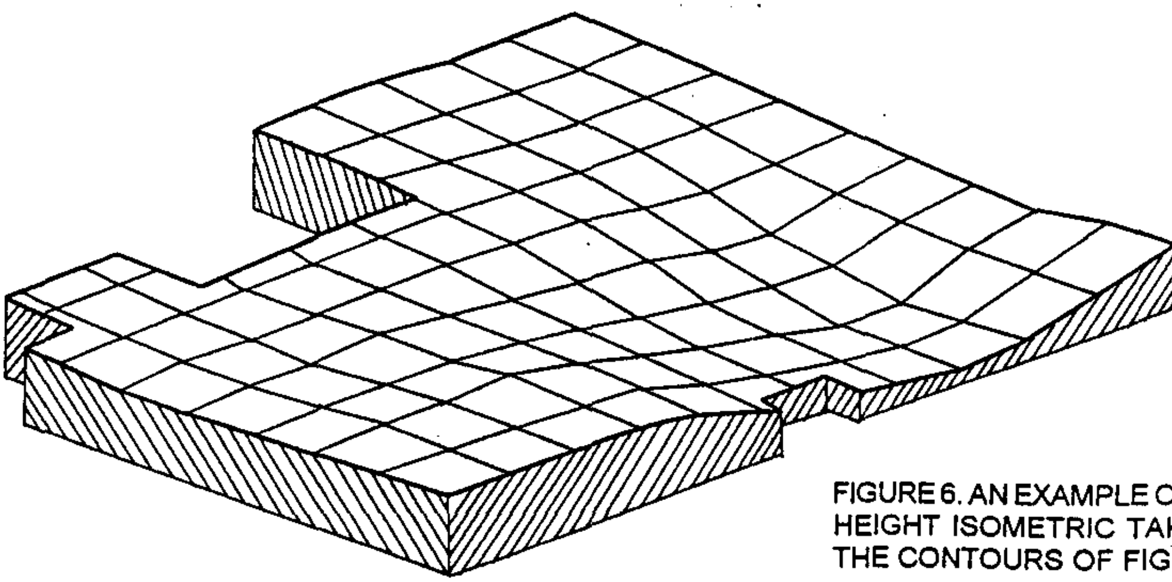


FIGURE 6. AN EXAMPLE OF A FLOOR HEIGHT ISOMETRIC TAKEN FROM THE CONTOURS OF FIGURE 5.

SOILS-STRUCTURE INTERACTION SEMINAR

SPONSORED BY THE FOUNDATION PERFORMANCE COMMITTEE

July 25, 1996

FOUNDATION DISTRESS EVALUATION AND ASSESSMENT

FOR

RESIDENTIAL STRUCTURES

presented by
Donald E. Lenert, P. E.
Structural Engineer
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Curriculum Vitae of
DONALD E. LENERT, P. E.
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CAREER HIGHLIGHTS

- Founder and President of Associated Engineering Consultants (1966)
  A consulting engineering firm offering structural, civil, mechanical and electrical engineering services. 120 people employed.
- Founder and President of Lenert Engineers (1969)
  A consulting firm offering structural engineering services. This company later became Lenert, Hourani & Assoc. 18 people employed.
- Chief Structural and Civil Engineer for CRS Architects-Abu Dhabi (1979)
  In charge of all structural and civil aspects of a new city for 90,000 people built in the United Arab Emirates. It was the single largest project in the UAE in 1981 (one billion dollars) and included support facilities such as: schools, hotels, apartments, warehouses, shopping centers, road and utility lines and a modern sewage treatment plant. My responsibilities included inspection, contract administration, plan and design checking, quality and schedule control and direction of a team of 7,000 multi-national personnel in the Middle East.
- Present position: Owner, Lenert Engineers, Inc. (1984)
  My position has many duties, such as project engineer, inspector, checker, computer programmer, report writer and general trouble-shooter on various projects all over the United States. I specialize in unusual or special problems on apartment and multi-storied buildings requiring original engineering concepts to solve. I work on projects varying in size from small residences to generating 400 page architectural and structural reports on $400,000,000 office buildings.

PROFESSIONAL EXPERIENCE

My total engineering experience includes over 35 years in responsible charge of projects such as office buildings, schools, shopping centers, churches, hotels and apartments, banks, parking garages, public/governmental projects and industrial facilities. I am qualified as a design structural engineer, expert court witness, field inspector and contract administrator. I am author of many computer programs, engineering reports and technical manuals, a speaker at local seminars and am an experienced general construction estimator.

EDUCATION and BACKGROUND

- Bachelor of Science in Civil Engineering-Texas A&M University 1957
- Registered Professional Engineer - Texas #22916
- <u>Memberships</u>: National Society of Professional Engineers
  International Concrete Repair Institute
  Post-Tensioning Institute

OUTLINE OF PRESENTATION

1) Introduction to various Building Code requirements (use variation of Kirby Meyer chart).
   a) Deflections, differential movement, tilt in residence foundations.
   b) Slopes - Introduction
      - SD - Slope Distance/360 vs. L/360 -
      - Examples - exterior & interior materials act differently

2) Example of typical residence foundation analysis using SD criteria.
   a) Importance of actual slab performance vs. theoretical design.
   b) How to plot contour lines
      - Show high and low elevations in micro-elevation survey
      - Explain how contours are used in analysis (forest vs. trees)
      - Puddles, center settlement, upheavals, edge settlement
   c) How to test contours using SD/360 or SD/240 allowable slopes
   d) Profile drawings determine relationship of slope, tilt & differential movement.

3) Introduction to the PHENOMENA PLAN
   a) Importance of confirming the micro-elevation survey data with negative phenomena
      - Why negative phenomenon is essential to confirm differential movmnt
      - The homeowner's perception of problems (real or imagined)
   b) Importance of establishing a historical record of negative phenomena and elevations
   c) The significance of supporting and/or conflicting data

4) Methods to conduct an actual residential elevation survey
   a) Measure the building and draw a plan
   b) Interview the homeowner
      - Their perception of problems (real or imagined) is of paramount importance
   c) Log significant negative phenomena on plan using symbols
      - Show how door slopes, diagonal cracks, etc. are drawn on phenomena plan
      - Not all negative phenomena need be shown
   d) Photographs - show representative examples of negative phenomena
   e) Survey instruments *(already given by Richard Peverley)*

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TABLE OF CONTENTS

DEFLECTION CRITERIA FOR DETERMINING FOUNDATION PERFORMANCE

1) The purpose of this paper is to discuss the recommendations provided by the Deflection Criteria Subcommittee in their independent report. This information is intended to be used as a guide for assessing and evaluating the technical aspects of residential foundation performance.

2) Review of various national and local building code requirements will help determine allowable deflections for new structures. Structural engineers are aware that the allowable deflections mentioned below are intended to be applied to a member spanning between two supports. The allowable deflection code values for a spanning structural member in the ACI Code (Table 9.5b) specify:

a) 1:180 for flat roofs not likely to be damaged by large deflections;
b) 1:360 for floors not supporting non-structural elements likely to be damaged by large deflections;
c) 1:480 for roofs or floors supporting non-structural elements likely to be damaged by large deflections;
d) 1:240 for roofs or floors supporting non-structural elements not likely to be damaged by large deflections.

3) The allowable deflection code values for a spanning structural member in the Houston Building Code (Table 23-D) specify:

a) 1:240 for a roof member or a floor member supporting plaster (Total Load)
b) 1:360 for a roof member or a floor member supporting plaster (Live Load)
c) 1:500 to 1:600 for a member supporting masonry.

4) The allowable deflection code values for a spanning structural member in the Uniform Building Code Table 9.5b (UBC 1994 Edition) *<most likely to be adopted by the City of Houston>* specify:

a) 1:240 for a roof member or a floor member supporting plaster (Total Load)
b) 1:360 for a roof member or a floor member supporting plaster (Live Load)
c) 1:600 for a member supporting masonry.

5) The allowable deflection code values for a spanning structural member in the Standard Building Code, Table 1210.1 (SBCCI) specifies:

a) 1:240 for a roof member or a floor member supporting plaster (Total Load)
b) 1:360 for a roof member or a floor member supporting plaster (Live Load)
c) 1:240 for a roof member supporting nonplastered ceilings (Total Load)
d) 1:120 for a roof member supporting nonplastered ceilings (Live Load)
e) 1:240 for exterior and interior partitions with brittle finishes (Live Load)
f) 1:120 for exterior and interior partitions with flexible finishes (Live Load)

6) The Post-Tension Institute Design Manual specifies 1:360 as the allowable design deflection for slabs-on-grade. BRAB recommends 1:200 for wood, 1:300 for masonry or sheetrock and 1:360 for stucco or plaster (7.2 - Table III). Other building codes will also have some minor variations to the above values.

7) Brick (a non-structural masonry element) is likely to be damaged by smaller deflections, while the more resilient sheetrock and composition roof elements would require larger deflections before damage would occur. It may not be possible to design the components of a single building foundation using two separate deflection criteria, but it is possible to analyze it for performance, no matter where the actual deflection might be.

8) Modification of these Codes is usually necessary in order to apply them to existing residential slab-on-grade construction. These alterations will allow the inspecting expert to modify the accepted Building Code values using variations that pertain only to residential-type slab-on-grade buildings.

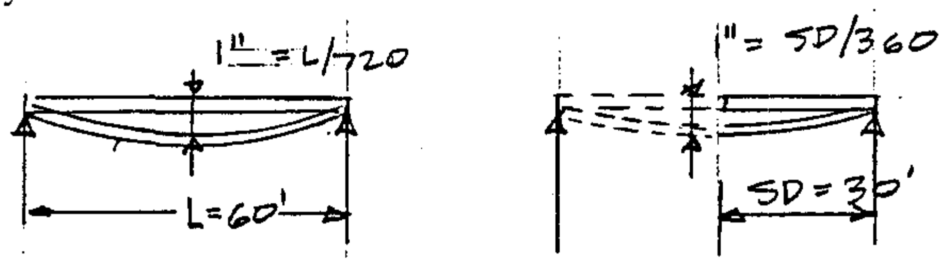
DIFFERENCES BETWEEN "SLOPE", "DEFLECTION" AND "TILT"

9) *Deflection* is technically defined as the vertical height occurring between two supports (e.g., as a simple supported concrete beam spanning between two supports) or occurring as a cantilevered beam where soil support does not exist at one end.

$M = EI\,(d^2y/d^2x)$ {See *Manual of Steel Construction*, AISC, eighth edition, Page 2-112} where x is the abscissa and y is the ordinate. The first integration gives the *slope*, and the second integration gives the *deflection*.

10) The significance of this definition is that if $y = x$, there is no deflection and tilting has occurred. Deflection only occurs where $y > x$; e.g., there is bending in the foundation. It is the bending in the foundation that induces stresses in the upper structure and allows cosmetic damages to occur. Thus, if $y = 0$, then there is no deflection, and the foundation is said to have *tilted.*

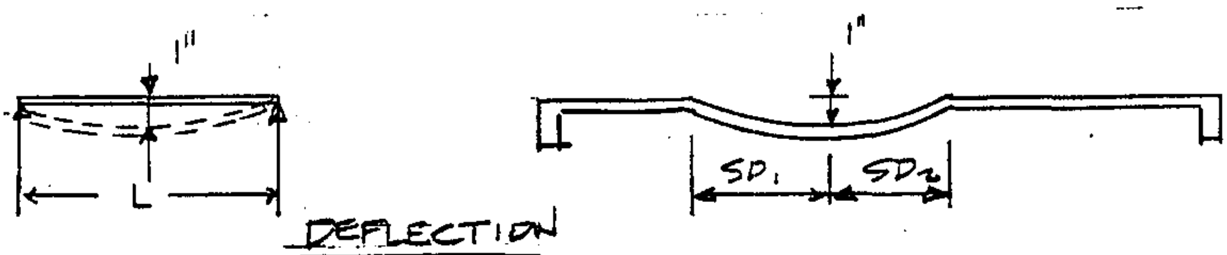
11) Slope Distance "SD" is a special term used to identify the distance between the high and low points of a foundation system. It is not erroneous to express slope in terms of total measured elevation difference. Actual slab-on-grade performance is rarely "textbook", and will tend to be random. This is due to irregularities in the construction as well as the soil/foundation interface movements. For the "SD" calculation, the extreme high and low points should typically be used, since the actual contours are probably "wavy" in-between these two points. If uniform contour lines start to systematically "stack up" (thus indicating a major change in the RATE of slope), then a second "sub-SD" calculation is probably appropriate. The Slope Distance "SD" is technically derived thus:



A *slope* of 1" is thus:

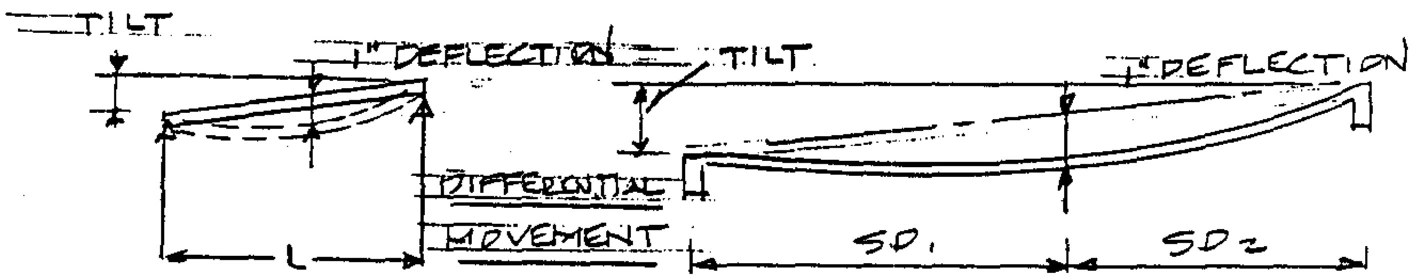
12) ***Deflection*** is defined in slab-on-grade analysis as the maximum vertical height occurring between any two points that may or may not be supports. Due to the cyclic nature of soil movements, there is no assurance that the differential deflection at the time of the measurement will be at its maximum value. Therefore, a conservative assumption is justifiable. A simple beam span will deflect the most, while a beam with continuity on both ends will deflect the least. A foundation supported by drilled footings would be analyzed as a member spanning between two supports.

A *deflection* of 1" is thus:



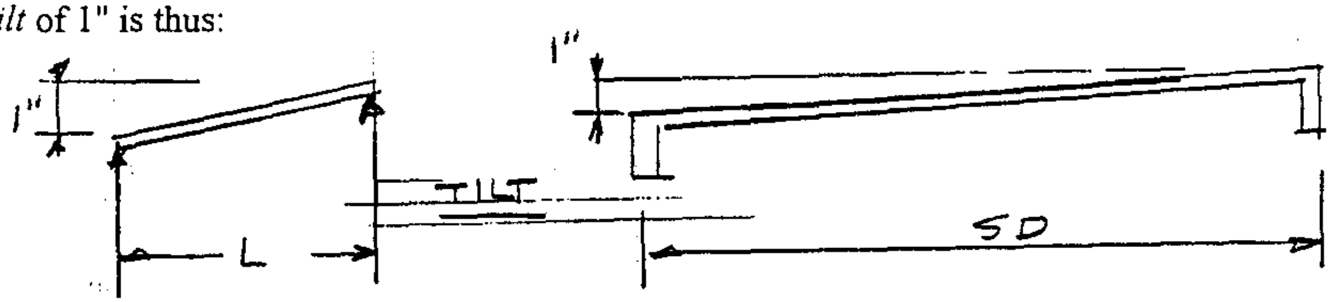
13) A ***differential movement*** is the vertical difference between two points, whether tilted, horizontal or sloping. It is often used interchangeably with the term *deflection*, but does imply that some movement occurred after the construction was completed and the member was loaded. Typically, an elevation variation of about 3/4" is found in foundations for most Houston homes immediately after construction due to construction errors and/or tolerances.

A *differential movement* of 1" is thus:

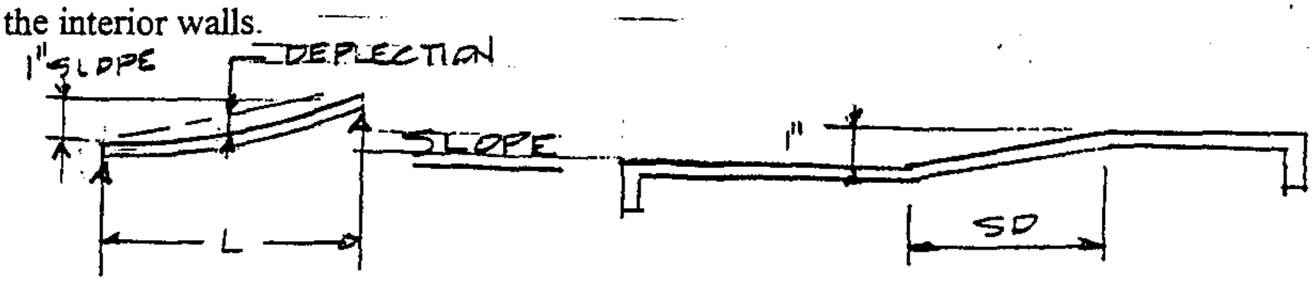


14) A ***tilt*** is a relatively uniform slope from one part of a building to the other. Tilting can occur as the result of uniform soils heaving or settlement and without foundation bending having occurred. Typically, there is little damage when this type of tilting occurs. Framing and walls are perpendicular to the foundation. Counters, sills, etc. are parallel to the floors. Tilting can also be the result of the foundation slab having been placed in an unlevel condition. Under such conditions, walls are generally vertical and counters, sills, etc. are in a level plane.

A *tilt* of 1" is thus:



15) A ***slope*** is the vertical difference at the ends of two horizontal points. In foundation analysis, slope may or may not be a straight line. When slope is a curved line, the curvature may be irregular, or even reversed, along its length. The length in which a slope occurs is called the ***Slope-Distance*** or ***(SD)***, and is usually expressed in slab-on-grade systems as the maximum vertical measured difference that occurs at the extreme high and low points of a floor or slab. *SD* may be calculated along the exterior walls of the building as well as at the high and low points of the interior. This is necessary since the allowable slopes for the exterior walls may be different from the interior walls.



16) A simple beam span will deflect the most, while a beam with continuity on both ends will deflect the least. If the span is 60', then the allowable deflection for a 1:600 criteria would be 1.2". The Slope Distance "SD" involved to obtain the 1.2" deflection is half of the 60' span, or 30'. The allowable deflection for the 30' SD thus becomes 1.2/(30*12) or 1:300. We prefer to use SD/360 for this condition, which is slightly more conservative than the Uniform Building Code. Since floating slabs-on-grade do not have "spans" as such, we recommend the engineer identify the apparent high and low points of a foundation and test the performance between these locations using the allowable Building Code values accordingly. +Due to the cyclic nature of soil movements, there is no assurance that the deflection at the time of measurement will be at its' maximum. The conservative assumption above should be justified, since a structural member suspended in space by columns would not require this consideration.

DEFLECTION CRITERIA SUBCOMMITTEE RECOMMENDATIONS

Allowable Deflections For Existing Slab-On-Grade Construction

17) The Building Codes are designed to be used for NEW construction, but do not address the allowable deflection parameters for EXISTING or OLD construction. We recommend that the applicable Building Codes be used as a basis for establishing whether deflections are excessive in any given residential or commercial project. Structural Building Codes nation-wide, including the BRAB Report, the P.T.I. Report, the Uniform Building Code, the BOCA National Building Code, the SBCCI Standard Building Code and the American Concrete Institute *in general* recommend the following criteria:

18) The various Building Codes always specify that engineers should only use one value (usually the most restrictive) for *design*, although a single deflection value may not be appropriate for *performance*. Some engineers believe that the only deflection allowed should always be 1" vertical in a 30' horizontal distance (SD/360), while more liberal engineers may allow up to SD/120.

a) Brick and stucco walls are limited to 1" differential vertical movement in 30' horizontally.

b) Interior surfaces such as roofs, sheetrock walls or wood siding are limited to 1" differential vertical movement in 20' horizontally.

Please note that tile floors may also be placed in these two categories, depending on whether it is a brittle ceramic tile (SD/360) or a more flexible Saltillo-type tile (SD/240).

19) The Deflection Criteria Subcommittee recommends that the maximum slope or deflection on a residence be typically limited to 3" maximum. Foundation movements in excess of 3" may generally be considered to have failed to maintain the interaction between the building and the underlying soils within tolerable limits. Several exceptions to this criteria are:

a) If the <u>slope</u> of a building exceeds 3" maximum, and the negative phenomenon (cracks) are very extensive, then some structural members may be considered to have failed their intended function (i.e., to have maintained the interaction between the soils and the foundation structure) so that the amount of damages caused by soil movement variations is limited to certain areas.

NOTE: the 3 inch maximum is an arbitrary limit based on experience, since large cracks are usually present when a 3 inch slope with differential movement is present.

b) If the <u>slope</u> of a building exceeds 3" maximum, but there is very little negative phenomenon, then appropriate structural members should be analyzed using the deflection criteria to see if it has *tilted*. The maximum tilt allowed should never exceed 6" or SD/180.

c) If the <u>slope</u> of a building does not exceed 3" (but has exceeded the SD/240 or SD/360 criteria), and the negative phenomenon are very extensive, then appropriate structural members should be analyzed using the deflection criteria to see if it has *tilted* or *failed*.

d) If the <u>slope</u> of a building does not exceed 3" (but has exceeded the SD/240 or SD/360 criteria), and there is very little negative phenomena, then the structural members may be analyzed using the deflection criteria to see if it has *tilted*.

e) If the <u>tilt</u> of a building does exceeds 6" or SD/180, but the negative phenomenon are minimal, then the structure should be analyzed using the deflection criteria to see if it has *failed*. The owner or buyer should be notified in writing of the condition.

f) If the <u>tilt</u> of a building does not exceed 6" or SD/180, but is more than 3", and the negative phenomenon are minimal, then the owner or buyer should be notified in writing of the condition.

MICRO-ELEVATION SURVEY PLAN

20) We recommend the micro-elevation survey as an excellent technical method for assessing an existing structural system. This becomes especially important when the original plans and design are no longer available for review. In such cases, <u>performance</u> may be the best criteria to be used to rationally evaluate a foundation. Destructive and non-destructive testing should also be used when appropriate.

PHENOMENA PLAN

21) The measurement of the elevations determines the actual technical performance of a foundation system. The presence of negative phenomena establishes that post-construction movements has occurred. These two factors are used as a <u>guide</u> by the investigative engineer, just as the L/360 values are used as a <u>guide</u> by the design engineer. On a building that is being investigated for foundation performance, the design and construction are already completed. The performance may be assessed by the use of micro-elevations, but should be compared with existing negative phenomenon, including many of the following items that are shown on the <u>Phenomena Plan</u>:

- a)* Obviously sloping floors; binding doors or "pie-shaped" gaps above door heads;
- b)* Diagonal or vertical masonry and sheetrock wall cracks;
- c) Brick chimney leaning outwards away from main building;
- d) Separations in ceilings and crown moldings;
- e) Concrete slab or floor tile cracks;
- f) Baseboard separations at the interior walls;
- g) Floor tile pulling away from baseboards;
- h) Presence of algae at the exterior, indicating super-saturated conditions exist;
- j) Existence of earth cracks next to the exterior walls, indicating that an extremely dry condition exists;
- k) Separation of wood trim from adjacent wall elements such as at windows, brick, stucco or sheet rock; "Popped" nails in sheetrock walls;
- l)* Pulling away of roof frieze boards (typically a 1" x 4" below the roof soffit); Roof leaks despite roofing material that is in good condition;
- m) Horizontal brick cracks just above the grade beam may indicate a differential settlement, even though there are no corresponding diagonal wall cracks;
- n) Poor concrete and reinforcing placement or lack of curing; "Soft" concrete with lack of good durability.
- p) Corner sheetrock cracks at the top of windows or doors.

***Note:** Show the direction of downward slopes where applicable, and note any contradictions between observed phenomenon & micro-elevation data.

EVALUATION OF DATA

22) The micro-elevation survey plan and phenomena plan should be compared to confirm whether differential foundation movements have occurred. The presence of a change in the slab elevation (slope) does not necessarily mean that differential movement has occurred. We may assume that the construction of slabs-on-grade is seldom closer than 3/4" in vertical elevation control, so it is essential that any measured sloping floor systems be accompanied by some type of negative phenomenon, such as described above. If these are not present, then it is quite possible that the building foundation was originally built out of level.

---------------- end ----------------

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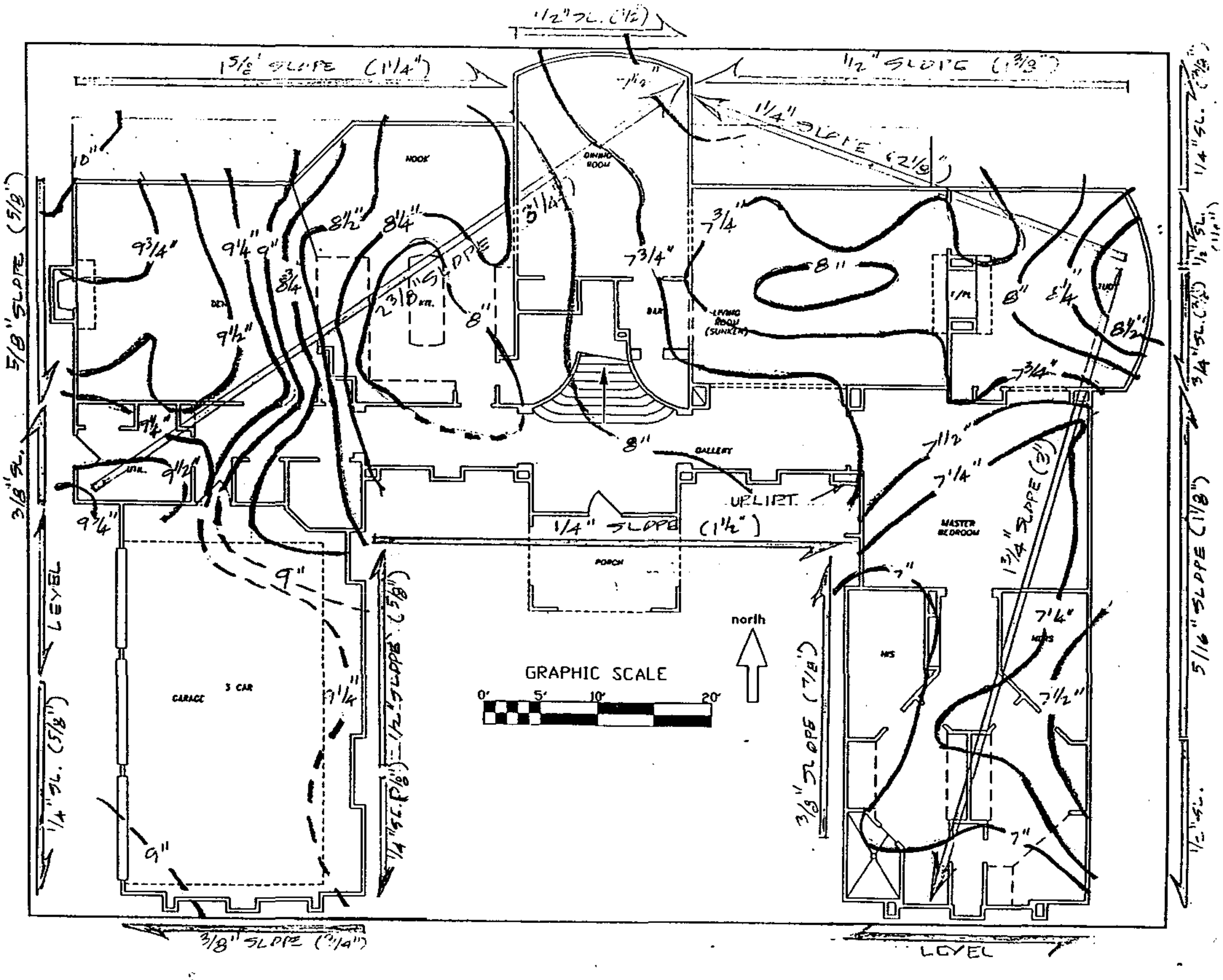
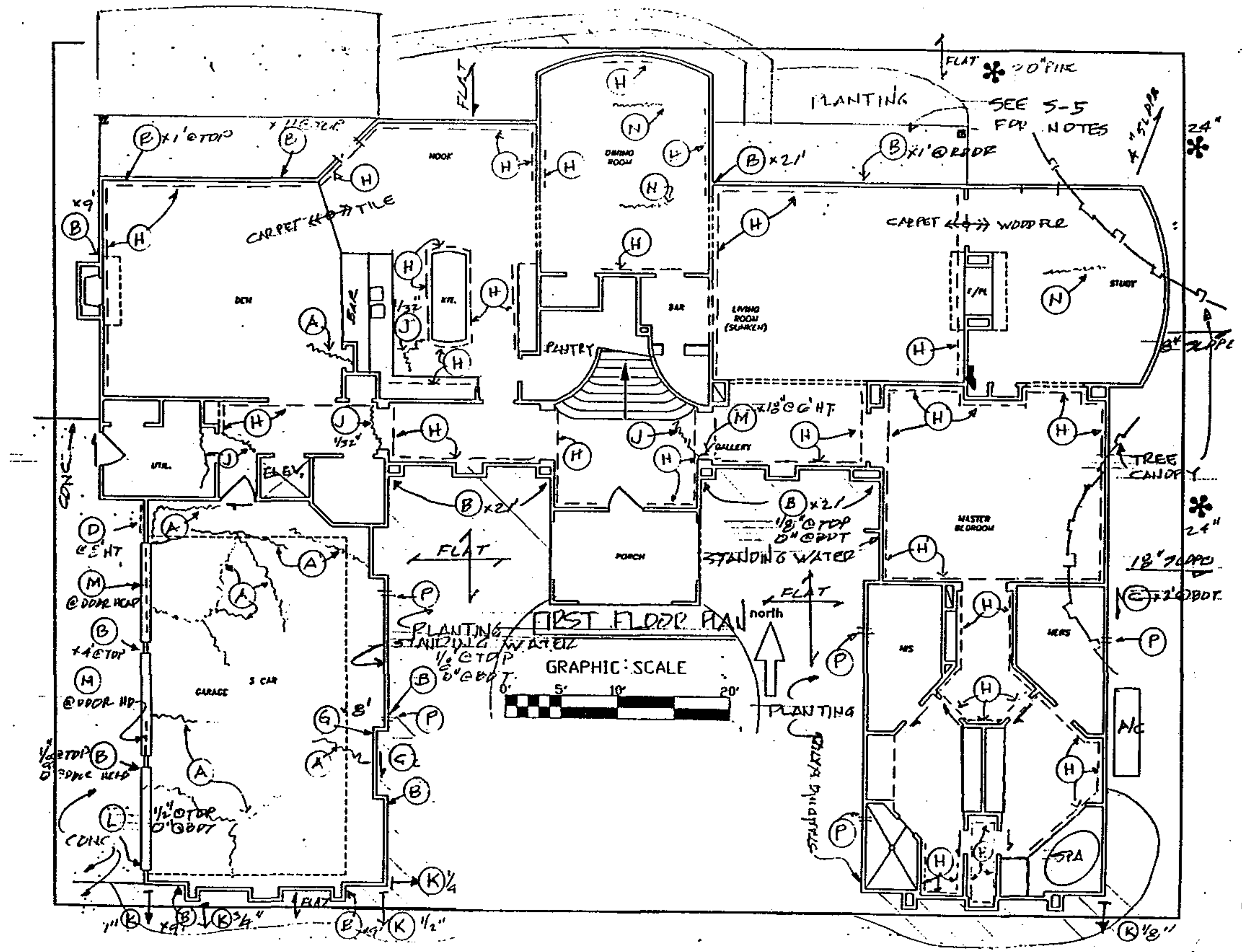
SUBJECT: SAMPLE OF TECHNICAL ANALYSIS ON HOME
MICRO-ELEVATION CONTOURS

SHEET S-1 OF 11
DATE: 7/25/96
BY: DEL





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SAMPLE OF TECHNICAL ANALYSIS ON HOME

PHENOMENA PLAN

DATE: 7/25/96

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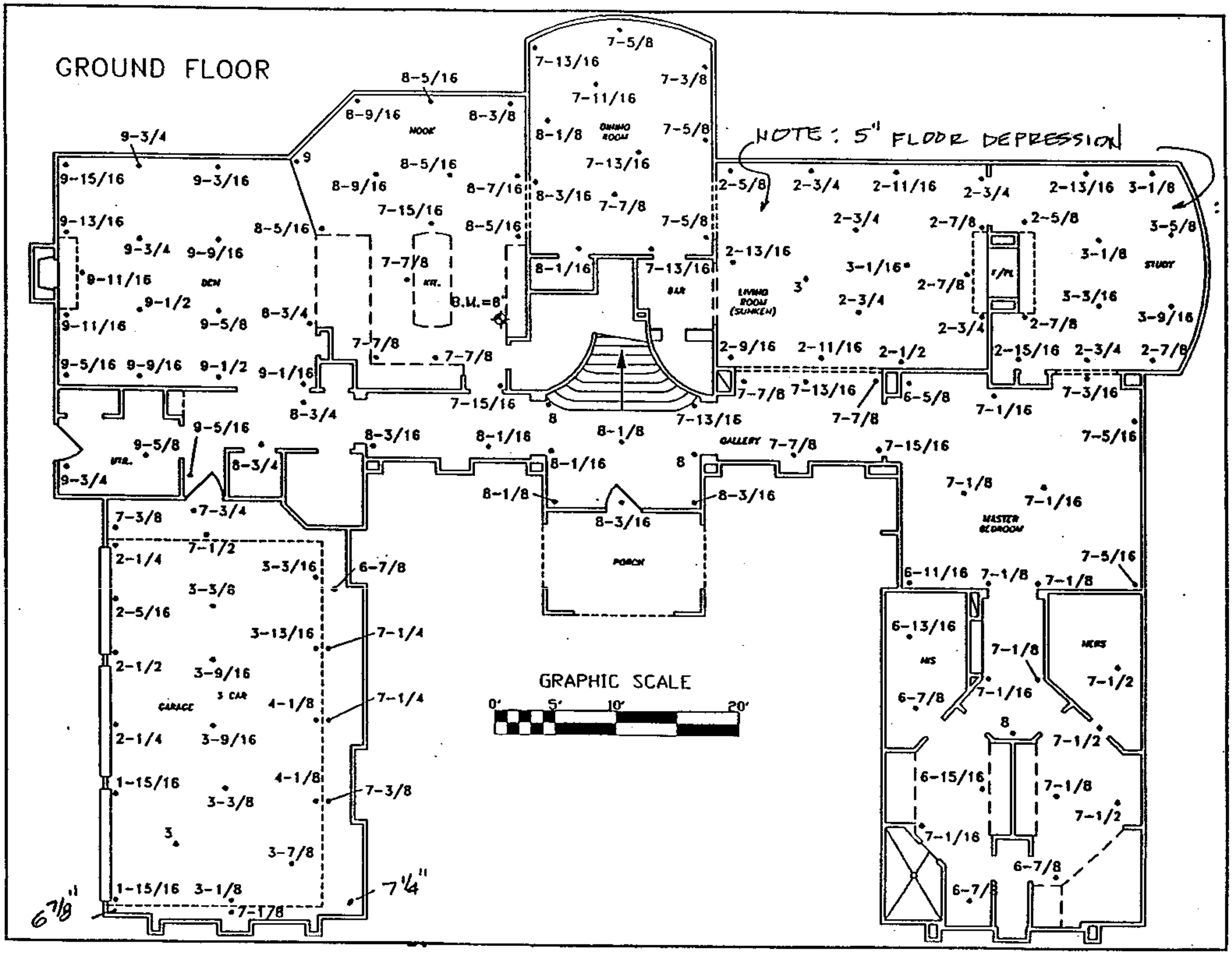

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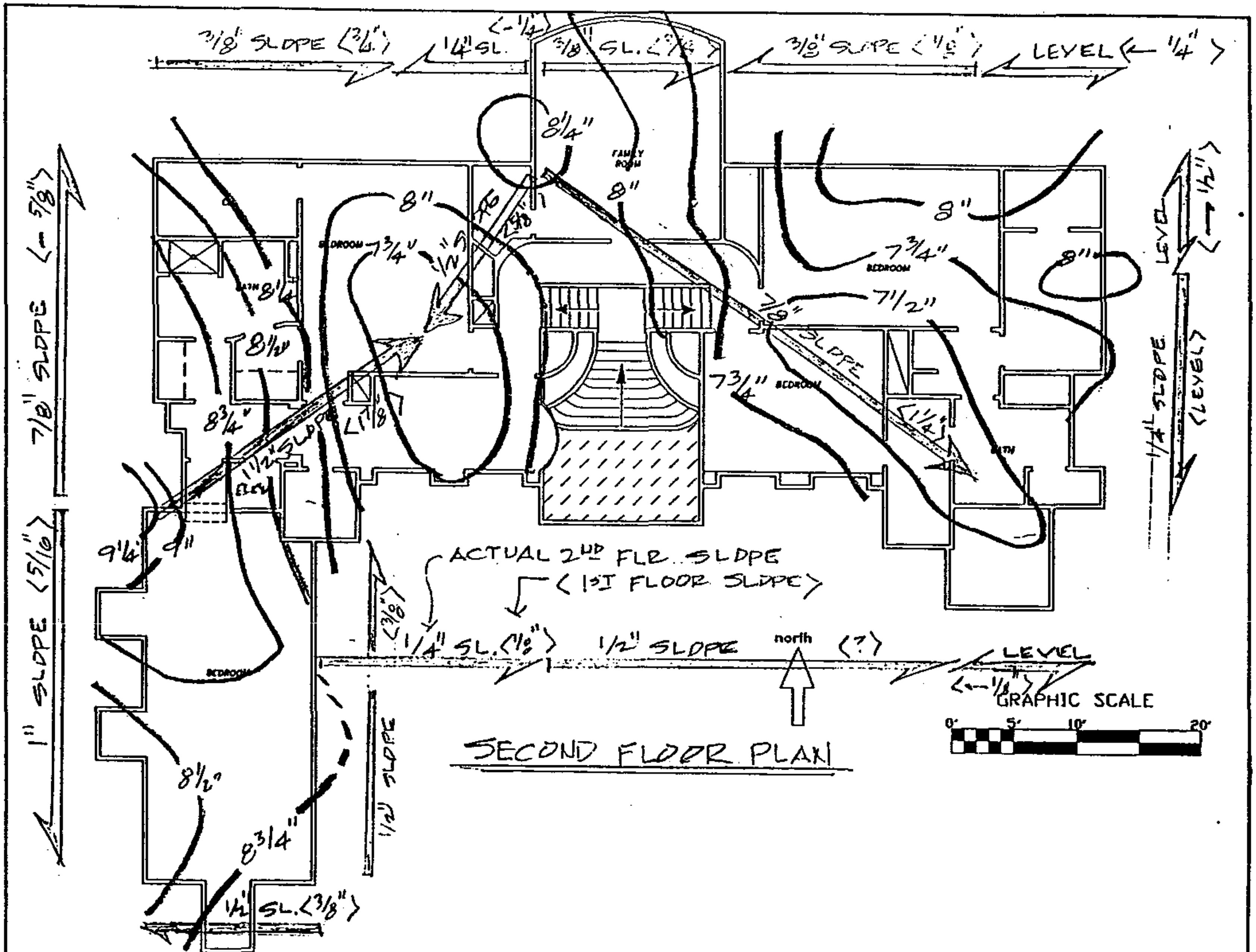
SUBJECT: SAMPLE OF TECHNICAL ANALYSIS ON HOME

MICRO-ELEVATION SURVEY

SHEET 2 OF 11

DATE: 7/25/96

BY: DEL



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SUBJECT: SAMPLE OF TECHNICAL ANALYSIS ON HOME

MICRO-ELEVATION CONTOURS

SHEET S-4 OF 11
DATE: 7/25/96
BY: DEL

OUTLINE OF PRESENTATION

1) Introduction to various Building Code requirements (use variation of Kirby Meyer chart).
   a) Deflections, differential movement, tilt in residence foundations.
   b) Slopes - Introduction
      - SD - Slope Distance/360 vs. L/360 -
      - Examples - exterior & interior materials act differently

2) Example of typical residence foundation analysis using SD criteria.
   a) Importance of actual slab performance vs. theoretical design.
   b) How to plot contour lines
      - Show high and low elevations in micro-elevation survey
      - Explain how contours are used in analysis (forest vs. trees)
      - Puddles, center settlement, upheavals, edge settlement
   c) How to test contours using SD/360 or SD/240 allowable slopes
   d) Profile drawings determine relationship of slope, tilt & differential movement.

3) Introduction to the PHENOMENA PLAN
   a) Importance of confirming the micro-elevation survey data with negative phenomena
      - Why negative phenomenon is essential to confirm differential movmnt
      - The homeowner's perception of problems (real or imagined)
   b) Importance of establishing a historical record of negative phenomena and elevations
   c) The significance of supporting and/or conflicting data

4) Methods to conduct an actual residential elevation survey
   a) Measure the building and draw a plan
   b) Interview the homeowner
      - Their perception of problems (real or imagined) is of paramount importance
   c) Log significant negative phenomena on plan using symbols
      - Show how door slopes, diagonal cracks, etc. are drawn on phenomena plan
      - Not all negative phenomena need be shown
   d) Photographs - show representative examples of negative phenomena
   e) Survey instruments *(already given by Richard Peverley)*

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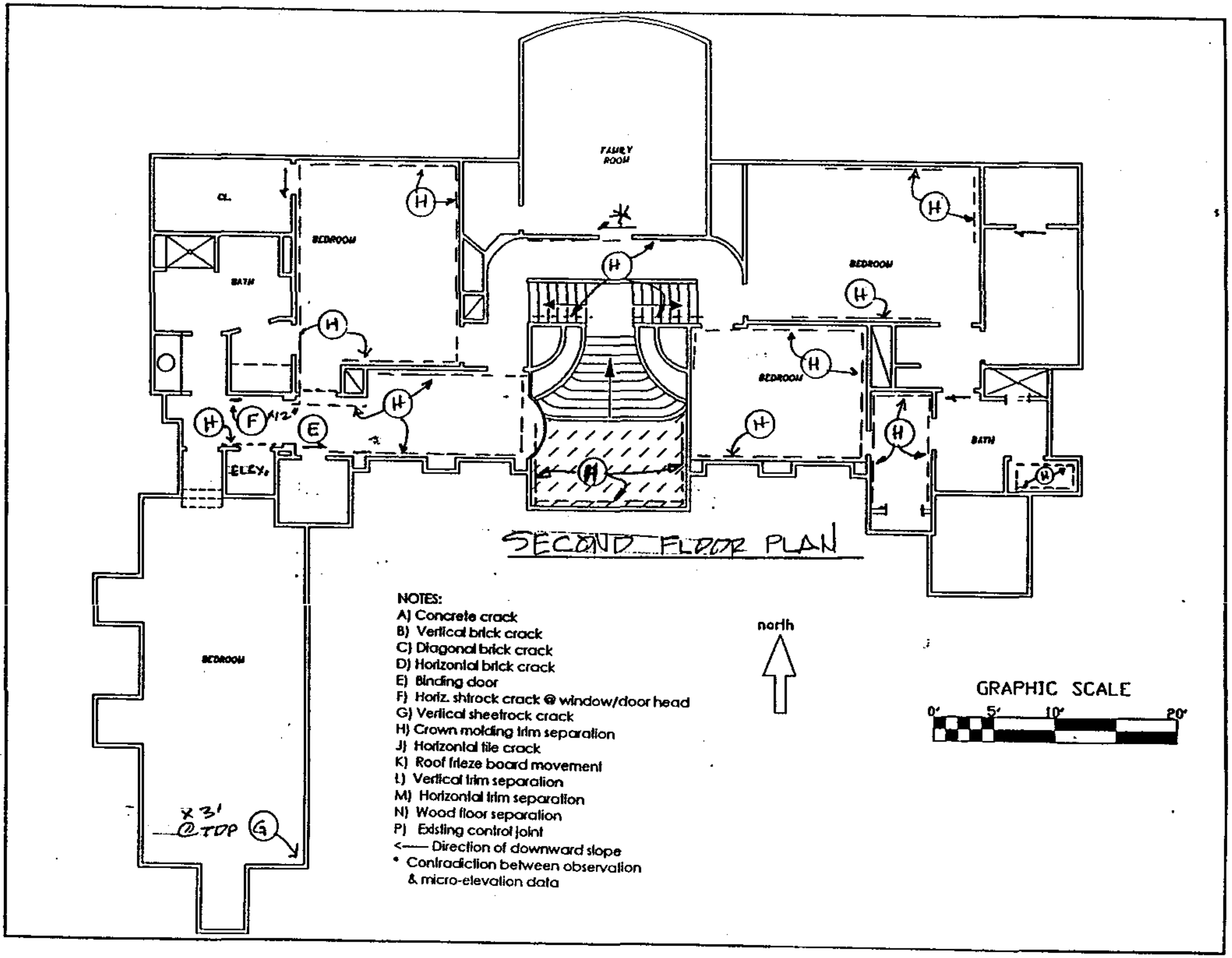

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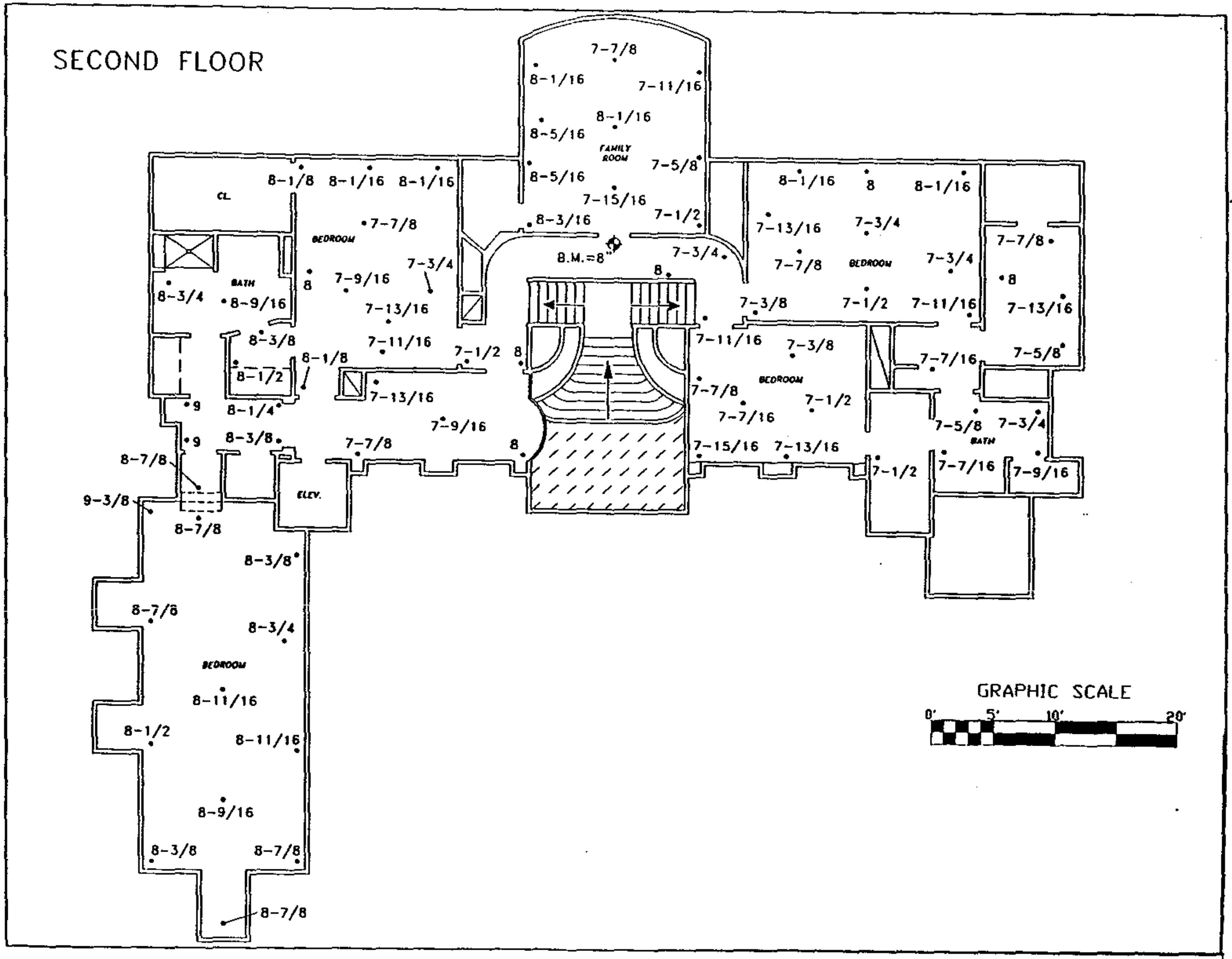
SUBJECT: SAMPLE OF TECHNICAL ANALYSIS ON HOME

PHENOMENA PLAN

SHEET [illegible] OF 11
DATE: 7/25/96
BY: DEL



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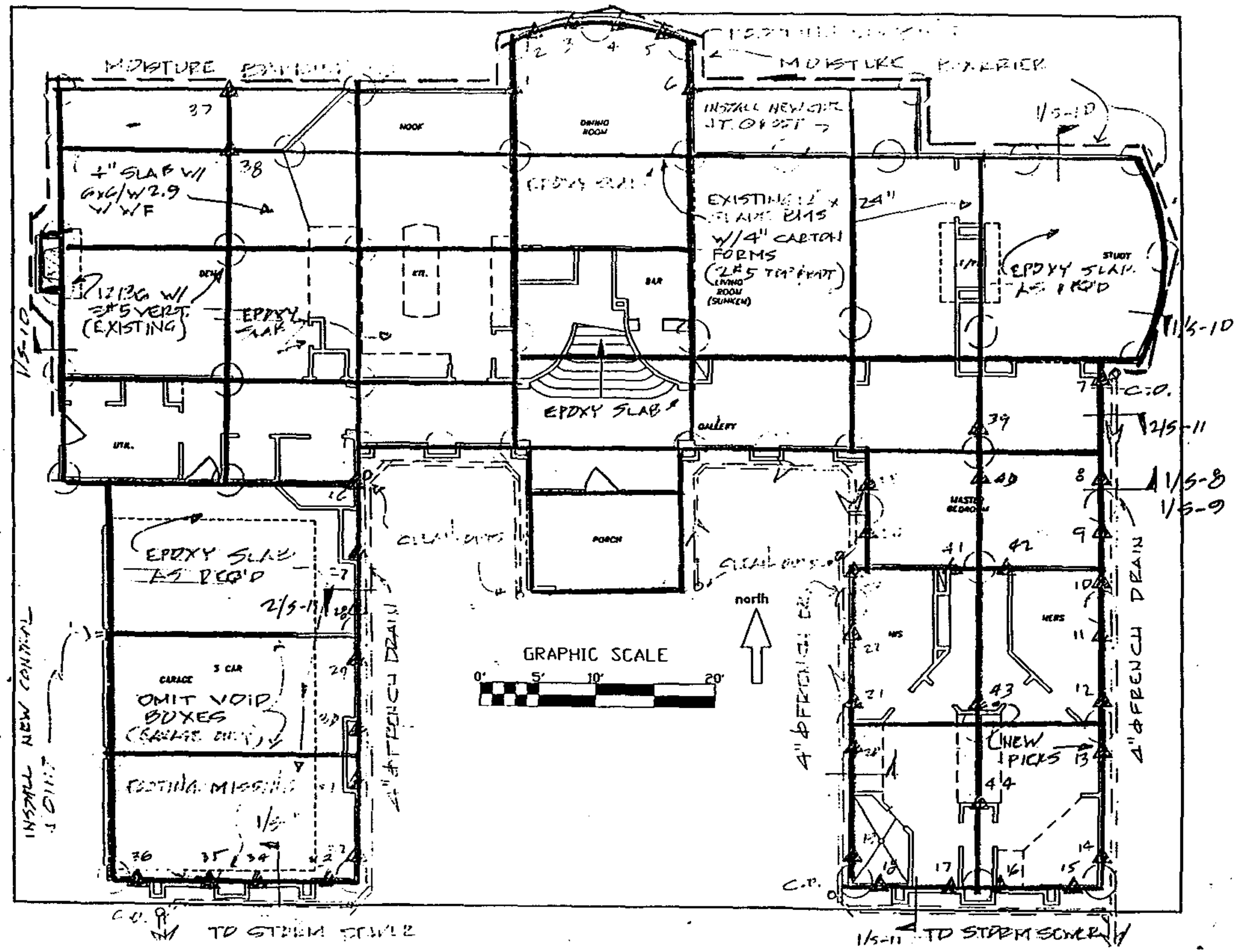
SUBJECT: SAMPLE OF TECHNICAL ANALYSIS ON HOME

MICRO-ELEVATION SURVEY

SHEET S-6 OF 11
DATE: 7/25/96
BY: DEL



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FOUNDATION PLAN

DATE: 7/25/96
BY: DEL

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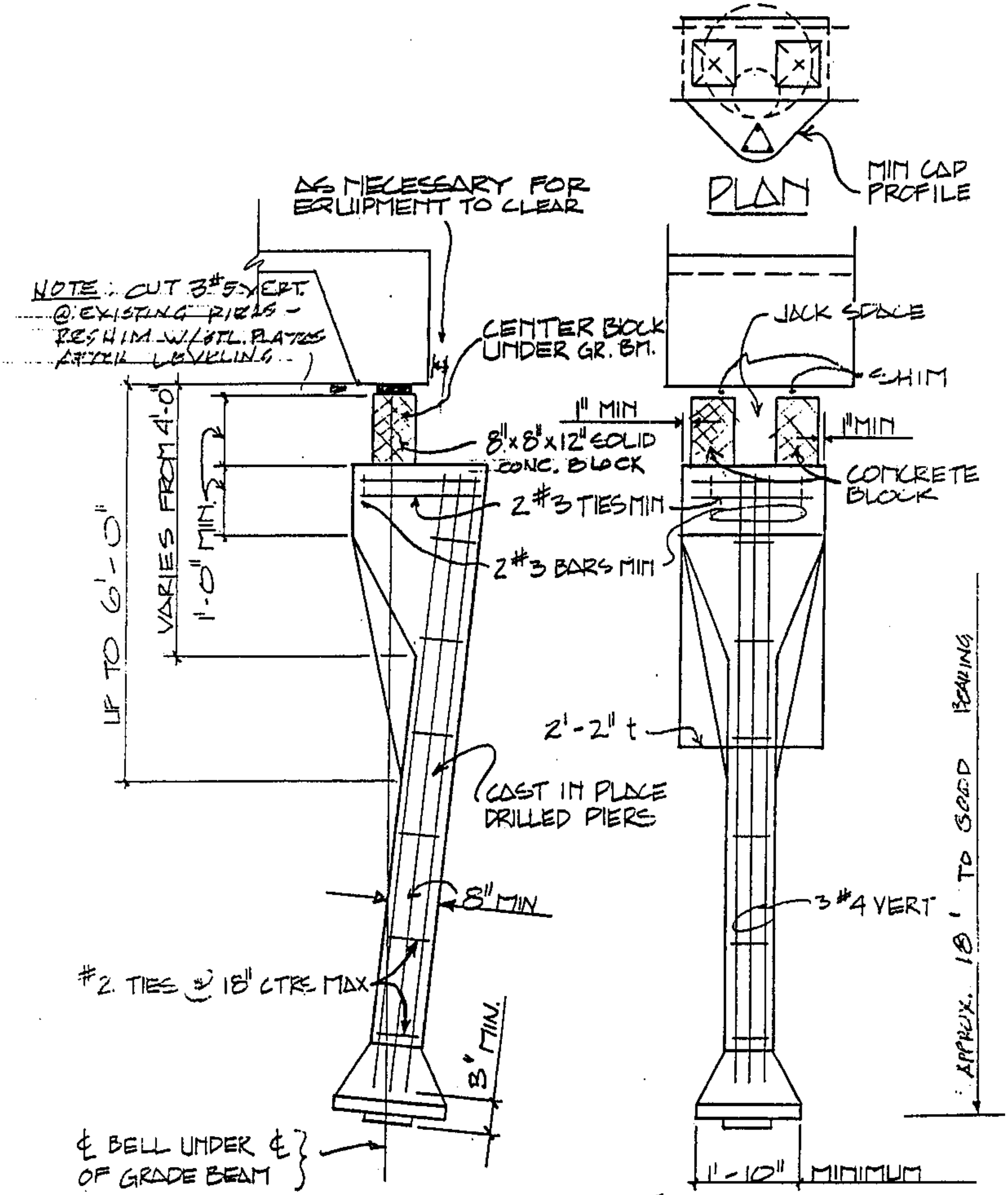
FOUNDATION DETAILS

DATE: 7/25/96
BY: DEL



1/S-8 Cross-Section Front View

TYPICAL GRADE BEAM LEVELING DETAILS

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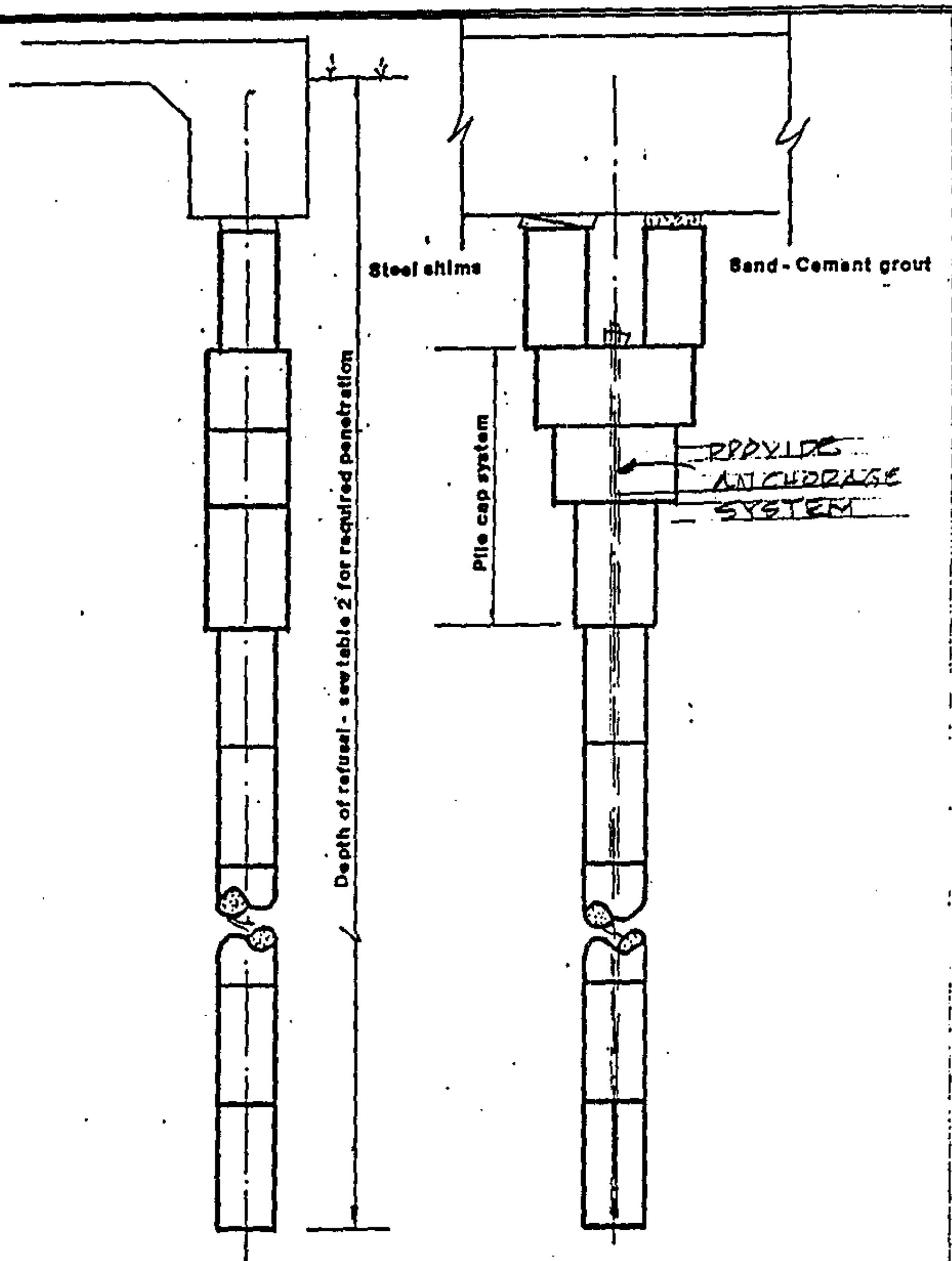
SUBJECT: SAMPLE OF TECHNICAL ANALYSIS ON HOME FOUNDATION DETAILS

DATE: 7/25/96
BY: DEL



Completed Perma-Pile Installation
Figure 7

T/S-9

I-6

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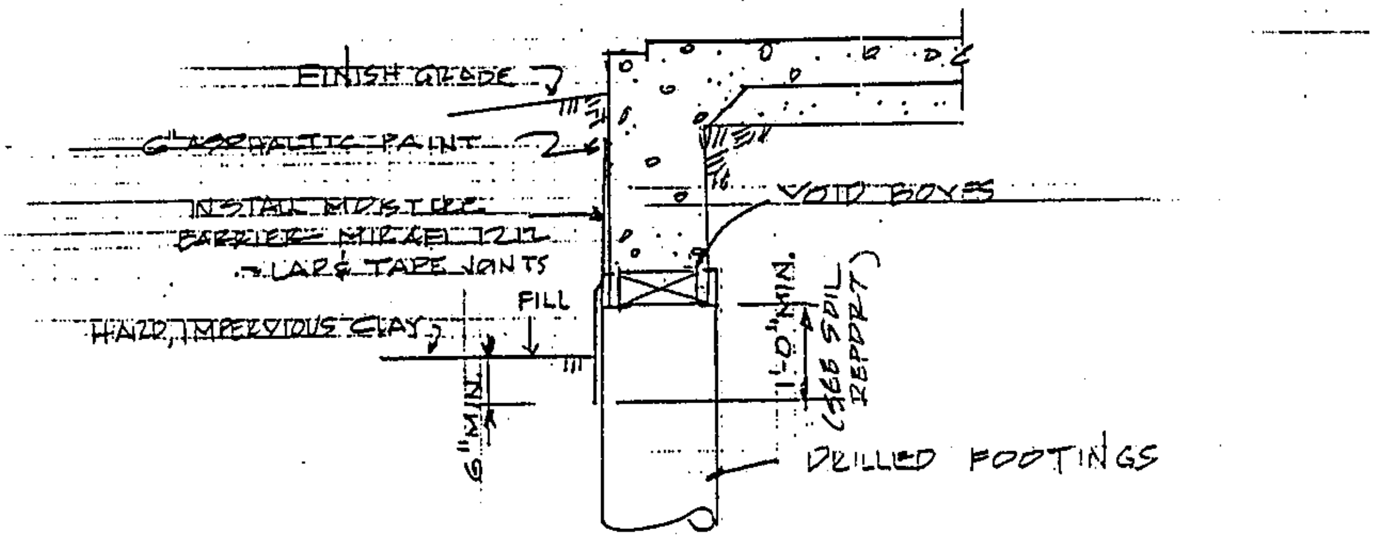
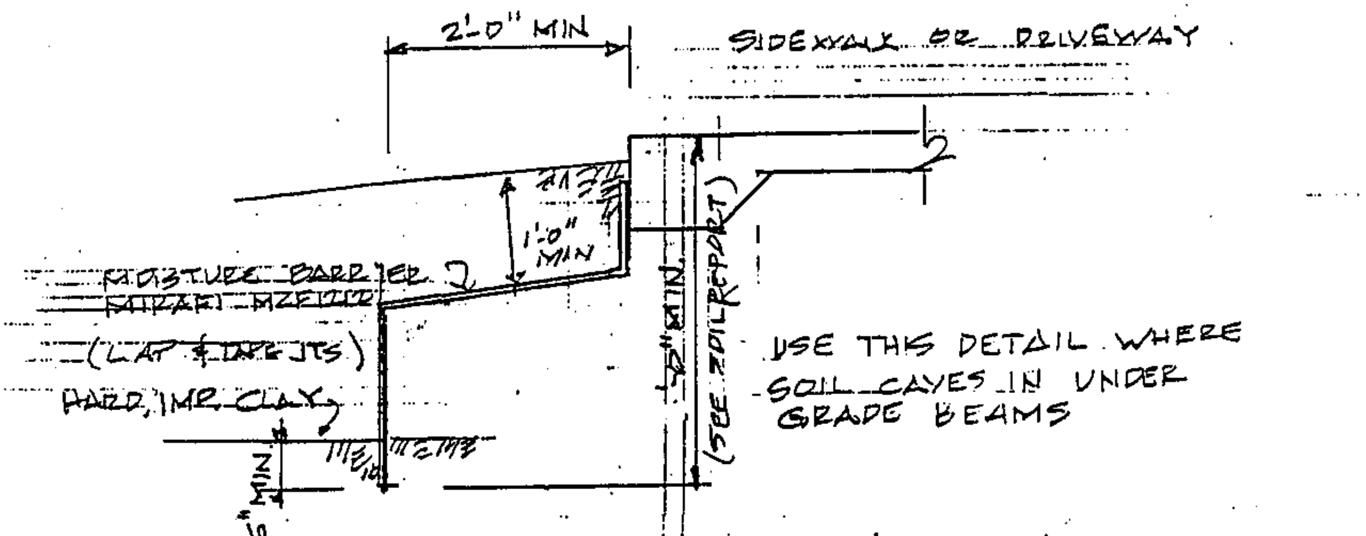


SECTION 1/S-10



SECTION 2/S-10

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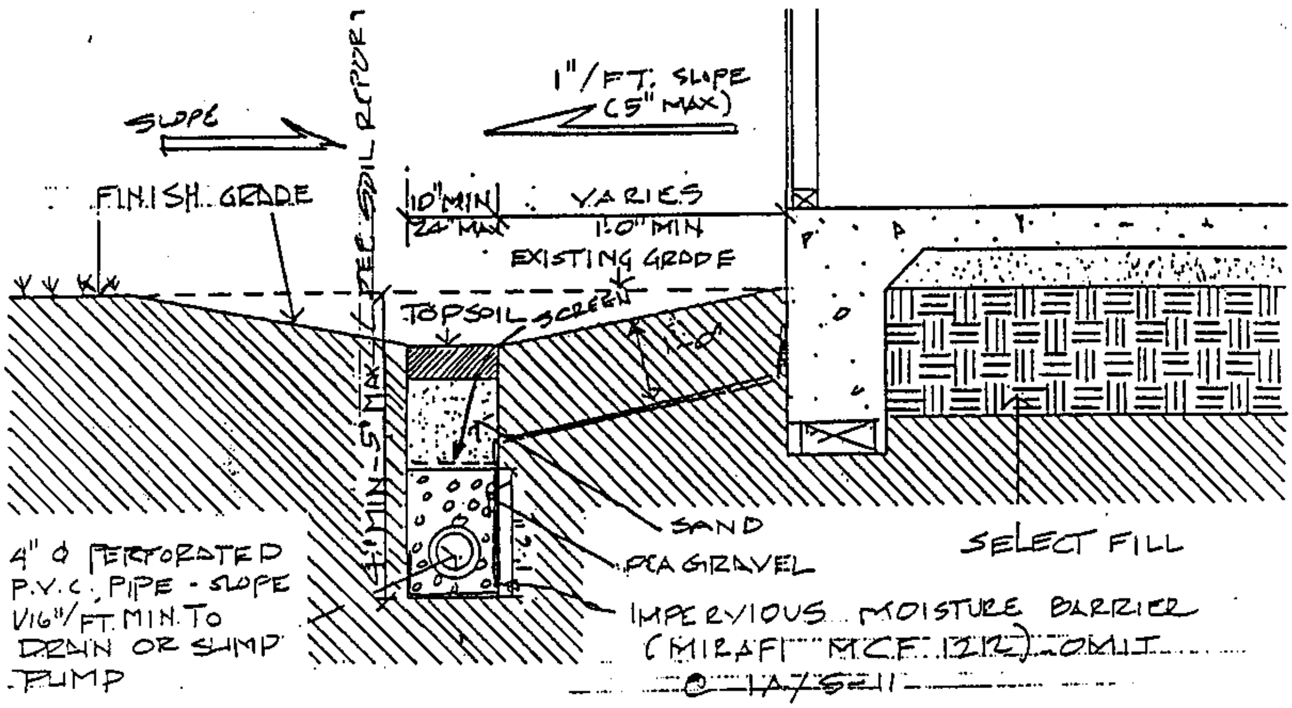
SUBJECT: SAMPLE OF TECHNICAL ANALYSIS ON HOME

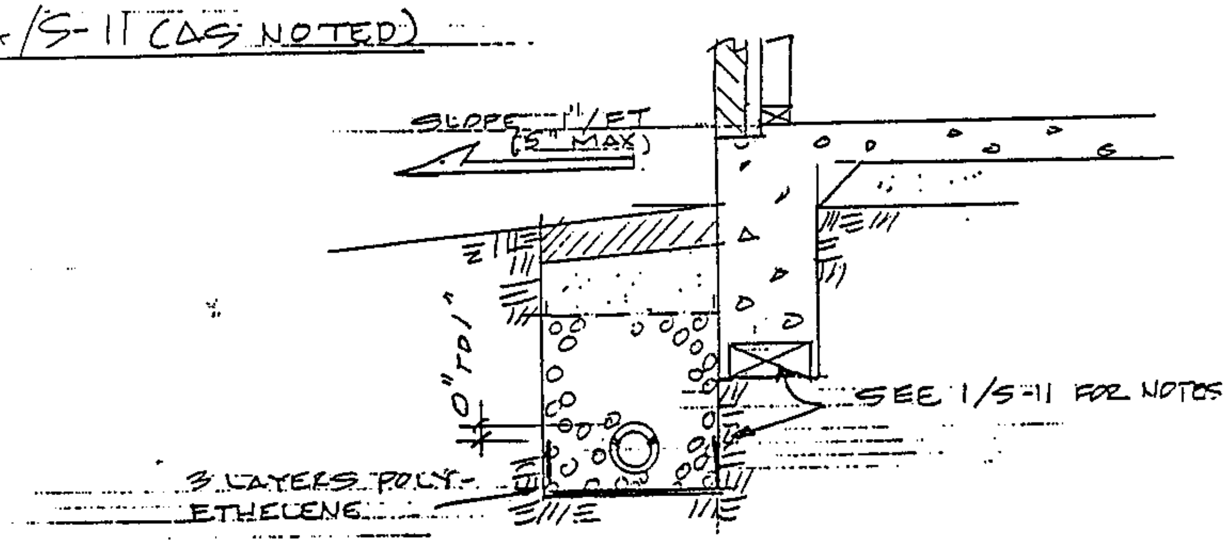
FRENCH DRAIN DETAILS

DATE: 7/25/96
BY: DEL



1/S-11 FRENCH DRAIN - PROPERLY INSTALLED

1A/S-11 (AS NOTED)



2/S-11 SECTION

FOUNDATION REPAIR TECHNIQUES

BY

JAMES DUTTON

DU-WEST FOUNDATION REPAIR

THE HELICAL PIER SYSTEM

The concept is founded on the principle of screwing a helical plate attached to a steel shaft into stable subsoil strata until the torque applied indicates that the necessary load capacity has been achieved. Adjustable brackets are then attached to the base of your foundation. The weight of your home is then shifted to the piers. In the process, foundations, walls and floors are repositioned and retained from further movement.

The Helical Pier system may be installed only by contractors who have been certified by the Chance Company. The load bearing steel shafts are screwed into the ground independent of the structure and their bearing or holding capacity is verified as the system is installed.

Following the design specifications, the contractor will excavate down to the footing at each pier location. A notch will be chipped out of the footing to accommodate a support bracket. A high-torque hydraulic drive head will screw the piers into stable subsoil until the prescribed pier depth is reached. A steel L-shaped bracket placed on top of each pier will connect to the base of the foundation wall. The weight of your home then will be transferred to the piers by a calculated procedure of hydraulic jacking and adjustment of the brackets. Finally, all excavation will be backfilled.

Settling, cracked or bulging concrete floors are also the result of soil movement and are corrected in much the same way. An access hole is cut through the floor at the prescribed location. A Helical Pier is inserted through the opening and screwed into stable subsoil. The top of the pier is then fitted with a steel channel plate that spans the diameter of the hole. Screwing a bolt through the channel plate applies the load to the pier shaft and the floor is raised. After the correction is made, the access holes are filled with concrete.

Buckled foundation walls are also stabilized by Helical Pier anchoring. The contractor first carefully excavates a narrow trench outside, along the foundation wall, to relieve pressure and provide room for repositioning the wall. A small hole is drilled through the wall at the affected area. From inside, a steel shaft is inserted through the hole and a helical screw plate is attached outside. Then the contractor uses a drive motor to install the pier to its proper depth. A ribbed steel plate positioned over the shaft protruding inside the wall is secured by a nut. Tightening the nut counteracts further movement and, in many cases, straightens the wall.

The system components include solid steel shafts of round or square configuration to most economically meet any design-load requirement. The standard underpinning bracket typically comes complete with the hardware required for assembly to the Helical Pier shaft. The lifting assembly, consisting of the underpinning bracket and jacking tool, is designed to lift with hydraulic jack assistance.

Hardware is also available for specialized applications, such as the Uplift bracket for seismic conditions, as well as a variety of extensions, adapters, wall anchor kits and slab-repair brackets.

FOUNDATION MAINTENANCE

There are two major villains you must be aware of when dealing with proper maintenance of your first foundation of soil ----- **EXPANSIVE SOIL AND MOISTURE CHANGE.**

Expansive soils are clay soils which have the unique property of expanding when moist and shrinking when dry. When a dry clay soil absorbs moisture and expands it can produce enough lift to raise a two story house. Conversely, if the moisture evaporates that same slab or a corner of it can drop.

Moisture change is the common thread that produces damage to foundations through expansions and contractions of the clay soil during wet/dry weather cycles. Trees also play an important role in moisture content as a tree's roots can remove 100 gallons to 600 gallons of water a day from the soil.

If a home is built on expansive clay soil which has sufficient moisture at the time of the building the foundation causing the soil to be in an expanded state, and the optimal moisture content is maintained over the life of the home, little movement or damage will occur. Such conditions however, are ideal and only occur if the homeowner practices proper moisture maintenance.

The performance of your soil foundation, whether or not it holds your home steady and undamaged throughout the years of use and weather changes, depends on three basic factors:

1.) Proper analysis of the soil before the house is built
2.) Proper design and construction of the house, including the man-made foundation
3.) Most importantly, proper maintenance by the homeowner of the soil moisture

Giving the soils around the house a controlled amount of moisture can be very beneficial to your home. A little water on a regular basis is all it takes. ***It is very important not to over water***. The purpose of the watering is to stabilize the moisture changes in the soil. Over watering may cause more damage than under watering. The idea is to maintain a moist soil, not a saturated condition. The ground around the foundation should slope gently away from the house so as not to pond any excess water near the slab. This way with an irrigation system you are in control of the amount of water the soils under the home receives, not an irregular Mother Nature.

Remember --- no matter how well a home is built, based on sound engineering and incorporating high standards of quality in construction, a wide variety of factors, soil conditions and climatic extremes can cause major foundation problems. Constant vigilance concerning moisture maintenance around a foundation is absolutely necessary.

ROOT BARRIERS

Dry foundation soils can be caused by more than the weather. Tree roots have a tendency to grow under a concrete foundation to rob the moisture which naturally resides there. As trees take this moisture out the soils begin to dry and shrink. This is especially true if they are clay based soils. Once the soils shrink they leave the foundation unsupported and foundation failure can occur. This can happen any time but the foundation is particularly vulnerable to this on excessively hot dry years when trees are searching for any source of moisture they can find. Since some trees can consume upwards of 600 gallons of water a day, protecting the soils under the foundation from thirsty tree roots can be very important.

Installing a poly-ethylene Root Barrier between the house and damaging tree can help provide the home with protection from damaging tree roots. The majority of a tree's roots run 18" and shallower in the soil. Most root barriers are installed by cutting a 30" deep trench 4" wide and installing some type of barrier. There are many different materials used for barriers:

1.) 1/8" thick non-biodegradable high density poly-ethylene
2.) Chemically treated root cloth
3.) Concrete
4.) Fiberglass panels
5.) Bentonite

Determining the age of the tree versus the age of the house is very important before deciding to install a root barrier or remove a tree. If the tree is much older than the existing house, the soils around and under the home were accustomed to the moisture draw of the tree before the structure was built and removing that moisture draw may be detrimental to the soils and foundation. If a tree is younger than the house a root barrier may be very beneficial in maintaining proper moisture content under the foundation.

Remember, this is preventative maintenance, not a foundation repair. As with other preventative maintenance programs it can help protect the home from some possible causes of foundation failure; however, this cannot guarantee the foundation will not fail.

BELL BOTTOM PIERS

Bell bottom piers, belled piers, FHA style piers, whichever name traditionally used, are all basically the same design. They have been around for years and are known as the traditional underpinning. In order to install a bell bottom pier, dig a box, drill, and bell off the bottom of the pier.

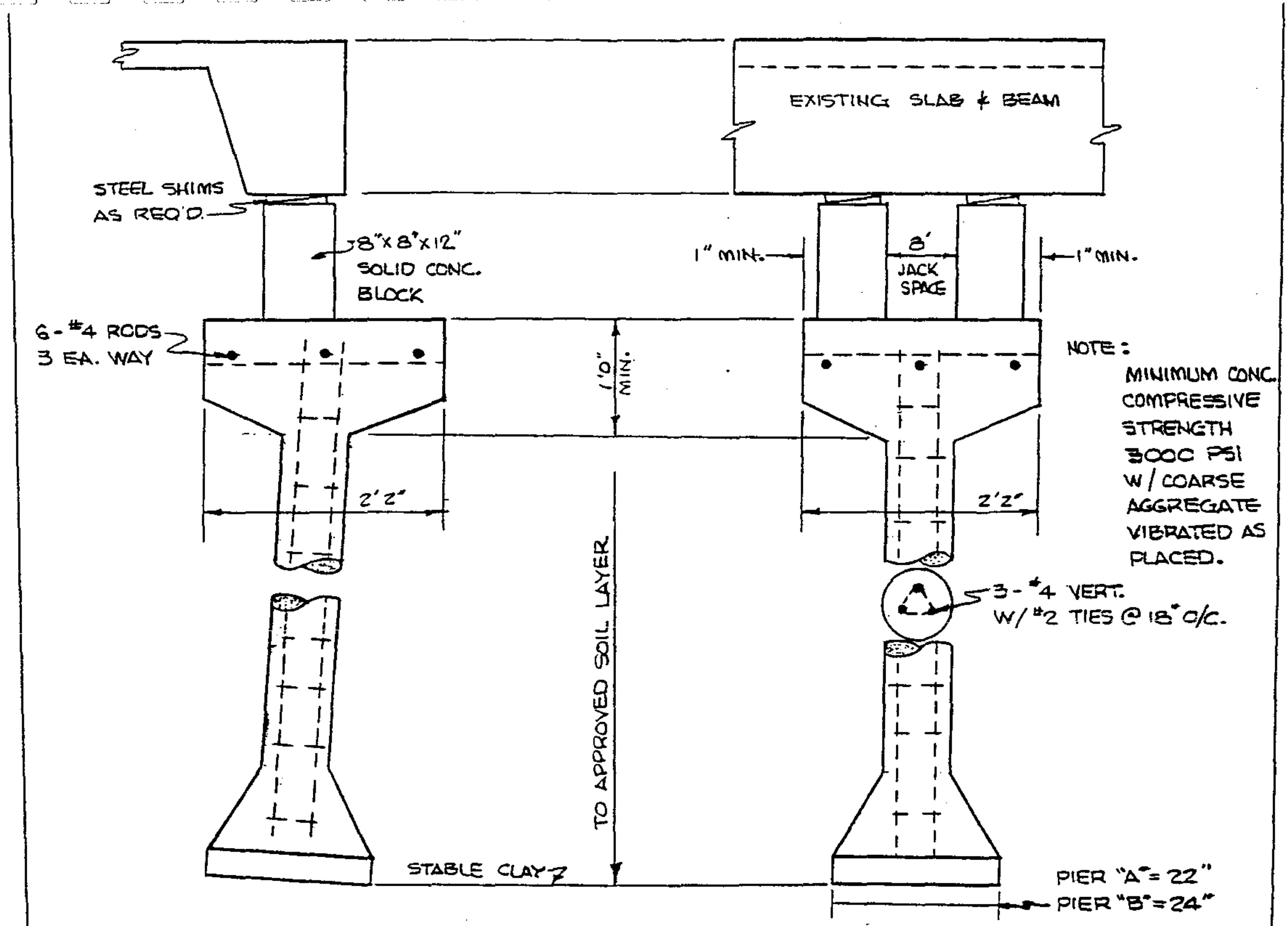
In the belling out process, it is very critical that all loose debris be removed from the bottom of the bell. If not, you face potential settlement of this debris and consequently settling of the structure.

The concrete is poured in place after the steel is installed and then you wait 7-10 days for the concrete to cure before leveling.

The bell bottom pier has a lot of common uses such as builders' piers, which are installed prior to construction, and the traditional after market piers. The biggest downfall of the bell bottom pier is a common mistake of not having the proper soil analyses done prior to installation. If the soil analysis is not done to the proper depth your bell will not have the structural support under it to support the structure for a long period of time.

When a bell bottom pier is used, you are transferring the load from the surface to the bottom of the bell creating a ball of pressure underneath the bell. It is the soil that is in the range of the ball of pressure that most critically needs analyzing to determine its structural strength.

I will not go into a lot of detail on bell bottom piers due to the fact that it's common knowledge in the industry at this time.



-PIER DETAILS-	DU-WEST FOUNDATION REPAIR	
	310 SOUTH MAIN ST. PASADENA, TEXAS 77506	PHONE (713) 473-7156 FAX (713) 473-7359 DRAWN BY - J. N.

PRECAST CONCRETE PILINGS

BY HANK DESHAZER

I. HISTORY OF THE PRESSED PILING

A. ORIGINATED IN THE LATE 1970'S - GENE WILCOX
B. FIRST REAL SUCCESS IN HOUSTON - MID 80'S
C. TRANSFORMED THE FHA STANDARDS - 1987
D. SOME ESTIMATE TODAY 50-75% OF HOMES REPAIRED IN HOUSTON USED SOME FORM OF PRESSED PILES

II. INSTALLATION PROCESS

A. MATERIALS USED
B. EQUIPMENT NEEDED
C. MANPOWER ESTIMATES

III. WHAT MAKES IT WORK

A. SYSTEM TEST THE SOILS
B. SYSTEM TEST THE MATERIALS
C. VALIDATES THE BEARING CAPABILITY CREATED BY THE FRICTION OF CYLINDER AND SOIL WILL SUPPORT THE STRUCTURE

IV. SAFETY FACTOR

A. WEIGHT OF STRUCTURE/PILING SPACING
B. DRIVING PRESSURES
C. THIXOTROPY - SOIL FREEZE UP

HISTORY OF THE PRESSED PILING

IN THE LATE 1970'S GENE WILCOX DEVELOPED THE PRESSED PILING SYSTEM FOR THE REPAIR OF RESIDENTIAL AND LIGHT STRUCTURES. ALTHOUGH PILINGS HAD BEEN USED FOR MANY YEARS IN CONSTRUCTION, WE BELIEVE GENE'S PERMA PILE SYSTEM WAS THE FIRST TIME A SEGMENTED PILING WAS USED IN STRUCTURE LEVELING. WHILE THE SYSTEM WAS DEVELOPED IN THE BEAUMONT AREA IT WAS MADE POPULAR IN HOUSTON BY UP TO TEN DIFFERENT FRANCHISED COMPANIES UTILIZING THE PERMA PILE SYSTEM.

THE SUCCESS OF THE PERMA PILE SYSTEM LED TO THE TRANSFORMING OF FHA STANDARDS FOR FOUNDATION REPAIR IN THE HOUSTON AREA. TILL THE LATE 1980'S ONLY THE BELL-BOTTOM PIER WAS ACCEPTED AS A REPAIR METHOD.

VARIOUS STUDIES EVALUATING THE SIMPLE PRESSED PILING SYSTEM HAVE LED TO MANY ENHANCEMENTS IN THE 15 PLUS YEARS IT HAS BEEN IN USE. THE ENHANCEMENTS HAVE BEEN DIRECTED TOWARD CYLINDER ALIGNMENT, PILING REINFORCEMENT, DEPTH ANALYSIS, CAP ALIGNMENT, LATERAL MOVEMENT, REINFORCED CAPS, INSPECTABILITY, INSTALLATION CONTROL, AND POST INSTALLATION CONTROL SUCH AS UPLIFT.

WHILE NO METHOD IS AVAILABLE TO DETERMINE SPECIFICALLY THE TYPE AND QUANTITY OF HOMES REPAIRED AND REPAIR METHOD USED, IT IS GENERALLY BELIEVED THAT BETWEEN 50 AND 75 PERCENT OF THE HOMES REPAIRED IN HOUSTON ARE REPAIRED UTILIZING SOME TYPE OF PILING SYSTEM.

INSTALLATION OF PRESSED PILINGS

ONLY THE SIMPLE PRESSED PILING WILL BE DISCUSSED AS THERE ARE MANY MODIFICATIONS AND ENHANCEMENTS.

TYPICALLY, A HYDRAULIC PUMP IS USED CAPABLE OF EXERTING 10,000 PSI OF PRESSURE ON A HYDRAULIC RAM WITH 25 TON JACKING CAPACITY. THE RAM IS USED TO DRIVE SIX INCH DIAMETER CONCRETE CYLINDERS(USUALLY 3-6 THOUSAND PSI CASTING) INTO THE GROUND DIRECTLY UNDER THE BEAM OF THE

STRUCTURE. THE SURFACE AREA OF THE DRIVE HEAD APPLIED TO A 5000 PSI CAST CONCRETE CYLINDER WILL ENABLE UP TO 150,000 POUNDS OF PRESSURE. HOWEVER, LOADS IN EXCESS OF 50 - 60 THOUSAND ARE SELDOM NEEDED.

TO FACILITATE INSTALLATION OF THE CYLINDER AN OPENING APPROXIMATELY 30 INCHES WIDE IS EXCAVATED ALONG THE FACE OF THE GRADE BEAM. THE OPENING IS DUG APPROXIMATELY 30 INCHES AWAY FROM THE BEAM AND 30 INCHES BELOW THE BEAM. THE UNDER SIDE OF THE BEAM IS EXPOSED TO ENABLE DRIVING THE CYLINDERS DIRECTLY UNDER THE BEAM.

STARTING OF THE DRIVING PROCESS IS CRITICAL AND EXPERIENCED COMPANIES AND DRIVERS USE MANY TECHNIQUES TO INSURE THE VERTICALNESS OF THE FIRST PILING. THE CYLINDER IS FORCED INTO THE GROUND BY THE HYDRAULIC PUMP AND RAM. EACH RAM GENERALLY HAS A STROKE OF 7 TO 9 INCHES. SINCE THE CYLINDER IS LONGER THAN THE RAM VARIOUS TYPES OF DRIVING BLOCKS ARE USED TO EXTEND AND FACILITATE THE DRIVING OF THE CYLINDERS. THE BLOCKS ARE GENERALLY MADE OF A METAL SUBSTANCE STRONG ENOUGH AND AS LIGHT AS POSSIBLE TO EASE THE WORK EFFORT. THE CYLINDERS ARE FORCED INTO THE SOILS ONE AFTER THE OTHER UNTIL THE DESIRED DEPTH IS OBTAINED. HOW THAT IS DETERMINED IS ADDRESSED LATER.

ONCE THE DEPTH IS OBTAINED, A JACKING CAP IS PLACED ON TOP OF THE STACK OF DRIVEN CYLINDERS. THE TYPE OF CAP VARIES WIDELY WITH DIFFERENT COMPANIES. ONCE THE CAP IS IN PLACE AND THE PILING IS COMPLETED IT IS OF UTMOST IMPORTANCE THAT THE PILING BE SHIMED OFF BETWEEN THE PILING AND THE BEAM BECAUSE RECOIL OF THE PILING CAN OCCUR. THE PILING MUST STAY IN PLACE WITH THE LOAD IN PLACE UNTIL THIXOTROPY (SOIL FREEZE UP) TAKES PLACE. DEGREE OF FREEZE UP VARIES WITH ESTIMATES IN THE HOUSTON AREA OF 1.1 TO 2.0 TIMES ORIGINAL STRENGTH.

ALSO OF SIGNIFICANT IMPORTANCE IS THE SPACING BETWEEN THE PILINGS AT DRIVING TIME. DRIVING SHOULD NEVER TAKE PLACE WITH LESS THAN 25 FEET OF SPACE BETWEEN ANY TWO PILINGS BEING DRIVEN SIMULTANEOUSLY. FAILURE TO MAKE THIS ALLOWANCE WILL RESULT IN DECREASING THE LOAD APPLIED TO AN INDIVIDUAL PILING AND REDUCING THE SAFETY FACTOR ASSOCIATED WITH EXPECTATIONS FOR THE INDIVIDUAL PILINGS.

TIME REQUIRED TO DIG, DRIVE, AND FINALIZE A PILING IS NORMALLY IN THE 5 TO 7 MAN HOURS PER PILING. THIS CAN VARY WIDELY DUE TO DIGGING AND ACCESSIBILITY TO THE DESIRED POSITION FOR INSTALLING THE PILING. HOWEVER ONCE THE DRIVING PROCESS BEGINS IT SHOULD NOT BE INTERRUPTED. PROLONGED LAPSES OF TIME IN THE DRIVING PROCESS WILL RESULT IN NOT OBTAINING THE DESIRED DEPTH. DEPTHS OF PILINGS IN THE HOUSTON AREA VARIES WIDELY WITH SOIL CONDITIONS AND WEIGHT OF STRUCTURE. MY OWN EXPERIENCE

SHOWS DEPTHS UP TO 50 FEET IN THE SUGARLAND AREA. THE AVERAGE DEPTHS FOR THE HOUSTON AREA ARE IN THE 16-18 FEET RANGE, GENERALLY MORE SHALLOW IN THE SANDY SOILS NORTH OF I-10 AND DEEPER IN THE CLAYS IN SOUTHWEST HOUSTON. PILING DEPTHS OF LESS THAN 9-10 FEET ARE UNACCEPTABLE EXCEPT IN SPECIAL SITUATIONS,IE. AS AN ALTERNATIVE TO PADS. TO OBTAIN THE DEPTHS DESIRED WATER JETTING THE PILING AREA MAY BE NEEDED. EXPERIENCE IN CORPUS. SAN ANTONIO. DALLAS, AND TULSA SHOW MINOR DIFFERENCES, BUT NOT SIGNIFICANT. FOR INTEREST, CYLINDERS DRIVEN IN THE NEW ORLEANS AREA HAVE SEEN DEPTHS OF 70 TO 80 FEET.

WHAT MAKES PILINGS WORK

IN REALITY EACH PILING DRIVEN IS AN ASTM PILE LOAD TEST TO FAILURE. MEANING, AS EACH PILING IS INSTALLED IT TEST THE SOILS, TESTS THE CONCRETE, EVALUATES THE LOAD AND INSURES THE PILINGS CAPABILITY OF CARRYING NOT ONLY ITS NECESSARY LOAD FOR THIS DESIGN, BUT UP TO 5 OR 6 TIMES ITS DESIGNED REQUIREMENT.

AS A CYLINDER IS DRIVEN INTO THE SOILS THE DISPLACED SOILS CURL OUTWARD AND UPWARD ALONG THE SIDE OF THE DRIVEN CYLINDER. AS EACH CYLINDER IS DRIVEN THE FRICTION BETWEEN THE SOIL AND THE CYLINDER IS ACCUMULATED UNTIL IT EXCEEDS THE LOAD BEING PLACED UPON THE PILING. REMEMBER THE LOAD PLACED ON THE PILING UNDER A SINGLE DRIVEN PILING LOCATION WILL EXERT PRESSURE AGAINST A MUCH LARGER SURFACE THAN THE REPAIR DESIGNED. THE TYPE SOIL MAY VARY GREATLY. SOMETIMES FROM ONE PILING LOCATION TO ANOTHER AND MOST ASSUREDLY BETWEEN SAY SUGARLAND AND KINGWOOD. ALSO THE WEIGHT PLACED ON A PARTICULAR PILING LOCATION(EXTERIOR CORNER OF A HOUSE VERSUS AN INTERIOR CORNER) WILL VARY GREATLY.

SAFETY FACTOR FOR PRESSED PILINGS

A DRIVEN PILING MUST HAVE SOME CALCULATABLE SAFETY FACTOR TO BE CONSIDERED A VIABLE REPAIR METHOD. OFFSHORE PILINGS ARE REQUIRED TO HAVE A SAFETY FACTOR OF 1.5 TO 2.0 TO BE ACCEPTABLE. THE SAFETY FACTOR FOR THE PILING SYSTEM USED IN FOUNDATION REPAIR IS NORMALLY IN THE 4.0 TO 6.0 RANGE. THIS IS A CONFIRMED AND VERIFIED SAFETY FACTOR NOT A CALCULATED AND GUESSED SAFETY FACTOR. THE SAFETY FACTOR IS CONFIRMED AND VERIFIED AS FOLLOWS:

APPROXIMATE WEIGHT PER LINEAR FOOT

525 LBS	-	6 FT SLICE OF SLAB (12 IN X 24 IN BEAM)
60 LBS	-	6 FT SLICE OF ROOF
10 LBS	-	ONE STORY FRAMING
35 LBS	-	SECOND STORY FRAMING WITH FLOOR
290 LBS	-	BRICK @ 8 FOOT HEIGHT
5 LBS	-	SIDING @ 8 FOOT HEIGHT

DRIVING FORCES: ONE STORY BRICK 142 PSF
TWO STORY BRICK 158 PSF

CORNER - ONE STORY DF=(113 SF)(142 PSF) = 16,046 LBS
TWO STORY DF=(113 SF)(158 PSF) = 17,854 LBS

MIDDLE - ONE STORY DF=(226 SF)(142 PSF) = 32,092 LBS
TWO STORY DF=(226 SF)(158 PSF) = 35,708 LBS

LOADS TO BE SUPPORTED:

CORNER WITH 6 FOOT SPACING

ONE STORY SL=(9 SF)(142 PSF) = 1,278 LBS
TWO STORY SL=(9 SF)(158 PSF) = 1,422 LBS

MIDDLE WITH 6 FOOT SPACING

ONE STORY SL=(36 SF)(142 PSF) = 5,112 LBS
TWO STORY SL=(36 SF)(158 PSF) = 5,688 LBS

$$\text{SAFETY FACTOR} = \frac{\text{DRIVING FORCES}}{\text{LOADS TO BE SUPPORTED}} = \frac{35{,}708}{5{,}688} = 6.29$$

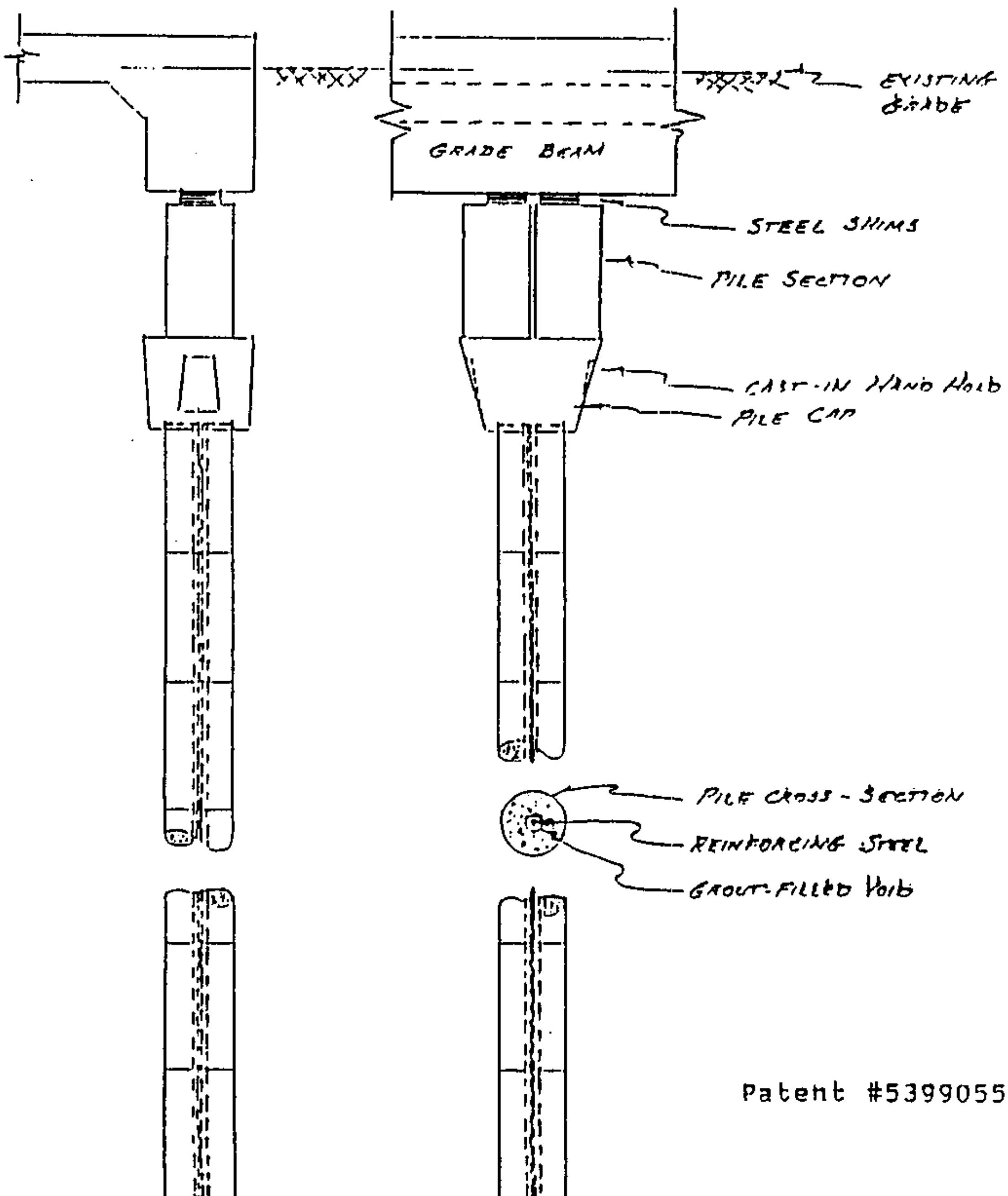
THIS SAFETY FACTOR AS CALCULATED GIVES NO CONSIDERATION TO ANY BENEFIT OF THIXOTROPY(SOIL FREEZE UP FACTOR). THE REASON I HAVE NOT USED THIXOTROPY IS IN OUR METHOD ITS VALUE IS UNKNOWN. ITS BENEFIT IS BASED UPON THE SOIL'S CHARACTERISTICS. IN THE PRESSED PILING SYSTEM THE SOILS ARE TESTED AS PART OF THE ASTM PILE LOAD TEST, BUT IS NOT CALCULATABLE WITHOUT A GEOTECHNICAL SOIL ANALYSIS. HOWEVER IN THE HOUSTON AREA THIS BENEFIT IS NORMALLY BETWEEN 1.1 AND 2.0. IF SO THE ABOVE SAFETY FACTOR COULD BE AS HIGH AS 12.58.

CONCLUSION

THE SIMPLE PRESSED PILING SYSTEM IS A VIABLE FOUNDATION REPAIR SYSTEM PROVEN BY ONGOING PERFORMANCE OVER MORE THAN FIFTEEN YEARS AND SATISFYING ENGINEERING REQUIREMENTS AND STANDARDS FOR PERFORMANCE AND SAFETY FACTORS. THE METHOD HAS BEEN USED FOR REPAIRS ON MORE THAN 20,000 HOMES IN THE HOUSTON AREA AND IS CURRENTLY THE DOMINANT METHOD. CERTAIN PILING CHARACTERISTICS ARE NOT AVAILABLE IN THE SIMPLE PRESSED PILING SYSTEM. IF YOU HAVE CONCERNS WITH ALIGNMENT, LATERAL MOVEMENT, CONNECTED CYLINDERS, UPLIFT, CONCRETE REINFORCEMENT AND POST IMPLEMENTATION ANALYSIS YOU MUST UTILIZE A PILING SYSTEM WITH ENHANCEMENTS TO THE ORIGINAL PILING SYSTEM.

ULTRA PILE

The ULTIMATE in foundation repair



Patent #5399055

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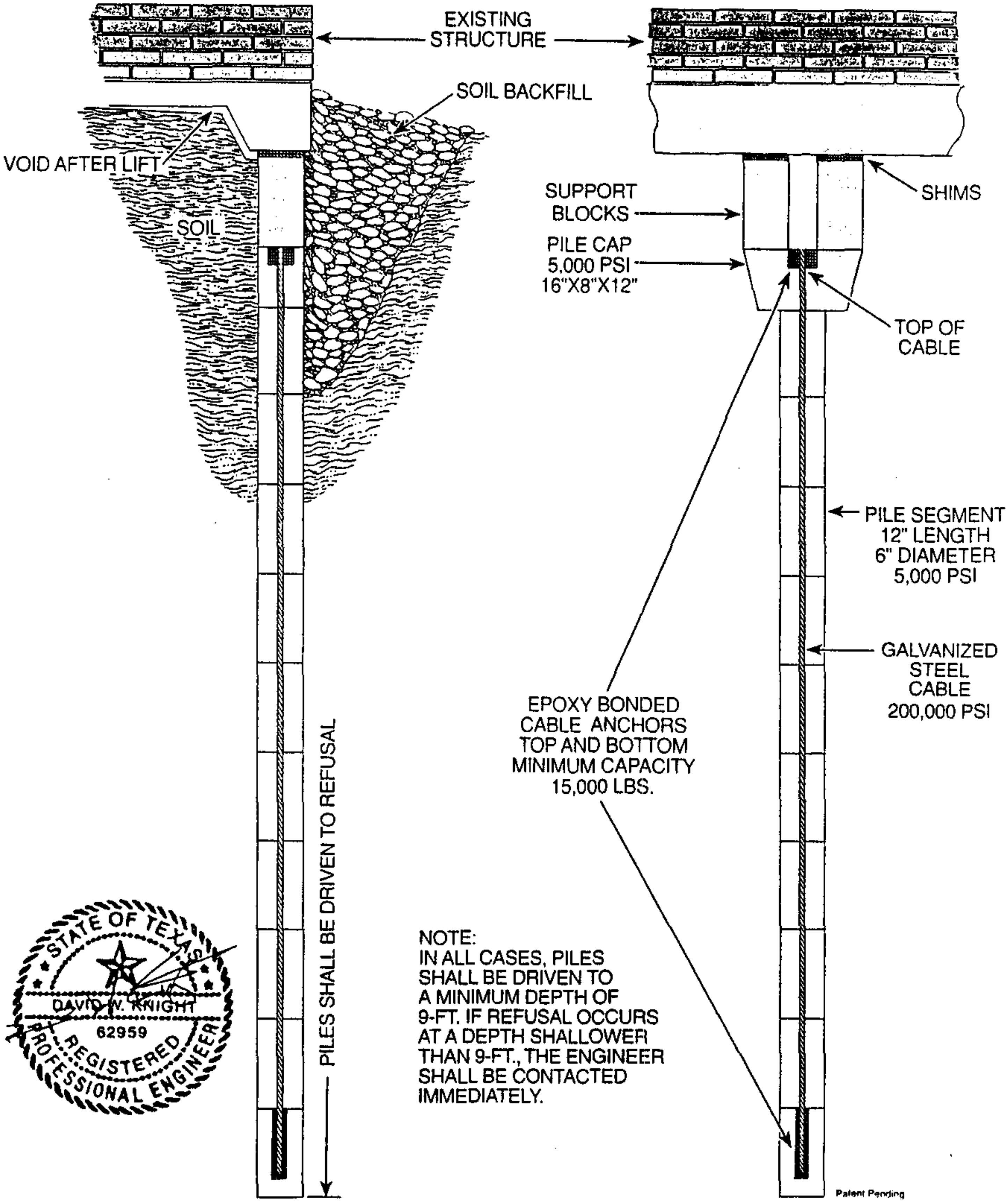
- One inch center hole provides access for "water jetting" - allows better penetration in "difficult soils" and allows verification of depth.
- Rebar ensures pile alignment and adds tensile strength.

Cable Lock FOUNDATION REPAIR



RAM JACK PIER SPECIFICATION

PIER COLUMN

1. 2 7/8" O. D., N-80/J-55 API Grade steel tubing

2. .25" Wall Thickness

3. Weight - 6.5 pounds/foot

4. 2 3/8" Connector- .25 Wall Thickness Precision Cut 12" length

5. Starter is plugged and has a 3 1/2" O.D. expansion ring to reduce side wall friction as the pier is advanced. The starter is 10" long and has a 9.6 sq. inch bearing surface.

6. Pier sections are 5' long.

BRACKET ASSEMBLY

1. **Support Bracket** - The support bracket is composed of a 10" section of heavy wall steel tubing 4.5" O.D. The tubing weighs 17 lbs. per linear foot and is a high grade, high carbon steel. A 10" long section of I-beam is welded to the support sleeve by gas-wire (mig) welding. The I-Beam is an ASTM-3 structural steel with 6" web, 4" flange and weighs 17.25 lbs. a linear foot.

2. Extended Guide Sleeve

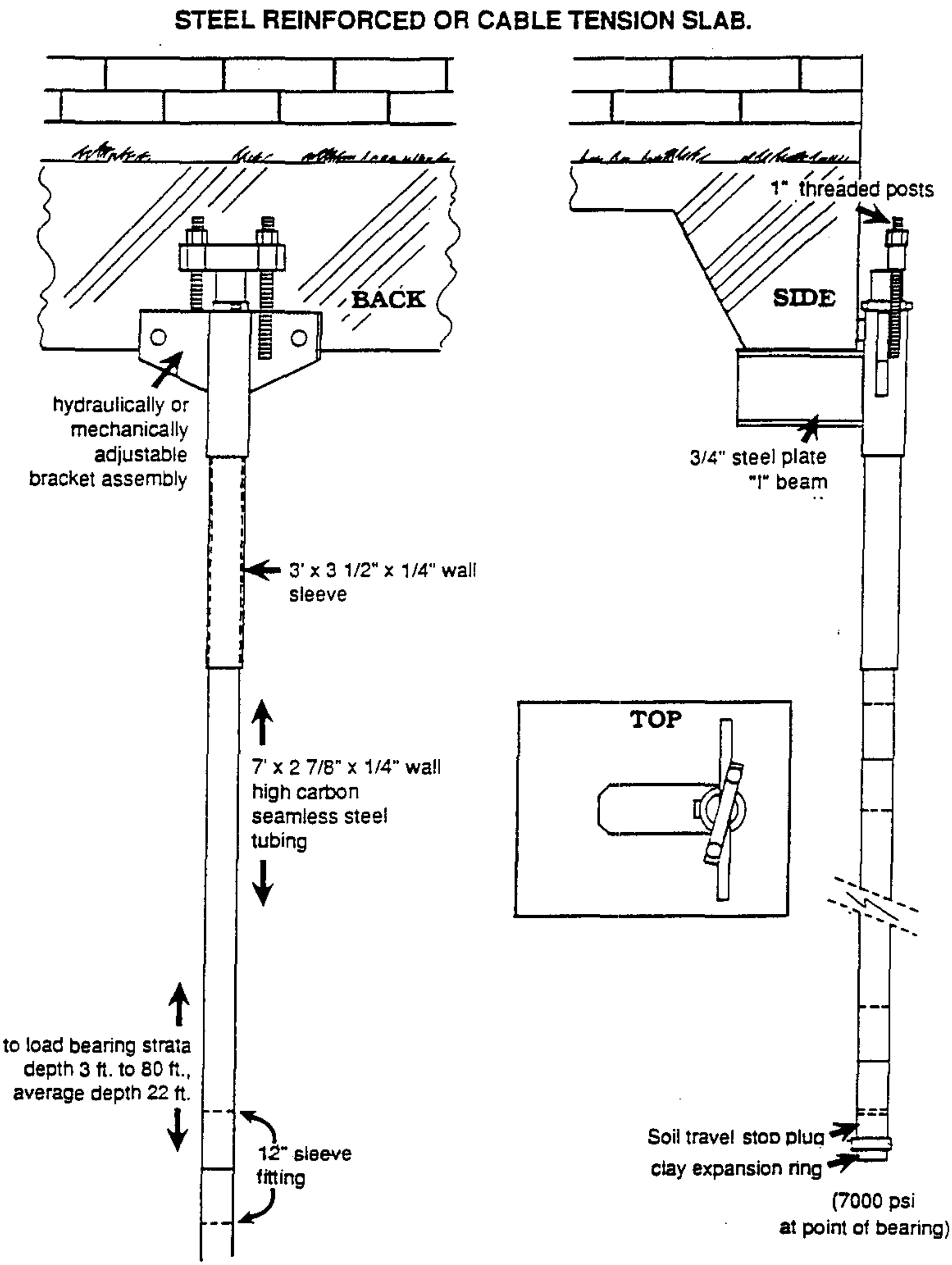
(a). 36" Section of N-80/J-55 API Grade steel tubing - 3.5" O.D.
(b). .250 Wall Thickness and weighs 9.3 lbs. a linear ft.

3. Securing Apparatus

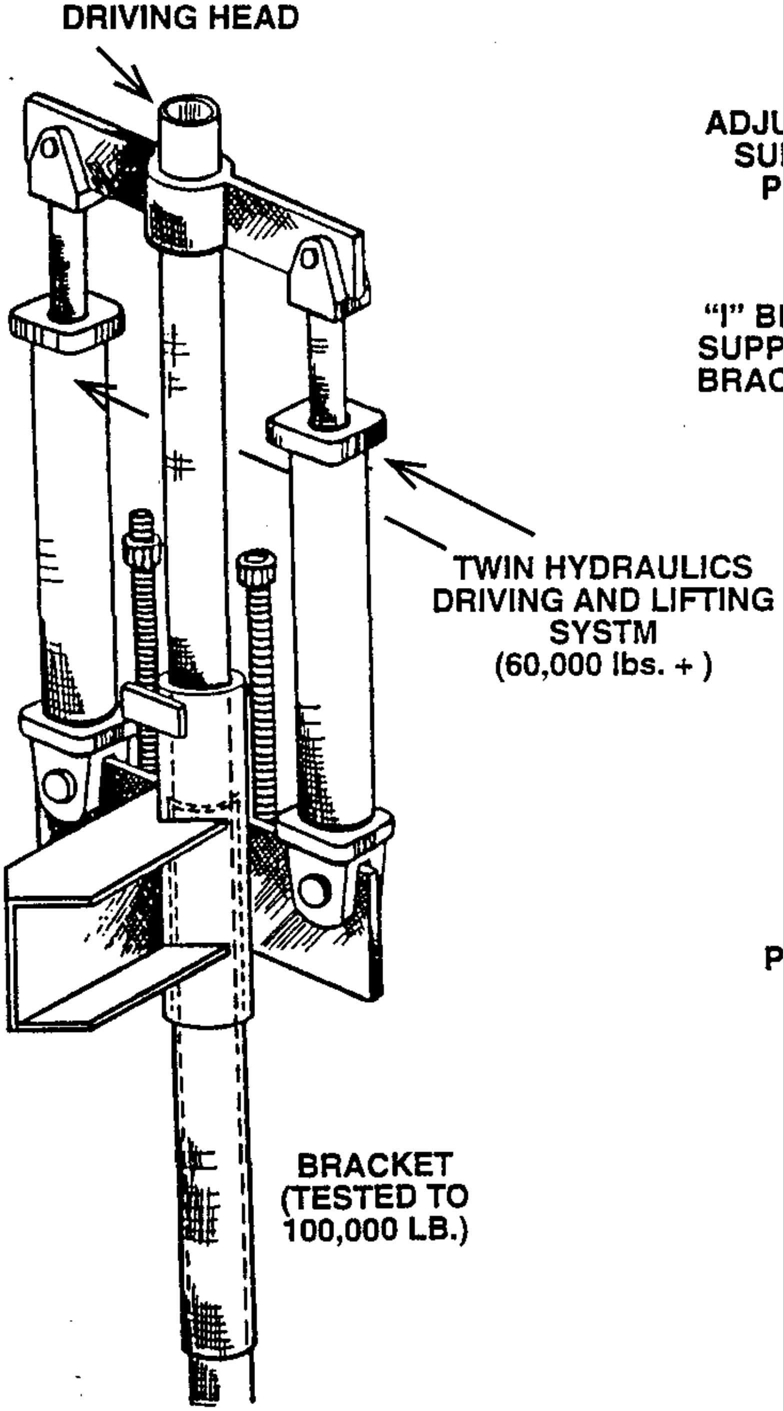
(a). Structural steel strap 1" thick x 2" wide x 6" long.
(b). 1" I.D. x 2" length carbon steel tubing is welded to the strap.
(c). Two 1" x 2" nuts are welded to flanges on either side of the support bracket. Two 1" nuts secure support strap in place by means of two 1" all thread bolts connected to nuts on support bracket.

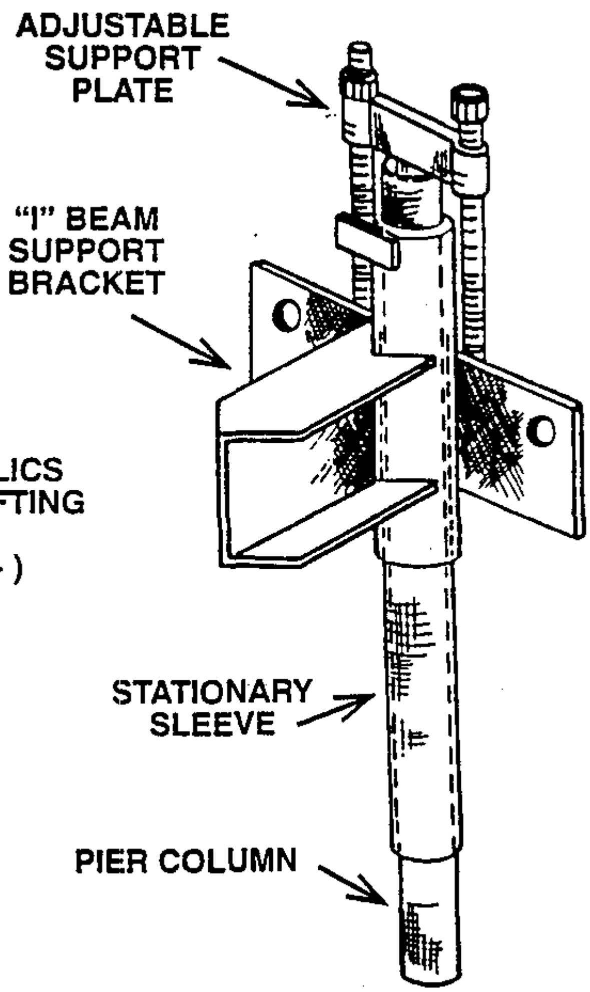
4. Corrosion Protection - The Bracket Assembly is coated with corrosion inhibitor for protection from oxidation.

STEEL PILING AND LIFTING BRACKET ASSEMBLY



RAM JACK BRACKET AND LIFT SYSTEM





PILING INSTALLED

ADVANTAGES OF THE RAM JACK STEEL PILINGS

1. Fast - If there are no time consuming obstacles such as deep footings, deep pier drives, and concrete demolition, a three man crew can install 6 to 10 piers in one day.

2. Dependable - of the ten's of thousands of installations, the Ram Jack Commercial Bracket has proven to be extremely reliable. Only a few adjustments have been necessary because the heaving of expansive clay soils lifted the foundation up off of the piers. Adjustments are quick and easy, requiring only a few minutes. It is not essential to use the Ram Jack Hydraulic System in order to make these adjustments.

3. End Bearing - The steel pier is end bearing and has an insufficient surface area available for skin friction. Expansive clay soils will shift piers that depend upon skin friction or the soil strength for support.

4. Limited Access - Very limited access is required in order to install the Ram Jack Steel pier. This affords an opportunity to install foundation shoring that otherwise may not exist.

5. Adaptable - a myriad of adaptations have been improvised to accommodate various foundation shoring problems which are clean, time-saving, economical, and more reliable than conventional methods of shoring.

6. Upheaval - The low side-wall friction co-efficient on the 3" diameter steel piling makes it impossible for the pier column to be subjected to upheaval from positive skin friction of expanding clay soils.

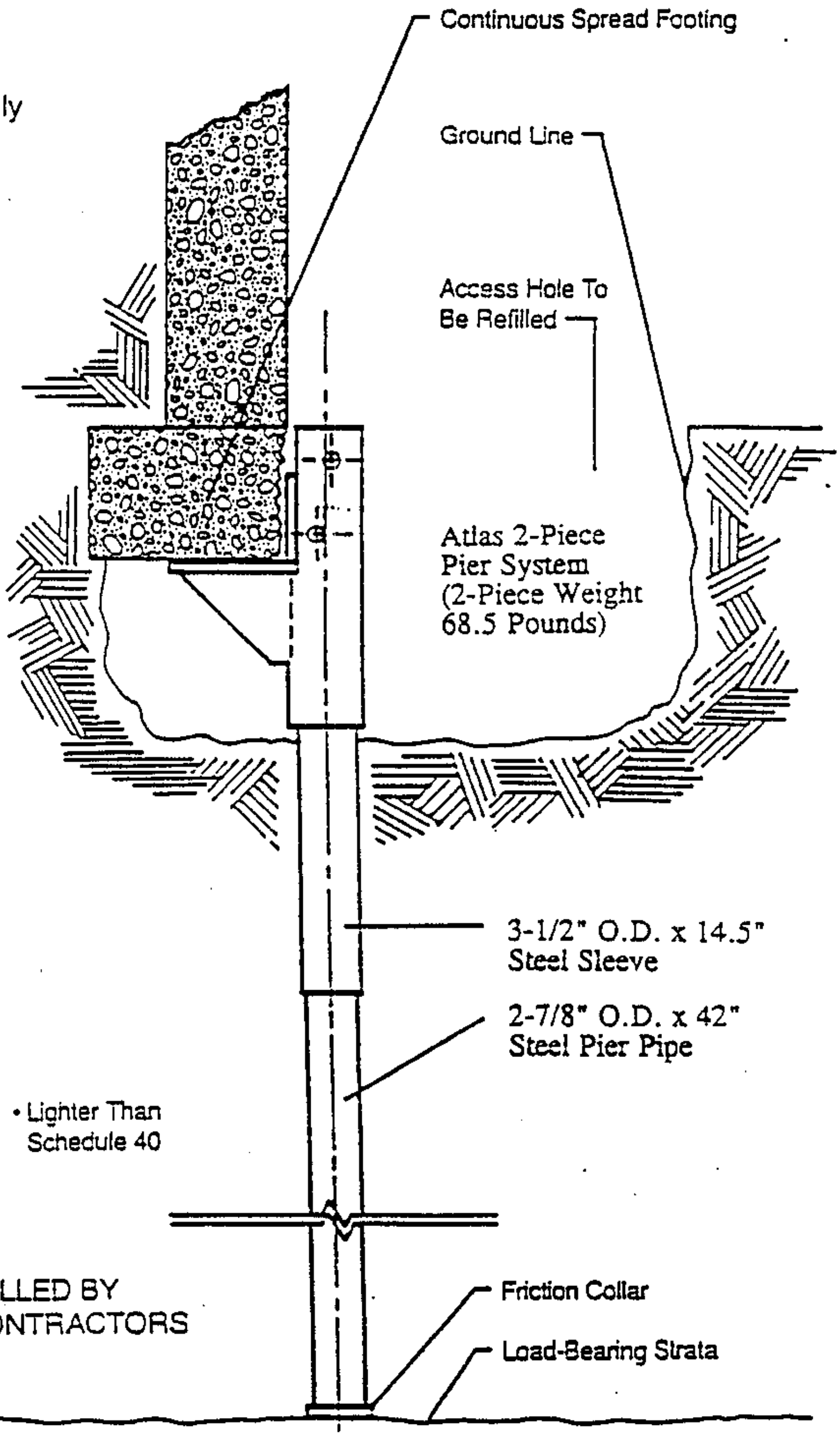
7. Materials - only quality materials are used. Metallurgists have reported that Ram Jack pier material has a service life of over 50 years. Studies by the U.S. Corp. of Engineers on the longevity of vertical steel piers bear this out.

8. No Heavy Equipment - All shallow excavations are by hand (2 to 5 feet). All equipment is portable and hand carried. This prevents damage to landscape, sidewalks, driveways, etc.

MODEL AP2.875S
2-PIECE STANDARD PIER

ATLAS PIERS' UNIQUE FEATURES

- Load Carried on Top of Pier
- Measured Design Load
- No Lateral Movement of Pier Assembly
- No Concrete Shrinkage
- No Angled Support
- No Heavy Equipment
- No Yard Destruction
- Fast Installation—Average job done in 2 days.
- No Guesswork
- Least Costly Method
- Certified Welders



ATLAS PIERS® ENGINEERED AND DESIGNED FOR LASTING SUPPORT

SOLD AND INSTALLED BY AUTHORIZED CONTRACTORS

All Atlas Piers are U.S. Patented Products

INSTALL - INSIDE OR OUTSIDE

Atlas Piers
Resistance Product Designator

Atlas Pier Systems can be installed in either an interior or exterior location. Every Atlas Pier System provides for a two-stage system of initially driving the manufactured piers to load bearing support then, using hydraulics, lifting the structure to the desired elevation. Atlas Piers not only stop settlement, but actually raise the structure, closing cracks and correcting other structural flaws caused by the settlement and/or ground movement. Design should involve professional engineering input. Specific information involving the structures, soil characteristics and foundation conditions must be used for the final design.

It is recommended that the design be conducted by a Registered Professional Engineer.

ATLAS STANDARD AND MODIFIED 2-PIECE SYSTEMS
Specify Pier Type and Finish Code Letter*

Pier Type	Load	Features to Assist in Selection
AP2(*)-2875	Ultimate = 60,000# Design = 30,000#	• High Capacity • Easy Installation • Lowest Cost • Cold Formed, Induction Heat Treated Steel 2-7/8 inch dia. Pier Pipe • Used for Lifts Up to 1-1/2 inches
AP2(*)-3500 Note: Not Available With Plain Steel Pipe (AP2P-3500 not available)	Ultimate = 85,000# Design = 42,000#	• Higher Capacity than AP2-2875 • Easy Installation • Low Cost • Exclusive Cold Formed, Induction Heat Treated 3-1/2 inch Pier Pipe with "Flow Coat" Corrosion Protection Standard. • Can Be Installed Using Helical Outriggers for Supplemental Drive Resistance • Used for Lifts Up to 4 inches
AP2(*)-3500M Note: Not Available With Plain Steel Pipe (AP2P-3500M not available)	Ultimate = 90,000# Design = 45,000#	• All Features of the AP2-3500 Plus; • Higher Capacity than AP2-3500 • Increased Rotational Stiffness at Pier Bracket • Recommended in application where pier pipe is not laterally supported near the footing, or when the soils just below the footing are very weak.

Note: Pier is Modified by installing a 4 inch diameter by 42 inch long pipe OVER the Standard 3-1/2 Inch Pier. Designer to specify the length of sleeving required. Sleeve Part Number is: AP(*)-MPS-4000 (Available with all finishes below).

*** FINISHES AVAILABLE:**

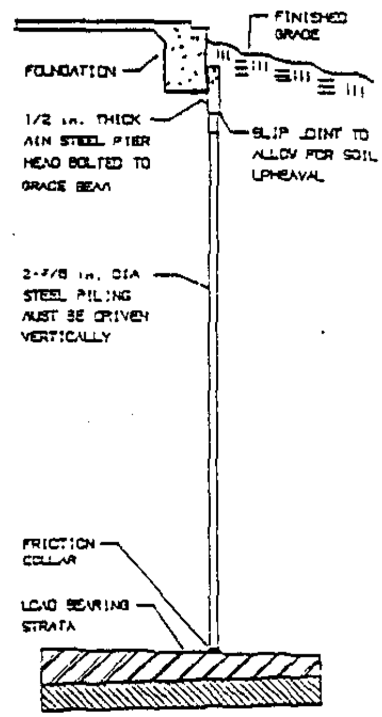
P = Entire product supplied plain steel
G = Entire product supplied galvanize
S = Only pier pipe supplied galvanized
E = Entire product supplied Epoxy coated
C = Custom Finish as Specified by Engineer

STEEL PIER SPECIFICATIONS
(2-7/8 DIAMETER PIER)

PIER DETAIL

Steel piers shall be driven vertically to a load bearing strata and shall be placed as shown on the attached plan. **Any variance to the pier placement design shall be submitted to the engineer for approval prior to construction.** Where it is necessary to break out concrete to install the piers, the contractor is to saw-cut the top edge of the concrete for a neat appearance.

The pier head shall have a minimum bearing area on the grade beam of [illegible]0 square inches, and shall be firmly attached to the grade beam. A chipping hammer shall be used to prepare the area of pier head mounting. The vertical and bottom face of the grade beam shall be smooth and free of dirt and loose concrete prior to installing the pier head. Pressure bearing grout with a minimum three day strength of 4,500 psi. shall be used to provide proper bearing if the pier head is not properly and continuously bearing on the beam.



Prior to driving the piers, the vertical alignment shall be checked with a carpenter's level. Piers are to be driven as close to vertical as possible, in no case will a pier be driven when the level shows the bubble edge over the line of the vial.

The pier pipe shall be 2-7/8 inch outside diameter, minimum, with a 3-1/2 inch diameter friction collar on the first section of pipe. Pipes shall have a minimum 0.165 inch wall with a yield of 50,000 psi. The pipe shall have a corrosion protection coating. Piers will be hydraulically driven until rock or an equal bearing strata is reached as defined by a total pier load of 40,000 pounds or until lift of the structure is obtained. Each pier is to be driven separately and the structure not lifted nor a load placed upon any pier head until all piers have been driven to the total pier bearing load.

Mechanically raise the foundation to the original position where possible without causing additional damage to the structure. Pier load shall not exceed 25,000 pounds. Once the structure is restored to its approximate original state, shims shall be inserted as recommended by the manufacturer to provide support.

Soil backfill around the pier shall be placed in 8 inch, maximum, lifts and compacted as dense as possible using hand tools and a small amount of water. Final backfill in area of work shall be native topsoil and properly graded for drainage away from the foundation. The contractor shall replace and match as closely as possible the concrete removed for access to install the piers. Job site will be left clean and neat.

Provide the customer and the engineer with a pier installation record at the completion of the job. The installation record shall include the driving load, the depth to bearing strata, the vertical lift, and the lift load for each pier.

THE PermaJack® SYSTEM

④ How the Perma-Jack System works

An opening is made adjacent to the foundation and enough dirt is removed so that the Perma-Jack Bracket (A) (the core element of the system . . . see diagram at right) can be placed under the foundation. This bracket, a strong structural steel weldment weighing 44 pounds, is permanently installed under the foundation. Next, a pier formed from one or more pipe support columns (B) is placed through the bracket. These pipe support columns are aligned and tightly connected by a column connector (C).

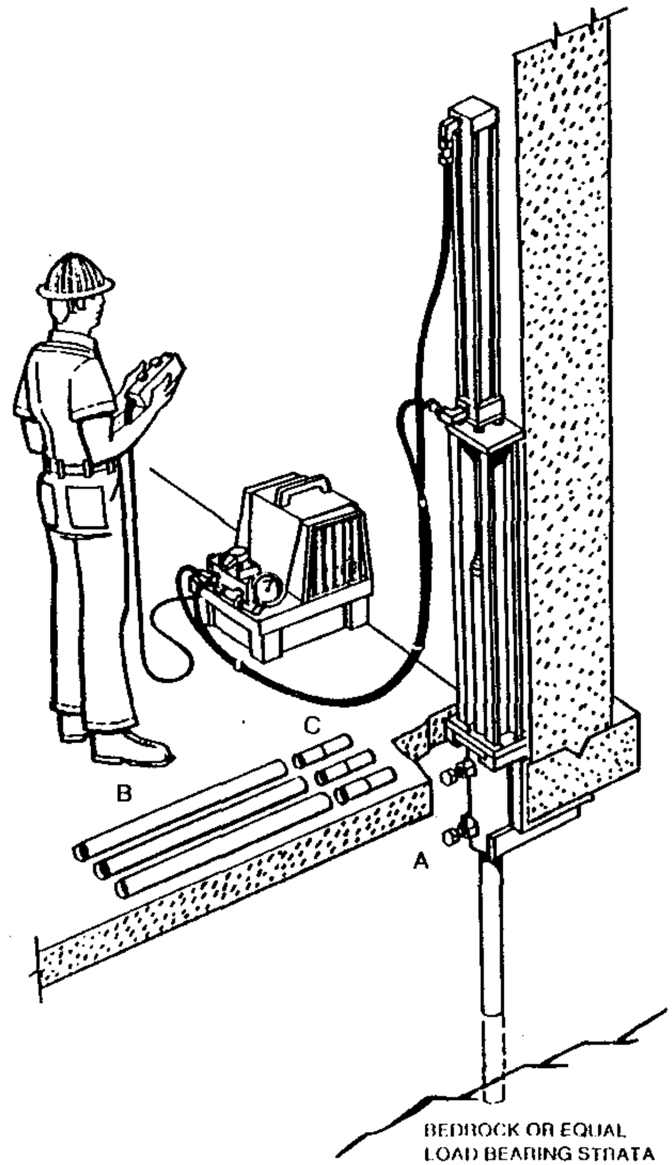
Hydraulic pressure is then applied to force the pier into the ground until it hits bedrock or equal load bearing strata. The hydraulic equipment that is used for this operation is capable of testing each pier at 24,000 LBS. of force—yet it operates quietly . . . at a maximum of 80 decibels.

Pipe support columns are connected and forced into the soil to form a sturdy, stable steel pier reaching as deep as is necessary to contact solid bedrock or equal load bearing strata. The competency of the bearing material is verified by the very nature of the tested installation. Steel piers are positioned wherever needed under the structure to effectively support the foundation.

Why is Perma-Jack better?

The Perma-Jack System is a patented process that actually forces steel piers all the way down to bedrock or equal load bearing strata . . . so your house or commercial building is as solid as rock. Most other systems simply reinforce the foundation by using concrete as a spacer between it and the earth at a slightly lower level.

Concrete can shift and settle again. Perma-Jack's steel piers securely support your house or building to **bedrock or equal load bearing strata** . . . assuring that there will be **no** future vertical settlement of your foundation in the area where the Perma-Jack piers are installed.



Perma-Jack System being installed

How is Perma-Jack faster?

The Perma-Jack System is faster than the old method of piering because there is less excavating than in concrete reinforcements. In addition, when the Perma-Jack piers are tested, they can be locked in place immediately without waiting for concrete to harden (taking 28 days). Repair time varies with each building, depending on the extent of damage, but as an example, where other systems would take an average of two weeks to do the job, Perma-Jack would take 2 **days!**

How is the Perma-Jack System different?

Perma-Jack uses high-pressure equipment to install steel reinforcement from **inside** your building . . . so **no** expensive excavation is required and the Perma-Jack System can be installed year round. (Perma-Jack can also be installed from the outside, where desirable, with minimum excavation and with all lawn, shrubbery, etc., being quickly returned to it's original condition.)

It is based on an exclusive, patented process which uses steel piers similar to those used under many large office buildings . . . a much stronger and longer-lasting solution than plain concrete spacers. EACH PIER IS INDIVIDUALLY HYDRA-TESTED*.

Some other systems may claim to use similar techniques, but no other system offers the assurance that the Perma-Jack process does.

How do you know when you need the Perma-Jack System?

When doors or windows stick . . . when large gaps appear in door and window frames . . . when cracks appear in your foundation walls . . . when floors settle . . .**you need Perma-Jack.**

All of these symptoms may be indications that your building's foundation has settled in one or more places . . . and needs to be stabilized quickly, before more costly damage occurs.

How much will the Perma-Jack System cost?

Naturally the cost will vary according to the extent of the damage to the foundation, but the Perma-Jack System usually costs less than any other reputable repair method.

And Perma-Jack offers future savings too. Most other systems will require costly call-back repairs, but once the Perma-Jack System is installed, there will be no call-back expenses.

How do you arrange for a Perma-Jack repair?

If you have signs of foundation failure, simply call your franchised Perma-Jack System installer today for an appointment. He will inspect your home or building and give you an estimate of the cost of correcting the problem, with Perma-Jack, at no obligation to you.

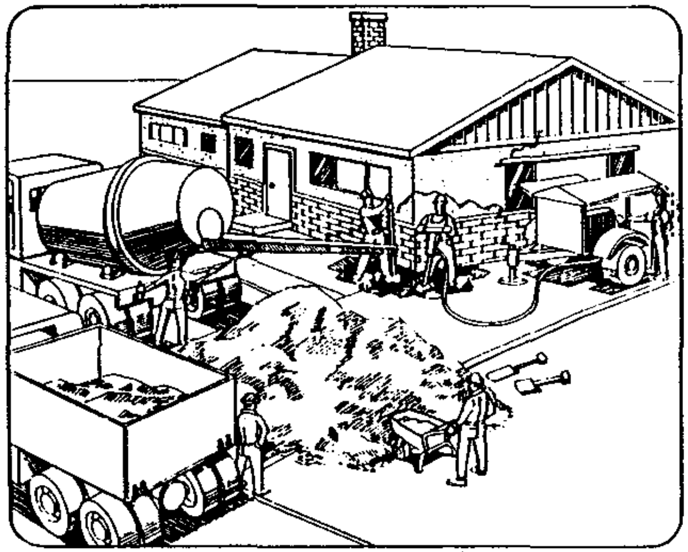
Your Perma-Jack System installer is

Perma Jack® St. Louis

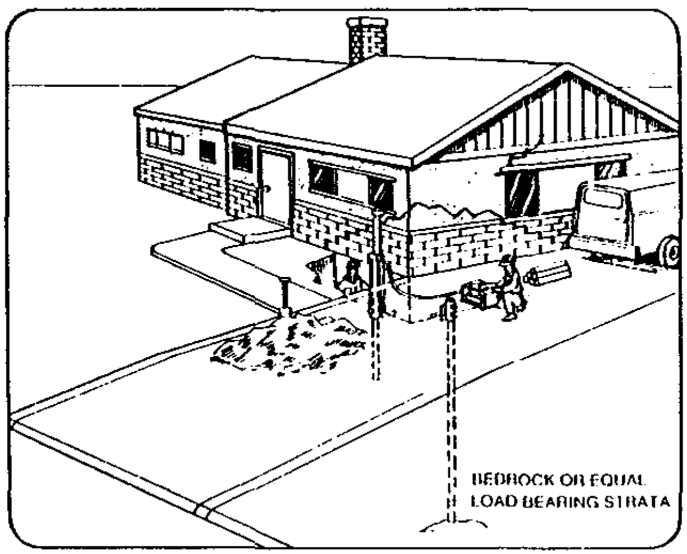
by St. Louis Stabilizing, Inc.
1127 Country Stone Dr.
Valley Park, MO 63088-1405
314-225-2553

THE Perma Jack® SYSTEM

You Have a Choice

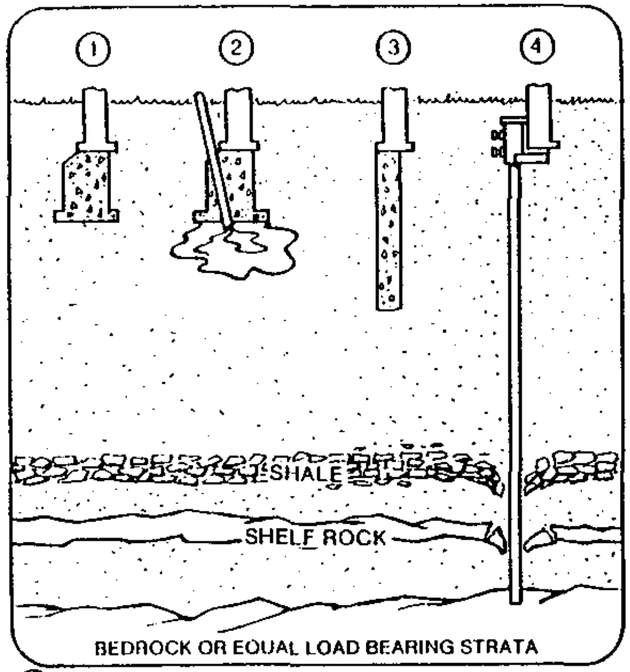


THE OLDER METHODS ① ② ③
OR



④

THE PermaJack® SYSTEM
Fast-Economical



① **POST AND BEAM**

Hand dug excavation, usually one to four feet below the footing of the foundation. These are in or near nonsupporting earth that failed and caused the original foundation to fail. A large amount of earth is removed below the foundation in excavating for the placement of the lower footing. Further shrinking or settling of the earth below the new pad will allow the foundation to sink further. This method does not contact rock.

② **POST AND BEAM AND MUD PUMPING**

Similar to the Post and Beam, but a force is applied with a mud-pump after the concrete hardens. Concrete should harden 28 days before a load is placed on it which delays completion of the job. The same instability of the earth exists in the area of this type of repair.

③ **HAND DUG OR DRILLED CONCRETE PIERS, EITHER FRICTION OR TO ROCK**

They are usually dug to rock, but are also used as friction piers (not to rock) when the rock is deeper than about twenty-five feet. This method is good but requires much more labor than any of the others. Round cardboard forms are used with this system. The esthetic repairs must be deferred until the concrete piers are shrunken and grout is placed between the top of the pier and the bottom of the footing. (Usually after about twenty- eight days.)

④ **PERMA-JACK — ALWAYS TO ROCK, OR AN EQUAL LOAD BEARING STRATA BY ACTUAL LOAD TEST OF EACH INSTALLATION**

EDWARDS CONSULTING COMPANY
"Ultimate Consulting"

Affiliated With Texas Municipal Consulting Group

Joseph A. Edwards
President

Danna J. Edwards
Vice - President

RESIDENTIAL SOIL AND FOUNDATION REQUIREMENTS BY GOVERNMENTAL AGENCIES

BY JOE EDWARDS
EDWARDS CONSULTING COMPANY
JULY 25, 1996

OVERVIEW OF SOIL AND FOUNDATION REQUIREMENTS FOR THE FOLLOWING CITIES:

1. CITY OF BELLAIRE
2. HEDWIG VILLAGE
3. CITY OF HOUSTON
4. CITY HUMBLE
5. CITY OF LA MARQUE
6. CITY OF LA PORTE
7. CITY OF MISSOURI CITY
8. CITY OF ROSENBERG
9. CITY OF SPRING VALLEY
10. CITY OF STAFFORD
11. CITY OF SUGAR LAND
12. CITY OF WEST UNIVERSITY

THE TREND

P.O. Box 741201 • Houston, Texas 77274-1201 • Phone/Fax (713) 783-2229 • Pager (713) 536-9381

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OVERVIEW OF SOIL AND FOUNDATION REQUIREMENTS FOR THE FOLLOWING CITIES:

CITY	SOILS REPORT REQUIRED	ENGINEERED DESIGN	ENGINEER INSPECTION	ENGINEER CERTIFICATION
1. BELLAIRE	YES	YES	YES	YES
2. HEDWIG VILLAGE	NO	NO	NO	NO
3. HOUSTON	NO	YES	NO	NO
4. HUMBLE	YES	NO	NO	NO
5. LA MARQUE	NO	NO	NO	NO
6. LA PORTE	NO	NO	NO	NO
7. MISSOURI CITY	YES	NO	NO	NO
8. ROSENBERG	NO	NO	NO	NO
9. SPRING VALLEY	NO	YES	NO	NO
10. STAFFORD	NO	YES	NO	NO
11. SUGAR LAND	NO	YES	NO	NO
12. WEST UNIVERSITY	YES	YES	YES	YES

P.O. Box 741201 • Houston, Texas 77274-1201 • Phone/Fax (713) 783-2229 • Pager (713) 536-9381

EDWARDS CONSULTING COMPANY
"Ultimate Consulting"

Affiliated With Texas Municipal Consulting Group

Joseph A. Edwards
President

Danna J. Edwards
Vice - President

THE TREND

SOME TWO YEARS AGO I REPORTED TO YOU AT OUR LAST SEMINAR THE TREND FOR THE AREA MUNICIPALITIES WAS ONE LEANING TOWARD MORE RESTRICTIVE CODES AND ORDINANCES REGARDING RESIDENTIAL FOUNDATION REQUIREMENTS. WHILE THERE HAS CERTAINLY BEEN A POSITIVE EFFORT IN THIS DIRECTION, YOU CAN SEE FROM THE CHART THERE IS ROOM FOR MORE IMPROVEMENT IN THIS AREA. SOME OF THIS HAS TO DO WITH THE VARIOUS POLITICAL CLIMATES, WHILE OTHER INVESTIGATIONS SHOW THE LOCAL AUTHORITY HAS NOT STRESSED THE IMPORTANCE OF WHY A GOOD FOUNDATION IS IMPORTANT TO THE LIFE OF A HOUSE OR ANY STRUCTURE. THE MORE CONSCIOUS HOME BUILDERS IN THE AREA, REGARDLES OF THE REQUIREMENTS BY THE CITIES, HAVE STARTED REQUIRING SOILS REPORTS, ENGINEERED DESIGNED FOUNDATIONS AND INSPECTION BY THE DESIGN ENGINEER. THIS HAS CERTAINLY BEEN A PLUS IN MANY AREAS ESPECIALLY WHERE THE CONSUMER IS CONCERNED. THE FOUNDATION PERFORMANCE COMMITTE HAS BEEN WORKING OVER THE YEARS TO DEFINE WHAT CONSTITUTES FOUNDATION FAILURE AND TO ALSO DEVELOP FAILURE CRITERIA. I SEE THE CITIES ON A WHOLE STILL NEEDING TO INCREASE THEIR MINIMUM REQUIREMENTS FOR FOUNDATIONS, BUT I ALSO SEE THE NEED TO INVOLVE THE SOIL ENGINEERS AND THE DESIGN ENGINEERS AS WE MOVE INTO A DIFFERENT WORLD OF EXPECTATIONS AS SEEN THROUGH THE EYES OF THE CONSUMER.

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THE TREND CONTIMUES

SO CALLED FOUNDATION FAILURES HAVE BECOME MORE PREVALENT IN THE PAST FEW YEARS WHICH IN TURN PROMULGATES POTENTIAL LITIGATION. THE CONSUMER IN THE HOUSTON AREA, FOR WHAT EVER REASON, HAS DEVELOPED A MENTALITY THAT WHEN THEY OBSERVE A CRACK IN THEIR FOUNDATION OR BRICK IT CONSTITUTES A FAILURE. WE NEED TO ADDRESS UP FRONT EXPLAINING THAT WE LIVE IN AN AREA CONTAINING HIGHLY EXPANSIVE SOILS WHICH HAVE A TENDENCY TO MOVE UNDER EXTREME WET OR DRY CLIMATIC CONDITIONS. WE ALL NEED TO WORK TOGETHER, USING OUR OWN AREAS OF EXPERTISE, TO COUNTERACT WHAT CONSUMERS HAVE NOW CONCEIVED TO ALWAYS BE A FAILURE WHEN THEY OBSERVE A CRACK IN THEIR FOUNDATION OR BRICK. WITH ALL THE PROFESSIONALS DOING THEIR PART, WE WILL NOT ONLY IMPROVE COMMUNICATIONS BETWEEN ALL PARTIES, BUT WILL DEVELOP, DESIGN AND BUILD THE BEST FOUNDATIONS AVAILABLE TO US TODAY.

THANK YOU FOR ATTENDING TODAY'S SEMINAR AND WE LOOK FORWARD TO YOUR PARTICIPATION IN THE PANEL DISCUSSIONS.

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Vice - President

ACTIVITIES & EXPERIENCE: JOSEPH A. EDWARDS

Retired after nineteen years as the Chief Building Official for the City of Bellaire, Texas.

Fifteen Years as an Instructor for Building Codes, Building Construction and Housing Real Estate Inspections in conjunction with the Building Officials Association of Texas, Texas A&M University Engineering Extension Service and the Texas Assiciation of Real Estate Inspectors.

Consultant to various Cities regarding construction techniques, building code interpretations, plan checking and building permit office procedures.

Qualified in multi-disciplines of building construction.

Expertise in all types of construction including high-rise structures.

Recognized as an expert in soil mechanics and cement and concrete technology.

Service provided to Legal Firms regarding expert testimony on Building Codes and evaluation of sub-standard structures.

Associated with Building Codes, general construction and related areas for the past thirty-eight years.

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PAST & PRESENT
PROFESSIONAL ASSOCIATION MEMBERSHIPS

Past Vice President - Board of Directors - Greater Houston Builders Association.

Outstanding Associate Member - 1970 Greater Houston Builders Association.

Past President - Building Officials Association of Texas.

Founding President - Gulf Coast Association of Building Officials.

Honorary member - Texas Association of Real Estate Inspectors.

International Conference of Building Officials.

International Association of Plumbing & Mechanical Officials.

Licensed Plumbing Inspector - State of Texas.

Texas State Association of Plumbing Inspectors.

Construction Specifications Institute.

Southern Building Code Congress International.

Texas Public Health Association.

Texas Enviromental Health Association.

Recognized and listed in Who's Who in Government in America.

State of Texas Building Official of the year - 1992.

Past Chairman - International Conference of Building Officials Evaluation Service, a technical engineering committe dealing with Building Codes, designs and material usage across the United States and its Possessions.

Presently serving on the International Conference of Building Officials Evaluation Service Inc. Board of Directors.

The Plaintiff's Perspective
Filing Suit Under the DTPA & RCLA

by

James R. Moriarty
Moriarty & Associates
Houston, Texas

Deceptive Trade Practices Act
(DTPA)

I. Texas Business & Commerce Code §17.01 *et seq*.

A. Recent Texas Supreme Court Opinions

The Polybutylene Cases: *Amstadt et al v. United States Brass, United States Brass et al v. Kochie et al* and *United States Brass et al v. Andraus et al*

In these three cases, homeowners sued the manufacturers of a polybutylene plumbing system for negligence and violations of the Deceptive Trade Practices Act (DTPA). The issue before the Supreme Court was whether the Legislature intended that upstream suppliers of raw materials and component parts be liable under the DTPA when none of their misrepresentations reached the consumers.

The Texas Supreme Court ruled that homeowners cannot recover against upstream suppliers of raw materials under the DTPA if the suppliers' misrepresentations didn't reach the consumers. In rationalizing their actions, the Court said that the Legislature more likely intended for consumers to seek DTPA recourse against those with whom they have engaged in a consumer transaction; i.e. the builders/contractors, etc. Furthermore, the Court said that if the builders' DTPA liability is caused or contributed to by the otherwise actionable conduct of upstream manufacturers or suppliers, the builder may seek contribution or indemnity against them.

In effect, the Supreme Court stripped the consumer's ability to sue an upstream supplier under the DTPA and shifted the burden of making that upstream supplier pay for their misrepresentations to the builder/contractor.

B. General Provisions

1. Effective date of the act and amendments: The effective date of the act or practice giving rise to the cause of action under the DTPA determines which versions of the DTPA applies. Woods v. Littleton, 554 S.W. 2d 662 (Tex. 1977).

2. Cumulative remedies: Remedies under DTPA are cumulative, not exclusive. Consumers may avail themselves of common law or other

statutory remedies in addition to the remedies available under the DTPA. Berry Property Management Co. Inc. v. Bliskey, 850 S.W.2d 644.

1995 Amendments adopted a cross-reference to the Residential Construction Liability Act (RCLA). Now, both the DTPA and RCLA provide the RCLA applies when there is an overlap between the two statutes.

3. Construction of the act: §17.44 provides the act shall be liberally construed and applied to promote its underlying purpose; to protect consumers against false, misleading and deceptive acts and practices, unconscionable acts and breaches of warranty.

4. Who can sue? §17.50(a) Consumers-defined as an individual, partnership, corporation, this state, or a subdivision or agency of this state who seeks or acquires by purchase or lease, any goods or services..." Note, consumer need **not** have sought or acquired the goods or services from the defendants; i.e., no requirement of privity. Cameron v. Terrell & Garrett, Inc., 618 S.W.2d 535 (Tex. 1981), Flenniken v. Longview Bank & Trust Co., 661 S.W.2d 705 (Tex. 1983).

5. Pre-suit notice: Consumer must give 60 days written notice to the person against whom the consumer is filing suit. Failure to give notice, results in abatement, not dismissal. Hines v. Hash, 843 S.W.2d 464 (Tex. 1992).

6. Who may be sued? Any "person" who commits a violation of DTPA or Art. 21.21 of Insurance Code. "Person" is defined as an individual, partnership, corporation, association, or other group,however organized. Only exception is advertising media.

1995 Amendments added an exemption for claims based on the rendering of professional services, the essence of which is providing advice, opinion, judgment, or similar professional skill, that is not an express misrepresentation, nondisclosure, unconscionable conduct, or breach of an express warranty.

7. *Waiver of DTPA: 1995 Amendments allow written waivers to be signed by the consumer in any transaction where the consumer is not in significantly disparate position and is represented by independent legal counsel, provided that the agreement contains specific notice of the waiver.*

C. Prohibited conduct: False, Misleading or Deceptive Acts

1. Laundry list: Of the 23 listed items, the most frequently used are items (5) & (7) which deal with representations about the quality of goods and services and (23) failing to disclose known facts. 1995 *Amendments added a requirement of detrimental reliance as a necessary element to recover for a violation of the laundry list.*

2. Breach of warranties

a) Express

Any representation of fact or promise as to the title, condition or quality of goods or services will constitute an express warranty. For instance, a representations that a product is in "good working order" or "top quality" constitute an express warranty. Woods v. Littleton 554 S.W.2d 662 (Tex. 1977), Chrysler Plymouth City v Guerrero, 620 S.W.2d 700 (Tex.Civ.App.-San Antonio, 1981, no writ).

b) Implied

i) Merchantability: New goods are fit for their intended use. Does not apply to used good, but has been extended to the sale of used homes. Thornton Homes, Inc. v. Greiner, 619 S.W.2d 8 (Tex.Civ.App.-Estland 1981, no writ).

ii) Good workmanship: New homes must be constructed in a good workmanlike manner. Evans v. J. Stiles, Inc., 689 S.W.2d 399 (Tex. 1985)

iii) Good and workmanlike repair: Services involving the repair or modification of existing tangible goods or property. Melody Home Mfg. v. Barnes, 741 S.w.2d 349 (Tex. 1987)

iv) Good and workmanlike development: Developer has implied duty to develop in a good and workmanlike manner. Luker v. Arnold, 843 S.W.2d 108 (Tex.App.-Fort Worth 1993, no writ)

c) Disclaimers: Must be conspicuous. "As is" effectively disclaims all implied warranties.

3. Unconscionable acts: Taking advantage of a consumer to a grossly unfair degrees; it need not occur at time of sale and consumer does not have to show the defendant acted with intent, knowledge or conscious indifference. In one case, court held failure to install patio using good and workmanlike manner deemed unconscionable. Thrall v. Renno, 695 S.W.2d 84 (Tex. App-San Antonio 1985, writ ref'd n.r.e.)

1995 Amendments repealed the language prohibiting gross disparity between consideration paid and value received.

D. Producing cause: A consumer can only maintain an action if the false, misleading or deceptive act or practice is the producing cause of actual damages. This is a lesser standard than proximate cause and has been liberally interpreted to mean any conduct by the defendant which factually causes any of the consumer's harm is sufficient to establish producing cause.

E. Damages

1. Recovery of actual damages: Defined as those damages recoverable at common law. Consumer can recover the greatest amount of actual damages he alleges and proves. Farrell v. Hunt, 714 S.W.2d 298, 300 (Tex. 1986).

2. Elements/Measure of damages available

a) Direct losses: all pecuniary losses caused by the wrongful conduct can be recovered.

Examples

I) Out of pocket: difference between what the consumer gave versus what he got in return.

ii) Lost benefit of the bargain: difference between what was promised and what was actually received.

iii) Amount of consideration paid: upon recision, the amount of consideration paid for the goods or services.

iv) Cost of repair

b) Consequential losses

I) Lost profits- typically used in breach of contract cases.

ii) Interest- when a consumer purchases goods on credit and the purchase is induced by a deceptive trade practice, the finance charges which the consumer becomes bound to pay can be recovered.

iii) Expenses- any expense directly or indirectly caused by the defendant's misconduct is recoverable; i.e., car rental expenses.

c) *Personal injury/mental anguish: 1995 Amendments excluded claims for bodily injury or death, and mental anguish, but mental anguish is allowed if defendant acted "knowingly."*

d) *Treble damages: 1995 Amendments changed the automatic trebling of the first $1,000. Now, first $1,000 is trebled only at the discretion of the court and only if the defendant acted "knowingly."*

1995 Amendments redefined "knowingly" to mean "actual awareness, ***at the time of the act or practice complained about****, of the falsity, deception, or unfairness of the act or practice; or actual awareness of the condition, defect, or failure constituting breach of warranty.*

Under 1995 Amendments, mental anguish damages trebled only if defendant acted "intentionally."

e) Multiple recoveries: Consumer can recover both DTPA trebled damages and common-law punitive damages when separate findings under different theories of recovery are obtained.

3. Attorney's fees

F. Miscellaneous Provisions

1. *Mediation: 1995 Amendment adopted a procedure that allows any party to compel mediation.*

2. *Settlement Offer: If the defendant tenders a settlement offer and it is unreasonable rejected, the consumer's recovery will be limited accordingly.*

Residential Construction Liability Act
(RCLA)

II. Residential Construction Liability Act (RCLA -- Texas Property Code §27.001 *et seq.*

A. Applicability 27.002

1. Applies only to residential construction.

2. Applies to "construction defects" -- but does not apply to actions for damages for personal injury (excluding mental anguish), survival, wrongful death or for damage to goods.

3. "Construction defect": any matter concerning the design, construction or repair of a new residence, or the remodeling of an existing residence. Includes any "appurtenances" to a residence i.e., swimming pool, detached garage, etc.

B. Who is proper Defendant? "Contractors" §27.003

1. Defined as a person contracting with an owner for the construction or sale of a new residence constructed by that person or of an alteration or addition to an existing residence, or construction, sale alteration, addition, or repair of an appurtenance to a new or existing residence.

2. The definition also includes a risk retention group that insures any part of a contractor's liability for the cost of repairing residential construction defects.

C. Who is a proper Plaintiff? §27.001 et seq

Anyone who suffers damages from a construction defect, i.e. anyone who seeks or acquires a contractor's services to design, build or repair a new home or to remodel or add to an existing home. A subsequent purchaser of the home is required to follow the RCLA procedures.

D. Proceeding under the act -- §27.004

1. Homeowner provides written notice of the construction defect in reasonable detail, by certified mail, return receipt requested at least 60 days before filing suit.

2. Inspection: contractor, upon written request, must be given opportunity to inspect within 35 days after receiving the notice.

3. Offer: contractor may make written off to repair or pay money within 45 days after receiving notice.

4. If homeowner accepts offer, repairs must be completed within 45 days (unless delayed by the claimant or events beyond the contractor's control).

5. If claimant unreasonably rejects offer or doesn't permit contractor reasonable opportunity to repair, claimant may not recover an amount in excess of the reasonable cost of repairs which are necessary to cure the construction defect and may only recover the amount of reasonable and necessary attorney's fees and costs incurred before the offer was rejected.

6. If a contractor fails to make a reasonable offer, or fails to make a reasonable attempt to complete the repairs, or fails to complete the repairs in a good and workmanlike manner, the limitations on damages and defenses to liability do not apply.

7. If procedures followed, claimant may only recover the following damages

   a) reasonable cost of repairs necessary to cure any construction defect that the contractor failed to cure;

   b) reasonable expenses of temporary housing necessitated by the repairs;

   c) reduction in market value of the residence, if any, due to structural failure; and

   d) reasonable and necessary attorney's fees.

8. Damages may not exceed the claimant's purchase price for the residence.

E. Defenses to Liability §27.003 & §27.004

1. Normal wear, tear, and deterioration.

2. Normal shrinking due to the drying or settlement of construction components within the tolerance of building standards.

3. Damages not *proximately caused* by the alleged construction defect.

4. Damages proportionally reduced by percentage due to failure by anyone other than contractor-- including the Owner-- to take reasonable action to maintain the residence.

5. Contractor reasonably relied upon written government information that was false or inaccurate.

6. Unlike the DTPA, all common law defenses apply to RCLA claims.

7. Abatement, if no or insufficient notice given.