SOILS-STRUCTURE INTERACTION SEMINAR FOR RESIDENTIAL AND LIGHT COMMERCIAL FOUNDATIONS

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

o	Introduction David Eastwood, P.E.	(5 minutes)
o	Foundation Failures Committee Report Jack Deal, P.E. - Jack Deal Consultants, Inc.	(15 minutes)
o	Foundation Failures In The Houston Area Richard Peverly, P.E. - Peverly Engineering, Inc.	(30 minutes)
o	State-of-Practice of Foundation Design Custom Homes - Ed Kile, P.E., - Structuneering, Inc. Track Homes - Lowell Brumley, P.E., - SEC, Inc.	(20 minutes) (20 minutes)
o	Break	(10 minutes)
o	Recommended Quality Control and Inspection Platt Thompson, P.E. - Thompson Engineering, Inc.	(20 minutes)
o	Guidelines For Geotechnical design, Construction, Quality Control, and Failure Evaluation For Residential Projects In The Houston Area David Eastwood, P.E. - Geotech Engineering and Testing	(45 minutes)
o	Break	(10 minutes)
o	Foundation Repair Techniques Don Lenert, P.E. - Don Lenert Engineers, Inc.	(25 minutes)
o	Builders Point Of View Jack Orem - JMC Homes, Inc.	(15 minutes)
o	Government Agency Point Of View Joe Edwards - City of Bellaire Building Official	(15 minutes)
o	Deceptive Trade Practice Act James Moriarty - Attorney-At-Law Dan Shank - Attorney-At-Law	(20 minutes) (15 minutes)
o	Break	(10 minutes)
o	Panel Discussion	(85 minutes)

Special Panel Discussion Expert:
Dutch Raitz - Arrow Foundation Company

The seminar will be held at the Briar Club, located at 2603 Timmons, Houston, Texas (Key Map No. 492S), from 1:00 to 7:00 p.m. on Wednesday June 16, 1993. RSVP Geotech Engineering and Testing, Ms. Kim Robinson (713) 683-0072 before June 11, 1993. Admission Fee $25. Course notes will be additional $10. Please make your check payable to Geotech Engineering and Testing. Please feel free to distribute this seminar information to your colleagues and clients so that we may have a good attendance.

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SOILS-STRUCTURE INTERACTION SEMINAR
FOR RESIDENTIAL AND LIGHT COMMERCIAL FOUNDATIONS
Houston, Texas
June 18, 1993

TO: Seminar Attendees

FROM: Committee to Define Foundation Failure: Jack Deal, PE Chairman (Committee members consist of all speakers in this seminar who are registered professional engineers. They are: David Eastwood, PE; Richard Peverly, PE; Ed Kile, PE; Lowell Brumley, PE; Platt Thompson, PE; and Don Lenert, PE)

SUBJECT: DEFINE FOUNDATION FAILURE

On March 24, 1993 this committee met to discuss criteria for defining foundation failures in residential and light commercial structures. There were two follow up meetings. In addition to committee members there were other guests (all PE's) in attendance.

Our discussion was informal and open. Although there was some difference of opinion on details, there was general consensus on the main issues. We did agree that foundation failure can be defined both informally (subjective evaluation based on performance) and formally (objective evaluation based on comparing quantitative analysis with governing codes).

During discussions, the chairman posed a list of relevant questions to the committee. Below is a very brief summary of the committees initial attempt at defining foundation failure followed by a listing of questions discussed and consensus opinions of the committee regarding same:

Before defining "foundation failure" it will be helpful to define a few other relative terms:

Foundation, definition; that structural component (footing, pile, pier, slab, etc.) of a total structural system which transfers load directly to load bearing soil or other earth element.

Foundation, function; to provide a stable support for applied loads.

Stable; conforming to normal and expected degree and rate of movement. (Conclusion: "normal and expected degree and rate of movement." must and can be defined),

Failure, definition; 1) to be lacking or insufficient, 2) a person or thing that fails. (Conclusion: in order for something to have failed, there must be an objective or intended function not met),

Evidences and consequences of foundation movement (E&C); Cracking of rigid materials (sheetrock, brick, concrete, etc.); separation of joined materials (frieze molding, rafters to ridge, window to brick, cabinet to wall, etc.); sloping of normally horizontal surfaces, wracking of structural members, etc..

FOUNDATION FAILURE DEFINED -----Using the above definitions of terms it becomes a simple matter to define foundation failure: **Foundation failure has occurred when a foundation no longer meets the performance objective of providing a stable support or when its capacity to meet this objective is determined to be lacking.**

The above definition of foundation failure has no meaning however, until and unless the definition of the all important term "stable" is expanded to include quantitative parameters for allowable "degree and rate" of foundation movement, i.e., how much movement can be allowed and how fast can it be allowed to happen? And to, the number and degree of evidences and consequences (cracks, slopes, elevation changes, etc.) of this movement must be taken into consideration.

The committee, after much discussion and debate, concluded that there are two basic ways to determine that foundation failure has occurred. They are by Subjective evaluation & by Objective evaluation:

Subjective evaluation of foundation failure: compares visual observations with normal performance standards. Currently these standards consist almost exclusively of the knowledge and experience of the inspector (whether he be a PE or a non-PE). There are no such written standards in existence in this area today (at least none that are widely accepted). It is the objective of our committee to develop and publish meaningful performance standards for determining foundation failure by subjective evaluation.

The committee agreed on factors which should be considered as performance standards are developed. Some of these are as follows:

* The age, type construction, and geometric shape of the foundation;
* Site conditions (drainage, vegetation, soil, etc.);
* Evidences & consequences of movement (cracks, separations, slopes, elevation changes, etc.); and
* Economic factors (possibly).

Objective evaluation of foundation failure: compares quantitative field measurements and lab test data of as-built construction with requirements of governing codes.

The committee agreed that objective formal evaluation of foundation failure should include the following as a minimum:

* Determine properties of supporting soil,
* Define as-built construction,
* Test strength and other properties of materials as required,
* Perform analysis and compare results with governing codes.

It was the committee's opinion that the level of investigation of foundation failure necessarily must be appropriate to the purpose of the investigation. That is, if responsibility for the failure is claimed to be the fault of the design engineer, then the evaluation must follow the formal objective evaluation described above. On the other hand, if a homeowner wants to know if his foundation has failed, then the engineer can use the subjective method.

QUESTIONS

Following are some of the questions (**in bold print**) posed to the committee. The accompanying answers represent a consensus of opinion but not necessarily unanimous agreement of committee members.

1. Can foundation failure be defined?
Subjectively ---yes, but it will be difficult and require establishing guidelines for performance standards, such as allowable deflection, etc.. Objectively--- yes, by comparing quantitative analysis of field measurements and lab test results with requirements of governing codes.

2. Must determination of foundation failure consider the interaction between the foundation and the supporting soil?
Yes, a house with a five degree lisp due to soil movement but without a single crack in concrete or walls has a foundation failure.

3. If failure has been determined to exist, must repair be performed?
Not necessarily---failure by objective evaluation (noncompliance with governing codes) may occur without exceeding parameters of subjective failure guidelines which considers age of structure, etc.. Failure and repair are not synonymous terms. Either one can occur without the existence of the other.

4. Should foundation failure be determined only by a PE?
Yes, though repair can reasonably be diagnosed as being desired or required by other than PE's. (this is the common practice today, it deserves further discussion).

5. Can the cause of foundation failure be determined without soils testing?
No, and the determination of cause must be by a PE.

6. If a foundation fails due to site conditions (drainage pattern, vegetation, etc.) within first two years, whose fault is it likely to be?
Probably the contractor due to construction error. However, the design should be studied to determine if detrimental site conditions (large trees and poor drainage) have been overlooked. The homeowner could be at fault if he has altered site drainage or has been neglectful in maintaining uniform perimeter soil moisture content.

7. If cause of failure is to be determined, must it be determined by a PE?
Yes, particularly if cause and "responsibility for failure" are to be determined. Failure evaluation where fault is to be determined must be by the objective method and be performed by a PE.

8. Subjective guidelines (Performance Standards)
The committee discussed possible guidelines at length and arrived at some tentative guidelines. It was felt that a broader survey is required before publishing any guideline parameters for performance standards.

9. Does the age of house affect the evaluation of failure or whether repair is required?
Yes.
Example: A house is 30 years old. It has 2 1/2 inches settlement, 1/4 inch brick cracks, a couple of sticking doors, 1/8 inch sheetrock cracks and some hairline cracks in the foundation. A competent and experienced PE renders the opinion that the condition is marginal but has not failed (by subjective evaluation) and does not require repair. The same house having all the same conditions, except it is 2 years old in lieu of 30, is inspected by the same PE. He renders the opinion that 2 1/2 inches movement alone does not constitute failure but that this amount of movement in just two years constitutes an unstable condition. Action is required. Since the house foundation is not stable, by definition failure has occurred. Stabilization is required (it is pointed out that this can be done by methods other than repair to the foundation (lime injection, watering systems, drainage control, etc.).

10 What is a cracked Slab?
Nobody knows!

(Due to time constraints this writing has not been reviewed by the entire committee. The committee will continue to meet and this paper will be expanded. Your comments are solicited. Contact Jack Deal at 667-1158 or any of the committee members).

FOUNDATION FAILURES IN THE HOUSTON AREA

Richard W. Peverley
Peverley Engineering, Inc.

SOILS-STRUCTURE INTERACTION SEMINAR
FOR RESIDENTIAL AND LIGHT COMMERCIAL FOUNDATIONS
Houston, Texas
June 16, 1993

INTRODUCTION

A series of weather-related events has occurred in the past ten years which, in turn, caused an extensive amount of damage to homes and businesses in the greater Houston area. In the month of August, 1983, the eye of hurricane Alicia passed directly over downtown Houston. The total damage caused by this hurricane was estimated to be approximately $600,000,000 in damage to homes in a six county area along its path. This event drew a substantial amount of publicity all over the country as well as in various parts of the world. In most cases, individual owners were reimbursed for damage that the storm had caused to single family homes. Government aid was also available. Yet, another weather-related event occurs in the greater Houston area on a daily basis whose destruction to residential and small commercial properties is, on a long-term basis, equal to or in excess of that caused by storms, such as Hurricane Alicia.

In the year 1987, we estimated that individuals the greater Houston area spent an approximate amount of $28,500,000 to repair the foundations in their homes for the sole purpose of being able to have them sold. Conservatively, at least half as many homes received foundation repair outside of the real estate market bringing the estimate up to $42,750,000. If one were to assume that hurricanes occur on a 10 year cycle, one could then estimate that the total damage cost to be $456,000,000. Considering the sharp increase in the number of companies performing foundation repairs during the drought period of 1988 through 1990, it would not be unrealistic to estimate the ten year cost to be between $500,000,000 and $600,000,000. This estimate does not include any costs to repair the damage that these foundation failures have caused, nor does it include the amount of money that has been wasted in litigation proceedings that have resulted.

There has been no publicity, to speak of, about this economic loss, and it certainly is not covered by insurance, or by any government aid. Although our estimate may not be totally accurate, we do believe it to be sufficient to prove the point that foundation failures do cause a severe drain to the Houston economy. At the present time, this problem has basically been ignored, not only by those government entities that should be concerned but also by the industry as well.

The greater Houston area is not unique among the major cities when it comes to having a high incidence of foundation failures, except, perhaps, in the wide variety of causes. We have assembled, herein, what we consider to be representative examples of the type of foundation failures that have occurred where we have been fortunate enough to have been given an opportunity to perform a sufficient diagnosis to be able to identify causes. Each of these examples is an actual case that occurred. In most of these examples, the amplitude of the deflections that occurred in these foundations and the damage they cause is certainly on the upper side of the median; however, they are not always the most extreme cases we have observed. The figures that accompany each of these cases show the sloping conditions on the interior floors in terms of contours of equal heights. These contours were drawn from relative height measurements made on the interior floors using a level manometer. The highest measured level in the foundation was the zero contour height in the drawings. After these examples have been presented, we will attempt to summarize the causes and offer suggestions on how remedies can be effected.

CASE HISTORIES

CASE 1

The first example is a single-family dwelling with brick veneer siding located in West University Place, which is a small enclave within the boundaries of the City of Houston, Texas. Our Client was the second owner. The building plans showed the foundation to be a reinforced concrete grade-beam-stiffened slab resting on drilled piers. The foundation plans, as depicted on the building drawings, is shown in Figure 1. Prior to the construction of this building, there had been an older structure on the site, which had been removed.

The contours of equal height are also shown in Figure 1. There is an obvious high spot near the center of the foundation, and a low spot toward the rear of the building. A substantial amount of foundation-induced damage had occurred. In fact, the damage to the brick veneer on the North side of the building was so bad that the Builder had the brick removed and replaced. The damage, in the form of cracks and distortions, continued to worsen with time.

The native soil had a high plasticity index of 54 percent at a depth of 13 ft. Cores cut from the slab showed the concrete to have a strength of over 4,000 psi. The wire reinforcement was found at the bottom of the slab. Fill soil under the slab was a mixture of clay and sand that was poorly consolidated. There was a trench on the North and South sides of the building which contained 6 inches of pea gravel and 12 inches of bedding sand.

The pier configuration was examined using a sampling technique. Probing revealed that one pier extended about 4 ft. into the soil, then rested on a piece of concrete. There were two piers which had bells; however, they were substantially undersized. Piers were not found at all of the design locations, as in Figure 1. Under questioning, the Contractor stated that the shallow interference we found at one pier was an old concrete slab which was never removed. He also stated that there were some piers left from the original building that were in the near vicinity of those shown on the drawings, so he simply used them. Based on our observations, it was our opinion, the failure of this foundation was caused by construction errors.

CASE 2

This example is a two-story, single-family dwelling with brick veneer and composition board siding. The building is located in the Champions Forest area, North of

Houston. The Client was the first owner of the building, which was originally a speculation home constructed by the Builder.

According to the building plans, the foundation was a reinforced concrete grade-beam-stiffened slab-on-ground type. The perimeter grade beams were 22 inches deep, 12 inches wide, and had 2 # 5 reinforcing steel bars on the top and bottom. The interior beams were only 18 inches deep. The foundation plan is shown in Figure 2.

The foundation had subsided near its center. The contours of equal heights are also shown in Figure 2. The building had sustained a significant amount of foundation-induced damage. The soil tests showed the upper 4 ft. of the soil to be soft and moisture sensitive. The allowable bearing strength was reported to be only 450 psf for dead load and 675 psf for dead + sustained live load. The soil from 4 to 10 ft. contained moderate PI clays with good bearing strengths. A perched water table condition was reported to exist. The original building site was heavily wooded.

Calculations showed the dead loads on the foundation to be 1500 psf on the exterior, and 1200 psf on the interior. Thus, the foundation appears to have been under-designed with regard to bearing. No measures were included in the foundation drawings nor were any measures taken by the Builder to provide for proper drainage to counteract the adverse effects of the perched water table condition. The failure of this foundation appears to be a combination of design and construction errors.

CASE 3

This example is a two-story dwelling with brick veneer siding. This building is located in West University Place. The building was designed and constructed as a custom home for the Owner. The foundation design was a reinforced concrete grade-beam-stiffened slab on drilled piers. Prior to the construction of this building, there had been a older building on the property that had been torn down. The foundation was designed by a P.E. based upon a soil test report. The building plan is shown in Figure 3.

At sometime subsequent to its original construction, the building began to show signs of movement. We had inspected the building in 1991 and 1992. The contours of equal height and section lines are also shown in Figure 3. The building obviously slopes from the front corner toward the side wall. As a result of soil testing and our analysis of the data, we determined that the sloping conditions were the result of soil heaving.

The original building was on the East side of the lot. The new building was constructed on the West. The original soil was graded such that there was a uniform slope from the front yard toward the foundation at the Northeast corner. The fill soil was a loam type. Rainwater falling on the East half of the front yard would flow through the loam soil on the surface only to be collected on the surface of the clay layer below, then run toward the foundation under the grade beam and down the side of the pier. The building had been constructed during the drought of 1988. As a result, there was an abnormal amount of soil heaving at the Northeast corner of the building. In our opinion, the foundation failure was the result of a construction defect; not so much in the physical construction of the building, but by the grading in the yard.

CASE 4

This case concerns a two-story, single-family dwelling with brick veneer siding located within the Village of Southside Place. This village is also entirely surrounded by the City of Houston, Texas. This was a custom-designed building which was constructed for the original Owner. The building had a reinforced concrete grade-beam- stiffened slab foundation resting on drilled piers. The foundation was designed by a P.E., based on a soil report. There had been an older building on the property, which had been torn down. The site plan is shown in Figure 5.

There had been three soil tests conducted, once before construction and twice during this investigation. The native soil was found to have a very high pi in the 50-60 percent range. The second soil test was conducted after the foundation was beginning to show signs of failing. Soil samples below the foundation slab showed that the select fill was not present, as required on the drawings. A third soil test was conducted in conjunction with litigation proceedings. The presence of the highly expansive soil at depth was confirmed.

Inspections were originally conducted in 1988 & 1989 because of cracks in the floor tiles. The floors were level and there was no other damage. An inspection made in 1991 showed the presence of sloping floors, accompanied by a significant amount of foundation damage. In the original construction, rainwater collected by the gutters was routed to the ground through downspouts and then collected into a drain pipe system which routed the water out to the street. It was later discovered that the Owner had a lawn drain installed in the back yard. The pipe from the back yard drain sump ran to the gutter drain system pipe next to the foundation; however, the pipe from the yard drain had not been connected. Thus, the water from the yard drain was directed toward the foundation and under the foundation where there were desiccated soils, with PI's in the upper 50 to lower 60 percent range. The addition of moisture to these soils caused uplift on the piers at the North end of the building, where the presence of soil heaving was evident, as shown in Figure 4.

There were two errors that occurred on this building. One was the placement of non-select fill; however, in our opinion, this was not a major contributor to the demise of this foundation. The most significant error was in the installation of the yard drain by the Owner which was never connected to the drain system placed by the builder.

CASE 5

This case concerns a two-story, single-family dwelling with brick veneer siding which is located in the town Westin Lakes near Fulshear, Texas. This town is approximately 30 miles West of the City of Houston, Texas. This was a custom-designed and constructed building which had been constructed for the original Owner. The building had a reinforced concrete grade-beam-stiffened slab-on- ground foundation. There was no previous building on this site. The foundation was designed by a P.E. There was no reference to the soil test report on the drawing. The foundation slab design is show in Figure 5.

At sometime after the Owners moved in, the walls began to show signs of cracking. The contour height measurements are also shown in Figure 6. From these measurements, it can be seen that there was a substantial amount of subsidence in the center of the building and toward the rear. Soil testing was then conducted which showed the surface soils to be soft and moisture-sensitive with low strengths, while the subsurface soils had high PI's with good strengths. Corings through the concrete showed the concrete strength to be 2,000 psi versus the design strength of 3,000 psi. Wire reinforcement was at the bottom of the slab. There was a void between the bottom of the concrete slab and the top of the soil.

A review of the drawings showed the absence of an effective interior grade-beam stiffener. The perimeter grade beams had a depth of 30 inches and a width of 10 inches, which was probably insufficient for such weak soils. The interior grade-beam stiffeners, were only 12 inches deep and 6 inches wide. Because of the presence of the firm subsoils, a foundation designed to rest on drilled piers would have probably functioned properly.

In our opinion, the initial failure was probably caused by a design deficiency; however, the presence of the weak concrete precluded proper repair. The building was eventually demolished.

CASE 6

This case concerns a two-story, single-family building with brick veneer siding. The building is located in the Wimbledon Lake Subdivision, in the general FM 1960 area, which is in the North part of the greater Houston area. This was a custom-designed building that was constructed for the current Owner. The foundation design shows it to be a reinforced concrete grade-beam- stiffened slab supported by drilled piers. The foundation was designed by a P.E. It was confirmed that no soil testing was conducted to support this design.

The building was constructed on a sloping lot. Soil testing conducted subsequent to the time the building was constructed showed the soils on the surface to be of a loam constituency of low strengths. The soils at depth had an allowable bearing strength of less than 3,000 psf. Coring showed the concrete strength to be only about 83 percent of the design strength.

Numerous construction errors were discovered in this building. The contractor had changed the grade-beam depth from 36 inches to 24 inches without contacting the Engineer. The Contractor had used dirt from the swimming pool excavations from other projects for fill. Pier bells were found to be 24 inches in diameter instead of 30 inches, as designed. Water had been added to the concrete trucks at the site. Prior to construction, the Owner had inquired about soil testing; however, the building designer had discouraged him from spending the money to have this done.

In our opinion, it probably was not prudent to have proceeded with the design of this foundation without soil testing; however, because of the numerous errors made by the Builder, the foundation would probably have failed anyway.

CASE 7

This case concerns a residence in the Tanglewood Subdivision, which is located in the inner part of the City of Houston, Texas. The foundation is a reinforced concrete, grade-beam-stiffened slab-on-ground foundation supported on drilled piers. The foundation was designed by a PE. The foundation plan is shown in Figure 7. No reference was made to a soil test report. The building was constructed during the drought that occurred during the summer of 1988.

The building was observed to have a high degree of slope which was accompanied by a severe amount of foundation-induced damage. The contours of equal height are also shown in Figure 7.

This is a typical example of the type of failure that occurred as a result of the drought of 1988. At the time this foundation was constructed, the soil was desiccated to distances further below the surface that were deeper than anyone can remember seeing in the past. In the year 1990, the amount of rainfall began to increase at a steady rate until the year 1993, when the rainfall was abnormally high. As the expansive soils imbibed the rain water, the soil began to swell and force the foundation upward. In this building, the piers on the high side of the building were secured to the foundation grade beams. Thus, it appears that the piers, per se, were the structural elements that were forced upward. Many soil reports we reviewed advised that piers be designed for an upward force of 1,000 psf. For a 12 inch diameter pier that is 10 feet deep, there is a potential for the upward force to be as much as 31,400 pounds.

CASE 8

The foundation in this case is a post-tensioned concrete slab-on-ground type which supports a one-story wood frame dwelling with brick veneer siding. The building was erected in the 1988 to 1989 time period. The soil characteristics can be described as moisture sensitive loam over expansive clays. The foundation had deflected to the point that a significant amount of foundation induced damage had occurred. The contours of equal heights are shown in Figure 8. Obviously, there is a steep downward slope from the back wall towards the center of the front of the building.

Perhaps, the most interesting aspect of this case is the amount of denial that was a major part of the young history of this building. Shortly after the building was purchased by the first Owner, cracking developed on the interior of this building. When summoned, the builder attributed the cracking to "normal settlement." The first owner was transferred and the relocation company purchased the house, after a "clean" inspection report had been obtained by a PE. After two contracts had been cancelled by buyers because of adverse foundation inspection reports, we were hired by the relocation company and, as a result, identified the failure of this foundation. The builder then attributed the foundation failure to poor drainage and offered to install a yard drainage system. Because their investment was tied-up in a house they could not sell and because litigation could have tied this investment up for several years, the relocation company had the house underpinned and raised. The home was sold shortly thereafter.

CASE 9

To end this discussion on a positive note, this was a building well over fifty years old that was located in the River Oaks Subdivision. The building had not been occupied for over two years. The yard was over grown with bushes and weeds. The lawn was nearly dead because of a lack of water. The interior was dusty and had a high concentration of cobwebs. Despite this lack of attention and despite the fact that deformed 60 ksi steel had not been developed at the time this building was constructed, the floors were level (as shown in Figure 9), there were no interior or exterior cracks, and every door frame and window frame was square. There were foundation plans which showed the foundation to be a grade-beam-stiffened slab type resting on spread footings. The soil was a moderate PI clay. When was the last time a modern foundation was supported on spread footings?

Good foundations can be built. The design needs to be proper for the existing soil conditions and there must be a high degree of quality control in the construction processes.

CONCLUSIONS

By far, the cause of the majority of the foundation failures we have reviewed in relatively new residential buildings are construction related; i.e., the failure to construct the foundation in accordance with the drawing requirements. One exception may have occurred during the drought of 1988 and 1989 when heaving soils caused some very dramatic failures in many pier supported foundations. This observation is obviously being made in retrospect. I do not, however, remember seeing soil test reports that included design recommendations which would have avoided such an occurrence, or warnings that some extraordinary preventive measures were required. Can these failure then be blamed on the geotechnical community? Soil heaving is a condition which the foundation designers all know to well can be destructive and needs to be taken care of. Can the engineering community be blamed for not requiring that the soil test reports address the extreme soil heaving potential?

Builders and house designers endeavor to cut cost to their lowest and are successful in finding engineers who will work at rates so low they can not afford to conduct a detailed design analysis and/or will provide marginal designs in the construction drawings for the sole purposes of cutting costs. Who is to blame - the contractors and house designers who make such demands or the engineers who acquiesce to them.

Design drawings often contain adequate quality control requirements but seldom contain any requirements for enforcement. Again, who is to blame?

Finally, the public demands the most gingerbread per square foot at the lowest cost? When the cost of constructing a good foundation is sacrificed in favor of gingerbread, the public is often the offended party when, in reality, it is the demands of the public that are the primary cause of the failure occurring.

The problem is obviously very complex. There are many needs to be satisfied and many an ox that is in endanger of being gored. Who's to bless and who's to blame? Certainly, the only real beneficiaries are the attorneys. This problem will not be resolved until such time as the litigation burden becomes too much to bear or until someone takes to lead in affecting a resolution. Perhaps the engineering community can provide the leadership in getting this problem resolved. The suggestions contained in the following section of this paper are provided in this regard.

RECOMMENDATIONS

The following suggestions are offered for the purpose of improving the design and construction of residential foundations:

1. All foundations designs must be the product of a design analysis conducted by a Registered Professional Engineer.

2. The requirements of the Engineering Board that all of the designs of residential foundations that are done by a PE must be based on a soil test report for that specific building site.

3. The Engineer must report directly to the end user of the design; i.e., the buyer of a custom built home and not the designer/architect or the builder.

4. The Engineer shall charge sufficient fee's to make the necessary analysis and to conduct the necessary calculations to assure that any foundation so designed will, if constructed properly, perform the functions for which intended.

5. The Engineer shall personally prepare the drawings or have them prepared by someone working directly for the engineer. Such drawings may not be prepared by an architect or house designer.

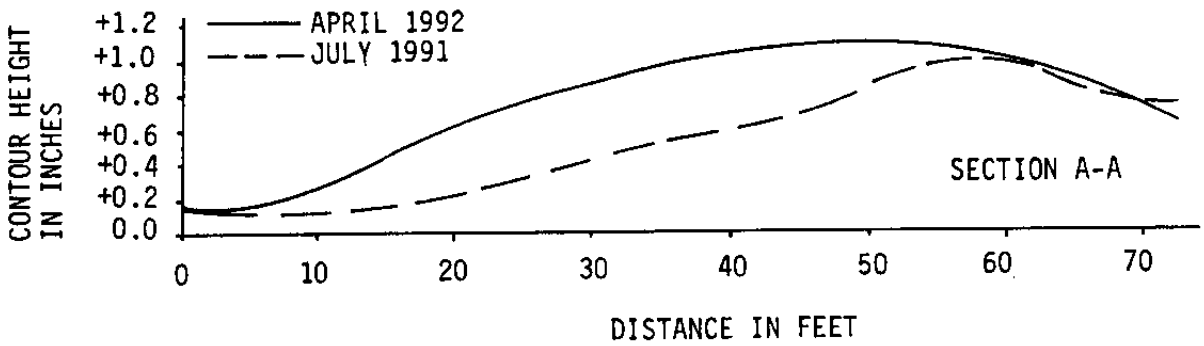
6. The construction drawings issued by the Engineer shall contain sufficient detail as to eliminate constructions questions that might otherwise be raised by a qualified and trained craftsman.

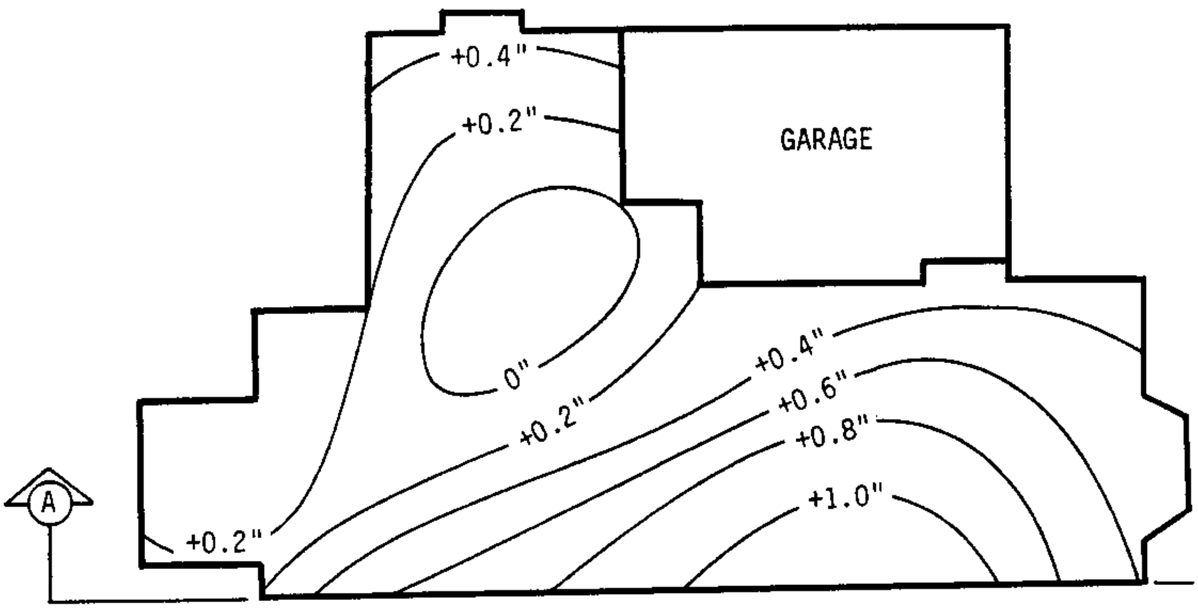
7. The contract between the Engineer and the client shall include fee's for the inspection of the work in-progress. The contract shall grant the Engineer the authority to stop-work were drawing deviations have occurred.

8. The Engineer shall have all calculations and drawings checked by another engineer before the drawings are issued for construction. Such records shall be maintained for a period of 10 years.

9 The Engineering community, shall seek out new methods of designing and constructing residential foundations and shall assess existing methods, as well.

In todays world, such suggestions are obviously idealistic. Neither the builders, the architects, nor the house designers are willing, at this time, to relinquish this type of control to the engineering community. It would be foolish to believe that building codes in an around the City of Houston are going to change without some outside impetus. However, if changes are going to be made, they need to start somewhere and perhaps we the only people who can get this done. Thus, it is my proposal that we form a committee of engineers either under the sponsorship of one of the Engineering societies, or on our own, to begin this task. We must first rewrite the set of rules I have suggested above to make them more workable. Second, we must begin to educate the architects, the house designers, the builders, and the people that make decisions that cause changes to occur in the building codes. It is most important that we find ways to educate the public. Recently, television Channel 11, under Dr. Neil Frank, has begun the task of educating the public on the need to build their homes in such a manner that they can survive a Class 4 hurricane. We need to embark on a similar venture. Help is available if we only seek it out. In my experience with the last Thanksgiving tornados, all of the owners of homes in the Kellywood subdivision that needed to have their homes rebuilt because of tornado damage, had hurricane provisions included in their rebuilding. I absolutely believe that given an option to have a foundation on a new home properly designed and constructed, a vast majority of the owners would willingly spend the extra money. In my opinion, we are the only people that can start the momentum to give them a choice.





PIER 1. PIER 4' 6" DEEP. TERMINATED AT OLD PORCH SLAB.
PIER 2. PIER AT 10' DEEP. BELL UNDERSIZED BY ONE FOOT.
PIER 3. PIER AT 10' DEEP. BELL UNDERSIZED BY ONE FOOT.
PIER 4. PROBING FAILED TO SHOW THE EXISTENCE OF A PIER.
PIER 5. PROBING FAILED TO SHOW THE EXISTENCE OF A PIER.

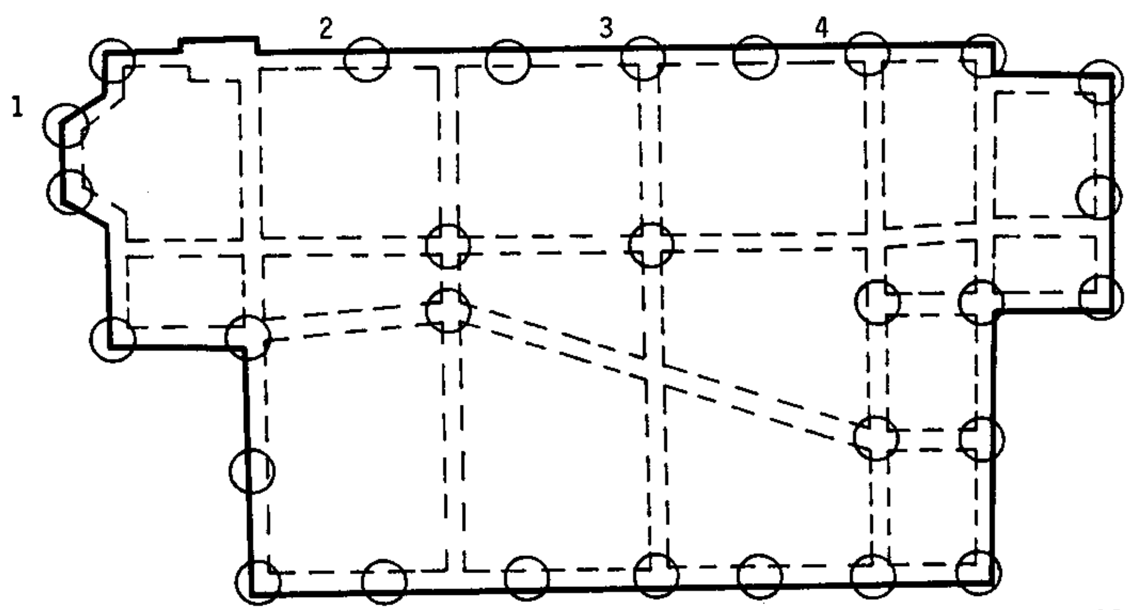


FIGURE 1. FOUNDATION DEFLECTIONS ON A PIER SUPPORTED FOUNDATION THAT WAS FOUNDED ON VERY EXPANSIVE SOILS WHERE SOIL HEAVING HAD OCCURRED.

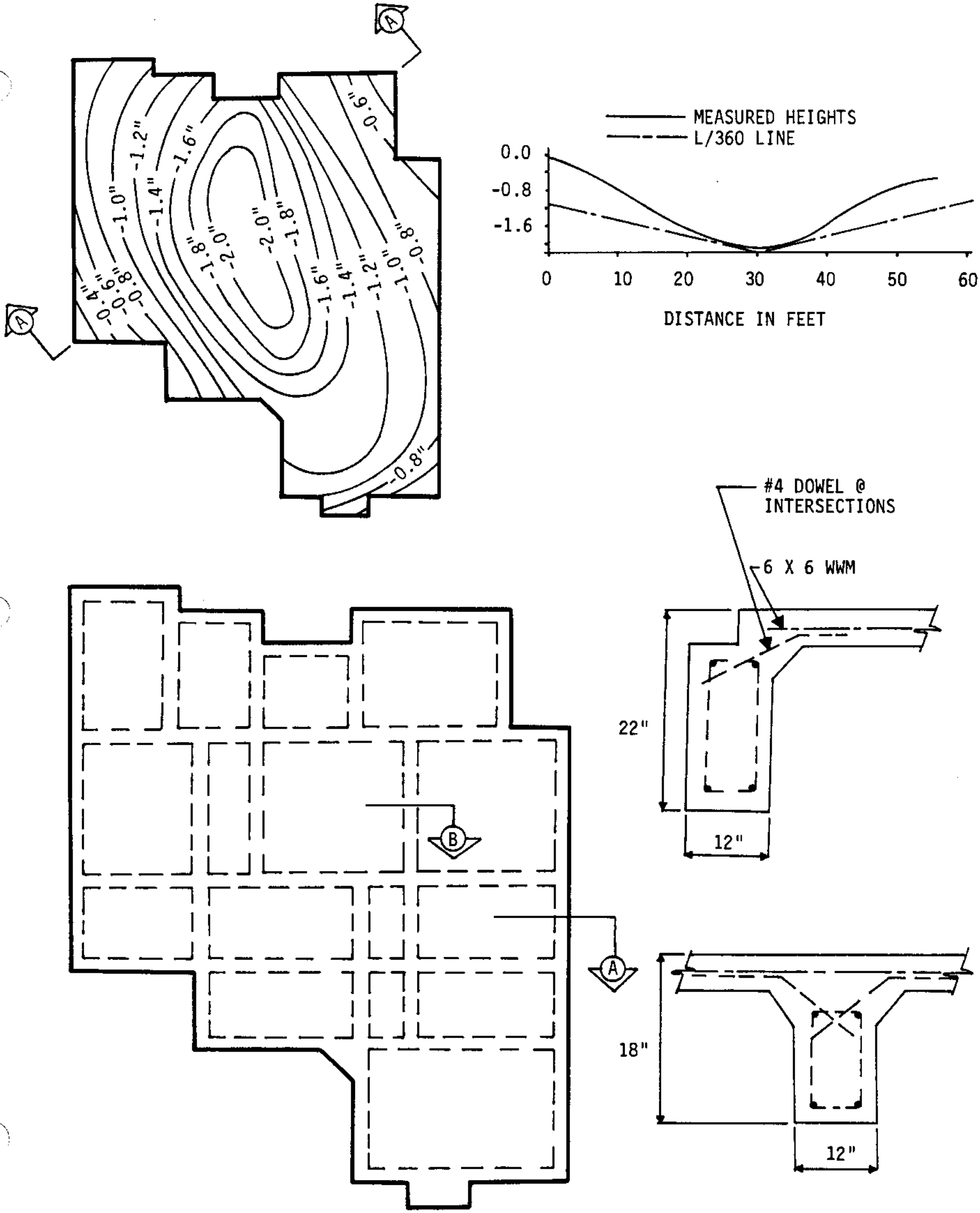


FIGURE 2. FOUNDATION DEFLECTIONS THAT OCCURRED ON A SLAB-ON-GROUND FOUNDATION THAT IS RESTING ON SOFT, MOISTURE SENSITIVE SOILS.

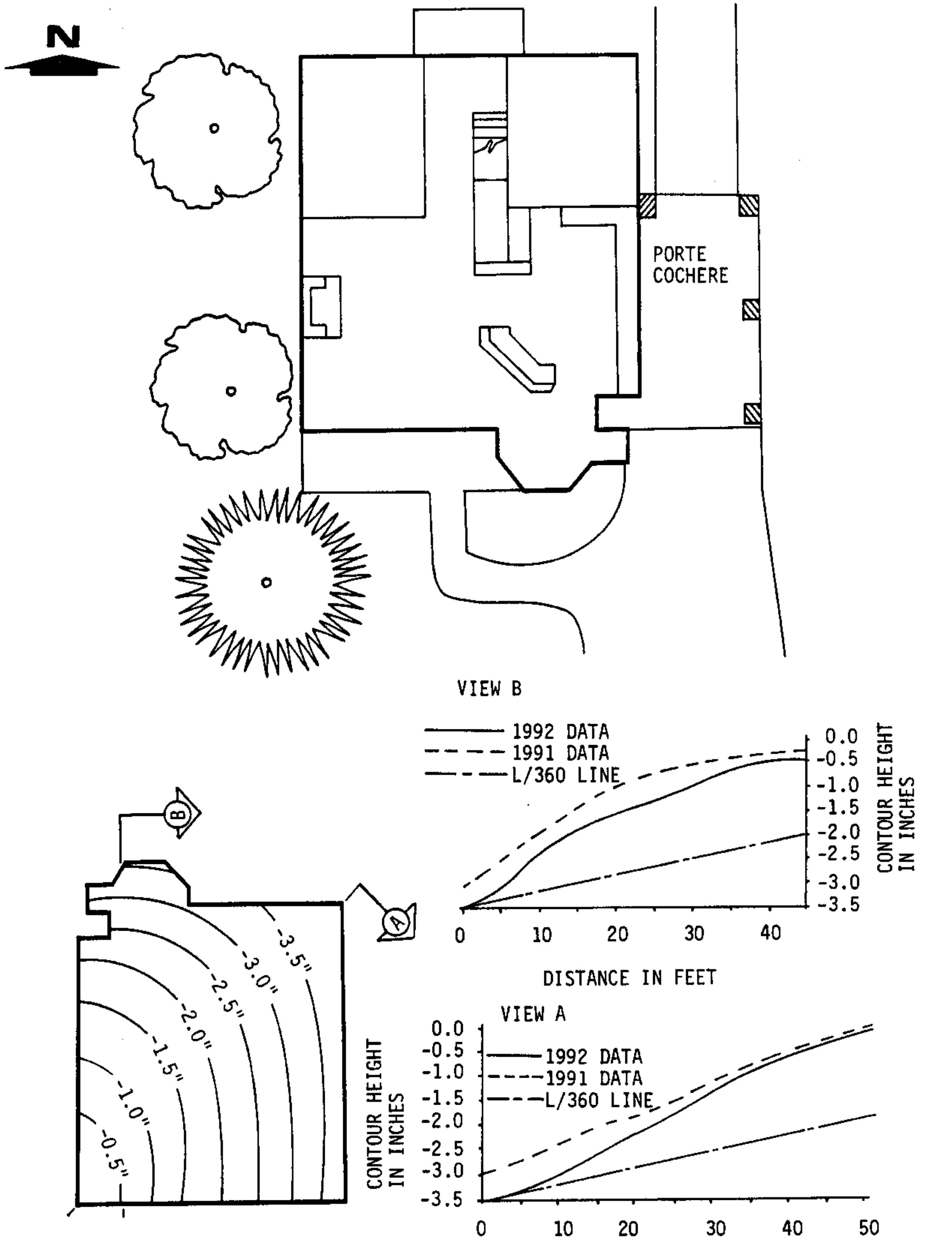
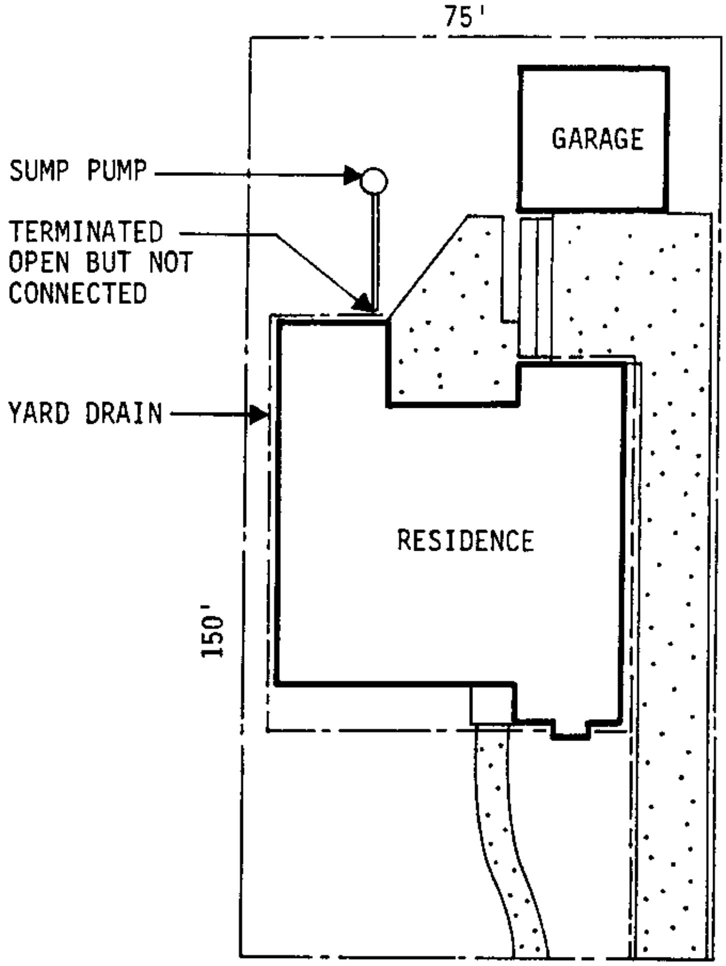


FIGURE 3. AN EXTREME EXAMPLE WHERE A SLAB TYPE OF FOUNDATION SUPPORTED ON DRILLED PIERS HAD HEAVED AT ONE CORNER BECAUSE OF THE LACK OF ATTENTION TO THE FLOW OF RAIN RUN-OFF WATER.



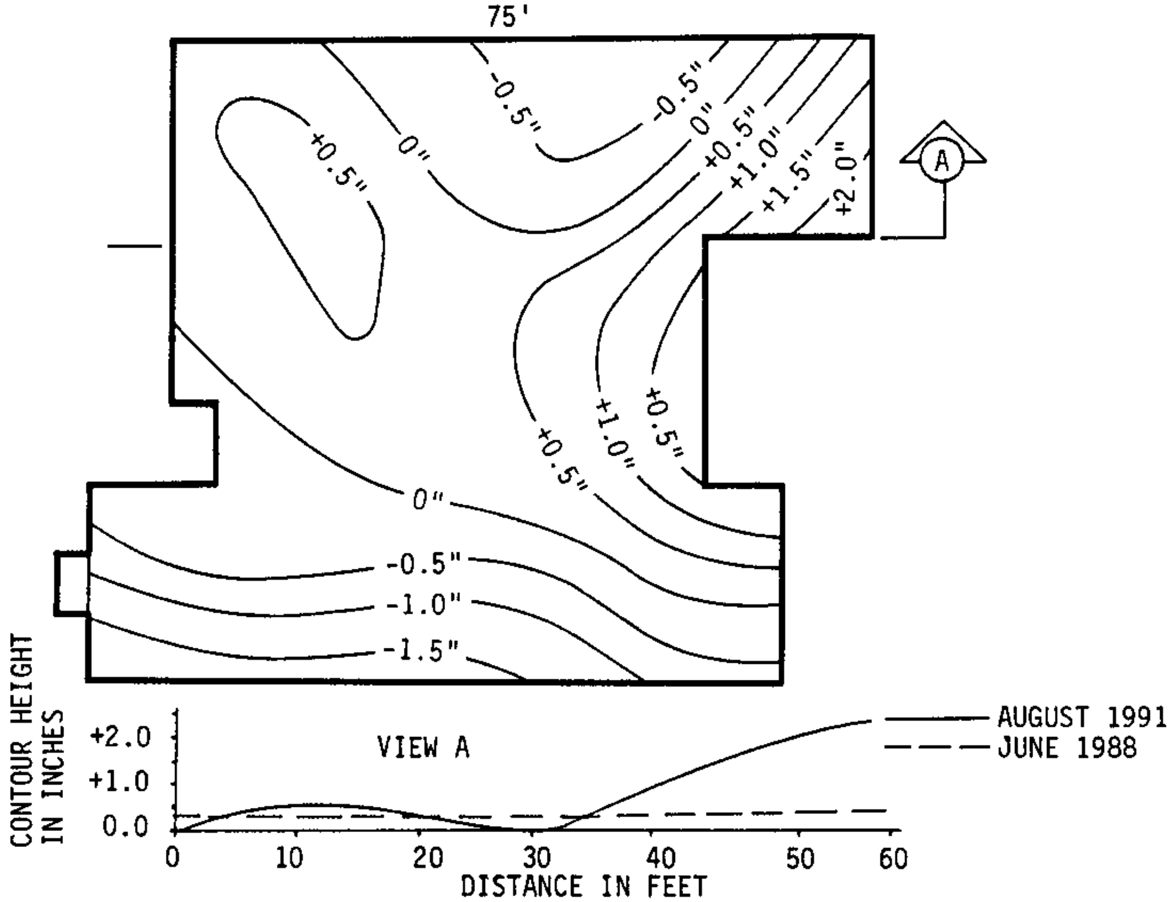


FIGURE 4. AN EXAMPLE OF A PIER SUPPORTED SLAB TYPE OF FOUNDATION THAT WAS ADVERSELY EFFECTED BY AN ERROR MADE DURING THE INSTALLATION OF A YARD DRAIN SYSTEM.

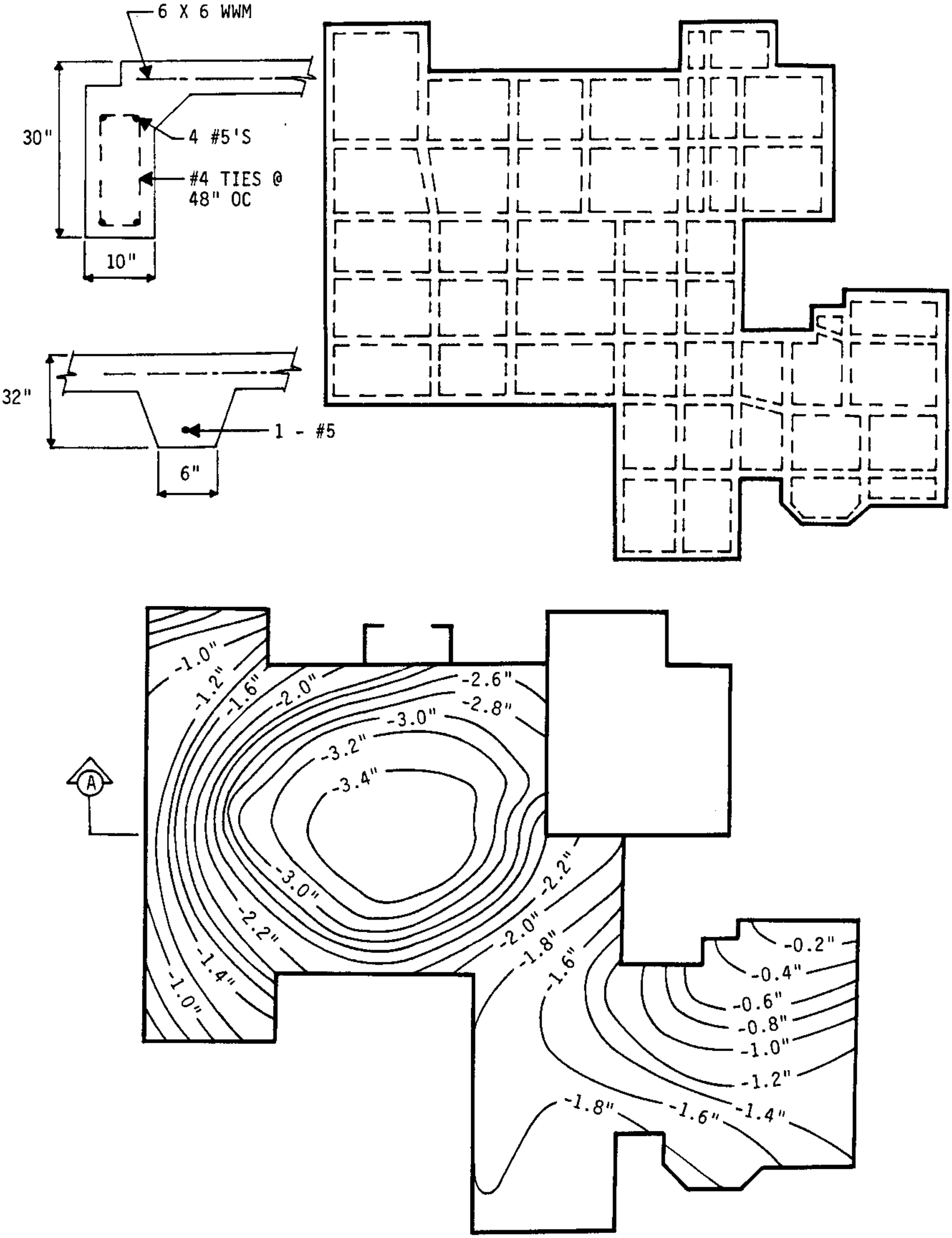


FIGURE 5. AN EXTREME EXAMPLE OF A LARGE AND EXPENSIVE HOME WITH A FOUNDATION THAT HAD FAILED BECAUSE OF A COMBINATION OF DESIGN AND CONSTRUCTION ERRORS.

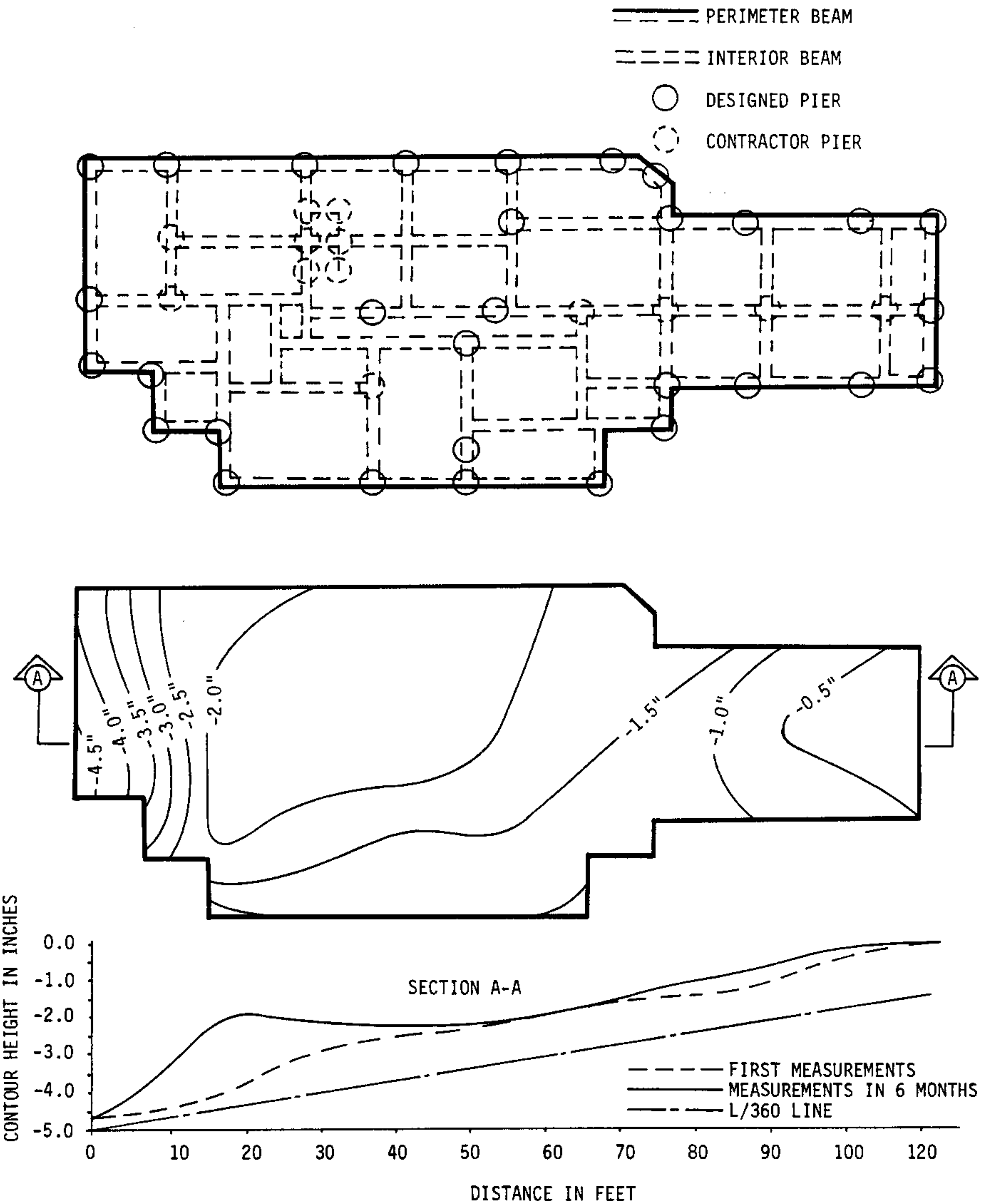


FIGURE 6. AN EXAMPLE OF A LARGE HOME IN THE NORTH PART OF HARRIS COUNTY THAT HAD BEEN ADVERSELY EFFECTED BY CONSTRUCTION ERRORS.

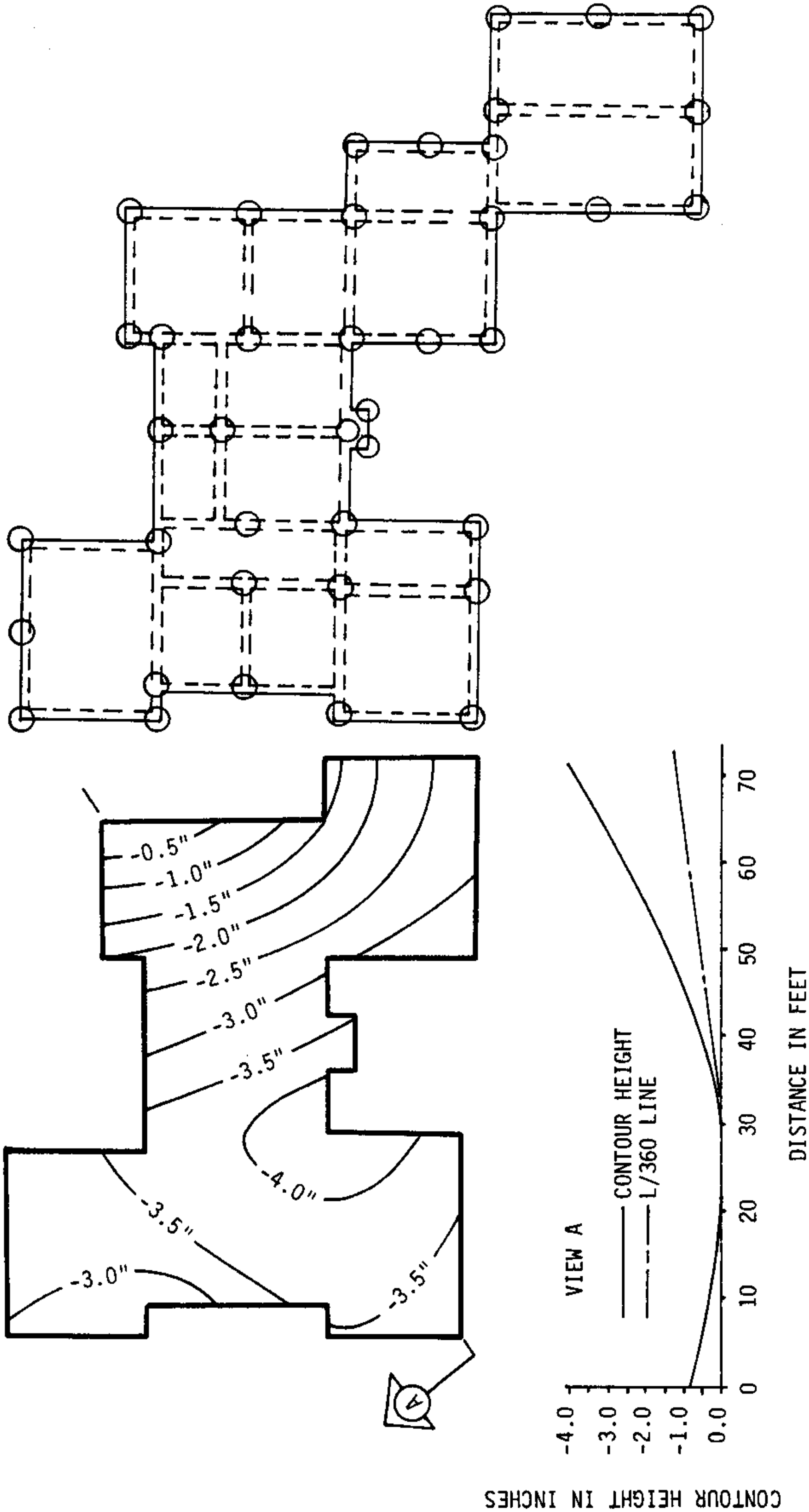


FIGURE 7. AN EXAMPLE OF A FOUNDATION UNDER A HOME IN AN UPSCALE NEIGHBORHOOD THAT HAD DEFLECTED BECAUSE OF THE ADVERSE EFFECTS OF SOIL HEAVING.

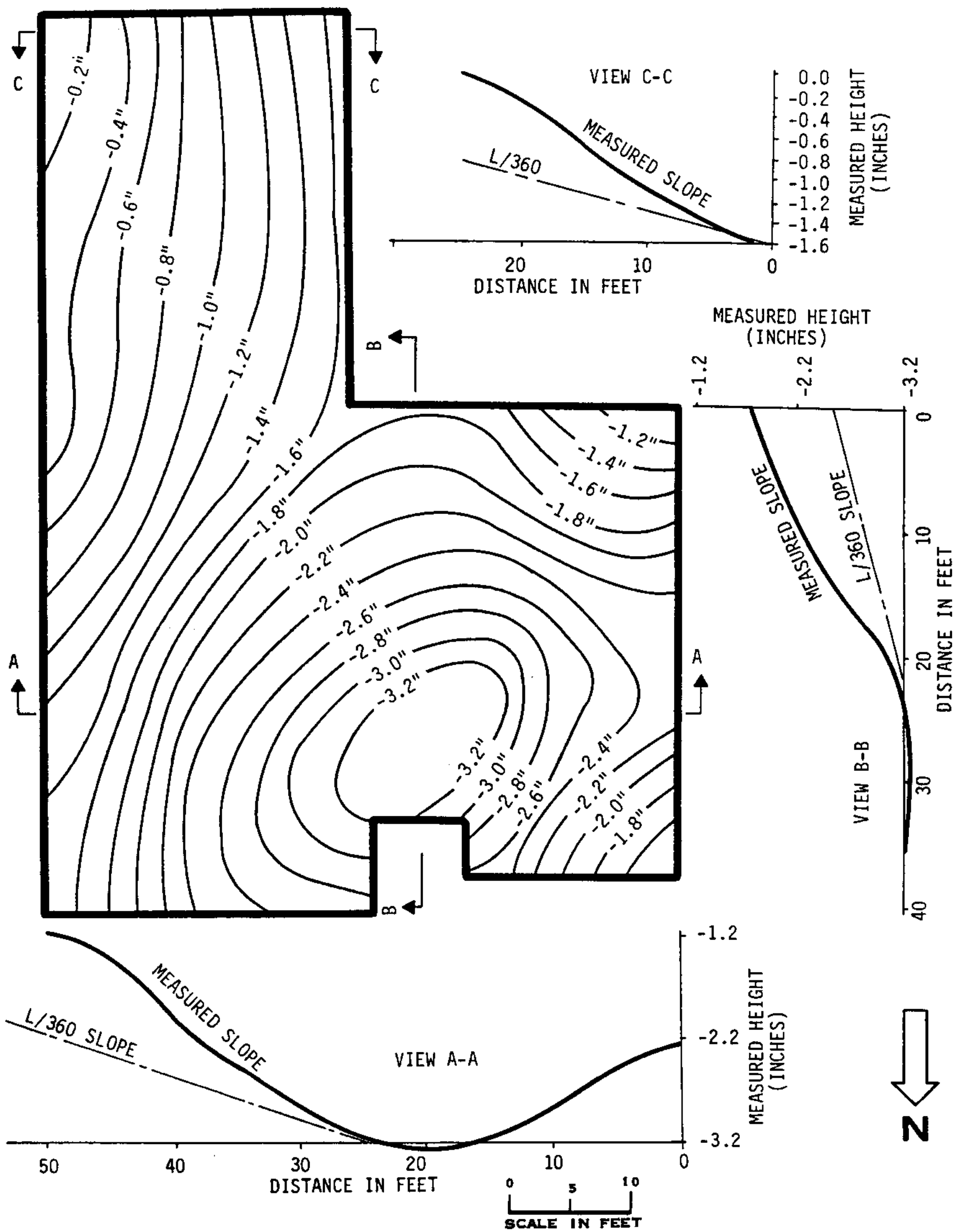


FIGURE 8. A HOME SUPPORTED ON A REINFORCED CONCRETE SLAB-ON-GROUND FOUNDATION BUILT ON A SOIL THAT WAS SOFT ON THE SURFACE WITH CLAY BELOW.

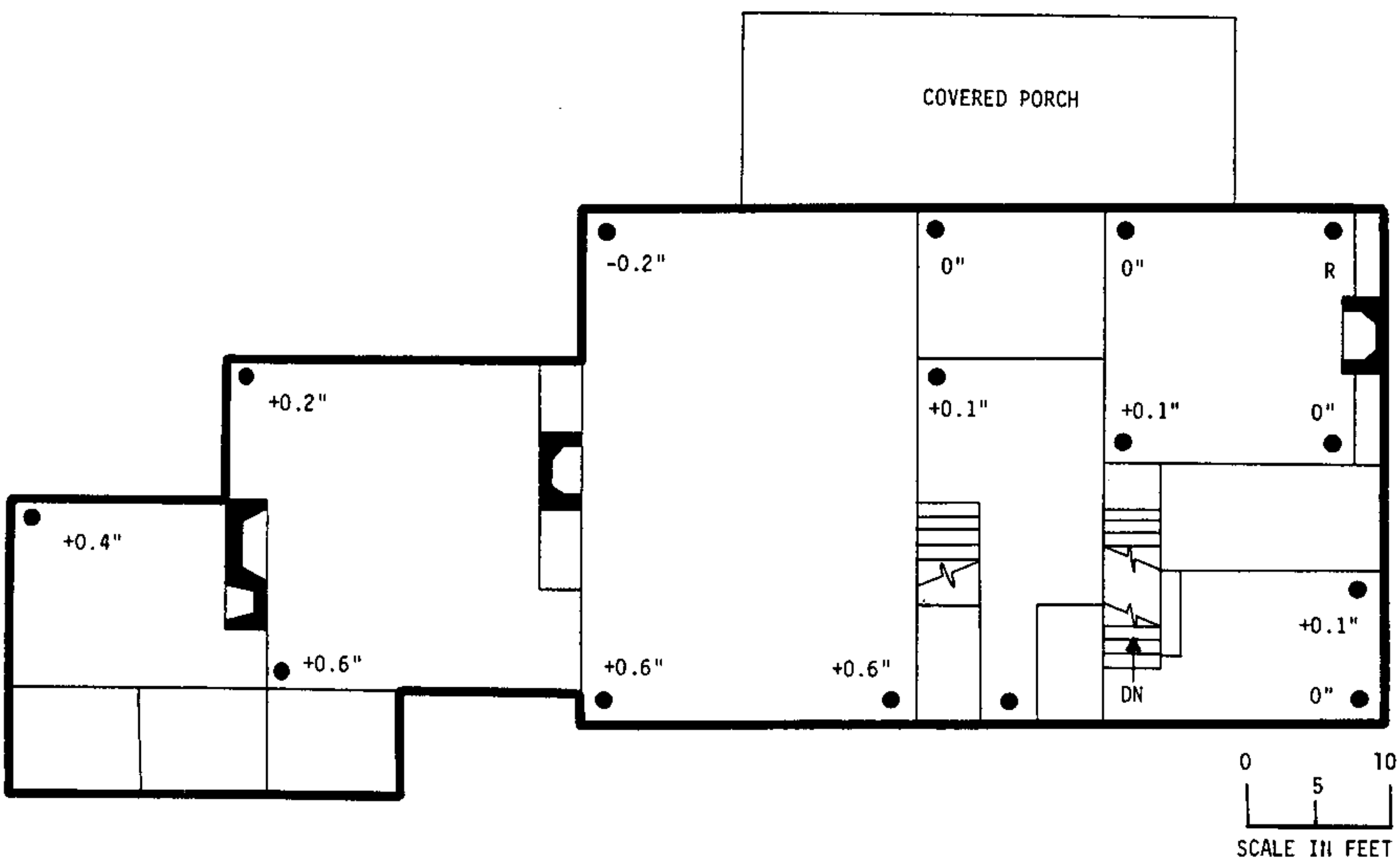


FIGURE 9. RELATIVE HEIGHT MEASUREMENTS MADE ON THE INTERIOR OF A SLAB-ON-GROUND FOUNDATION UNDER A 50 + YEAR OLD RESIDENCE.

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GUIDELINES FOR THE SELECTION, CONSTRUCTION REVIEW, AND MAINTENANCE OF RESIDENTIAL FOUNDATIONS

The selection of the appropriate type of residential foundation can be a critical decision in the Houston area because of the prevalence of highly expansive clay soils. The following discussion describes the various options for a residential foundation and identifies the risks associated with each type. Recommendations are provided for the role of the structural engineer during the foundation selection, design, and construction phases. Finally, suggestions are provided for the maintenance of the residential foundation.

A. SELECTION OF THE TYPE OF FOUNDATION FOR YOUR RESIDENCE

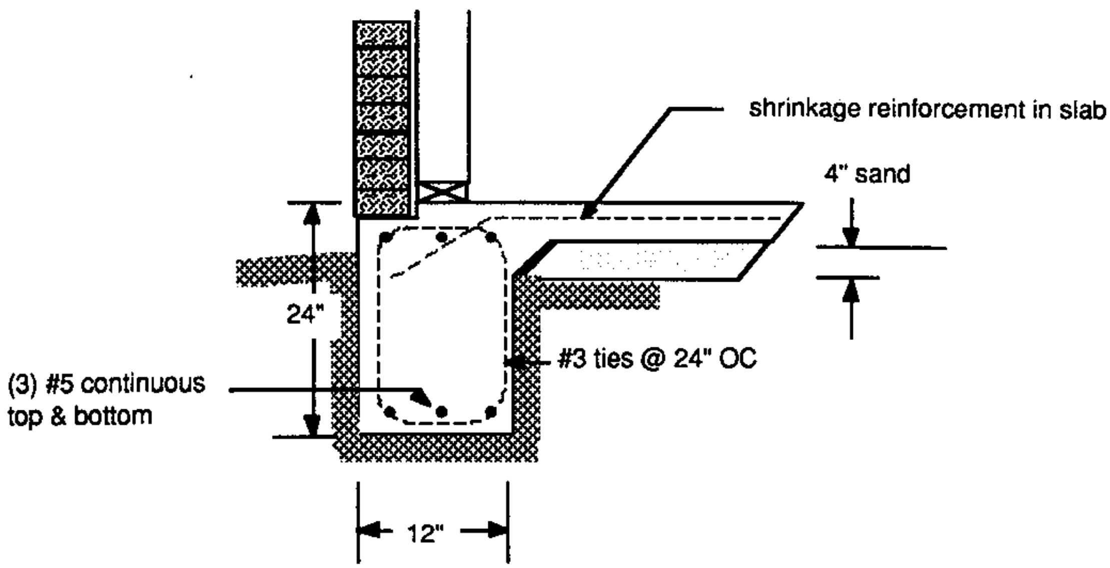
There are three basic types of residential foundations:

1. Floating slab
2. Grade beam-on-drilled pier; slab-on-fill
3. Structural slab or pier-and-beam

1. FLOATING SLAB FOUNDATION

The floating slab literally "floats" on the existing soils. The floating slab typically consists of continuous grade beams designed to stiffen the slab against movements of the supporting soils below.

A floating slab may be either reinforced with "conventional" steel rebar reinforcement or with post-tensioning cables. An example of the exterior grade beam section of a conventionally reinforced floating slab is shown below.



GRADE BEAM -FLOATING SLAB

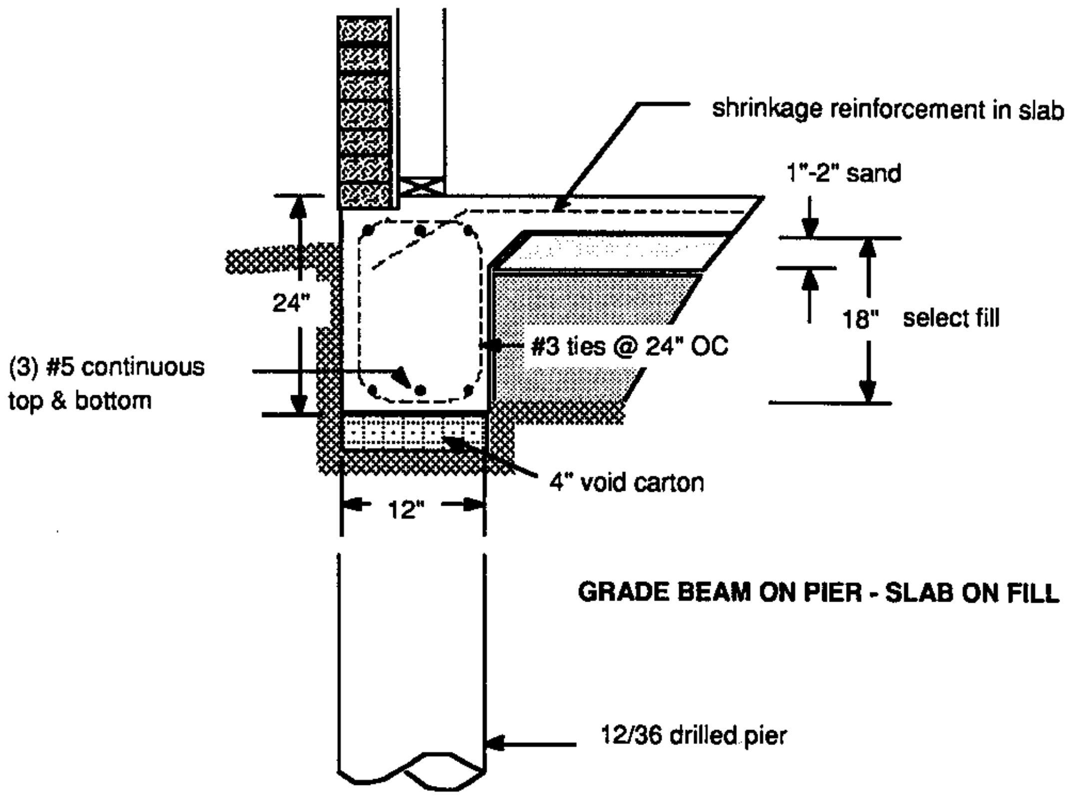
The floating slab approach assumes that the foundation will move as the clay soils expand or shrink due to changes in moisture. The intent is that the foundation will be adequately stiffened to resist the soil movements so that undesirable wall cracks do not occur. The effects of the soil expansion are incorporated into the foundation design. However, the accuracy of the estimates of the soil uplift pressures are debatable.

2. GRADE BEAM-ON-DRILLED PIER; SLAB-ON-FILL FOUNDATION

This type of residential foundation depends on drilled piers to support the major downward loads on the foundation. The drilled piers are located under the load bearing walls. The drilled piers are founded at a depth below the zone of moisture fluctuation. Therefore, the drilled piers are not expected to be moving upward or downward with the expanding and shrinking surface soils. Void cartons are typically placed beneath the grade beams to isolate the beams from the expansive soils below.

The portion of the slab between grade beams typically rests on compacted select fill material. The select fill material is typically a non-expansive sandy clay. The intent of the fill material is to reduce the expected vertical rise which may occur if the soils beneath the slab experience an increase in moisture content. However, note that this foundation type does not eliminate all uplift soil pressures. The effects of the expansive soil pressures on the slab are typically not included in the foundation design.

A typical exterior grade beam of a grade beam-on-drilled pier; slab-on-fill foundation is shown below.



GRADE BEAM ON PIER - SLAB ON FILL

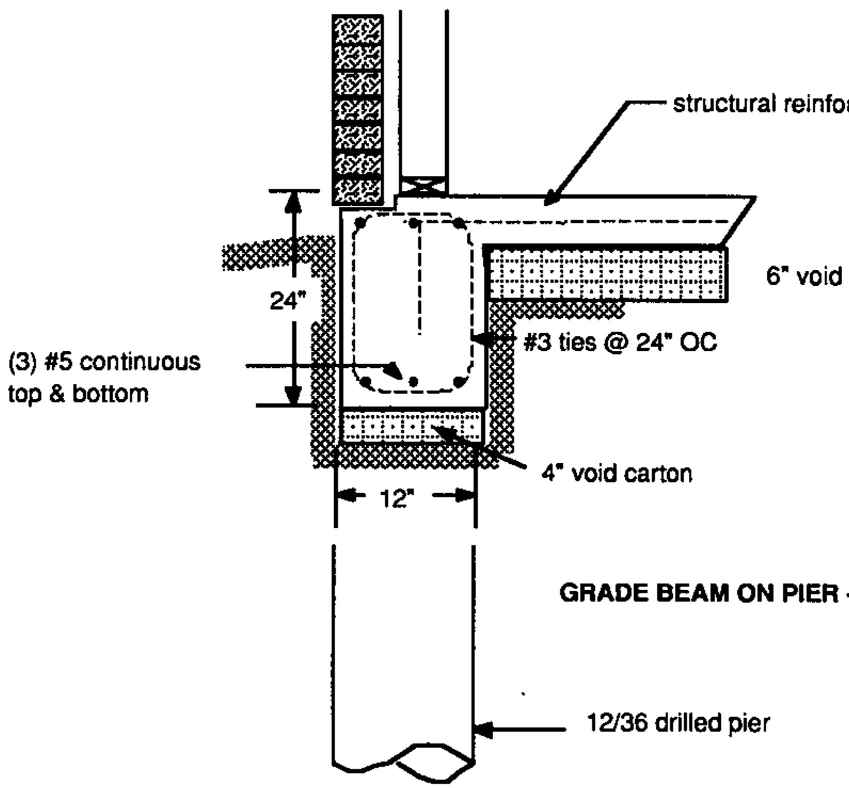
3. STRUCTURAL SLAB AND PIER-AND-BEAM FOUNDATIONS

The structural slab and the pier-and-beam foundations are designed and constructed such that all loads are transmitted through the drilled piers. The drilled piers are founded at a depth below the zone of moisture fluctuation. Therefore, the drilled piers are not expected to be moving upward or downward with the expanding and shrinking surface soils.

A structural slab has the following characteristics:

a. Void cartons beneath the slab and the grade beams to eliminate <u>all</u> upward loads due to expanding clay soils.
b. Structural reinforcement in the slab to transmit <u>all</u> downward loads to the grade beams.

A typical sectional view of an exterior structural slab grade beam is shown below.

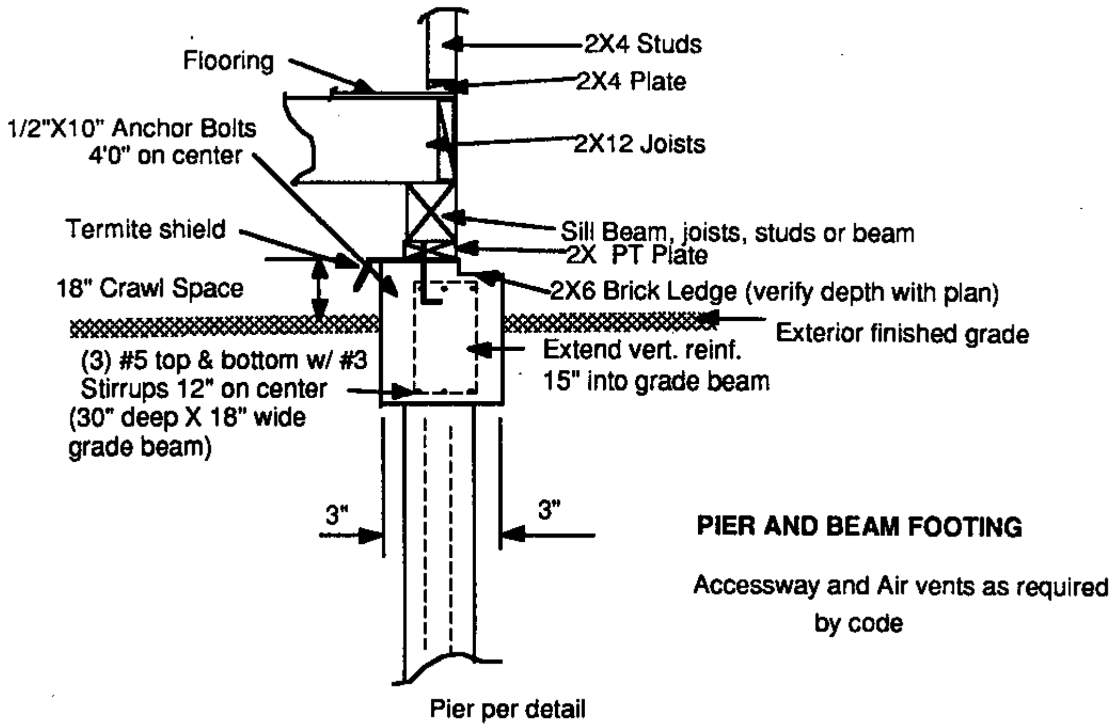


GRADE BEAM ON PIER - STRUCTURAL SLAB

A pier-and-beam foundation has the following characteristics:

a. Wood framing at the first floor level to transmit all downward loads to the drilled piers.
b. A crawl space between the existing soils and the bottom of the first floor framing to eliminate the transfer of upward loads due to expanding clay soils into the wood framing.

A typical sectional view of a pier-and-beam foundation is shown below.



The design procedures for both the structural slab and the pier-and-beam foundations do not include soil uplift pressures because in both instances the foundation has been isolated from the surface soils. Movements in the foundation can only occur due to movements of the drilled piers.

B. RELATIVE RISKS OF THE VARIOUS TYPES OF FOUNDATIONS

The risks of all foundation types are a function of the expansiveness of the existing soils at the residence site. Any assessment of the relative risks of the various types of residential foundations is dependent upon the designer's experiences and biases.

1. Floating slab foundation: This foundation is largely dependent upon the near-surface soil conditions. The moisture content in these soils can vary significantly. Risk Level: Low to moderate risk in non-expansive soils. Moderate

to high risk in expansive soil conditions.

2. Grade beam-on-drilled pier; slab-on-fill foundation: This foundation is dependent upon both the near-surface soil conditions and the soil conditions at the base of the drilled piers. Risk Level: Low risk in non-expansive soils. Low to moderate risk in expansive soil conditions.

3. Structural slab or pier-and-beam foundation: These foundations are totally dependent upon the soil conditions at the base of the drilled piers. Risk Level: Low risk in expansive soil conditions.

C. RECOMMENDATIONS FOR THE DESIGN AND CONSTRUCTION REVIEW OF RESIDENTIAL FOUNDATIONS

The following recommendations are made for the design and construction of a quality residential foundation:

1. Obtain a soils report. Consult with the structural (foundation design) engineer regarding which geotechnical engineering firm to retain for the soils testing and report. The structural engineer may be retained to both select a geotechnical engineering firm and to procure the tests and report for you.

2. Select the appropriate foundation type for the residence. Consult with the geotechnical engineer, the structural engineer, and the contractor. Selection should be based upon information obtained from the soils report, the relative risks of each feasible foundation type, and the relative construction costs of each foundation type.

3. Obtain a foundation drawing. It is recommended that the foundation design engineer provide the foundation drawing.

4. Obtain construction reviews and testing of the foundation construction. It is recommended that the structural engineer be retained to observe the foundation construction process to verify that the construction is in compliance with the drawings. It is recommended that the following tests be performed:

   a. Compressive strength tests of the concrete.
   b. Compaction tests of the select structural fill material.

D. RECOMMENDATIONS FOR THE MAINTENANCE OF THE RESIDENTIAL FOUNDATION.

Many residential foundation problems are the result of changing moisture conditions in the soils. These changes in moisture can be the result of poor drainage or plumbing leaks.

It is recommended that the moisture content of the soils under and near the residential foundation vary as little as possible. This can be accomplished by:

1. Providing proper drainage away from the foundation.
2. Providing lime stabilization of expansive clay soils.
3. Removing all trees and shrubs near the foundation.
4. Providing root barriers between nearby trees and shrubs which prevent all roots from protruding beneath the foundation.
5. Providing a concrete cover around the perimeter of the residence.
6. Providing deeper exterior grade beams.
7. Checking for plumbing leaks periodically.
8. Providing a watering system at the perimeter of the foundation.

A more complete explanation of a recommended residential foundation maintenance program can be found in the following reference. This article appeared in the April, 1990 issue of the *Houston Builder* magazine.

> "Recommended Homeowner Foundation Maintenance Program for Residential Projects in the Houston Area"; David A. Eastwood, Geotech Engineering and Testing.

CURRENT DESIGN PROCEDURE

RECOMMENDED BY

THE POST TENSION INSTITUTE

Reference: Design and Construction of Post-Tensioned Slabs-On Ground - First Edition, Post-Tensioning Institute

6.0 STRUCTURAL DESIGN PROCEDURE

6.1 General

On the basis of the design parameters discussed in Chapter 4, and the results of the soil-structure interaction analysis described in Chapter 5, specific structural design formulas and procedures for moment, shear, deflection and slab-subgrade friction are presented in this chapter for slabs on expansive soils. Design formulas are also presented for slabs constructed on compressible soils. An equation is developed for calculation of the stress due to concentrated line loads on slabs.

The design procedure for post-tensioned slabs constructed over expansive clays should include the following steps:

1. Assemble all the known design data.
2. Divide an irregular slab plan into overlapping rectangles and design each rectangular section separately (Fig. 6.1).
3. Assume a trial section in both the long and short directions of the design rectangle.
4. Calculate the service moment the section will be expected to experience in each direction for either the center lift or edge lift conditions.
5. Determine the allowable moment capacity of the assumed section in each direction and compare to the expected service moment.
6. Determine if the trial sections will meet differential deflection criteria in each direction.
7. Calculate the expected shear force in the assumed sections.
8. Determine the maximum allowable shear capacity of the sections and compare to the expected shearing force.
9. Repeat steps 4 through 8 for the opposite swelling condition.
10. Check the design for the first swelling condition to ascertain if adjustments are necessary to compensate for any design changes resulting from the second design swelling condition (Step 9).
11. Check the effect of slab-subgrade friction to assure a residual compressive stress of 50 psi at the center of each design rectangle in both directions. Adjust post-tensioning force if necessary.
12. Calculate stresses due to any heavy concentrated loads on the slab and provide special load transfer details when necessary.

The design procedure for slabs on compressible soils is similar to the above except that different equations are used and the primary bending deformation is usually similar to that shown in Fig. 4.2 for the edge lift loading case.

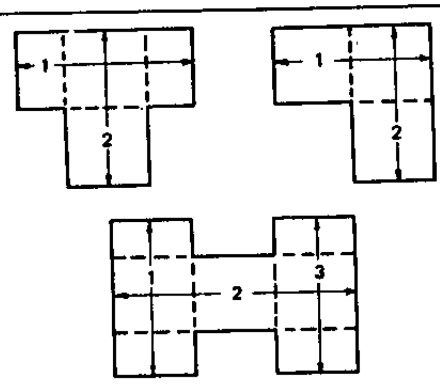


Fig. 6.1 Design rectangles for slabs of irregular shape

6.2 Required Design Data

The soils and structural properties needed for design are as follows:

A. Soils properties
  - (1) Allowable soil bearing pressure, q_{allow}, in pounds per square foot.
  - (2) Edge moisture variation distance, e_m, in feet.
  - (3) Differential soil movement, y_m, in inches.
  - (4) Slab-subgrade friction coefficient, μ.

B. Structural data and materials properties.
  - (1) Slab length, L, in feet.
  - (2) Perimeter loading, P, in lbs. per foot.
  - (3) Stiffening beam spacing, S, in feet.
  - (4) Beam depth, d, in inches.
  - (5) Compressive strength of the concrete, f'_c.
  - (6) Allowable tensile stress in the concrete, f_t.
  - (7) Allowable compressive stress in the concrete, f_c.
  - (8) Type, grade, and strength of the prestressing steel.
  - (9) Grade and strength of conventional reinforcement, if needed.
  - (10) Prestress losses.

6.3 Slabs of Irregular Shape

Slabs of irregular shape should be divided into overlapping rectangles so that the resulting boundary provides complete congruence with the slab perimeter. See Figure 6.1 for examples. A separate design must be made for each of the component rectangles of the slab (except for instances where the overlapping rectangles are of nearly similar dimensions).

6.4 Trial Section Assumptions

A. Assume Beam Depth and Spacing. An initial estimate of the depth of the stiffening beam can be obtained from solving either Equation (27) or Equation (28) for the beam depth yielding the maximum allowable differential deflection. A preliminary estimate of the allowable differential deflection can be made as follows:

(1) Determine the maximum distance over which the allowable differential deflection will occur, L or 6β, whichever is smaller. As a first approximation, use $\beta = 8$ feet.

(2) Select the permissible deflection ratio, e.g.,

(a) Center Lift

$$\frac{\Delta}{L \text{ or } 6\beta} = \frac{1}{360} \quad (1)$$

(b) Edge Lift

$$\frac{\Delta}{L \text{ or } 6\beta} = \frac{1}{1700} \quad (2)$$

The 1/1700 deflection ratio is only used to initially estimate the required beam depth for the edge lift condition.

(3) Assume a beam spacing and solve for beam depth, d:

(a) Center Lift

$$\text{Set } X = \frac{(y_m L)^{0.205}(S)^{1.059}(P)^{0.523}(e_m)^{1.296}}{380\,\Delta} \quad (3a)$$

Then

$$\log_{10}(d) = \frac{1}{1.214}\log_{10}(X) \quad (3b)$$

or,

$$d = X^{0.824} \quad (3c)$$

(b) Edge Lift

$$\text{Set } X = \frac{(L)^{0.35}(S)^{0.88}(e_m)^{0.74}(y_m)^{0.76}}{12\Delta(P)^{0.01}} \quad (4a)$$

Then

$$\log_{10}(d) = \frac{1}{0.85}\log_{10}(X) \quad (4b)$$

or,

$$d = X^{1.176} \quad (4c)$$

In most cases, the depth of the beams should be the same for all beams in both directions.

B. Determine Section properties. The moment of inertia, section modulus, cross sectional area of the slab and eccentricity of the prestressing force may be calculated for the trial beam depth determined above in accordance with normal structural engineering procedures, or by use of design aids presented in Appendix A.5. These procedures are illustrated in the design examples presented in Appendices A.6, A.7 and A.8.

6.5 Design Stresses

The following design stresses are recommended:

A. Allowable Tensile Stress

$$f_t = 6\sqrt{f'_c} \quad (5)$$

B. Allowable Compressive Stress

$$f_c = 0.45\, f'_c \quad (6)$$

C. Estimated Tensile Cracking Stress

$$f_{cr} = 7.5\sqrt{f'_c} \quad (7)$$

D. Bearing Stress at Anchorages

(1) At Service Load

$$f_{bp} = 0.6\, f'_c\sqrt{(A'_b/A_b)} \leq f'_c \quad (8)$$

(2) At Transfer

$$f_{bp} = 0.6\, f'_{ci}\sqrt{(A'_b/A_b)} - 0.2 \leq f'_{ci} \quad (9)$$

where,

A_b = Loaded Area

A'_b = Maximum area of the portion of the supporting surface that is geometrically similar to and concentric with the loaded area

E. Shear Stress

(1) Permissible Shear Stress

$$v_c = 1.5\sqrt{f'_c} \quad (10)$$

(2) Design Shear Stress

$$v = \frac{VW}{ndb} \quad (11)$$

F. Prestressing Steel. The maximum stress in the prestressing steel during stressing shall not be greater than 0.80 times the guaranteed ultimate strength of the prestressing steel, or 0.94 times the specified yield strength of the prestressing steel, whichever is smaller. The maximum stress in the prestressing steel immediately after anchoring shall not exceed 0.70 times the guaranteed ultimate strength of the steel.

6.6 Prestress Losses

Loss of prestress due to elastic shortening of the concrete, creep of concrete, shrinkage of concrete, and steel relaxation shall be taken as 30,000 psi for wire and strand tendons and 20,000 psi for bar tendons, unless more exact determination of these individual losses can be made. The losses specified in this section comply with those presented in the Post-Tensioning Manual.[70] Prestress losses due to intentional and unintentional curvature of the tendons shall be calculated in accordance with Chapter 18 of the ACI 318-77 Building Code.

6.7 Slab-Subgrade Friction

The effective prestressing force in post-tensioned slabs-on-ground is reduced by the frictional resistance to movement of the slab on the subgrade during stressing as well as the frictional resistance to dimensional changes due to concrete shrinkage or temperature variations. The largest amount of prestress loss due to slab-subgrade friction occurs in the center regions of the slab. The greatest structural requirement for prestress force, however, is at the location of the maximum moment, which occurs at approximately one β-length inward from the edge of the slab. For normal construction practices, the value of the coefficient of friction should be taken as 0.75 for slabs on polyethylene and 1.00 for slabs cast directly on a sand base.

To provide assurance against cracking resulting from subgrade frictional resistance to movements induced by prestressing, concrete shrinkage, or temperature variations, the prestressing force provided in each direction shall not be less than provided by Equation (12). For very short slabs where the β-length is approximately equal to one-half of the length of the design rectangle, a prestressing force equivalent to one-half the weight of the stiffened slab multiplied by the coefficient of friction shall be deducted from the total prestressing force in calculating the net prestressing force available to provide resistance to applied bending moments.

$$P_r \geq \frac{W_{slab}}{2000} + .05A \quad (12)$$

The maximum spacing of tendons should not exceed that which would produce a minimum average effective prestress of 50 psi after allowance for slab-subgrade friction. The maximum spacing of tendons placed in the slab portion of the cross-section can be estimated from Figure 6.2 (coefficient of friction assumed to be 0.75). Figure 6.2 was developed presuming tendons stressed from both ends. This is usually not necessary or practical for slabs for single family residences. Tendon spacings obtained from Figure 6.2 may have to be reduced to provide sufficient post-tensioning force to satisfy moment requirements.

6.8 Maximum Design Moments

The maximum moment will vary, depending upon the swelling mode and the slab direction being designed. Moments for the center lift condition will, in general, be greater than edge lift moments. Moments in the short direction will, in general, be slightly greater than moments in the long direction.

A. Center Lift Moment

(1) Long Direction. The following equations may be used to calculate maximum design moments for center lift bending in the long direction:

$$M_\ell = A_o\left[B(e_m)^{1.238} + C\right] \quad (13)$$

where,

M_ℓ = Design moment in long direction, ft-kips/ft.

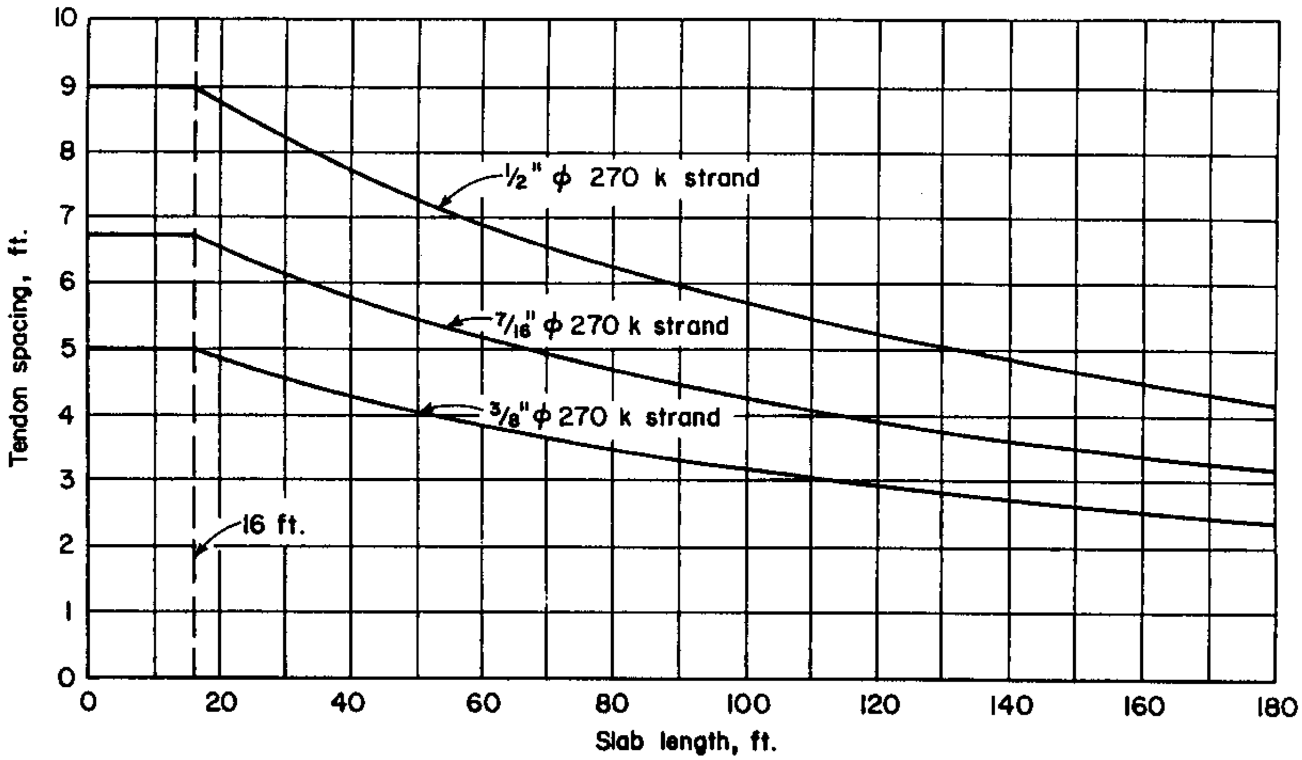


Fig. 6.2 Maximum slab tendon spacing to overcome slab-subgrade friction (friction coefficient = 0.75) and retain 50 psi residual prestress compression at midpoint of stiffened slab on ground.

$$A_o = \frac{1}{727}\left[(L)^{0.013}(S)^{0.306}(d)^{0.688}(P)^{0.534}(y_m)^{0.193}\right] \quad (14)$$

and for

$0 \le e_m \le 5 \quad B = 1, \quad C = 0$

$$5 < e_m \quad B = \left(\frac{y_m - 1}{3}\right) \le 1.0,$$

$$C = \left[8 - \left(\frac{P - 613}{255}\right)\right]\left[\frac{4 - y_m}{3}\right] \ge 0 \quad (15)$$

(2) Short Direction. The maximum design moment in the short direction for center lift bending may be calculated as follows:

$$M_s = \left[\frac{58 + e_m}{60}\right] M_\ell \quad (16)$$

where

M_s = Design Moment in short direction, in ft-kips/ft.

B. Edge Lift Moment

(1) Long Direction. The maximum design moment in the long direction for edge lift bending may be calculated as follows:

$$M_\ell = \left[\frac{(S)^{0.10}(de_m)^{0.78}(y_m)^{0.66}}{7.2\,(L)^{0.0065}(P)^{0.04}}\right] \quad (17)$$

(2) Short Direction. The maximum design moment in the short direction for edge lift bending may be calculated as follows:

$$M_s = (d)^{0.35}\left[\frac{19 + e_m}{57.75}\right] M_\ell \quad (18)$$

6.9 Maximum Allowable Service and Cracking Moments

A. Allowable Service Moments. The maximum moments to which the assumed sections can be subjected, consistent with the design stresses, can be determined from the familiar bending stress formula, rearranged so as to be able to solve for the maximum allowable external moments. The sign convention adopted is to represent compressive forces and eccentricities above the neutral axis as positive. The form of Equations (19) through (24) have been adjusted for the sign difference between tensile and compressive stresses. The following equations for allowable service moments must be evaluated for both the long and short direction.

(1) Negative Bending Moment, ${}_nM$

(a) Tension in Top Fiber

$$_nM_t = S_T\left(\frac{P_r}{A} + f_t\right) + P_r e \quad (19)$$

where

S_T = Section modulus for top fiber, inches^3
P_r = Prestressing force, kips
A = Cross-sectional area, inches^2
f_t = Allowable tensile stress, kips/inches^2
e = Eccentricity of prestressing force, inches

(b) Compression in Bottom Fiber

$$_nM_c = S_B\left(f_c - \frac{P_r}{A}\right) + P_r e \quad (20)$$

where

S_B = Selection modulus for bottom fiber, inches[3]

f_c = Allowable compressive stress, ksi

The maximum external negative moment that can be carried by the section is the smaller of the moments calculated by equations (19) and (20).

(2) Positive Bending Moment, $_pM$

(a) Tension in Bottom Fiber

$$pM_t = S_B \left(\frac{P_r}{A} + f_t\right) - P_r e \qquad (21)$$

(b) Compression in Top Fiber

$$pM_c = S_T \left(f_c - \frac{P_r}{A}\right) - P_r e \qquad (22)$$

The maximum external positive service moment that can be carried by the section is the smaller of the moments calculated by equations (21) and (22).

B. Tensile Cracking Moments. Stiffened slabs-on-ground are usually designed to be under reinforced. As long as the actual moment acting in the slab is below the tensile cracking moment, the stiffening beams may be assumed to act in their elastic range, and the assumed use of the gross section in computing deflection criteria is justified.

(1) Negative Bending Moment, $_nM_{cr}$

$$nM_{cr} = S_T \left(\frac{P_r}{A} + f_{cr}\right) + P_r e \qquad (23)$$

(2) Positive Bending Moment, pM_{cr}

$$pM_{cr} = S_B \left(\frac{P_r}{A} + f_{cr}\right) - P_r e \qquad (24)$$

C. Compare Allowable and Cracking Moments to be Expected Service Moment. The design moments expected to occur in both directions, as calculated from Equations (13) and (16) through (18) must be compared to the allowable moments determined in Equations (19) through (22). If either the short direction or long direction design moments exceed the allowable service moments, the moment capacity of the section must be increased. Means of increasing the moment capacity include:

(1) Deepening the stiffening beams (for deficient negative and positive moment capacity);

(2) Decreasing the beam spacing (for deficient negative and positive moment capacity);

(3) Increasing the prestressing force (for deficient negative moment capacity);

(4) Decreasing the prestress eccentricity by carrying tendons below the neutral axis (for deficient positive moment capacity).

If the moment capacity of the assumed section exceeds the design moment, economies may be realized by performing the opposite to the actions suggested above for increasing moment capacities.

6.10 Differential Deflection

Allowable and expected differential deflections may be calculated from the equations presented in the following sections.

A. Relative stiffness length, β, may be calculated as follows:

$$\beta = \frac{1}{12} \sqrt[4]{\frac{E_c I}{E_s}} \qquad (25)$$

where

β = Relative stiffness length, in feet

E_c = Creep Modulus of Elasticity of Concrete, psi

E_s = Modulus of Elasticity of Soil, psi

I = Gross Moment of Inertia of Section, inches[4]

If the creep modulus of elasticity of the concrete is not known, it can be closely approximated by using 0.5 of the normal or early life concrete modulus of elasticity. If the modulus of elasticity of the clay soil is not known, use 1000 psi.

B. Differential Deflection Distance. The differential deflection may not occur over the entire length of the slab, particularly if the slab is longer than approximately 50 feet. Thus, the effective distance for determining the allowable differential deflection is the smaller of the two distances, L or 6β, both expressed in feet.

C. Allowable Differential Deflection.

(1) Center Lift.

$$\Delta_{allow} = \frac{12\ (L \text{ or } 6\beta)}{360} \qquad (1)$$

where

Δ_{allow} = Allowable differential deflection, in inches

L = Total slab length, in feet

β = Relative stiffness length, in feet

(2) Edge Lift.

$$\Delta_{allow} = \frac{12\ (L \text{ or } 6\beta)}{800} \qquad (26)$$

The more stringent allowable differential deflection for the edge lift is specified because edge lift deflections are normally much less than center lift deflections and stems of beams resisting positive moments may be unreinforced.

D. Expected Differential Deflection Without Prestressing.

(1) Center Lift.

$$\Delta_o = \left[\frac{(y_m L)^{0.205} (S)^{1.059} (P)^{0.523} (e_m)^{1.296}}{380\ (d)^{1.214}}\right] \qquad (27)$$

where

Δ_o = Expected differential deflection, in inches

(2) Edge Lift

$$\Delta_o = \left[\frac{(L)^{0.35} (S)^{0.88} (e_m)^{0.74} (y_m)^{0.76}}{15.90\ (d)^{0.85} (P)^{0.01}}\right] \qquad (28)$$

E. Deflection Reduction Due to Prestressing. Normally, most of the prestressing is placed in the slab, and the centroid of the prestressing force is above the center of gravity of the section. Because of this, any deflection due to negative bending must first overcome a slight amount of positive deflection or camber caused by the prestressing. This differential deflection advantage of prestressing can be calculated by:

(1) Calculate the percent of differential deflection reduction

$$\Delta_c = e \sqrt{\frac{6400}{9L}} \qquad (29)$$

where

Δ_c = Differential deflection correction, in percent.

e = Eccentricity of prestressing force, in inches.

(2) Calculate corrected differential deflection.

$$\Delta = \Delta_o \left[\frac{100 - \Delta_c}{100}\right] \qquad (30)$$

where

Δ = Expected deflection, in inches

The effect of prestressing usually adds to the deflection due to edge lift bending. However, deflections due to this bending mode are usually smaller than center lift deflections.

F. Compare expected to Allowable Differential Deflection. If the expected differential deflection as calculated by either Equations (27) or (28) adjusted for the effect of prestressing exceeds that determined from Equations (1) or (26), respectively, the assumed section must be stiffened. This can be accomplished in at least three ways:

(1) Deepening the stiffening beams,
(2) Decreasing the beam spacing, or
(3) Adding additional prestressing tendons above the neutral axis.

6.11 Shear

A. Expected Service Shear. Expected values of service shear forces in kips per ft. of width or length of slab may be calculated from the following formulas:

(1) Center Lift.

(a) Short Direction Shear.

$$V_s = \frac{1}{1350}\left[(L)^{0.19}(S)^{0.45}(d)^{0.20}(P)^{0.54}(y_m)^{0.04}(e_m)^{0.97}\right] \quad (31)$$

(b) Long Direction Shear.

$$V_{\ell} = \frac{1}{1940}\left[(L)^{0.09}(S)^{0.71}(d)^{0.43}(P)^{0.44}(y_m)^{0.16}(e_m)^{0.93}\right] \quad (32)$$

(2) Edge Lift

For both directions:

$$V = \left[\frac{(L)^{0.07}(d)^{0.40}(P)^{0.03}(e_m)^{0.16}(y_m)^{0.67}}{3.0\,(S)^{0.015}}\right] \quad (33)$$

where

V, V_s, V_{ℓ} = Shear force, in kips/ft.

B. Allowable Shear Stresses

(1) Nominal Total Design Shear Stress, v. Only the beams may be considered in calculating the cross-sectional area resisting shear force.

$$v = \frac{VW}{ndb} \quad (11)$$

where

V = Total shear force acting on the section, kips.

(2) Nominal permissible Shear Stress, v_c. Unless the permissible shear stress can be determined by testing or by more rigorous analysis, the maximum shear stress permitted shall be given by

$$v_c = 1.5\sqrt{f'_c} \quad (10)$$

where v_c and f'_c are both expressed in psi

C. Compare v to v_c. If v exceeds v_c, shear reinforcement in accordance with ACI 318-77 and the Post-Tensioning Manual must be provided. Possible alternatives to reinforcement include:

(1) Increasing the beam depth,
(2) Increasing the beam width, or
(3) Increasing the number of beams (decrease beam spacing).

D. Shear Reduction Due to Prestressing. An advantage of curved or draped prestressing tendon in beam stems is that due to the upward force exerted by the tendon on the concrete, shear compensation in an amount equal to $P_r \sin\alpha$ is obtained. The design shear force carried by the beams is reduced accordingly. Figure 6.3 shows the effect of draped prestressing tendons on shear reduction.

6.12 Other Applications of Design Procedure

The design procedure presented in this manual has other practical slab-on-ground applications besides construction on expansive clays, as discussed below.

A. Design of Conventionally Reinforced Slabs-on-Ground. The design equations presented (Equations 13, 16-18, 27, 28, and 31-33) produce the values of bending moment, shear, and differential deflection that can be expected to occur using a given set of soil and structural parameters. These design values may be calculated for slabs reinforced with mild steel as well as for post-tensioned slabs. Once these design parameters are known, design of either type of slab can proceed. However, reinforcement calculations and limiting values of deflections for non-prestressed slabs must be developed by interested parties using conventional reinforced concrete technology. To conform to the same deflection

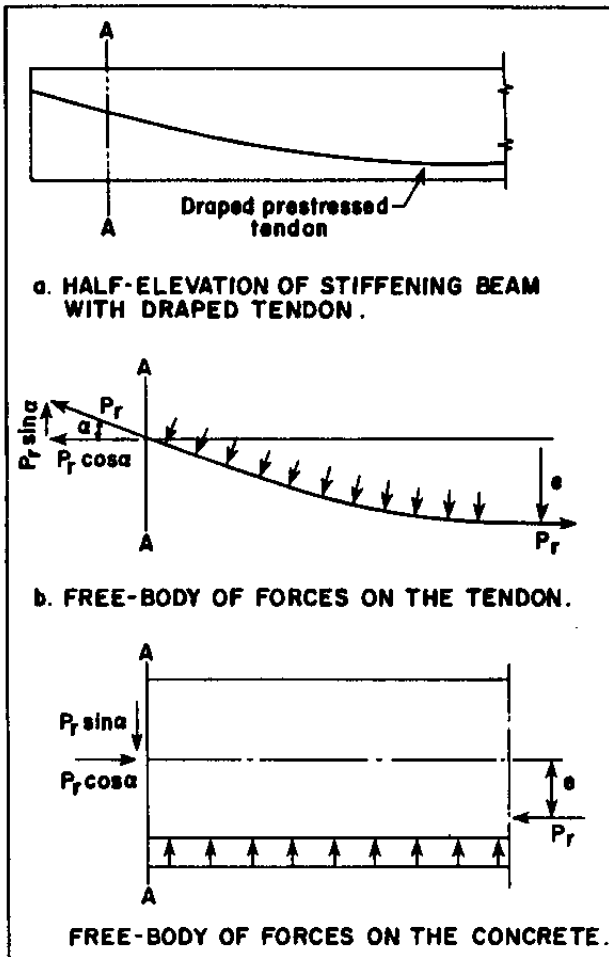


Fig. 6.3 Free-body diagrams for draped beam tendon and concrete section.

criteria, conventionally reinforced slabs designed on the basis of cracked sections will have to have significantly deeper beam stems than prestressed slabs. The deeper sections will, in turn, result in larger design moments.

B. Design of Slabs Subject to Frost Heave. Design moments, shears and deflections due to frost heave can be approximated by substituting anticipated frost heave for expected swell of an expansive clay. The value of e_m for frost heave would have to be estimated from values comparable to those for expansive soils.

C. Slabs-on-Ground Constructed over Compressible Soils. Design of slabs constructed over compressible soils can proceed in a manner similar to that of the edge lift condition for slabs on expansive soils. Compressible soils are normally assumed to have allowable values of soil bearing capacity, q_{allow}, equal to or less than 1500 pounds per square foot. Special design equations are necessary for this problem due to the expected in situ elastic property differences between compressible soils and the stiffer expansive soils. These equations are:

(1) Moment

(a) Long Direction

$$M_{cs_\ell} = \left(\frac{\delta}{\Delta_{ns_\ell}}\right)^{0.50} M_{ns_\ell} \quad (34)$$

where

$$M_{ns_\ell} = \left[\frac{(d)^{1.35}(S)^{0.36}}{80(L)^{0.12}(P)^{0.10}}\right] \quad (35)$$

$$\Delta_{ns_\ell} = \left[\frac{(L)^{1.28}(S)^{0.80}}{133(d)^{0.28}(P)^{0.62}}\right] \quad (36)$$

and,

δ = Expected settlement, in inches, due to the total load expressed as a uniform load; reported by the Geotechnical Engineer, and all other symbols are as previously defined.

(b) Short Direction

$$M_{cs_s} = \left(\frac{970 \cdot d}{880}\right) M_{cs_\ell} \quad (37)$$

(2) Differential Deflection

$$\Delta_{cs} = \delta \exp(Z) \quad (38)$$

where

Δ_{cs} = Expected Differential Deflection, in inches

$Z = 1.78 - 0.103\,(d) - 1.65 \times 10^{-3}(P) + 3.95 \times 10^{-7}\,(P^2)$ (39)

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

(3) Shear

(a) Long Direction

$$V_{cs_\ell} = \left[\frac{\delta}{\Delta_{ns_\ell}}\right]^{0.30} V_{ns_\ell} \quad (40)$$

where

$$V_{ns_\ell} = \left[\frac{(d)^{0.90}(PS)^{0.30}}{550(L)^{0.10}}\right] \quad (41)$$

(b) Short Direction

$$V_{cs_s} = \left[\frac{116-d}{94}\right] V_{cs_\ell} \quad (42)$$

6.13 Calculation of Stress in Slabs Due to Load Bearing Partitions

The equation for the allowable tensile stress in a slab beneath a bearing partition may be derived from beam-on-elastic foundation theory. The maximum moment directly under a point load, P, in such a beam is given by

$$M_{max} = -\frac{P\beta}{4} \quad (43)$$

where

M_{max} = the maximum moment in (in-lb) per linear foot of bearing partition in a direction at right angles with the bearing partition

$$\beta = \left[\frac{4\,E_c I}{kb}\right]^{1/4}, \text{ relative stiffness length in inches} \quad (44)$$

where

E_c = Creep modulus at elasticity of concrete

I = Moment of inertia of loaded slab width

B = Assumed beam (slab) width

k = Soil modulus

P = Bearing partition load in lb/ft of length, + upward

$\frac{I}{B} = \frac{t^3}{12}$

with the concrete and soil properties generally assumed (E_c = 1.5×10^6 psi, k = 4 pci),

$$\frac{4\,E_c}{k} = 1.5 \times 10^6 \text{ in.}$$

and β becomes:

$$\beta = 18.8\,t^{3/4}$$

therefore

$$M_{max} = -\frac{18.8\,Pt^{3/4}}{4} = -4.7\,Pt^{3/4} \quad (45)$$

The equation for allowable tensile stress, f_t, is

$$f_t = \frac{M_{max}C}{I} - f_p \quad (46)$$

where f_p = minimum compressive stress in the concrete due to prestressing (usually 50 psi).

Since

$$\frac{I}{C} = \frac{b\,t^3}{12}\left(\frac{2}{t}\right) = \frac{b\,t^2}{6}$$

and

b = 12 in. (one linear foot of bearing partition)

then

$$\frac{I}{C} = 2t^2$$

Thus, the allowable tensile stress is

$$f_t = \frac{4.7\,P\,t^{3/4}}{2\,t^2} - f_p$$

$$f_t = 2.35\,\frac{P}{t^{1.25}} - f_p \quad (47)$$

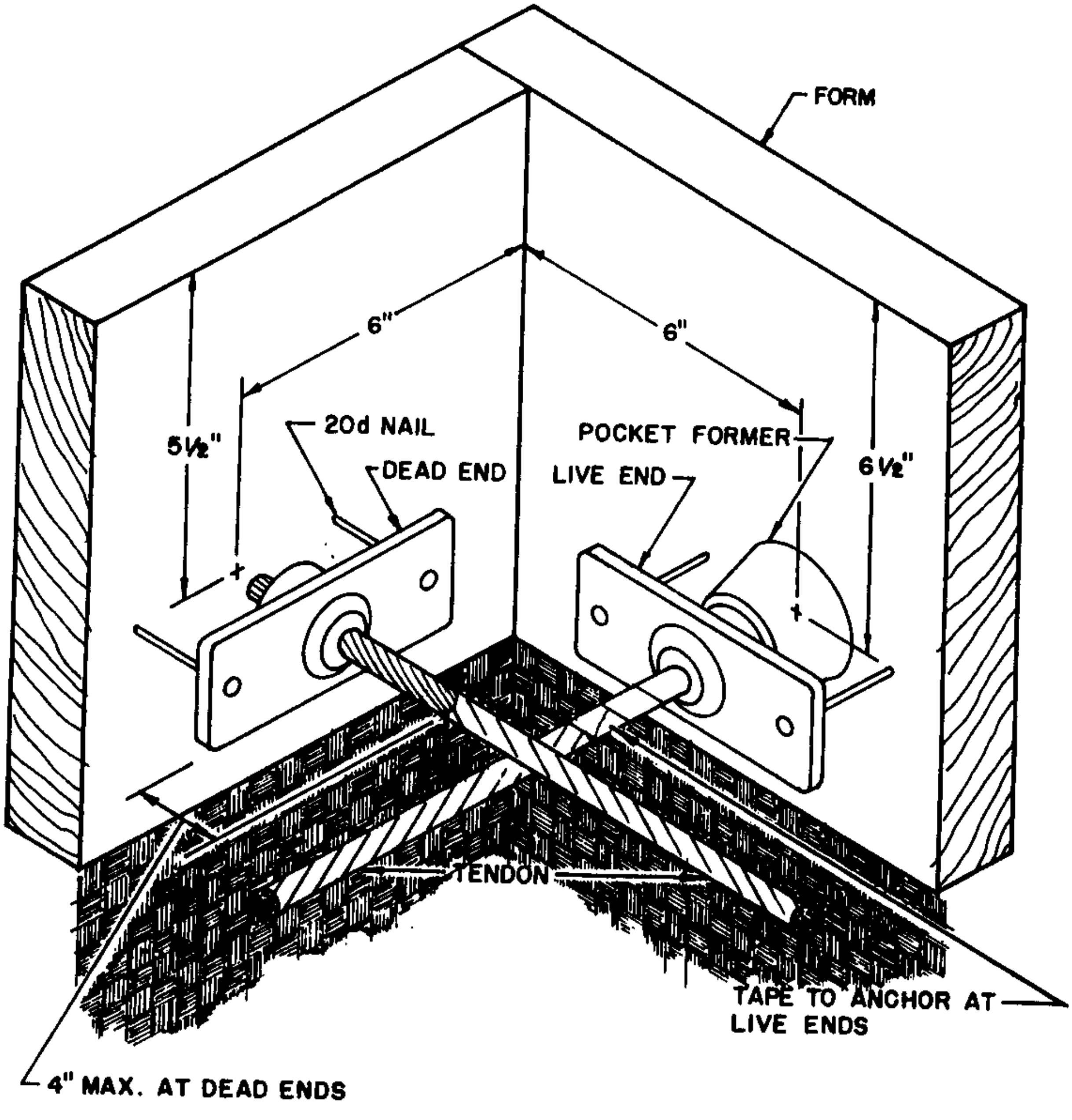
The constant 2.35 depends upon the assumed value of subgrade modulus, k. The following table illustrates the variation in this constant for values of the subgrade modulus:

Type of Subgrade	k, lb/in^3	c
Lightly compacted, high plastic, Compressible Soil	4	2.35
Compacted, low plastic soil	40	1.34
Stiff, compacted, select granular or stablized fill	400	0.74

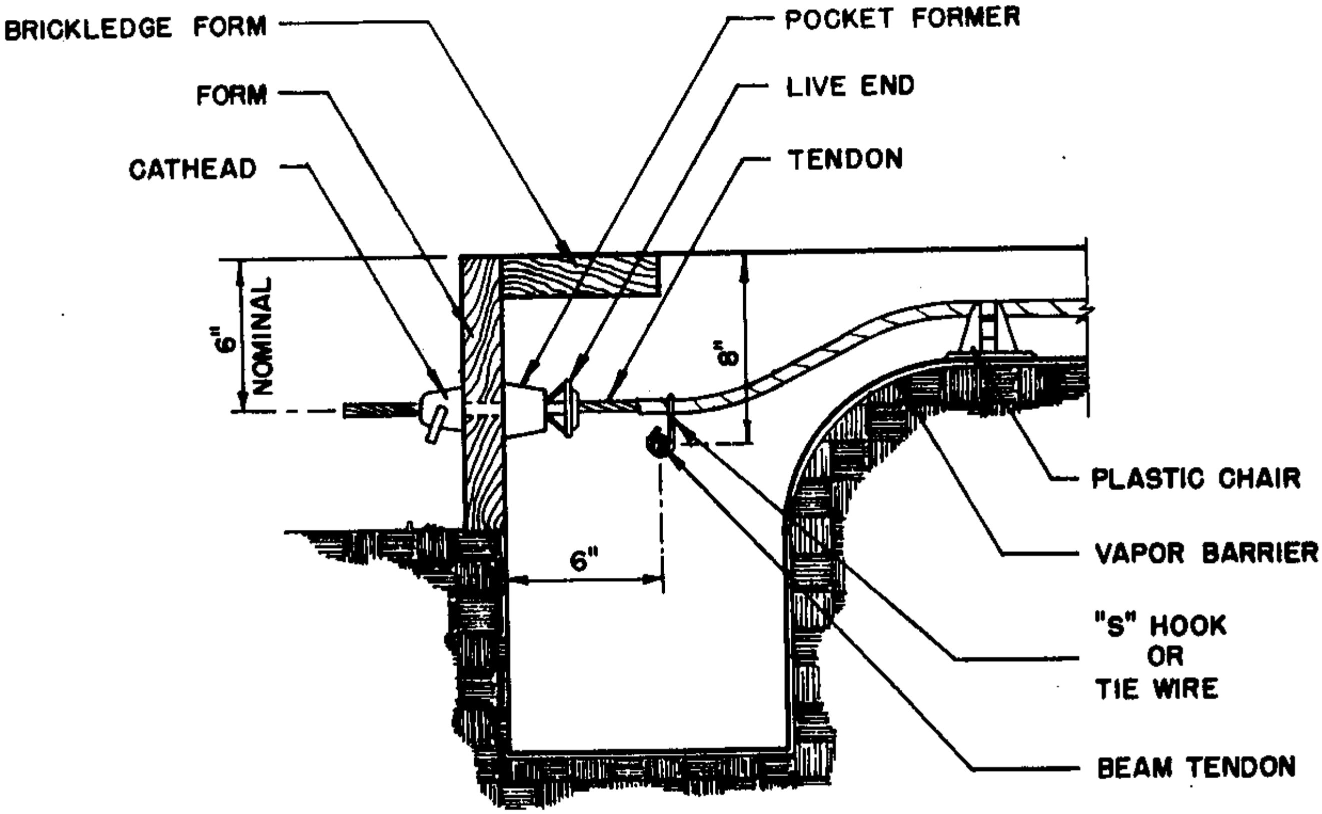
If the allowable tensile stress (say $6\sqrt{f'_c}$) is exceeded by the results of the above analysis, a thicker slab section should be used under the loaded area, or a stiffening beam should be placed directly beneath the concentrated line load.

APPENDIX A

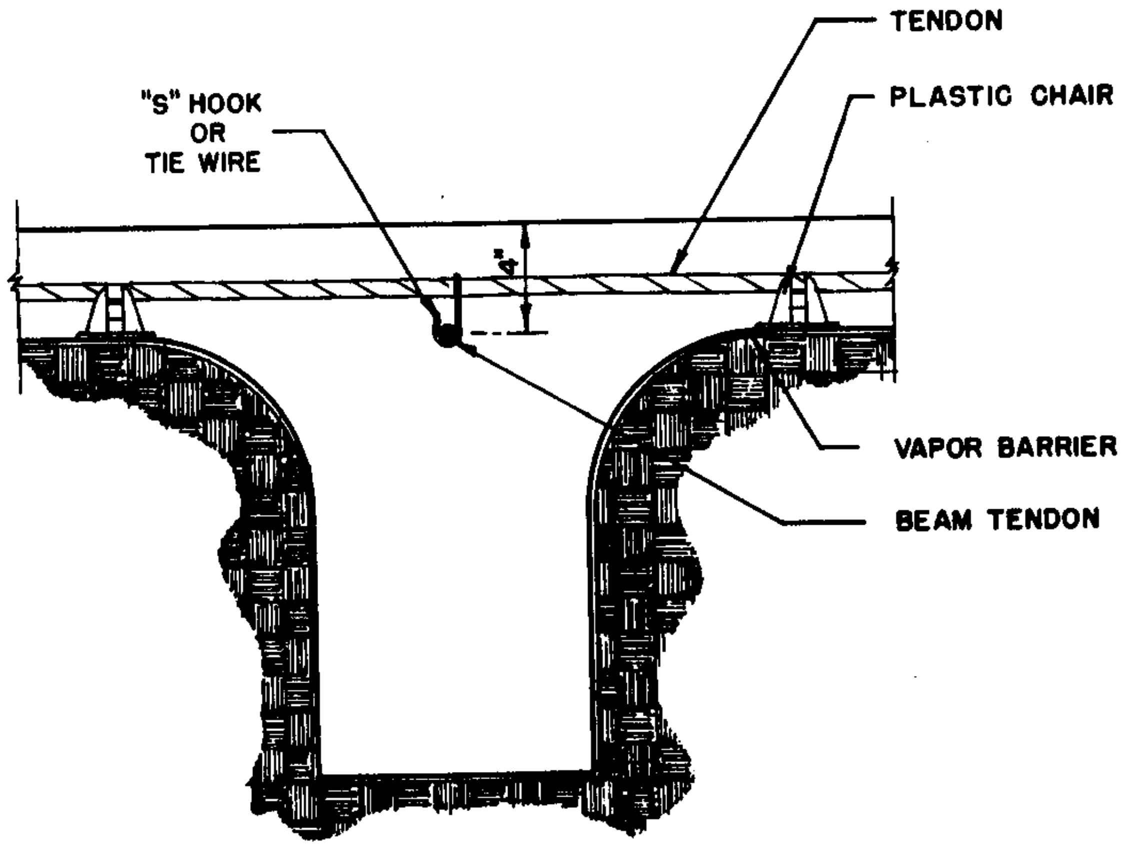
TYPICAL FOUNDATION PLAN AND DETAILS



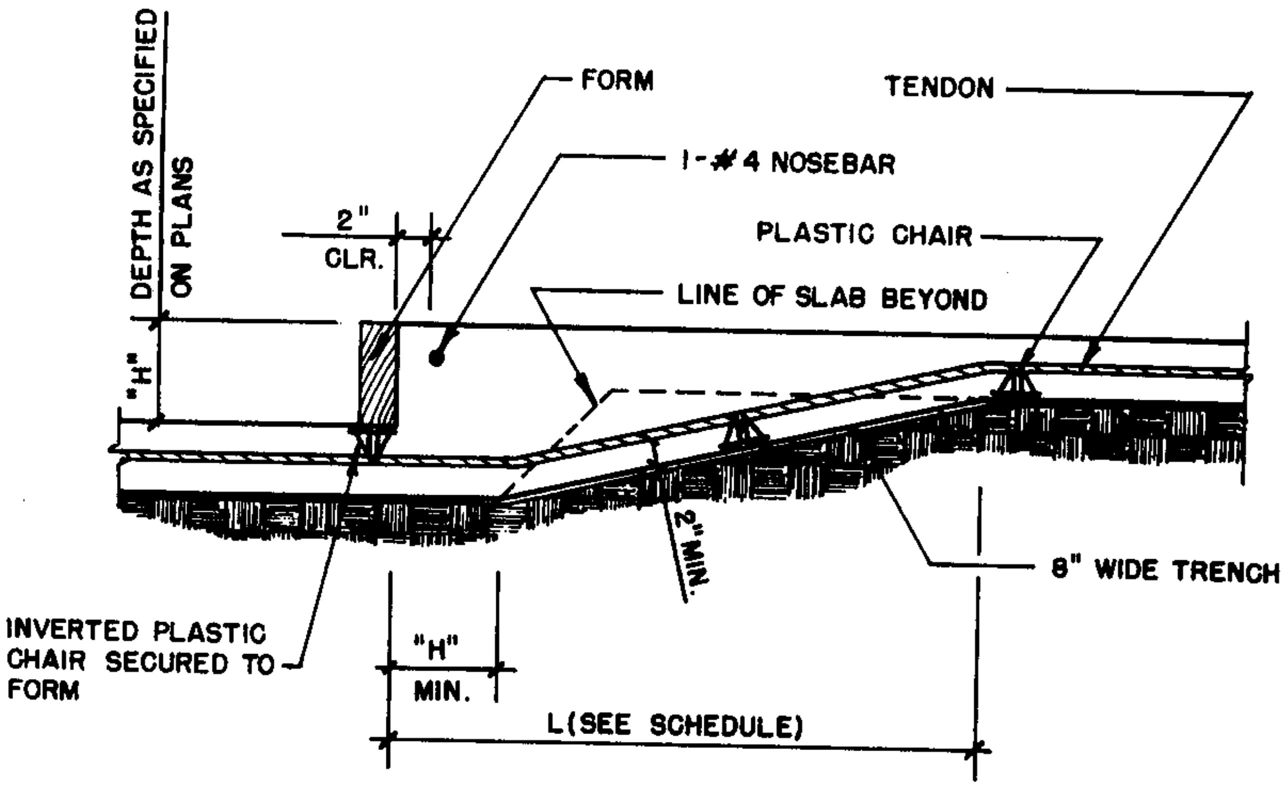
Typical Outside Corner



TYPICAL PERIMETER BEAM



TYPICAL INTERIOR BEAM



SCHEDULE FOR TYPICAL TENDON TRENCH AT DROPS

NOMINAL DROP (H)	TRENCH LENGTH (L)
2"	2' - 0"
4"	3' - 0"
6"	4' - 0"
8"	5' - 0"
10"	6' - 0"
12"	7' - 0"

TYPICAL DETAIL AT DROP

APPENDIX B

TYPICAL GENERAL NOTES

GENERAL NOTES - DESIGN

1. This foundation is designed in accordance with current acceptable engineering practices for the site shown on the plans and may not be used in any other location.

2. As with all ground supported slabs, this foundation is designed to move with the underlying soils while sustaining a calculated amount of flexure. It may also sustain normal temperature and shrinkage cracks as a result of the concrete curing process.

3. The design is based on the following assumptions:

   A. Final grading is completed as outlined in the General Notes - Sitework.

   B. Final grade and a fairly uniform moisture level is maintained for the life of the foundation.

   C. The foundation is not installed during a dry or wet period which is considered extreme or abnormal for the area. If such is the case, builder shall notify the engineer prior to trenching for a possible re-design.

4. This foundation is designed in accordance with the following geotechnical investigation:

   Soil Report #: ______________________

   By: ______________________

   Dated: ______________________

GENERAL NOTES - SITEWORK

1. Site preparation beneath the slab shall be in accordance with the soil report and shall meet the following minimum requirements:

   A. Strip all vegetation down to natural soil. Remove all trees within a close proximity of the foundation.

   B. Proof-roll exposed sub-grade. Backfill and compact tree-holes or soft pockets with material similar to the site materials.

   C. Bring subgrade to required elevation with select fill material. Select fill shall be sandy clay or clayey sand, free of organic material, having a plasticity index greater than 7, but less than 20.

   D. Fill shall be placed in maximum 8" lifts and compacted to 95% of its maximum dry density as determined by ASTM D698 (Standard Proctor). Where large depths of fill occur, field density tests are required for each lift located at or below the bottom of grade beams.

2. The four-inch sand fill shall be well-compacted bank sand or other clean granular material.

3. Initial site grading shall be completed prior to setting forms. Final grade shall slope away from the foundation one-inch/foot for the first five feet such that positive drainage away from the slab is assured.

GENERAL NOTES - CONCRETE

1. Concrete shall be supplied and constructed in accordance with ACI-318 latest edition and shall have a minimum 28-day compressive strength of 2500 PSI.

2. Water shall not be added to concrete at the jobsite unless approved by the engineer. If more workability is needed, contractor shall specify required slump on job order. Concrete plant to increase workability by adding up to 5% air entrainment, additional cement, or other approved admixtures.

3. Calcium chloride or admixtures containing calcium chloride shall not be used as additives. Where fly ash is used, only type C fly ash shall be accepted and a maximum of 15% may be substituted for cement.

4. Concrete shall not be placed at temperatures below 40 degrees Fahrenheit, in rainy weather or in other adverse weather conditions.

5. Concrete shall be well consolidated, especially in the vicinity of tendon anchorages.

6. A 6 mil polyethylene vapor barrier shall be placed under all slabs. All laps shall be taped.

7. Forms to be stripped no less than 24 hours and no more than six days after placement of concrete.

8. Builder shall verify all dimensions, drops, offsets, brickledges, inserts and openings with architectural drawings.

GENERAL NOTES - REINFORCING STEEL

1. Reinforcing steel shall be per ASTM grade 60 with deformations per ASTM A305 and shall be detailed and installed per ACI-318 latest edition.

2. Welded wire fabric shall be 6 x 6 x W2.9 x W2.9 WWF (6 gage) per ASTM A185. Where shown on the plans, WWF shall be supplied in sheets and shall be placed two inches below the top of concrete.

3. Where field splices in the continuous reinforcing occur, bars shall be lapped a distance of 30 times the bar diameter.

4. Where reinforcing steel is shown in the exterior grade beams, provide corner bars in the outside face to match the horizontal steel from the intersecting interior and exterior grade beams.

5. At all re-entrant corners provide 2 #4 x 5'-0" in the slab.

GENERAL NOTES - TENDONS

1. Prestressing steel tendons shall consist of seven-wire stress-relieved strand conforming to ASTM A416 with a minimum ultimate tensile strength of 270,000 PSI.

2. Tendons shall be coated with a permanent rust preventative lubricant within a plastic sheath. Tape all breaks in sheathing and tape sheathing ends up to live end anchors and to within four inches of dead end anchorages.

3. Tendons shall be initially prestressed to hand-tightness against the forms and shall be supported on chairs at 38 inches each way. All chairs shall be tied and all S-hooks shall be crimped.

4. Acceptable tolerances for the tendon placement shall be as follows:

Beam tendons	± 1 in. vert., ± 1/2 in. horiz.
Slab tendons	± 1/2 in. vert., ± 12 in. horiz.

Note that slab tendon horizontal deviation shall be limited to one-inch/foot of cable in order to miss obstructions.

GENERAL NOTES - STRESSING

1. Tendons shall be stressed to 33.0 KIPS per strand and shall have a minimum set load of 28.9 KIPS.

2. Actual tendon elongations shall measure within 10% of theoretical elongations and corresponding pressure gauge readings.

3. Tendons shall be stressed no earlier than three days and no later than ten days after concrete placement. During cold weather conditions, stressing shall take place between seven and fourteen days after concrete placement.

4. Concrete shall have attained a minimum compressive strength of 70% of its 28-day strength at the time of stressing.

5. Brickwork shall not begin before stressing is completed.

6. Tendons shall be cut or burned at one inch from the wedges. Pockets shall be filled with non-shrink grout.

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MINE IS NOT TO RUN THIS TRAIN, THE
WHISTLE, I CAN'T BLOW.

MINE IS SURELY NOT TO SAY HOW FAR
THIS TRAIN CAN GO.

I'M NOT ALLOWED TO BLOW OFF STEAM,
OR EVEN RING THE BELL.

BUT LET THIS TRAIN RUN OFF THE TRACK,
AND SEE WHO CATCHES HELL!

REAL ESTATE TITLES

One petroleum Company has a Real Estate Manager who is exceedingly meticulos about title flaws. In a correspondence with a lawyer regarding the titles to some loan in Louisiana, the lawyer gave information only as far back as 1803. The Real Estate Manager wrote the lawyer asking who owned the land before that. He received the following reply:

"Louisiana was purchased from France in 1803. The title to land was acquired by France by right of conquest from Spain.

"The land came into the possession of Spain by right of discovery made in 1492 by Christopher Columbus, who had been granted the privilege of seeking a new route to India by Queen Isabella.

The Queen, being a pious woman and careful about titles, (almost as careful as you are) secured the blessings of the Pope upon the voyage. The Pope is the emissary of Jesus Christ, who is the Son of God and God made the World.

"Therefore, I believe, you are safe in assuming that the original title goes back to God . . . and I hope to Hell you are satisfied."

I BETTER GET AT IT!

"The population of this country in which we live is 185 million, but there are 87 million over 60 years of age, leaving 98 million to do the work.

"People under 21 total 54 million, which leaves 44 million to do the work.

"Then there are 21 million people employed by the government and that leaves 23 million to do the work.

"There are 10 million in the armed forces, which leaves 13 million to do the work.

"Deduct 12,800,000, the number in state and city offices, and that leaves 200,000 to do the work.

"There are 126,000 in hospitals, insane asylums and so forth, which leaves 74,000 to do the work, but 62,000 of these are bums or others who won't work — so that leaves 12,000 to do the work.

"Now, it may interest you to know that there are 11,998 people in jail so that leaves two people to do the work. That's you and me, brother — and I'm getting tired of doing everything myself."

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SEQUENCE OF CONSTRUCTION FOR SLABS

CONSTRUCTION TECHNIQUES, DRAINAGE, AND OBSERVATIONS

There are five (5) basic time frames in the proper execution of a structurally sound ground supported concrete slab:

1. Site Preparation
2. Foundation Forms
3. Fill Within the Forms
4. Steel Placement
5. Concrete Placement

1. SITE PREPARATION
   - A. Prior to Foundation
     Primary Grading Plan
     Building Pad or Pads
     Area Drains
     Vegetation - Trees
   - B. Subsequent to Construction
     Drainage Away From Foundation to Inlets
     Downspout Drains - Splash Blocks or Underground Air Conditioner Drains, Condensate and Overflow

2. FOUNDATION FORMS
   Alignment
   Grade
   Tightness
   Bracing

3. FILL WITHIN THE FORMS
   Compaction
   Moisture Content
   Backfill Around Plumbing Trenches
   Grading - Constant Slab Thickness
   Beam Shapes, Size and Cleanliness
   Membrane Placement

4. STEEL PLACEMENT
   Beam Steel, Size, Grade and Location
   Corner Bars
   Stirrups
   Slab Steel, Size, Grade and Location
   Compliance with Plans
   Supports for Beam and Slab Steel

5. CONCRETE PLACEMENT
   Proper Design - Seasonable Requirements - Weather
   Mixing Time - "Hot Concrete" - Color
   Placement Procedures - Troughs, Pumps, Drops
   Slump
   Vibration Equipment
   Finishing
   Curing

SOILS DESCRIPTIONS AND CHARACTERIZATIONS

CLAY

Clays are defined as soils composed of particles less than two microns in dimensions.

The direction and magnitude of the swell potential of clays depends on the manner in which it was deposited; that is by salt or fresh water. Examples are: montmorillonite which was normally deposited by salt water and the molecules are "flocculated" or oriented in every direction and consequently the swell and shrinkage potential is effective in all directions; Illite and kaolinite clays were normally deposited by fresh water and the molecules are basically oriented parallel to the surface of the ground and the swell and shrinkage potential is primarily in the vertical directions. These clays are heavier than montmorillonite.

CLAY MINERALS WHICH MAY BE PRESENT IN ALL FORMATIONS

MONTMORILLONITE — (p.i. range from 40-200) - Montmorillonite is a clay molecule of a ribbon shape and capable of absorbing great quantities of water. Another name often used for this clay is "bentonite."

ILLITE — (p.i. range from 15-40) - Illite is a clay molecule with a basic disc shape and is not usually found in large quantities and considerably less active than montmorillonite in water absorption capacities.

KAOLINITE — (p.i. range from 10-20) - Kaolinite is a clay of rectangular or cubical shape molecule and is the least active of the three basic clays. These clays have very little absorption capacity.

<u>CONCRETE/CEMENT, ADMIXTURES AND FLY ASH</u>

CONCRETE

Comprised of: Fine and Coarse Aggregate, Cement and Water.

Cement - "Portland Cement": A hydraulic cement consisting essentially of hydraulic calcium silicates usually containing one or more forms of calcium sulfate.

TYPE I:	Most common everyday use.
TYPE II:	Used for moderate sulfate resistance or moderate heat of hydration applications.
TYPE III:	High early strength requirements.
TYPE IV:	Low heat of hydration applications.
TYPE V:	High sulfate resistance applications.
TYPE K:	Shrinkage compensation cement (expands first and then shrinks)

Add the letter "A" to type to specify air entrainment.

The "Air" consists of large number of minute air bubbles in the cement paste and have spacings of less than 0.008 inches.

ADMIXTURES

Accelerators - avoid use of calcium chloride.
Water reducing and set controlling - 4 classes.

Class 1 & 3 are water reducing and set retarding
Class 2 & 4 are water reducing, but usually do not change set time.

FLY ASH

Three (3) types or class-obtained from burning ground or powdered coal (Class "F" & "C") Class "N" - natural

Class "N":	Calcined natural pozzolans (not usually considered)
Class "F":	Burning anthracite or bituminous coal - contains some pozzolans.
Class "C":	Burning lignite or sub-bituminous coal - contains pozzolans and has cementitious property.

NOTE: Only Class "C" can replace cement in concrete <u>BUT NEVER MORE THAN 20%</u>.

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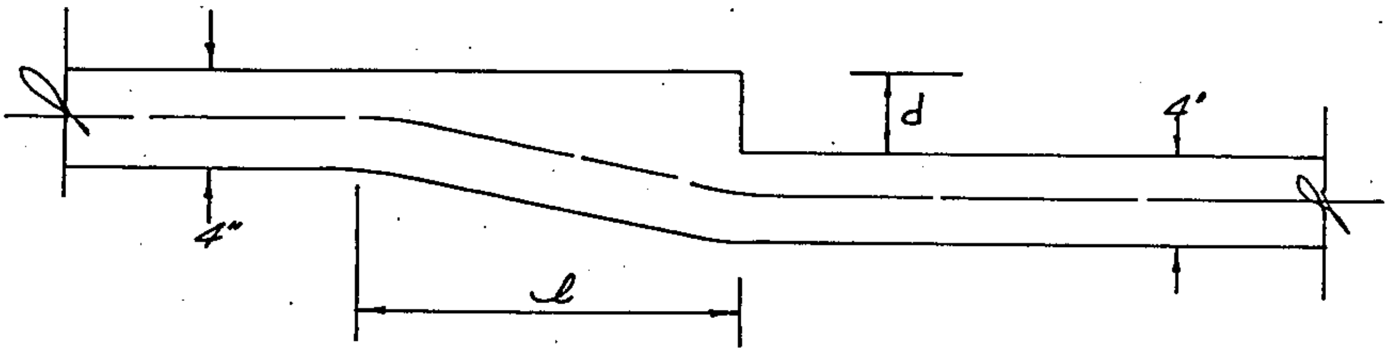
TRANSITION LENGTHS FOR CHANGE IN SLAB ELEVATIONS



d	l
1"	16"
2"	2'- 0"
3"	3'- 0"
4"	3'- 4"
5"	4'- 0"
6"	4'- 5"
7"	4'-11"
8"	5'- 4"
9"	5'- 7"
10"	6'- 0"

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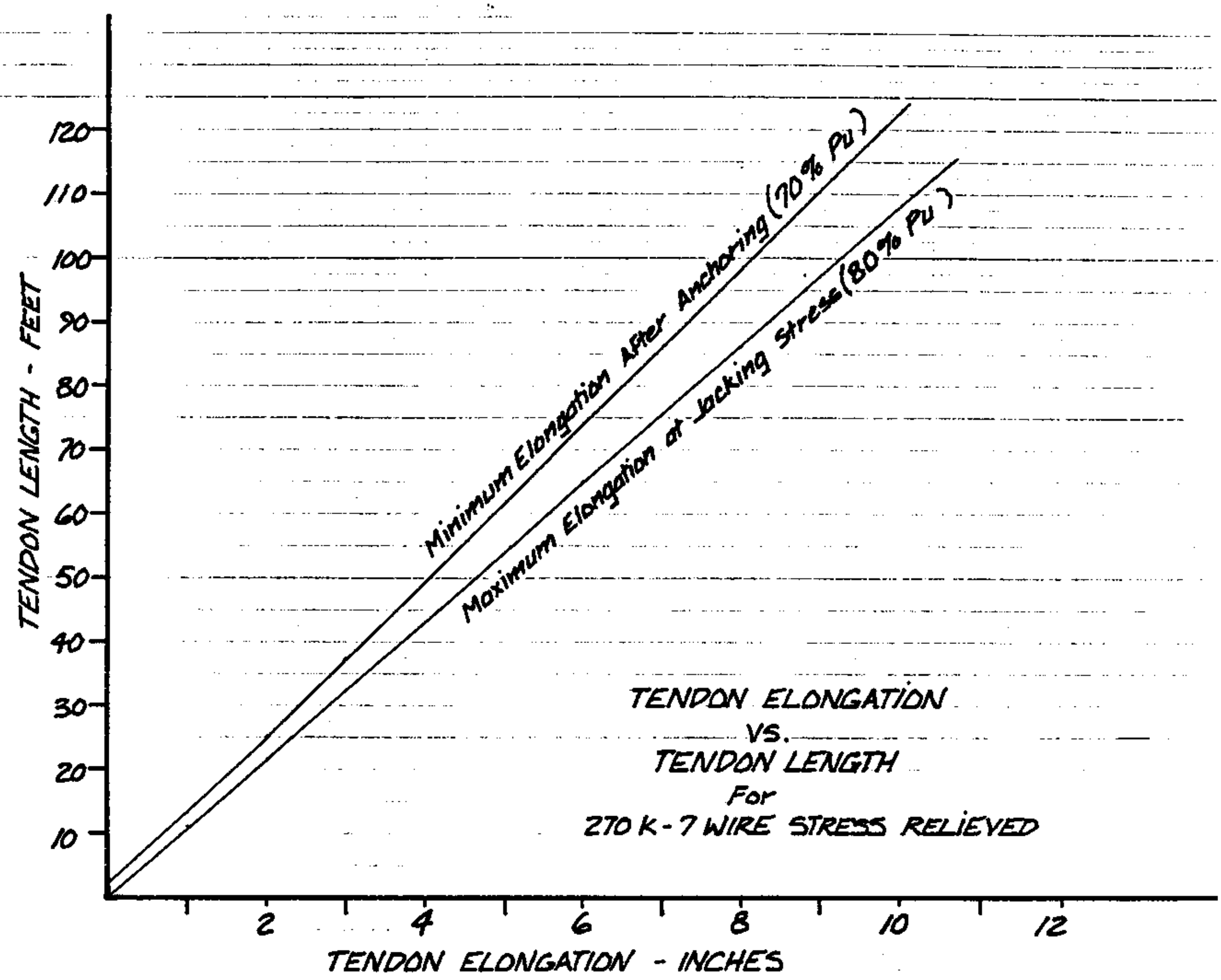

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FIELD CONTROL OF DEFLECTION

DEFLECTION CONTROL

Simple Span: $\Delta = \dfrac{5\,w\ell^4}{384EI}$ $\quad M = \dfrac{w\ell^2}{8}$

Divide Δ by M: $\dfrac{\Delta}{M} = \dfrac{5\ell^2}{48EI}$

Cantilever Span: $\Delta = \dfrac{w\ell^4}{8EI}$ $\quad M = \dfrac{w\ell^2}{2}$

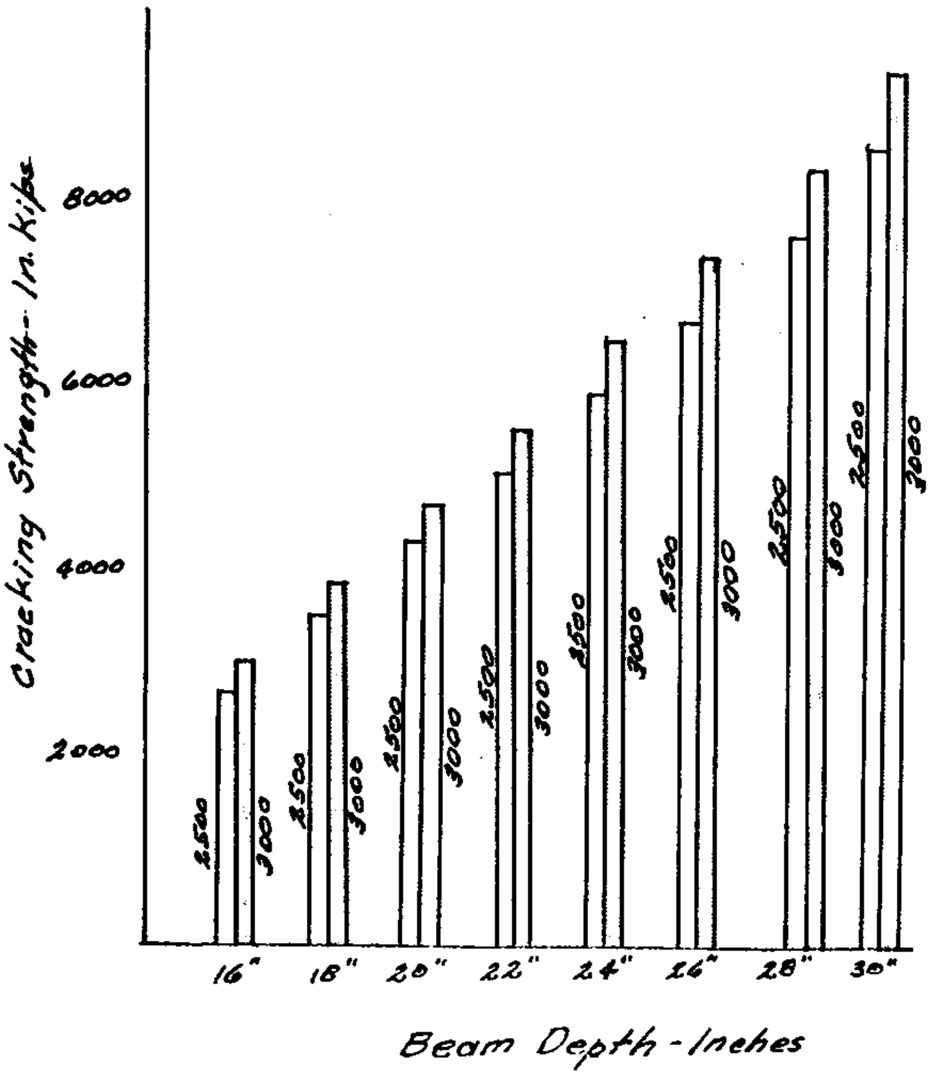
Divide Δ by M: $\dfrac{\Delta}{M} = \dfrac{\ell^2}{4EI}$

Field Superintendent cannot change "ℓ", "48", "4", or "E"

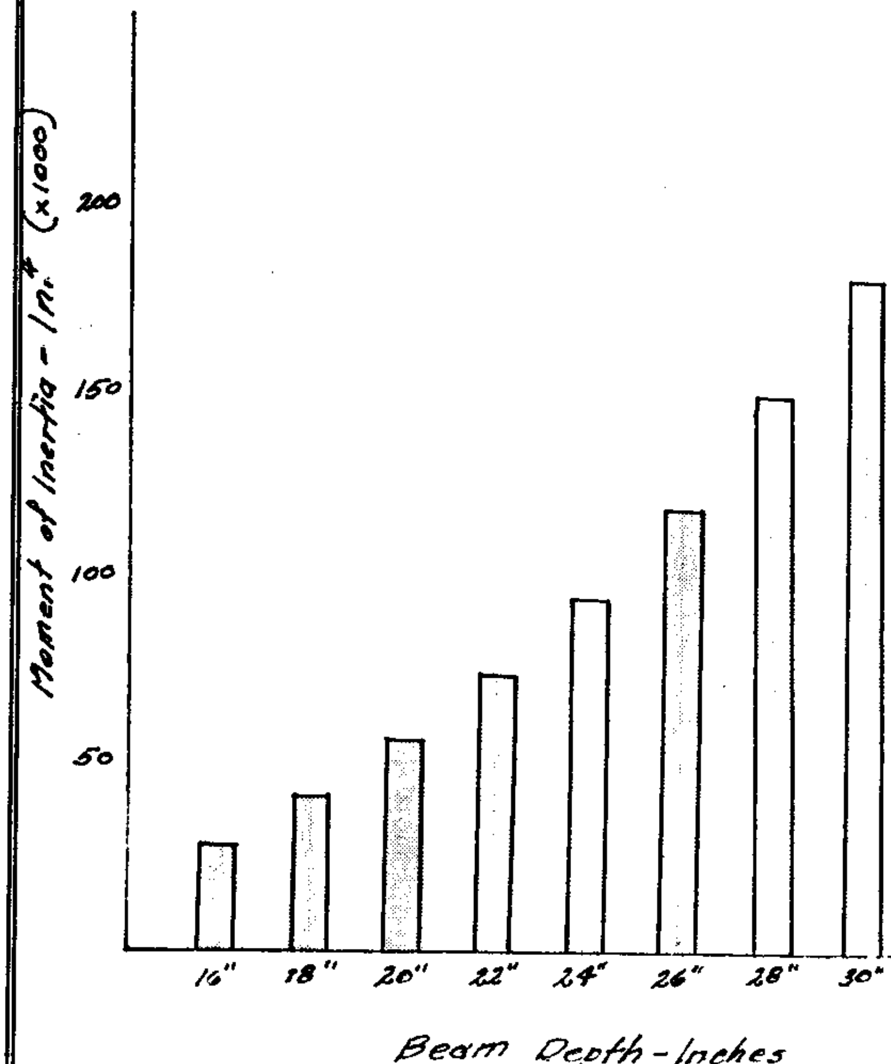
Field Superintendent CAN change "I".

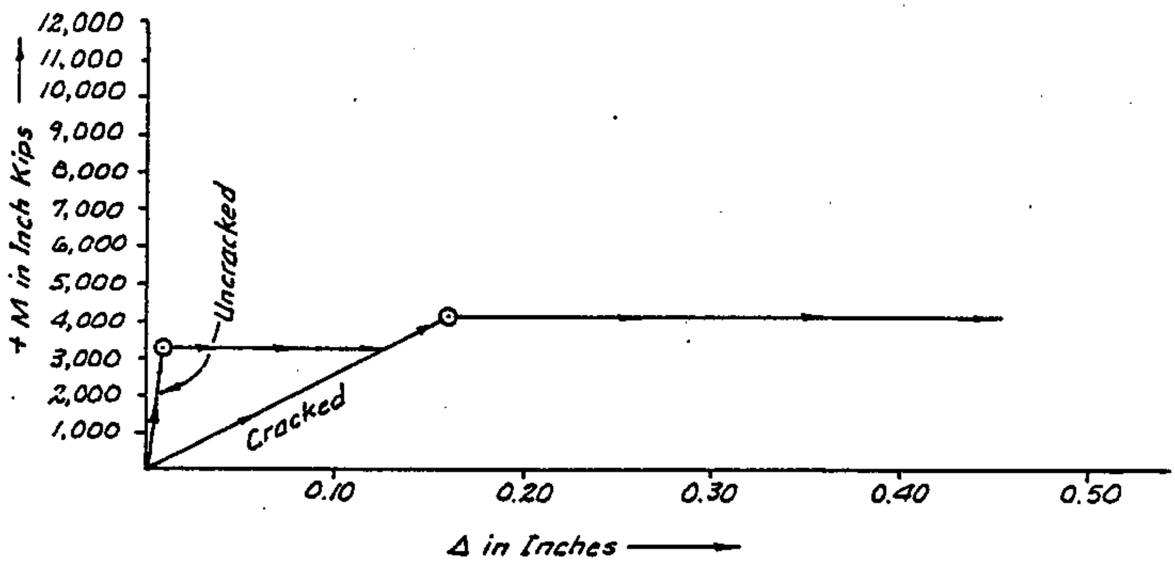
30' Wide Slab with 3-12" Wide Beams

Cracking Strength
2500 psi Conc. Vs. 3000 psi Conc.

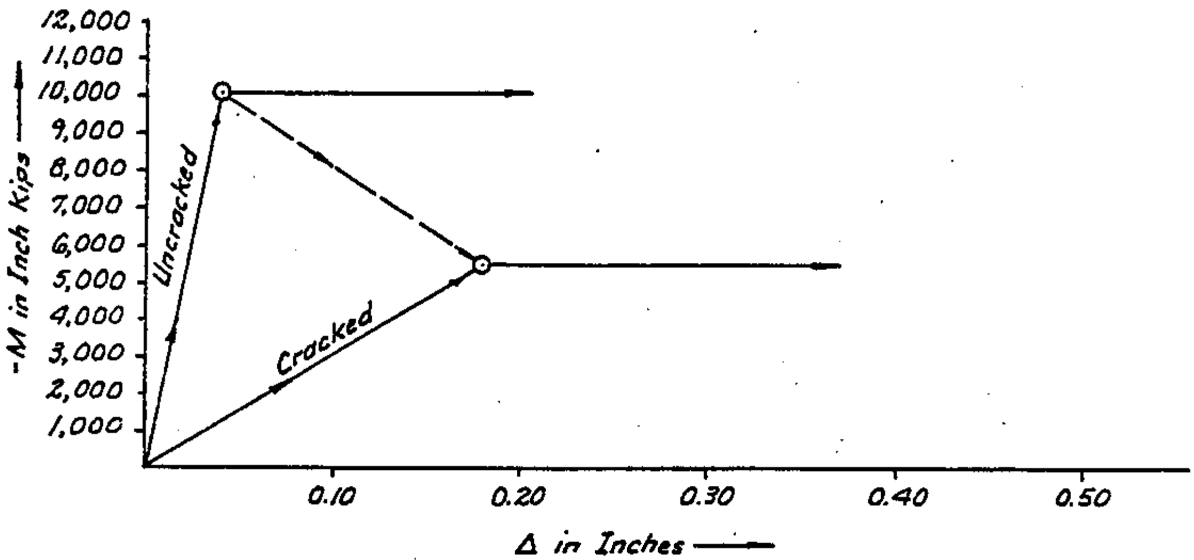


Moment of Inertia Capacity
Resistence to Deflection

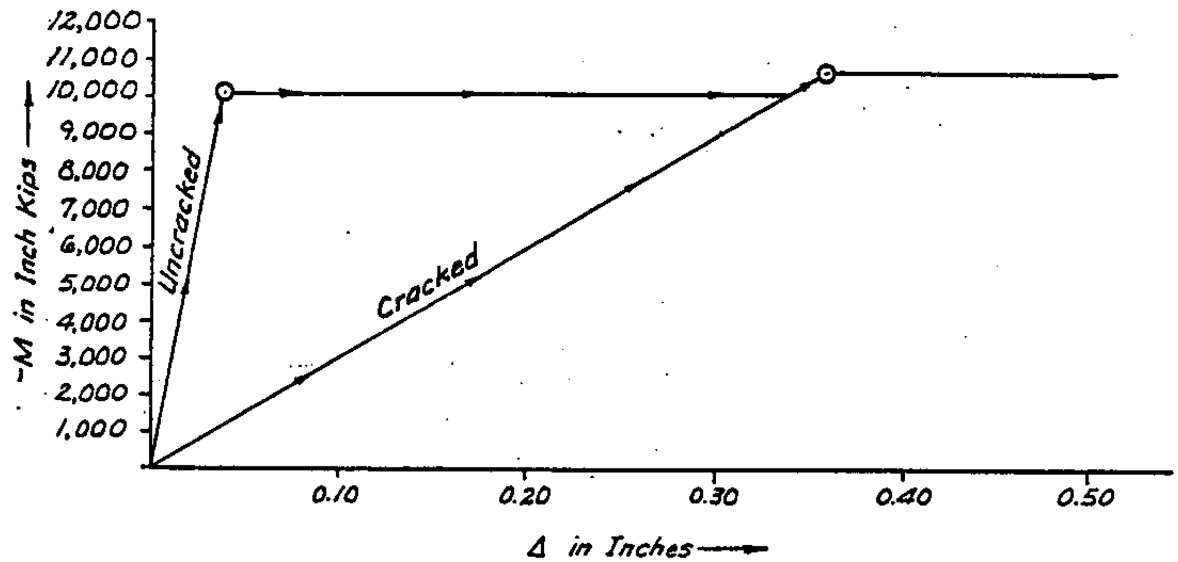




POSITIVE MOMENT VS. DEFLECTION
MILD STEEL AND POST TENSIONED



NEGATIVE MOMENT VS. DEFLECTION
MILD STEEL



NEGATIVE MOMENT VS. DEFLECTION
POST TENSIONED

GEOTECHNICAL GUIDELINES FOR DESIGN OF RESIDENTIAL PROJECTS IN THE HOUSTON AREA

BY

DAVID A. EASTWOOD, P.E.

Introduction

The variable subsoil conditions in the Gulf Coast area has resulted in very special design requirements for residential foundations. The subsoil conditions should be carefully considered when a subdivision is to be built. Proper planning from the stand point of hazardous waste, subsidence, faulting, and soil conditions should be considered prior to any development.

The purpose of this article is to recommend a 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 these studies should be performed prior to 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. In addition, recommendations are given for foundation stabilization and underpinning.

Environmental Site Reconnaissance Study

Environmental site assessment studies are recommended on the tracks of land for subdivision development. A study like this is 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 hazardous waste that is on or used to be on a project site prior to development. The study is divided into two phases, Phase I and Phase II. 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, and (e) a report of observations and recommendations.

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

Subsidence

Potential subsidence problems should be considered on the coastal areas, such as Clear Lake, Seabrook, Baytown, etc. This type of study is 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.

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 and false color, 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 is very difficult. A study of geologic faulting is recommendaed prior to development of any subdivision in the Gulf-coast area.

Geology

The Houston area is located on the Gulf of Mexico Coastal Plain, which is underlain largely by unconsolidated 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, and strength. It is very important that foundations for residential 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.

Location	Soil Conditions
Northwest and Northeast Houston, including Kingwood, The Woodlands, Cypresswood, Atascocita area and Oaks of Devon-shire	Generally sandy soils occur in these areas. The sands are generally loose and underlain by relatively impermeable clays and sandy clays. This condition promotes perched water table formation which results in the loss of bearing capacity in the shallow foundations such as slab-at-grade or post-tensioned slabs. This condition also causes subsequent foundation settlement and failure.

	Shallow foundations in these soils have to be designed, assuming a saturated soil condition, with low bearing capacities. Drilled footings can also be used as foundations in these soils, but due to sandy soil conditions and potential caving problems, casing method of pier construction may have to be used.
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 in these soils should be designed, assuming a perched water condition.
Central Houston, including Bellaire, West University, River Oaks.	Highly expansive clays, drilled footings are the preferred foundations system. Soft soils are observed in some lots.
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	Highly expansive clays on top of loose silts and sands. Variable soil conditions. Slab-at-Grade is a typical foundation. Piers can also be used at some locations. Soft soils in some lots. Shallow water table.

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, site features, and soil conditions. As a general rule, a minimum of one boring for every four lots should be performed for FHA 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 subdivision. In the event that a drilled footing foundation is to be used, a minimum of one boring per lot is recommended. In case of variable subsoil conditions, one to two 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.

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 evaluate the property of fill soils that have been placed on the lot. All fill soils should have been tested for plasticity and compaction prior to placement on the lot. Typical structural fill properties in the Houston area consist of silty clays and sandy clays (not sands) with liquid limits less than 40 and plasticity index between 8 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 D698-78).

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 cost of soil testing for the lots should be the builders responsibility.

In the areas where no fill will be placed on a lot 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, compaction, strength, and swell potential.

Foundation Underpinning

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.

Residential 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.

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 watr source becomes available.

Foundation Type

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 and conventionally reinforced slabs perform satisfactory on most subsoils. Drilled footings provide a superior foundation system when significant offsets or differential loading (such as brick loading) occurs on the foundations.

In the areas where highly expansive soils are present, the drilled footings should be founded in a strong soil stratum below the Active Zone. Active Zone is the zone at which Houston soils experience shrink and swell movements. This depth is about 10- to 12-feet. The depth of the active zone should be verified by a geotechnical exploration. 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. Void boxes should be used under the grade beams to separate the expansive soils from the grade beams.

The grade beams for a slab-at-grade foundation should penetrate clay soils a minimum of 12-inches. The beam penetrations into the surficial sands should be at least 18-inches to develop the required bearing capacity to minimize foundation settlements.

Foundations and Risks

Many of the lightly loaded foundations in the Houston area are designed and constructed on the basis of economics, risks, soil type, foundation shape and structural loading. Many times, due to economic reasons, higher risk are accepted in foundation design. Most of the time, the foundation types are selected by the client. It should be noted that some level of risk is associated with all types of foundations and there is no such thing as zero risk foundation. The following are the foundation types used in the Houston area with increasing levels of risk and decreasing levels of cost:

Foundation Type	Remarks
Structural Slab With Piers	This type of foundation which is referred to as a pier and beam foundation with a crawl space is considered to be a minimum risk foundation. Usually, a minimum crawl space of six-inches or larger is required.

Slab-On-Fill Foundation Supported On Piers	This type of foundation has some minimum risk with respect to foundation distress and movements. However, if positive drainage and vegetation control are provided, this type of foundation should perform satisfactorily. The drilled footings in this type of foundation are generally corrected to the grade beams to resist uplift movement of the slabs. The fill thickness is elevated such that the potential vertical rise (PVR) is less than one-inch.
Floating (Stiffened) Slab Supported On Piers The Slab Can either Be A Conventionally-Reinforced Or a Post-Tensioned Slab	This type of foundation system has some risk; however, the level of risk on this type of foundation is less than a floating slab without piers. Due to presence of piers, the slab can move up, but not down. In this case, the steel from the drill piers should not be dowelled into the grade beams. Furthermore, void boxes should be provided under the grade beams to separate the expansive soils from the grade beams.
Floating Slab Foundation (Conventionally-Reinforced Or Post-Tensioned Slab)	This type of foundation has higher risk than any of the above. However, if it is built together with positive drainage and vegetation control it should perform satisfactorily. No piers are used in this type of foundation.

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.

Foundation Design

The design of foundations should be performed by an experienced structural 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.

Foundation Construction and Quality Control

Some of the major components of foundation construction include site preparation, drilled footings installation and concrete placement. These items are described in the following sections.

Site Preparation

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. Average stripping depth should be six-inches. This depth should be verified at the time of construction by a soil technician.

2. Any on-site fill soils identified in the borings or discovered during the construction must have records of successful compaction tests. These test 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 replaced in accordance with the site preparation recommendations.

3. The subgrade areas should then be proofrolled with a loaded truck, heavy 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 if necessary and recompact to 95% of the maximum dry density as determined by ASTM D 698-78 (Standard Proctor). The moisture content at the time of compaction of subgrade soils should be within ±2% of the proctor optimum value. The degree of compaction and moisture in the subgrade soils should be verified by field density tests at the time of construction.

5. Structural fill beneath the floor slabs should consist of inorganic silty clays or sandy clays with a liquid limit of less than 40 and a plasticity index between 8 and 20. 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 698-78 (Standard Proctor). The moisture content of the fill at the time of compaction should be within ±2% of the optimum value. The degree of compaction and moisture in the fill soils should be verified by field density tests at the time of construction.

6. 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.

7. The subgrade and fill moisture content and density must be maintained until paving or floor slabs are completed. These parameters should be verified by field moisture and density tests at the time of construction.

<u>Drilled Footing Inspection</u>

In the event that the structure is supported by drilled footings, the installation of the footings should be observed by a geotechnical technician. So many drilled footings are built in the Houston area without bells, with undersized bells, or on top of soft soils.

A technician conducts 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 soft soils are encountered. Therefore, minimizing costly construction delays.

<u>Concrete Inspection</u>

The concrete sampling and testing in the floor slab areas should be conducted in accordance with ASTM standards. A technician will monitor batching and placing of the concrete. Four to eight concrete cylinders should be made for each floor slab pour. Half of the concrete cylinders are tested at seven days and the other half at 28 days.

<u>Other Construction Considerations</u>

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 698-78). This should be confirmed by conducting a minimum of four field density tests per slab, per lift.

3. Minimum concrete strength should be 2,500 psi with a maximum slump of 5-inches. 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. Tree stumps should not be left under the slabs. This may result in future settlement and termite infestation.

6. Trees should not be planted closer than half the canopy diameter of mature trees from the grade beams, typically a minimum of 20-feet. Alternatively, root barriers must be placed near the exterior grade beams to minimize tree root movements to under the floor slabs. This will minimize possible foundation settlement as a result of tree root systems.

7. Site drainage should be well developed. Surface water should be directed away from the foundation soils (use a slope of about 5% within 10-feet of foundation). No ponding of surface water should be allowed near the structure. In the area of expansive soils, sprinkler systems used should be placed all around the house to provide a uniform moisture condition throughout the year.

Foundation Stabilization

General. Several methods of foundation stabilization are presented here. These recommendations include foundation underpinning, using drilled footings or driven precast piles, 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 precast driven piles has been used in the Houston area for a number of years. The construction of a drilled footing consists of drilling a shaft, about 8 to 12-inches in diameter (or larger) underneath a 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 concrete, and the grade beams are jacked to a level position and shimmed to level the foundation system.

In a case of driven precast piers, 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 piers 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 active zone to resist the uplift loads as a result of underlying expansive soils.

The use of drilled footings/driven piers 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 precast concrete piles can not resist uplift loads as a result of skin friction of expansive soils; therefore, if the units are not properly connected they will not provide any tensile load transfer. Furthermore, the depth of penetration of these piles maybe less that the depth of the active zone in some cases. The construction of each method should be monitored by an experienced geotechnical/structural engineer.

Partial underpinning is used in the areas where maximum distress is occurring under a slab. In general, full underpinning which includes placement of piers/driven precast piers underneath all foundations is a better method of stabilizing foundations. 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.

<u>Moisture Stabilization.</u> 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 and The Woodlands. This method could be effective in the areas of highly expansive soils such as 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 three 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.

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 P.E. designation with a geotechnical engineering background should be requiered. A civil engineer with a master's degree or higher is preferred.
- The engineer should be a "disinterested" party (hired by the party he is representing). If the engineer has more business to gain a conflict may be possible.

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

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RECOMMENDED HOMEOWNER FOUNDATION MAINTENANCE PROGRAM FOR RESIDENTIAL PROJECTS IN THE HOUSTON AREA

BY

DAVID A. EASTWOOD, P.E.

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 and 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.

Typical Foundations

Foundations for support of residential structures in the Houston area consist of pier and beam type foundation, spread footing foundation, conventionally reinforced slab, or a post-tensioned slab. A soils exploration must be performed before a proper foundation system can be designed.

General Soil Conditions

Variable subsoil conditions exist in the Houston Metro area. Highly expansive soils exist in the West University, Bellaire, Southwest Houston, Clear Lake, Friendswood, Missouri City, and First Colony areas. Sandy soils with potential for severe perched water table problems as a result of poor drainage are present in the North and West Houston, including portions of Piney Point, Hedwig Village, The Woodlands, Kingwood, Atascocita, Cypresswood, Fairfield, etc.

A perched water table condition can occur in an area consisting of surficial silty sands or clayey sands underlain by impermeable clays. During the wet (rainy) season, water can pond on the clays (due to poor drainage) and create a perched water table condition. The sands become extremely soft, wet, and lose their load carrying capacity.

Drainage

The initial builder/developer site grading 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 is extremely important in minimizing soil-related foundation problems. Sometimes, the homeowners, mount the flowerbed areas, creating a dam, 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 select fill compacted to 90 percent of the maximum dry density as determined by ASTM D 698-78 (standard proctor). This level of compaction is required to minimize subgrade settlements near the foundations and the subsequent ponding of the surface water.

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.

Grading and drainage should be provided for structures constructed on slopes, particularly for slopes greater than 9 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, ground-water and underground streams, and surface water penetrating through pervious or fissured and highly permeable soil. Drains can help control the water table in expansive soil. Furthermore, since drains cannot stop the migration of moisture through expansive soil beneath foundations, they will not prevent the long-term swelling.

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).

It is recommended that at least six-inches of clearing be developed between the grading and the wall siding. This will minimize surface water entry between the foundation and the wall material, promoting 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, gutters are recommended all around the roof line. The 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 pipes 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 where poorly compacted backfill fissures and slickensides in the soil mass may allow the water to seep directly into the areas of the foundation and floor slabs.

Landscaping

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.

Planting 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 the 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 North and West Houston, where sandy, non-expansive soils are present, next to the foundations with flowers and shrubs should not pose a major problem. 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 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 North and West 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. 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.

The presence of trees near a residence is considered to be a potential contributing factor to the foundation distress. Our experience shows that large trees in close proximity to residential structures can cause foundation and soil settlements. 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 4-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 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.

Foundations

Every homeowner should conduct a yearly observation of foundations and flatworks 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 10 years of a newly built home because this is usually the time of the most severe adjustment between the new construction and its environment.

Some cracking will occur in foundations. Foundations can experience some cracking. 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 the foundation problems.

Biography
David Eastwood, P.E.

David Eastwood is the president of Geotech Engineering and Testing. Mr. Eastwood has practiced consulting engineering for about 16 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 and industrial to commercial buildings. Geotech Engineering and Testing 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, apartment buildings, shopping centers, and office buildings. Mr. Eastwood received his Bachelor and Masters of Science from the University of Houston with specialization in soils engineering. 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 for the geotechnical committee of Post-Tensioning Institute Slab-On-Grade Committee.

administ\bio.dae

SOILS-STRUCTURE INTERACTION SEMINAR FOR RESIDENTIAL & LIGHT COMMERCIAL STRUCTURES

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FOUNDATION REPAIR TECHNIQUES

by

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(seminar1.doc LE#25)

TOPIC OUTLINE

INTRODUCTION

ENGINEERING STANDARDS FOR TESTING EXISTING FOUNDATION PERFORMANCE

- DEFLECTION PARAMETERS - L/240, L/360 & L/500
  - DIFFERENCE BETWEEN "DESIGN" AND "PERFORMANCE"
  - DEFINITION OF "DEFLECTION" VS. "SLOPE"

- MICRO-ELEVATION SURVEY PLAN
- PHENOMENA PLAN
- GEOTECHNICAL AND SITE PROBLEMS

SOLUTIONS

- SITE WORK
  - FRENCH DRAINS
  - POLY WATER BARRIERS

- CONTROL JOINTS
- DRILLED PIERS / PRESSED PILES / HELICAL ANCHORS
- DISCUSSION ON BUILDER'S PIERS
- CHECKING TENDON STRESSES

- HYBRID REPAIR SYSTEMS (THE BRIDGE)
- SOIL STABILIZATION (CONDOR SS, LIME STABILIZATION, ETC.)
- SPECIAL PROBLEMS
- DESIGN DEFICIENCIES
  - "EGG CARTON" GRID SYSTEMS
  - POST-TENSIONING BEAMS WITH EXTRA MILD STEEL

APPENDIX

SAMPLE FOUNDATION PROBLEMS AND CORRECTION TECHNIQUES

INTRODUCTION

1) This paper is presented as a preliminary introduction to help establish design and construction standards for solving the problems that exist on residential and light commercial projects, including:

a) Post-tensioned slabs-on-grade
b) Conventionally reinforced "floating" slabs-on-grade
c) Conventionally reinforced "pier-supported" slabs-on-grade
d) "West-University" type foundation systems
e) Light commercial structures

2) We hope that others involved in the solving of foundation problems will find the information contained in this paper to be beneficial. This paper covers the summary of over 30 years of experience in dealing with foundation design and failure analysis along with a long (and continuing) tenure in the "School of Hard Knocks". It seems that, as engineers, we will always be running into new problems that require revising old theories from time to time. The fact is, residential design, investigation and problem solving is probably more difficult and certainly more complex than that required for most shopping centers and multi-storied office buildings. We recommend that the design or investigating engineer approach the realism of residential slab-on-grade design or failure analysis with a clear and open mind, and be prepared to revise any initial impressions or preconceived ideas as the actual facts present themselves.

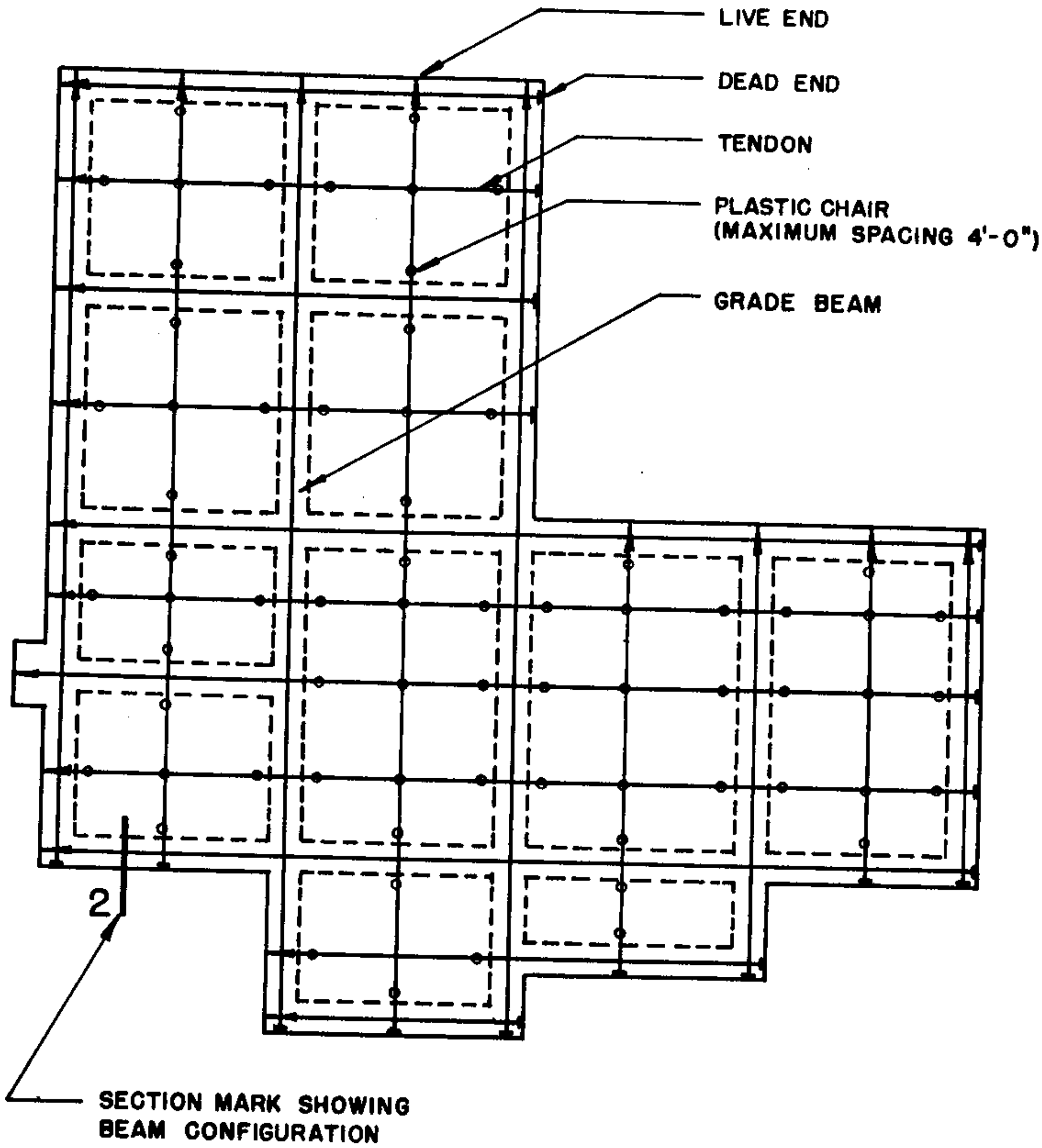
ENGINEERING STANDARDS FOR TESTING EXISTING FOUNDATION PERFORMANCE

DEFLECTION PARAMETERS - L/240, L/360 & L/500

3) We recommend that the existing Building Codes be used as a method of 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:

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.



TYPICAL FOUNDATION PLAN

DIFFERENCE BETWEEN "DESIGN" AND "PERFORMANCE"

4) The Building Codes are quite clear that engineers should only use one value (usually the most restrictive) for design, but a single deflection value may not be appropiate for performance. For example, the Houston Building Code (UBC) stipulates in Table 23-D that a roof or floor member supporting live and dead loading not deflect more than 1:240, while a member supporting masonry is limited to 1:500 to 1:600 maximum deflection. While it may not be possible to design the components of a single building foundation using separate deflection criterias, it may be appropiate to analyze it for performance using applicable criterias for different materials.

DEFINITION OF "DEFLECTION" VS. "SLOPE"

6) Structural engineers are aware that a simple beam span will deflect the most, while a beam with continuity on both ends will deflect the least. If the span is 30', then the allowable deflection for a 1:600 would be .6" maximum. The distance involved to obtain the .6" "deflection" is half of the 30' span, or 15'. Since floating slabs-on-grade do not have "spans" as such, we recommend the engineer identify the observed high and low points of a foundation and test the performance between these locations using the appropiate Code values accordingly. Thus, .6" becomes the "slope" in a 15' distance. The allowable "slope" for this 15' distance thus becomes .6/(15*12) or L/300. 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, so the conservative assumption above may be justified. We may therefore choose to use L/360 as a limit for this condition, since it is slightly more conservative than all Building Codes, including the Houston Code (UBC).

W A R N I N G : Differential movement is not to be confused with 'slope' 'deflection'. Refer to other seminar papers for definitions and proper usage. An experienced structural engineer usually is required to evaluate and establish the significance between such differences.

M I C R O - E L E V A T I O N S U R V E Y S

7) We recommend the micro-elevation survey as one of the best methods for assessing any existing structural system. This becomes especially important when the original plans and design are no longer available for review. In such cases, performance may be the only criteria that can be used to rationally evaluate a foundation.

8) Such a micro-elevation survey may be accomplished using a surveyor's level instrument, a laser survey instrument or a water level (manometer). We prefer the latter for residential projects since there usually are so many rooms and partitions involved that too much time would be wasted setting up the first two instruments. A water level, properly used, should be able to achieve an accuracy of 1/16" to 1/4", depending on the length, tubing diameter and time allowed to achieve each reading.

PHENOMENA PLAN

9) On a building that is being investigated for potential foundation problems, design and construction are already completed and are in the past. The performance may be assessed by the use of micro-elevations, but should be compared with existing negative phenomena, which could include any of the following and are located on the PHENOMENA PLAN:

a) Binding doors or "pie-shaped" gaps above door heads;
Obvious sloping of floors;

b) Diagonal or vertical masonry and sheetrock wall cracks;
Brick chimney leaning outwards away from main building;

c) Separations in ceilings and crown moldings;

d) Concrete slab or floor tile cracks;

e) Baseboard separations at the interior walls;
Floor tile pulling away from baseboards;

f) Presence of algae at the exterior, indicating super-saturated conditions exist on a permanent basis;

g) Existence of earth cracks next to the exterior walls, indicating that an extremely dry condition exists around the perimeter of the building;

h) Separation of wood trim from adjacent wall elements such as at windows, brick, stucco or sheet rock;
"Popped" nails in sheetrock walls;

j) 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;

k) Horizontal brick cracks just above the grade beam may indicate a differential settlement, even though there are no corresponding diagonal wall cracks;

l) Poor concrete and reinforcing placement or lack of curing;
"Soft" concrete with lack of good durability.

m) Corner sheetrock cracks at the top of windows are often NOT a negative phenomena, since almost all houses have this characteristic. The 45 degree corner separations at door jambs, as well as short horizontal sheetrock cracks at window or door heads, may not necessarily be an indication of negative foundation phenomena, and may only indicate normal wood stud shrinkage and shortening;

10) 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 itemized above. If these are not present, then consideration should be made that the building was originally cast out of level (see drawing SK-2 for an example).

GEOTECHNICAL AND SITE PROBLEMS

11) Many slab-on-grade problems could be easily avoided if normal geotechnical design criterias were met. In general, a majority of the settlement and/or differential movement problems associated with slab-on-grade foundations are due to factors including:

a) Flat back yards with poor drainage (poor siting);

b) Lack of thick select fill pad to help absorb movements between expansive clays and foundation system;

c) Lack of adequate compaction;

d) Lack of adequate embedment;

e) Flower bed reverse-drainage problems or presence of deep, water-retaining mulch or sand;

f) Lack of proper owner watering techniques.

S O L U T I O N S :

S I T E W O R K

12) Since poor siting and inadequate embedment deficiencies are found so often, one of the basic techniques used quite frequently in controlling excessive cracking in foundations is to desensitize the exterior grade beams from the effects of sudden moisture changes. This involves either adding additional slope to divert the water away from the building, including:

a) Extending downspout discharge away from the foundation;

b) Installation of French drain systems that allow surface water collection and dispersal into the street or storm sewer system using either natural drainage or sump pumps.

c) Installation of water barriers underneath the existing grade, such as 3 layers of polyethylene installed 12" below finish grade and 4' to 6' away from the building;

d) "Leaky pipe" installation to help maintain uniform moisture conditions around portions of the building.

CONTROL JOINTS

13) Often thermal cracks in brick walls are interpreted as differential movement problems. One method to control differential movement problems in buildings having brick veneer is to install vertical control joints at 20' maximum spacings at window and/or door openings where large areas of wall mass are missing.

14) Sometimes the foundation slopes are not enough to violate the Building Code parameters, yet cracking phenomena exists. Rather than justify drilled piers, with the accompanying loss of property value due to major foundation repairs, control joints may be strategically placed to divide long masonry walls into smaller panels so that the walls can absorb normal thermal or differential foundation movements without cracking. This is a well known "secret" in the apartment industry, where knowledgeable builders traditionally install alternate panels of brick and wood wall construction as a technique for reducing visible distortions in minimal foundation systems.

LEVELING PIERS

15) Using drilled leveling piers is a common technique to correct excessively sloping foundation systems. See drawing SK-10 for an example of placement. Pressed piles and helical anchors are also used for this purpose. Keep in mind that new leveling piers are always used to raise the foundation, but are never used to lower it! Some engineers have been known to place drilled builder's piers around the perimeter of the buildings with no piers on the inside. While this may be acceptable if the building was constructed during normal or dry conditions, if constructed during very wet site conditions, center settlement may eventually occur. Sometimes one end of the foundation is found to have heaved upwards from swelling clays next to deeply mulched flower beds or flat back yards (see appendix for examples). Does this mean that the part of the foundation that is working okay must now be raised to the level of the foundation that is not? We are of the opinion that leveling should be the LAST option used to correct a foundation, only after other methods have been ruled out or are not deemed adequate. We do not believe that piers are the only solution to level buildings, especially since the Appraisers will automatically devalue a property if foundation leveling has been done.

16) ADDITIONAL CONSIDERATIONS:

a) Mud-jacking: is okay on sands and silts, but should be used with care on expansive clays.
b) Voids under grade beams: are not needed on sands and silts, but should be used on highly expansive clays (or if clays on site are very dry at the time of leveling).
c) Correct elevation to raise a foundation? if 50% of foundation needs to be raised, should piers be placed on remainder that is presently performing satisfactorily? If builder's piers are present, should they be used to level or reused with new piers?

DISCUSSION OF BUILDER'S PIERS

17) There is an ongoing controversy between structural engineers regarding extending vertical pier reinforcement into the grade beams. Drilled footings that are used to repair existing foundations have vertical steel in the pier shafts that obviously cannot extend into the existing grade beams. A closer look at the problem will reveal that this type of assumption is at least partially erroneous and potentially offers the following problems:

a) If "edge lift" exists, the interior piers will function well, but the exterior piers will allow the swelling clays to lift the foundation upwards without offering any resistance.

b) If "center lift" exists, the exterior piers will function well, but the interior piers will allow the swelling clays to lift the foundation upwards without offering any resistance.

c) If excessive uplift occurs in either of the two above conditions, the vertical steel may be insufficient to resist it, and will break or pull out for lack of sufficient bond. For this reason, when new leveling piers are used on foundations built having existing builder's footings, the forces on the new piers is often sufficient to break the existing pier steel without needing to cut it first.

d) Therefore, we conclude that for <u>small</u> upheaval conditions, the vertical steel will help keep the foundation level. If there is no vertical steel, the foundation instantly becomes a "floating" system once the grade beams are lifted off the drilled footings by swelling soils, since the deeper footings would no longer be engaged or serve any purpose whatsoever. If the grade beams were placed under the load bearing walls (as they should have been), then there is no foundation system continuity, and "hinges" will develop at every location where the grade beams offset. The grade beams should be able to span even with a reversal of load direction, since continuous top and bottom steel is usually provided. The slab steel can also span even with a reversal of load direction, since the steel is always provided in the middle of the slab. (Wire mesh should NEVER be used as slab reinforcement, since it is almost impossible to achieve center placement, irregardless of the engineer's specifications to the contrary).

e) For serious upheaval conditions, vertical steel may be unable to hold the foundation in proper vertical alignment due to the large forces involved. Thus, the foundation would become a "floating" system anyway, and failure would subsequently result. We conclude that during the time period between a "small" foundation upheaval and a "large" one, satisfactory foundation performance could easily be maintained by the presence of some limited vertical steel. For initial upheaval movements, we recommend that 3-#4 vertical bars be extended 12" to 18" into the grade beams.

C H E C K I N G   T E N D O N   S T R E S S E S

18) How do we know if post-tensioned tendons have been stressed? A clue to stressing not having been done is an unusually high incidence of shrinkage cracks, especially on the sides of the exterior grade beams. Chipping out at least two live end anchorages on each side and inspecting the shims, one can see if they are properly seated or not. If it is not clear whether or not they are, then the tendons should be tested to 50% design stress using a calibrated hydraulic ram jack. If the shims do become not unseated, it may be assumed that at least 50% of the design tensile force is present. We do not recommend that the full design force be applied, since if the gripping shims slip, the cable end will end up several inches into the grade beam and very costly repairs will then be necessary.

H Y B R I D   S L A B   S Y S T E M S   (T H E   B R I D G E)

19) In example SK-23 in the appendix, swelling soils caused severe edge lift damage to the interior slab of an Office Building slab, although the grade beams were held in place by drilled piers and did not move as much. The solution involved building an isolated slab system so that perimeter moisture changes would not affect the first 15′ of the perimeter of the slab-on-grade system. An alternate (more economical but less effective) method proposed shows a stiffened slab with tapered grade beams to achieve a similar result.

S O I L   S T A B I L I Z A T I O N

20) Available soil stabilization methods for existing buildings:

- a) Condor SS injection (an ionization treatment for clays)
- b) Lime injection
- c) Water barriers
- d) Polyurethane injection
- e) Improved moisture control using deep sump pumps
- f) Barriers at pipe trench entrances to foundation system
- g) "Leaky pipe" systems

S P E C I A L   P R O B L E M S

21) Pipe trenches have traditionally been installed using bank sand as a backfill material. Sand is dumped into the open trench and water-compacted to achieve the necessary Proctor density. We have encountered numerous instances, particularly on apartments and commercial buildings, where these same pipe trenches have become a channel for transmitting excessive water into the interior of the building, and heaving of the clay soils and cracking of the interior finish materials have resulted. Although seldom addressed by structural engineers, care should be taken to specify that the ends of pipe trenches be sealed off at the perimeter of the foundations. Suggested cures to this problem include water barriers, clay fill, French drains, polyurethane injection or other methods.

DESIGN DEFICIENCIES

22) In regards to design of "floating" slab-on-grade foundation systems, we recommend that full beam continuity, or an "egg-carton" grid layout, be maintained along both major axis of the building, regardless of the actual bearing wall configuration. This implies that engineers do not extend beams into the building, then stop and move the beams at bearing wall offsets. In many instances, engineers will place grade beams under load bearing walls, and the foundation system appears as if it were meant to be supported by drilled piers, but the piers were then omitted. These foundations offer little system strength to transmit major grade beam bending moments across the axis of the building, since only torsional resistance is available at the offsets. Thus wherever offsets occur, a "hinge" is formed, and foundation rotation and deflection becomes a possibility at that location.

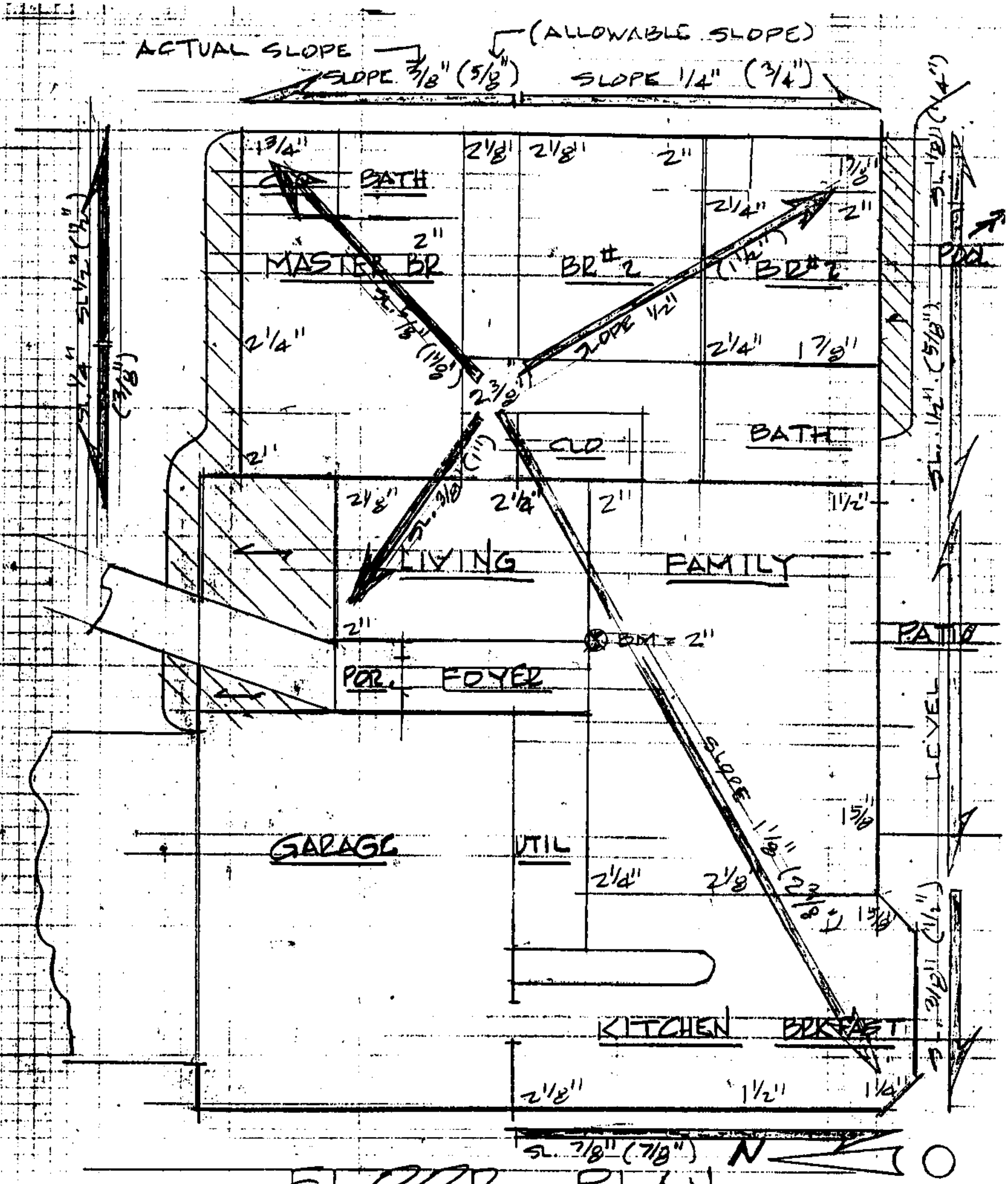
23) Another common design problem is lack of adequate top and bottom mild steel reinforcing in post- tensioned foundation systems. Quite often grade beams up to 24" in depth will be used with only one tendon placed approximately 8" below the top of the slab. No responsible structural engineer would ever consider placing the main reinforcing on a 24" deep beam 16" above the bottom if the system were, say, on the second floor of a concrete-framed building. However, this is frequently used for residential and apartment foundations in the Houston area. It is essential that potential tension (bending) in the bottom of the beam be satisfied by providing additional mild reinforcing steel. This is already recognized by the Houston Building Code, which requires extra mild steel be provided at the top and bottom extremities of post-tensioned grade beams. Nevertheless, engineering offices are still churning out plans in the Houston area having only post-tensioned tendon reinforcement. We recommend that 2-#5 conventionally reinforced bottom bars be provided to enable bending in both directions (positive and negative) rather than merely the center lift furnished by tendons when installed at the slab level only. This also serves as temporary reinforcement against shrinkage until the tendons are stressed (usually 5-10 days after pouring the concrete).

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

A P P E N D I X

SAMPLE FOUNDATION PROBLEMS AND CORRECTION TECHNIQUES

EXAMPLE OF CENTER LIFT CONFIGURATION ON EXPANSIVE SOIL - Drawing SK-1

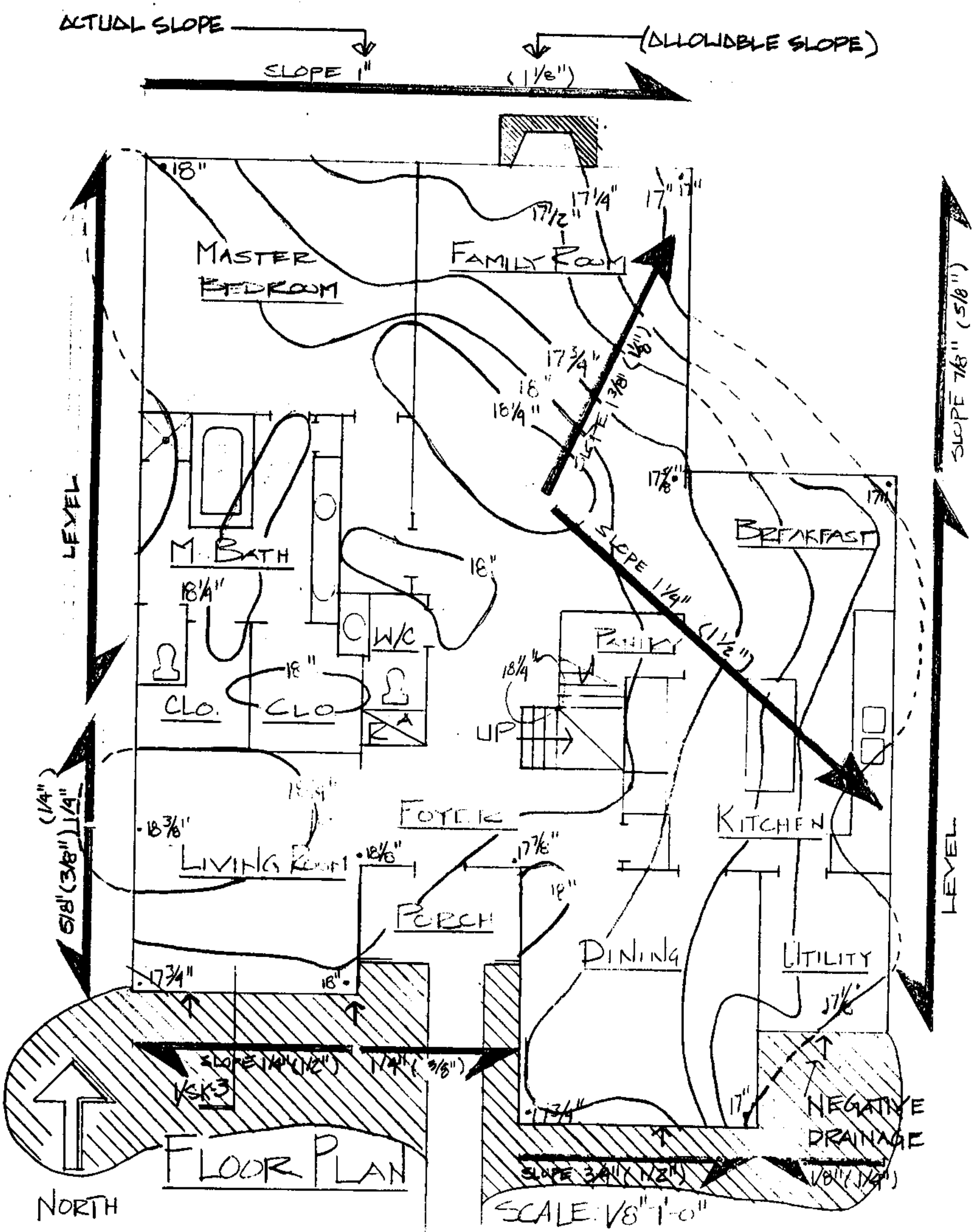


FLOOR PLAN

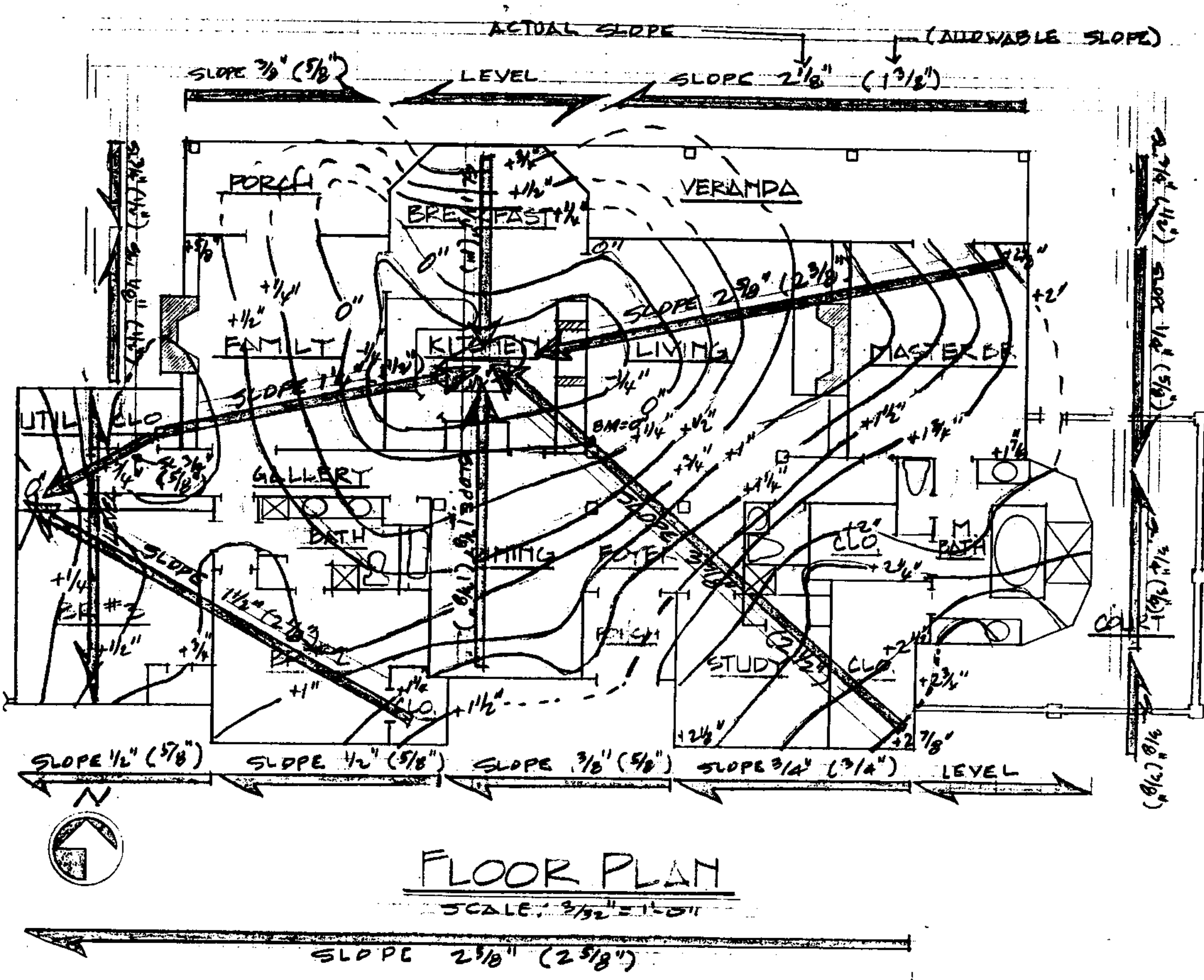
SCALE: APPROX 1/8" = 1'-0" +/-

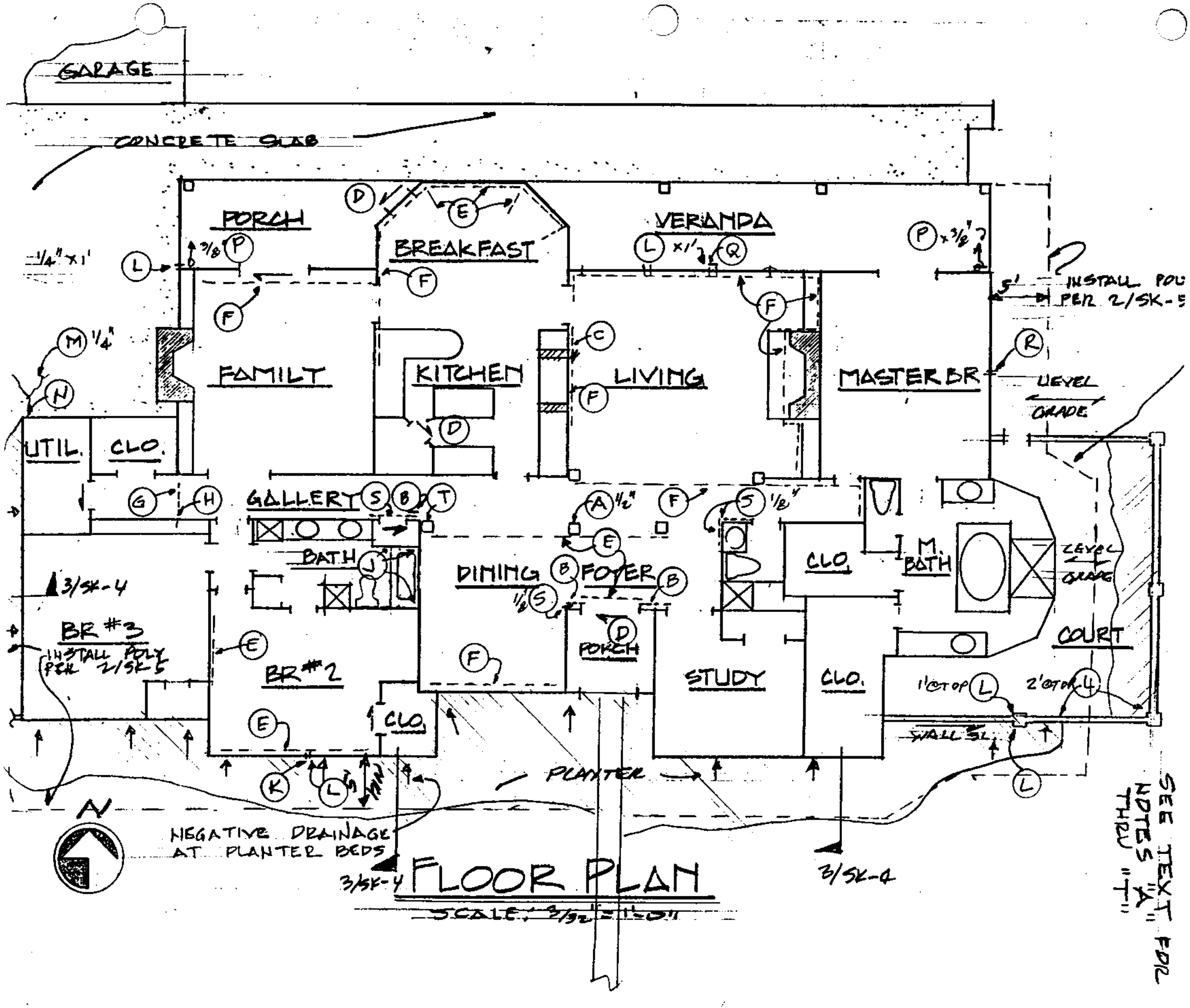
EXAMPLE OF CLASSIC "LEVEL" SLAB CONFIGURATION - Drawing SK-2

SHOWING "PUDDLES" AND MINOR CENTER LIFT



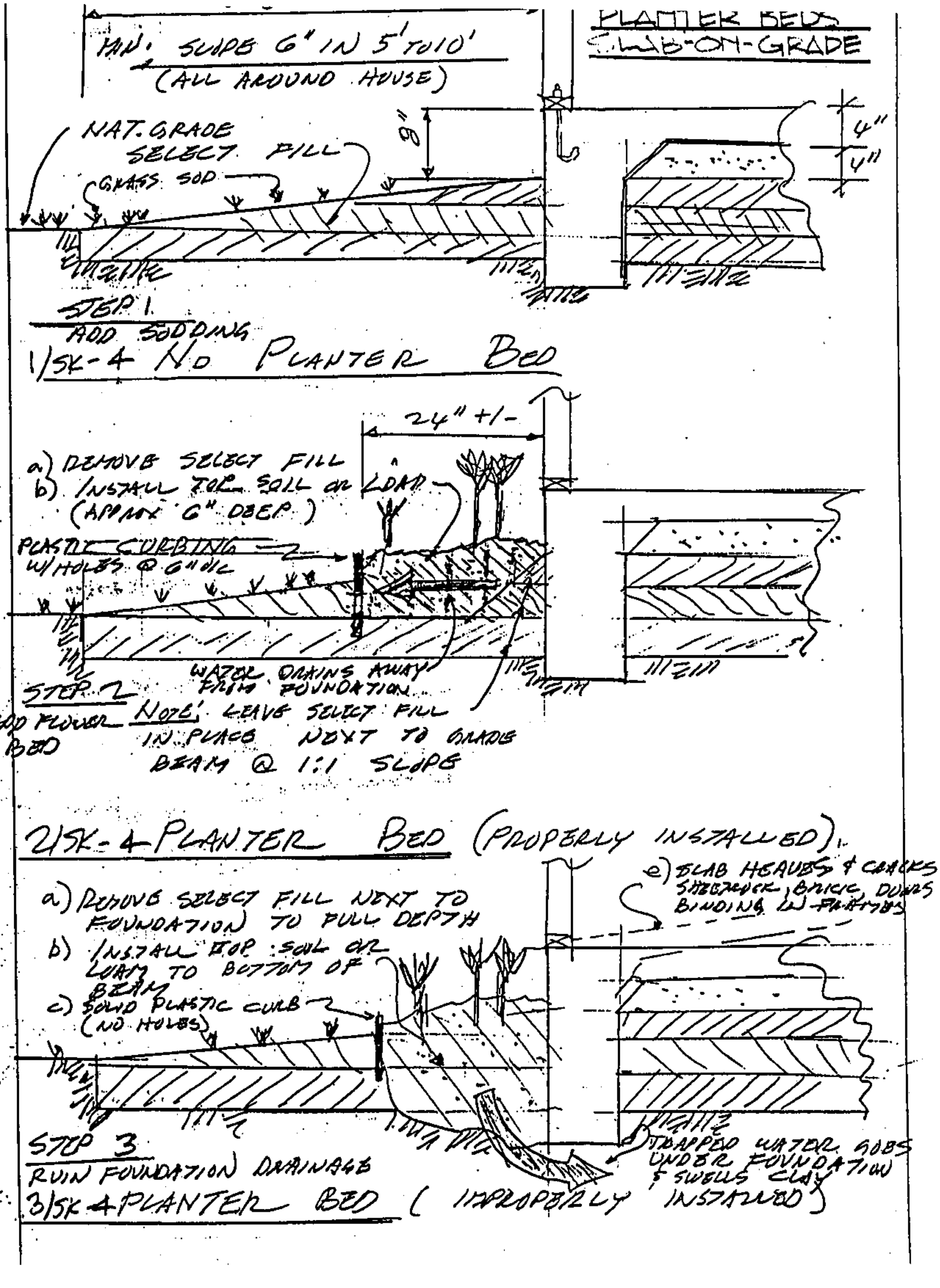
EXAMPLE OF EDGE LIFT CONTOUR PLAN - Drawing SK-3





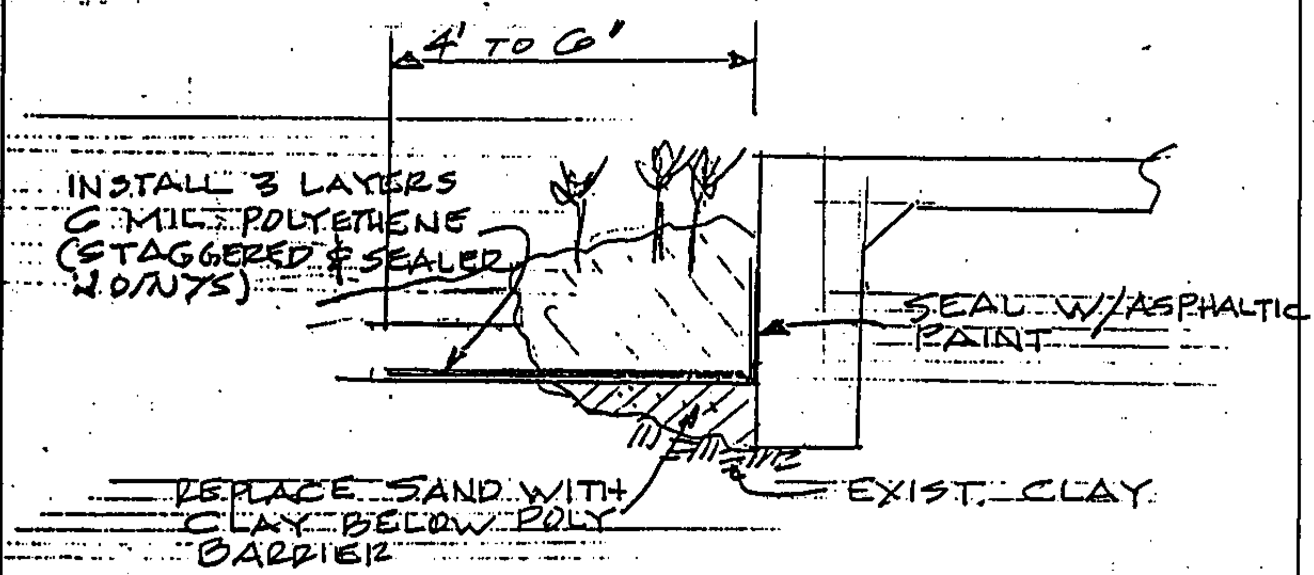
EXAMPLE OF EDGE LIFT PHENOMENA PLAN - Drawing SK-4

EXAMPLE OF EDGE LIFT - Drawing SK-5
INITIAL GRADING AND PROPER FLOWER BED INSTALLATION
IMPROPER FLOWER BED INSTALLATION

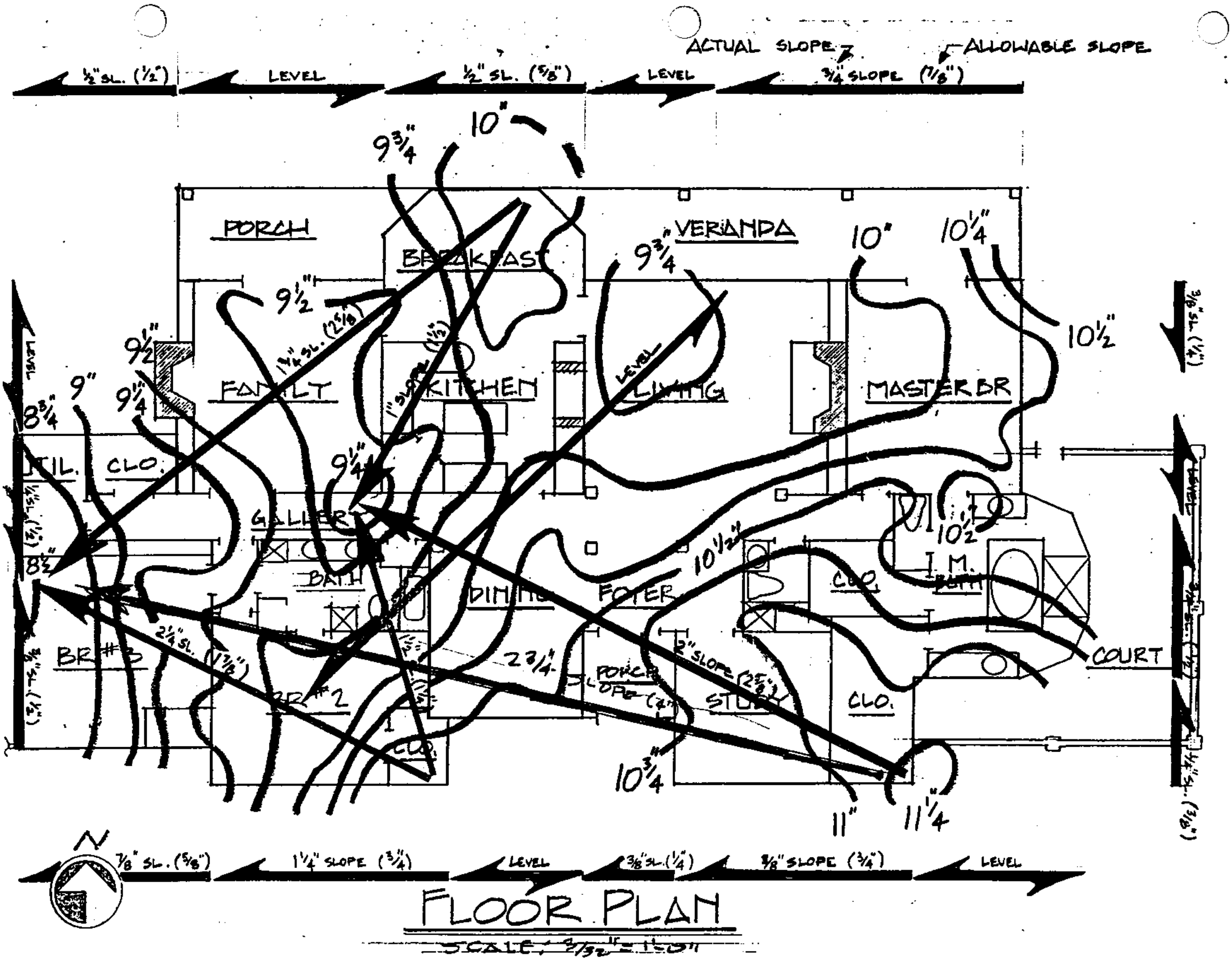


EXAMPLE OF EDGE LIFT - Drawing SK-6

CORRECTED FLOWER BED INSTALLATION USING POLY BARRIER



2/SK-5 PLANTER BED (CORRECTED INSTALLATION)

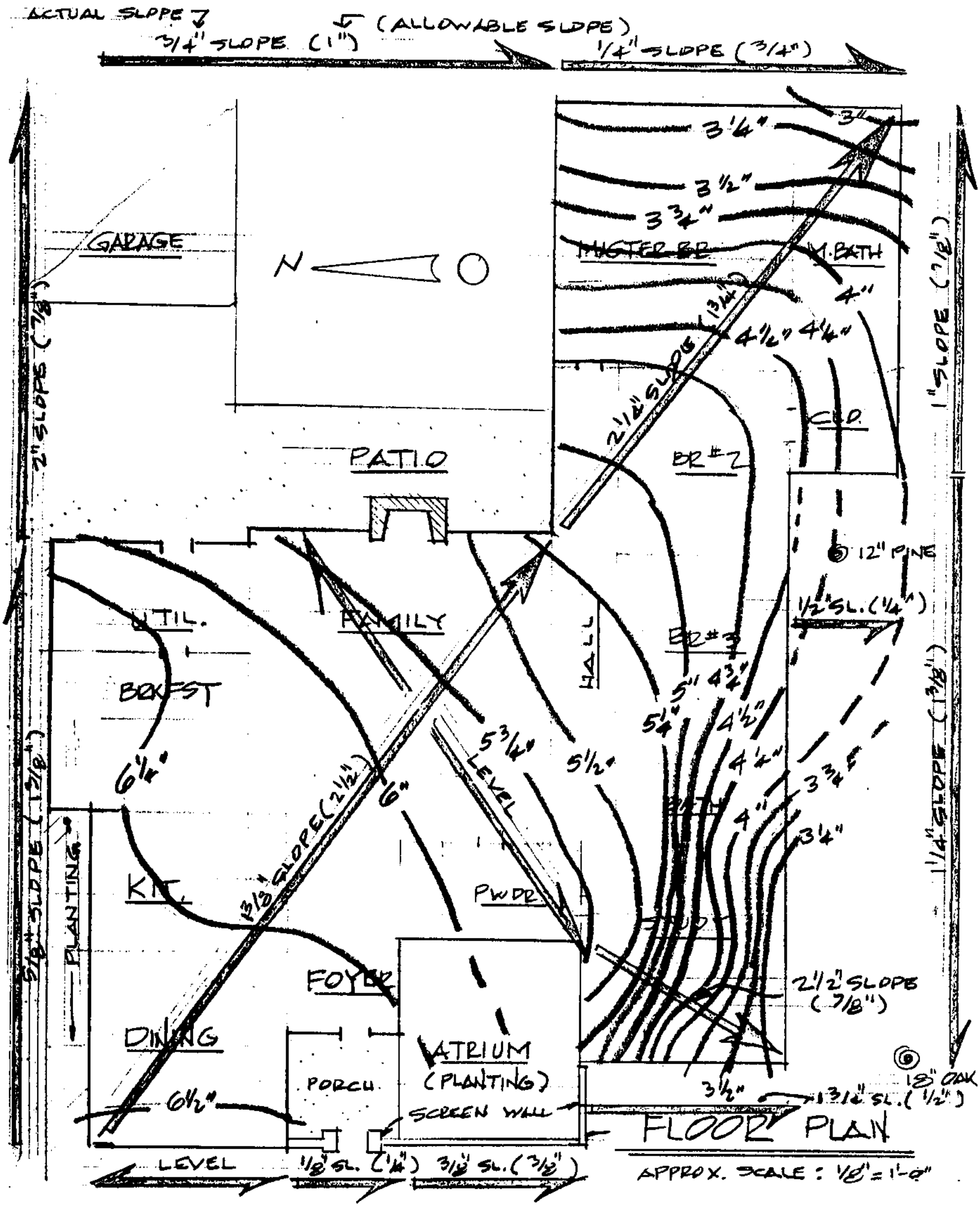


EXAMPLE OF CORRECTED EDGE LIFT CONDITION
ONE YEAR AFTER DRAINAGE CORRECTIONS
(SEE SK-3 FOR INITIAL CONDITION)

- Drawing SK-7

EXAMPLE OF EDGE COLLAPSE (CLAYS) - Drawing SK-8

CONTOUR PLAN



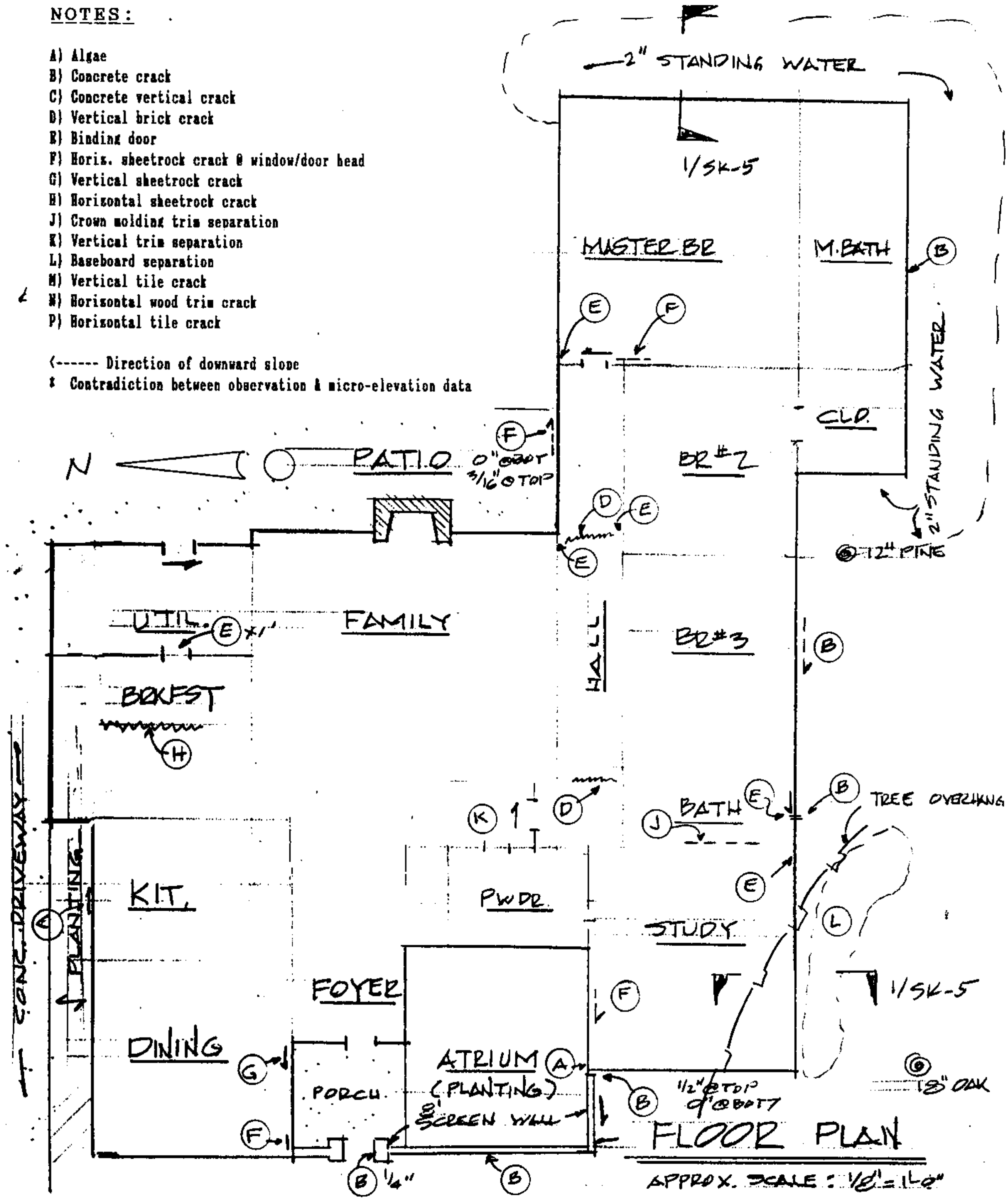
EXAMPLE OF EDGE COLLAPSE (CLAYS) - Drawing SK-9

PHENOMENA PLAN

NOTES:

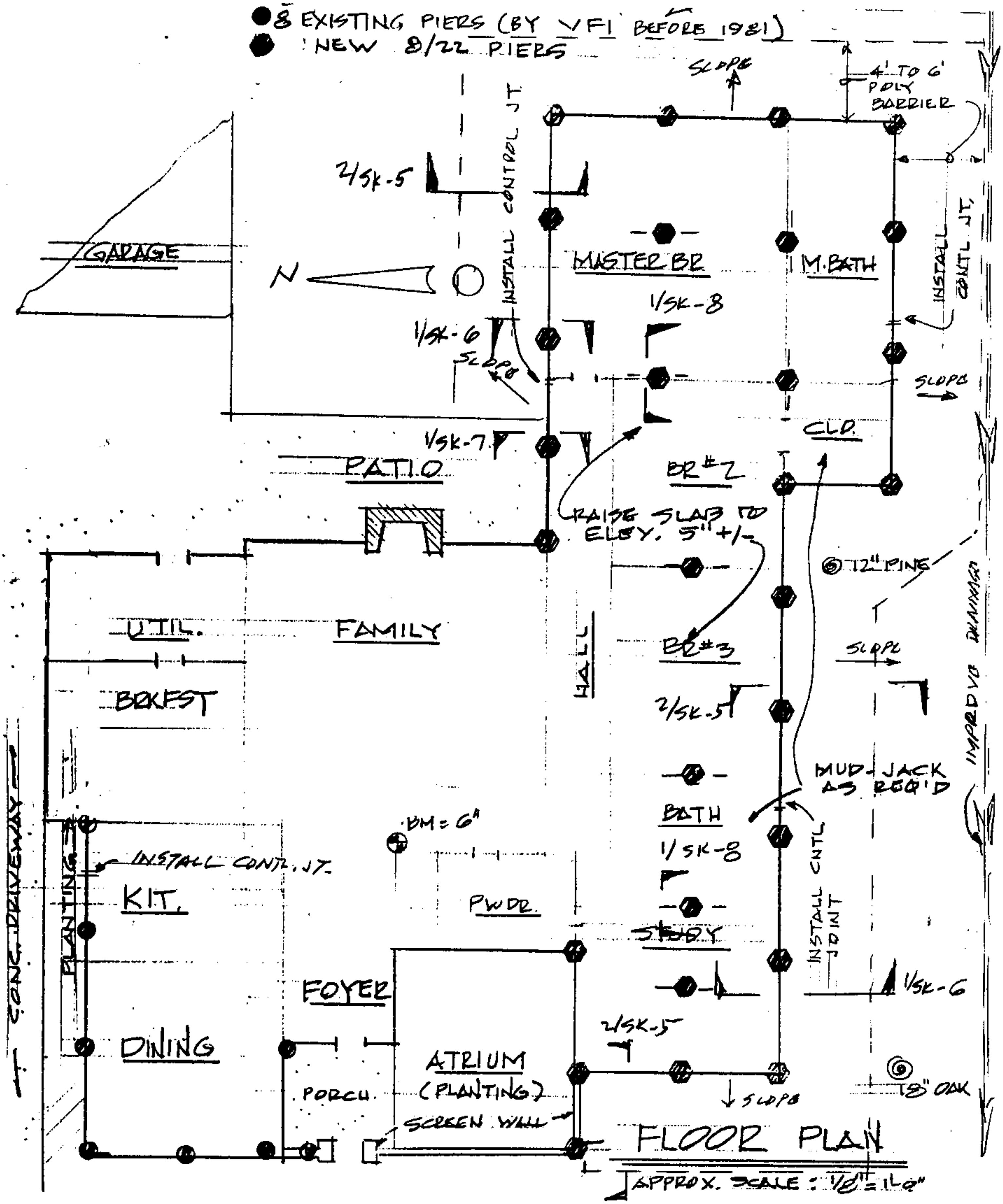
A) Algae
B) Concrete crack
C) Concrete vertical crack
D) Vertical brick crack
E) Binding door
F) Horiz. sheetrock crack @ window/door head
G) Vertical sheetrock crack
H) Horizontal sheetrock crack
J) Crown molding trim separation
K) Vertical trim separation
L) Baseboard separation
M) Vertical tile crack
N) Horizontal wood trim crack
P) Horizontal tile crack

<------ Direction of downward slope
* Contradiction between observation & micro-elevation data



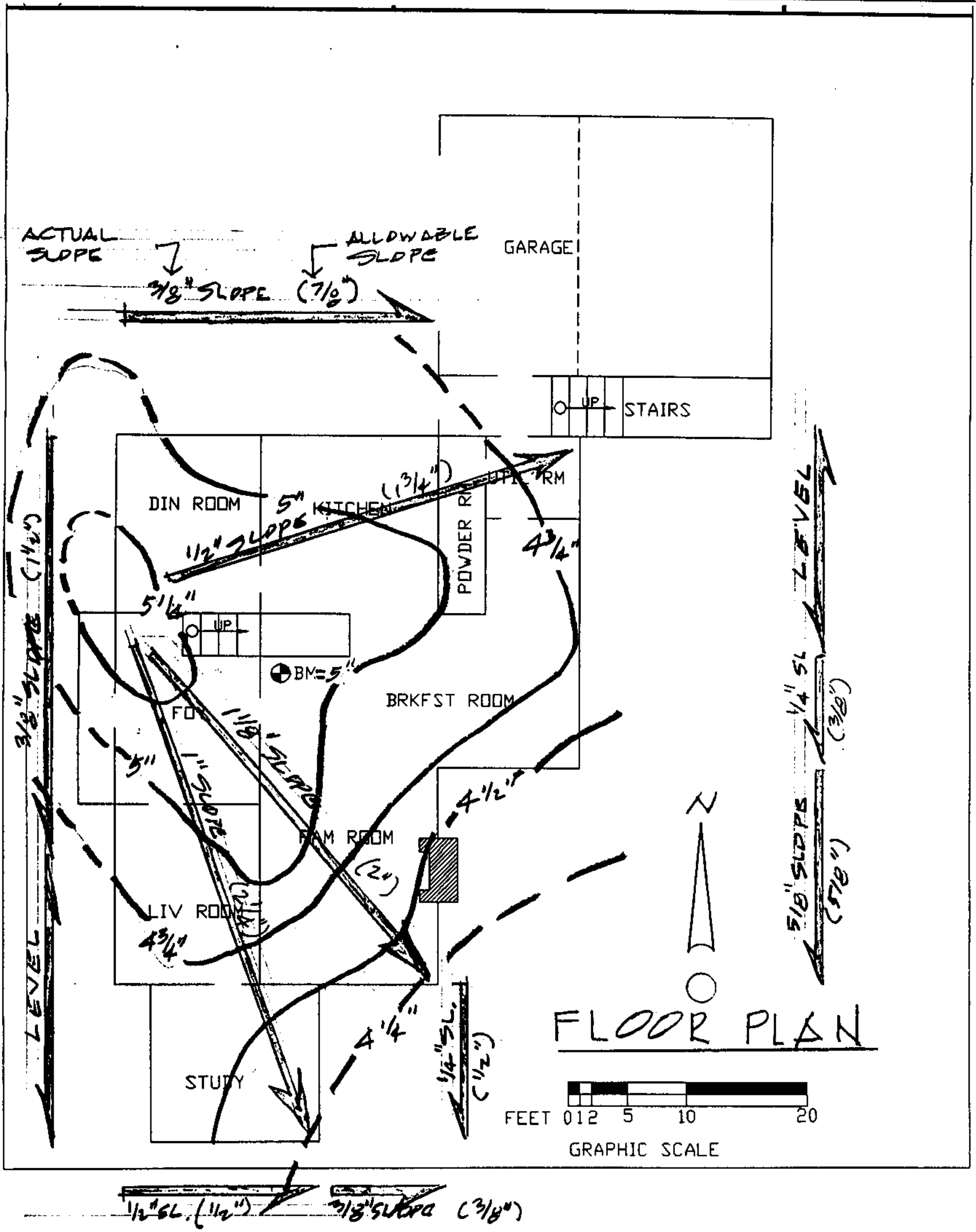
EXAMPLE OF EDGE COLLAPSE (CLAYS) - Drawing SK-10

LEVELING PIER PLAN



EXAMPLE OF EDGE COLLAPSE (SILTS) - Drawing SK-11

CONTOUR PLAN

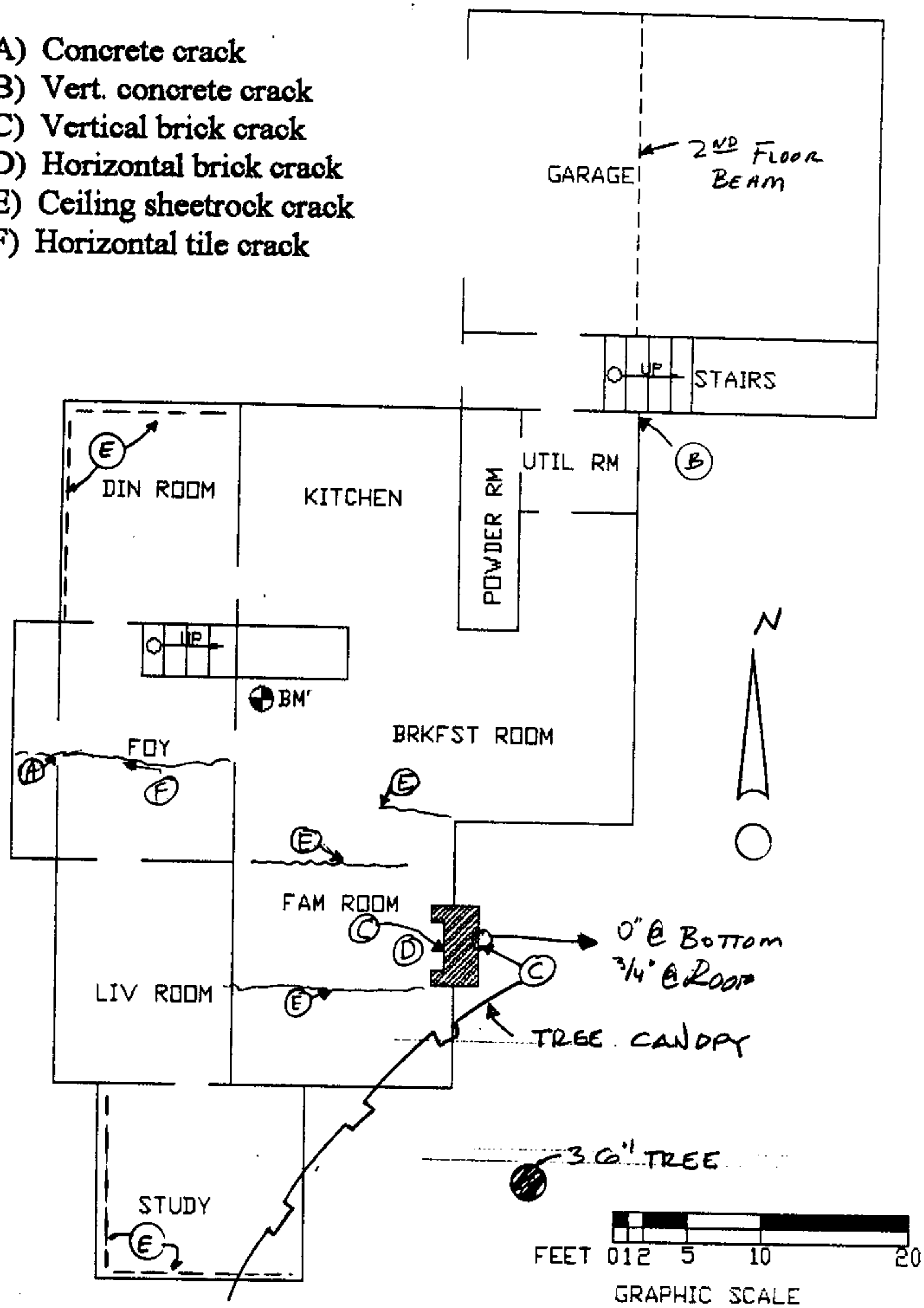


EXAMPLE OF EDGE COLLAPSE (SILTS) - Drawing SK-12

PHENOMENA PLAN

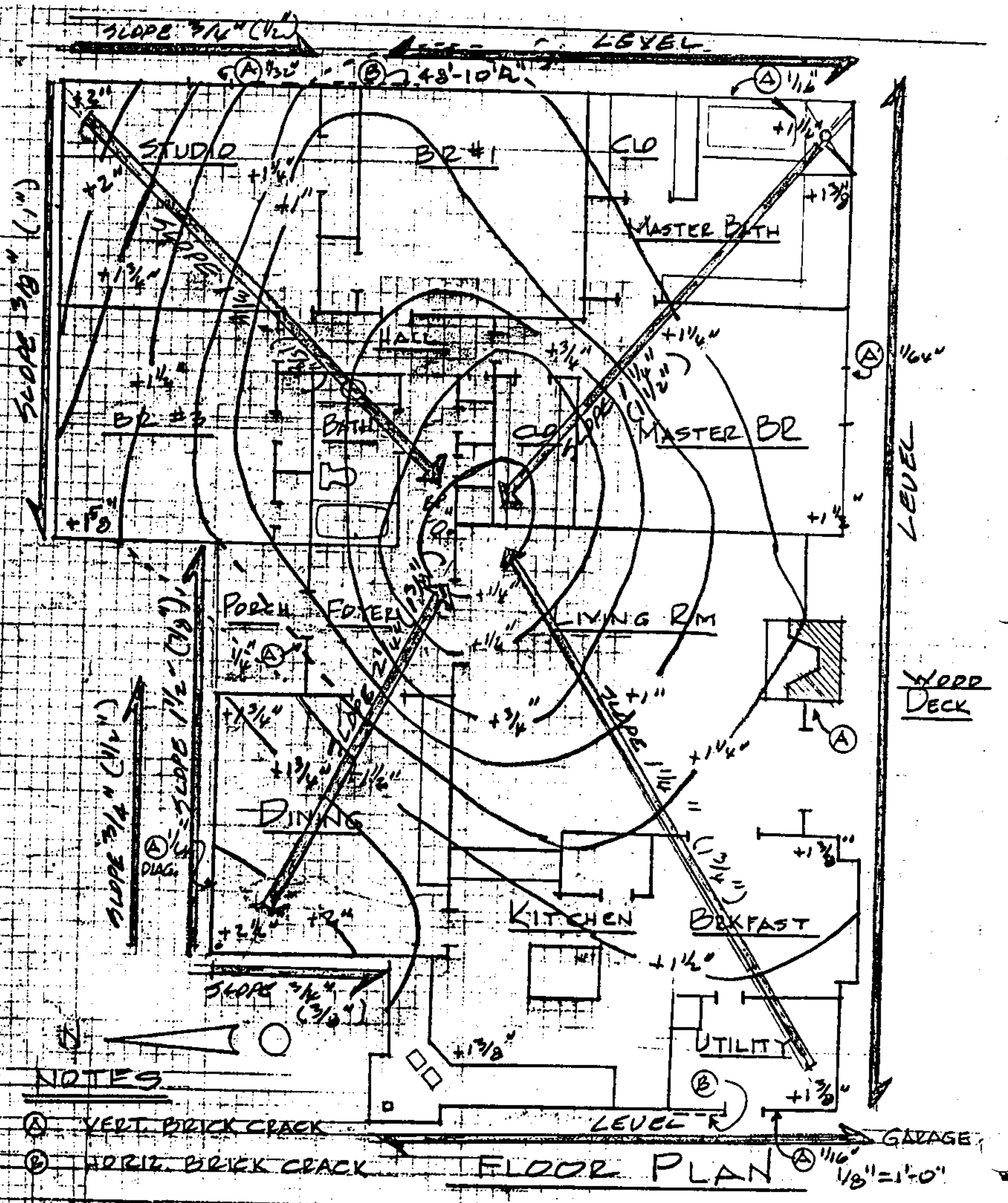
LEGEND:

A) Concrete crack
B) Vert. concrete crack
C) Vertical brick crack
D) Horizontal brick crack
E) Ceiling sheetrock crack
F) Horizontal tile crack



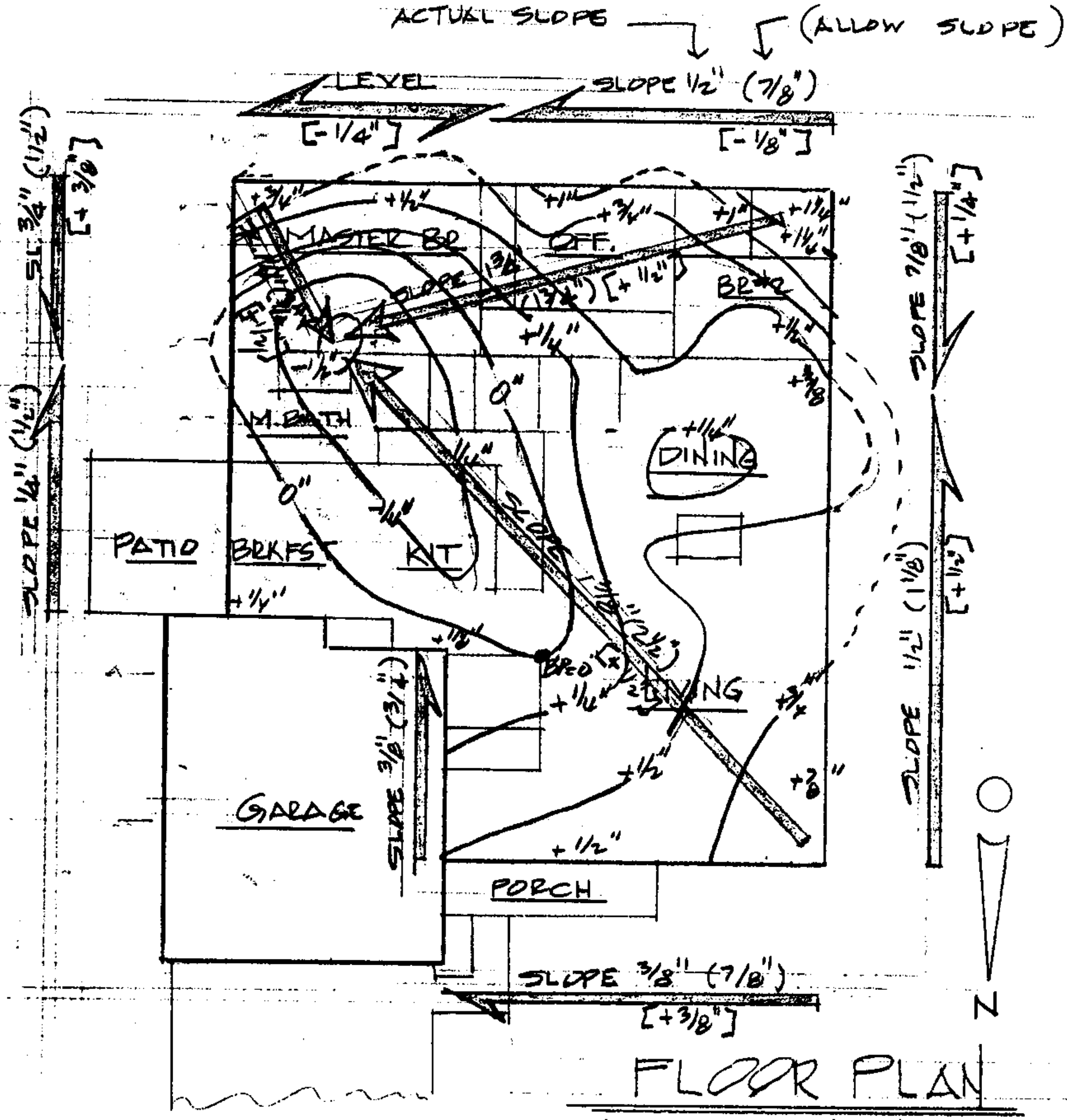
CENTER COLLAPSE (SYMMETRICAL) - Drawing SK-13

CAUSED BY LACK OF ADEQUATE COMPACTION



CENTER COLLAPSE (NON-SYMMETRICAL) - Drawing SK-14
PROBABLE CAUSE IS LACK OF UNIFORM INTERIOR COMPACTION
(PLUS LACK OF ADEQUATE DRAINAGE IN BACK YARD)

[+1/2"] + = INCREASE IN SLOPE SINCE SURVEY OF 6/14/90
- = DECREASE - DO -



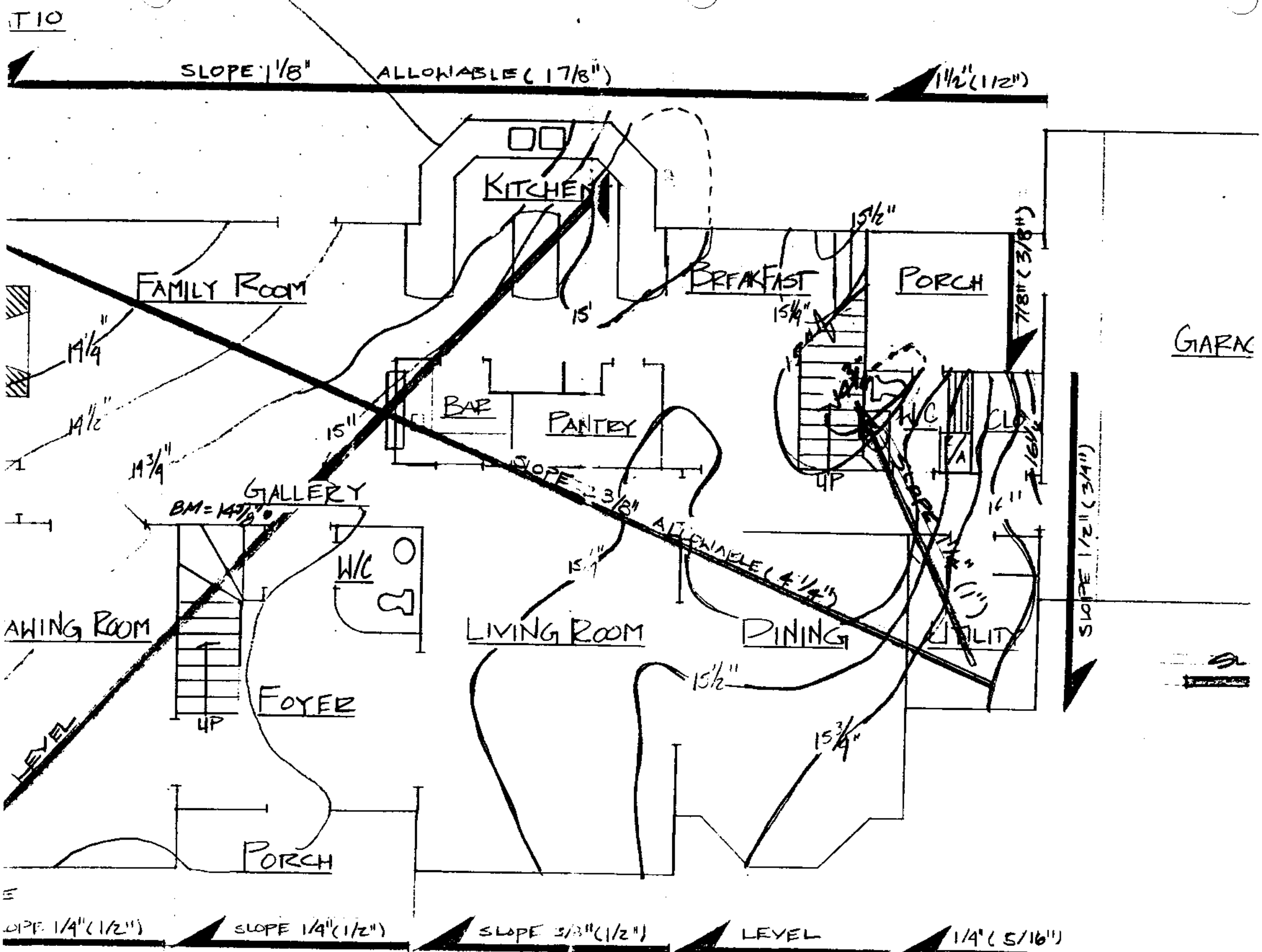
FLOOR PLAN

SCALE: 1" = 10'

DRILLED FOOTING COLLAPSE

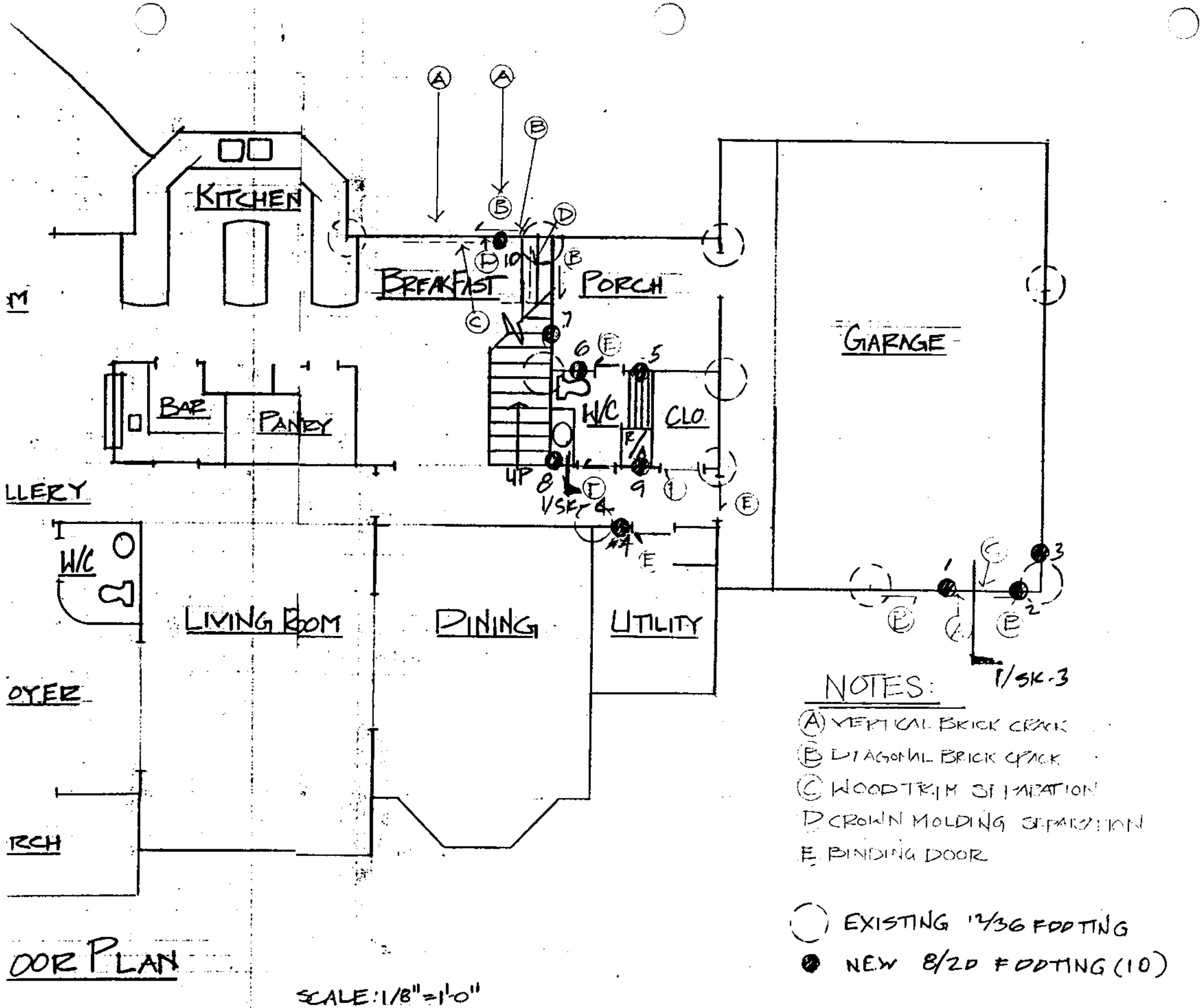
CONTOUR PLAN

- Drawing SK-15



FLOOR PLAN

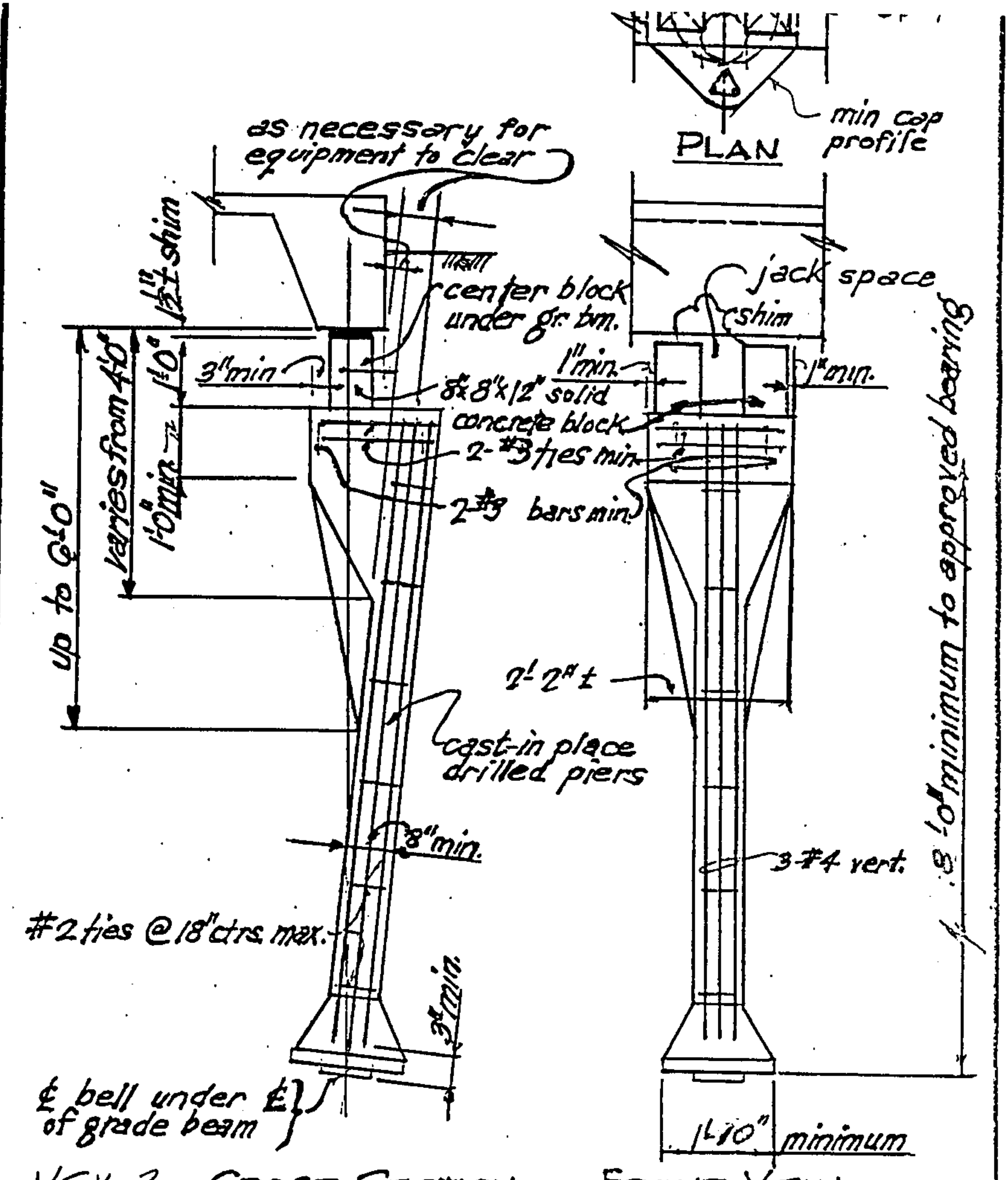
SCALE: 1/8" = 1'0"



DRILLED FOOTING COLLAPSE

PHENOMENA & LEVELING PIER PLAN

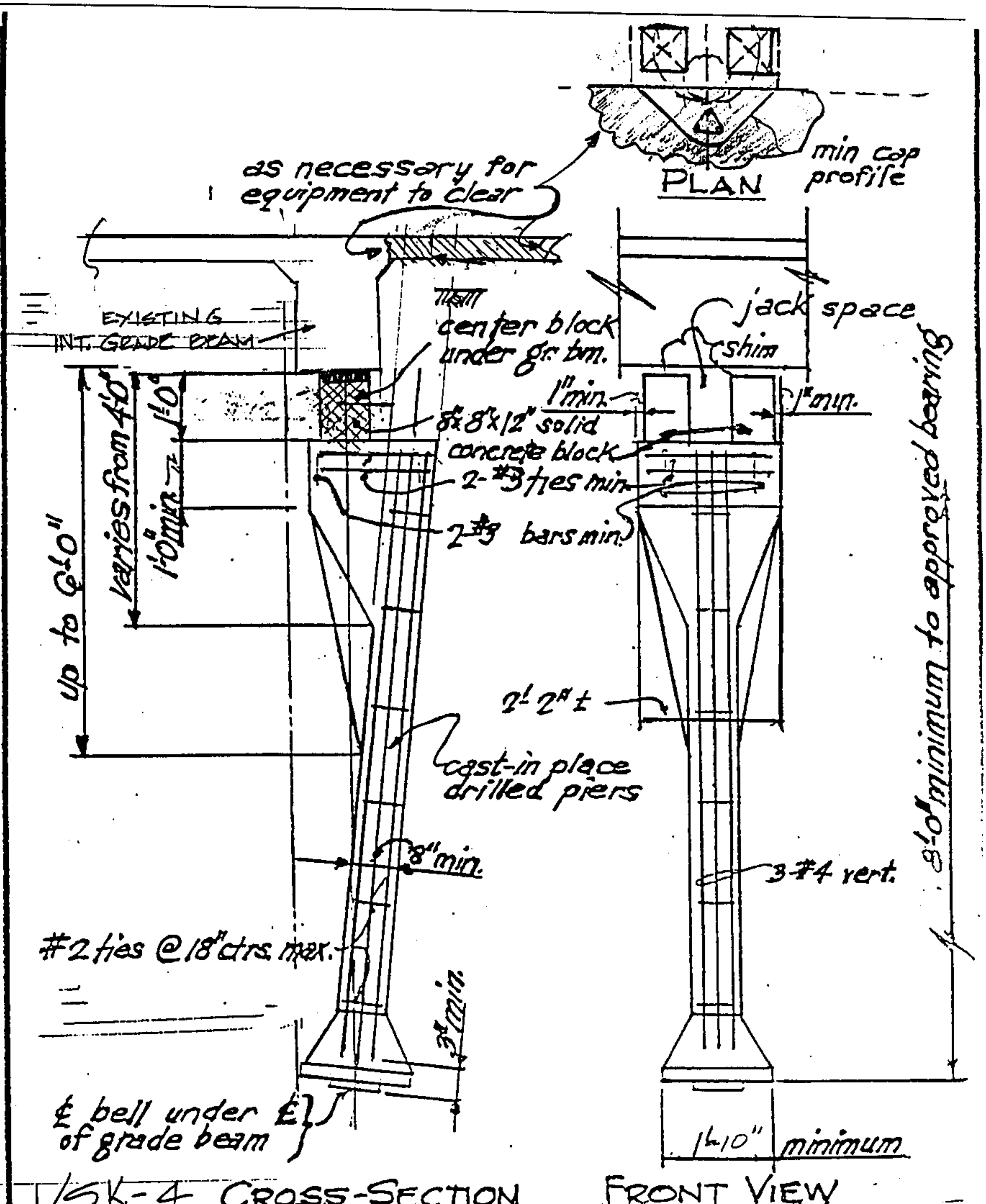
- Drawing SK-16



1/SK-3 CROSS-SECTION

FRONT VIEW

TYPICAL GRADE BEAM LEVELING DETAILS



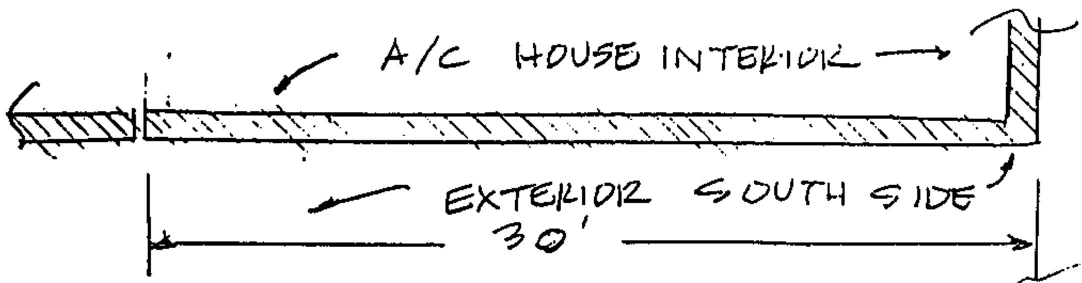
TYPICAL GRADE BEAM LEVELING DETAILS

TYPICAL CORNER GRADE BEAM THERMAL CRACK - Drawing SK-19

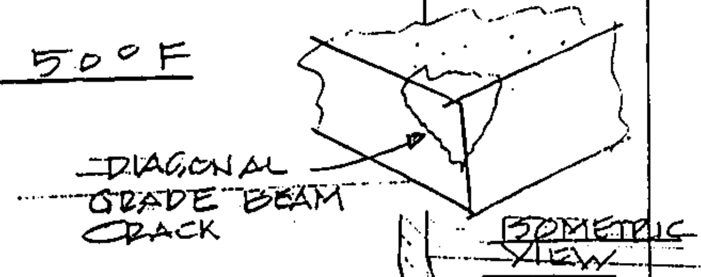
CALCULATIONS INCLUDED FOR 30' LONG MASONRY WALL

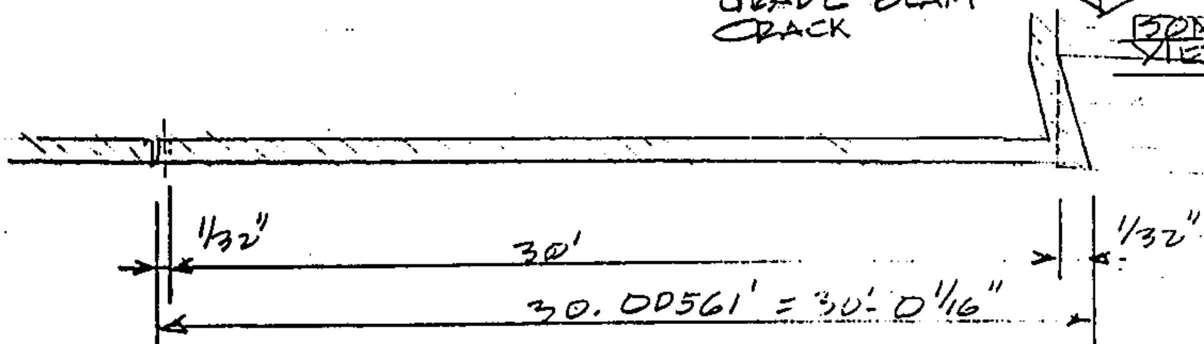
CHECK BRICK WALL 30' LONG BETWEEN ENDS

COEFF. OF EXPANSION OF BRICK = .00034 / 100 DEGREES



CONDITION AT 50°F





CONDITION AT 105°F

$$\text{CHANGE IN LENGTH} = \frac{.00034 \times (105-50) \times 30'}{100} = .00561'$$

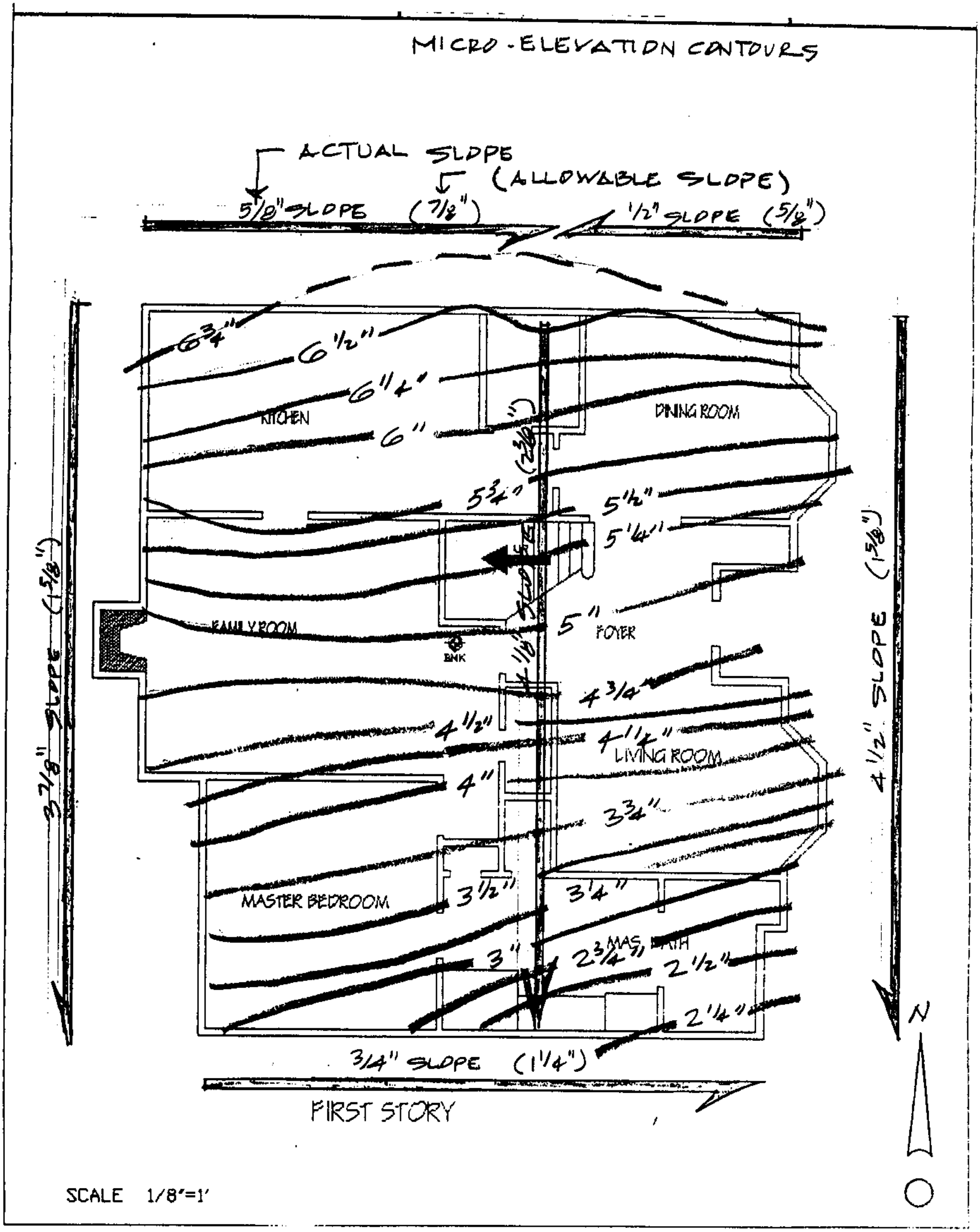
$= 1/16"$

$= 1/32"$ PER END

THE CONCRETE TEMPERATURE REMAINS RELATIVELY CONSTANT, SINCE THE EARTH AND AIR CONDITIONING SERVE TO PREVENT EXPANSION OF THE GRADE BEAM.

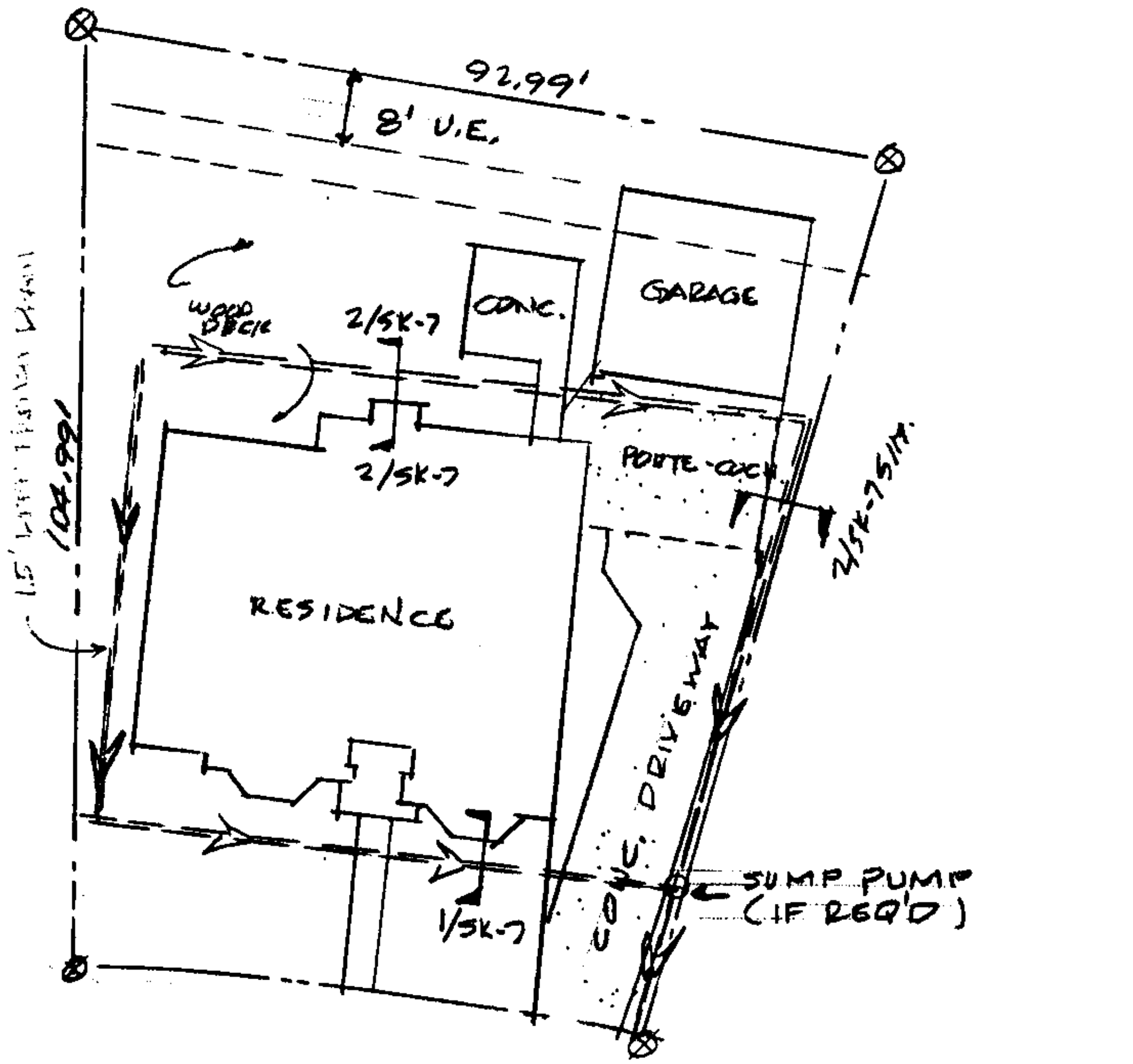
EXTREME TILTING FOUNDATION CONFIGURATION - Drawing SK-20

NOTE: UNIFORM CONTOURS INDICATE LACK OF ANY DIFFERENTIAL MOVEMENT



EXTREME TILTING FOUNDATION CONFIGURATION - Drawing SK-21

SITE CORRECTION WORK FOR BROKEN WATER LINE (OR WATER BEARING STRATA)

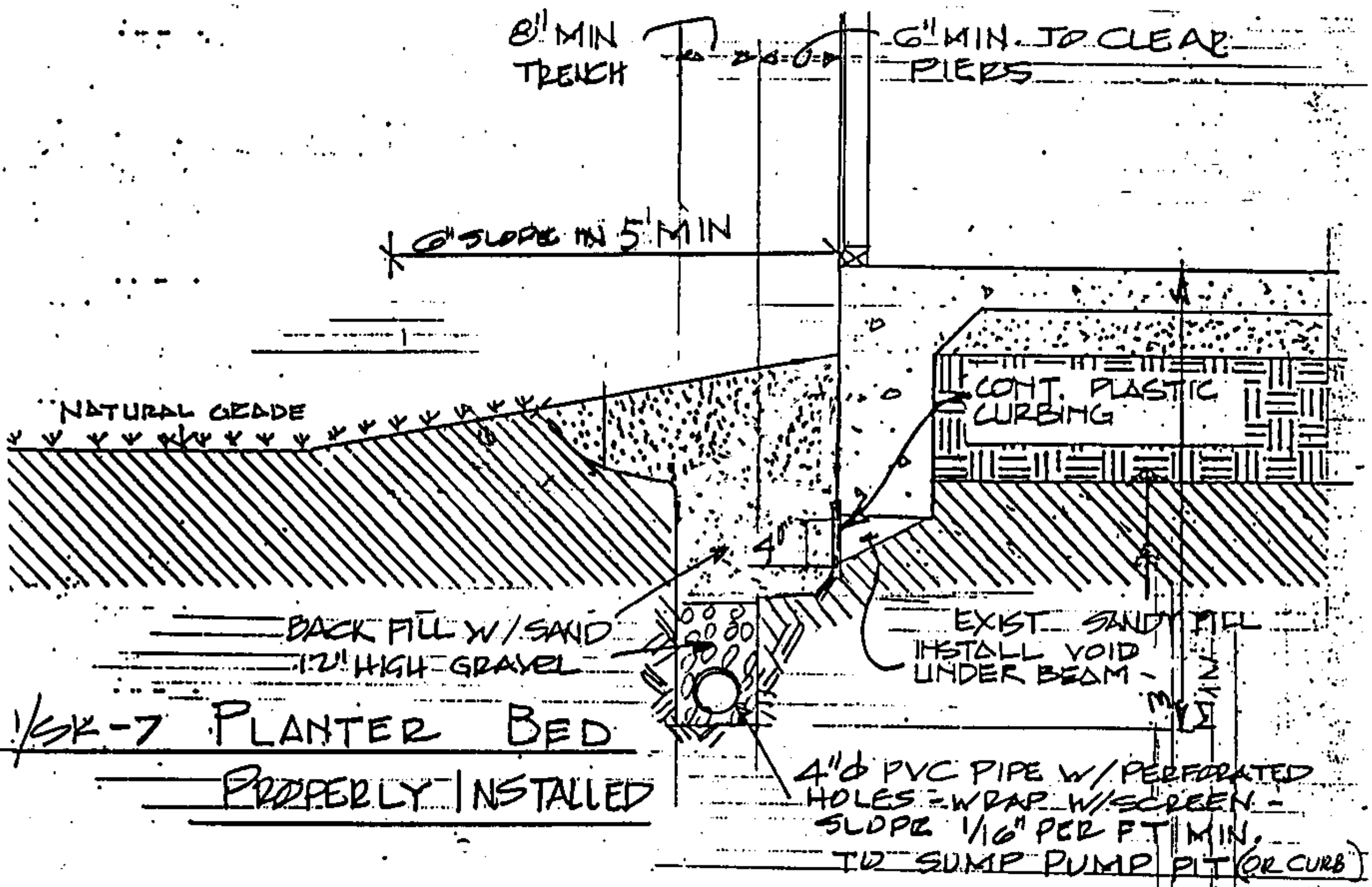


SITE PLAN

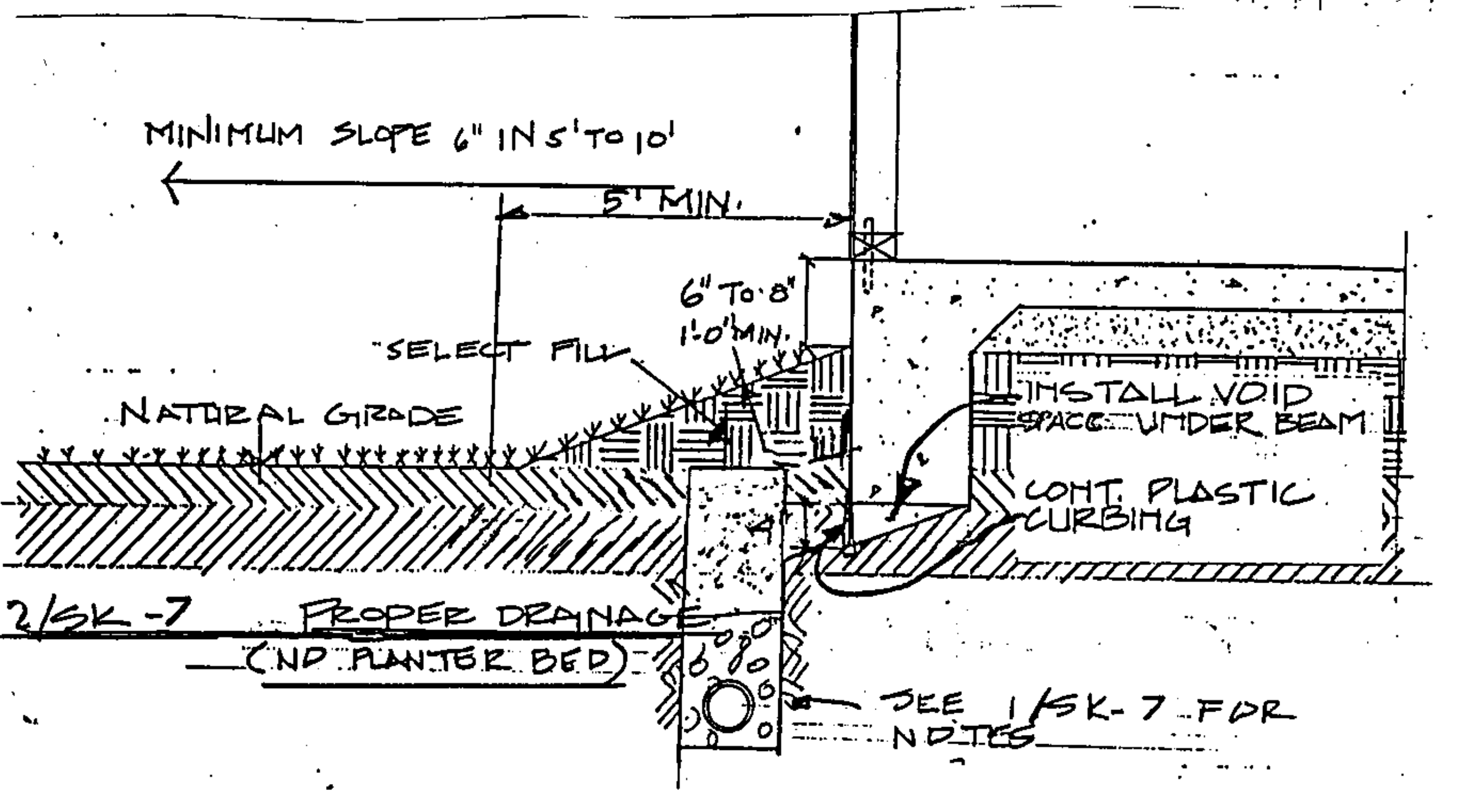
1" = 20'

EXTREME TILTING FOUNDATION CONFIGURATION - Drawing SK-22

CORRECTION DETAILS FOR SPECIAL FRENCH DRAIN SYSTEM

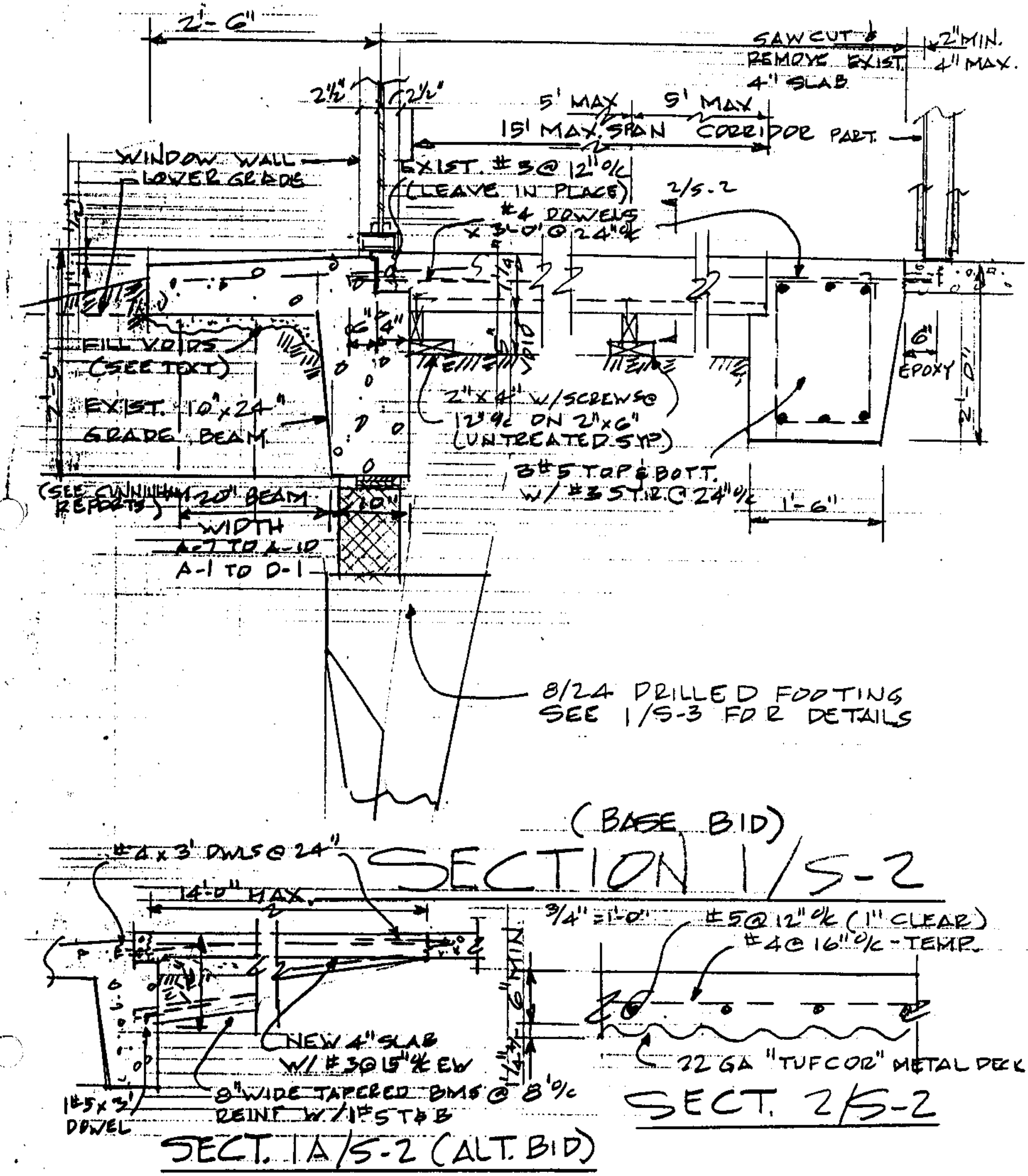


1/SK-7 PLANTER BED PROPERLY INSTALLED



2/SK-7 PROPER DRAINAGE (NO PLANTER BED)

EXAMPLE OF "BRIDGE" (FOR COMMERCIAL BLDG) - Drawing SK-23
(ALTERNATE SYSTEM "1A" SHOWN ALSO)
ISOLATION OF 15' OF PERIMETER SLAB FROM EXTERIOR WALLS



SOILS-STRUCTURE INTERACTION SEMINAR
FOR RESIDENTIAL AND LIGHT COMMERCIAL
FOUNDATIONS

June 16, 1993

John Ruskin said: When we build, let us think that we build forever. Let it not be for present delight nor for present use alone. Let it be such work as our descendants will thank us for and let us think, as we lay stone on stone, that a time will be held sacred because our hands have touched them and that men will say, as they look upon the labor and wrought substance of them, "See!. This our father did for us".

In my builder point of view:

I think the building industry has done a fantastic job providing housing and millions of jobs in this industry. Occasionally, a mistake will be made. We will not deny that. Builders today spend small fortunes preparing to build a home. They are constantly trying to learn more as you are today. Continuing education is a must in our business.

After the exciting part of signing the contract and securing building permits, etc., we start the slab process.

We builders strive to provide more for less and sometimes that gets us into trouble.

You've heard the statement, "a dishwasher is a dishwasher is a dishwasher". Well, that's not true, and neither is the statement, "a box is a box is a box". What's this got to do with housing? Today, all we seem to talk about is price per sq. ft.

Compared to what? One 2,000 sq. ft. box is not the same as the next 2,000 sq. ft. box. The builder who constructs his foundations and frames to structural designs and codes spends more money than the builder who does not, and the box is no longer an equal box.

Justification in appraisals should reflect the designs and costs, but they do not. And, as Paul Harvey would say, "You know the rest of the story".

We all know the first step in foundation prep is the proper scraping of the pad site and cutting the contour swells in for future Class "A" drainage requirements. In some cases, the lot scrape is not **adequate**, the **minimum** of 2" or **optimum** 4" of organic raw materials was not **removed** from the pad site. We also did not have the beams cut sharp and clean. If beam steel was used, it was not a minimum of 3" off bottom of beam, (Beam steel does not prevent cracks. It comes into play after the crack.)

It is extremely important to follow the engineer's designed beam details, cables and steel placements. He and he alone has determined the loads calculations and displacements. If the design shows 4'-4" O.C. for the cable placement, that's what it means. Not 5' O.C.

Placing of concrete:

Adding water to the pre-mixed load at the job site is biggest problem we face today. The first thing the concrete contractor says to the driver is "Put 10 gallons in and we'll look at it." Most concrete arrives on the job site with the required slump of 4 to 5", which is the ideal house slab mix. Water added at the job site accounts for most of the surface <u>scaling</u>, <u>dusting</u>, <u>crazing</u> and <u>hairline</u> <u>cracks</u>, which are <u>cosmetic</u> but they create problems for the builder with his homebuyer. Although these cracks do not affect the integrity of the foundation in our Houston climate, they could in the hard freeze areas of the northern climates.

In my 28 years of residential/lt. commercial construction, I have never met a concrete contractor who was an expert or even remotely qualified to second-guess the engineer. I know many who are extremely good at their work, but they follow the plans and specifications. The specifications are the controlling documents and should be followed by all. By all. I want to be careful now or they will find me floating in the Gulf of Mexico!

Most builders employ experienced and talented superintendents, and they are doing a very good job. Some do not. In my point of view, the real estate inspector is the most important link here. We can talk about good slabs, bad slabs and what creates them. We can have the best design in the best location and still have a problem or vice versa. There are many, many reasons a slab can have problems. Many of them can be contributed to construction practices and many to the homeowner's lack of proper maintenance.

So who do we rely upon? We must rely upon the inspector. The one person who is unbiased, has no interest in the property, except a duty to perform a visual inspection of application of plans and specs to the governing codes.

Speaking of codes:

Nothing **<u>infuriates</u>** <u>me more</u> than when I hear a mechanical contractor or framer say, "This is the way we do it in the county". I, of course, quickly inform them that the codes do apply in the county. They are <u>just not enforced</u>.

Speaking of enforcement:

I have many builders ask me about the City of Humble and their strict code enforcement. Well, it is a pleasure for me to say (and not just because Mr. Boyles, the Chief Building official for the City of Humble is in the audience) that I thoroughly enjoy my association with the Humble Building Department. "Tough enforcement." That's a mild statement, but I have never built where all the inspectors were experts in the codes and were willing to hold classes in the field for mechanical contractors who do not know the codes or applications. It is done frequently and with great success.

I had an inspector ask me one time, just how far do I push your concrete man. I said excuse me, I did not understand what you said. And he said, "Well, I uh, know you have used the subcontractor off and on for several years. He seems to work well for you, but I have had problems in the past with him. I don't want to make him <u>mad</u>". "<u>Mad</u>", I said. "I could care less how mad he gets. He's being paid to do the job and do it right. You have the engineering plans and specs. I do not want more or less. But I do want what the engineer says is needed, the correct application. I'm the guy you don't want to make <u>mad</u>."

I have many inspector friends, and some not so friendly; but I do believe they all belong in the ranks with policemen, firemen and teachers, the ultimate forces in our society. They provide us with security, safety, knowledge and structural integrity in our homes. Of course, inspectors are like policemen, firemen and teachers. They are grossly underpaid, intimidated and sanctioned when enforcing the responsibilities of their disciplines.

In this builder's point of view:

The slab foundation is being unjustly questioned in most cases concerning sheetrock cracks, sticking doors and popped nail heads, etc. Many of the sheetrock and door problems are from improper installation. There are many problems related to the frame structure due to construction practices not related to foundation design or soil movement. Yes, movements are taking place, but in the frame structure due to lack of sufficiently placed windbracing, over-spanded materials, shrinkage and thermal expansion and contractions.

"Do not misunderstand me." The slab is the most important part of the integrity of the home, but the frame structure is the back bone of the structure and if not assembled correctly and tight, it will eventually show signs of movement and stress.

In my opinion, more emphasis must be put on the frame structure and its correct application. I did not slight the R.I.A.T. Group earlier when I mentioned inspectors. You sometimes save the best for last.

I had the pleasure of setting-in on a H.O.W. sponsored training session awhile back for builders that was instructed by Mr. Dave Nesbit, Billy Shaw, and Bill Drew and others of the R.I.A.T. Group. Mr. Nesbit exhibited heavy emphasis on <u>framing integrity</u> and <u>structural applications</u>. This type of training must be on-going for all builders, <u>new and old</u>. The engineers, designers, and architects design the plan from builder's idea; and it's the builder's <u>responsibility</u> to <u>implement</u>.

And before closing, I want to say something about the superintendent:

The on-site superintendent is next to God in my heart. He's the only person in a homebuilding company that has all the responsibilities and the least authority of all. He has to have the calculating mind of Albert Einstein and a heart of stone. He likes nothing; nobody likes him and even he/she doesn't like himself. He's a psychologist, a mind reader, sociologist, brother, father, organizer, scheduler, coach, instructor, pessimist, optimist and scapegoat. If everything is right, somebody else gets the credit, but if something goes wrong, guess who get the credit?

And in closing, I think the **builder's over-all point of view** is to provide a good home, constructed right, provide long-term employment for its employees, supporting suppliers and subcontractors, pay his taxes and be part of a demanding industry that has its moments, but is most fulfilling.

Thank you.

Jack Orem

15 min. Builder's Point of View

CITY OF BELLAIRE
(713) 662-8222 • 7008 South Rice Avenue, Bellaire, Texas 77401-4495

RESIDENTIAL SOIL AND FOUNDATION REQUIREMENTS
GOVERNMENT AGENCY POINT OF VIEW

BY JOE EDWARDS
BUILDING OFFICIAL
CITY OF BELLAIRE,TEXAS
JUNE 16,1993

I. Listed is an overview of soil and foundation requirements from the following cities.

A. City of Bellaire
The soil engineer and structural engineer shall certify separately by letter to the City of Bellaire that inspections have been made and based upon the review of data, that the foundation as constructed and poured substantially conforms to the design and the intent of the soil exploration and foundation plan which has been submitted for a permit under other provisions of the Code of Ordinances of the City of Bellaire.

B. City of Missouri City
Soil reports are required. Structural Engineer to design foundation or use City's minimum requirements.

C. City of West University
See attached.

D. City of Houston
See attached.

II. Foundation Repair

III. The Trend

City of West University

amended by adding the following at the first line of said chart, immediately beneath the headings:

(Type of Permit)	(Day When Term Ends)
Construction of a new principal building	365th day following day of issuance

(existing provisions in chart not changed)

Section 4. That the reference to the "1988 edition" of the Standard Building Code appearing in the first sentence of Section 6-51 of the Code of Ordinances of the City of West University Place, Texas is hereby amended so that it shall read "1991 edition".

Section 5. That Section 6-52 (relating to exceptions) of the Code of Ordinances of the City of West University Place, Texas is hereby amended to read in its entirety as follows:

Section 6-52. Exceptions

The following exceptions are made from the Standard Building Code adopted by this article:

(1) All roofs must have a Class C or better fire resistance as determined in accordance with Section 706 of the Building Code.

Foundation Requirements

(2) All foundations for new construction of buildings, and foundation repairs involving the installation of piers, shall be designed and inspected by a registered professional engineer and shall meet all of the following requirements:

(a) The foundation or foundation repair shall be illustrated in complete plans and specifications signed and sealed by the registered professional engineer.

(b) The foundation design for new construction of buildings shall be based upon a soils "SR" report prepared by a recognized and reputable soils investigation agency or firm.

EXCEPTION: Foundations for single story accessory structures containing less than four hundred fifty feet (450) square feet of gross floor area do not require a soils report.

(c) The foundation or foundation repair shall be inspected by a registered professional engineer and the engineer's report certifying the proper construction shall be submitted to the Building Official prior to additional work being done.

CITY OF HOUSTON

Building Inspection Division

CODE WORD 91

INTERPRETATIONS & APPLICATIONS OF THE UNIFORM CODES, '91 EDITION

CW No. 91-54

PUBLICATION: August 20, 1992

SUBJECT: Policy - Minimum Required Foundation

CODE: Building

SECTION: 2907

A foundation which 1) is classified as exempt by Section 20 (f) of the Texas Engineering Practice Act and 2) meets or exceeds the specifications contained on page 2 of this policy shall be considered to comply with the Houston Building Code. No engineer's seal and no soils report is required. Other designs, including post-tension designs, must bear the seal of a Texas registered engineer.

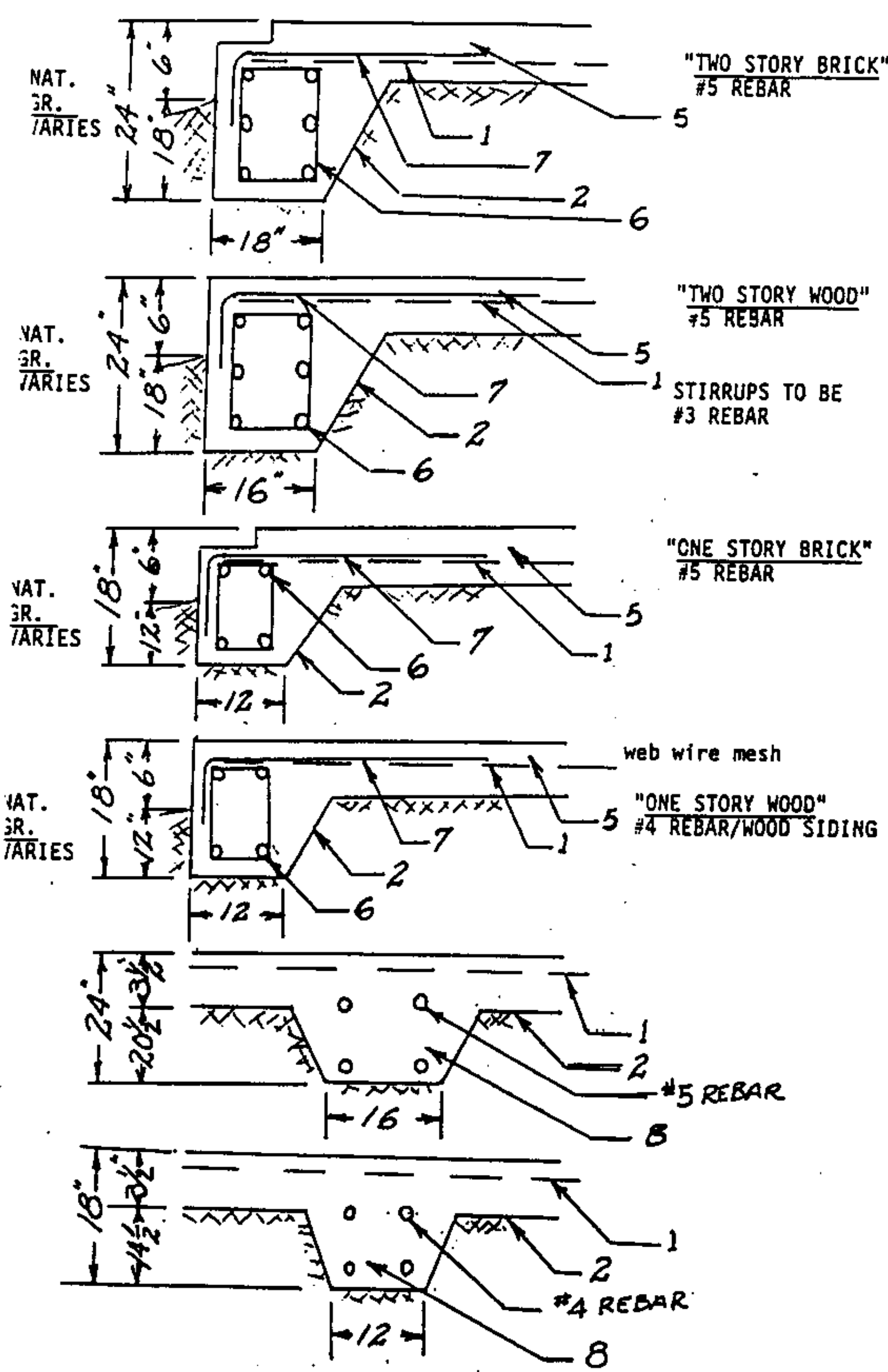
J. Hal Caton
Chief Building Official

CITY OF HOUSTON
Building Inspection Division

CODE WORD 91

INTERPRETATIONS & APPLICATIONS OF THE UNIFORM CODES, '91 EDITION

CW No. 91-54



CONSTRUCTION NOTES

1. All slabs shall be reinforced. #6 web wire mesh 6" x 6" minimum.
2. All house slabs shall have a 6 mil vapor barrier using poly or approved material.
3. All slabs shall be a min. of $3\frac{1}{2}$" thick with a 4" sand cushion.
4. Concrete shall have a minimum of 2000 PSF in 28 days.
5. Steel shall be covered with a 2" of concrete.
6. Stirrups to be #3 rebar.
7. Shear reinforcing at intersection of slab and all beams to be #4 rebar, 5' long, 5' on center.
8. Steel shall be covered with 3" of concrete.
9. Interior beams every 20 linear ft. or under bearing partition.

CITY OF HOUSTON
Building Inspection Division

CODE WORD 91

INTERPRETATIONS & APPLICATIONS OF THE UNIFORM CODES, '91 EDITION

CW No. 91-51

AMENDED:	August 19, 1992
INITIAL PUBLICATION:	November 21, 1991
SUBJECT:	Policy - Requirements for Classification of Soil
CODE:	Building
SECTION:	2904 & 2905

This section required the classification of the soil at each building site to be determined by an engineer or architect licensed by the State or by an approved agency. The classification shall be based on observation and any necessary tests of the materials disclosed by borings or excavation made in appropriate locations. A written report of the investigation shall be submitted with construction drawings for a building permit.

EXCEPTIONS:

1. Buildings constructed with joists and sills supported on blocks and bases.

2. Group M1 and M2 occupancies that are not required to be designed by a professional engineer.

3. Buildings or additions not exceeding two stories and not exceeding 600 square feet of foundation area, provided the spacing of beams do not exceed 12 feet.

4. Repairs to foundations that are performed in accordance to policy issued November 8, 1985, by the Code Enforcement Division.

5. Foundation designed and sealed by a structural engineer licensed by the State. (Soil classification and design bearing capacity shall be noted on plans.)

CW NO: 91-51

6. Foundations for structures which are exempted from the State Engineering Practice Act by Section 20 (f) of that Act, provided the foundation meets the City of Houston's Minimum Required Foundation policy.

J. Hal Caton
Chief Building Official

CITY OF BELLAIRE
(713) 662-8222 • 7008 South Rice Avenue, Bellaire, Texas 77401-4495

JOSEPH A. EDWARDS
CHIEF BUILDING OFFICIAL
CITY OF BELLAIRE, TEXAS
713-662-8230

Activities and Experience: Chief Building Official for the City of Bellaire, Texas for the past 17 years.

For the past 15 years I have taught Building Codes, Building Construction, and Housing Real Estate Inspections. This has been in conjunction with the Building Officials Association of Texas, Texas A&M Engineering Extension Services, and the Texas Association of Real Estate Inspectors. I have been a consultant to various cities pertaining to construction techniques, code interpretations and plan checking. Qualified as Building, Electrical, Plumbing, Mechanical, Housing and Health Inspector. Expertise in all types of construction including high-rise structures. Recognized as an expert in soil mechanics and cement and concrete technology. Have been associated with Building Codes, general construction and related areas for the past thirty-five years.

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 and Mechanical Officials
Licensed Plumbing Inspector-State of Texas
Texas State Association of Plumbing Inspectors
International Association of Plumbing Inspectors
Construction Specifications Institute
Southern Building Code Congress International
Texas Public Health Association
Texas Environmental Health Association

Past Chairman-International Conference of Building Officials Technical Engineering Evaluation Committee. This committee deals with building codes, building systems and material usage across the United States and its possessions.

Member of ICBO ES Committee since 1985

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

Presently serving on ICBO Evaluation Service, Inc. Board of Directors

State of Texas Building Official of the Year - 1992

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A PROFESSIONAL CORPORATION
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The attached article by William T. Little and Stephen Paxson, "Builder Liability," originally appeared in the May 1993 *Texas Bar Journal.*

It has been reprinted with the permission of the authors.

1950 HERITAGE PLAZA 1111 BAGBY HOUSTON, TEXAS 77002
(713) 654-1181 (800) 677-7095 FAX (713) 652-9415

Builder Liability

The Implied Warranties of Good Workmanship and Habitability and the Builder's Statute of Repose

By William T. Little
And Stephen Paxson

How long is a homebuilder responsible for his handiwork? The answer is probably not what you might think.

Obviously, a builder is liable for defects in material and workmanship under the terms of any verbal or written (express) warranties he provides. However, where latent defects are discovered in a structure, the builder may also be liable for the breach of certain implied warranties for up to 10 years (in some cases, even up to *12 years*) after the substantial completion[1] of the improvements. The builder's or contractor's ability to limit or disclaim this extended responsibility for construction defects has not been explicitly addressed by Texas courts and remains a subject of debate. What is clear, however, is that this extended implied warranty (if not otherwise limited) will benefit the first owner (and all *subsequent* owners) of the structure for 10 years following the completion of construction.

In effect, Texas law extracts an "automatic" 10-year warranty against latent defects from every builder. In return, the law offers builders the assurance that no claims for such defects can be brought against them after this automatic warranty expires.

This article is concerned with the nature and extent of the liability arising from implied warranties connected with residential construction activities.[2]

Express and Implied Warranties

With the construction and sale of any new structure, the builder typically provides the purchaser with various verbal or written statements that guarantee the quality or physical characteristics of the structure's materials and workmanship. These "express"[3] warranties are generally tied to a specified period of time. Similar warranties often accompany remodeling or repair projects. These warranties arise by agreement and are essentially verbal or written contracts governed by established contract law principles; hence, they are often referred to as "contractual warranties."

Irrespective of any express warranty or other contractual agreement that a builder might provide, Texas court decisions impose additional warranty obligations on builders. These obligations are known as *implied* warranties and they arise automatically by operation of law. No action need be taken by the parties to create these warranties.

The two implied warranties of significance to new home builders are the implied warranty of *habitability* and the separate implied warranty of *good workmanship*.[4] Under the implied warranty of habitability, the builder is required to furnish a home that is safe, sanitary, and otherwise suitable for human habitation.[5] Under the implied warranty of good workmanship, the builder is required to construct the home in accordance with standards that reflect the quality of work performed by one who has the knowledge, training, or experience necessary for the successful practice of the trade. The implied warranty of good workmanship also applies to those who provide remodeling and/or repair services. This implied warranty does not require the service provider to "guarantee" the results of his work. Rather, this warranty requires that the work performed must be considered proficient by those capable of making such judgments.[6]

The scope of written express warranties can be ascertained by the terms and specifications stated in the contract; or, if verbal, by the recollection of the parties and past performance. However, the legal obligations imposed by implied warranties cannot be so easily determined, since the breach of such a warranty is premised on the often varying professional judgment of engineers, architects, and other members of the building and repair trade.

In addition to the uncertainties as to the scope of these implied warranties, there remains a question as to the ability of builders to disclaim or limit them. The Supreme Court of Texas has explicitly held that the implied warranty of good workmanship cannot be disclaimed in connection with *repair* or *remodeling* services.[7] However, there is no clear authority as to the legal effect of a disclaimer of such implied warranties in connection with *new construction*.[8] What is clear is that these warranties arise by operation of law in connection with the construction and sale of a new structure, without regard to the parties' intentions or written agreement.

It is noteworthy that, although express warranties may be enforced only by those in privity with the warrantor, Texas courts have held that the implied warranties of habitability and good workmanship extend to subsequent purchasers.[9] Thus, if the original homeowner sells to a purchaser who had no dealings with the builder, the implied warranties still apply.

Claims for Breach Of Implied Warranties

A construction defect claim based upon an alleged breach of an implied warranty will generally be brought under the provisions of one of two interrelated statutory regimes: the Texas Deceptive Trade Practices — Consumer Protection Act (the "DTPA")[10] or the Residential Construction Liability Act (the "RCLA").[11] Prior to the enactment of the RCLA, the DTPA was typically applied in construction defect cases because such claims are usually based on an alleged breach of warranty and/or some alleged violation of the "laundry list" provisions in §17.46(b) of the DTPA. Not surprisingly, plaintiffs pursuing a claim for a construction defect favored the DTPA because of the deliberate pro-consumer orientation of that statute and also because of its provisions allowing for the maximum recovery of damages.[12] With the advent of the RCLA, an alleged breach of warranty involving a "construction defect" in a new residence should be dealt with under the RCLA.[13]

The RCLA became effective in 1989 and is intended for the exclusive benefit of builders involved in the construction, remodeling, or repair of *residences*.[14] The RCLA is significant because it provides certain new defenses and limits the liability of builders in cases involving construction defect claims. The extent of the interaction between the RCLA and the DTPA is not yet clear, although §27.002 of the RCLA provides that it "prevails" over the DTPA to the extent of any "conflict" between the two. While the RCLA is relatively new and untested in the courts, some potentially significant areas of conflict with the DTPA appear to exist. For example, the RCLA provides several explicit limitations of liability for builders and specifies that the act does not limit or bar any defenses that would otherwise be applicable to a construction defect claim.[15] This runs directly counter to the DTPA, which strips away common law defenses. The availability of common law defenses under the RCLA also reinforces the notion that implied warranties can be disclaimed.

A detailed discussion of the type of damages that might be recovered in a DTPA/RCLA construction defect action based upon a breach of either of the implied warranties of habitability and good workmanship is beyond the scope of this article. Both statutes provide similar mechanisms whereby the builder can attempt to limit his total exposure to damages to the amount of a "reasonable" settlement tendered prior to suit.[16] The RCLA further provides that, if the builder fails to cure the construction defect within a reasonable time, the owner can have the repairs made and sue for the reasonable cost of repairs "in addition to any other damages recoverable under any law not inconsistent with the [RCLA]."[17] Presumably, damages under the DTPA (*i.e.*, all manner of actual and consequential damages, personal injury, and "mental anguish" damages) are recoverable, plus up to three times those amounts and all attorney's fees, interest, and court costs. The amounts and kinds of damages recoverable in such cases seem limited only by the facts and the creativity of the plaintiff's attorney.[18]

When Can Claims for Breach Be Brought?

The RCLA does not contain a specific limitations period. Since it does, to some degree, interact with the DTPA, this would lead to the conclusion that any claim for a breach of the implied warranties arising from construction must be brought within two years after it occurs.[19] However, this is not an inflexible rule because the DTPA also provides that claims may be brought within two years after the consumer actually discovers or, in the exercise of reasonable diligence, should have discovered the defect that forms the basis of his claim.[20] This "discovery rule" is intended to protect consumers against "latent defects not discoverable by a reasonably prudent inspection of the building at the time of the sale."[21] This rule is commonly applied in cases where the alleged defect does not manifest itself until years after the completion of the structure (such as with an alleged defective design and/or an alleged improper construction of a foundation).[22]

The problem with the "discovery rule" is that its application varies from case to case and is fact specific. Builders and others subject to this rule have no way to anticipate when claims for latent defects might arise — and they can arise many years after the completion of the construction work. How does a builder cope? How does a builder plan for insurance coverage? At least part of the answer is provided by the 10-year builder's statute of repose.[23]

The Builder's Statute of Repose

Statute of Repose

A "statute of repose" is a legislative enactment that prescribes a period of time within which certain claims or actions must be brought. It is similar to a statute of limitation in effect, but somewhat different in operation. The statute of repose cuts off a claim after a specified time that is measured from the delivery of a product or the completion of construction work, regardless of the time the claim arose.[24]

Scope

The application of the discovery rule could expose a builder to a breach of implied warranty/construction defect claim for an indefinite period of time were it not for the builder's statute of repose. Like a limitations statute, the statute of repose prescribes a period of time within which a claim may be brought. However, the statute of repose does more. It is effective without regard to the latency of the claimed defect or the operation of the discovery rule.[25]

The operative time frame under the builder's statute of repose is 10 years. More specifically, an owner must present the builder with a "written claim for damages" involving that defect before the expiration of 10 years after the substantial completion of the improvements. However, if the damage or injury occurs in the 10th year, then the owner may bring suit on that claim up to two years after the written claim is presented or the damage occurs.[26] In any other case, the claim must be brought within two years after the injury or damage occurs or the latent defect is discovered ***and*** within 10 years of the substantial completion of the construction of the improvement.

The statute of repose applies by its terms to the construction or repair of an "improvement to real property."[27] An "improvement" includes the structure itself and all integral systems such as: a foundation;[28] an electrical wiring bus in an airport terminal building;[29] a residential heater-air conditioning unit;[30] an apartment wall heater;[31] and a swimming pool.[32] Generally speaking, an "improvement" (for purposes of this statute) has been held to encompass "everything that permanently enhances the value of the premises..."[33] including a "permanent connection" or something attached to the structure for an extended period.[34] It does not appear to be of any special significance for purposes of this classification that the item in question may be *capable* of independent or portable operation. What matters is *how* it was actually utilized in the structure.[35]

Operation

The builder's statute of repose does not replace the statute of limitations; rather, it complements it. A plaintiff must still assert his breach of implied warranty/construction defect claim within two years of its occurrence or discovery as required by the DTPA (and, therefore, the RCLA). The builder's statute of repose merely places a limit on the operation of the discovery rule. Thus, if the defect is latent and not discoverable within the 10 years *after* the substantial completion of the construction, then the claim is barred. If the claimed defect is discovered sooner than 10 years after substantial completion, the claim must be brought within two years from discovery or within the limits imposed by the statute of repose — whichever is less.

A key consideration in determining the applicability of this statute of repose is the activity performed by the one seeking to bar a claim for latent defect. For example, the limitations imposed by the statute do *not* extend to component part manufacturers, suppliers, or materialmen.[36] This statute of repose was intended to apply to litigation by tenants and owners who possess or control the property against architects, engineers, and builders actually involved in designing, planning, inspecting, and constructing improvements to real property, as distinguished from materialmen, vendors, and suppliers.[37] One must actually perform the work incident to the installation or attachment of the improvement to the structure or the property, or put the improvement into service, in order to secure the benefits of this statute.[38]

The greatest benefit conferred by the builder's statute of repose is that it bars *all* suits after 10 (or in some cases, 12) years, including claims for: damage or loss to real or personal property; personal injury; wrongful death; and contribution or indemnity.[39] For example, this statute has been applied to bar suits for personal injury caused by electrocution;[40] personal injury caused by diving into the shallow end of a swimming pool;[41] wrongful death by electrocution caused by a residential HVAC unit;[42] and wrongful death due to a malfunctioning apartment wall heater.[43]

The statute of repose does not apply to bar any claims regarding fraudulently concealed construction defects. In such cases, limitations begin to run when the claimant learns of the facts that give rise to this claim or, in the exercise of reasonable diligence, should have learned of those facts.[44]

Summary

Builders remain liable for the quality of their workmanship for as long as they agree to be in their express warranties. Additionally, they may be liable for the quality of their workmanship and the habitability of the structure they built under *implied* warranties for a period of two years after the alleged construction defect is discovered or should have been discovered by the owner. Liability under this "discovery rule" extends for 10 years after the substantial completion of the improvement to real property. In certain cases where the injury or damage is suffered in the 10th year, the overall period may be extended by an extra two years. Thus, with regard to latent construction defects, the total period of potential liability is a *maximum* of 12 years from the date of substantial completion.

Recommendations

When Settling Claims, Be Sure the Defect Is Repaired

Because any subsequent owner of improved real property may benefit from the implied warranty of good workmanship within the extended time provided by the discovery rule as limited by the statute of repose, builders need to consider the full range of their potential liability when responding to construction defect claims. In the event a homeowner complains about an alleged construction defect and the builder acknowledges the validity of the complaint or agrees to compromise and settle the claim, care must be taken to ensure that the defect is actually repaired — if not by the builder, then by some other qualified person. If the builder pays the owner a cash settlement and the proceeds are not used by the claimant to actually repair the defect made the subject of the claim, subsequent owners might well reassert this same claim against the builder (if the construction claim defect is not by then barred by limitations or the statute of repose). A cash settlement only resolves the personal claim of the current aggrieved owner — it does nothing to prevent subsequent owners from claiming the benefits of the implied warranties of habitability and of good workmanship for latent defect unless the builder takes the extra step of preparing a memorandum of the settlement agreement for filing in the official records of the real property maintained by each county clerk.

Limit Liability Through Contract Structuring

As noted earlier,[45] a builder may be able to limit his liability for breach of these implied warranties by providing an express limited warranty that prescribes a specific remedy or by disclaiming these warranties entirely in *new construction* projects. This could be supplemented by disclaimers placed in the deed to the new purchaser that would serve as constructive notice to future owners of the absence of any implied warranties on the structure. These steps would provide the builder with a greater degree of certainty as to the scope of his responsibility for his handiwork and give rise to a possible defense to future claims premises on implied warranties.

Conclusions

The builder's, architect's, and engineer's statutes of repose have successfully withstood all manner of constitutional and other challenges by disappointed plaintiffs with various kinds of construction defect claims.[46] They have also been expansively interpreted and vigorously enforced by Texas courts. These statutes are solid authority that builders and those in related professions can rely on to protect themselves from unlimited liability for future latent defect claims. Knowledge of the benefits of the builder's statute of repose and the prospects for limiting or disclaiming automatic implied warranties can be useful tools in developing a comprehensive strategy to reduce exposure to litigation of construction defect claims.

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1. The term "substantial completion" is not defined by the statutes here in question, nor has it been clearly defined in this context by Texas courts. Apparently, both the legislature and the judiciary believe that this term has a common meaning. "It has been uniformly held that 'substantial completion' of a construction contract is regarded, in legal parlance, as 'full performance.'" *Transamerica Insurance Co. v. Housing Authority of Victoria, Texas*, 669 S.W.2d 818, 823 (Tex. App. — Corpus Christi 1984, writ ref'd n.r.e.). For the purposes of this article, it appears that the term references the actual completion of construction. *See Klafehn v. Fain*, 643 S.W.2d 227, 228 (Tex.App. — Fort Worth 1982, writ ref'd n.r.e.); *Skeen v. Monsanto Co.*, 569 F. Supp. 232, 233-234 (S.D. Tex. 1983).
2. Implied warranties that arise in connection with the sale of goods are governed by the Uniform Commercial Code, Tex. Bus. & Com. Code Ann. §§ 2.314-.317 (Vernon 1968). Such warranties are not generally applicable to the construction of permanent improvements to real property, and this article does not intend to address them.
3. "An express warranty is created when a seller makes an affirmation of fact or a promise to the purchaser, which relates to the sale and warrants a conformity to the affirmation as promised...." *McDade v. Texas Commerce Bank, Nat'l Ass'n.*, 822 S.W.2d 713, 718 (Tex. App. — Houston [1st Dist.] 1991, writ denied); *see Lujan v. Tampo Mfg. Co., Inc.*, 825 S.W.2d 505, 511 (Tex. App. — El Paso 1992, no writ); *Southwestern Bell Telephone Co. v. FDP Corp.*, 811 S.W.2d 572, 576 n.3 (Tex. 1991).
4. *Haney v. Purcell Company, Inc.*, 796 S.W.2d 782, 786 (Tex. App. — Houston [1st Dist.] 1990, writ denied).
5. *Kamarath v. Bennett*, 568 S.W.2d 658, 660 (Tex. 1978); *Bolin Development Corp. v. Indart*, 803 S.W.2d 817 (Tex. App. — Houston [14th Dist.] 1991), writ denied *per curiam*, 814 S.W.2d 750 (Tex. 1991); *Miller v. Spencer*, 732 S.W.2d 758, 760 (Tex.App.

— Dallas 1987, no writ).

6. *Melody Home Mfg. Co. v. Barnes*, 741 S.W.2d 349, 352, 354-5 (Tex. 1987); *Bowe v. General Motors Corp./Pontiac Div.*, 830 S.W.2d 775, 779 (Tex. App. — Houston [1st Dist.] 1992, writ denied); *City Public Service Bd. v. General Electric Co.*, 947 F.2d 747, 748 (5th Cir. 1991) (Texas law).
7. *Melody Home*, 741 S.W.2d at 355; Tex. Bus. & Com. Code Ann. § 17.42 (Vernon 1987). *But cf, Southwestern Bell Telephone Co. v. FDP Corp.*, 811 S.W.2d 572 (Tex. 1991) (the UCC common law of warranty that allows the disclaimer or limitation of a warranty "does not offend" the "no waiver" provision of DTPA § 17.42 in a DTPA breach of warranty action).
8. In the case of *G-W-L, Inc. v. Robichaux*, 643 S.W.2d 392, 393 (Tex. 1982), the Texas Supreme Court held that a builder *may* disclaim these implied warranties. In the subsequent case of *Meloy Home Mfg. Co. v. Barnes*, 741 S.W.2d 349, 355 (Tex. 1987), the Texas Supreme court held that the implied warranty of good workmanship may not be disclaimed in connection with services rendered to *repair* or *modify* existing tangible goods or property. The court went on to point out that the *Robichaux* decision was overruled "to the extent that it conflicts with this opinion...." *id. Melody Home* dealt only with repairs — not with new construction as did the *Robichaux* case. The Texas Supreme Court's writings in several analogous decisions also suggest that implied warranties can be waived. For example, the court has recognized that implied UCC sales warranties involving goods may be disclaimed. *Cate v. Dover Corp.*, 790 S.W.2d 559, 562 (Tex. 1990). The court has also suggested that the common law implied warranty of habitability/suit-ability as to leased premises can be waived, *Kamarath v. Bennett*, 568 S.W.2d 658, 660 n.2 (Tex. 1978) (residential lease); *Davidow v. Inwood North Professional Group-Phase 1*, 747 S.W.2d 373, 377 (Tex. 1988) (commercial lease).
9. *Lujan v. Tampo Mfg. Co. Inc.*, 825 S.W.2d 505, 511 (Tex. App. — El Paso 1992, no writ) (contractual or express warranties may be enforced only by those in privity with the warrantor). *Gupta v. Ritter Homes, Inc.*, 646 S.W.2d 168, 169 (Tex. 1983); *March v. Thiery*, 729 S.W.2d 889, 892 (Tex. App. — Corpus Christi 1987, no writ) (privity is not required to enforce implied warranties).
10. Tex. Bus. & Com. Code Ann. § 17.41-.63, specifically § 17.50(a)(2) (Vernon 1987 & Supp. 1993) [DTPA].
11. Tex. Prop. Code Ann. § 27.001-.004, specifically § 27.002 (Vernon Supp. 1992) [RCLA].
12. See, *e.g.*, DTPA § 17.50(b).
13. "A 'construction defect' means a matter concerning the design, construction, or repair of a new residence, of [sic] an alteration of or addition to an existing residence, or of an appurtenance to a residence, on which a person has a claim against a contractor [i.e., builder]". RCLA § 27.001(2).
14. RCLA §§ 27.001(2), (4).
15. *See* RCLA §§ 27.002, .003(b); William T. Little, A Lawyer's Guide to the RCLA, Houston Lawyer, Nov.-Dec. 1990, at 36, 38.
16. *See* DTPA § 17.505; RCLA § 27.004.
17. *See* RCLA §§ 27.003, .004(e), (j).
18. *See id.*; DTPA §§ 17.44, .50(b).
19. DTPA § 17.565; RCLA §§ 27.002, .005; *see* Tex. Civ. Prac. & Rem. Code Ann. § 16.003(a) (Vernon 1986).
20. DTPA § 17.565.
21. *Gupta*, 646 S.W. 2d at 169; *see Bowe v. General Motors Corp./Pontiac Division*, 830 S.W.2d 775, 778 (Tex. App. — Houston [1st Dist.] 1992, writ denied).
22. *See, e.g., Tumminello v. U.S. Home Corp.*, 801 S.W.2d 186 (Tex. App. — Houston [1st Dist.] 1990, writ denied).
23. Tex. Civ. Prac. & Rem. Code Ann. § 16.009 (Vernon 1986). Section 16.008 provides similar protection for architects and engineers furnishing design, planning, or inspection services in connection with the construction of improvements to real property. Section 16.011 protects surveyors.
24. *Johnson v. City of Fort Worth*, 774 S.W.2d 653, 654 n.l (Tex. 1989); *see* Black's Law Dictionary 1411 (6th ed. 1990).
25. *Johnson*, 774 S.W.2d at 654 n.1; However, if the claimant can prove that the cause of action for a latent defect is based on wilful misconduct or fraudulent concealment, the statute of repose will not apply and the claim can be brought within two years after the discovery of the defect, irrespective of when the defect is discovered. *See* Tex. Civ. Prac. & Rem. Code Ann., § 16.009(e)(3) (Vernon 1986); *Lambert v. Wansbrough*, 783 S.W.2d 5, 7 (Tex.App. — Dallas 1989, writ denied).
26. Tex. Civ. Prac. & Rem. Code Ann. §§ 16.009(c), (d) (Vernon 1986).
27. *Id.* at § 16.009(a).
28. *Tumminello*, 801 S.W. 2d at 187.
29. *Barnes v. J.W. Bateson Co., Inc.*, 755 S.W.2d 518, 520 (Tex. App. — Fort Worth 1988, no writ).
30. *Rodarte v. Carrier Corp.*, 786 S.W.2d 94, 96 (Tex. App. — El Paso 1990).
31. *Dubin v. Carrier Corp.*, 731 S.W.2d 651, 652 (Tex. App. — Houston [1st Dist.] 1987, no writ), *after remand*, 798 S.W.2d (Tex. App. — Houston [14th Dist.] 1990, no writ).
32. *McCulloch v. Fox & Jacobs, Inc.*, 696 S.W.2d 918, 920 (Tex. App. — Dallas 1985, writ ref'd n.r.e.). A component part of an outdoor elevator (an electric hoist) has not been considered an "improvement" for purposes of this statute.
33. *Dubin*, 731 S.W.2d at 653.
34. *Rodarte*, 786 S.W.2d at 96. *See* Black's Law Dictionary 757 (6th ed. 1990).
35. *Dubin*, 731 S.W.2d at 653. *But see Conkle v. Builders Concrete Products Mfg. Co.*, 749 S.W.2d 489, 491 (Tex. 1988).
36. *Reddix v. Eaton Corp.*, 662 S.W.2d 720, 724 (Tex. App. — San Antonio 1983, writ ref'd n.r.e.).
37. *McCulloch*, 696 S.W.2d at 922; *Kazmir v. Suburban Homes Realty*, 824 S.W.2d 239 (Tex. App. — Texarkana 1992, writ denied).
38. *Conkle*, 749 S.W.2d at 491; *Dubin*, 798 S.W.2d at 652.
39. Tex. Civ. Prac. & Rem. Code Ann. § 16.009(b) (Vernon 1986).
40. *Barnes*, 755 S.W.2d at 518.
41. *McCulloch*, 696 S.W.2d at 918.
42. *Rodarte*, 786 S.W.2d at 94.
43. *Dubin*, 731 S.W.2d at 651.
44. *See Arabian Shield Development Co. v. Hunt*, 808 S.W.2d 577 (Tex. App. — Dallas 1991, writ denied).
45. *See supra* note 7, note 8.
46. Directly upholding the constitutionality of this statute of repose: *Texas Gas Exploration Corp. v. Fluor Corp.*, 828 S.W.2d 28, 31-32 (Tex. App. — Texarkana 1991, writ denied); *Rodarte*, 786 S.W.2d at 96; *Barnes*, 755 S.W.2d at 521-522; *Suburban Homes v. Austin-Northwest Development Co.*, 734 S.W.2d 89, 92 (Tex. App. — Houston [1st Dist.] 1987, no writ); *McCulloch*, 696 S.W.2d at 923-925; *Nelson v. Metallic-Braden Bldg. Co.*, 695 S.W.2d 213, 215 (Tex. App. — Houston [1st Dist.] 1985, writ ref'd n.r.e.); *Sowders v. M.W. Kellogg Co.*, 663 S.W.2d 644, 647-648 (Tex. App. — Houston [1st Dist.] 1983, writ ref'd n.r.e.). *See Jones v. Pullman Kellogg Corp.*, 785 F.2d 1270, 1272-1273 (5th Cir. 1986); *Brown v. M.W. Kellogg Co.*, 743 F.2d 265, 268-269 (5th Cir. 1984); *Skeen*, 569 F.Supp. at 233 (S.D. Tex. 1983). Upholding this statute by implication: *Johnson*, 774 S.W. 2d at 654-655.

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<u>The Texas Deceptive Trade Practices Act and Foundation Cases: The Defendant's Perspective</u>
or
<u>Are Foundation Cases All They Are Cracked Up to Be?</u>

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I. Brevity Is the Soul of Wit

POLONIUS: My liege, and madam, to expostulate
What majesty should be, what duty is,
What day is day, night night, and time is time,
Were nothing but to waste night, day, and time;
Therefore, since brevity is the soul of wit,
And tediousness the limbs and outward flourishes,
I will be brief. Your noble son is mad. . . .

WILLIAM SHAKESPEARE, HAMLET act 2, sc. 2.

II. Texas Deceptive Trade Practices-Consumer Protection Act (DTPA) -- Texas Business & Commerce Code §§ 17.41 *et seq.*

A. Who Can Sue? Plaintiff must be a "consumer"

1. Consumer:

a. Must "seek *or* acquire"

b. "goods *or* services"

(1) DTPA covers mixed purchases of goods and services, such as construction of a house. *Norwood Builders, Inc. v. Toler*, 609 S.W.2d 861 (Tex. Civ. App.--Houston [14th Dist.] 1980, writ ref'd n.r.e.) (holding that a contract for the construction of a new home is a "sale of goods").

c. by purchase *or* lease.

(1) Purchase need not be consummated if Plaintiff in good faith sought to complete it and had the capability of completing it. *Anderson v. Havins*, 595 S.W.2d 147 (Tex. Civ. App.--Amarillo 1980, writ dism'd) (finding that the DTPA applies, even though the Plaintiff did not complete the purchase of real property).

(2) Person who seeks or acquires the goods or services does not have to be same as person who pays for them. (Subsequent purchasers may qualify as consumers).

2. Business consumer with assets of less than $25 million. DTPA § 17.45(4).

a. "Business consumer" defined: Individual, partnership or corporation that seeks or acquires, by purchase or lease, any goods or services *for commercial or business use.*

B. Who May Be Sued? Privity not required.

1. Coverage of DTPA includes *any* deceptive practice made in connection with the purchase of goods or services. The courts have not required privity, instead allowing as Defendants all those "inextricably intertwined" in the sale or lease transaction. *Flenniken v. Longview Bank & Trust Co.*, 661 S.W.2d 705 (Tex. 1983).

a. A consumer can therefore sue an engineer, contractor, subcontractor, supplier, real estate broker, inspector, real estate appraiser, that commits a deceptive practice related to the construction or design of the house. Even more far reaching cases have involved developers and lenders.

C. Liability for a defective foundation might be premised on one or more of the following grounds:

1. "Laundry List" of 24 False, Misleading, or Deceptive Acts or Practices DTPA §§ 17.50(a)(1) & 17.46(b)(1)-(24)

a. Representing that a built project in general, or its foundation in particular, has "characteristics, ingredients, uses, benefits or quantities" that it does not actually have. (e.g., misrepresenting that a foundation will not shift or crack, or the amount of steel that the foundation contains).

b. Representing that a project or its foundation is "of a particular standard, quality, or grade." *Jim Walter Homes, Inc. v. Chapa*, 614 S.W.2d 838 (Tex. Civ. App.--Corpus Christi 1981, writ ref'd n.r.e.) (builder's misrepresentation that home would be built in a "good, substantial, and workmanlike manner" created grounds for DTPA liability).

c. Failing to meet contractual obligations to supervise and inspect the work of employees. *Building Concepts, Inc. v. Duncan*, 667 S.W.2d 897 (Tex. App.--Houston [14th Dist.] 1984, writ ref'd n.r.e.).

d. Passing off goods and services as those of another;

e. representing that an agreement confers rights, remedies or obligations which it does not have.

f. representing that a guarantee or warranty confers rights or remedies which it does not have.

g. representing that work or services have been performed on goods when the work or services were not actually performed.

2. Breach of an Express or Implied Warranty -- DTPA § 17.50(a)(2)

a. Express warranties

(1) Example: Representation that all defects in house will be repaired by builder. *Moore Bros. Lumber Co. v. Toombs*, 614 S.W.2d 858 (Tex. Civ. App.--Texarkana 1981, no writ).

b. Implied warranties -- implied by law

(1) Three types of applicable to construction and development:

(a) Implied warranty of good and workmanlike construction: House was constructed in a good and workmanlike manner. *Melody Home Mfg. Co. v. Barnes*, 741 S.W.2d 349 (Tex. 1987).

(b) Implied warranty of habitability: House is suitable for human habitation. *Humber v. Morton*, 426 S.W.2d (Tex. 1968).

(c) Implied warranty of good and workmanlike development. *Luker v. Arnold*, 843 S.W.2d 108 (Tex. App.--Fort Worth 1992, n.w.h.).

(2) These implied warranties may not be waived.

(3) Implied warranties do not yet apply to professional services, when not combined with a product..

(4) These implied warranties are automatically extended to subsequent purchasers to cover latent defects not discoverable by a reasonably prudent inspection at the time of the later sale.

3. Unconscionable Action -- DTPA § 17.50(a)(3)

a. *Pfeiffer v. Ebby Halliday Real Estate, Inc.*, 747 S.W.2d 887 (Tex. App.--Dallas 1988, no writ) (finding no showing of unconscionability in case involving foundation problems due to soils).

4. An independent inspection may constitute a new and independent intervening cause of a purchase and sale transaction with a subsequent purchaser.

D. Proceeding With a DTPA Action: Statutory Notice of Offer of Settlement Requirements -- DTPA § 17.505

1. Consumer must give 60 days written notice before filing suit;

2. Notice must reasonably detail the specific complaint and the amount of actual damages and expenses incurred; and

3. Consumer must allow an opportunity to inspect (unreasonable refusal to inspect results in loss of automatic trebling of actual damages under $1,000).

Rather than dismissing action when notice requirements are not followed, a court will merely abate action. *Hines v. Hash*, 843 S.W.2d 464 (Tex. 1992).

E. Damages Available -- DTPA § 17.50(b)

1. Purchaser could seek Rescission -- to "undo" the sale. *Coyter v. MCR Construction Co.*, 673 S.W.2d 938, 941 (Tex. Civ. App.--Dallas 1984, writ ref'd n.r.e.). However, the seller is entitled to the fair market rental value of the house for the time the Plaintiffs occupied the home. This offset will reduce damages and in some cases could actually require the Plaintiff to pay the seller to rescind the sale. An argument also exists that the purchaser's tax benefits (tax deductions taken for points, mortgage interest, and taxes paid) should be accounted for, but this has not yet been addressed by a Texas court.

a. Example:

Plaintiff's Expenses	
Past Repairs	500
Mortgage Interest	30,000
Closing Costs & Down Payment	10,000
Subtotal I	40,500
Less: FMV Rental for	
42 Months @ $1,000	(42,000)
Subtotal II	(1,500)
Less: Tax Benefits --	
Interest payments @ 28%	(9,000)
Net Amount Due Seller	$10,500

b. Another downside of rescission, from purchaser's perspective, is requirement that Buyer tender real estate back to Seller.

c. Arguably, mental anguish is not recoverable in a rescission claim.

2. Actual Damages

a. "Benefit of the Bargain" Measure of Damages

(1) Comprises difference between amount actually paid and value of home with the alleged defects. *Jim Walter Homes, Inc. v. Gonzalez*, 686 S.W.2d 715 (Tex. Civ. App.--Corpus Christi 1985, writ dism'd).

(2) Applicable when builder has not substantially complied with building contract. *Turner, Collie & Braden, Inc. v. Brookhollow, Inc.*, 642 S.W.2d 160 (Tex. 1984).

(3) May result in further damages due to reduced market value of "damaged goods," because of the homeowner's own legal obligation to inform a subsequent buyer of the repaired defect, and the "stigma" related to such repair.

(4) Election to seek benefit-of-the-bargain damages may preclude Plaintiff from obtaining damages for mental anguish. *Keith v. Stoecting, Inc.*, 915 F.2d 966, 999 (5th Cir. 1990).

b. Remedial or Out-of-Pocket Measure of Damages

(1) Includes all of Plaintiff's expenses necessitated by the defect, including all necessary repairs, as well as all future repair costs. *Brighton Homes, Inc. v. McAdams*, 737 S.W.2d 340 (Tex. App.--Houston [14th Dist.] 1987, writ ref'd n.r.e.); *Jim Walter Homes, Inc. v. Gonzalez, supra.* Typical compensable repair costs would include soils analysis, foundation stabilization, cosmetic repairs, and landscaping repairs.

(2) Includes consequential damages (e.g., loss of use of property, temporary housing costs during repairs).

(3) Includes any diminution in market value of the property after repairs are made. *Ludt v. McCullom*, 762 S.W.2d 575 (Tex. 1988).

(4) Includes damages for mental anguish ("soft" damages). *J.B. Custom Design & Bldg. v. Clawson*, 794 S.W.2d 38 (Tex. App.--Houston [1st Dist.] 1990, no writ); *HOW*

Insurance Co. v. Patriot Financial Services of Texas, Inc., 786 S.W.2d 533 (Tex. App.--Austin 1990, writ denied).

3. Automatic trebling of any actual damages of $1,000 or less.

4. "Additional damages" increasing any actual damages over $1,000 -- up to three times the amount of actual damages -- <u>if</u> Plaintiff shows that the Defendant committed the deceptive acts or practices "knowingly." *See March v. Thiery*, 729 S.W.2d 889 (Tex. App.--Corpus Christi 1987, no writ) ("knowingly" means actual awareness of defects in construction of house); *Jim Walter Homes, Inc. v. Valencia*, 690 S.W.2d 239 (Tex. 1985).

5. Court costs and reasonable and necessary attorneys' fees are recoverable.

F. Remedies Provided by DTPA Are Not Exclusive -- DTPA § 17.53

1. But a Plaintiff may not obtain double recovery of actual or punitive damages where the same acts comprise the DTPA violation and the basis for the other cause of action.

G. Defenses to Liability under the DTPA

1. Plaintiff is not a "consumer"

a. Burden of proof is upon claimant to establish his status as a consumer. *Farmers & Merchants Bank v. Ferguson*, 617 S.W.2d 918 (Tex. 1981).

2. If Defendant responded to Plaintiff's demand letter with a settlement offer that was (a) the same as, (b) more than, or (c) substantially the same as, the actual damages found by jury, then

a. Plaintiff may not recover more than *the lesser* of (1) the amount tendered in the settlement offer, or (2) the amount of actual damages found by the jury. (Thus, no treble damages or attorneys' fees).

This provision allows a Defendant to offer "substantially the same as" the amount of actual damages, which may be <u>less</u> than actual damages. However, the offer must include an offer of attorneys' fees. *Cail v. Service Motors, Inc.*, 660 S.W.2d 814 (Tex. 1983).

3. Plaintiff has more than $25 million in assets, and thus does not qualify as a "business consumer." *Eckman v. Centennial Savings Bank*, 784 S.W.2d 672 (Tex. 1990).

4. Lapse of statute of limitations

   a. Lawsuit brought more than 2 years after consumer discovered or should have discovered deceptive act or practice or breach of warranty is barred.

5. Defendant was merely "puffing"

   a. Mere expressions of opinion by a seller not made as a representation of fact are not actionable under the DTPA. *Dowling v. NADW Marketing, Inc.*, 631 S.W.2d 726 (Tex. 1982).

6. Note: If the court finds that Plaintiff's action is groundless, or was brought in bad faith or for the purpose of harassment, Defendant may recover its attorneys' fees and court costs as a counterclaim. DTPA § 17.50(c).

III. **Residential Construction Liability Act (RCLA)** -- Texas Property Code § 27.001 *et seq.* (Amended just this past session by House Bill No. 1395; amendments effective Sept. 1, 1993).

A. Applicability

1. Applies only to residential construction: Single-family, duplexes, triplexes, quadruplexes, and condominium and cooperative apartment units. RCLA § 27.001.

2. Applies only to "construction defects" -- but does not include actions for damages for personal injury (including mental anguish) or death, or for damages to goods. RCLA § 27.002.

3. "Construction defect": matter concerning design, construction or repair of a new residence, or the remodeling of an existing residence.

   a. Also extends to any "appurtenances" to a residence (e.g., swimming pool, detached garage, etc.), or the real property on which the residence or appurtenance is built.

b. Appurtenances do not include furnishings or other personalty. Damages for these items must be sought through the DTPA or some other legal remedy.

B. Who May Invoke RCLA?

1. Only a "contractor" responsible for design, construction or repair of a new residence, or remodeling of or addition to an existing residence. Thus, if a Plaintiff sends a DTPA notice letter to a contractor, the contractor should invoke RCLA and inform the Plaintiff that he must comply with the RCLA requirements.

a. "Contractor" includes a risk retention group that insures any part of a contractor's liability for the cost of repairing residential construction defects.

C. RCLA vs. DTPA

1. RCLA preempts the DTPA only where the two statutes conflict. Thus, the DTPA continues to apply to (a) engineers, architects, home designers, and other non-contractors involved in the design, construction and repair of homes or structural foundations; (b) appraisers; (c) real estate brokers; (d) lenders; (e) developers; and (f) the involvement of any of these persons with non-residential projects.

2. RCLA will not preempt the DTPA if:

a. a claimant reasonably rejects a RCLA settlement offer; or

b. the contractor fails to repair the defects within the allowed time in a good and workmanlike manner.

D. Who Is a Proper Plaintiff?

1. 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.

E. Proceeding Under RCLA -- RCLA § 27.004

1. As with the DTPA, claimant must first give the contractor written notice of the construction defect claim, by certified mail--return receipt requested (*newly-added requirement*), at least 60 days before filing suit.

2. Contractor must be given a reasonable opportunity to inspect the residence within 35 days (*new time*) after receiving the written notice of claim.

3. Within 45 days (*new time*) after receiving notice of claim, the contractor must make a written offer for money damages or to repair. The contractor may offer either:

   a. to repair the construction defect or to have the defect repaired by an independent contractor

      OR

   b. monetary settlement -- typically the cost to repair plus attorneys' fees reasonably and necessarily incurred by Plaintiff.

   c. Note: The claimant and the contractor may agree in writing to extend the statutory period for notice, offer, and repair. (*Newly-added provision*).

   Overall Rationale of RCLA: Promotion of reasonable settlements. Proceeding under RCLA minimizes the involvement of the lawyers and keeps the courts free of cases involving only minor damages. RCLA capitalizes on the fact that the contractor is often in the best position to quickly and inexpensively repair any defects. *See Hines v. Hash*, 843 S.W.2d 464 (Tex. 1992).

4. If the contractor's offer to repair is accepted, the repairs must be completed within 45 days (unless delayed by the claimant or events beyond the contractor's control -- e.g., weather, materials shortages).

   a. contractor must make a "good faith" effort to repair defect;

   b. the repairs must cure the defect;

   c. the repairs must be accomplished in a good and workmanlike manner.

5. If an offer of settlement is not accepted within 25 days after Plaintiff receives it, the offer is deemed rejected and Plaintiff may file suit under the DTPA or any other law.

   a. If offer of settlement is unreasonably rejected, claimant's damages are limited to reasonable cost to repair defect plus attorneys' fees reasonably and necessarily incurred up until the time of rejection.

F. Defenses to Liability

1. Alleged defect is merely normal wear, tear, and deterioration. RCLA § 27.001(a)(3).

2. Alleged defect is merely "normal shrinking due to the drying or settlement of construction components within the tolerance of building standards." RCLA § 27.001(a)(4).

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

4. Damages against contractor will be proportionally reduced by percentage due to negligence of a subcontractor or his employee or agent. RCLA § 27.003(a)(1).

5. Damages will be proportionally reduced by percentage due to failure by anyone other than contractor--including the Owner--to take reasonable action to mitigate the damages. RCLA § 27.003(a)(2)(A).

6. *New provision*: Damages will be proportionally reduced by percentage due to failure by anyone other than contractor--including the Owner--to take reasonable action to maintain the residence. RCLA § 27.003(a)(2)(B).

7. *New provision*: Contractor reasonably relied upon written government information that was false or inaccurate. RCLA § 27.003(a)(5).

8. Contractor offered a reasonable settlement, which the fact finder determines to have been unreasonably rejected.

    a. claimant's damages are limited to reasonable cost to repair the construction defect plus any attorneys' fees reasonably and necessarily incurred up until the time of rejection.

9. Statute of limitations.

10. Unlike the DTPA, all common law defenses apply to RCLA claims. RCLA § 27.001(a)(5).

If Plaintiff did not give written notice of the complaint at least 60 days before filing a lawsuit, the court will probably follow DTPA abatement procedures (discussed above).

G. Damages

1. If contractor follows RCLA procedures, the new RCLA amendments provide that the claimant may recover only the following damages, if proximately caused by a construction defect:

   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 attorneys' fees.

2. The new amendments limit damages in a proceeding under RCLA: Damages may not exceed the claimant's purchase price for the residence. RCLA § 27.004(f)(1)-(4)

3. However, if contractor fails to make an offer of settlement, or its offer is reasonably rejected, a claimant may file suit under DTPA or any other legal remedy. Damages under such a proceeding may include:

   a. Actual Damages

      (1) "Benefit of the Bargain" damages;

      (2) Remedial or "Out-of-Pocket" measure of damages, which may include damages for mental anguish; or

      (3) Rescission damages.

   b. Trebling of any actual damages of $1,000 or less.

   c. "Additional damages" of up to three times any actual damages over $1,000, upon showing that the contractor knowingly committed one of the prohibited deceptive practices.

   d. Court costs and attorneys' fees.

4. Failure to meet provisions of RCLA may thus expose contractor to the DTPA's "additional" damages provisions (see above).

5. Contractors therefore have a great incentive to make a reasonable settlement offer under RCLA and to meet the deadlines for carrying out the settlement.

6. Unreasonable rejection of a contractor's reasonable settlement offer limits damages to the cost of repairing the defect and attorneys' fees.

IV. Practical Tips in Defending Foundation Defect Cases

A. The DTPA

1. As drafted, the DTPA is often vague.

2. Lower liability threshold required under the DTPA.

    a. Deceptive practice need only be a "producing" cause of damages, compared with "proximate" cause required to show negligence.

3. Juries practically apply instructions and usually require Plaintiffs to show violation of industry standards and causation.

4. Potential exists for runaway verdict in egregious situations.

5. The prospect of treble damages and attorneys' fees makes cases dangerous and creates settlement value.

6. Potential to preempt the DTPA: A clause in the sale agreement that requires resolution of any disputes through binding arbitration under the Federal Arbitration Act preempts the DTPA. *Jack B. Anglin Co. v. Tipps*, 36 Sup. Ct. J. (Tex. 1992).

B. Problems with cases involving multiple Plaintiffs

1. "Slop-over" evidence.

2. Transactional defense costs create incentive for insurance carriers to settle on a nuisance or non-liability basis.

3. "Subdivision falling into the sea" hysteria -- aggravates damage claims.

4. Efforts by Plaintiffs to create their own stigma in a marketplace.

C. Problems with "Junk Science"

1. Expert witnesses are the key to trying foundation cases. Principal testimony of experts relates to whether the homes or foundations were:

   a. not constructed according to industry standards;

   b. defectively designed; or

   c. misrepresented by the seller or broker involved.

2. No industry standards exist as a basis for defining what comprises a "defective" foundation.

3. Problems exist with individuals making the judgment calls in vague areas -- a growth industry involving the biased "independent" expert.

4. Beauty truly is in the eye of the beholder: When is "too much movement too much?"

5. Subjective versus objective findings.

6. Expert witnesses must be qualified

7. Factual basis must exist for expert testimony.

   a. May be based on hearsay (i.e., evidence not otherwise admissible at trial).

8. The expert testimony must assist the trier of fact:

   a. to understand the evidence, or

   b. to determine a fact in issue.

9. Expert may give an opinion on an ultimate issue.

10. Reliability versus Credibility: Issues relating to the admissibility of expert opinion testimony.

    a. Trial court has wide discretion regarding admissibility and scope of expert opinions.

    b. Most judges leave credibility to jury.

c. May attack expert opinion admissibility and reliability.

d. Preparation is the key in both direct and cross-examination.

e. Standard for admissibility of expert testimony. *Christophersen Allied-Signal Corp.*, 939 F.2d 1106 (5th Cir. 1991) (en banc), *cert. denied*, 112 S. Ct. 1280 (1992). The Court held that the following factors should be considered:

(1) whether the expert is generally qualified to express an expert opinion on the question in issue (credentials alone are not necessarily determinative of the expert's qualifications);

(2) whether the facts upon which the expert relies are the same type as are relied upon by other experts in that expert's field;

(3) whether the expert used a well-founded methodology in reaching its conclusion (the basis for the *Christophersen* court's exclusion of expert testimony); and

(4) whether the testimony has the potential for unfair prejudice that substantially outweighs its probative value.

One Texas state court recently applied the factors outlined in *Christophersen*, with some variation. See *Maritime Overseas Corp v. Ellis*, No. C14-91-00795-CV (Tex. App.--Houston [14th Dist.], Dec. 31, 1992, n.w.h.) (applying Federal law). Arguably, under the Texas Rules of Evidence, similar criteria can be applied.

f. "Alchemy versus certainty" as to causation: "Soil is often 'mucky.'"

11. The "Symposium Problem"

a. Experts gathering to create a standard of care in their industry.

b. Recognize conflict of interest involved

(1) Plaintiffs
(2) Defendants
(3) Experts
(4) Practitioners

c. Professional witnesses seeking to create peer review and accepted industry standards: Who pays in the short term versus the long run?

12. Failure to Keep Documents

a. Problems for the small contractor, design, or brokerage firm -- failure to keep records.

b. Documenting construction and design generally undercuts the Plaintiff's case.

13. Problems with Punch-lists and Homeowner Hysteria

a. Did the Plaintiffs get the home they bargained for?

b. Are the Plaintiffs looking for a windfall for a defect that doesn't exist?

c. Ask jurors to use their common sense -- they ordinarily do.

14. The Role of the Professionals

a. The Architect/Engineer

(1) Proper design

(2) Proper factual basis for design

(3) Proper construction inspections

b. The Developer

(1) Depends on scope of information provided to builder

(2) Developers give an implied warranty to develop in a good and workmanlike manner, creating a potential basis for DTPA liability. *Luker v. Arnold*, 843 S.W.2d 108 (Tex. App.--Fort Worth 1992, n.w.h.).

(3) Usually a reach to find liability.

c. The Lender

(1) Depends on scope of involvement with construction inspections and draw reports. Generally speaking, a lender owes no duty of care to a prospective purchaser. *Baskin v. Mortgage & Trust, Inc.*, 837 S.W.2d 743 (Tex. App.--Houston [14th Dist.] 1992, writ denied).

(2) With foreclosure and resale, lender becomes the seller.

(3) If builder went bankrupt, did lender finish construction?

(4) Otherwise, lender liability is an extreme reach. There is no cause of action for negligent lending to a developer or a builder. *Baskin*, *supra.*

d. The Broker

(1) Absent specific agreement, broker is generally the agent of the seller.

(2) Broker is a "limited" or "special" agent.

(3) Potential arguments regarding this limited authority, based on ratification by seller's benefitting from the broker's affirmative misrepresentations, may require seller to rescind sale to protect itself from broker's conduct.

(4) Real estate agents and brokers have no legal duty to inspect property for defects beyond asking sellers if such defects exist. *Kubinsky v. Van Zandt Realtors*, 811 S.W.2d 711 (Tex. App.--Fort Worth 1991, writ denied).

(5) There is an implied warranty of good and workmanlike performance with respect to services of real estate brokers.

D. Regarding subcontractors, engineers, architects and brokers, contractors, developers, and prospective purchasers may want to require proof of insurance (review certificates of insurance/policies)

E. Indemnities/Disclaimers

1. Disclaimers of DTPA liability are normally void. DTPA § 17.42.

2. Under "fair notice requirements," any contractual disclaimer must be conspicuous. *Dresser Industries, Inc. v. Page Petroleum, Inc.*, 1993 WL 101861 (Tex. 1993).

3. Texas follows the "express negligence" test regarding disclaimers of negligence. *Ethyl Corp. v. Daniel Construction Co.*, 725 S.W.2d 705 (Tex. 1987).

F. Warranty Companies

1. "Benefit of the Bargain" Argument

2. Standard: Uninhabitable, unsanitary, or unsafe ("UUU")

   a. Differs from industry standards of construction and design-build.

   b. Example: "Sticking doors" are not defective construction or design, in and of themselves, but may trigger the HOW Warranty.

   c. Provide home purchasers with maintenance manual at closing.

G. "L/360" -- ACI 318

1. Allowable post-tension movement < L/360

2. Slope vs. deflection

3. Disagreements as to how measured in industry -- Is it misapplied?

4. Really begs the question: Is the balance of the structure failing due to the foundation's movement?

5. Everyone knows that minor foundation movement is normal in Houston, Texas;

6. Everyone knows that cure cracks occur in concrete;

7. Everyone knows that sheetrock cracks occur on a new home.

8. References to BRAB, Snowden & Littleton, and Post-Tension Institute.

9. No foundation is ever poured absolutely level.

10. L/360 is really a standard for *new* construction -- technically, it only applies at construction.

V. More Matter with Less Art

Polonius:	Your noble son is mad: Mad I call it, for to define true madness, What is't but to be nothing else but mad? But let that go.
QUEEN:	More matter with less art.
POLONIUS:	Madam, I swear I use no art at all. That he's mad, 'tis true, 'tis true 'tis pity, And pity 'tis 'tis true--a foolish figure, But farewell it, for I will use no art.

WILLIAM SHAKESPEARE, HAMLET act 2, sc. 2.