

FOUNDATIONS ON EXPANSIVE SOILS

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Case VI

AN ANATOMY OF A LAWSUIT

GENERAL PROCEDURE FOR GEOTECHNICAL INVESTIGATION

The procedures most geotechnical engineers follow for the investigation of a building site are as follows:

For a large tract of land, where there is a choice of building location, a preliminary soil investigation usually is conducted to provide recommendations as to the most favorable location for the proposed building from a geotechnical standpoint.

When the footprint for the building is established, a final geotechnical report is prepared. The report recommends the foundation type, slab construction, drainage precautions and others. The structural engineer uses the report to design the foundation system, and the architect uses the report for site preparation and landscaping.

Sometimes the structural engineer and/or the architect asks the geotechnical engineer to review the final plans and specifications.

During construction, the owner, or the architect who acts as the representative of the owner, asks the geotechnical engineer to examine the drilling of the pier holes, the placement of fill or the installation of the drain system. The scope of the service is specified in the specifications.

ABSTRACT FROM PRELIMINARY SOIL REPORT

The project is the Colorado State Veterans Nursing Home located at Florence, Colorado. A preliminary geotechnical report was prepared in 1973 for the purpose of determining the most desirable location for construction.

On site selection

The northwestern portion of the site is located in a broad valley where the bedrock is generally deep, and the upper soils do not possess swell potential. This area (north of the trail and west of contour line 5300) in our opinion appears to be the most desirable location for construction as shown on Figure VI-1. The figure also shows the final selected location of the building.

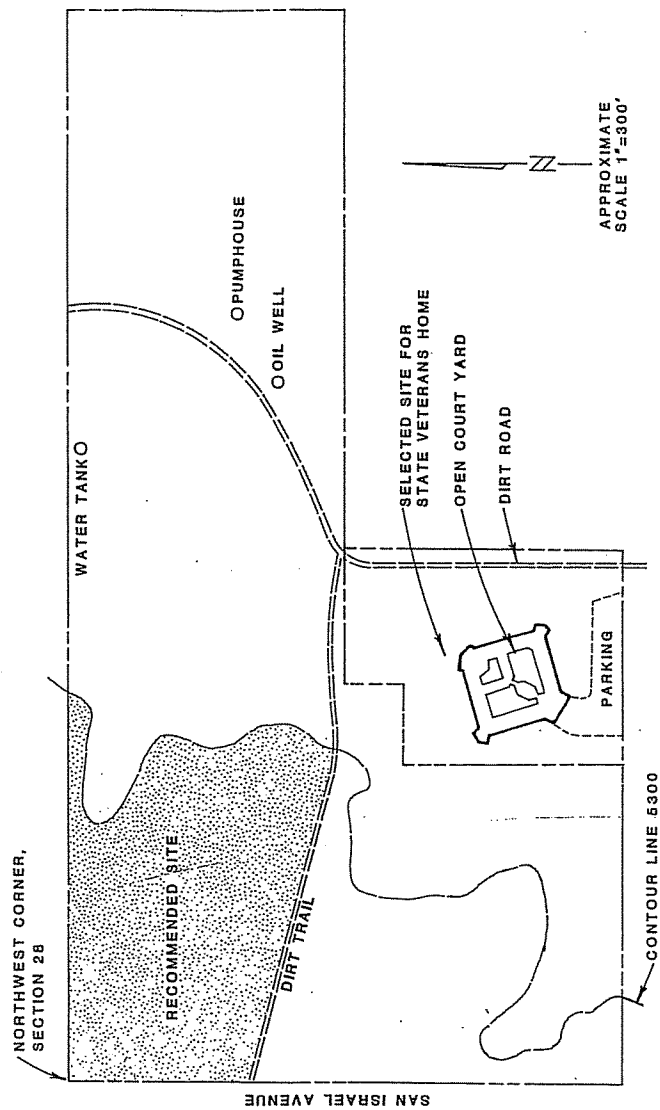


Figure VI-1. Proposed and final location of State Veterans Home.

On foundation system

Where the bedrock is relatively deep and the upper soils do not possess swell potential, spread footing foundations can be used. Where the bedrock is high, such as the area south of the trail, it is desirable to use a drilled pier foundation to support the structure.

On floor slab

Where the upper soils do not possess swelling potential, slab-on-ground construction can be successfully used. However, where bedrock is shallow, interior floor slabs are placed directly on bedrock. There is a strong possibility that heaving soils pose a problem to slab-on-ground construction. Special consideration should be given to slab-on-ground construction to prevent heaving soils from affecting the stability of the structure.

ABSTRACT FROM GEOTECHNICAL REPORT

On foundation system

Considering the subsoil conditions and proposed construction, the most safe and desirable type foundation would be straight-shaft piers drilled into the claystone bedrock. The following design and construction details should be observed:

- (1) Piers should be designed for a maximum end pressure of 30,000 psf and a skin friction of 3,000 psf for the portion of pier in the bedrock.
- (2) Piers should also be designed for a minimum dead-load pressure of 15,000 psf to resist the potential expansion of the upper soils.
- (3) Piers should penetrate a minimum of four feet into bedrock and have a minimum total length of twelve feet.
- (4) Piers should be reinforced their full length with at least two #5 bars to resist uplift.
- (5) A minimum four-inch void should be provided beneath the grade beam between the piers to prevent uplift on the bottom of the grade beam and to concentrate the load on the piers.
- (6) All pier holes should be thoroughly cleaned before placing concrete.

On floor slab

Floor slabs placed on the claystone-sandstone bedrock have a risk of heaving and cracking if the underlying subsoils become wetted. Considering the moderate-to-high expansive potential of the claystone bedrock, it is reasonable to consider a structural floor system with an air space beneath it. Providing the owner is aware of the risk and slab-on-ground floors are required, the following details should be observed:

- (1) Floor slabs should be separated from all bearing walls and columns with a positive expansion joint.
- (2) Interior partitions resting on the floor slabs should be provided with a slip joint, preferably at the bottom, so that in the event the floor slabs move this movement is not transmitted to the upper structure. This detail is also important for wallboards and door frames.
- (3) Floor slabs should be provided with control joints to minimize damage due to shrinkage cracking and they should be reinforced.
- (4) A four-inch gravel layer should be placed beneath the floor slabs.
- (5) It has been our experience that the risk of floor slab movement can be minimized by removing at least three feet of expansive soil and replacing it with a compacted nonexpansive fill. This should be a granular soil and compacted to at least 90% standard Proctor density at optimum moisture content.

The above precautions do not prevent the movement of floor slabs in the event the floor slabs become wetted; however, they minimize the damage if such movement occurs.

On drainage

The following drainage precautions should be observed during construction and maintained at all times after the building has been completed:

- (1) Excessive wetting or drying of the foundation excavation should be avoided during construction.
- (2) Backfill around the building should be moistened and compacted to at least 85% standard Proctor density.
- (3) The ground surface surrounding the exterior of the building should be sloped to drain away from the building in all directions. We recommend a minimum slope of six inches in the first ten feet.

- (4) Roof downspouts and drains should discharge well beyond the limits of all backfill.
- (5) Landscaping which requires excessive watering and lawn sprinkler heads should be located at least ten feet from the foundation walls of the building.

Although no ground water was encountered in our test holes at the time of drilling, it is possible that a perched water table condition could occur from time to time due to heavy precipitation or local irrigation. Where the lower floor is below the surface of bedrock, it is possible that this trapped perched water table could seep into the lower floors causing wet conditions. Where the lower floor is below the surface of bedrock, we recommend that an underdrain around the periphery of the building be installed.

DISTRESS AND PUBLICITY

About two years after the completion of the building, it was found that the floor slab had heaved. Upon examination, it was found that a slab-bearing partition wall had not been provided with the necessary slip joints as designed. As the result, not only did the partition wall show cracks, but the walls also pushed against the ceiling and resulted in heavy distortion.

The initial design team advised the administrator to regulate their watering practice, especially in the open courtyard area, and was ignored.

In the meantime, a great deal of publicity was generated, blaming the design engineers and architect for the problem. One paper had the heading, "Chen & Associates charged in negligent construction of Veterans' Home."

SUMMONS

A summons was delivered to the geotechnical engineer in August 1979.

On floor slab

Defendant Chen negligently and improperly recommended slab-on-ground construction with knowledge of the possibility or probability that heaving soil would pose a problem.

The plaintiff, relying on the conclusions and recommendations of Chen for slab-on-ground construction, authorized construction of the Veteran's Nursing Home utilizing slab-on-ground type construction.

As a direct and proximate result of the improper recommendations of Chen to use slab-on-ground construction when the site was not fit for this kind of construction, the plaintiff has been damaged in the manner and in the amounts set forth below.

On pier foundation

Defendant Chen negligently and improperly inspected and supervised the pouring of the concrete piers which resulted in the concrete piers, which are the foundation and support for the Veteran's Nursing Home, not conforming to specifications in that they are larger in diameter than specified.

It was the duty of defendant Chen to notify the contractor of any errors in the pouring of the concrete piers, including errors in the size of said piers. Notwithstanding said duty, defendant Chen improperly failed to notify the contractor of the piers being larger than specified.

On inspection

Defendant Chen improperly failed to notify the contractor that several of the piers had a mushroom or bell formation at the top so that the surface area at the top of the pier was larger than the remainder of the pier and larger than called for by the specifications.

RESPONSE

On floor slabs

Defendant clearly recommended a structural floor system with an air space beneath it rather than slab-on-ground construction. Said report also relates an understanding that the construction will probably be slab-on-ground and states as follows:

"Providing the owner is aware of the risk and slab-on-ground floors are required, we suggest the following details be observed:"

And then there follows five specific recommendations, concluding with the statement that:

"The above precautions will not prevent the movement of floor slabs in the event the floor slabs become wetted; however, they will minimize the damage if such movement occurs."

It is this defendant's contention that the report submitted by the defendant shows on its face that it did not recommend slab-on-ground construction, and, to the contrary, discussed slab-on-ground construction as an alternative with respect to which special precautions and special construction steps had to be observed in order to minimize damage which would have occurred from slab movement if the expansive soil had become wet. It is further this defendant's position that the report made a full disclosure of the dangers of utilizing slab-on-ground construction and this defendant's statements and recommendations contained in the said reports, as a matter of law, do not amount to negligence.

The affiant has since learned that after issuance of the Chen and Associates, Inc., report of July 5, 1974 the architect as well as members of the State Department of Administration and other executive persons of the state of Colorado interested in the project, applied to the appropriate committees of the legislature for additional funding authorization in order to permit the construction of the facility with a structural floor system as recommended in the report of July 5, 1974, but were not successful. Neither the affiant nor the defendant Chen and Associates, Inc., were ever consulted or contacted with respect to those efforts.

On pier size

With respect to the inspection and the supervision function which defendant, Chen & Associates, did undertake, the drilling of the holes for the piers included ascertaining that where an 8" pier was called for in the specifications the hole was 8" in diameter and that all holes were to the proper depth. A letter attached from the structural engineer to the architect stated,

"I received a call from Chen & Associates advising that the contractor was drilling 10" round piers in lieu of 8" round shown on the drawings. As we discussed, it was my understanding that the contractor had asked for a substitution to use 10" round piers. Upon checking, we found that the 10" pier could be substituted for the piers, providing 1'-0" additional minimum penetration into bedrock is provided."

The above letter clearly shows that there was a change in the specifications and the contractor was permitted to substitute 10" diameter piers for the 8" diameter piers.

The structural engineer on the project was charged with the duty of approving or disapproving of such changes. That letter together with the pier inspection reports of the defendant, Chen & Associates, show clearly that all pier holes drilled and approved were approved in accordance with the project specifications as modified and approved by the structural engineer. In addition, it is clearly shown by Mr. Chen's testimony that the increase in the size of the piers which was approved by the structural engineer was still within the minimum dead-load pressure parameter of 15,000 pounds per square foot recommended by the defendant, Chen & Associates, Inc.

On mushroom

The plaintiff alleges that during construction the defendant improperly failed to notify the contractor that several of the piers had a mushroom bell formation at the top so that the surface area at the top of the pier was larger than the remainder of the pier and larger than called for by specifications.

Excerpts from the construction documents which set forth the responsibilities of the soils engineer on the project are as follows:

- The owner shall employ a soils engineer to inspect the bearing material. If the bearing stratum at design depth is not suitable, the excavation shall be drilled deeper as directed by the soils engineer or the architect.
- Holes shall be inspected by the architect immediately prior to placing of concrete. Notify architect at least forty-eight hours before beginning the drilling operation.

The above documents clearly show that defendant, Chen & Associates, Inc., undertook to perform only those functions required by the construction documents to be performed by the soils engineer. The only functions relating to the piers performed by the soils engineer pursuant to the construction documents were the inspection and supervision of the drilling of the holes for the piers, which did not include the subsequent separate operation of pouring the piers themselves or placing steel reinforcement in the holes prior to the pouring of the concrete. Thus, defendant, Chen & Associates, Inc., had no duties whatsoever with respect to the inspection of

poured piers and consequently no duty to ascertain whether or not mushroom or bell shaped formations appeared thereon after they were poured.

EXPERT TESTIMONY

Throughout the lawsuit, no less than 30 witnesses were called. Among them were five structural engineers, four geotechnical engineers and two architects. Some of the abstract of the testimony is given as follows:

Architect testimony (plaintiff)

The plaintiff engaged an architect from out of state who had no experience on actual construction and nothing on expansive soils. He made the following comments on the geotechnical involvement,

For the preliminary report:

- a. In our opinion, the Engineer's report is confusing, erratic and contradictory. It is difficult to understand how a site can be described in the first instance as having no unusual subsoil conditions and in the second instance described as having erratic bedrock with high swell potential and upper soils that will settle excessively upon wetting.
- b. We find the slab-on-ground recommendation very risky on the site. The recommendation is made for situations where soils do not swell. However, according to the report, lower portions of bedrock possess swell potential and upper soils consolidation potential. There are cautions against slab-on-ground construction making the recommendation even more confusing.
- c. The recommendation for spread footings, even if on natural soils, and in consideration of the possibility of consolidating soils, in our opinion, is improper."

For the final report:

- a. The engineer's statement of Proposed Construction indicates the Architect, presumably based on the first soils report, has designed the building with slab-on-ground.
- b. This report generally repeats the caution of slab-on-ground construction, and includes a recommendation for structural floor slabs

with air space under. The report goes on, however, to approve slab-on-ground construction suggesting a risk and recommending a design to minimize damage.

- c. The above situations certainly are confusing and contradictory enough; however, to add to the problem the recommendations on roof drains are short sighted and dangerous if the previous caution given by the Engineer to maintain excavations in a state of equilibrium, i.e., not allowing wetting or drying of foundations excavations, is valid. Roof drainage, if the situation could be critical, should be piped off the site without the possibility of wetting soils.
- d. With the possibility of erratic soil conditions, including moderate-to-high swell potential for claystone bedrock, drilled pier foundations appear to be a risky recommendation. In our opinion, the drilled pier is vulnerable from skin friction and lifting once swelling takes place due to wetting. In addition, if soils absorb moisture, said moisture has access to highest swell area due to drilled piers.

The allegation of the state against the geotechnical engineers appeared to be based entirely on the above testimony. As stated by a structural engineer,

"In general, this report strikes me as a 'quick and dirty' report by a person with little or no experience or understanding of expansive soil foundation problems. This needs to be brought out. The only purpose I can see for the report was to get a lawsuit started."

He states that the soils reports are "confusing, erratic and contradictory." He probably thinks it is erratic and contradictory because the report was for two entirely different building sites which he apparently did not take the time to discover.

He further states that drilled pier foundations appear to be a risky recommendation. This is probably the best statement in the whole report to discredit his opinion. Drilled pier foundations are used very extensively throughout Colorado and, in most cases, they are used most specifically to minimize the effect of expansive soil. For all intents and purposes, there is no other practical foundation system that will accomplish as much to prevent problems with expansive soil. He obviously does not understand the mechanisms of expansive soil and what proper engineering design does to minimize these effects.

Geologist testimony (plaintiff)

The state further sought comment from the state geologist and their comments on the geotechnical engineer are as follows:

1. The owner accepted a degree of risk when the site with its expansive soils was selected, in light of known problems with other state buildings in other areas on expansive soils.
2. The soils engineer identified the expansive characteristics of the soils, recommended ways to cope with these soils and how to keep them dry but I feel did not emphasize strongly enough the dire consequence of poor roof and site drainage.
3. The design of the structure with its open courtyards, lack of positive interior roof drainage, lack of positive outer lawn drainage is highly at fault as to the long-term performance of the foundation and slab system. The fact that these problems were not identified at the time of construction indicates that there was no responsible individual on the job who knew the consequence of these design and construction deficiencies.
4. A structural floor slab system was the first recommendation with no stated risk. Slab-on-ground floors could be used if certain details were observed but being clearly stated that such floors could heave and crack if the underlying subsoils became wet. In other words, even if the stated precautions were observed, if the soils under the slab became wet, the floor slab would move.

The plaintiff saw that the state geologist did not find any fault on the geotechnical engineer, made a strong point that, "The geotechnical engineer did not emphasize strongly enough the dire consequence of poor roof and site drainage." This later became the central target of the state against the defendant.

Structural engineer testimony (defendant)

A structural engineer who has vast experience on structural damage on expansive soil reported as follows:

"It is also my opinion the recommendations in the Chen report are relatively standard for situations of this nature and are in accord with normal engineering practice.

"Some of the prior investigative reports indicated the possibility of grade beam and foundation movement. However, at the time of my inspection

there was little obvious evidence of foundation movement, although no actual measurements were made. The building damage consisted primarily of cracks and other distress that had occurred in the drywall partitions, doorways, ceilings and floors. It appeared most and possibly all of this damage was attributable to movement of the concrete floor slab which in turn was causing movement of the partitions built on it.

"Considering the highly expansive nature of the supporting soil, the extremely poor surface drainage on all sides of the building, the excessive irrigation that has been reported, and the potential for really severe problems, the building was in relatively good condition. Most of the cracking should be considered minor and no serious structural problems were noted.

"Slab-on-ground construction is not a 'negligent or improper' recommendation. Buildings are designed and constructed on expansive soils using slab-on-ground construction constantly throughout Colorado. Very few building owners are willing to spend the substantial extra money necessary to eliminate slab-on-ground construction.

"The increase in drilled pier (or caisson) diameter was a properly approved design change that occurred during construction."

This report was not considered seriously by the state. They claim that local engineers tend to protect fellow engineers.

Academician testimony (plaintiff)

A college professor from Chicago provided a geotechnical report. He first performed an analysis on the clay mineral content of the claystone shale and concluded:

1. The clay-shale foundation rock has a potential to and did swell.
2. The flare and the enlarged pier diameter allow more force from the heaving shale to be transferred to the pier than would original design.
3. The crack at the bottom shows that the pier did not provide sufficient anchorage to counteract the forces created by the swelling shale."

It is interesting to note that the crack developed on the pier can only indicate that there is sufficient anchorage of the pier.

Structural engineer testimony (defendant)

In direct response to the academician's report, the structural engineer stated:

1. The change from eight-inch diameter piers to ten-inch diameter piers was also checked, and we found that this met the design criteria as approved by the original design engineer.
2. The mushrooming (flare) at the top of the caissons is not termed as critical. It is the opinion of an independent geotechnical engineer that the additional anchorage into the claystone bedrock more than offsets the uplift on the additional small area created by the mushroom effect.

Geotechnical expert testimony (defendant)

The state of Colorado finally sought testimony from a top geotechnical engineer in the field of expansive soil from Washington, D.C. The state expected that this witness could discredit the geotechnical engineer's report. To their surprise, the expert fully agreed with Chen & Associates' report and actually blamed the state for over-irrigation.

*Remainder of article
cut for academic
Purposes*