Geotechnical investigations and data sources in New Mexico

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Introduction

Development in New Mexico has generally taken place on building sites with stable soil conditions. However, as the population has grown, more and more structures are being constructed in areas characterized by unstable soil conditions. Problems with unstable areas can often be anticipated by reviewing readily available maps and reports. With the aid of engineering geologists and civil engineers, marginally unstable conditions can often be rendered stable and safe. This article provides information about common techniques and tests that may be used to identify potential problems with building sites. It also identifies sources where additional geotechnical information can be obtained. The objective of this report is to provide general technical guidance that can be used during the preliminary or feasibility stage of a project. Description of site-specific tests and studies that are recommended before or during construction are beyond the scope of this report.

New Mexico building codes do not require rigorous geotechnical investigations for all building sites. Fortunately, however, many lending agencies require at least minimal testing of foundation materials. Also, many homeowners and developers independently seek geotechnical data before beginning construction. The major causes of structural failure described below can be identified from relatively simple field and laboratory tests or observations. The extent of a testing program for a particular project depends on both the available funding and the geologic setting. Most of the physical tests described herein apply to relatively small, low-cost construction projects such as a single family dwelling in a relatively simple geologic setting. The tests are most effective when considered before construction has been started.

The physical properties of the geologic materials (soil or rock) determine whether or not structures will perform as they were designed. Such properties can vary depending on the geologic setting and the degree of human modification. Among the causes for foundation failure are collapsible soils, excessive ground-water withdrawal, debris flows, rock dissolution, soil liquefaction, expansive soils, and compressible soils. Other less common causes such as rockfalls and landslides also occur periodically.

As used in this report, soil is defined as the naturally occurring superficial deposits overlying bedrock (International Conference of Building Officials, 1982), and rock is defined as material that cannot be drilled with an earth auger and requires special techniques or equipment (such as blasting or rock-core barrels) to excavate.

Typical foundation problems in New Mexico

Structures built on geologically young mudflow deposits may become damaged if the soils beneath consolidate and settle (because of lawn watering, poorly maintained and leaky utilities, or other causes). These soils are referred to as collapsible. Alternatively, structures built on soils containing certain clays may become damaged due to wetting and the subsequent expansion of the clay minerals. Structures can also be damaged if they are built on weathered rock. Commonly, this latter type of damage results from differential soil settlement, due in part to the weight of the structure. Excessively wetted soils beneath a structure can be substantially weakened, which may result in loss of their bearing capacity. A number of geologic or man-induced processes can cause differential soil settlement. Another major cause is withdrawal of ground water and subsequent lowering of the water table.

Rock falls, rock topples, and rock slides are of concern in areas where structures are built along mountain flanks. Earth movement of this type can occur in response to intense rainfall, ground shaking from earthquakes, or even sonic booms. Of even greater concern, in areas that flank mountain fronts, is potential damage from debris flows. The most common cause of the flows is intense, short-duration rainfall, but they have also been caused by failure of manmade embankments designed to retard or stop runoff.

There are several other potential problems with building sites. Areas underlain by soluble rock such as limestone are likely to contain cavernous voids at shallow depths (karst topography). Houses and roads have been damaged by the sudden collapse of overburden into such features. Damage can also arise from the use of concrete aggregate containing certain deleterious materials; chert and obsidian are known to slowly but adversely react with concrete, which leads to cracking and weakening of the concrete. This phenomenon is known as alkali reactivity. Another notable problem is related to carbonate cementation of soil. Near-surface carbonate (caliche) may cause excavation difficulties. This problem is especially costly when a contractor's charges increase greatly because of "changed conditions." Finally, structures may be damaged by liquefaction of the underlying soils. Liquefaction is the transformation of a granular material, such as sandy soil, into a liquid state because of sudden increase in pore pressure; liquefied soil loses all its strength and can no longer support the load of a building. It occurs most commonly in saturated sandy soils that become subjected to ground shaking from earthquakes. In New Mexico, such soils are known to flank sections of the Rio Grande, but they may also exist in places where ground water is very shallow.

Rock and soil classification systems

A simple, yet very useful, rock classification system and two common soil classification systems are discussed because these systems enable geotechnicians to transmit meaningful technical data about a potential building site to builders, homeowners, or engineers.

Unified Rock Classification System

Although most urban development in New Mexico is on soil, situations arise periodically where one wishes to build a structure partially or wholly on rock. One problem is that design engineers may become confused by technical data collected by nonengineers (e.g., geologists). To circumvent this problem, the Unified Rock Classification System (URCS) was developed in 1959 to bridge the gap between the traditional geologic and engineering descriptions of the same material. It was first used during the construction of major flood control dams built by the U.S. Army Corps of Engineers. Because the URCS is so applicable to construction projects, it is summarized in Table 1.

The URCS provides a way to clarify terminology when classifying rock for civil engineering purposes: slight emphasis is placed on naming a rock and great emphasis is placed on describing important physical properties of rock material. The physical rock properties described are: 1) degree of weathering, 2) estimated strength, 3) discontinuities, and 4) unit weight or density (Table 1). By establishing limiting values for these physical properties, the URCS provides a means of transmitting reliable, meaningful data. In addition, it gives useful estimates of compressive strength, permeability, and shear strength—three important properties of rock masses.

To estimate the degree of weathering, one simply uses a hand lens and finger pressure to observe rock color and resistance to fracture. Strength is estimated by striking a sample with a hammer. The character of the impact mark gives an indication of unconfined compressive strength. The development of discontinuities (directional weaknesses), which affect the excavatability of a rock mass, are determined by observing the visible rock features, obvious fractures, alignment of mineral grains, and by striking the rock with a hammer and observing the nature of the fractures.

Unit weight or density, one of the more useful geotechnical properties, can be estimated in the field by weighing a sample of rock in air and then reweighing it while it is submerged in water. The unit weight is the weight in air divided by the weight loss when submerged. In general, the higher the unit weight of a rock the more suitable it is for construction purposes (Table 1).
A system of letters is used in the URCS to identify the four fundamental physical properties described in Table 1. In general, rock material designated “AAAA” will require the least design evaluation while material designated “EEEE” will require the most and may, in fact, be totally unsuitable for the intended purpose.

U.S. Department of Agriculture soil classification system

The U.S. Department of Agriculture (USDA) soil classification system, used in county soil survey reports in the U.S., is based on the particle-size distribution of a soil. The older soil surveys emphasized the agricultural potential of soils, but recent reports also emphasize the suitability of soils for urban uses. Examination of the USDA textural classification chart (Fig. 1) reveals information about the suitability of the various classes of soils for building sites.

Sandy soils, in the lower left corner of the USDA chart, typically occur on gentle slopes and represent excellent building sites. With the exception of certain sands that may liquefy or collapse when wetted, localities containing sand and admixtures of sand, silt, and clay generally characterize high quality building sites.

Silty soils, in the lower right corner of the USDA chart, may represent suitable building sites, but it is prudent to consult with experts (Table 2) when considering development. Silty soils are prone to collapse when wet and commonly occur on flatter slopes, which are more susceptible to sheetwash flooding. Favorable attributes of silty soils are that they drain well yet retain enough water and fertilizer for crops to flourish, and they are relatively easy to excavate.

Clayey soils, in the top portion of the USDA chart, are soft, sticky, and weak when wet and very hard and strong when dry. These characteristics make their identification relatively easy; however, because clayey soils are nearly impermeable, drainage is poor and septic tanks do not function well. On steep slopes these soils are prone to soil creep and landslides.

Unified Soil Classification System

The Unified Soil Classification System (USCS) is utilized extensively by engineering geologists when classifying soil for use at building sites. The system is based on Atterberg limits and particle-size analyses (Fig. 2). Atterberg limits define the water-content boundaries between the liquid and plastic states (liquid limit) and between the plastic and semisolid states (plastic limit) of soil (explained below). In this system, soils are either coarse grained or fine grained. Coarse-grained material is divisible into gravel and sand and further divisible into eight groups based on grading, plasticity index, or Atterberg limits. Fine-grained material is divisible into silts and clays, which are further divisible into six groups based on plasticity index and liquid limit. A final division is made for highly organic soils such as peat and muck (Fig. 2). With few exceptions, any soil can be identified tentatively in the field and later identified more precisely in the laboratory using simple equipment. In this manner, one can rapidly classify a soil and generally assess its foundation suitability.

Clayey soils with high plasticity (Fig. 2, CH) may be susceptible to expansion because of high clay content. These soils are commonly associated with areas of soil creep or landslides. They are not suitable for septic tanks because they drain very slowly. Clayey soils with lower plasticity indices (Fig. 2, CL) are slightly more suitable for foundations, but they should be avoided if possible because they are likely to contain expansive clays and are also considered unsuitable for septic tanks. Special attention should be given to expected engineering performance of this class of soils before construction.

Organic soils (Fig. 2, OL and OH) commonly occur in marshy areas. Because of their high organic content they can be expected to
compress considerably. Usually, costly measures must be employed to render these soils suitable for construction.

Silty soils of high plasticity (Fig. 2, MH) must be examined on a case-by-case basis because there may be problems similar to the finer grained soils described above. However, in places where they have been built upon, they seem generally suitable for smaller structures such as single family dwellings.

Silty soils with low plasticity (Fig. 2, ML) are more suitable for foundations than any of the soils discussed so far in this section because they drain better and are easier to excavate. However, these soils are susceptible to liquefaction when saturated. In the arid and semi-arid environments of much of New Mexico this problem is not great, except perhaps along the floodplains of perennial rivers and around the edges of reservoirs and lakes. Also, these soils are related to a family of soils in New Mexico that could be collapsible. Soils that are potentially collapsible require additional field and laboratory testing to confirm how they will perform after construction and human modification (Johnpeer et al., 1985).

The coarse-grained sands and gravels (Fig. 2, upper portion) represent, with some exceptions, soils most desirable for building foundations. The coarse-grained soils generally have good drainage characteristics, stand well during excavations for pipelines, electric utilities, etc., and compact well when backfilled. Where foundation conditions are not suitable, coarse-grained material is usually hauled in to improve the site conditions. However, poorly graded sand can liquefy and some sandy soils are known to be collapsible; many of these soils are thought to have been deposited as debris flows in the recent geologic past.

Common physical tests on soils

Simple physical tests are used routinely to supply information about the suitability of a site for the intended use. There are a number of field tests and studies that can be conducted to provide evaluations of site conditions. These range from complex geophysical tests using borehole devices to simple tests using only a hand lens. The following discussion is concerned only with simple tests that are conducted routinely in the laboratory. The USCS classification system (Fig. 2) is used in the test descriptions.

Particle-size distribution

Particle-size distribution is a common means of identifying the particle-size groups that a soil contains. The test is conducted by sieving material through a stack of mesh sieves (Fig 3). Material that
is too small to sieve (silt and clay) is commonly analyzed using a hydrometer or pipette settling technique. The results of a particle-size analysis are presented graphically on a grain-size chart as distribution curves (Fig. 4). To a trained interpreter, the shape of a particle-size distribution curve also shows the general engineering characteristics of a soil.

Atterberg limits

Atterberg limits are the liquid limit, plastic limit, and plasticity index of a material. The liquid limit is determined by filling a small bowl with wetted soil in a liquid-limit device (Fig. 5). A groove is made through the soil with a specially calibrated tool that makes a 1-cm-wide groove through the center of the sample. The liquid-limit device is designed to drop the sample a standard distance until the groove closes. The moisture content is varied until it takes 25 drops to close the groove, and the moisture content or liquid limit is then determined by oven drying the sample. The plastic limit is determined by rolling a long thread of soil into a standard diameter of 1/16 inch (Fig. 6). The moisture content at the point the soil begins to crumble is the plastic limit. The numerical difference between the liquid limit and plastic limit is defined as the plasticity index. This is a useful value because some soils with high plasticity indices, such as expansive clays, can absorb large quantities of water that will produce significant volume changes. The plasticity index indicates the range of moisture contents within which the soil has plastic properties. Clean sands and silty sands characteristically have low (or no) plasticity indices. Soils with high plasticity indices may be highly compressible. In general, soils with high plasticity indices are more likely to cause foundation failure than soils with low plasticity indices.

Clay mineralogy

As is evident from the above discussion, both clay mineralogy and water content can have significant effects on the physical properties of a soil. Although the moisture content is easily determined, the clay mineralogy (do not confuse with clay size material, which is less than 2 microns in diameter) is more difficult to determine and is therefore usually determined only in special circumstances. One means of identifying the clay mineralogy is with an x-ray diffraction device. A common procedure is to place a sample of clay size material containing clay minerals on a glass slide. The slide is placed in the path of an x-ray beam, and the angle of x-ray diffraction is measured. The very small distance between successive layers of clay atoms can be determined. This so-called "d-spacing" is used to identify the clay mineralogy. Other nonclay minerals can also be identified in this manner.

Two types of clay, either expansive or nonexpansive, commonly occur in soils. A main objective for studying clay mineralogy is to determine the dominant type of clay or the relative abundance of each type. Smectite and vermiculite are clays that can expand when they become moist. If expansive clays are used in foundation material they may later dry and leave large desiccation cracks as the clays shrink. Mica and chlorite are generally nonexpansive clays, but they can weather to become expansive clays. Kaolinite is an end product of the weathering process and as such does not expand. The pressures produced by some expansive clays are tremendous; if not properly designed for, they can differentially raise and destroy a foundation. In general, when placing a foundation on soils containing expansive clays, the footings should extend below the depth of annual moisture change. In addition, proven landscape techniques have been designed that provide for drainage of surface water before it can soak in. Concrete foundations, substantially strengthened with rebar, can withstand the pressures that could arise from building on either expansive clays or collapsible soils. The advice of experts is highly recommended when construction is anticipated on soils containing expansive clays.

Data Sources

In the quest for geotechnical data the professional as well as the homeowner is often perplexed. Frequently much time and money are expended searching for information, only to find that with the proper "lead" it could have been obtained much earlier and perhaps at a considerable cost savings. Actually, the body of existing data that pertains to most sites is remarkably large. The types of data concerned with engineering geology studies generally fall within six categories: topography, geology, geophysics, remote sensing, hy-
TABLE 2—Geotechnical data sources for New Mexico. *See reference list for full citation.

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<th>Geotechnical data—general</th>
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1. Aerial Photography Field Office
   USDA-ASC, P.O. Box 30010
   Salt Lake City, UT 84130–0010
   (801) 524–5856

2. American Society of Civil Engineers
   United Engineering Center
   345 E. 47th Street
   New York, NY 10017–2398
   (202) 705–7491

3. American Society of Photogrammetry
   210 Little Falls Street
   Falls Church, VA 22046–4398
   (703) 534–6617

4. Berquist et al., 1981

5. Consulting Engineers Council of New Mexico
   P.O. Box 3642
   Albuquerque, NM 87190
   (505) 242–5700

6. Dodd et al., 1985*

7. Environmental Evaluation Group
   320 Marcy Street, P.O. Box 968
   Santa Fe, NM 87504–0968
   (505) 827–8280

8. Environmental Improvement Division
   P.O. Box 968
   Santa Fe, NM 87504–0968
   (505) 984–0020

9. EROS Data Center
   User Services Section
   U.S. Geological Survey
   Sioux Falls, SD 57198
   (605) 594–6511

10. Federal Emergency Management Agency
    National Flood Insurance Program
    500 C Street, SW
    Washington, DC 20472
    (202) 646–2500 general
    (202) 646–4600 publications

11. Geological Society of America Engineering Geology Division
    3300 Penrose Place
    P.O. Box 9140
    Boulder, CO 80301
    (303) 447–8850

12. GEOREF
    American Geological Institute
    4200 King Street
    Alexandria, VA 22302
    (800) 336–4764

13. Hydrologic Information Unit
    U.S. Geological Survey
    419 National Center
    1221 Sunrise Valley Drive
    Reston, VA 22092
    (703) 860–6675

14. Dr. Kenneth Kunkel
    State Climatologist
    New Mexico State University
    Las Cruces, NM 88003
    (505) 646–3007

15. National Archives and Records Service
    Cartographic Archives Division
    National Archives and Records Administration
    Washington, DC 20408

16. National Cartographic Information Center
    U.S. Geological Survey
    507 National Center
    Reston, VA 22092
    (703) 860–6045

17. National Geodetic Information Center, OA/C18
    National Oceanic and Atmospheric Administration
    Rockville, MD 20852
    (301) 443–8631

18. National Oceanic and Atmospheric Administration
    National Geophysical Data Center
    Mail Stop E/CG–1
    325 Broadway
    Boulder, CO 80302
    (303) 497–6607

19. National Technical Information Service
    U.S. Department of Commerce
    National Technical Information Service
    5285 Port Royal Road
    Springfield, VA 22161
    (703) 487–4650

20. NEDRES Program Office
    Assessment and Information Services Center

21. New Mexico Bureau of Mines and Mineral Resources
    New Mexico Institute of Mining and Technology
    Socorro, NM 87801
    (505) 334–5420

22. New Mexico Geographic Information Advisory Committee
    c/o Technology Application Center
    2500 Central, SE
    University of New Mexico
    Albuquerque, NM 87131
    (505) 277–2622

23. New Mexico Geological Society
    Denver, CO 80202
    (303) 873–5420

24. New Mexico Water Resources Research Institute
    P.O. Box 3167
    New Mexico State University
    Las Cruces, NM 88003–3167
    (505) 646–4337

25. Nuclear Regulatory Commission
    Regional Office (Region 4)
    611 Plaza Drive, Suite 1000
    Arlington, TX 76011
    (817) 860–8100

26. Petroleum Information Log Service
    300 North Baird Street
    P.O. Box 1356
    Midland, TX 79702
    (915) 682–0591

27. Noel M. Rosenberg
    Executive Director
    Association of Engineering Geologists
    P.O. Box 1068
    Brentwood, TN 37027
    (615) 377–3578

28. Soil Conservation Service
    Education and Publications Office
    U.S. Department of Agriculture
    P.O. Box 2890
    Washington, DC 20013
    (202) 477–5973

29. Soil Conservation Service
    517 Gold Ave., SW, Room 3301
    Albuquerque, NM 87102
    (505) 766–3277

30. State Engineer Office
    101 Batan Memorial Building
    Santa Fe, NM 87503
    (505) 927–6140

31. Technology Application Center
    2500 Central, SE
    University of New Mexico
    Albuquerque, NM 87131
    (505) 848–3341

NOAA/NESDIS
3300 Whitehaven Street, NW
Washington, DC 20235
(202) 534–7722
It was technically reviewed by Cathy Aimone, Danny Bobrow, David Kulhawy (1983), and additional specific sources are given for libraries, federal agencies, and state agencies. Affordable computerized data bases of the U.S. Department of Commerce and the National Oceanic and Atmospheric Administration can also provide rapid access to specific types of studies within all six categories.

The data sources listed in Table 2 are the general sources one might consult during the preliminary or feasibility phase of a project. They are intended to serve as guides for those seeking engineering geologic data. Site-specific data are not included here because such data generally require both surface and subsurface investigations by a qualified geotechnical engineer or engineering geologist. Although many of the data are highly technical, many are easily understood by the layman. Some of the data sources were taken from Trautmann and Kulhawy (1983), and additional specific sources are given for New Mexico.

In New Mexico, structural damage has occurred from a number of causes including collapsing soil, liquefaction, ground-water withdrawal, landslides and debris flows, ground subsidence, rock dissolution, alkali reactivity, and expansive soils. In many instances, the major causes of foundation failure could have been mitigated if proper studies had been made of prospective building sites. Using the data sources given in Table 2 and the advice of engineering geologists and geotechnical engineers, marginal construction sites may be rendered stable and safe.

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References

Summary
In New Mexico, structural damage has occurred from a number of causes including collapsing soil, liquefaction, ground-water withdrawal, landslides and debris flows, ground subsidence, rock dissolution, alkali reactivity, and expansive soils. In many instances, the major causes of foundation failure could have been mitigated if proper studies had been made of prospective building sites. Using the data sources given in Table 2 and the advice of engineering geologists and geotechnical engineers, marginal construction sites may be rendered stable and safe.

Society of Economic Paleontologists and Mineralogists upcoming projects
April 7–9, 1986 SEPM short course "Platform margin and deep water carbonates," in Calgary, Alberta.

For more information or to register for any of the above courses, contact: Joni C. Merkel, Society of Economic Paleontologists and Mineralogists, P.O. Box 4756, Tulsa, Oklahoma 74159-0756, (918) 743-2498.

New Mexico Geological Society news
The New Mexico Geological Society will hold its annual spring meeting on Friday, April 4, 1986, in the Macey Center on the campus of New Mexico Tech in Socorro, from 9 to 5. This meeting, which is intended to disseminate the results of recent research on the geology of New Mexico, will include four sessions: mineral fuels (oil, gas, coal, and uranium), ground water, sedimentary geology, and a general session. A cocktail party and banquet will conclude the day’s activities.

Information on registration, accommodations, and other activities planned for this meeting will be mailed to NMGS members in February. Inquiries should be directed to Ron Broadhead or Dave Love, General Chairmen, NMBMMR, Campus Station, Socorro, NM 87801, (505) 835-5202 or 835-5146.

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