Property Risk Consulting Guidelines

A Publication of AXA XL Risk Consulting

PRC.15.3

EARTH MOVEMENT

INTRODUCTION

Earth movement is differential movement of the earth's crust. It may consist of a change of local land elevation, subsidence or sudden land collapse, or sinking. It can be said, that any movement of the earth that damages property, regardless of its origin or cause, is earth movement. This document uses examples of and discusses earth movement perils within the contiguous 48 states in the U.S. It also discusses the three hazards commonly associated with earth movement: landslides; subsidence; and unstable soils. Apply these same processes worldwide. Comments in this section apply universally.

POSITION

Know about exposure of a facility to earth movement and whether or not buildings are designed for the potential structural stress. Be aware of recent earth movement events. Also be aware of historical records of earth movement incidents in the geographical area of their territory.

Be able to visually recognize property loss potentials. For example, a facility built on a slope of high clay content soils in a rainy area known for slumps or slope slides is susceptible to earth movement damages. The Survey Guide provided in PRC.15.3.A highlights other loss potentials.

DISCUSSION

Landslide

Landslides are common in mountainous areas and areas near rivers and streams. However, a slide can occur anywhere the underlying or lateral support loses stability.

Landslides can occur as a result of natural, manmade, and combination events. Natural events include vibrations generated by an earthquake of volcanic activity, as a result of excessive rain, a wildfire followed by rain, erosion caused by flowing water. Manmade events include vibration caused by blasting or traffic, clearing land for development then rain falls in the area.

The landslide starts as a result of either increasing the shear stress between the rock and soil or reducing the shear strength. An example of increasing the shear stress is the movement of the rock and soil due to vibration. An example of reducing the shear strength is when ground water raises and makes the material slipperier.

Potential landslide slopes have the following characteristics:

- Uneven slumping of the soil;
- Poorly drained ground surface;
- Disarray of trees and other vegetation.

Slope steepness is referenced by the terms slope ratio, angle of slope in degrees or percent slope. Figure 1 describes these terms.

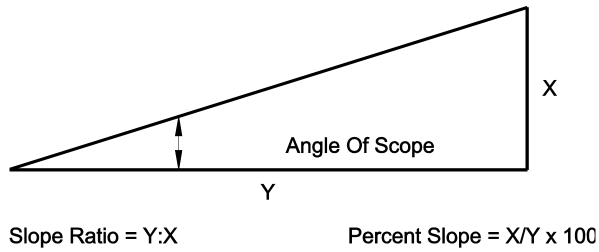

Figure 1. Slope Steepness Chart.

Slopes at 26 degrees or less, also expressed as 2:1 slope ratio or 50% slope, are usually considered stable. Steeper and wetter slopes have a more severe slide potential than shallower slopes. A rockfall normally requires a steep slope. Flows and slumps usually involve mud and loosely consolidated soils or soils with a high clay makeup on relatively flat slopes (100:1 ratio).

A map showing leading landslide problem areas in the contiguous 48 states in the U.S. is illustrated in Figure 2. Comparable illustrations on a worldwide basis have not been located at this time.

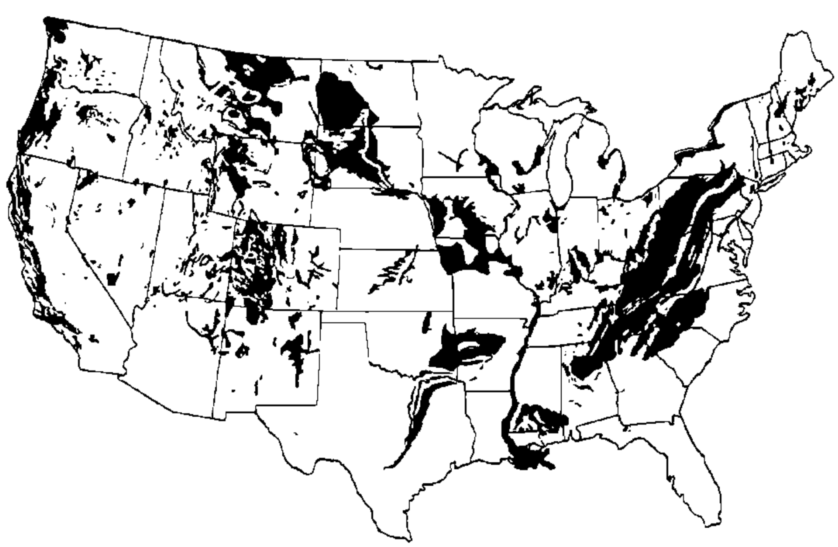

Figure 2. OVERVIEW Map Of Potential Landslide Areas Of The Lower 48 United States.
From U.S.G.S. Professional Paper 1183-Plate 1.

Many conditions reduce slope stability at any steepness. These include undercutting by construction or quarrying, stream or drainage erosion, wave or tidal erosion, or loading the head of the slope. Constructing buildings or other structures on a slope can overload slopes. The same can result from stockpiling or dumping materials. Natural overloading can result from the weight of water, snow, ice or accumulations of rock debris. Excessive wetness because of poor drainage or heavy rains adds weight, reduces the strength of soils, and lubricates zones of potential slope failure.

A potentially unstable slope can be stabilized by excavation, slope trimming, anchoring, grouting or erosion management. Drainage can be adjusted to ease runoff.

Damage potentials of existing construction on a slope can be reduced by slope management techniques. A building can be protected by buttresses, piles, walls and diversion structures.

Subsidence

Subsidence refers to surface material moving downward with little or no horizontal movement. Any area where local mining, quarrying, construction or other environmental changes have occurred generally has a greater potential for earth movement. Subsidence or sinkhole collapse can occur where:

- underground excavation exists,
- a water or sewer line wash out the soil,
- the ground water level drops due to a drought or excessive pumping, or
- the bedrock is subject to the karst process, the ground water dissolves soluble rocks such as limestone, dolomite, and gypsum leaving a large underground cavern.

Subsidence can result in major structural damage or total loss of buildings.

Sink or sinkhole is largely a U.S. term. The same physical process of subsidence or collapse depression formation occurs in Europe, Asia, the Caribbean Islands and other parts of the world. The resulting physical features are called by various names. The names most commonly applied outside of the U.S. are doline, cenote, shakehole, swallet, or swallow hole.

Regions of potential subsidence in the U.S. are illustrated in Figures 3 through 5. Refer also to Table 1, “Causes of Subsidence.” Mining voids resulted in subsidence collapses in Wyoming, Illinois, Pennsylvania, Virginia, West Virginia, North Dakota, Montana, Iowa and Colorado. Subsidence also occurred where groundwater was withdrawn in California, Texas, Arizona, Georgia and Louisiana. It occurred when oil and gas were withdrawn in California and Texas. Likewise, solution mining of soluble minerals, such as salt and gypsum, resulted in subsidence perils.

Identifying local subsidence and discovering the potentials for loss may require the use of a hazards map or investigation report.

TABLE 1
Causes of Subsidence
(Illustrated by U.S. example)

CATEGORY	TYPE CAUSE	POTENTIAL
1. **Local Subsidence** - Limestone (Ls), coal, other mining related or unusual soil conditions	• Coastal Plain - Aquifer related	Moderate
	• Intermountain - Valley water table related (Figure 4)	High
	• Lowlands - Adequate supporting cover, Ls below water table (Figure 4)	Low
	• Plateau - Ls above water table (Figure 4)	Low
	• Adequate supporting Ls at or near surface (Figure 4)	Low
	• Coal or “hardrock” mining (Figure 3)	High
	• Unusual soil characteristics (Figure 5)	High
2. **Regional Subsidence**	• Oil and Gas withdrawal	High
	• Salt, Gypsum, Sulfur, or other economic mineral extraction by “fluid” methods	High
	• Dewatering - Withdrawal of large volumes of water with resultant decreasing artesian pressure and/or ground water level (may also be active on “local” scale)	High

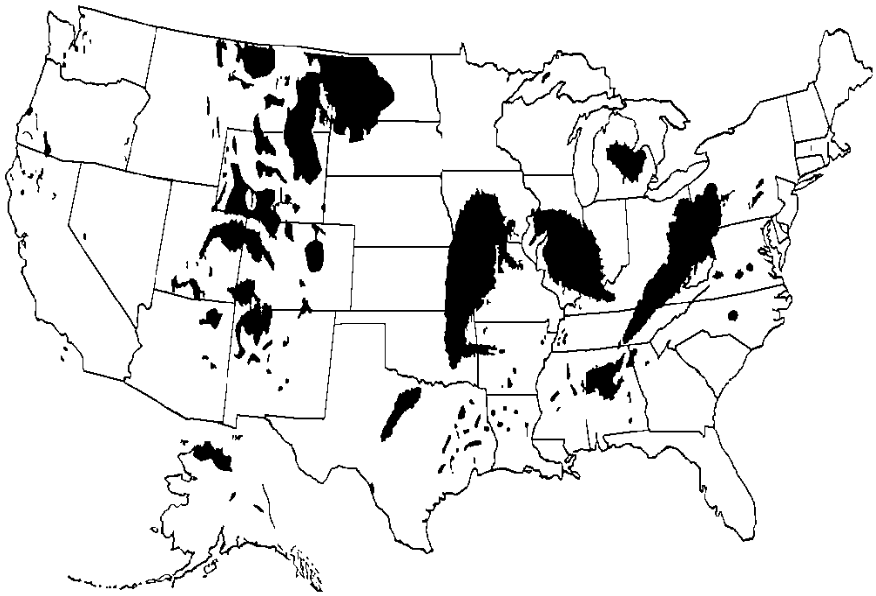

Figure 3. OVERVIEW Map Of Coal Fields In The United States.
From U.S.G.S. Professional Paper 1240-B.

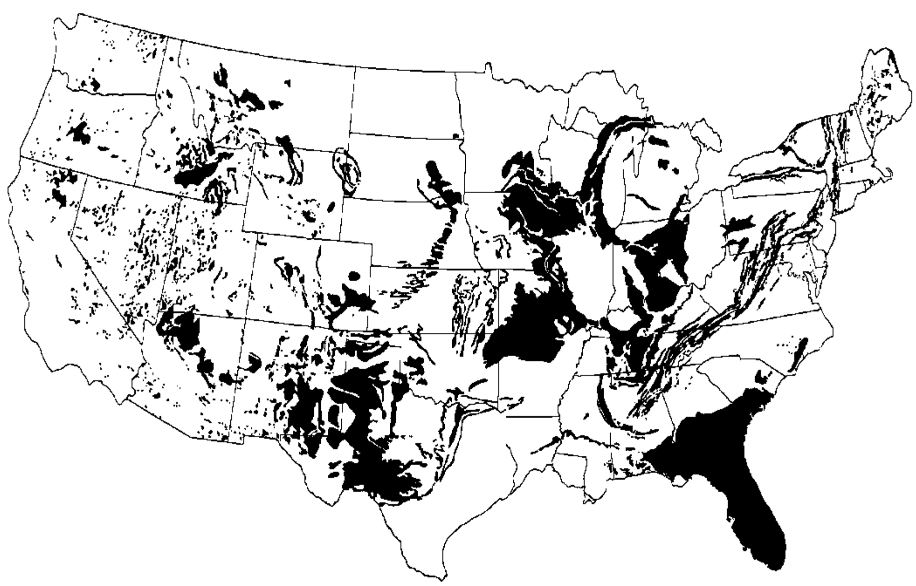

Figure 4. OVERVIEW Of Limestone Areas In The United States.
From U.S.G.S Professional Paper 1240-B.

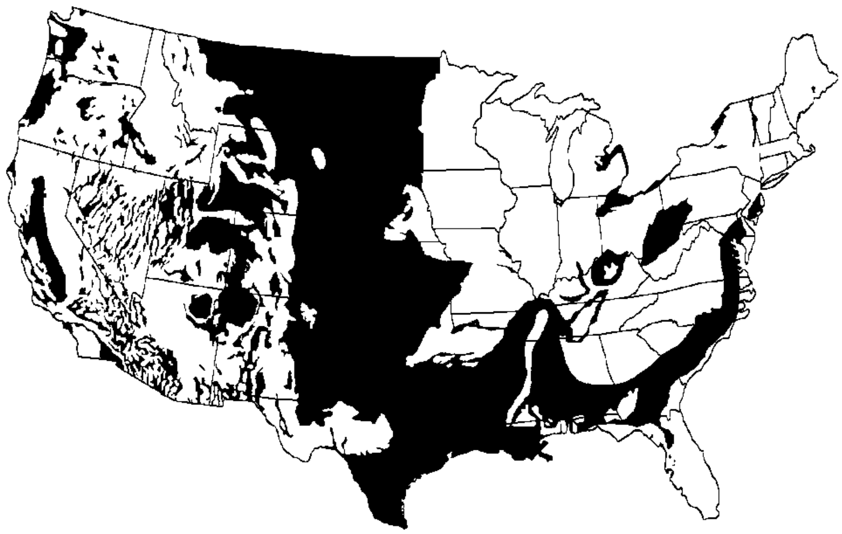

Figure 5. Unstable Soils. Greatest Occurrence Is The Shaded Area.
From U.S.G.S. Professional Paper 1240-B.

Maps of caves, caverns, and mines throughout the world can be found at website showcaves.com, (http://www.showcaves.com/english/explain/Index/index.html). The site is maintained and operated by Jochen Duckeck.

Unusual disappearance or appearance of water may indicate the presence of underground cavities.

Subsidence can also result from fluid withdrawal, such as withdrawal of gas or oil. Subsidence because of fluid withdrawal usually occurs slowly and gradually. By contrast, subsidence caused by coal or hard rock mining, abandoned underground workings or sinkhole collapse because of limestone cavities can occur quickly and without warning.

Signs of developing soil weakness or void spaces beneath the ground surface include:

- Streams or drainage discharging into openings in the ground;
- Sudden draining of a surface water impoundment;
- Sudden draining or muddying of a well;
- Circular or linear cracks, or depressions in the soil;
- Unusual cracks in paving, building floors, walls or foundations;
- Slumping, sagging, or tilting of roadways, fences, poles or other vertical or horizontal structures.

These indicators, especially cracking, slumping, sagging and surface depressions appearing in an area of known cavities, quarrying, mining and fluid withdrawal, strongly signify subsidence potential.

Unstable soils

Unstable soils are difficult to recognize. A puffy popcorn appearance with desiccation cracks on the surface is characteristic of one clay mineral. Other signs are clay cracks and unexplained upheaving or depressions of the surface and foundation. Still others are floor dislocation and cracking, particularly where there is intermittent transient water or uncontrolled drainage.

Positive identification of unstable soils requires laboratory testing. Local history can be the first indication of poor soils. If there have been signs of collapsing or expanding soils in the area, unstable conditions should be anticipated.

Unstable soils that contain clay exist throughout the United States and many regions of Europe and Asia. Soils that lack cohesion and have a high clay content and are weak. When water is added, a volume change can occur. Particles may rearrange themselves or interact with the water until the soil consistency is altered. The soils may then either expand or collapse. Figure 5 shows the areas where this type of soil is prominent in the U.S.

Other Resources

Federal, regional or local agencies have available information on earth movement perils. The most useful is the state Geological Survey. The staff and sales office is usually located in the city of the state capitol. There will be an index of materials available as well as a library containing a copy of all materials available. Out-of-print documents can be perused, reviewed and copied, if necessary. The resident state or staff geologist will be more than willing to assist and discuss problem areas in their respective state and recommend specific maps and reports. The peril of concern can most easily be identified in an investigation report or study, which usually includes a map of incident areas. With this basic information, it is a simple task to correlate the facility site to the susceptible hazard. In general, geologic maps identify rock types within a geographic area by color and letter code with an accompanying lithologic description. A section is also provided which identifies depth and direction trends.

Special investigation reports provide close scrutiny of the hazard. Lakes, rivers, roads and highways can be easily identified and are useful for locating the facility site relative to the hazard area.

Federal (All Countries Maintain An Agency For Earth Science Research)

- Geological Survey - Investigation Reports and Geologic Maps
- National Earth Science Agency
- National Mines Agency
- University Earth Science Departments
- Depository Libraries - Public and university libraries maintain copies of reports and maps

State (All Countries Have Localized Entities Within The Country Political Framework)

- State Geological Survey (Sometimes called Department of Natural Resources, Environmental Resources, Bureau of Mines, Water and Land Development, Department of Conservation, Environmental Quality Engineering, State Cartographer, Natural History, etc.)
- State and Private Universities
- Libraries
- State Highway Engineering
- Department of Transportation
- County, City, and Town Engineers

EARTH MOVEMENT
SURVEY GUIDE

1. What are the categories of recognized natural hazards for the geographic area of the plant site? (i.e., limestone caused subsidence, mining collapse, landslide, expanding/ shrinking soils, fluids withdrawal subsidence, etc.) (Refer to Table 1 of PRC.15.3.)
2. How far away is the nearest body of water? (Lake, stream, dry stream bed, pond, marsh area, springs, etc.)
3. What are the general ground materials in the region? (Soils, dirt, rock, sand, clays, etc.)
4. Is the plant site on filled land?
5. What courses (ditches, ravines, yard swales, dry stream beds, etc.) are available for the natural drainage of rain, snowmelt or a sudden discharge of water?
6. Is protection for building and structure foundations provided against transient water in areas of expansive or collapsing soils?
7. Are there large or unusual cracks or distortion of building walls, floors or foundations?
8. Are there unusual building construction features, unusual structures or noticeably unusual ground conditions on site? (Retaining walls, reinforced/braced or strengthened foundations, unexplained poor lawn growth, etc.)
9. Have there been natural hazard peril incidents nearby? (Subsidence, landslides, rock falls, ground slump, etc.)
10. Are there or have there been mining or quarrying operations in the area?
11. What are the landforms of adjacent properties? (Steep slopes, river bank, hilly, rocky, depressions, etc.)
12. Are there indications of movement on nearby slopes? (Slump, slide, fall, etc.)