Quake Defense

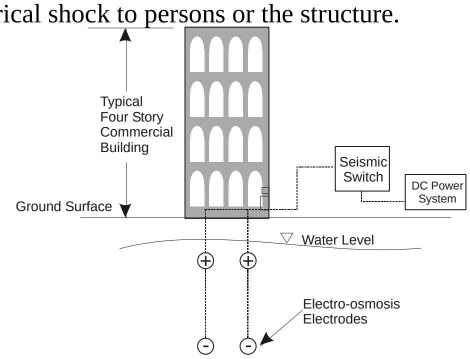
Liquefaction & Base Isolation

Electro-Osmosis for Earthquake Damage Prevention
GeoSierra's Quake Defense System

Individual Highlights:

GeoSierra has been researching and developing the technologies to utilize electro-osmosis to prevent damage to existing structures during an earthquake event. One of the most destructive effects of the stress waves generated during a seismic event results from their induced shaking or vibratory shearing of saturated, loose fine sand or silty sand, causing a phenomenon known as liquefaction. When loose sands and silts are subjected to repeated shear strain reversals, the volume of the soil contracts and results in an immediate rise in the pore water pressure within the soil. If the pore water pressure rises sufficiently high, then the effective stress reduces to zero, and the soil mass will lose all shear strength. Such temporary loss of shear strength can have a catastrophic effect on earthworks or structures founded on these deposits. Major landslides, settling or tilting of buildings and bridges and instability of dams or tailings ponds have all been observed in recent years and efforts have been directed to prevent or reduce such damage.

The electro-osmosis technology involves reducing the pore water pressure build up in soils during an earthquake event by activating an electro-osmotic gradient away from the foundation of the structure. This negates the impact of the earthquake shaking and by reducing the soil pore water pressure maintains the soil shear strength and foundation structural stability. Soil liquefaction prevention by electro-osmosis can be retrofit to protect existing structures with minimal disruption or disturbance to the structure. A seismic switch monitors local seismic precursor events, such as early arrival ground motion, and electrically energizes the electrodes beneath the structure to move the groundwater by electro-osmosis away from the foundation of the structure and thus maintain structural stability of the foundation by preventing liquefaction of the sub-base soils during an earthquake event. The energized electrodes are completely safe and there is no potential for any electrical shock to persons or the structure.



GeoSierra's Quake Defense System to Protect an Existing Building against Liquefaction

Buildings Destroyed due to Liquefaction of Subsurface Soils

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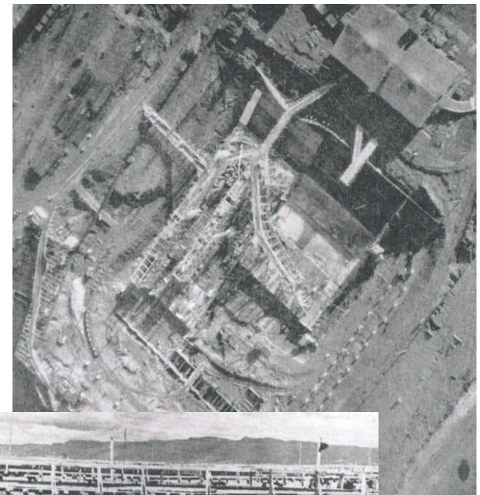
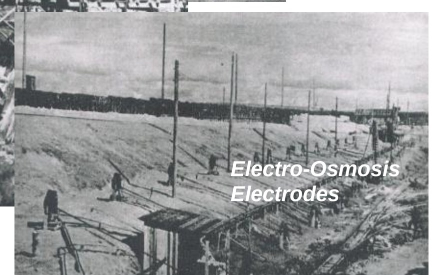
History & Background on Electro-Osmosis and Geotechnical Applications

In 1939, Casagrande (1952) demonstrated that by applying electro-osmosis to certain fine-grained soils, the resulting electrical field immediately redirected the pore water seepage force. This resulted in an immediate increase in the effective stress in the soil thereby increasing the soil shear strength to such a degree that even steep cuts remained stable in an otherwise unstable sediment. Casagrande utilized electro-osmosis in field applications in Germany and Norway during the 1940s and subsequently in North America. It was demonstrated from Casagrande's work, that electro-osmosis could immediately stabilize slopes and long-term application of electro-osmosis could lead to dewatering and soil strength increases. A quote from Terzaghi on Casagrande's field demonstrations "…seepage pressures due to electro-osmotic flow can be created in directions away from the faces of the excavation and toward the cathodes. The stabilizing influence of these pressures is in many instances spectacular and occurs as soon as the current is turned on."

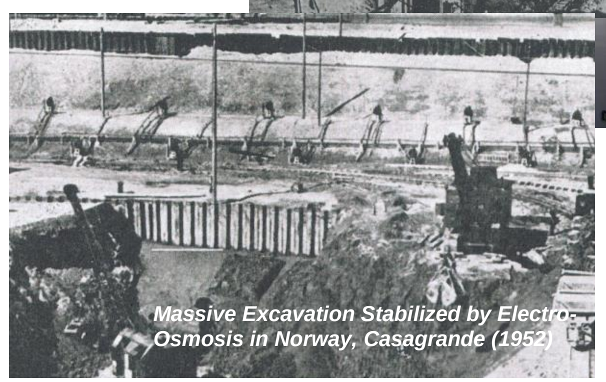
Electro-osmosis involves the application of a d-c current between electrodes inserted in the saturated soil, which gives rise to pore fluid movement in negatively charged soils from the anode electrodes towards the cathode electrodes and thus modifies the soil pore water pressure. Electro-osmosis has been used for: 1) improving excavation stability; 2) decreasing pile driving resistance; 3) increasing pile strength; 4) stabilizing soils; 5) dewatering of sludge; 6) reducing water intake into petroleum recovery wells and; 7) removing contaminants from low permeable soils. Electro-osmosis has not been used extensively due to the high cost of maintaining the d-c potential over long periods of time and the drying out and chemical reactions that occur if the system is activated for long periods of time. For short-term stabilization by pore water pressure reduction, electro-osmosis is very effective in certain soil types such as fine sands, silty sands and silts.



Unstable Excavation



Electro-Osmosis Electrodes



Massive Excavation Stabilized by Electro-Osmosis in Norway, Casagrande (1952)

Site Liquefaction Assessment Tool

Current methods for evaluating the liquefaction potential of soils consist of a combination of laboratory tests and indirect empirical in situ tests based on the resistance to driving using the Standard Penetration Test (SPT) and/or the Cone Penetration Test (CPT). The cone penetration resistance is empirically correlated to the observed occurrence or non-occurrence of liquefaction of sites during past earthquake events. Such an empirical procedure based on anecdotal evidence is not appropriate for scientifically quantifying soil liquefaction potential nor is it able to be used to determine electro-osmosis applicability to soil liquefaction prevention.

GeoSierra has developed a direct in situ tool for determining the liquefaction potential of a saturated soil by a direct-push probe, much like a CPT, but with an expanding/contracting set of bladders. The bladders impose under zero volume change a cyclic shear stress reversal on a body of soil in situ similar to that experienced in an earthquake, and the liquefaction potential of the soil can be quantified from the subsequent measurement of pore water pressure response. A pore water pressure increase during cyclic shear stress reversals indicates a contractive soil, which has the potential to liquefy. The tool can also quantify the potential of electro-osmosis in preventing soil liquefaction by energizing electrodes within the device during the imposed cyclic shear stress reversals on the in situ soil.

GeoSierra's In Situ Tool for Liquefaction Assessment & Electro-Osmosis Applicability

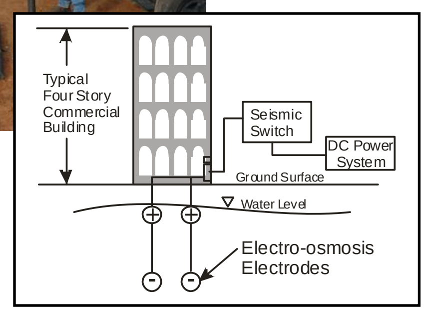
GeoSierra's Quake Defense System for Liquefaction Prevention

GeoSierra's liquefaction prevention system consists of a seismically triggered switch that activates a d-c potential difference across electrodes installed in the ground horizontally (as shown), or vertically, to negate by electro-osmosis the rise in pore water pressure induced by an earthquake event, and thus prevent soil liquefaction beneath a structure or works, such as a building, bridge, dam, pier, excavation, pipeline, runway or tailings pond. The electrodes are spatially located in the saturated soil beneath the structure to induce groundwater flow, either away from the foundation of the structure, or towards pressure relief wells associated with the cathode electrodes. The locations of the electrodes and the applied d-c potential difference will vary depending on the soil conditions and the structure.

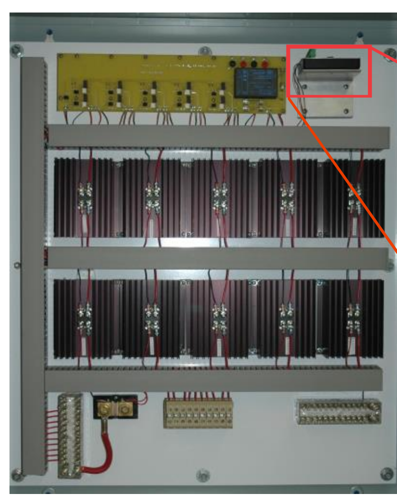
GeoSierra's Seismic Switch & Electro-Osmosis Control System Installed at Ground Floor Level of Office Building

The seismically triggered switch consists of a monitored accelerometer with an algorithm to activate the switch if ground motions of certain magnitude and frequency are experienced. The seismically triggered switch electrically energizes the array of electrodes in the saturated ground. These electrodes induce groundwater flow by electro-osmosis in negatively charged soils from the anode electrodes to the cathode electrodes and thus prevent the rise in pore water pressure in the soil during the earthquake event. The d-c power source is either lead acid batteries or a quick start generator or a combination thereof.

Electro-Osmosis Graphite Electrodes for GeoSierra's Quake Defense System

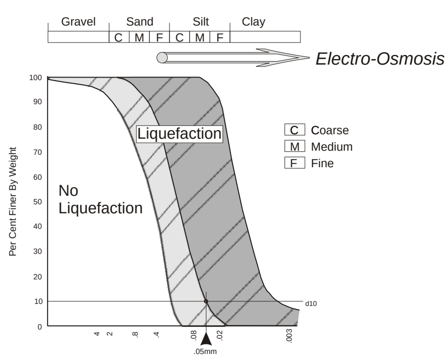


The electrodes are installed beneath the existing structure by precise drilling techniques as used for underground utility installation. The anode electrodes are graphite with the cable connection crimped and sealed inside of the graphite electrode. The cathode electrodes are stainless steel screens as used in groundwater monitoring wells. The control panel is located on the ground or basement level of the structure along with the d-c power supply. The seismic switch not only activates and energizes the electrodes but also records accelerations during earthquake events, which are uploaded to a central server. The microprocessor controlled panel also remotely checks cable and electrode integrity plus monitors battery condition and charge level. The d-c power supply is capable of energizing the electrodes throughout the largest earthquake and associated aftershocks.



Microprocessor Controlled Switch & Monitoring System

GeoSierra's Quake Defense 1/10th MegaWatt System DC 200Volts 500Amps Seismic Switch & Controls



GeoSierra's In Situ Tool Determines Electro-Osmosis Applicability to Site Soils

GeoSierra is a privately held corporation, based in the USA and UK. GeoSierra specializes in innovative solutions in the earth sciences, to provide more efficient, and environmental sustainable solutions to issues relating to the Earth, Energy and Environment.

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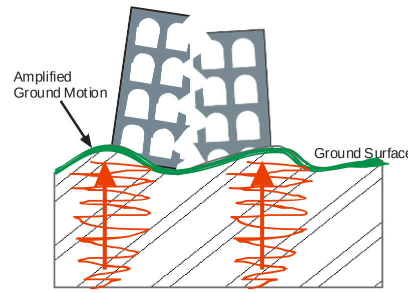
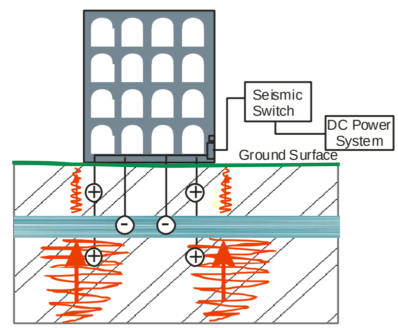
GeoSierra's Quake Defense for Base Isolation During an Earthquake Event

Earth ground motions experienced during an earthquake are actually quite complex; however, the resulting ground motion imposed on the soil and the overlying structure are predominantly from the upward propagation of the S-wave components from the underlying bedrock. Deposits of thick soft soils can give rise to amplification of these ground motions in particular in the long period (low frequency) content of the earthquake induced shaking. Such amplification of earthquake induced ground motions can cause extensive damage to buildings, bridges, pipelines, embankments, dams, slopes, and other structures and works constructed on soft soil deposits.

Building Destroyed by Amplified Ground Motion During an Earthquake Event

Deposits of soft soils, such as silts and clays are most likely to amplify ground motions during an earthquake. Structures constructed on such soils can be extensively damaged by even a moderate size earthquake; e.g. the two recent earthquakes, 1985 Michoacan (Mexico) and 1989 Loma Prieta (California), highlight the extensive damage that occurs to structures located on soft soil deposits.





Building with & without Quake Defense. With Quake Defense the Structure is "Base Isolated" from the Amplified Ground Motion

GeoSierra's Quake Defense system isolates a structure from earthquake ground motion by preferentially inducing soil liquefaction within a particular soil horizon beneath the structure. The seismic switch energizes electrodes in the ground thereby raising the pore water pressure in the soil horizon and thus preferentially inducing localized soil liquefaction of the particular soil horizon. This localized liquefied zone isolates the structure from the upward propagating shear wave ground motions arising from the earthquake event. The soil horizon is selected at depth below the structure to avoid any surface impact due to the localized liquefaction.

Patents on GeoSierra's Quake Defense System and In Situ Tool

US Patents 6,308,135, 6,615,653, 6,792,720 and 7,331,143 with foreign patents awarded in Canada, China, Europe, Japan, Mexico and New Zealand.

About GeoSierra...

GeoSierra, a privately owned corporation, based in Atlanta, GA, USA and London, England. We are known for our expertise and patented technology involving vertical hydraulic fracturing of ductile formations for groundwater remediation and enhanced oil and gas recovery. The family of "Quake Defense" solutions described above leverages our expertise and is a natural extension of our products and services. We are capable of providing turnkey completion of projects from investigation, testing, design and construction; however, we are interested in participating in teaming arrangements with specialized solution providers focusing on Earthquake related services.