

Appendix J
Glossary of Terms

December 2019

Report of the Expert Panel on the Technical Causes of the Failure of Feijão Dam I
Appendix J – Glossary of Terms

anisotropy—having different properties in different directions.

Atterberg limits—“limits of consistency” of fine-grained soils, typically referring to the liquid limit, plastic limit and, sometimes, the shrinkage limit.

beach—tailings slope between the dam crest and the pond formed on deposition of tailings as a slurry from the dam crest.

berm—an engineered earth fill.

bonding—formation of cements between particles; for Dam I, most likely due to oxidation of iron present in the tailings.

coarse tailings—for Dam I, materials presenting predominantly sand-sized gradation on particle size distribution (PSD) plots.

clay (clay soil)—fine-grained soil or the fine-grained portion of soil that exhibits plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry.

coefficient of permeability (permeability)—the rate of discharge of water under laminar flow conditions through a unit cross-sectional area of a porous medium (soil) under a unit hydraulic gradient and standard temperature conditions (usually 20° C).

compaction—the densification of a soil by means of mechanical energy.

cone penetration test with measurement of pore pressure dissipation (CPTu)—a penetration test in which a steel cone that has a 60° point is pushed into the ground at a continuous rate of 2 centimeters per second. The resistance to penetration is measured electronically at the cone tip and cone sleeve, in addition to the pore water pressure between the tip and the sleeve.

consolidation—the gradual reduction in volume of a fine-grained soil mass resulting from a decrease in excess pore water pressure induced by an applied stress.

constant-head boundary—the conceptual representation of a natural feature such as a lake or river that effectively fully penetrates the aquifer and prevents water-level change in the aquifer at that location.

contractive tailings—when on shearing of a loose particle arrangement of tailings, the particles move together and the tailings compress.

creep—a condition of ongoing internal strain within a dam under essentially constant load that can result in accumulated deformation over time.

Report of the Expert Panel on the Technical Causes of the Failure of Feijão Dam I
Appendix J – Glossary of Terms

crest—the top of a dam or berm slope.

critical state line (CSL)—the relationship between the void ratio, e , and the mean effective stress, p' , for a given soil unit, at a condition when the soil will shear at constant volume and constant shear stress.

decant tower—structure used to remove supernatant water produced from deposited tailings and any rainfall runoff on Dam I.

deep horizontal drains (DHPs, or drenos horizontais profundos)—lateral drains installed within the dam and tailings intended to drain water from within the dam and tailings.

deformation—the displacement or movement of a soil mass in response to loading.

deformation analysis—a computer model that yields the deformation of the tailings in response to applied loads.

dilatant (or dilative) tailings—when on shearing of a tightly packed arrangement of tailings particles, the particles must first move apart in order to move past each other.

direct simple shear (DSS) testing—soil testing for the investigation of stress-strain strength relationships for horizontal loading situations.

downstream slope—the slope of a dam or berm farthest away from the tailings pond. Downstream means the direction away from the tailings pond, while upstream means the direction towards the pond.

drainage blanket (blanket drain)—a layer of pervious material placed over foundation material to facilitate drainage of the berm.

drained condition— in soil mechanics, the condition in which loading or unloading of a soil does not result in a change in pore water pressure, due to either high permeability of the soil or low rate of load application, which allows pore water to flow from the soil as rapidly as it is loaded or unloaded.

dynamic loading—repetitive inertial loading imposed by vibrating machinery, blasting, earthquake shaking, or other sources. Cyclic loading is usually considered a case of dynamic loading imposed by an earthquake.

effective stress—the difference between the total stress and the pore water pressure in an element of soil.

factor of safety (FS or FOS)—the ratio of the available strength to the shear stress imposed by self-weight and loadings on the soil slope.

Report of the Expert Panel on the Technical Causes of the Failure of Feijão Dam I
Appendix J – Glossary of Terms

failure envelope—the envelope of a sequence of Mohr circles or peak shear stresses, usually in a p - q plot representing stress conditions at failure for a given soil.

fine tailings—for Dam I, materials presenting predominantly silt-sized gradation on PSD plots.

flow meters—an instrument used to measure linear, nonlinear, mass, or volumetric flow rate of a liquid (usually water) or a gas.

flowslide—flowslide or flow liquefaction occurs when the shear stresses required for static equilibrium of a soil mass exceed the shear strength of the soil in its liquefied state.

field vane shear tests (FVT)—an in-place shear test in which a rod with thin radial vanes at the end is pushed into the soil and the resistance to rotation (or torque) of the vanes is determined.

gradation (grain-size distribution, particle-size distribution)—the proportions by mass of a soil or fragmented rock distributed in specified grain or particle-size ranges.

groundwater—that part of the subsurface water that is in the saturated zone of a soil mass.

groundwater table (water table)—the surface of a groundwater body at which the water pressure equals atmospheric pressure.

Guelph permeameter—a constant-head permeameter or shallow pump-in technique for measuring soil hydraulic properties in the unsaturated zone.

head—water pressure at a point in a soil mass, expressed in terms of the vertical distance of the point below the water surface.

hydraulic gradient—the change in head over a given flow path length.

hydrostatic pore water pressure—the equilibrium pressure exerted by water in the pores of a saturated soil at a given point due to gravity, which increases in proportion to depth below the water table.

impoundment—tailings containment.

in situ—applied to a rock or soil when occurring in the situation in which it is naturally formed or deposited.

inclinometer—device that measures changes in angles (i.e., deformations) over depth within the embankment and tailings material.

index properties—the properties that facilitate identification and classification of soils for engineering purposes.

Report of the Expert Panel on the Technical Causes of the Failure of Feijão Dam I
Appendix J – Glossary of Terms

infiltration test—a field test to determine the rate at which surface water passes into the soil profile. The “infiltration rate” refers to the speed at which water enters the soil.

interferometric synthetic aperture radar (InSAR)—a technique for mapping surface deformation and/or surface moisture and vegetation using radar images of the Earth’s surface that are collected from orbiting satellites. Synthetic Aperture Radar (SAR) imagery is produced by reflecting radar signals off a target area and measuring the two-way travel time between the satellite and the target area.

internal erosion—the formation of voids within a soil caused by the removal of fine particles by seepage through the soil.

internal friction angle—the proportion of the shear strength of a soil or rock due to the interlock of particles and the sliding of particles over one another.

isotropy—having the same properties in all directions.

kilopascal (kPa)—unit of pressure measurement equivalent to 1000 newtons per square meter.

light detection and ranging (LiDAR)—a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses, combined with other data recorded by the airborne system, generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.

limit equilibrium method (LEM)—a method of calculating the factor of safety of a slope in which a force and/or moment balance is performed on a sliding mass.

line-of-sight (LOS)—a line from an observer’s eye to a distant point.

liquefaction—process whereby loose, saturated or near-saturated silty sand or sandy silt soils lose strength due to pore pressure increase on loading or unloading and behave like a liquid rather than a solid.

loading—net increase in applied stress.

material point method (MPM)—a numerical technique used to simulate the large-strain behavior of a loaded or unloaded soil mass, in which material points represent the mesh or grid.

matric suction—the capillary action between particles in an unsaturated soil. Capillary action refers to the movement of water within the spaces of a porous material due to the forces of adhesion, cohesion, and surface tension.

mean effective stress—the average of the principle effective stresses.

Report of the Expert Panel on the Technical Causes of the Failure of Feijão Dam I
Appendix J – Glossary of Terms

modulus of elasticity (elastic modulus, modulus of deformation)—the ratio of stress to strain for a material under given loading conditions; numerically equal to the slope of the tangent or the secant of a stress-strain curve.

peak shear strength—maximum shear strength along a failure surface.

permeability (hydraulic conductivity)—the volume of water at the existing kinematic viscosity that will move in a unit time under a unit hydraulic gradient through a unit area of soil or rock measured at right angles to the direction of flow.

phreatic surface—water table defined by zero pore water pressure.

piezometer—device used to measure the height to which a column of the water within a soil or rock mass rises against gravity at a specific point. A Casagrande piezometer is a simple type of manually-read piezometer and consists of a pipe having an opening, called a screen, at its lower end installed inside a borehole. Vibrating wire piezometers and pressure transducers are electronic devices installed in a borehole that measure water pressure electronically.

piezometric surface—a surface that coincides with the water level within a soil or rock mass.

pipng—internal erosion that develops into an open “pipe” through the soil.

plasticity—the property of a material to continue to deform indefinitely while sustaining a constant stress.

pore water pressure—pressure measured relative to atmospheric pressure within the pores of a saturated soil or rock mass.

pressure transducer—instrument that converts pressure into an electrical signal by the deformation of strain gages that are bonded into a diaphragm.

reconstituted—a soil test specimen formed in the laboratory to prescribed conditions by a specified procedure.

remolded—a soil whose structure has been modified by shear distortion, while attempting to maintain constant water content and density.

reservoir gauge—a device used to measure the elevation of the surface water surrounding the decant tower of Dam I.

residual soil/colluvium—native soil beneath or adjacent to Dam I, which may include unconsolidated sediments that have been transported and deposited known as colluvium.

Report of the Expert Panel on the Technical Causes of the Failure of Feijão Dam I
Appendix J – Glossary of Terms

residual stress—internal stress locked into a material after all external loading has been removed, due to the material obtaining equilibrium after it has undergone plastic deformation.

scanning electron microscopy (SEM)—use of a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The signals that derive from electron-sample interactions reveal information about the sample, including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample.

seismic shear wave velocity (V_s) tests—a technique to measure the velocity of induced shear waves passing through a soil or rock.

setback—the upstream relocation of the dam crest alignment.

shear strength—strength of a soil or rock measured parallel to the direction of loading.

shear strength reduction (SSR) method—the systematic use of finite element analysis to determine the reduction factor applied to the shear strength of all material in a slope that brings the slope to the verge of failure.

shear wave—wave in which a medium changes shape without change of volume (shear-plane wave in isotropic medium is transverse wave).

slimes—for Dam I, materials that are upstream of the Slimes boundary defined in Appendix F, determined through air photograph and cone penetration test (CPTu) interpretation, presenting predominantly clay-sized gradation in PSD plots.

slip surface—the surface within a soil mass along which failure occurs under loading.

soil behavior type—soil classification system based on parameters obtained from CPTu results.

soil profile—vertical section of a soil, showing the nature and sequence of the various layers, as developed by deposition or weathering, or both.

soil-water characteristic curve (SWCC)—the hysteretic semi-logarithmic relationship between volumetric water content and matric suction of soils over wetting and/or drying cycles.

specific gravity—the ratio of the density of a solid particle to the density of water at a specified temperature and pressure.

stability analysis—an analytical or numerical method that compares the available resistance of a soil slope to the shear stresses imposed on that slope.

Report of the Expert Panel on the Technical Causes of the Failure of Feijão Dam I
Appendix J – Glossary of Terms

standard penetration test (SPT)—a penetration test in which a split-barrel sampler is driven to obtain a representative disturbed soil sample for identification purposes, and to measure the resistance of the soil to penetration of the sampler.

standard Proctor—a laboratory compaction procedure whereby a soil at a known water content is placed in a specified manner into a mold of given dimensions, subjected to a compactive effort of controlled magnitude, and the resulting unit weight is determined. The procedure is repeated for various water contents sufficient to establish a relationship between water content and dry density.

starter dam—the initial dam in a tailings dam, usually built of earthfill, to create initial tailings storage.

state parameter—the difference between the current and critical void ratios at the same mean effective stress. When the state parameter is positive, the material has a tendency to contract upon shearing, whereas when the state parameter is negative, the tendency of the material is to dilate during shearing.

static liquefaction—flow of a saturated or near-saturated, loose, sandy material that occurs when the effective stress is reduced essentially to zero, corresponding to complete loss of shear strength and resulting from a single sudden occurrence of change in stress (“monotonic loading”), rather than a cyclic event (such as an earthquake or vibration).

steady-state flow conditions—the condition where the fluid properties at any single point in the system do not change over time.

stochastic distribution—a probabilistic variation in material properties.

stratigraphy—the layering of soil and/or rock.

stress-strain curve—the relationship between the applied load per unit area and the resulting deformation relative to the original dimension of a soil mass.

survey marker (survey monument)—an object used in geodetic and land surveying to mark key survey points on the Earth’s surface.

tailings—finely ground soil and rock particles remaining after the ore extraction process.

toe—the intersection of the dam slope with the natural ground.

total station—electronic/optical instrument used for surveying composed by a theodolite integrated with electronic distance measurement (“EDM”) to measure both vertical and horizontal angles and the slope distance from the instrument to a particular point.

Report of the Expert Panel on the Technical Causes of the Failure of Feijão Dam I
Appendix J – Glossary of Terms

transient flow conditions—the condition where the fluid properties at any single point in the system change over time.

triaxial tests—a standard soil shear test in which a cylindrical sample of soil encased in a membrane is subjected to an increasing or decreasing vertical load while confined by constant cell pressure.

undrained condition— in soil mechanics, the condition in which loading or unloading of a soil results in a change in pore water pressure, due to either low permeability of the soil or high rate of load application, which does not allow pore water to flow from the soil as rapidly as it is loaded or unloaded.

undrained strength—the strength of a soil when loaded sufficiently fast that pore pressures cannot dissipate. For a given soil, undrained strength is a function of density, stress path, and rate of loading, among many other factors.

undrained strength ratio—the ratio of undrained strength to effective stress.

unloading—net decrease in applied stress.

unsaturated—a condition in which all drainable voids between particles in a soil mass are filled only with air.

vibrating wire piezometer—instrument that converts water pressure to a frequency signal via a diaphragm, a tensioned steel wire, and an electromagnetic coil.

void—space in a soil or rock mass not occupied by solid mineral matter. This space may be occupied by air, water, or other gases or liquids.

void ratio—in soils and rock, the ratio of the volume of voids to the volume of solids.

water level indicator (INA, or indicador de nivel d'água)—a manually read instrument used to determine the water level within a soil mass.

X-ray diffraction (XRD)—a nondestructive technique that provides detailed information about the crystallographic structure, chemical composition, and physical properties of materials. The phenomena by which X-rays are reflected from the atoms in a crystalline solid is called diffraction. The diffracted X-rays generate a pattern that reveals structural orientation of each atom in a given compound.