

Soil parameters

Soil elastic Young's modulus Geotechdata.info - Updated 17.09.2013

Soil Young's modulus (E), commonly referred to as soil elastic modulus, is an elastic soil parameter and a measure of soil stiffness. It is defined as the ratio of the stress along an axis over the strain along that axis in the range of elastic soil behaviour. The elastic modulus is often used for estimation of soil settlement and elastic deformation analysis.

Soil elastic modulus can be estimated from laboratory or in-situ tests or based on correlation with other soil properties. In laboratory, it can be determined from [triaxial test](#) or indirectly from [oedometer test](#). On field, it can be estimated from [Standard penetration test](#), [Cone penetration test](#), [pressuremeter](#) or indirectly from [dilatometer test](#).

Typical values of soil Young's modulus for different soils according to USCS

In general, the soil stiffness and elastic modulus depends on the consistency and packing (density) of the soil. Typical values of soil Young's modulus are given below as guideline.

Typical values of Young's modulus for GRANULAR MATERIAL (MPa) (based on Obrzud & Truty 2012 compiled from Kezdi 1974 and Prat et al. 1995)

| USCS | Description | Loose | Medium | Dense |
|--------|--------------------------|-------|--------|---------|
| GW, SW | Gravels/Sand well-graded | 30-80 | 80-160 | 160-320 |
| SP | Sand, uniform | 10-30 | 30-50 | 50-80 |
| GM, SM | Sand/Gravel silty | 7-12 | 12-20 | 20-30 |

Typical values of Young's modulus for COHESIVE MATERIAL (MPa) (based on Obrzud & Truty 2012 compiled from Kezdi 1974 and Prat et al. 1995)

| USCS | Description | Very soft to soft | Medium | Stiff to very stiff | Hard |
|--------|----------------------------------|-------------------|---------|---------------------|---------|
| ML | Silts with slight plasticity | 2.5 - 8 | 10 - 15 | 15 - 40 | 40 - 80 |
| ML, CL | Silts with low plasticity | 1.5 - 6 | 6 - 10 | 10 - 30 | 30 - 60 |
| CL | Clays with low-medium plasticity | 0.5 - 5 | 5 - 8 | 8 - 30 | 30 - 70 |
| CH | Clays with high plasticity | 0.35 - 4 | 4 - 7 | 7 - 20 | 20 - 32 |
| OL | Organic silts | - | 0.5 - 5 | - | - |
| OH | Organic clays | - | 0.5 - 4 | - | - |

REFERENCES

- Obrzud R. & Truty, A. THE HARDENING SOIL MODEL - A PRACTICAL GUIDEBOOK Z Soil.PC 100701 report, revised 31.01.2012
- Kezdi, A. (1974). Handbook of Soil Mechanics. Elsevier, Amsterdam.
- Prat, M., Bisch, E., Millard, A., Mestat, P., and Cabot, G. (1995). La modelisation des ouvrages. Hermes, Paris.

Citation : Geotechdata.info, Soil Young's modulus, <http://geotechdata.info/parameter/soil-elastic-young-modulus.html> (as of September 17.09.2013).

Soil friction angle Geotechdata.info - Updated 02.12.2013

Soil friction angle is a shear strength parameter of soils. Its definition is derived from the Mohr-Coulomb failure criterion and it is used to describe the friction shear resistance of soils together with the normal effective stress.

In the stress plane of Shear stress-effective normal stress, the soil friction angle is the angle of inclination with respect to the horizontal axis of the Mohr-Coulomb shear resistance line.

Typical values of soil friction angle for different soils according to USCS

Some typical values of soil friction angle are given below for different USCS soil types at normally consolidated condition unless otherwise stated. These values should be used only as guideline for geotechnical problems; however, specific condition of each engineering problem often needs to be considered for an appropriate choice of geotechnical parameters.

| Description | USCS | Soil friction angle [°] | | | Reference |
|---|------|-------------------------|-----|----------------|---------------|
| | | min | max | Specific value | |
| Well graded gravel, sandy gravel, with little or no fines | GW | 34 | 39 | | [1],[2],[3], |
| Poorly graded gravel, sandy gravel, with little or no fines | GP | 35 | 41 | | [1],[3], |
| Silty gravels, silty sandy gravels | GM | 32 | 37 | | [1],[3], |
| Clayey gravels, clayey sandy gravels | GC | 29 | 33 | | [1], [3], |
| Well graded sands, gravelly sands, with little or no fines | SW | 36 | 41 | | [1], [3], |
| Poorly graded sands, gravelly sands, with little or no fines | SP | 32 | 38 | | [1], [2],[3], |
| Silty sands | SM | 33 | 35 | | [1], [3], |
| Clayey sands | SC | 31 | 35 | | [1], [3], |
| Inorganic silts, silty or clayey fine sands, with slight plasticity | ML | 29 | 37 | | [1], [3], |
| Inorganic clays, silty clays, sandy clays of low plasticity | CL | 27 | 31 | | [1], [3], |
| Organic silts and organic silty clays of low plasticity | OL | 22 | 32 | | [1], |
| Inorganic silts of high plasticity | MH | 24 | 29 | | [1], [3], |
| Inorganic clays of high plasticity | CH | 18 | 25 | | [1], [3], |
| Organic clays of high plasticity | OH | 17 | 35 | | [1], |
| Peat and other highly organic soils | Pt | 0 | 10 | | [2], |

Correlation between SPT-N value, friction angle, and relative density

| Correlation between SPT-N value and friction angle and Relative density (Meyerhoff 1956) | | | |
|--|-------------|-------------------------|-----------------------|
| SPT N3 [Blows/0.3 m - 1 ft] | Soi packing | Relative Density [%] | Friction angle [°] |
| < 4 | Very loose | < 20 | < 30 |
| 4 - 10 | Loose | 20 - 40 | 30 - 35 |
| 10 - 30 | Compact | 40 - 60 | 35 - 40 |
| 30 - 50 | Dense | 60 - 80 | 40 - 45 |
| > 50 | Very Dense | > 80 | > 45 |

REFERENCES

1. Swiss Standard SN 670 010b, Characteristic Coefficients of soils, Association of Swiss Road and Traffic Engineers
2. JON W. KOLOSKI, SIGMUND D. SCHWARZ, and DONALD W. TUBBS, Geotechnical Properties of Geologic Materials, Engineering Geology in Washington, Volume 1, Washington Division of Geology and Earth Resources Bulletin 78, 1989, [Link](#)
3. Carter, M. and Bentley, S. (1991). Correlations of soil properties. Penetech Press Publishers, London.
4. Meyerhof, G. (1956). Penetration tests and bearing capacity of cohesionless soils. J Soils Mechanics and Foundation Division ASCE, 82(SM1).

Citation : Geotechdata.info, Angle of Friction, <http://geotechdata.info/parameter/angle-of-friction.html> (as of September 16.09.2013).

COHESION

| Cohesion From Geotechdata.info | | Updated April 29, 2011 | |
|--|---|------------------------|---|
| <p>The cohesion is a term used in describing the shear strength soils. Its definition is mainly derived from the Mohr-Coulomb failure criterion and it is used to describe the non-frictional part of the shear resistance which is independent of the normal stress. In the stress plane of Shear stress-effective normal stress, the soil cohesion is the intercept on the shear axis of the Mohr-Coulomb shear resistance line.</p> | | | |
| Typical values for Cohesion; Provided by Geotechdata.info | | | |
| USCS | Description | Average value (kPa) | Value from literature [Ref] (kPa) |
| GW | Well graded gravel, sandy gravel, with little or no fines | 0 ± 0 | 0 [1]; |
| GP | Poorly graded gravel, sandy gravel, with little or no fines | 0 ± 0 | 0 [1]; |
| GM | Silty gravels, silty sandy gravels | 0 ± 0 | 0 [1]; |

| | | | |
|----|---|-------------|------------------|
| GC | Clayey gravels, clayey sandy gravels | 0 ± 0 | 0 [1]; |
| SW | Well graded sands, gravelly sands, with little or no fines | 0 ± 0 | 0 [1]; |
| SP | Poorly graded sands, gravelly sands, with little or no fines | 0 ± 0 | 0 [1]; 0 [2]; |
| SM | Silty sands | 0 ± 0 | 0 [1]; |
| SC | Clayey sands | 0 ± 0 | 0 [1]; |
| ML | Inorganic silts, silty or clayey fine sands, with slight plasticity | 0 ± 0 | 0 [1]; |
| CL | Inorganic clays, silty clays, sandy clays of low plasticity | 20 ± 10 | 20 ± 10 [1]; |
| OL | Organic silts and organic silty clays of low plasticity | 10 ± 5 | 10 ± 5 [1]; |
| MH | Inorganic silts of high plasticity | 5 ± 5 | 5 ± 5 [1]; |
| CH | Inorganic clays of high plasticity | 25 ± 10 | 25 ± 10 [1]; |
| OH | Organic clays of high plasticity | 10 ± 5 | 10 ± 5 [1]; |
| Pt | Peat and other highly organic soils | 5 ± 5 | 0-10 [1]; |

REFERENCES

1. Swiss Standard SN 670 010b, Characteristic Coefficients of soils, Association of Swiss Road and Traffic Engineers
2. JON W. KOLOSKI, SIGMUND D. SCHWARZ, and DONALD W. TUBBS, Geotechnical Properties of Geologic Materials, Engineering Geology in Washington, Volume 1, Washington Division of Geology and Earth Resources Bulletin 78, 1989, [Link](#)

Citation :Geotechdata.info, Cohesion, <http://geotechdata.info/parameter/cohesion> (as of April 29, 2011).

Dry unit weight Geotechdata.info - Updated 29.08.2013

Soil unit weight, as referred to as Specific weight, is the weight per unit volume of soil. It may refer to

- *Wet unit weight*: Unit weight of the soil when the pore are fully or partially filled with water.
- *Dry unit weight*: Unit weight of the soil the pores are filled only with air without any water.

$$\text{Gamma}_d = \text{Gamma} / (1 + w)$$

where

Gamma_d : dry unit weight
 Gamma : unit weight
 w: soil water content

The soil unit weight, of course, depends on the packing, compaction, and humidity condition of the soil. But as a general guideline, some typical values of dry unit weight are given below for different types of soil.

Typical values of soil dry unit weight for different soils according to USCS

| USCS | Description | Average value (kN/m ³) | [Ref] |
|------|---|------------------------------------|-------|
| GW | Well graded gravel, sandy gravel, with little or no fines | 21 ± 1 | [1]; |
| GP | Poorly graded gravel, sandy gravel, with little or no fines | 20.5 ± 1 | [1]; |
| GM | Silty gravels, silty sandy gravels | 21.5 ± 1 | [1]; |
| GC | Clayey gravels, clayey sandy gravels | 19.5 ± 1.5 | [1]; |
| SW | Well graded sands, gravelly sands, with little or no fines | 20.5 ± 2 | [1]; |
| SP | Poorly graded sands, gravelly sands, with little or no fines | 19.5 ± 2 | [1]; |
| SM | Silty sands | 20.5 ± 2.5 | [1]; |
| SC | Clayey sands | 18.5 ± 1.5 | [1]; |
| ML | Inorganic silts, silty or clayey fine sands, with slight plasticity | | [1]; |
| CL | Inorganic clays, silty clays, sandy clays of low plasticity | | [1]; |
| OL | Organic silts and organic silty clays of low plasticity | | [1]; |
| MH | Inorganic silts of high plasticity | | [1]; |
| CH | Inorganic clays of high plasticity | | [1]; |
| OH | Organic clays of high plasticity | | [1]; |
| Pt | Peat and other highly organic soils | | [1]; |

REFERENCES

1. Swiss Standard SN 670 010b, Characteristic Coefficients of soils, Association of Swiss Road and Traffic Engineers

Citation : Geotechdata.info, Dry unit weight, <http://geotechdata.info/parameter/soil-dry-unit-weight.html> (as of August 29, 2013).

Soil void ratio Geotechdata.info - Updated 16.11.2013

Soil void ratio (e) is the ratio of the volume of voids to the volume of solids:

$$e = (V_v) / (V_s)$$

Where V_v is the volume of the voids (empty or filled with fluid), and V_s is the volume of solids.

Void ratio is usually used in parallel with [soil porosity \(n\)](#), which is defined as the ratio of the volume of voids to the total volume of the soil. The porosity and the void ratio are inter-related as follows:

$$e = n / (1-n) \quad \text{and} \quad n = e / (1+e)$$

The value of void ratio depends on the consistence and packing of the soil. It is directly affected by compaction. Some typical values of void ratio for different soils are given below only as general guidelines.

Typical values of soil void ratio for different soils

Some typical values of void ratio are given below for different USCS soil types at normally consolidated condition unless otherwise stated. These values should be used only as guideline for geotechnical problems; however, specific condition of each engineering problem often needs to be considered for an appropriate choice of geotechnical parameters.

| Description | USCS | Void ratio [-] | | | Reference |
|---|---------|----------------|------|----------------|----------------|
| | | min | max | Specific value | |
| Well graded gravel, sandy gravel, with little or no fines | GW | 0.26 | 0.46 | | [1], |
| Poorly graded gravel, sandy gravel, with little or no fines | GP | 0.26 | 0.46 | | [1], |
| Silty gravels, silty sandy gravels | GM | 0.18 | 0.28 | | [1], |
| Gravel | (GW-GP) | 0.30 | 0.60 | | [2], |
| Clayey gravels, clayey sandy gravels | GC | 0.21 | 0.37 | | [1], |
| Glacial till, very mixed grained | (GC) | - | - | 0.25 | [4 cited in 5] |
| Well graded sands, gravelly sands, with little or no fines | SW | 0.29 | 0.74 | | [1], [2], |
| Coarse sand | (SW) | 0.35 | 0.75 | | [2], |
| Fine sand | (SW) | 0.40 | 0.85 | | [2], |
| Poorly graded sands, gravelly sands, with little or no fines | SP | 0.30 | 0.75 | | [1], [2], |
| Silty sands | SM | 0.33 | 0.98 | | [1], [2], |
| Clayey sands | SC | 0.17 | 0.59 | | [1], |
| Inorganic silts, silty or clayey fine sands, with slight plasticity | ML | 0.26 | 1.28 | | [1], |
| Uniform inorganic silt | (ML) | 0.40 | 1.10 | | [3], |
| Inorganic clays, silty clays, sandy clays of | CL | 0.41 | 0.69 | | [1], |

| | | | | | |
|---|---------|------|------|------|------------------|
| low plasticity | | | | | |
| Organic silts and organic silty clays of low plasticity | OL | 0.74 | 2.26 | | [1], [3], |
| Silty or sandy clay | (CL-OL) | 0.25 | 1.80 | | [3], |
| Inorganic silts of high plasticity | MH | 1.14 | 2.10 | | [1], |
| Inorganic clays of high plasticity | CH | 0.63 | 1.45 | | [1], |
| Soft glacial clay | - | - | - | 1.20 | [4 cited in 5] |
| Stiff glacial clay | - | - | - | 0.60 | [4 cited in 5] |
| Organic clays of high plasticity | OH | 1.06 | 3.34 | | [1], [3], |
| Soft slightly organic clay | (OH-OL) | - | - | 1.90 | [4] cited in [5] |
| Peat and other highly organic soils | Pt | - | - | | [4 cited in 5] |
| soft very organic clay | (Pt) | - | - | 3.00 | [4] cited in [5] |

REFERENCES

Swiss Standard SN 670 010b, Characteristic Coefficients of soils, Association of Swiss Road and Traffic Engineers

Das, B., Advanced Soil Mechanics. Taylor & Francis, London & New York, 2008.

Hough, B., Basic soil engineering. Ronald Press Company, New York, 1969.

Terzaghi, K., Peck, R., and Mesri, G., Soil Mechanics in Engineering Practice. Wiley, New York, 1996.

Obrzud R. & Truty, A. THE HARDENING SOIL MODEL - A PRACTICAL GUIDEBOOK Z Soil.PC 100701 report, revised 31.01.2012

Citation : Geotechdata.info, Soil void ratio, <http://geotechdata.info/parameter/soil-void-ratio.html> (as of November 16, 2013).

Soil permeability coefficient Geotechdata.info - Updated 07.10.2013

The soil permeability is a measure indicating the capacity of the soil or rock to allow fluids to pass through it. It is often represented by the permeability coefficient (k) through the Darcy's equation:

$$V=ki$$

Where v is the apparent fluid velocity through the medium i is the hydraulic gradient , and K is the coefficient of permeability (hydraulic conductivity) often expressed in m/s

K depends on the relative permeability of the medium for fluid constituent (often water) and the dynamic viscosity of the fluid as follows.

$$K= (\text{Gamma}_w)*K/ (\text{eta})$$

where Where Gamma_w is the unit weight of water Eta is the dynamic viscosity of water K is an absolute coefficient depending on the characteristics of the medium (m²)

The permeability coefficient can be determined in the laboratory using [falling head permeability test](#), and [constant head permeability test](#). On the field, the permeability can be estimated using [Lugeon test](#).

Typical values of soil permeability

Some typical values of permeability coefficient are given below for different soil types. It refers to normally consolidated condition unless otherwise mentioned. These values should be used only as guideline for geotechnical problems; however, specific condition of each engineering problem often needs to be considered for an appropriate choice of geotechnical parameters.

| Description | USCS | min (m/s) | max (m/s) | Specific value (m/s) | Reference |
|---|---------|-----------|-----------|----------------------|-----------------|
| Well graded gravel, sandy gravel, with little or no fines | GW | 5.00E-04 | 5.00E-02 | | [1], |
| Poorly graded gravel, sandy gravel, with little or no fines | GP | 5.00E-04 | 5.00E-02 | | [1], |
| Silty gravels, silty sandy gravels | GM | 5.00E-08 | 5.00E-06 | | [1], |
| Alluvial sand and gravel | (GM) | 4.00E-04 | 4.00E-03 | | [2&3 in 4] |
| Clayey gravels, clayey sandy gravels | GC | 5.00E-09 | 5.00E-06 | | [1], |
| Well graded sands, gravelly sands, with little or no fines | SW | 1.00E-08 | 1.00E-06 | | [1], |
| Very fine sand, very well sorted | (SW) | | | 8.40E-05 | [5] , |
| Medium sand, very well sorted | (SW) | | | 2.23E-03 | [5] , |
| Coarse sand, very well sorted | (SW) | | | 3.69E-01 | [5] , |
| Poorly graded sands, gravelly sands, with little or no fines | SP | 2.55E-05 | 5.35E-04 | | [1], [2&3 in 4] |
| Clean sands (good aquifers) | (SP-SW) | 1.00E-05 | 1.00E-02 | | [5], |
| Uniform sand and gravel | (SP-GP) | 4.00E-03 | 4.00E-01 | | [2&3 in 4] |
| Well graded sand and gravel without fines | (GW-SW) | 4.00E-05 | 4.00E-03 | | [2&3 in 4] |
| Silty sands | SM | 1.00E-08 | 5.00E-06 | | [1], |
| Clayey sands | SC | 5.50E-09 | 5.50E-06 | | [1], [5] |
| Inorganic silts, silty or clayey fine sands, with slight plasticity | ML | 5.00E-09 | 1.00E-06 | | [1], |
| Inorganic clays, silty clays, sandy clays of low plasticity | CL | 5.00E-10 | 5.00E-08 | | [1], |
| Organic silts and organic silty clays of low plasticity | OL | 5.00E-09 | 1.00E-07 | | [1], |
| Inorganic silts of high plasticity | MH | 1.00E-10 | 5.00E-08 | | [1], |
| Inorganic clays of high plasticity | CH | 1.00E-10 | 1.00E-07 | | [1], |
| Compacted silt | (ML-MH) | 7.00E-10 | 7.00E-08 | | [2&3 in 4] |
| Compacted clay | (CL-CH) | - | 1.00E-09 | | [2&3 in 4] |
| Organic clays of high plasticity | OH | 5.00E-10 | 1.00E-07 | | [1], |
| Peat and other highly organic soils | Pt | - | - | | |

Empirical relations for determine the soil permeability coefficient

For Sands, the coefficient of permeability can be estimated from the Hazen's equation:

$$k = 10^{-2} D_{10}^2$$

D_{10} is the effective size in mm.

REFERENCES

1. Swiss Standard SN 670 010b, Characteristic Coefficients of soils, Association of Swiss Road and Traffic Engineers
2. Carter, M. and Bentley, S. (1991). Correlations of soil properties. Penetech Press Publishers, London.
3. Leonards G. A. Ed. 1962, Foundation Engineering. McGraw Hill Book Company
4. Dysli M. and Steiner W., 2011, Correlations in soil mechanics, PPUR
5. West, T.R., 1995. Geology applied to engineering. Prentice Hall, 560 pp.

Citation : Geotechdata.info, Soil void ratio, <http://geotechdata.info/parameter/permeability.html> (as of October 7, 2013)

Soil porosity Geotechdata.info - Updated 18.11.2013

Soil porosity (n) is the ratio of the volume of voids to the total volume of the soil:

$$n = (V_v) / V$$

Where V_v is the volume of the voids (empty or filled with fluid), and V is the total volume of the soil.

Porosity is usually used in parallel with [soil void ratio \(\$e\$ \)](#), which is defined as the ratio of the volume of voids to the volume of solids. The porosity and the void ratio are inter-related as follows:

$$e = n / (1-n) \quad \text{and} \quad n = e / (1+e)$$

The soil porosity depends on the consistence and packing of the soil. It is directly affected by compaction.

Typical values of soil porosity for different soils

Some typical values of soil porosity are given below for different USCS soil types at normally consolidated condition unless otherwise stated. These values should be used only as guideline for geotechnical problems; however, specific condition of each engineering problem often needs to be considered for an appropriate choice of geotechnical parameters.

| Description | USCS | Porosity [-] | | | Reference |
|---|------|--------------|------|----------------|-----------|
| | | min | max | Specific value | |
| Well graded gravel, sandy gravel, with little or no fines | GW | 0.21 | 0.32 | | [1], |
| Poorly graded gravel, sandy gravel, with little or no fines | GP | 0.21 | 0.32 | | [1], |
| Silty gravels, silty sandy gravels | GM | 0.15 | 0.22 | | [1], |

| | | | | | |
|---|---------|------|------|------|------------------|
| Gravel | (GW-GP) | 0.23 | 0.38 | | [2], |
| Clayey gravels, clayey sandy gravels | GC | 0.17 | 0.27 | | [1], |
| Glatial till, very mixed grained | (GC) | - | - | 0.20 | [4 cited in 5] |
| Well graded sands, gravelly sands, with little or no fines | SW | 0.22 | 0.42 | | [1], [2], |
| Coarse sand | (SW) | 0.26 | 0.43 | | [2], |
| Fine sand | (SW) | 0.29 | 0.46 | | [2], |
| Poorly graded sands, gravelly sands, with little or no fines | SP | 0.23 | 0.43 | | [1], [2], |
| Silty sands | SM | 0.25 | 0.49 | | [1], [2], |
| Clayey sands | SC | 0.15 | 0.37 | | [1], |
| Inorganic silts, silty or clayey fine sands, with slight plasticity | ML | 0.21 | 0.56 | | [1], |
| Uniform inorganic silt | (ML) | 0.29 | 0.52 | | [3], |
| Inorganic clays, silty clays, sandy clays of low plasticity | CL | 0.29 | 0.41 | | [1], |
| Organic silts and organic silty clays of low plasticity | OL | 0.42 | 0.68 | | [1], [3], |
| Silty or sandy clay | (CL-OL) | 0.20 | 0.64 | | [3], |
| Inorganic silts of high plasticity | MH | 0.53 | 0.68 | | [1], |
| Inorganic clays of high plasticity | CH | 0.39 | 0.59 | | [1], |
| Soft glacial clay | - | - | - | 0.55 | [4 cited in 5] |
| Stiff glacial clay | - | - | - | 0.38 | [4 cited in 5] |
| Organic clays of high plasticity | OH | 0.50 | 0.75 | | [1], [3], |
| Soft slightly organic clay | (OH-OL) | - | - | 0.66 | [4] cited in [5] |
| Peat and other highly organic soils | Pt | - | - | | [4 cited in 5] |
| soft very organic clay | (Pt) | - | - | 0.75 | [4] cited in [5] |

REFERENCES

1. Swiss Standard SN 670 010b, Characteristic Coefficients of soils, Association of Swiss Road and Traffic Engineers
2. Das, B., Advanced Soil Mechanics. Taylor & Francis, London & New York, 2008.
3. Hough, B., Basic soil engineering. Ronald Press Company, New York, 1969.
4. Terzaghi, K., Peck, R., and Mesri, G., Soil Mechanics in Engineering Practice. Wiley, New York, 1996.
5. Obrzud R. & Truty, A. THE HARDENING SOIL MODEL - A PRACTICAL GUIDEBOOK Z Soil.PC 100701 report, revised 31.01.2012

Citation : Geotechdata.info, Soil void ratio, <http://geotechdata.info/parameter/soil-void-ratio.html> (as of November 16, 2013).