Package 'soilphysics'

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R topics documented:

soilphysics-package 2
bulkDensity 3
compaction 4
criticalmoisture 5
fitbusscher 6
fitlbc 7
fitsoilwater 8
fun2form 9

getInitiallbc 10
liquidlimit 11
maxcurv 12
Rsq 13
sigmaP 14
Sindex 16
soilwater 18
SSlbc 19
voidratio 20

Index **22**

`soilphysics-package` *Soil Physical Analysis*

Description

Basic and model-based soil physical analyses.

Details

Package:	soilphysics
Type:	Package
Version:	1.1
Date:	2014-07-17
License:	GPL (>= 2)

This package contains functions for modelling the soil water retention, the load bearing capacity and the penetration resistance. There are some useful and easy-to-use functions to perform parameter estimation of these models. Methods to obtain the preconsolidation stress are available, such as Casagrande (1936) and so on. There is a function to determine the soil critical moisture and the maximum bulk density for one or more samples, based on the Proctor (1933) compaction test. Also, others utilities like a function to calculate the soil liquid limit, the void ratio and to determine the maximum curvature point are available.

Note

soilphysics is an ongoing project. We welcome any and all criticism, comments and suggestions.

Author(s)

Anderson Rodrigo da Silva, Renato Paiva de Lima

Maintainer: Anderson Rodrigo da Silva <anderson.agro@hotmail.com>

References

ABNT - Associacao Brasileira de Normas Tecnicas. (1990). *Ensaio de adensamento unidimensional*: NBR 12007. Rio de Janeiro. 13p.

Arvidsson, J.; Keller, T. (2004). Soil precompression stress I. A survey of Swedish arable soils. *Soil & Tillage Research*, 77:85-95.

Bowles, J. A. (1986). *Engineering Properties of Soils and their Measurements*. 3rd ed. McGraw-Hill Book Company, Inc. NY, 218pp.

Busscher, W.J. (1990) Adjustment of flat-tipped penetrometer resistance data to common water content. *Transactions of the ASAE*, 3:519-524.

Casagrande, A. (1936). *The determination of the pre-consolidation load and its practical significance*. In: Proceedings of the International Conference on Soil Mech. and Found. Eng. (ICSMFE), Cambridge, MA, 22-26 June 1936, vol. 3. Harvard University, Cambridge, MA, USA, pp. 60-64.

Dexter, A. R. (2004). Soil physical quality Part I. Theory, effects of soil texture, density, and organic matter, and effects on root growth. *Geoderma*, 120:201-214.

Dias Junior, M. S. (1994). *Compression of three soils under longterm tillage and wheel traffic*. 1994. 114p. Ph.D. Thesis - Michigan State University, East Lansing.

Dias Junior, M. S.; Pierce, F. J. (1995). A simple procedure for estimating preconsolidation pressure from soil compression curves. *Soil Technology*, 8:139-151.

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Mualem, Y. (1976) A new model for predicting the hydraulic conductivity of unsaturated porous media. *Water Resources Research*, 12:513-522.

Proctor, E. R. (1933). Design and construction of rolled earth dams. *Eng. News Record*, 3:245-284, 286-289, 348-351, 372-376.

Silva, A. P. et al. (2010). Indicadores da qualidade fisica do solo. In: Jong Van Lier, Q. (Ed). *Fisica do solo*. Vicosa (MG): Sociedade Brasileira de Ciencia do Solo. p.541-281.

Sowers, G. F. (1965). Consistency. In: BLACK, C.A. (Ed.). *Methods of soil analysis*. Madison: American Society of Agronomy. Part 1, p.391-399. (Agronomy, 9).

Sowers, G. F. (1965). Consistency. In: KLUTE, A. (Ed.). 2nd ed. *Methods of soil analysis*. Madison: American Society of Agronomy. Part 1, p.545-566.

`bulkDensity` *Soil Bulk Density Dataset*

Description

This dataset refers to five observations of soil bulk density and soil moisture per sample. There are four soil samples.

Usage

```
data(bulkDensity)
```

Format

A data frame with 20 observations on the following 3 variables.

`Id` a factor with levels `s1` `s2` `s3` `s4`, the 'ID' of each soil sample.

`MOIS` a numeric vector containing soil moisture values (cm^3 / cm^3).

`BULK` a numeric vector containing soil bulk density values (g / cm^3).

Source

Simulated data.

Examples

```
data(bulkDensity)
summary(bulkDensity)
```

`compaction` *Soil Compaction Dataset*

Description

This dataset refers to physical soil variables related to soil compaction.

Usage

```
data(compaction)
```

Format

A data frame with 50 observations on the following 4 variables.

`PR` a numeric vector containing soil penetration resistance values (MPa).

`BD` a numeric vector containing soil bulk density values (g / cm^3).

`Mois` a numeric vector containing soil moisture values (cm^3 / cm^3).

`PS` a numeric vector containing soil preconsolidation stress values (kPa).

Source

Simulated data.

Examples

```
data(compaction)
summary(compaction)
```

`criticalmoisture` *Critical Moisture and Maximum Bulk Density*

Description

Function to determine the soil Critical Moisture and the Maximum Bulk Density based on the Proctor (1933) compaction test. It estimates compaction curve by fitting a quadradtic regression model.

Usage

```
criticalmoisture(theta, Bd, samples = NULL, graph = TRUE, ...)

maxbulkdensity(theta, Bd, samples = NULL, graph = TRUE, ...)
```

Arguments

`theta`	a vector containing the soil moisture values.
`Bd`	a vector containing the the soil bulk density values.
`samples`	optional; a vector indicating the multiple samples. Default is NULL (one sample). See details.
`graph`	logical; if TRUE (default), the soil compaction curve is plotted.
`...`	further graphical arguments.

Details

If `samples` is ispecified, then it must has the same length of `theta` and `Bd`.

Value

An object of class 'criticalmoisture', i.e., a matrix containing the quadratic model coefficients (rows 1 to 3), the R-squared (row 4), the sample size (row 5), the critical soil moisture (row 6) and the maximum bulk density (row 7), per sample.

Note

`maxbulkdensity` is just an alias of `criticalmoisture`.

Author(s)

Anderson Rodrigo da Silva <anderson.agro@hotmail.com>

References

Proctor, E. R. (1933). Design and construction of rolled earth dams. *Eng. News Record*, 3: 245-284, 286-289, 348-351, 372-376.

Silva, A. P. et al. (2010). Indicadores da qualidade fisica do solo. In: Jong Van Lier, Q. (Ed). *Fisica do solo*. Vicosa (MG): Sociedade Brasileira de Ciencia do Solo. p.541-281.

See Also

maxcurv

Examples

```
# example 1 (1 sample)
mois <- c(0.083, 0.092, 0.108, 0.126, 0.135)
bulk <- c(1.86, 1.92, 1.95, 1.90, 1.87)
criticalmoisture(theta = mois, Bd = bulk)

# example 2 (4 samples)
data(bulkDensity)
attach(bulkDensity)
criticalmoisture(theta = MOIS, Bd = BULK, samples = Id)

# End (not run)
```

---

fitbusscher — *Self-starting Nls Busscher's (1990) Model for Soil Penetration Resistance*

Description

Function to self start the nonlinear Busscher's (1990) model for penetration resistance, i.e., $Pr = b0 * (\theta^{b1}) * (Bd^{b2})$. It creates initial estimates (by log-linearization) of the parameters b0, b1 and b2 and uses them to provide its least-squares estimates via nls.

Usage

```
fitbusscher(Pr, theta, Bd, ...)
```

Arguments

Pr	a numeric vector containing penetration resistance values.
theta	a numeric vector containing soil moisture values at which to evaluate the model.
Bd	a numeric vector containing bulk density values at which to evaluate the model.
...	further arguments to nls.

Value

A nls output (see help(nls)).

Author(s)

Anderson Rodrigo da Silva <anderson.agro@hotmail.com>

References

Busscher, W. J. (1990). Adjustment of flat-tipped penetrometer resistance data to common water content. *Transactions of the ASAE*, 3:519-524.

See Also

fitlbc, nls, summary.nls, predict.nls, Rsq

Examples

```
data(compaction)
attach(compaction)
out <- fitbusscher(Pr = PR, theta = Mois, Bd = BD)
summary(out)
Rsq(out)

# 3D plot
X <- seq(min(Mois), max(Mois), len = 30) # theta
Y <- seq(min(BD), max(BD), len = 30) # Bd
f <- function(x, y) coef(out)[1] * (x^coef(out)[2]) * (y^coef(out)[3])
Z <- outer(X, Y, f)
persp(X, Y, Z,
xlab = "Soil moisture",
ylab = "Soil bulk density",
zlab = "Penetration resistance",
ticktype = "detailed",
phi = 20, theta = 30)

# End (not run)
```

---

fitlbc — *Parameter Estimation of the Load Bearing Capacity Model*

Description

This function creates initial parameter estimates of the nonlinear Load Bearing Capacity (Dias Jr., 1994) model, i.e., $\sigma_P = 10^{(b0+b1*\theta)}$, by using two methods: a getInitial method or a log-linearization. Then, it uses them to provide its least-squares estimates via nls.

Usage

```
fitlbc(theta, sigmaP, ...)
```

Arguments

`theta`	a numeric vector containing soil moisture values.
`sigmaP`	a numeric vector containing values of soil preconsolidation stress.
`...`	further arguments to nls.

Value

A nls output (see help(nls)).

Author(s)

Anderson Rodrigo da Silva <anderson.agro@hotmail.com>

References

Dias Junior, M. S. (1994). *Compression of three soils under longterm tillage and wheel traffic*. 1994. 114p. Ph.D. Thesis - Michigan State University, East Lansing.

See Also

sigmaP, fitbusscher, maxcurv, Rsq

Examples

```
data(compaction)
attach(compaction)
out <- fitlbc(theta = Mois, sigmaP = PS)
summary(out)
Rsq(out)
curve(10^(coef(out)[1] + coef(out)[2]*x))

# End (not run)
```

---

fitsoilwater *Interactive Estimation of van Genuchten's (1980) Model Parameters*

Description

This function consists in an interactive graphical adjustment of the soil water retention curve via van Genuchten's (1980) formula. The nonlinear least-squares estimates can be achieved taking the graphical initial values.

Usage

```
fitsoilwater(theta, x, xlab = NULL, ylab = NULL, ...)
```

Arguments

theta	a numeric vector containing the values of soil water content.
x	a numeric vector containing the matric potential values.
xlab	a label for the x axis; if is NULL, the label "Matric potential" is used.
ylab	a label for the y axis; if is NULL, the label "Soil water content" is used.
...	further graphical arguments; see par.

Value

A plot of `theta` versus `x` and the curve of the current fitted model according to the adjusted parameters in an external interactive panel. Pressing the button "NLS estimates" a `nls` summary of the fitted model is printed on console whether convergence is achieved, otherwise a warning box of "No convergence" is shown.

Author(s)

Anderson Rodrigo da Silva <anderson.agro@hotmail.com>

References

Genuchten, M. T. van. (1980). A closed form equation for predicting the hydraulic conductivity of unsaturated soils. *Soil Science Society of America Journal*, 44:892-898.

See Also

`nls`, `soilwater`

Examples

```
# Liu et al. (2011)
h <- c(0.001, 50.65, 293.77, 790.14, 992.74, 5065, 10130, 15195)
w <- c(0.5650, 0.4013, 0.2502, 0.2324, 0.2307, 0.1926, 0.1812, 0.1730)
fitsoilwater(w, h)

# End (not run)
```

`fun2form` *Converting Function to Formula*

Description

An accessorial function to convert an object of `class` 'function' to an object of `class` 'formula'.

Usage

```
fun2form(fun, y = NULL)
```

Arguments

`fun`	a object of class 'function'. It must be a one-line-written function, with no curly braces "{}".
`y`	optional; a character defining the lef side of the formula, `y = fun()`.

Value

An object of class `formula`.

Warning

Numerical values into `fun` with three or more digits may cause miscalculation.

Author(s)

Anderson Rodrigo da Silva <anderson.agro@hotmail.com>

See Also

`function`, `formula`

Examples

```
g <- function(x) Asym * exp(-b2 * b3 ^ x) # Gompertz Growth Model
fun2form(g, "y")

# f1 <- function(w) {exp(w)} # error
# fun2form(f1, "x")
f2 <- function(w) exp(w) # ok
fun2form(f2, "x")

# End (not run)
```

---

getInitiallbc — *Get Initial Parameter Estimates for the Load Bearing Capacity Model*

Description

This is a `getInitial` function that evaluates initial parameter estimates for the Load Bearing Capacity model via `SSlbc`.

Usage

```
getInitiallbc(theta, sigmaP)
```

Arguments

`theta`	a numeric vector containing values of soil moisture.
`sigmaP`	a numeric vector containing values of preconsolidation stress.

Value

A numeric vector containing the estimates of the parameters b0 and b1.

Author(s)

Anderson Rodrigo da Silva <anderson.agro@hotmail.com>

References

Dias Junior, M. S. (1994). *Compression of three soils under longterm tillage and wheel traffic*. 1994. 114p. Ph.D. Thesis - Michigan State University, East Lansing.

See Also

getInitial, SSlbc, nls, sigmaP

Examples

```
data(compaction)
attach(compaction)
getInitiallbc(theta = Mois, sigmaP = PS)

# End (not run)
```

---

liquidlimit *Soil Liquid Limit*

Description

Function to determine the soil Liquid Limit by using the Sowers (1965) method.

$$LL = \theta * (n/25)^{0.12}$$

.

Usage

```
liquidlimit(theta, n)
```

Arguments

theta	the soil mositure value corresponding to n drops.
n	the number of drops.

Value

The soil moisture value corresponding to the Liquid Limit.

Author(s)

Anderson Rodrigo da Silva <anderson.agro@hotmail.com>

References

Sowers, G. F. (1965). Consistency. In: BLACK, C.A. (Ed.). *Methods of soil analysis*. Madison: American Society of Agronomy. Part 1, p.391-399. (Agronomy, 9).

Sowers, G. F. (1965). Consistency. In: KLUTE, A. (Ed.). 2 ed. *Methods of soil analysis*. Madison: American Society of Agronomy. Part 1, p.545-566.

See Also

criticalmoisture

Examples

```
liquidlimit(theta = 0.34, n = 22)

M <- c(0.34, 0.29, 0.27, 0.25, 0.20)
N <- c(22, 24, 25, 26, 28)
liquidlimit(theta = M, n = N)

# End (not run)
```

---

maxcurv — *Maximum Curvature Point*

Description

Function to determine the maximum curvature point of an univariate nonlinear function of x.

Usage

```
maxcurv(x.range, fun, graph = TRUE, ...)
```

Arguments

`x.range`	a numeric vector of length two, the range of x.
`fun`	a function of x; it must be a one-line-written function, with no curly braces '{}'.
`graph`	logical; if TRUE (default) a curve of `fun` is plotted.
`...`	further graphical arguments.

Value

A list of

`fun`	the function of x.
`x0`	the x critical value.
`y0`	the y critical value.

Warning

Numerical values into `fun` with three or more digits may cause miscalculation.

Author(s)

Anderson Rodrigo da Silva <anderson.agro@hotmail.com>

See Also

`function`, `curve`

Examples

```
# an exponential model
f <- function(x) exp(-x)
maxcurv(x.range = c(1, 5), fun = f)

# Load Bearing Capacity Model
b0 = 2.79
b1 = -2.34
lbc <- function(x) 10^(b0 + b1*x)
maxcurv(x.range = c(0, 1), fun = lbc)

# Gompertz Growth Model
Asym <- 8.5
b2 <- 2.3
b3 <- 0.6
g <- function(x) Asym * exp(-b2 * b3 ^ x)
maxcurv(x.range = c(0, 20), fun = g)

# Lessman & Atkins (1963) model for optimum plot size
a = 40.1
b = 0.72
cv <- function(x) a * x^-b
maxcurv(x.range = c(1, 50), fun = cv)

# End (not run)
```

Rsq — *Multiple R-squared*

Description

Function to calculate the *multiple R-squared* and the *adjusted R-squared* from a fitted model via `lm` or `aov`, i.e., linear models. For a model fitted via `nls`, nonlinear models, the *pseudo R-squared* is returned.

Usage

```
Rsq(model)
```

Arguments

`model`	a model fitted via `lm`, `aov` or `nls`.

Value

A list of

`R.squared` the multiple R-squared (for linear models) or the Pseudo R-squared (for nonlinear models).

`adj.R.squared` the adjusted R-squared.

Author(s)

Anderson Rodrigo da Silva <anderson.agro@hotmail.com>

See Also

`lm`, `summary.lm`, `aov`, `nls`

Examples

```
# example 1 [linear model]
y <- rnorm(10)
x <- 1:10
fit <- lm(y ~ x)
summary(fit)
Rsq(fit)

# example 2 [nonlinear model for Load Bearing Capacity]
data(compaction)
attach(compaction)
out <- fitlbc(theta = Mois, sigmaP = PS)
summary(out)
Rsq(out)

# End (not run)
```

`sigmaP` *Preconsolidation Stress*

Description

A function to determine the preconsolidation stress (σ_P).

Usage

```
sigmaP(voidratio, stress, n4VCL = 2,
    method = c("casagrande", "VCLzero",
    "reg1", "reg2", "reg3", "reg4", "pacheco"),
    mcp = NULL, graph = TRUE, ...)
```

Arguments

`voidratio`	a numeric vector containing void ratio (or bulk density) values.
`stress`	a numeric vector containing the applied stress sequence; see Note.
`n4VCL`	the number of points for calculating the slope of the soil Virgin Compression Line (VCL), which is obtained by linear regression.
`method`	a character indicating which method is to be computed; one of the following: `casagrande` (default), `VCLzero`, `reg1`, `reg2`, `reg3`, `reg4` or `pacheco`; see Details.
`mcp`	the maximum curvature point in log10 scale of `stress`; required only if the method `casagrande` is used.
`graph`	logical; if TRUE (default) the compression curve is plotted.
`...`	further graphical arguments.

Details

`casagrande` is the method proposed by Casagrande (1936). The preconsolidation stress obtained via `VCLzero` corresponds to the intersection of the soil *Virgin Compression Line* (VCL) with the x-axis at zero applied stress, as described by Arvidsson & Keller (2004). `reg1`, `reg2`, `reg3` and `reg4` are regression methods that obtain the preconsolidation stress value as the intercept of the VCL and a regression line fitted with the first two, three, four and five points of the curve, respectively, as described by Dias Junior & Pierce (1995). `pacheco` is the method of Pacheco Silva (ABNT, 1990).

Value

`sigmaP` returns the preconsolidation stress value.

Note

The standard values for the applied stress sequence are: 25, 50, 100, 200, 400, 800 and 1600 kPa, according to Bowles (1986).

Author(s)

Anderson Rodrigo da Silva <anderson.agro@hotmail.com>

References

ABNT - Associacao Brasileira de Normas Tecnicas. (1990). *Ensaio de adensamento unidimensional*: NBR 12007. Rio de Janeiro. 13p.

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Bowles, J. A. (1986). *Engineering Properties of Soils and their Measurements*, 3rd edition. McGraw-Hill Book Company, Inc. NY, 218pp.

Casagrande, A. (1936). *The determination of the pre-consolidation load and its practical significance*. In: Proceedings of the International Conference on Soil Mech. and Found. Eng. (ICSMFE), Cambridge, MA, 22-26 June 1936, vol. 3. Harvard University, Cambridge, MA, USA, pp. 60-64.

Dias Junior, M. S.; Pierce, F. J. (1995). A simple procedure for estimating preconsolidation pressure from soil compression curves. *Soil Technology*, 8:139-151.

See Also

voidratio, maxcurv, fitlbc

Examples

```
pres <- c(1, 12.5, 25, 50, 100, 200, 400, 800, 1600)
VR <- c(0.99, 0.97, 0.95, 0.89, 0.78, 0.61, 0.43, 0.23, 0.01)

plot(VR ~ log10(pres), type = "b") # find the 'mcp'
sigmaP(VR, pres, method = "casagrande", mcp = 1.6)

sigmaP(VR, pres, method = "pacheco")

sigmaP(VR, pres, method = "reg3")

# End (not run)
```

Sindex *The S Index*

Description

Function to calculate the S index (Dexter, 2004) for evaluating the soil physical quality based on the *Water Retention Curve* (van Genuchten, 1980).

$$S = -n * (\theta_S - \theta_R) * (1 + 1/m)^{-(1+m)}$$

Usage

```
Sindex(theta_R, theta_S, alpha, n, m = 1 - 1/n, vcov = NULL,
nsim = 999, conf.level = 0.95, graph = TRUE, ...)
```

Arguments

`theta_R`	the residual water content.
`theta_S`	the water content at saturation.
`alpha`	a scale parameter of the van Genuchten's formula.
`n`	a shape parameter in van Genuchten's formula.
`m`	a shape parameter in van Genuchten's Formula. Default is $1 - 1/n$ (Mualem, 1976).
`vcov`	optional (default is `NULL`); a variance-covariance matrix of the estimates which is used to perform Monte Carlo simulations of the parameters `theta_R`, `theta_S`, `alpha` and `n` for building a simulated confidence interval of the S index (in modulus).

`nsim`	the number of Monte Carlo simulations; default is 999. It is used only if `vcov` is specified.
`conf.level`	the confidence level; default is 0.95. It is used only if `vcov` is specified.
`graph`	logical; if TRUE (defaul), the soil water retention curve is plotted.
`...`	further graphical arguments.

Value

A list of

`h_i`	the modulus of the water potential at the inflection point.
`theta_i`	the water content at the inflection point.
`S.index`	the modulus of the S index.
`PhysicalQuality`	A character indicating the soil physical quality, as proposed by Dexter (2004).
`simCI`	the simulated confidence interval. It is stored only if `vcov` is specified.
`conf.level`	the confidence level for the simulated confidence interval. It is stored only if `vcov` is specified.

Author(s)

Anderson Rodrigo da Silva <anderson.agro@hotmail.com>

References

Dexter, A. R. (2004). Soil physical quality Part I. Theory, effects of soil texture, density, and organic matter, and effects on root growth. *Geoderma*, 120:201-214.

Genuchten, M. T. van. (1980). A closed form equation for predicting the hydraulic conductivity of unsaturated soils. *Soil Science Society of America Journal*, 44:892-898.

Mualem, Y. (1976). A new model for predicting the hydraulic conductivity of unsaturated porous media, *Water Resource Research*, 12:513-522.

See Also

`soilwater`, `fitsoilwater`

Examples

```
# Dexter (2004, Table 1)
Sindex(0, 0.395, 0.0217, 1.103, xlim = c(0, 1000))
Sindex(0, 0.335, 0.0616, 1.139, xlim = c(0, 1000))
# ...
Sindex(0, 0.226, 0.0671, 1.581, xlim = c(0, 1000))

# End (not run)
```

`soilwater` *Soil Water Retention*

Description

Function to calculate the soil water content based on the van Genuchten's (1980) formula:

$$\theta = \theta_R + (\theta_S - \theta_R)(1 + (\alpha x)^n)^{-m}$$

Usage

```
soilwater(x, theta_R, theta_S, alpha, n, m = 1 - 1/n,
    saturation.index = FALSE)
```

Arguments

`x`	the matric potential.
`theta_R`	the residual water content.
`theta_S`	the water content at saturation.
`alpha`	a scale parameter of the van Genuchten's formula.
`n`	a shape parameter in van Genuchten's formula.
`m`	a shape parameter in van Genuchten's Formula. Default is $1 - 1/n$ (Mualem, 1976).
`saturation.index`	logical; if FALSE (default) the outcome is the soil water content, otherwise the saturation index is returned.

Value

The the soil water content or the saturation index (a value between 0 and 1).

Author(s)

Anderson Rodrigo da Silva <anderson.agro@hotmail.com> (code adapted from the function swc(), package *soilwater* (Cordano *et al*., 2012).)

References

Genuchten, M. T. van. (1980). A closed form equation for predicting the hydraulic conductivity of unsaturated soils. *Soil Science Society of America Journal*, 44:892-898.

Mualem, Y. (1976). A new model for predicting the hydraulic conductivity of unsaturated porous media. *Water Resources Research*, 12:513-522.

See Also

`fitsoilwater`

Examples

```
# example 1
soilwater(x = 0.1, theta_R = 0.06, theta_S = 0.25, alpha = 21, n = 2.08)
curve(soilwater(x, theta_R = 0.06, theta_S = 0.25, alpha = 21, n = 2.08))

# example 2 (punctual predictions)
p <- seq(0, 1, length.out = 10)
m <- soilwater(x = p, theta_R = 0.06, theta_S = 0.25,
alpha = 21, n = 2.08)
points(m ~ p, type = "b", col = "red")

# End (not run)
```

SSlbc — *Self-Starting Nls Load Bearing Capacity Model*

Description

A selfStart model that evaluates the Load Bearing Capacity (Dias Jr., 1994) function and its gradient. It has an initial attribute that creates initial estimates of the parameters b0 and b1.

Usage

```
SSlbc(theta, b0, b1)
```

Arguments

theta	a numeric vector of soil moisture values at which to evaluate the model.
b0	a numeric parameter.
b1	a numeric parameter.

Value

a numeric vector with the same length of theta. It is the value of the expression $10^{(b0+b1*\theta)}$. Also, the gradient matrix with respect to the parameters is attached as an attribute named *gradient*.

Author(s)

Anderson Rodrigo da Silva <anderson.agro@hotmail.com>

References

Dias Junior, M. S. (1994). *Compression of three soils under longterm tillage and wheel traffic*. 1994. 114p. Ph.D. Thesis - Michigan State University, East Lansing.

See Also

getInitiallbc, fitlbc, selfStart, nls, sigmaP

Examples

```
data(compaction)
attach(compaction)
ss <- SSlbc(Mois, 2.79, -2.33)
ss[1:50] # prediction
PS # original data of preconsolidation stress
ss # prediction and gradient

# End (not run)
```

`voidratio` *Void Ratio*

Description

A function to calculate the soil void ratio.

Usage

```
voidratio(wetsoil, drysoil, diam.cylinder, height.cylinder,
    dens.particle, deformation)
```

Arguments

`wetsoil`	the weight of wet soil.
`drysoil`	the weight of dry soil.
`diam.cylinder`	the diameter of the cylinder.
`height.cylinder`	the heigth of the cylinder.
`dens.particle`	the particle density.
`deformation`	a numeric vector containing soil deformation values.

Value

A numeric vector with same length of `deformation` containig void ratio values.

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See Also

`sigmaP`

Examples

```
def <- c(0.1, 17, 30, 51, 97, 145, 201, 260, 325) / 100
pres <- c(1, 12.2, 25, 50, 100, 200, 400, 800, 1600)
VR <- voidratio(147.66, 118.13, 6.4, 3.4, 2.7, def)
VR
plot(VR ~ log10(pres), xaxt = "n", type = "b",
ylab = "Void ratio",
xlab = expression(Log[10]~Applied~stress~(kPa)),
main = "Compression curve")
axis(side = 1, at = pretty(log10(pres)),
labels = 10^pretty(log10(pres)))

# End (not run)
```

Index

∗Topic **datasets**
  bulkDensity, 3
  compaction, 4

aov, *13, 14*

bulkDensity, 3

compaction, 4
criticalmoisture, 5, *12*
curve, *13*

fitbusscher, 6, *8*
fitlbc, *7*, 7, *16*, *19*
fitsoilwater, 8, *17, 18*
formula, *9, 10*
fun2form, 9
function, *10*, *13*

getInitial, *10, 11*
getInitiallbc, 10, *19*

liquidlimit, 11
lm, *13, 14*

maxbulkdensity *(*criticalmoisture*)*, 5
maxcurv, *6*, *8*, 12, *16*

nls, *6–9*, *11*, *13, 14*, *19*

par, *8*
predict.nls, *7*

Rsq, *7, 8*, 13

selfStart, *19*
sigmaP, *8*, *11*, 14, *19, 20*
Sindex, 16
soilphysics *(*soilphysics-package*)*, 2
soilphysics-package, 2
soilwater, *9*, *17*, 18
SSlbc, *10, 11*, 19

summary.lm, *14*
summary.nls, *7*

voidratio, *16*, 20