Package ‘GeoRiskR’

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Type Package

Title Data and functions for Geotechnical Risk Assessment

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Description Data sets and functions for geotechnical reliability analysis. The GeoRiskR develops for geotechnical engineers to perform reliability analysis. Firstly, several existing data sets (soil shear strengths, rock shear strengths, GCL shear strengths, soil texture, and the relation between initial void ratio and compression index) are compiled. The collected datasets are adopted from the existing literature, for instance,the data of shear strength parameters of soils composed by 509 paired parameters (including cohesion and inner friction angle) observed at 22 locations from 12 published papers. Secondly, twelve full-scale static axial compression loading test databases (consists of 463 samples at six sites) from the Beijing region are compiled. For the CFG pile, containing length, diameter, maximum loading, maximum settlement, Kur, and curve regression parameters (p1 , p2 , h1 , and h2); for the pile-soil intermediate (PSI) containing bearing plate area, maximum bearing pressure, maximum settlement, Kur, and regression parameters (p1 , p2 , h1 , and h2). Thirdly, the source code for the reliability analyses are provided, including the widely-used first-order relaliability method (FORM), second-order reliability method (SORM).

Depends R(>= 2.12.0), mvtnorm, gsl, fitdistrplus, copula

License GPL (>= 3)

LazyLoad true

LazyData true

Suggests MASS

R topics documented:

`GeoRiskR-package` *GeoRisk-package*

Description

Shear strength parameters of soils, rocks, geosynthetics, regression parameters of pile loading-settlements curves, some useful functions for multivariate analysis and reliability analysis (first-order reliability method, FORM; second order reliability method, SORM) in geotechnical engineering

Details

Package:	GeoRiskR
Type:	Package
Version:	1.0
Date:	2015-5-21
License:	GNU 2.15 or later
LazyLoad:	yes

Author(s)

Xing Zheng Wu Maintainer: <xingzhengwu@gmail.com>

References

Wu XZ. 2015. Implementing multivariate fitting and reliability analyses for geotechnical engineering problems in R. Journal of Earth System Science.

Examples

```
## listing the data for soils
SoilShear
## listing the data for rocks
RockShear
## listing the data for geosynthetic
GCLShear
## listing the data for soils by Mousavi et al. 2011
```

```
MousaviSet
## listing the data for regression parameters of CFG pile
CFGRegPars
## listing the data for regression parameters of pile-soil intermediate
PSIRegPars
```

CFGRegPars *Regression parameters for bearing capacity versus settlement curve of CFG pile*

Description

Data sets covers the regression parameters via hyperbolic and power law

Usage

```
CFGRegPars(h1, h2)
CFGRegPars(p1, p2)
```

Arguments

h1	a hyperbolic regression parameter
h2	a hyperbolic regression parameter
p1	a power law regression parameter
p2	a power law regression parameter

Details

The data set contains several columns : no, diameter, length, Qmax, Smax, Kur, p1, p2, h1, h2.

Value

Returns a matrix that contains above values for each sites included in the data set.

Note

Please read the following references for the original data (adopted from):

[1] Wu XZ. Xin J-X. 2015. Probabilistic analysis of load-displacement behaviour of cement fly-ash gravel piles. under review.

Author(s)

Xingzheng Wu <xingzhengwu@gmail.com>

References

Wu XZ. 2015. Implementing multivariate fitting and reliability analyses for geotechnical engineering problems in R. Journal of Earth System Science. .

See Also

Wu X.Z. 2013. Probabilistic slope stability analysis by a copula-based sampling method. Computational Geosciences. 2013. 17(5):739-755.

Examples

```
##---- Should be DIRECTLY executable !! ----
##--listing data.
CFGRegPars[["name"]]  ##column named "name"

which(CFGRegPars[["name"]]=="TZCFG")  ##returns a vector of the indices of x
which(CFGRegPars[["type"]]=="CP")  ##returns a vector of the indices of x at a site
CFGRegPars[which(CFGRegPars[["type"]]=="CP"),]   ##listing a matrix where the site = 'CP'
CFGRegPars[which(CFGRegPars[["type"]]=="CP"),7:8]
##listing a matrix where the p1-p2 parameters at site = 'CP'
CFGRegPars[which(CFGRegPars[["type"]]=="CP"),9:10]
##listing a matrix where the h1-h2 parameters at site = 'CP'
```

---

e0cc *initial void ratio and compression index for settlements*

Description

Data sets covers the initial void ratio and copression index from soils

Usage

```
e0cc(e0, cc)
```

Arguments

e0	a numeric for the initial void ratio
cc	a numeric for compression index

Details

The data set contains several columns : e0, cc, e1, investigator, published year, soil name.

Value

Returns a matrix that contains above values for each soils included in the data set.

Note

Please read the following references for the original data (adopted from):

[1] Abbasi N, Javadi AA, Bahramloo R. 2012. Prediction of compression behaviour of normally consolidated fine-grained soils, World Applied Sciences Journal, volume 18, no. 1, pages 6-14.

[2] Keller T., Lamande M., Schjoning, P., Dexter, A. R. 2011. Analysis of soil compression curves from uniaxial confined compression tests. Geoderma. 163, (1-2), 13-23.

Author(s)

Xingzheng Wu <xingzhengwu@gmail.com>

References

Wu XZ. 2015. Implementing multivariate fitting and reliability analyses for geotechnical engineering problems in R. Journal of Earth System Science.

Examples

```
##---- Should be DIRECTLY executable !! ----
##--listing data.
e0cc[["name"]]  ##column named "name"

which(e0cc[["name"]]=="Keller-et-al")  ##returns a vector of the indices of x
which(e0cc[["type"]]=="fine-grained")  ##returns a vector of the indices of x
e0cc[which(e0cc[["type"]]=="fine-grained"),]
##listing a matrix where the soil type = 'fine-grained'
```

FORM-AT — *Solution of the first-order reliability method (FORM) using Ang and Tang (1984) 's algorithm*

Description

Application to a bearing capacity problem associated with two variables

Arguments

mu1	mean of unit weight
sd1	standard deviation of unit weight
mu2	mean of internal angle of friction
sd2	standard deviation of internal angle of friction
rou	correlation coefficient between unit weight and internal angle of friction

Details

The case study discusses the solution with a correlated bivariate distribution.

Value

Returns a reliability index.

Note

Please read the following references for the original data (adopted from):

[1] Ang A H S and Tang W H 1984 Probability Concepts in Engineering Planning and Design. Volume II, Decision, risk and reliability; John Wiley, New York, 562pp.

[2] Phoon K K and Honjo Y 2005 Geotechnical reliability analyses: towards development of some user-friendly tools; In Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical engineering. Osaka.

Author(s)

Xingzheng Wu <xingzhengwu@gmail.com>

References

Wu XZ. 2015. Implementing multivariate fitting and reliability analyses for geotechnical engineering problems in R. Journal of Earth System Science.

See Also

Wu X.Z. 2013. Probabilistic slope stability analysis by a copula-based sampling method. Computational Geosciences. 2013. 17(5):739-755.

Examples

```
##---- Should be DIRECTLY executable !! ----
##--listing the code.
library(rootSolve) #for uniroot.all( )
library(mosaic) #for D( )
Y_mu=18; Y_sd=Y_mu*0.1; Z_mu=40; Z_sd=Z_mu*0.2; X12.Corr<-0.66
DD<-10; BW<-1; ed<-1; FL<-1000
dTerm<-0.5/(ed+DD)*BW*DD^3
corrm2<-matrix(c(1,X12.Corr,X12.Corr,1.0),ncol=2,nrow=2,byrow=TRUE)
eig<-eigen(corrm2,EISPACK=FALSE); eig.X01<-eig$values[1];
eig.X02<-eig$values[2]; tranMat<-eig$vectors;
for (iTer in 1:100) { # iteration start
if (iTer==1) {Y1<-0; Y2<-0; X0.sigma.mat<-diag(c(Y_sd,Z_sd));
muX<-as.matrix(c(Y_mu,Z_mu));
CY<-X0.sigma.mat * tranMat;

#----------------------------------------------------------------------
# please replace * by %*% for matrix Multiplication in above line or see demo code !!!!
#----------------------------------------------------------------------

Beta<-0.0; BetaNew1<-3
}

dBeta<-abs(Beta-BetaNew1)
if (dBeta<=0.0002) {Beta; break} #success and exit

if (iTer!=1) {Y1<-X21.Mn; Y2<-X22.Mn}
Beta<-BetaNew1
D.Y1Fun<-D(dTerm*(CY11*Y1+CY12*Y2+muX1)*(tan((45+0.5*(CY21*Y1+CY22*Y2+muX2))/180*pi))^2-FL~Y1)
D.Y2Fun<-D(dTerm*(CY11*Y1+CY12*Y2+muX1)*(tan((45+0.5*(CY21*Y1+CY22*Y2+muX2))/180*pi))^2-FL~Y2)
D.Y1Val<-D.Y1Fun(CY11=CY[1,1],CY21=CY[2,1],CY12=CY[1,2],Y1=Y1,CY22=CY[2,2],
Y2=Y2,muX2=muX[2],muX1=muX[1],dTerm=dTerm,FL=FL)
D.Y2Val<-D.Y2Fun(CY11=CY[1,1],CY21=CY[2,1],CY12=CY[1,2],Y1=Y1,CY22=CY[2,2],
Y2=Y2,muX2=muX[2],muX1=muX[1],dTerm=dTerm,FL=FL)
D.Y1Vals<-D.Y1Val*sqrt(eig.X01); D.Y2Vals<-D.Y2Val*sqrt(eig.X02)

Alfa.Y1<-D.Y1Vals/sqrt(D.Y1Vals*D.Y1Vals+D.Y2Vals*D.Y2Vals)
Alfa.Y2<-D.Y2Vals/sqrt(D.Y1Vals*D.Y1Vals+D.Y2Vals*D.Y2Vals)
DP.Y1<--Alfa.Y1*sqrt(eig.X01); DP.Y2<--Alfa.Y2*sqrt(eig.X02)

CY11=CY[1,1]; CY21=CY[2,1]; CY12=CY[1,2]; CY22=CY[2,2]; muX1=muX[1]; muX2=muX[2];
```

```
g109.x<-function(x)(dTerm*(CY11*x*DP.Y1+CY12*x*DP.Y2+muX1)*(tan((45+0.5*
(CY21*x*DP.Y1+CY22*x*DP.Y2+muX2))/180*pi))^2-FL)
BetaNew<-uniroot.all(g109.x, interval=c(0,250)); BetaNew1<-min(BetaNew)

X21.Mn<-DP.Y1*BetaNew1; X22.Mn<-DP.Y2*BetaNew1;
} #next iTer
BetaNew1
```

FORM-LT *Solution of the first-order reliability method (FORM) using Low and Tang (2007) 's algorithm*

Description

Application to a bearing capacity problem associated with two variables

Arguments

mu1	mean of unit weight
sd1	standard deviation of unit weight
mu2	mean of internal angle of friction
sd2	standard deviation of internal angle of friction
rou	correlation coefficient between unit weight and internal angle of friction

Details

The case study discusses the solution with a correlated bivariate distribution.

Value

Returns a reliability index.

Note

Please read the following references for the original data (adopted from):

[1] Low B K and Tang W H 2007 Efficient spreadsheet algorithm for first-order reliability method; J. Eng. Mech. 133(12) 1378-1387.

[2] Phoon K K and Honjo Y 2005 Geotechnical reliability analyses: towards development of some user-friendly tools; In Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical engineering. Osaka.

Author(s)

Xingzheng Wu <xingzhengwu@gmail.com>

References

Wu XZ. 2015. Implementing multivariate fitting and reliability analyses for geotechnical engineering problems in R. Journal of Earth System Science.

See Also

Wu X.Z. 2013. Probabilistic slope stability analysis by a copula-based sampling method. Computational Geosciences. 2013. 17(5):739-755.

Examples

```
##---- Should be DIRECTLY executable !! ----
##--listing the code.
## install.packages("Rdonlp2")  #Rdonlp2_0.3-1.zip
library(Rdonlp2)
nVars<-2; ncols<-nVars; nrows<-nVars

FunXiLT<-function(DistName,para1,para2,ni){if (DistName=="norm") {
xi_LT=para1+ni*para2}; list(xi_LT=xi_LT)
}

ObjFn<-function(par){
x1<-par[1]; x2<-par[2];
ncols<-2; nrows<-2
X12.Corr<-0.66; X21.Corr<-0.66
corrm4<-matrix(c(1,X12.Corr,X21.Corr,1.0),ncol=ncols,nrow=nrows,byrow=TRUE)
CormInv<-solve(corrm4)
matXMinusM<-t(t(c(x1,x2)))
sqrt(t(matXMinusM) * CormInv * matXMinusM)

#----------------------------------------------------------------------
# please replace * by %*% for matrix Multiplication in above line or see demo code !!!!
#----------------------------------------------------------------------

}
par.l<-c(-500,-500); par.u<-c(50,60)
nlinbd<-matrix(0,nr=1,nc=2)

gFn<-function(par){
x1<-par[1];x2<-par[2];
X1_mu=18.00; X1_sd=1.8; X2_mu=40.00/180*pi; X2_sd=8/180*pi;
z1<-FunXiLT("norm",X1_mu,X1_sd,x1)$xi_LT
z2<-FunXiLT("norm",X2_mu,X2_sd,x2)$xi_LT
BW<-1; DD<-10; ed<-1; FL<-1000
z1*BW*DD^3/(2*(ed+DD))*tan(pi/4+z2/2)^2-FL
}
nlinbd[1,]<-c(-Inf,0)
p0<-c(0.0,0.0) #n1,n2
cntl<-donlp2.control(del0=0.2,tau0=1.0,tau=0.1,taubnd=5e-6)
res<-donlp2(par=p0,fn=ObjFn,par.u=par.u,par.l=par.l,nlin=list(gFn),nlin.upper=nlinbd[,2],
nlin.lower=nlinbd[,1],control=cntl)
beta1<-res$f
```

FORM-XiFun *Define the original basic variables by the dimensionless numbers using Low and Tang (2007) 's algorithm*

Description

Application xi funtion to derive x from xi for any distribution types

Arguments

mu	mean
sd	standard deviation
para1	parameter of a distribution
para2	parameter of a distribution
DistName	name of a distribution

Details

The distribution can be specified by the normal, lognormal, Gumbel, Weibull, gamma, and beta.

Value

Returns xi.

Note

The following R code is modified from the VB ones written by Low and Tang (2007).

Author(s)

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References

[1] Low B K and Tang W H 2007 Efficient spreadsheet algorithm for first-order reliability method; J. Eng. Mech. 133(12) 1378-1387. [2] Low B K and Tang W H 1997 Efficient reliability evaluation using spreadsheets; J. Eng. Mech. 123(7) 749-752.

See Also

Wu X.Z. 2013. Probabilistic slope stability analysis by a copula-based sampling method. Computational Geosciences. 2013. 17(5):739-755.

Examples

```
##---- Should be calling by FORM-LT !! ----
##--listing the code.
 ln <- function(x) { log(x, 2.718281828)}

FunXiLT<-function(DistName, para1,para2, ni){
if (DistName=="norm") {
  xi_LT=para1+ni*para2
}
if (DistName=="lnorm") {
  lamda=log(para1)-0.5*log(1+(para2/para1)^2)
  zeta = sqrt(log(1+(para2/para1)^2))
  xi_LT = exp(lamda+zeta*ni)
}
if (DistName=="gumbel") {
```

```
    alfa=1.28255/para2
    u=para1-0.5772/alfa
    xi_LT =u-log(-log(pnorm(ni)))/alfa
  }
  if (DistName=="weibull") {
    xi_LT =para2*(-log(1-pnorm(ni)))^(1/para1)
  }
  if (DistName=="gamma") {
    xprev=para1*para2
    for (i in 1:100) {
      pdfg=dgamma(xprev,para1,1/para2)
      xnew=xprev-(CDFg-pnorm(ni))/pdfg
      if (abs((xnew-xprev)/xprev)<0.000001) break
      if (xnew<=0) xnew=0.5*xprev
      xprev=xnew
    }
    xi_LT=xnew
  }

  list(xi_LT=xi_LT)
  }
```

GCLShear *Shear strengths of GCLs*

Description

Data sets covers the shear strengths from geosynthetics

Arguments

cohesion	a numeric for the cohesion, in kPa
friction angle	a numeric for the inner friction angle, in degree

Details

The data set contains several columns : cohesion, friction angle, unit grivity, investigator, published year, rock name.

Value

Returns a matrix that contains above values for each GCL included in the data set.

Note

Please read the following references for the original data (adopted from):

[1] McCartney, J.S., Zornberg, J.G., Swan Jr., R.H., Gilbert, R.B., 2004. Reliability-based stability analysis considering GCL shear strength variability. Geosynthetics International 11 (3), 212-232.

Author(s)

Xingzheng Wu <xingzhengwu@gmail.com>

References

Wu XZ. 2015. Implementing multivariate fitting and reliability analyses for geotechnical engineering problems in R. Journal of Earth System Science.

See Also

Wu X.Z. 2013. Using copulas to characterise the dependency of GCL shear strengths. Geosynthetic International. 20 (5):1-14.

Examples

```
##---- Should be DIRECTLY executable !! ----
##--listing data.
GCLShear[["name"]]  ##column named "name"

which(GCLShear[["name"]]=="McCartney-et-al")  ##returns a vector of the indices of x
which(GCLShear[["type"]]=="set3")  ##returns a vector of the indices of x
GCLShear[which(GCLShear[["type"]]=="set3"),]
##listing a matrix where the set type = 'set3'
```

`MousaviSet` *Large data base by Mousavi et al. 2011*

Description

Data sets covers the shear strengths, properties from undisturbed soils by triaxial test

Arguments

`cohesion`	a numeric for the cohesion, in kPa
`friction angle`	a numeric for the inner friction angle, in degree
`unit gravity`	a numeric for the unit gravity, in kN/m^3

Details

The data set contains several columns : No. FC CC D10 D30 D60 Cu Cc LL Gamma W Gammad c phi, investigator, published year, rock name.

Value

Returns a matrix that contains above values for each soils included in the data set.

Note

Please read the following references for the original data (adopted from)

[1] Mousavi SM, Alavi AH, Gandomi AH, Mollahasani A. Nonlinear genetic-based simulation of soil shear strength parameters. J. Earth Syst. Sci.120(6): 1001-1022.

Author(s)

Xingzheng Wu `<xingzhengwu@gmail.com>`

References

Wu XZ. 2015. Implementing multivariate fitting and reliability analyses for geotechnical engineering problems in R. Journal of Earth System Science.

Examples

```
##---- Should be DIRECTLY executable !! ----
##--listing data.
MousaviSet[["name"]]  ##column named "name"
MousaviSet[1,]  ##1st row

MousaviSet[["friction.angle"]]
##listing a matrix where the soil type = 'friction.angle'
```

PSIRegPars *Regression parameters for bearing capacity versus settlement curve of pile-soil intermediate (PSI)*

Description

Data sets covers the regression parameters via hyperbolic and power law

Usage

```
PSIRegPars(h1, h2)
PSIRegPars(p1, p2)
```

Arguments

h1	a hyperbolic regression parameter
h2	a hyperbolic regression parameter
p1	a power law regression parameter
p2	a power law regression parameter

Details

The data set contains several columns : no, area, Pmax, Smax, Kur, p1, p2, 10000*h1, 100*h2.

Value

Returns a matrix that contains above values for each sites included in the data set.

Note

Please read the following references for the original data (adopted from):

[1] Wu XZ. Xin J-X. 2015. Probabilistic analysis of load-displacement behaviour of cement fly-ash gravel piles. under review.

Author(s)

Xingzheng Wu <xingzhengwu@gmail.com>

References

Wu XZ. 2015. Implementing multivariate fitting and reliability analyses for geotechnical engineering problems in R. Journal of Earth System Science.

See Also

Wu X.Z. 2013. Probabilistic slope stability analysis by a copula-based sampling method. Computational Geosciences. 2013. 17(5):739-755.

Examples

```
##---- Should be DIRECTLY executable !! ----
##--listing data.
PSIRegPars[["name"]]  ##column named "name"

which(PSIRegPars[["name"]]=="TZPSI")  ##returns a vector of the indices of x
which(PSIRegPars[["type"]]=="CI")  ##returns a vector of the indices of x at a site
PSIRegPars[which(PSIRegPars[["type"]]=="CI"),]   ##listing a matrix where the site = 'CI'
PSIRegPars[which(PSIRegPars[["type"]]=="CI"),6:7]
##listing a matrix where the p1-p2 parameters at site = 'CI'
PSIRegPars[which(PSIRegPars[["type"]]=="CI"),8:9]
##listing a matrix where the h1-h2 parameters at site = 'CI'
```

RockShear *Shear strengths of rocks*

Description

Data sets covers the shear strengths from rocks

Arguments

`cohesion`	a numeric for the cohesion, in kPa
`friction angle`	a numeric for the inner friction angle, in degree
`unit gravity`	a numeric for the unit gravity, in kN/m^3

Details

The data set contains several columns : cohesion, friction angle, unit grivity, investigator, published year, rock name.

Value

Returns a matrix that contains above values for each rocks included in the data set.

Note

Please read the following references for the original data (adopted from):

[1] Gay Geoffrey, Schad Herman, 2001. Landslides and Rockfall in Keuper. Otto-Graf-Journal. Vol. 12, 201-214.

[2] Goodman, R.E., Algren, Ch.S. 2000. Evaluating safety of concrete gravity dam on weak rock: Scott dam. J. Geot. Geoenvironmental Eng., 126(5): 429-442.

[3] Lanaro F., Fredriksson A. 2005. Rock mechanics characterisation of the rock mass summary of primary data. Preliminary site description version 1.2. R-05-21. Swedish Nuclear Fuel and Waste Management Co. http://193.235.25.3/upload/publications/pdf/R-05-21webb.pdf.

[4] Lindquist, E.S. 1994. The strength and deformation properties of melange.PhD Thesis, Dept. of Civil Engineering, University of California. Berkeley.

[5] Young DS. 1986. A generalized probabilistic approach for slope analysis: practicalapplication to an open pit iron ore mine. Int J Mining Geol Eng 4(1):3-13

[6] Wang XG, Dong YJ. Shear strength parameters of rock mass. Beijing: China Water Power Press; 2010 [in Chinese].

Author(s)

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References

Wu XZ. 2015. Implementing multivariate fitting and reliability analyses for geotechnical engineering problems in R. Journal of Earth System Science.

See Also

Wu XZ. 2013. Uncertainty and statistical dependence of shear strength parameters of rocks. International Journal of Rock Mechanics and Mining Sciences. Under review.

Examples

```
##---- Should be DIRECTLY executable !! ----
##--listing data.
RockShear[["name"]]  ##column named "name"

which(RockShear[["name"]]=="Young")  ##returns a vector of the indices of x
which(RockShear[["type"]]=="Melange")  ##returns a vector of the indices of x
RockShear[which(RockShear[["type"]]=="Melange"),]
##listing a matrix where the rock type = 'Melange'
```

`SoilShear` *Shear strengths of soils*

Description

Data sets covers the shear strengths from soils

Arguments

`cohesion`	a numeric for the cohesion, in kPa
`friction angle`	a numeric for the inner friction angle, in degree

Details

The data set contains several columns : cohesion, friction angle, unit grivity, investigator, published year, soil name.

Value

Returns a matrix that contains above values for each soils included in the data set.

Note

Please read the following references for the original data (adopted from):

[1] Cherubini, C., 2000. Reliability evaluation of shallow foundation bearing capacity on c-phi soils. Canadian Geotechnical Journal, 37, 264-269.

[2] Forrest William S. and Orr Trevor L.L. 2010. Reliability of shallow foundations designed to Eurocode 7, Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards, 4:4, 186-207.

[3] Hata Yoshiya, Ichii Koji and Tokida Ken-ichi. 2011. A probabilistic evaluation of the size of earthquake induced slope failure for an embankment, Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards, DOI:10.1080/17499518.2011.604583.

[4] Hatanaka M. and Uchida A. 1996. Empirical correlation between penetration resistance and internal friction angle of sandy soils. Soils and Foundations, 36(4):1-9.

[5] Lumb, P. 1970. Safety factors and the probability distribution of soil strength. Can. Geotech. J., 7(3), 225-242.

[6] Matsuo, M., and Kuroda, K., 1974. Probabilistic approach to design of embankments: Jour. Japanese Society of Soil Mechanics and Foundation Engineering, v. 14, no. 2.

[7] Schultze E. 1971. Frequency distributions and correlations of soil properties. In Lumb, P. (ed.) Statistics and Probability in Civil Engineering (Int. Conf. Appl. Stat. Prob. Soil Struct. Eng.). Hong Kong Univ. Press, 372-387.

[8] Parker, C., Simon, A., Thorne, C.R., 2008. The effects of variability in bank material properties on riverbank stability: Goodwin Creek, Mississippi. Geomorphology, 101, 533-543.

[9] Ngoc PQ. An investigation on petrophysical and geotechnical properties of soils uing multivariate statistics. Clausthal University of Technology. Germany, 2012.

Author(s)

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References

Wu XZ. 2015. Implementing multivariate fitting and reliability analyses for geotechnical engineering problems in R. Journal of Earth System Science.

See Also

Wu X.Z. 2013. Probabilistic slope stability analysis by a copula-based sampling method. Computational Geosciences. 2013. 17(5):739-755.

Wu X.Z. 2013. Trivariate analysis of soil ranking-correlated characteristics and its application to probabilistic stability assessments in geotechnical engineering problems. Soils and Foundations. 2013. 53(4):540-556.

Examples

```
##---- Should be DIRECTLY executable !! ----
##--listing data.
SoilShear[["name"]]  ##column named "name"

which(SoilShear[["name"]]=="Lumb")  ##returns a vector of the indices of x
which(SoilShear[["type"]]=="MBC")  ##returns a vector of the indices of x
SoilShear[which(SoilShear[["type"]]=="MBC"),]
##listing a matrix where the soil type = 'MBC'
```

SORM *Solution of the second-order reliability method (SORM) using Phoon (2008) 's algorithm*

Description

Application to a bearing capacity problem associated with two variables

Arguments

`mu1`	mean of unit weight
`sd1`	standard deviation of unit weight
`mu2`	mean of internal angle of friction
`sd2`	standard deviation of internal angle of friction
`rou`	correlation coefficient between unit weight and internal angle of friction

Details

The case study discusses the solution with a correlated bivariate distribution.

Value

Returns a reliability index.

Note

This subroutine can be run after calling the first-order reliability analysis, i.e., FORM-LT.

Please read the following references:

[1] Breitung K 1984 Asymptotic approximations for multinormal integrals; J. Eng. Mech. (ASCE), 110(3) 357-366.

[2] Phoon K K 2008 Numerical recipes for reliability analysis!*a primer; In: Phoon, K.K. (Ed.), Reliability-based Design in Geotechnical Engineering: Computations and Applications. Taylor & Francis (Chapter 1).

[3] Phoon K K and Honjo Y 2005 Geotechnical reliability analyses: towards development of some user-friendly tools; In Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical engineering. Osaka.

[4] Tvedt L 1983 Two second-order approximations to the failure probability. Veritas Report RDIV/20-004083. Det norske Veritas. Veritas Report RDIV/20-004083: Oslo.

[5] Tvedt L 1990 Distribution of quadratic forms in normal space: Application to structural reliability; J. Eng. Mech. (ASCE), 116(6) 1183-1197.

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References

Wu XZ. 2015. Implementing multivariate fitting and reliability analyses for geotechnical engineering problems in R. Journal of Earth System Science.

See Also

Wu X.Z. 2013. Probabilistic slope stability analysis by a copula-based sampling method. Computational Geosciences. 2013. 17(5):739-755.

Examples

```
##---- Should be DIRECTLY executable !! ----
##--listing the code.
pf1<-pnorm(-beta1)
zz<-ret$par; mm<-nVars
grad<-matrix(nrow=mm,ncol=1)
for (i in 1:mm) {ww<-zz;
ww[i]<-zz[i]+0.01; P2<-gFn(ww);
ww[i]<-zz[i]-0.01; P1<-gFn(ww);
grad[i]<-(P2-P1)/2/0.01}
Hess<-matrix(nrow=mm,ncol=mm)
for (i in 1:mm){
for (j in 1:mm){ww<-zz;
if (i==j) {P0<-gFn(ww); ww[i]<-zz[i]+0.01;
P2<-gFn(ww); ww[i]<-zz[i]-0.01;
P1<-gFn(ww); Hess[i,j]<-(P2-2*P0+P1)/(0.01)^2}
if (i!=j) {ww[i]<-zz[i]+0.01; ww[j]<-zz[j]+0.01;
P6<-gFn(ww); ww[j]<-zz[j]-0.01;
P5<-gFn(ww); ww[i]<-zz[i]-0.01;
P3<-gFn(ww); ww[j]<-zz[j]+0.01;
P4<-gFn(ww); Hess[i,j]<-(P6-P4-P5+P3)/4/(0.01)^2}}}
library(pracma) #Norm function
dP<-Norm(grad); QQ<-diag(mm);
QQ[1:mm,1]<-zz; qrstr<-qr(QQ)
QQR<-qr.Q(qrstr); QQR1<-t(apply(QQR,1,rev))
AA<-t(QQR1) * Hess * QQR1;

#----------------------------------------------------------------------
# please replace * by %*% for matrix Multiplication in above line or see demo code !!!!
```

```
#---------------------------------------------------------------------

AAN<-AA[1:mm-1,1:mm-1]/dP
tmpEG=eigen(AAN); WW=tmpEG$values; kappa<-as.matrix(WW)
correction1<-prod(1.0/sqrt(1+beta1*kappa),1);
pf2<-pf1*correction1; #Breitung's formula
beta2<--qnorm(pf2);
TermAA<-beta1*pnorm(-beta1)-dnorm(-beta1)
correction2<-prod(1.0/sqrt(1+(beta1+1)*kappa),1);
A2Term<-TermAA*(correction1-correction2); i_complex<-sqrt(as.complex(-1))
correction3<-Re(prod(1.0/sqrt(1+(beta1+i_complex)*kappa),1));
A3Term<-(beta1+1)*TermAA*(correction1-correction3)
pf3<-pf1*correction1+A2Term+A3Term; #Tvedt's formula
beta3<--qnorm(pf3)

beta2 #Breitung's solution
beta3 #Tvedt's solution
```

`texture` *grain size (including sand, silt, and clay) distribution for soil classification*

Description

Data sets covers the ratio of sand-silt-clay from soils

Usage

```
texture(sand, silt, clay)
```

Arguments

`sand`	a numeric for the ratio of sand
`silt`	a numeric for the ratio of silt
`clay`	a numeric for the ratio of clay

Details

The data set contains several columns : sand, silt, clay, optimum water content, dry density, liquid limit, plastic limit, shrinkage limit, USCS classification, investigator, published year, soil name.

Value

Returns a matrix that contains above values for each soils included in the data set.

Note

Please read the following references for the original data (adopted from):

[1] Abbasi N, Javadi AA, Bahramloo R. 2012. Prediction of compression behaviour of normally consolidated fine-grained soils, World Applied Sciences Journal, volume 18, no. 1, pages 6-14.

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References

Wu XZ. 2015. Implementing multivariate fitting and reliability analyses for geotechnical engineering problems in R. Journal of Earth System Science.

Examples

```
##---- Should be DIRECTLY executable !! ----
##--listing data.
texture[["name"]]  ##column named "name"

which(texture[["name"]]=="Abbasi-et-al")  ##returns a vector of the indices of x
which(texture[["type"]]=="fine-grained")  ##returns a vector of the indices of x
texture[which(texture[["type"]]=="fine-grained"),]
##listing a matrix where the soil type = 'fine-grained'
```

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