

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON EARTH REINFORCEMENT  
FUKUOKA/KYUSHU/JAPAN/12-14 NOVEMBER 1996

# Earth Reinforcement

*Edited by*

HIDETOSHI OCHIAI  
NORIYUKI YASUFUKU  
KIYOSHI OMINE

*Kyushu University, Fukuoka, Japan*

VOLUME 1



Under the auspices of the Japanese Geotechnical Society  
A.A. BALKEEMA/ROTTERDAM/BROOKFIELD/1996



## Table of contents

Preface	XV
Organization	XVII
1 Testing and materials	
Analysis of geotextile-soil interaction in pull-out tests <i>S.Adanur, S.Mallick &amp; H.Zhai</i>	3
Experimental investigation of shearing behavior at cohesive soil-geotextile interfaces <i>G.A.Athanasiopoulos</i>	9
The connection strength of masonry block faced retaining walls <i>R.A.Austin &amp; C.Martin</i>	13
The creep behavior of geotextiles under confined and unconfined conditions <i>D.T.T.Chang, C.A.Chen &amp; Y.C.Fu</i>	19
Dynamic reinforcing effect of reinforced sands <i>T.C.Chen, R.H.Chen, Y.S.Lee &amp; J.C.Pan</i>	25
Performance and creep characteristics of synthetic geogrids following hot dry climate <i>M.El-Shabrawy &amp; H.Al-Mudhaf</i>	29
Displacement controlled pullout test of geotextile in granular soil <i>C.Ghosh &amp; A.Bhasin</i>	35
Dilatancy effects of granular soil on the pullout resistance of strip reinforcement <i>S.Hayashi, M.C.Alfarro &amp; K.Watanabe</i>	39
Long term testing of polyester yarn and product at 50°C and 23°C in different environments <i>J.M.Jailloux &amp; P.L.Anderson</i>	45
Use of decomposed granite soils as backfill for reinforced earth structures <i>S.K.Kim &amp; E.S.Lee</i>	51
Elastic considerations of field pull-out tests of polymer strip reinforcement <i>T.Konami, S.Imaizumi &amp; S.Takahashi</i>	57
Improvement of mechanical properties of continuous fiber reinforced sand <i>J.Kuwano, Y.Imamura &amp; T.Imanari</i>	63

A three-parameter model for the ultimate pull-out force of geogrids <i>Y.S.Lee, R.H.Chen &amp; T.C.Chen</i>	69
The study of reinforced soil and modeling test <i>S.Y.Lei, H.Q.Hui &amp; Q.Xue</i>	73
Experimental analysis of friction between sand and reinforcing elements using ring simple shear tests <i>P.Lerat, P.Unterreiner &amp; F.Schlosser</i>	77
Pullout tests on geogrids buried in lateritic soils <i>S.S.Lin, M.C.Chen, M.Y.Cheng &amp; S.H.Kuo</i>	83
Pull-out tests for the assessment of soil-geogrids interaction – Influence of some mechanical and physical parameters <i>M.L.Lopes &amp; M.Ladeira</i>	89
Mechanical characteristics of geosynthetic-enveloped soils <i>K.Makiuchi, Y.Kawaguchi &amp; K.Minegishi</i>	95
Bearing mechanism of steel grid reinforcement in pullout test <i>T.Matsui, K.C.San, Y.Nabeshima &amp; U.N.Amin</i>	101
Erosion resistance properties of fiber-reinforced soil <i>H.Miki, S.Mochimaru, K.Mori, T.Kumada &amp; K.Tajima</i>	107
Reinforced soil failure: Analysis at the biaxial compression test <i>J.C.Morel &amp; J.P.Gourc</i>	111
Short and long term behaviour of geogrids under static and cyclic load <i>N.Moraci &amp; F.Montanelli</i>	117
Some factors affecting the results of soil-geogrid direct shear test <i>T.Nakamura, T.Mitachi &amp; I.Ikeura</i>	123
In-soil tensile behaviour of geotextiles confined by fine soils <i>E.M.Palmeira, N.Tupa &amp; R.C.Gomes</i>	129
Effect of normal pressure and width of geosynthetic horizontal drain in pullout behaviour using saturated clay <i>T.B.S.Pradhan, D.R.Shiwakoti &amp; G.Imai</i>	133
Comparative study and measurement of the pull-out capacity of extensible and inextensible reinforcements <i>P.Segrestin &amp; M.Bastick</i>	139
A new experimental device for determining reinforcement mechanisms in soil nails <i>T.C.Sheahan &amp; I.Alvarado</i>	145
Durability of galvanized steel reinforcements as a function of their shape <i>A.Smith, J.M.Jailloux &amp; P.Segrestin</i>	151
Finite element analysis of a reinforced soil <i>K.M.Soni, A.Varadarajan &amp; K.G.Sharma</i>	157

An investigation of the durability of the soil nailing method <i>S.Tayama, Y.Kawai &amp; H.Maeno</i>	161
Strain-controlled pull-out tests on bamboo culm embedded in quarry dust <i>M.T.A.Wahab &amp; F.H.Ali</i>	167
Application of screw anchor to side shoring of two foundation pits <i>Z.Wang &amp; Z.D.Liu</i>	173
<b>2 Embankments</b>	
Chilean experiences with geosynthetics in embankments <i>P.M.Acevedo &amp; C.A.Martínez</i>	179
Effects of reinforcement rigidity on the behavior of reinforced soil wall-embankment system on soft ground <i>M.C.Alfaro, S.Hayashi &amp; N.Miura</i>	185
Limit design of earth reinforcement methods considering displacement field <i>K.Arai &amp; K.Kasahara</i>	191
Dynamic response analysis of geogrid reinforced steep embankment subjected to an earthquake <i>T.Fujii, N.Fukuda &amp; N.Tajiri</i>	197
Creep behavior of laboratory embankment reinforced with geogrid <i>H.Furuuya, M.Toriihara &amp; K.Hirama</i>	203
Geogrid reinforced railway embankment on piles – Monitoring <i>E.Gartung &amp; J.Verspohl</i>	209
In situ failure test of high water content soft clay embankments reinforced by GHDs <i>M.Kamon, T.Akai, M.Fukuda &amp; Y.Nanbu</i>	215
Direction and magnitude of reinforcement force in embankments on soft soils <i>S.R.Kaniraj</i>	221
Geosynthetic-reinforced soil retaining wall using clay on a very soft ground for Hokuriku bullet train yard in Nagano <i>K.Kojima, N.Sakamoto, M.Tateyama &amp; O.Maruyama</i>	227
Some factors affecting the structural performance of reinforced fills spanning voids <i>C.R.Lawson, C.J.F.P.Jones &amp; G.T.Kempton</i>	233
Importance of strong motion in the design of earth reinforcement <i>S.P.G.Madabhushi</i>	239
Effect of geogrid stiffness on the resistance behavior of reinforced embankment under loading <i>Y.Miyata, H.Ochiai &amp; K.Kogure</i>	245
Experimental evaluation of reinforcement in geogrid-soil structure <i>H.Ochiai, N.Yasufuku, T.Yamaji, G.L.Xu &amp; T.Hirai</i>	249

Numerical simulation of beam-shaped soil structure reinforced by geosynthetics <i>H.Ohta, S.Goren, A.Iizuka, T.Yamakami, K.Yamagishi &amp; N.Moroto</i>	255
A case history of the construction of a reinforced high embankment on an extra soft ground <i>H.Oikawa, S.Sasaki &amp; N.Fujii</i>	261
Centrifugal and finite element modelling of reinforced embankments on soft clay <i>J.S.Sharma &amp; M.D.Bolton</i>	267
Behavior of reinforced earth embankments on liquefiable sandy ground <i>R.Uzuoka, M.Mihara, F.Oka &amp; A.Yashima</i>	273
A partial factor approach for reinforced fill slope design in Hong Kong <i>H.N.Wong</i>	279
Application of the velocity field method to stability analysis of earth reinforcement <i>J.J.Yang, N.Moroto, H.Ochiai &amp; A.Suzuki</i>	285
Review of design temperature for reinforced fill slopes in Hong Kong <i>K.C.Yeo &amp; P.L.R.Pang</i>	289
<b>3 Wall structures</b>	
The need for standard safety factors in the determination of allowable tensile loads <i>P.Anderson, M.Boyd, P.Segrestin &amp; K.Worrall</i>	297
Mechanism of reinforcement from two field trials <i>R.Arab, P.Villard &amp; J.P.Gourc</i>	303
Use of double wedge equilibrium for reinforced earth structures design <i>M.Bastick &amp; P.Segrestin</i>	309
Construction and performance of an experimental large scale wall reinforced with geosynthetics <i>C.Benigni, G.Bosco, D.Cazzuffi &amp; R.De Col</i>	315
Reinforced earth seawalls at Sydney Airport <i>M.Boyd</i>	321
Prediction of reinforced soil retaining wall deformations: A review of two procedures <i>S.R.Boyle &amp; R.D.Holtz</i>	327
Effects of the transition zone in a nailed wall model test <i>K.T.Chang &amp; G.W.E.Milligan</i>	333
The effect of compaction on model fabric reinforced brick faced earth retaining walls <i>T.W.Cousens &amp; M.I.M.Pinto</i>	339
Reinforced earth walls withstand Northridge Earthquake <i>P.C.Frankenberger, R.A.Bloomfield &amp; P.L.Anderson</i>	345
The influence of the construction method on the behaviour of geosynthetic reinforced walls A numerical study <i>A.S.Cardoso &amp; M.L.Lopes</i>	351

Design of geocells reinforced soil structures through a homogenization method and a finite difference method: Comparison and charts <i>R.Gourvès, P.Reiffsteck &amp; J.F.Vignon</i>	357
Assessment of geogrids for soil reinforcement in Hong Kong <i>J.H.Greenwood &amp; K.C.Yeo</i>	363
Case history study on the application of reinforced earth technology in the loess area of China <i>Z.Y.Guo &amp; D.Z.Luo</i>	369
Infiltration tests on reinforced clay wall and test embankment <i>C.C.Huang &amp; B.N.Huang</i>	373
Stability and deformation of geosynthetic reinforced soil retaining wall <i>M.Hyodo, D.Jamalludin, H.Matsuoka, Y.Nakata, H.Murata, T.Konami &amp; J.Nishimura</i>	379
Design construction and monitoring of reinforced soil wall <i>P.Jagannatha Rao, A.Chatopadhyaya, Bindumadhava &amp; N.Venisri</i>	385
Internal stability analysis and deformation prediction for fabric reinforced earth structure <i>H.T.Kim, E.S.Lee, I.K.Kang &amp; Y.K.Bang</i>	389
The performance of reinforced earth structures in the vicinity of Kobe during the Great Hanshin Earthquake <i>K.Kobayashi, H.Tabata &amp; M.Boyd</i>	395
Classification of reinforced soil structures based on their possible failure mode <i>D.Leśniewska</i>	401
The study of the technique against the sliding of reinforced soil walls on soft subgrade <i>X.Lin</i>	407
The design of a very high reinforced earth retaining wall <i>D.Z.Luo &amp; Z.Y.Guo</i>	411
Towards a limit state design specification for reinforced soil walls <i>J.C-H.Mak &amp; S-C.R.Lo</i>	415
Innovative facing for a 24 meter high Terre Armée wall near Pont de Normandie <i>J.R.Marchal, M.Bastick &amp; F.Belblidia</i>	421
Field performance of a geotextile reinforced soil wall with concrete facing blocks <i>T.Nakajima, N.Toriumi, H.Shintani, H.Miyatake &amp; K.Dobashi</i>	427
FEM comparative analysis of facing rigidity of geotextile-reinforced soil walls <i>A.Nakane, M.Taki, Y.Yokota &amp; H.Miyatake</i>	433
Earthquake resistance of geogrid-reinforced soil walls based on a study conducted following the southern Hyogo earthquake <i>J.Nishimura, T.Hirai, K.Iwasaki, Y.Saitoh, M.Morishima, H.Shintani, S.Yoshikawa &amp; H.Yamamoto</i>	439
Centrifugal model test for a stability of the reinforced retaining wall considering three dimensional shape effect <i>K.Okabayashi, M.Kawamura &amp; Y.Okada</i>	445

Damage performance of steel-reinforced earth structures in the 1995 Hyogoken-Nambu Earthquake <i>Y.Otani, M.Mega &amp; T.Matsui</i>	451
Creep behaviour of model fabric reinforced brick faced earth retaining walls <i>M.I.M.Pinto &amp; T.W.Cousens</i>	457
Cohesive soil retaining walls reinforced with geotextile <i>A.Porbaha &amp; D.Goodings</i>	463
Use of reinforced fill structures in Hong Kong <i>W.K.Pun &amp; K.F.Man</i>	469
Analysis of anchored retaining walls <i>K.Rajagopal &amp; V.Sri Hari</i>	475
Design, construction and performance of a 40 m high reinforced fill wall in Hong Kong <i>M.J.Raybould, D.Hadley &amp; M.Boyd</i>	479
Some insights into reinforced wall behaviour based on finite element analysis <i>R.K.Rowe &amp; S.K.P.Ho</i>	485
Performance of a steel strip reinforced wall <i>S.Sakajo, J.C.Chai, K.Nishikawa &amp; T.Takai</i>	491
Shear-lag analysis of a geosynthetic reinforced soil wall <i>L.C.R.da Silva &amp; M.Abramento</i>	497
Anchored earth breast wall for a site in the sub-Himalayan region <i>R.B.Singh, K.K.Jain, R.K.Agrawal, S.N.Mane &amp; C.P.Gupta</i>	501
Design and construction of the Terratrel Ro-Ro ramp for Second Severn Crossing <i>R.Smith</i>	505
Behaviour of geogrid reinforced earth retaining walls <i>H.R.Sreekantiah &amp; V.Tito Kishan</i>	511
Design and performance of three reinforced earth tiered walls <i>J.D.Stewart, K.Truong &amp; P.Segrestin</i>	515
Construction of reinforced earth retaining structures on Ratnapura-Wewelwatte road in Sri Lanka <i>I.H.D.Sumanaratne &amp; D.P.Mallawaratchie</i>	521
Full-scale failure experiments of geotextile-reinforced soil walls with different facings <i>N.Tajiri, H.Sasaki, J.Nishimura, Y.Ochiai &amp; K.Dobashi</i>	525
Active earth pressures on walls retaining geogrid-reinforced soil <i>Y.Tsukamoto, K.Ishihara, T.Higuchi &amp; H.Aoki</i>	531
Performance of preloaded and prestressed geosynthetic-reinforced soil <i>T.Uchimura, F.Tatsuoka, T.Sato, M.Tateyama &amp; Y.Tamura</i>	537
Performance of a geosynthetic segmental block wall structure to support bridge abutments <i>G.W.Won, T.Hull &amp; L.De Ambrosis</i>	543

The research about designing method of vertical reinforced slopes <i>X.Q.Yang &amp; Z.D.Liu</i>	549
Development of horizontal earth pressures and behaviour of single and multi segmented walls <i>I.Yogarajah &amp; M.A.Saad</i>	553
A design approach to geosynthetic reinforced slopes for the agriculture saving heat room <i>Y.M.Zhang, Z.R.Wu &amp; Y.X.Liu</i>	559
<b>4 Foundations</b>	
Reinforced earth in pipeline construction <i>L.A.Babin, Y.I.Spector, N.F.Shchepin &amp; V.P.Kulagin</i>	565
The use of geotextiles to improve the structural stability of fill materials for Bandar Abbas runway construction <i>H.Behbahani</i>	569
Full scale laboratory testing on geosynthetics reinforced paved roads <i>A.Cancelli, F.Montanelli, P.Rimoldi &amp; A.G.Zhao</i>	573
Bearing capacity of strip foundation on geogrid-reinforced clay slope <i>B.M.Das, M.T.Omar, G.Singh &amp; E.C.Shin</i>	579
The influence of dimensional analysis on the interpretation of model loading tests of reinforced ground <i>A.Fakher, C.J.F.P.Jones &amp; N.A.B.Zakaria</i>	585
Effect of bending stiffness of geotextiles on bearing capacity improvement of soft clay <i>K.Hirao, K.Yasuhara &amp; Y.Tanabashi</i>	591
Behavior of sand replacement with geo-net on reclaimed marine clay <i>H.Imanishi, H.Ochiai, N.Haratake &amp; M.Asakuma</i>	597
Bearing capacity of sand foundation reinforced by geonet <i>J.W.Ju, S.J.Son, J.Y.Kim &amp; I.G.Jung</i>	603
Use of geosynthetics for strengthening road surface and subbase in areas with the mining activity <i>K.Ktosek</i>	609
Laboratory testing of reinforced unpaved roads <i>J.Knapton &amp; R.A.Austin</i>	615
Bearing capacity of inclined loaded footing on geotextile reinforced two-layer soil system <i>V.R.Manjunath &amp; D.M.Dewaikar</i>	619
Shaking table tests on floatation of buried pipes in backfilled sand layer reinforced with geotextiles <i>H.Nagase, T.Yanagihata &amp; H.Matsumoto</i>	623
Numerical study on uplift bearing capacity of caisson type pile with reinforcing bars <i>T.Nakai &amp; M.Ueno</i>	629

Settlement and bearing capacity of footings on reinforced sand <i>M.S.Nataraj, P.G.Hoadley &amp; K.L.McManis</i>	635
A study on the reinforcing effects of geogrids overlaid on pile group for the embankment foundations <i>T.Ohkubo, S.Asada &amp; D.Karube</i>	641
Bearing capacity analysis of reinforced ground <i>S.Ohtsuka, E.Yamada &amp; M.Matsuo</i>	647
Experimental study on localized deformation behavior of reinforced foundation ground <i>J.Otani &amp; K.Yamamoto</i>	653
An application of base sheet in a highway embankment: A case study in Thailand <i>V.Poopath</i>	659
Semi-rigid piled-raft system for soft subsiding ground <i>R.Shivashankar, M.R.Madhav, N.Miura, K.Umezaki &amp; Y.Gondoh</i>	665
Settlement of embankment on reinforced granular fill – Soft soil system <i>S.K.Shukla &amp; S.Chandra</i>	671
A finite element approach to the strength of granular soils reinforced with geosynthetics <i>P.Simonini</i>	675
Tensile force distribution along the reinforcement for reinforced soil foundations <i>T.G.Sitharam, B.R.Srinivasa Murthy &amp; H.B.Raghavendra</i>	681
In-site investigation and numerical estimation for bearing capacity improvement of very soft ground reinforced with geotextiles <i>Y.Tanabashi, K.Hirao, K.Yasuhara &amp; H.Itoh</i>	685
Foundation method combining clay-cement mixture with geogrid <i>K.Tanaka, Y.Kato, K.Kasahara, Y.Kadokawa, K.Arai, H.Machihara, K.Funaya &amp; A.Ohtani</i>	691
Localized deformation analysis of reinforced foundation ground <i>K.Yamamoto &amp; J.Otani</i>	697
Evaluation of the bearing capacity improvement of geogrid mattress foundations <i>N.Yasufuku, H.Ochiai, K.Omine, S.Ohno, K.Kawamata &amp; Y.Tsukamoto</i>	703
Design of reinforced foundations by the slip-line method <i>A.G.Zhao, P.Rimoldi &amp; F.Montanelli</i>	709
<b>5 Slopes and excavations</b>	
Stability analysis of reinforced soil structures introducing some linear constraint conditions upon the 3-D velocity field <i>A.Asaka, G.Pokharel &amp; T.Ochiai</i>	717
An innovative solution to the stabilisation of the Cairnmuir Landslide incorporating reinforced earth <i>D.Askey-Palmer, M.Gillon &amp; M.Boyd</i>	723
Deep seated stability of soil nailing walls <i>S.Bang, B.F.Wilkins &amp; C.K.Shen</i>	729

A design method for the 'reticulated pile structure' for the stabilization of slopes and excavations <i>R.Berardi</i>	735
Instrumentation and monitoring of a nailed mine-waste slope <i>E.C.Drumm, C.R.Tant, M.Mauldon &amp; R.M.Berry</i>	741
Parametric numerical analyses of soil nailing systems <i>M.Ehrlich, M.S.S.Almeida &amp; A.M.Lima</i>	747
Earth reinforcement application for hazardous waste containment <i>S.Ghalib, J.P.Seymour &amp; J.C.Volk</i>	753
Comparison of different design concepts in slope stability analysis of geosynthetic reinforced slopes <i>E.Güler, M.Ismek &amp; Y.Görken</i>	759
Ballistic soil nailing <i>T.S.Ingold &amp; B.Myles</i>	765
The effect of bending stiffness of soil nails on wall deformation <i>M.J.Kenny &amp; Y.Kawai</i>	771
A large-scale experimental study of soil-nailed structures <i>J.S.Kim, S.D.Lee, S.R.Lee &amp; C.L.Park</i>	775
In-situ test of reinforced volcanic ash with steel bars and panel facings <i>R.Kitamura, T.Iryo, K.Joumoto, M.Yoshida &amp; T.Ochiai</i>	781
Stability analysis of reinforced slopes based on apparent cohesion method <i>M.Kulczykowski</i>	785
Predicting seismic performance of geogrid-reinforced slopes <i>D.Y.Lin, S.S.Lin &amp; S.H.Kuo</i>	791
A new concept of seismic design of geosynthetic-reinforced soil structures: Permanent-displacement limit <i>H.I.Ling, D.Leshchinsky &amp; E.B.Perry</i>	797
Failure mechanism and effective reinforcement of granular soil slope <i>H.Matsuoka &amp; Y.Sugiyama</i>	803
Instability patterns of reinforced-soil structures <i>R.L.Michalowski</i>	809
Reaction of reinforcing force and restraint effect on soil nailing <i>K.Nishida &amp; T.Nishigata</i>	815
Seismic analysis of nailed soil slopes – A pseudo-dynamic approach <i>N.Sabahat, M.R.Madhav &amp; P.K.Basudhar</i>	821
Repairing the landslide 'Heroldsberg', Germany <i>F.Viel &amp; A.Jenne</i>	825
Dynamic failure of soil-nailed excavations in centrifuge <i>M.Vucetic, V.E.Iskandar, M.Doroudian &amp; L.Luccioni</i>	829

Stability analysis of slope reinforced by roots network <i>R.Yatabe, N.Yagi, K.Yokota, M.Enoki, S.Kobori &amp; M.Mukaitani</i>	835
Insitu test of steel-nailing reinforcement for cut slope with alternating sandstone and mudstone <i>J.M.Zhou, H.Yokota, M.Sezaki, H.Yakabe &amp; H.Minami</i>	841
Instrumentation for centrifuge modeling of geotextile reinforced slopes <i>T.F.Zimmie &amp; M.B.Mahmud</i>	847
Author index	853