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NEW FRONTIERS IN CHINESE AND JAPANESE GEOTECHNIQUES

Chongqing, China, November 4 - 7, 2007

Yangping Yao
Hirokazu Akagi
Ga Zhang
Editors

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NEW FRONTIERS IN CHINESE AND JAPANESE GEOTECHNIQUES

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FOREWORD

The 3rd Sino-Japan Geotechnical Symposium is held in Chongqing, China, from 4th to 7th November 2007. This volume contains 92 papers contributed by over 200 authors on the new frontiers in Chinese and Japanese geomechanics and geotechnical engineering.

In China, the speeding economic growth demands the development of civil projects. In recent years, considerable experiences of geotechnical engineering have been accumulated and geotechniques developed. In Japan, extensive civil projects have been developed along with many useful experiences and advanced techniques. While in both China and Japan, to meet people's ever-diversifying needs, there is an increased appreciation of innovative theories and creative technologies for further development of geotechnical engineering. Under these perspectives, CISMGE – CCES and JGS organize this joint symposium to provide a forum for researchers, engineers and project managers both from China and Japan to exchange information and share experiences in the field of geotechnical engineering.

We are most grateful to all the authors for their efforts in the preparation of the papers. We also wish to thank all of those who contributed to the success of the symposium and the publication of the proceedings. Special thanks are due to Mr. Naidong Wang, Ms. Wei Hou, Ms. Yuxia Kong , Mr. Enyang Zhu and Mr. Zhiwei Gao for their valuable assistance.

The Chinese Institution of Soil Mechanics and Geotechnical Engineering-The China Civil Engineering Society
and
The Japanese Geotechnical Society

Contents

Part I Keynote Papers

BEHAVIOR OF GROUND IN EXCAVATION PROBLEMS:MODEL TESTS AND NUMERICAL SIMULATIONS
…… T.NAKAI, F. ZHANG, H.M.SHAHIN and M.KIKUMOTO (3)
ADVANCED AND SPEICALIZED LABORATORY FACILITIES FOR SOIL TESTING - THE STATE OF THE ART
…… JIANHUA YIN, MD. KUMRUZZAMAN and WANHUAN ZHOU (21)
FLOCCULATION AND DEHYDRATION CONTROL DURING SOIL WASHING PROCESS USING SOIL PLASTICITY INDEX AND PH
…… HIROKAZU AKAGI and MITSUO MOURI (30)
JAPANESE EXPERIENCES ON SEISMIC STABILITY OF GEOSYNTHETIC-REINFORCED SOIL RETAINING WALLS
…… JUNICHI KOSEKI and JIRO KUWANO (46)

Part II Technical Papers

FULL-SCALE MODEL TEST ON PILE FOUNDATION EARTHQUAKE-RESISTANCE REINFORCEMENT METHOD USING GROUND SOLIDIFICATION BODY
…… Y.ADACHI, K.URANO, T.TAKENOSHITA, N.TANZAWA and M.KAWAMURA (59)
METHOD FOR INVESTIGATING EARTHQUAKE-RESISTANT STRENGTHENING OF DISASTER-PREVENTION BASES UTILIZING HAZARD MAP
…… REIKO AMANO, TAKEYUKI EBI, SHOGO HAYASHI and KIMIRO MEGURO (68)
SEISMIC/POST-SEISMIC RESPONSE OF A NATURAL SOIL IN DELAYED SETTLEMENT
…… AKIRA ASAOKA and TOSHIHIRO NODA (73)
EXPERIMENTAL INVESTIGATION ON OPTIMUM INSTALLATION DEPTH OF PVD UNDER VACUUM CONSOLIDATION
…… J.C. CHAI, N. MIURA and T. NOMURA (87)
ANALYTICAL SOLUTION FOR COMPRESSION ANCHOR UNDER PULL LOAD
…… GUOZHOU CHEN and JINQING JIA (95)
CALCULATION METHOD ON PRECISE GROUTING VOLUME USING IN-SITU DATA
…… J. CHEN, A. MATSUMOTO and M. SUGIMOTO (108)
MULTI-LAYER FUZY DECISION FOR IMPROVEMENT OF FREEWAY UNDERGROUND
…… XIANGYANG CHEN, YUANYOU XIA and HENGZHEN YAN (118)

PROPERTIES OF UNDISTURBED SAMPLES RETRIEVED FROM FAILED SLOPE DUE TO 2004 NIIGATA-KEN CHUETSU EARTHQUAKE
………………………… J.L. DENG, Y. TSUTSUMI, H. KAMEYA, T. SATO and J. KOSEKI (124)
APPLICATION OF 3D VISCOUS-SPRING ARTIFICIAL BOUNDARY ELEMENTS IN DYNAMIC RESPONSE INDUCED BY HIGH-SPEED TRAIN ALONG THE SLAB TRACK
………………………… L. DONG, C. G. ZHAO and D. G. CAI (135)
SEISMIC RESPONSE ANALYSIS ON UPPER RESERVOIR DAM OF YIXING POWER STATION
………………………… DAKUO FENG, WENJUN HOU, GAZHANG and JIANMIN ZHANG (145)
PERFORMANCE-BASED DESIGN AND IN-SITU TESTING FOR SPREAD FOUNDATIONS
………………………… HIROFUMI FUKUSHIMA, SATOSHI NISHIMOTO and KOUICHI TOMISAWA (151)
DEVELOPMENT OF GROUD IMPROVEMENT TECHNIQUE IN CHINA
………………………… XIAONAN GONG and HAIYING SHI (162)
CONSTRUCTION PERFOAMNCE OF EPB SHIELD TUNNELS ON CHANNEL RAIL LINK CONTRACT 220 IN LONDON
………………………… T. HAGIWARA, T. MINAMI, H. YAMAZAKI, Y. ANO, R. J. MAIR, K. SOGA,
………………………… J. WONGSARIOJ and X. BORGHI (170)
ANALYSIS OF CYLINDRICAL CAVITY EXPANSION IN FRICTIONAL COHESIVE SOIL BASED ON NON-BRITTLE SOFTENING MODEL
………………………… DONGXUE HAO, MAOTIAN LUAN and RONG CHEN (181)
MULTI-ANCHORED REINFORCED SOIL WALL METHODUSING CRUCHED SOIL AS A FILL MATERIAL
………………………… HIJIRI HASHIMOTO, SATOSHI NISHIMOTO, ATSUKO SATO and HIROCHIKA HAYASHI (188)
ELASTOPLASTIC CONSTITUTIVE EQUATION OF SHIRASU BASED ON THE EXTENDED SUBLOADING SURFACE MODEL
………………………… MIZUKI HIRA and KENTARO YAMAMOTO (194)
A STUDY ON EVALUATION OF LANDSLIDE RISK INDUCED BY RAINFALL WITH GEOGRAPHICAL INFORMATION SYSTEM
………………………… DAISUKE IRIKADO, ZEN KOUKI and GUANGQI CHEN (207)
FAILURE PATTERNS OF THE GROUND SURROUNDING RIGID PILES IN SAND SUBJECTED TO LATERAL SOIL MOVEMENTS
………………………… JINGCAI JIANG and TAKUO YAMAGAMI (213)
SEVERAL CRUCIAL PROBLEMS IN DETERMINATION PILE LENGTH USING REFLECTION WAVE METHOD
………………………… XUELIANG JIANG, PING CAO, HUI YANG and CHAOQUN LI (223)
CYCLIC SHEAR BEHAVIOR OF SAND UNDER COMPLEX INITIAL CONSOLIDATED CONDITION
………………………… DAN JIN, MAOTIAN LUAN, ZHENDONG ZHANG and QIYI ZHANG (229)
BEHAVIOR OF EXISTING TUNNEL BENEATH BRACED EXCAVATION
………………………… T. KAMADA, K. UENO, S. MORIOKA, Y. OJI, T. HASHIMOTO and T. KONDA (236)
SHAKING TABLE TESTS ON LIQUEFACTION AND ITS NUMERICAL SIMULATION

CONSIDERING EARTHQUAKE DURATION
……………………… KAZUHIRO KANEDA, HIROYUKI YAMAZAKI and KENJI NAGANO (247)
USE OF CPT FOR CONSOLIDATION CONTROL OF LAND RECLAIMED BY DREDGED CLAY
……… MASAAKI KATAGIRI, MASAAKI TERASHI, SHIRO MURAKAWA and TSUKASA YOSHIFUKU (255)
DYNAMIC CENTRIFUGE MODEL TESTS ON SHEET PILE QUAY WALL STABILIZED BY SEA-SIDE GROUND IMPROVEMENT
……………………………………………… M.R.A. KHAN, F. HAYANO and M. KITAZUME (269)
ISOTROPIC HARDENING MODEL FOR SOILS CONSIDERING STRESS-INDUCED ANISOTROPY
………………… M. KIKUMOTO, H. KYOKAWA, T. NAKAI, F. ZHANG and M. HINOKIO (278)
VERIFICATION OF MODIFIED MMX-MODEL USING ONE DIMENSIONAL CONSOLIDATION TEST AND ITS SIMULATION
……………… TAKUYA KUSAKA, KOICHI KADOTA, AKITOSHI MOCHIZUKI, YUJIAN LIU and
……………………………………………………………………………… XIANFENG MA (290)
EFFECTS OF CURING TIME AND STRESS ON MECHANICAL PROPERTIES OF CEMENT-MIXED SAND
…………………………………………………………… JIRO KUWANO and WEE BOON TAY (303)
INCREMENT OF EARTH PRESSURE ACTING ON A BURIED BOX STRUCTURE DUE TO DIFFERENTIAL SETTLEMENTS
…………………………… REIKO KUWANO, TOSHIYUKI HORII and HIDETOSHI KOHASHI (309)
EXPERIMENTAL STUDY ON DRAINED BEHAVIORS OF GRANULAR SOILS UNDER MONOTONIC SHEAR LOADING
……………………………………………… YI LENG, MAOTIAN LUAN and CHENGSHUN XU (315)
STUDY ON THE THREE-DIMENSIONAL CRITICAL STATE FOR GEOMATERIALS
……………………………… HANGZHOU LI, HONGJIAN LIAO, JIAN SHEN and JIAN HAN (329)
EFFECTS OF TIME-HISTORY VERTICAL ACCELERATION ON SEISMIC DESIGN OF HIGH ROCK-FILL DAMS
………………………………… HONGJUN LI, SHICHUN CHI, HONG ZHONG and GAO LIN (334)
NUMERICAL ANALYSIS ON A NEW FOUNDATION SYSTEM WITH COLUMNIFORM SOIL IMPROVEMENT
………… WEI LI, FENG LI, KINJI TAKEUTI, HARUYUKI YAMAMOTO, XIAOMING ZHANG and
……………………………………………………………………………… JIANBIN ZHAO (344)
A UNIFIED VISCOPLASTICITY DAMAGE CONSTITUTIVE MODEL FOR CONCRETE MATERIALS
……………………………………………… C.C. LIU, M. H. FENG, P. GUAN and H.X. LÜ (353)
POST LIQUEFACTION ANALYSIS BASED ON FLUID MECHANICS
…………………………………………………… HANLONG LIU, YUMIN CHEN and AN DENG (359)
3-D FEM-BASED NUMERICAL ANALYSIS ON REINFORCEMENT EFFECT OF BOLT IN ROCK JOINTS
……………………………………… HONGLIANG LIU, MAOTIAN LUAN and QING YANG (368)

STUDY ON STABILITY OF NATURAL SLOPE CUTTING WORK
…… QIANG LIU, JUNJIE YANG, YUANDONG DING, Y. TOYOSAWA, K. ITOH and N. HORII (375)
MODELING THE HYSTERESIS FOR SOIL-WATER CHARACTERISTIC CURVES
…… Y. LIU and C. G. ZHAO (383)
DYNAMIC RESPONSE OF POROUS SEABED-PIPELINE INTERACTION SYSTEMS UNDER WAVE-INDUCED LOADING
…… MAOTIAN LUAN, PENG QU, QING YANG and YING GUO (393)
SEEPAGE FAILURE ANALYSIS WITH EVOLUTION OF AIR BUBBLES BY SPH
…… KENICHI MAEDA and HIROTAKA SAKAI (402)
APPLICATION OF NEW WATER LEAKAGE REPAIR MATERIAL IN URBAN TUNNELS
…… MINORU MAEDA, YUKINORI KOYAMA and TOSHIHIRO ASAKURA (410)
A SIMPLIFIED ANALYTICAL METHOD FOR DEFORMATIONS OF MULTI-PILE FOUNDATIONS
…… HIROSHI MAEHARA and FUSANORI MIURA (419)
MODEL TESTS OF ANCHORED SHEET PILE WALLS ON THE EFFECT OF THE SECOND ANCORAGE WORK
…… YOSHIYUKI MORIKAWA, YOSHIAKI KIKUCHI and SHOJI OKA (428)
A SIMPLE MODELING OF STRUCTURED SOILS
…… T. NAKAI, F. ZHANG, H. KYOKAWA and M. KIKUMOTO (435)
MODELLING INSTABILITY OF SAND
…… H. PAN, M. D. LIU and J. P. CARTER (448)
SETTLEMENT PREDICTION FOR THE HIGH FILL EMBANKMENT VIA SUPPORT VECTOR MACHINE
…… LINYOU PAN and FUXUE SUN (455)
FORECASTING LANDSLIDE USING ELLIPTIC UMBILIC CATASTROPHE MODEL
…… PEI QIANG and JINMING XU (460)
FEM ANALYSIS OF DAM STABILITY AFFECTED BY WATER LEVEL CHANGE AND GEOGRID
…… JUNLING REN , PENG LV, HAI DENG and GUOAN WANG (466)
IMPROVEMENT OF HIGH-MOISTURE SOIL BY REPEATED FREEZING AND THAWING
ATSUKO SATO, TERUYUKI SUZUKI , SATOSHI NISHIMOTO and SATOSHI YAMASHITA … (471)
K_0-CONSOLIDATION BEHAVIORS OF AGED MARINE CLAYS
…… ICHIRO SEKO, LIN WANG, SHUNSAKU NISHE and LIN ZHANG (479)
A STRESS-STRAIN RELATIONSHIP WITH SOIL STRUCTURAL PARAMETER OF COLLAPSE LOESS
…… SHENGJUN SHAO, QINGGAO YU and JIYONG LONG (488)
ANALYSIS OF SETTLEMENT PATTERN DUE TO DOT-TUNNELLING IN SOFT DEPOSIT
…… SHUILONG SHEN, YESHUANG XU, JINHUI ZHANG and TINGPING LI (501)
NUMERICAL SIMULATION ON CONSTRUCTION PROCESS OF SALT-CAVE NATURAL GAS UNDERGROUND STORAGE AND ITS CASING DEFORMATION
…… XINPU SHEN, GUOXIAO SHEN and JIHANG LIU (507)

LIQUEFACTION CHARACTERISTICS OF INDUSTRIAL WASTE FILL MATERIALS
.... HIDEAKI SHIBATA, LIU PEN, MASATOMO TANAK and ISAMU ONO (515)
SEISMIC SETTLEMENT ESTIMATION ON PARTIALLY IMPROVED GROUND USING SHAKING TABLE
.... TOMOYUKI SHIGEOKA, KOUKI ZEN, GUANGQI CHEN and KIYONOBU KASAMA (521)
RELIABILITY ASSESSEMENT AND LIFE PREDICTION OF LANDSLIDE USING BAYESIAN APPROACH
.... QIANGHUI SONG, DONGSHENG LIU and JIE ZHANG (532)
NUMERICAL SIMULATION OF CENTRIFUGAL BEARING CAPACITY TESTS USING A NEW CONSTITUTIVE MODEL
...... SOKKHEANG SRENG, KOJI YAMADA, LIMING LI, AKITOSHI MOCHIZUKI and YUJIAN LIU (539)
ELASTOPLASTIC SIMULATION OF UNDRAIN BEHOVIOUR OF UNSATURATED SOILS
.... DE' AN SUN and LI XIANG (550)
STUDY OF MECHANICAL PROPERTIES OF WASTE GLASS FRAGMENT AS A SAND CUSHION MATERIAL FOR FLAT TYPE BLOCK
.... H. SUZUKI, S. UETA and K. MAKINO (559)
FINITE ELEMENT SIMULATION OF A TRIPLE-FACE SHIELD TUNNELLING
...... HIROKI TAKAHASHI, KAZUHITO KOMIYA, HIROKAZU AKAGI and TAKAAKI NISHIMURA (567)
NUMERICAL STUDY ON CONSOLIDATION OF COMPOSITE GROUND BY THEORY OF HOMOGENIZATION
.... XIAOWU TANG, GUANCHU CHENG and YUNMIN CHEN (575)
DEVELOPMENT OF A DYNAMIC HORIZONTAL LOADING TEST SYSTEM FOR PILES
.... KOICHI TOMISAWA, SEIICHI MIURA, TATSUNORI MATSUMOTO and EIJI KOJIMA (581)
STRAIN RATE DEPENDENCY ON CONSOLIDATION FOR PEATY SOILS IN HOKKAIDO ISLAND
.... A. TSUTSUMI and H. TANAKA (590)
THE STIFFENING EFFECTS OF SOIL IMPROVEMENT COLUMN WITH STEEL
.... SHOICHI TSUTSUMI and TAKESHI OSHITA (596)
A DAMAGE COUPLED VISCO-ELASTIC COMPONENT MODEL FOR BRITTLE ROCKS
.... C. WANG and Y. PENG (602)
A FIELD TESTING TO ATTEST THE STATIC FRICTION CHARACTERISTIC OF NEGATIVE SKIN FRICTION ALONG PILES
.... LANMIN WANG, JUNJIE SUN, ZHIJIAN WU, SHUNHUA XU and RENDONG QIU (609)
VISUALIZING THE EVOLUTION OF STRESS AND DEFORMATION OF THREE-DIMENSIONAL EARTH-ROCKFILL DAMS
.... SHU WANG, YUZHEN YU and XUN SUN (618)
TWO-DIRECTION ENERGY-GATHERING BLASTING TECHNOLOGY AND ITS APPLICATION
.... SHULI WANG and MANCHAO HE (624)
RESEARCH ON THE 3-D DEFORMATION EFFECT OF SURFACE MINE UNDER STEP-BY-STEP EXCAVATION AND ITS APPLICATIN TO MINING ENGINEERING

…………………………… SHUREN WANG, MANCHAO HE, HONGBIN ZHOU and GANG LI (632)
FEM ANALYSIS OF SEEPAGE DURING SUCTION PENETRATION OF BUCKET FOUNDATION
…………………………… KE WU, MAOTIAN LUAN, QINGLAI FAN and ZHIYUN WANG (639)
EXPERIMENTAL STUDY OF INFILTRATION TRENCH FOR HIGHWAY DRAINAGE
…………………………… YONGQIANG XU, TAKESHI OSHITA and SHOICHI TSUTSUMI (646)
BEARING CAPACITY OF REINFORCEMENT SOIL BY BAGS
…………………………… HARUYUKI YAMAMOTO, HAJIME MATSUOKA and SHAOHONG JIN (653)
SEISMIC BEARING CAPACITY OF SPREAD FOUNDATIONS ON SLOPING GROUND USING LIMIT ANALYSIS
…………………………… KENTARO YAMAMOTO, MIZUKI HIRA and NORITAKA ARAMAKI (659)
STUDY ON VARIANCE OF UNDRAINED SHEAR STRENGTH FROM CONE PENETRATION TEST AND LABORATORY TEST
…… NOBUYUKI YAMANE, TAKESHI FUKASAWA, HIROSHI HIRABAYASHI and TAKASHI TSUCHIDA (669)
SHAKING TABLE TEST OF CAISSON TYPE QUAYWALL CONSIDERING DIFFERENT EARTHQUAKE CONTINUATION TIMES
…………………………… HIROYUKI YAMAZAKI, KAZUHIRO KANEDA and KENJI NAGANO (678)
UH MODEL AND UNDRAINED SHEAR STRENGTH FOR OVERCONSOLIDATED CLAYS WITH INITIALLY STRESS-INDUCED ANISOTROPY
…………………………… YANGPING YAO, WEI HOU and ZHIWEI GAO (685)
OVERCONSOLIDATED CLAY MODEL BASED ON REVISED HVORSLEV ENVELOPE
…………………………… YANGPING YAO, ZIQIANG LI, WEI HOU and ZHENG WAN (698)
A UNIFIED APPROACH FOR FINITE ELEMENT MODELING OF STATIC AND DYNAMIC BEHAVIORS OF SCP IMPROVED GROUND
…………… GUANLIN YE, BIN YE, FENG ZHANG, MITSUHARU FUKUDA and JUNICHI NAGAYA (706)
ACOUSTIC RESPONSES ANALYSIS ON ROCK CORE UNLOADING-DISTURBANCE BASED ON WAVELET TRANSFORMATION
…………………… JIN YU, WEIBING ZHAO, XIAOZHAO LI, MINGJIE XU, YUNFEI GUAN (718)
LARGE DISPLACEMENT NUMERICAL ANALYSIS OF DEEP PENETRATION OF SQUARE FOOTINGS INTO TWO-LAYERED SOILS
…………………………… LONG YU, JUN LIU and XIANJING KONG (727)
END-BEARING COMPOSITE PILE FOUNDATION AND ITS DESIGN METHOD
…………………………… JINMIN ZAI, FENG ZHOU, GUOXIONG MEI and XUDONG WANG (739)
LATERAL RESPONSE OF PILE GROUPS DUE TO EXCAVATION INDUCED SOIL MOVEMENTS
…………………………… CHENRONG ZHANG, MAOSONG HUANG and ZAO LI (749)
BEHAVIOR OF LARGE DIAMETER CYLINDERS UNDER LATERAL LOADS
…………………………… JIANHONG ZHANG, HE LV, XIAOJING LIN and XIAOBING LU (759)
IMPROVEMENT ON METHOD OF FOUNDATION SETTLEMENT CALCULATION
…………………………… QINXI ZHANG and SHAOFENG FAN (768)

ULTIMATE BEARING CAPACITY OF TWO-LAYERED SOIL FOUNDATION UNDER HORIZONTAL AND VERTICAL LOADING
………………………………… QIYI ZHANG, MAOTIAN LUAN, QINGHUA WANG and DAN JIN (777)
NUMERICAL ANALYSES OF DYNAMIC RESPONSE OF SEABED-PIPELINE INTERACTION UNDER SEISMIC LOADING
…………………………… XIAOLING ZHANG, MAOTIAN LUAN, YING GUO and PENG QU (785)
FINITE ELEMENT ANALYSIS OF PILE-SOIL STRESS TRANSMISSION LAW OF COMPOSITE FOUNDATION WITH RAMMED SOIL-CEMENT PILE
……………………… ZHENSHUAN ZHANG, CHUNYUAN LIU, YU DENG and SHIFENG FU (793)
ESTABLISHMENT AND APPLIED RESEARCH OF IMPLICIT CONSTITUTIVE MODEL OF GEOTECHNICAL ENGINEERING MATERIAL
……………………………………………………………………………… JIANMING ZHU and YOU LU (799)
ANALYSIS OF VERTICAL BEARING CAPACITY OF SUPER-LONG ROCK-SOCKETED FILLING PILES
………………………………………………… XINJUN ZOU, MINGHUA ZHAO and LING ZHANG (806)

Part I

Keynote Papers

BEHAVIOR OF GROUND IN EXCAVATION PROBLEMS: MODEL TESTS AND NUMERICAL SIMULATIONS

T. NAKAI[i], F. ZHANG[i], H. M. SHAHIN[ii] and M. KIKUMOTO[ii]

ABSTRACT

In order to investigate the fundamental mechanisms of the generation of earth pressure and the ground movement in excavation problems such as tunneling and braced open excavation, 2D model tests and the corresponding elastoplastic finite element analyses were carried out. It is experimentally shown that the earth pressure and the ground movement are very much influenced by excavation patterns and existing building loads. In tunneling problems, the influence of deflection pattern of circular tunnel and the influence of existing building load on the earth pressure and the ground movements are discussed. In the open excavation problems, the influence of deflection process of wall and the influence of existing load are discussed. The numerical simulations using an elastoplastic constitutive model named subloading t_{ij} model, which can describe typical stress- strain behaviors in general stress conditions, describe well the observed earth pressure and ground movements in both excavation problems.

Key Words: Model Test, Numerical Simulation, Braced Open Excavation, Tunnel Excavation, Existing Load, Circular Tunnel

1 INTRODUCTION

In urban area, shallow tunnel excavation and open excavation cause problems to the deformation of surrounding ground and adjacent structure together with the stability of the tunnel, the retaining wall and the ground. At present practice, earth pressure of the tunnel and the retaining wall and their stability are predicted with rigid plasticity theory such as Terzaghi's loosening earth pressure theory and Rankine's earth pressure theory. The surface settlements in tunneling are predicted by elastic finite elements analysis or Gaussian distribution curve fitting, assuming volume loss due to tunneling. In the open excavation problems, the deflection of wall is predicted using beam spring model, and the deformation of the ground is estimated

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by elastic finite element analysis assuming the wall deflection calculated by the above beam spring model. In this research, model tests and corresponding finite element analyses are carried out to investigate the earth pressure and the ground movements for both excavation problems. In the case of tunnel excavation two types of grounds are considered − one is the Greenfield ground where no loads from existing super structures are employed, and the other is the ground with existing building loads. Two − dimensional finite element anlyses are carried out with FEMt_{ij}-2D using the elastoplastic subloading t_{ij} model (Nakai and Hinokio, 2004). This model can describe typical stress deformation and strength characteristics of soils such as the influence of intermediate principal stress, the influence of stress path dependency of plastic flow and the influence of density and/or confining pressure.

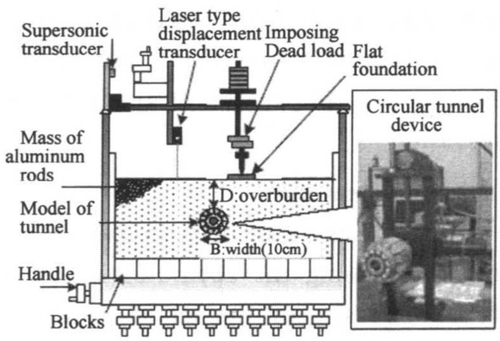
2 DESCRIPTION OF MODEL TEST

2.1 Tunnel excavation

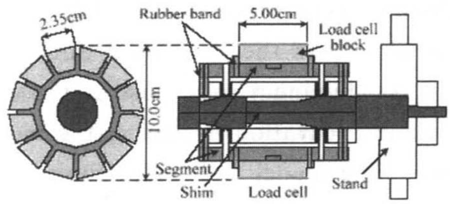
Apparatus of Model Test

Figure 1(a) shows a schematic diameter of 2D tunnel apparatus. Fig. 1 (b) represents a newly developed model tunnel with circular cross section. It consists of a shim at the center of the tunnel surrounded with 12 segments. The segments are strongly tightened all around the shim with rubber band. One motor is attached with the shim to pull it out in the horizontal direction. The model tunnel is kept in space with a vertical shaft, and can be moved in the vertical direction with another motor. Therefore, the device consists of two motors − one is for shrinking the tunnel whiles the other for moving the tunnel in the vertical direction to fix it at a chosen ground depth. It is possible to make these motors work simultaneously and individually together with controlling the speed of the motors. With the motor the shim is pulled out gradually which changes the diameter of the shim, consequently the segments move inward and the diameter of the tunnel is reduced. Changing the shape of the shim different kinds of excavation process, such as full face excavation, top and side drift and bench cut excavation can be reproduced with this apparatus. The reduction of tunnel diameter and the amount of radial shrinkage are obtained from a dial gauge reading which is determined from the calibration result. The vertical movement (if requires to impose) of the tunnel is also measured with another dial gauge. Therefore, the shrinkage of the tunnel can be attained in a controlled manner, which can simulate the condition of a real tunnel construction.

In the apparatus 12 load cells are used to measure earth pressure acting on the tunnel. The load cells are attached with the blocks which are placed surrounding the segments of the tunnel. Each load cell block is 2.35cm in width and 5.0cm in length. The blocks are tightly fastened with rubber band. Therefore, earth pressure can be obtained at 12 points on the



(a) Schematic diagram of 2D tunnel apparatus



(b) Circular tunnel device

Fig. 1

periphery of the tunnel at a time. Earth pressure can also be obtained at any other positions by rotating the tunnel around the tunnel axis. In this case, it would require to make the model ground once again. Including the load cell blocks the total diameter of the model tunnel is 10.0cm. The circular tunnel device is placed on an iron table that was used for the trap door tunnel apparatus (Nakai et al., 1997; Shahin et al., 2004). It has 10 moveable blocks above which the ground is made. The reason of using this type of base is to adjust the initial stress condition of the ground such a way that the stress distribution becomes similar to the ground without tunnel (K_0 stress condition). The surface settlement of the ground is measured using a laser type displacement transducer with an accuracy of 0.01mm and its position in the horizontal direction is incurred with a supersonic wave transducer. Photographs are taken during experiments which are later on used as input data for the simulation of ground movements with Particle Image Velocimetry.

To simulate building loads flat foundation is used. For applying dead loads on the top of the ground a plate of 8cm in width is placed at the surface of the ground adjacent to the model tunnel, and the load is applied at the middle of the plate before performing tunnel excavation. This load is kept fixed throughout the test. A constant value of dead load of $Q = 0.32$ ($\times 9.8$N/cm) is applied on the ground surface, which is around 1/3 to 1/2 of the ultimate bearing capacity of the ground.

Model Ground and Excavation Patterns

Firstly, the tunnel device is set at a height of 10cm; the height is measured from the bottom boundary to the tunnel invert. Varying the distance between the tunnel invert and the bottom boundary, several experiments were conducted. It was found that this height (10cm) is free from the influence of the bottom boundary. After setting the tunnel device, mass of aluminum rods, having diameters of 1.6 and 3.0mm and mixed in a ratio of 3 : 2 in weight, is stacked up to a prescribed depth. The unit weight of the aluminum rod mass is 20.4kN/m^3, and the length is 5.0cm. The initial ground is made in such a way that the earth pressure becomes similar to the earth pressure at rest adjusting the bottom moveable blocks of the apparatus. Great care is taken to make a uniform