PROCEEDING OF
International Symposium and The 2nd AUN/Seed-Net Regional Conference on Geo-Disaster Mitigation in ASEAN
FEBRUARY 25-26, 2010
BALI, INDONESIA

PROTECTING LIFE FROM GEO-DISASTER AND ENVIRONMENTAL HAZARDS

Editor:
Doni Prakasa Eka Putra
Wahyu Wilopo

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The International Symposium and 2nd AUN/Seed-Net Regional Conference on Geo-Disaster Mitigation in ASEAN is done on 25-26 February 2010 at Bali, Indonesia, with a selected theme “Protecting Life From Geo-Disaster and Environmental Hazards”. This event is organized by the Department of Geological Engineering, Faculty of Engineering, Gadjah Mada University in cooperation with the ASEAN Foundation, and AUN/Seed-Net JICA.

The symposium is feature oral and poster presentations, in which conference participants are share their experience on geo-disaster and environmental hazards mitigation including hazard assessment, prediction, reduction of risk and the development of early warning system. In this proceeding, various issues are being analyzed and review, including earthquakes, tsunamis, flooding, typhoons, volcanoes, landslides, disaster mitigation and policies, and groundwater contaminations.

We are indeed most grateful to the conference participants, all of whom promptly send their papers. Without their active collaboration and support, this proceeding simply would not possible. We would also like to express our very special appreciation to all members of organizer committee and organizations, for their support and effort to make this conference successful.

Dr. Doni Prakasa Eka Putra & Dr. Wahyu Wilopo
Editors
## CONTENT

### A. Earthquake

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors/Editors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeling Of Ground Profile In Padang By Using Microtremor Records</td>
<td>J. Kiyono., Y. Ono, M. Kubo, and T Noguchi</td>
<td>1</td>
</tr>
<tr>
<td>Seismotectonics Appraisal of Southeast Asia: Northeast India-Andaman-Sumatra-Java Region</td>
<td>J R Kayal</td>
<td>3</td>
</tr>
<tr>
<td>Time Recurrence Estimation of The 2006 Yogyakarta Blind Faulting For Geohazard Mitigation</td>
<td>Subagyo Pramumijoyo</td>
<td>5</td>
</tr>
<tr>
<td>Seismic Hazard Assessment of School Buildings in Peninsular Malaysia</td>
<td>K. T. Tan and Hashim A. Razak</td>
<td>9</td>
</tr>
<tr>
<td>Seismotectonic And Potensial Earthquake Hazard of Bali Island</td>
<td>A.Soeilami., A. Djujaroma, Sidarto and Robby Setianegara</td>
<td>19</td>
</tr>
<tr>
<td>1-D Dynamic Response Analysis in Southern Yogyakarta Area by Synthetic Waves of 2006</td>
<td>Yogyakarta Earthquake, Tun Naing, Subagyo Pramumijoyo, Hiroshi Kawase, Bambang Suhendra and Heru Hendrayana</td>
<td>27</td>
</tr>
<tr>
<td>Ulfl Geomagnetic Anomaly Possibly Related To 2004-2005 Sumatra Earthquakes</td>
<td>Sarmoko Saroso</td>
<td>35</td>
</tr>
<tr>
<td>Liquefaction investigation due to the 30S’09 Padang Earthquake</td>
<td>Abdul Hakam</td>
<td>43</td>
</tr>
<tr>
<td>Earthquake Risk of Jakarta Non-Engineered Houses: An Initial Assessment</td>
<td>Widjojo A. Prakoso</td>
<td>49</td>
</tr>
<tr>
<td>Application of Microtremor for Estimating Loose Sediment Thickness: Literature Reviews and Examples from Bantul, Yogyakarta</td>
<td>Saladin Husein and Subagyo Pramumijoyo</td>
<td>61</td>
</tr>
</tbody>
</table>
Earthquake Hazard And Risk Assessment Of Padang – Pariaman Destructive Earthquake Of September 30, 2009
Soehaimi, Kamanwan, Marjiyono, Sukahar Eka Adi Saputra, Yayan Sopian
Page 71

Local Site Response on Simulated Strong Earthquake Motion at LaemChabang Port, Thailand
Pulpong Pongvitayapanu and S. Teachavorasinskun
Page 87

Multi-Channel Analysis of Surface Wave (MASW) Technique for Generating Site Classification Map of Chiang Mai City, Thailand
Thanop Thitimakorn, Surichaipanich, and Phantubongraj
Page 95

B. Tsunami, Flooding and Typhoon

Verification of FEMA P646 Tsunami Loading with Experimental Results and Field Load Test
P. Lukkunaprasit and N. Thanasisathit
Page 101

Observed and simulated tsunamis induced by the 2003 Tokachi-oki earthquake (M8.0)
Tatsuoh Ohmachi, Shusaku Inoue, and Tetsuji Imai
Page 109

Analysis of HEC-HMS Hydrological Model for River Flood Risk Modelling
I. Abustan, S. Alaghmand, R. Abdullah, and E. Kordi
Page 115

Amplified risks: inland flooding of a highly urbanized area
G.P. Yumul, Jr., C.B. Dimalanta, , D.V. Faustino-Eslava, and N.T. Servando
Page 121

Assessment on the affect and damage by typhoon Ketsana and Flashed Flood in provinces of Cambodia
Vannada Kij, Boné Phat, and Chhorda Pen
Page 125

Estimation of Seismically-induced Potential Tsunami Penetration onto Coastal Terrains
EC Cruz
Page 131

Quantitative Analysis of Watersheds Shape of Cidurian and Cisaranten and The Implications for Disaster Risk of Flash Flood in Eastern Part of North Bandung
Mohamad Galuh Sagara, Edola Riono, R. Adityo, and Brahmanyo
Page 139

Impact of Typhoon Ketsana in southern part of Laos
Banthasith Vonphathone, and Vithaya Phonekeo
Page 145

Myanmar’s Vulnerability to Natural Hazard and Climate Change
Khin Kay Khaing
Page 151
C. Landslide

Monitoring and Early Warning of Slope Instabilities and Deformations by Sensor Fusion in Self-Organized Wireless ad-hoc Sensor Networks
R. Azzam, C. Arnhardt, and T. M. Fernández-Steeger
Page 157

Promoting a Model of Research-Based Education in Disaster Mitigation
Page 165

Numerical Simulation of Instrumented Experiments on Steady-state Seepage-Induced Landslides
Mark Alberi H. Zarco
Page 173

The mechanism of initiation and motion of the rapid and long runout landslides triggered by the 2008 Wenchuan earthquake
Fawu Wang, P. Sun, Q. G. Cheng, and H. Fukuako
Page 181

Real-time Monitoring and Early Warning of Landslides at Relocated Wushan Town, the Three Gorge Reservoir, China
Yueping Yin, Hongde Wang, Youlong Gao, Xiaochun Li
Page 189

Development of a Non-Expert Tool for Site-Specific Evaluation of Landslide Susceptibility
Daniel C. Peckley, Jr. E. T. Baglung and M. A. H. Zarco
Page 203

A Geotechnical-Hydrological Approach For Defining Critical Rainfall-Induced Shallow Landslides And Warning System At Large Scale
Arip, Takara, Yamashiki, Ibrahim, and Sassa
Page 209

Controls of Geological Structures on Cikangkareng Rockslide
Ign. Sudarno and Salahuddin Husein
Page 219

Development of landslide early warning system by online GPS in Central Java, Indonesia
Trias Adiya, Suharyanto, D. Kurniawati, and T. Faisal Fathani
Page 225

Analysis of Slope Stability in Banyumas Subdistrict with Culman Method
Indra Permanajati and Gentur Waluyo
Page 235

Development of an Early Warning System for Landslides Using Physical Models and Sensors
Catane, Zarco, Cordero, Kaimo, and Saturay Jr
Page 243

Application Of Probabilistic Model And GIS On Landslide Susceptibility Assessment In Kayangan Catchment, Java, Indonesia
Danang Sri Hadmoko, Franck Lavigne, and Junun Sartohadi
Page 251
Prediction Of Ground Movement Due To Block Caving Under Complex Surface Topographic And Irregular Mining Geometry Using GIS
Agung Setianto
Page 259

Application of Geographic Information System (GIS) for Mapping Landslide Susceptibility: A Case Study at Timor Tengah Selatan, NTT Province
Herry Zadraich Kotta, Kalvin Rantelobo and Salahuddin Husein
Page 267

Mineralogical Control On Landslide In Strongly Weathered Volcanic Terrain Case Study Padang Pariaman, West Sumatera
I.W. Warmad, W. Wilopo, and A. Harijoko
Page 275

Stability Assessment of Excavated Rock Slope at Jeruklegi Claystone Quarry, Cilacap Regency, Central Java Province, Indonesia
A. Dok, B. Phat, S. Pramumijoyo and T. F. Fathani
Page 281

Geological Analysis And Slope Stability For Landslides Mitigation At Guyon Village, Tengklik Subdistrict, Tawangmangu District, Karanganyar Regency, Central Java Province, Indonesia
Najib and Dwikorita Karnawati
Page 289

Layer Thickness Analysis of Land Zoning Based Avalanche Area and Resistivity Data Interpretation in Majakasingi District Giri Tengah Magelang Regency, Province of Central Java
A. Aziz Permana, Alfiady, Ismail Zulmi, Rio Kesumajaya, and Djoko Wintolo
Page 291

Recognition and measurement of some heavy metals in the sediment samples from Caspian Sea (Behshahr, Sari, Babolsar and Nosahar cities)
C.Mohammadi zadeh and H.Shalikar
Page 297

Effects Of Tunnel Excavation On Adjacent Buildings In Ho Chi Minh Urban Area
T.H. Tin, D. Karnawati, and T.F. Fathani
Page 305

The Effect Of Compressibility To Design Deep Foundation Of Behavior Earthfill In Jakarta
S. Rahman, H Pindratno, A. Assegaf, and Hindartan
Page 313

Mass Movement Hazardous Mapping in Piyungan District, Gunung Kidul Regency, Jogjakarta Special Province
Page 319

D. Groundwater Contamination and Other Issues

Properties of Alkaline Groundwater Seepage from a Tunnel and Its Neutralization by Dissolution of Atmospheric Carbon Dioxide
Toshifumi Igarashi, Takuya Aoki and Yoshitomo Iio
Page 327
Natural Analogue Studies for Long-term Safety Assessment of Radioactive Waste Disposal - Lessons learnt from Natural Processes and Role of Geologists, Geochemists, Geoengineers
M. Tsuiono Sato
Page 335

Assessment of Urban Groundwater Contamination Case Study: Yogyakarta Urban Area-Indonesia
Heru Hendrayana and Doni Prakasa Eka Putra
Page 337

The Evaluating Ability Of Rainwater Absorption Of Aquifers In Ho Chi Minh City When Artificial Recharge Is Applied
Nguyen Viet Ky and Ngo Duc Chan
Page 351

Arsenic Mobility From Hydrothermally Altered Rock In Laboratory Column Experiments Without Atmospheric Oxygen And Carbon Dioxide
C.B. Tabelin and T. Igarashi
Page 361

Using Mt3dms Model (A Package In Software Gms 3.1) For Solving Substance Dispersion Problem - A Case Study In Con Son Island
Dong Uyen Thanh and Ngo Duc Chan
Page 369

REE And Level Of NORM Radioactivity Hazardous Associated With Tin Tailing (Amang) Processing In Kinta Valley, Malaysia
Kamar Shah Ariffin
Page 375

Geoelectrical Resistivity, Hydrogeochemical and Soil Properties Analysis Methods for Groundwater Investigation in the Agriculture Area: A Case Study from Machang - Malaysia
Nur Islami, Samsudin Hj Taib, and Ismail Yusoff
Page 383

A Kinetic Study on the Adsorption of Heavy Metal on a Natural Clayey Soil
Wawan Budiania
Page 395

Saprolith Genesis As A Control For Surface Runoff In Jirak River Basin, Gunung Kidul, Yogyakarta
Srijono
Page 401

Estimating The Dispersion And Retardation Factors Of Lead, Chromium And Iron In Coco-Peat Using A Non-Equilibrium Sorption Model
Maria Antonia Tanchuling, Augustus Resurreccion, and Dennis Ong
Page 411

Environmental Impacts on Batu Hijau Porphyry Copper-Gold Deposit, Sumbawa Island, Indonesia
May Thwe Aye, A. Imai, N. Araki, S. Pramunijojo, A. Idrus, L D Setijadji And Johan Arif
Page 413

Assessment Of Groundwater Contamination Hazard: An Important Link Between Environmental Scientist And The Decision Makers
Doni Prakasa Eka Putra
Page 417
Hydrogeochemistry of Arsenic and Manganese in Groundwater at Batu Hijau, Sumbawa, Indonesia
Wahyu Wilopo
Page 425

Hydrogeological Factors Control On Groundwater Contaminant Movement From Landfill Leachate
Keophousone phonhalath, D. Karmawati, H. Hendrayana, DPE Putra, and Kenji Jinno
Page 431

Water Infiltration through Capillary Barrier Models
I Gde Budi Indrawan and Harianto Rahardjo
Page 439

Need to Conserve The Miocene Limestone in Bayat Area Central Jawa, Indonesia
S. S. Surjono and M. Datun
Page 447

Evaluation of the Efficiency of a Subsurface Constructed Wetland using HYDRUS-2D: A Numerical
Simulation of Water, Heat and Multiple Solutes in a Variably Saturated Media
Resurreccion, Martin, Mauricio, and Tanchuling
Page 455

E. Disaster Mitigation and Policy

LUSI Mitigation Implications of BPLS and Other Subsidence Measurements
Van S. Williams and Handoko T. Wibowo
Page 461

Beyond S&T in Disaster Preparedness: Other Dimensions of Disaster Reduction from Recent Philippine Experience
Eddie L. Listanco and Trina G. Listanco
Page 467

A Proposal of New Method of Groundwater Investigation for Mountainous Geo-hazard Mitigation
Atsuo Takeuchi
Page 473

The Geo-Disaster Mitigation Measures in Myanmar
Kyaw Huu
Page 481

Multi-Hazard, Multi-Sector, Multi-Discipline Approach to Disaster Risk Management: Examples in the Philippines
Benito M. Pacheco
Page 491

Disaster: Emergency, Preparedness And Planning
Poonam Bhatnagar
Page 499

Disaster Preparedness During Benign Periods: The 2009 Cold Front In Southern Philippines
Carla B. Dimalanta, Decibel V. Faustino-Eslava, Graciano P. Yumul Jr, Nathaniel T. Servando, Leo T. Armada and Ryan Viado
Page 503
Redefining geohazardous zones in the light of changing climatic conditions
Decibel V. Faustino-Eslava, Carla B. Dimalanta and Graciano P. Yumul, Jr.
Page 507

The Geology of CO2 Storage in Indonesia: An Outlook
Hendra Amijaya and Ferian Anggara
Page 511

Application And Some Limitation Of Microgravity Survey In Site Investigation-A Case Study
Samsudin bin Hj Taib
Page 515

Geogenensis of Wonosari and Baturetno Basin in Southern Mountains of East Java
Salahuddin Husein and Srijono
Page 521

F. Vulcanology

Caldera Activities in North Bali, Indonesia
Koichiro Watanabe, Takuji Yamanaka, Agung Harijoko, Satria, and I Wayan Warmada
Page 529

A Preliminary Result Of Continuous Seismic And Deformation Monitoring At Lokon Volcano, North Sulawesi-Indonesia
Hendra Gunawan
Page 537

Preliminary Paleoseismological Analysis of Lembang Fault, West Java
Dwi Sulistyoningrum, Subagyro Pramumijoyo, and Eko Yulianto
Page 549

Mapping Of Characteristic Deformation Of Batur Volcano By Geodetics Monitoring Methods
Ony K Suganda, Hasanuddin Z. Abidin, A. Kusman, and Teguh P. Sidiq
Page 557

Potential Hazards Of Volcanic Material From The Eruption Of Merapi Volcano
Agung Harijoko, Tri Wulaningsih, F Anggara and Koichiro Watanabe
Page 559
Effects Of Tunnel Excavation On Adjacent Buildings In Ho Chi Minh Urban Area

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ABSTRACT
Prediction on damage to existing buildings due to tunnel excavation is necessary for any tunnelling projects especially in urban area of Ho Chi Minh City where the Ben Thanh–Ba Son Railway Twin-Tunnel alignment underlay difficult subsoil condition of clayey sand, medium dense and presence of groundwater. The 3-storey building located close to the alignment has been focused in this paper.

Both of empirical method and finite element method (FEM) were used in this study. The empirical method so called “Greenfield” that was used for preliminary assessment. In detail evaluation, the Finite element method was applied. In the first simulation, the building was modelled with its equivalent piers; in the second case, the building was modelled with its real piles. According to analysis results, the building was predicted based on the Rankin damage classification (1988).

Analyses of tunnel excavation were carried out with various volume losses of 1.0% to 4.0%. Greenfield pointed out that the settlements were increased significant after each phase of excavation whereas analyses from Finite Element method showed the building settlement was slightly increased. Effects of excavation of Tube 1 on the building are less dangerous than from Tube 2 that were predicted in three approaches. Most analyses from the numerical model in both of two the simulations predicted similar damage categories and less than from the Greenfield. Finally, the building was predicted approximate damage category 3 due to tunnel excavation with occurrence of the volume loss of 3.0%.

Keywords: tunnelling, volume loss, greenfield, FEM, damage.

INTRODUCTION
The Ben Thanh–Ba Son Twin-Tunnel Alignment is a stretch of the Ben Thanh–Suoi Tien Railway project (Route No.1 in Figure 1). It is partially going to be excavated underground by Slurry Shield Machines. The tunnel layout in longitudinal section (Figure 2) and in transverse section (Figure 3) showed the twin-tunnel alignment consists of two tubes, down Tube (Tube 1) and up Tube (Tube 2). The depth of Tube 1 and Tube 2 axes are at 25.0 m and 13.0m below the ground surface, respectively. The ground surface elevation is at 2.0m above the sea level. The tunnel mostly underlay the medium dense Clayey sand of Pleistocene formation. Aim to avoid effects of the down Tube on the up Tube so that the tunnel excavation process is assumed that the Tube 1 will be carried out before the Tube 2.

METHODS OF STUDY
Predicting tunnel induced deformation of such buildings and assessing the damage is an essential part of planning, design and construction of tunnels in an urban environment (Mair et al., 1996). The main factor influences to results of tunnelling prediction that is the volume loss. It is the key in both empirical and numerical analyses. In these analyses, the volume loss (VL) was applied various values in the range 1% to 4%. In this study, the predictions were mainly divided into two stages of preliminary assessment and detail evaluation (Figure 5).

PRELIMINARY ASSESSMENT
In this stage, the Greenfield method is applied for the preliminary analysis. Assuming that building’s structures are completely flexible or without stiffness, and undergo the same deformation as the ground. Surface settlement due to tunnelling is a 3D problem (Fig. 4). In the case of a single tube and a homogeneous medium, the generalized expression is described as:

$$S_x = \frac{y_1}{\pi^2} e^{-y_1^2} \left[ \sqrt{\frac{i}{\pi}} - \sqrt{\frac{i}{\pi}} \right]$$

Where:
- $S_x$: Surface vertical settlement at an $(x, y)$ location (m); $x$: Distance of the considered point from the tunnel axis (m); $y$: Longitudinal position of the considered surface point (m); $y_1$: Volume of the settlement trough per meter of tunnel advance (m$^2$/m); $y_0$: Initial position or starting section of the tunnel (m); $y_1$: Position of the tunnel face (m); $i$: Trough width parameter, expressed as: $i = k(z_0 - z)$, where “$k$” is a dimensionless constant, depending on soil type, and “$z_0$” is the depth of the tunnel axis below surface. For clay soils $i \approx$
Figure 1. Ben Thanh-Ba Son railway tunnel Alignment No.1 (Tedisouth, 2007)

(0.4±0.6)(z_0 – z); non-cohesive soils is i ≈ (0.25±0.45).(z_0 – z).

Figure 2. Geoengineering profile along the Ben Thanh – Ba Son tunnelling alignment (Modified after Tedisouth, 2007)
G can be calculated for different values of \((y - y_0)/i\) and listed in standard probability tables such as given by Attewell & Woodman (1982) or in most statistics text books.

This 3D problem can be interested in evaluating 2D analysis of the transverse settlement trough in a certain section. If the position 'y' of the considered cross-section has the following characteristics: \((y - y_0)/i > 3\) and \((y - y_0)/i < -3\), then \(G((y - y_0)/i) = 1\) and \(G((y - y_0)/i) = 0\) (i.e., the cross-section is well behind the tunnel face, then the generalized expression (1) becomes as follows:

\[
S_v(x) = S_{v,max} \cdot e^{-\frac{y^2}{2\sigma^2}}
\]

\[
S_{v,max} = \frac{V_t}{2\sigma^2}
\]

\(S_{v,max}\) is the maximum vertical displacement at the transverse distance \((x=0)\); \(V_t\) is the volume loss.

Evaluating the settlement of the greenfield, Rankin (1988) provided guidelines of how the maximum settlement \((S_{max})\) and the maximum slope \((\theta_{max})\) of a potential building damage (Table 1). Once the maximum slope of more than
DETAIL EVALUATION

In this section, the finite element method is mainly applied for analysis of the interaction between soil and structures. In case of complex building foundation, including large amount of piles under the pile cap these piles can be simulated by an equivalent pier (Poulos & Davis, 1980). The Diameter and Young’s Modulus of the equivalent pier are calculated as:

\[ D_{eq} = 2 \left( \frac{E_p}{\pi} \right)^{1/2} \]
\[ E_{eq} = E_s + (E_p - E_s) \frac{A_p}{A_s} \]

Where

- \( A_p \): The plan area of the pile group as a block;
- \( E_s \): The Young’s Modulus of the piles;
- \( E_s \): The average Young’s Modulus of the soil;
- \( A_s \): The total cross-sectional area of the piles in the pile group.

The maximum slope (\( \theta_{max} \)) and maximum settlement (\( S_{c,max} \)) are the control parameters for evaluating the building damage. If the damage risk remains high the building has to be considered whether protective methods are necessary. In this study, the settlement control will only be required for the damaged buildings which were after detail evaluation remain in damage category more than 3 (Rankin damage classification, 1988).

RESULTS AND PREDICTION

Greenfield analysis of the building was based on assuming the building’s structures are completely flexible or without stiffness, same deformation as
Table 1: Damage Classification established by Rankin (1988)

<table>
<thead>
<tr>
<th>Damage Category</th>
<th>Severity Degree</th>
<th>Description of typical damage</th>
<th>Control Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(g_{max})</td>
</tr>
<tr>
<td>1. Aesthetic</td>
<td>Negligible</td>
<td>Superficial damage unlikely</td>
<td>&lt;1/500</td>
</tr>
<tr>
<td>2. Aesthetic</td>
<td>Slight</td>
<td>Possible superficial damage which is unlikely to have structural significance</td>
<td>1/500–1/200</td>
</tr>
<tr>
<td>3. Functional</td>
<td>Moderate</td>
<td>Expected superficial damage to buildings and expected damage to rigid pipelines</td>
<td>1/200–1/50</td>
</tr>
<tr>
<td>4. Serviceability and structural</td>
<td>High</td>
<td>Expected structural damage to buildings and to rigid pipelines; possible damage to other pipelines</td>
<td>&gt;1/50</td>
</tr>
</tbody>
</table>

the ground. The settlements of the building due to tunnel excavation were shown in Figures 6-13.

Finite element analysis of the building with its equivalent pier (FEM-equivalent pier) was modeled in the 2D simulation of tunnel excavation that the structure’s stiffness and the weight, as well as the surface loads were cooperated. The interaction between tunnel – soil – pier – building was performed in the same model. The settlements of the building due to tunnel excavation including its initial settlement were presented in the following Figures 6-13.

Finite element analysis of the building with its real piles (FEM-real piles) was modelled in the 2D simulation of tunnel excavation that factors were similarly considered to the previous approach of FEM-equivalent pier. However, in this approach, not only performance of interaction between tunnel – soil – pile – building but also interaction between pile and pile under each the pile cap were simulated in the same model. Therefore, the building settlement was predicted according to this approach is more reality. These results were compared with Greenfield and FEM-equivalent pier approach in Figures 6-13.

![Figure 6: Comparison of building settlements due to excavation of Tube 1 with VL =1.0% between Greenfield and FEM](image-url)
Figure 7: Comparison of building settlements after excavation of Tube 2 with VL = 1.0% between Greenfield and FEM

Figure 8: Comparison of building settlements due to excavation of Tube 1 with VL = 2.0% between Greenfield and FEM

Figure 9: Comparison of building settlements due to after excavation of Tube 2 with VL = 2.0% between Greenfield and FEM

Figure 10: Comparison of building settlements due to excavation of Tube 1 with VL = 3.0% between Greenfield and FEM

Figure 11: Comparison of building settlements due to after excavation of Tube 2 with VL = 3.0% between Greenfield and FEM

Figure 12: Comparison of building settlements due to excavation of Tube 1 with VL = 4.0% between Greenfield and FEM
Figure 13: Comparison of building settlements due to after excavation of Tube 2 with VL =4.0% between Greenfield and FEM

DISCUSSION
The building was damaged at category of 2 due to after completed Tube 2. Although this category is not required protecting the building however the control parameters came near to the category of 3. Moreover, these results are similar to the evaluation in the numerical modelling of the building with equivalent piers. In addition, Greenfield predicted that the building was approximately damaged category of 4. In this case, the building was susceptible significant and dangerous therefore requires controlling the volume loss of less than 3% and monitoring at the first and second columns from the tunnel axis.

CONCLUSION
Predictions from Greenfield on the building in this study were mostly larger damaged category than from analyses of the Finite element method due to tunnel excavation.

The 2D numerical modeling can be used for simulating the problem of tunnel excavation with cooperation of the buildings and its foundations (real piles and equivalent pier). Evaluations of the building with its equivalent piers were similarly results to the building with its real piles.

Settlement of the building due to excavation of Tube 2 was deeper and narrower than due to Tube 1 in all of three approaches.

The three-storey building located close to the Ben Thanh - Ba Son Railway Twin-Tunnel was damaged at category of 3 due to tunnel excavation with the volume loss of 4.0%. It was approximately category 3 due to tunnel excavation with the volume loss of 3.0%.

RECOMMENDATION
After carrying out the Tube 1 the building and the ground were settled and deformed. Most the initial conditions were changed therefore re-investigation is necessary before continue to excavate the Tube 2.

This prediction should be verified with the Plaxis 3D tunnel. It can give the full analysis of not only in transverse settlement but also in longitudinal settlement when driving the tunnel and the need of additional support to be installed ahead of the excavation which the 2D analyses were not capable of predicting the need of the pre-support.

The three-storey building was predicted at category 3 due to tunnel excavation. Therefore, requires controlling the volume loss of less than 3% and monitoring of the building at positions of the first column and second column from the tunnel axis.

Protective methods for the building structure are also necessary. The following typical methods for settlement control were introduced such as:

✓ Improvement of ground characteristics is used for reinforcement of the ground due to tunnel excavation.

✓ Structural stiffness improvement of buildings: One way of reducing the sensitivity of existing buildings prior to tunnel excavation.

✓ Increasing the rate of tunnel advance can be selected for improvement of volume loss.

REFERENCES


