SIBE2013

The Second International Conference on Sustainable Infrastructure and Built Environment

Faculty of Civil and Environmental Engineering
Institut Teknologi Bandung

PROCEEDING BOOK

VOLUME I

"Accelerating Sustainable Infrastructure Developement - Challenges, Opportunities, and Policy Direction"

In Collaboration with:

Sponsored by :

IPC
Energizing Trade, Energizing Indonesia.

BUKIT BAYUIGA
HARMONI KEHIDUPAN

PROCEEDING

Volume I

Topic 1 Structure and Material
Topic 7. Geotechnical Engineering

SIBE2013

The Second International Conference on Sustainable Infrastructure and Built Environment

Accelerating Sustainable Infrastructure Development – Challenges, Opportunities, and Policy Direction

BANDUNG – INDONESIA
NOVEMBER 19TH – 20TH, 2013

International Conference and Exhibition

Published by
Faculty of Civil and Environmental Engineering
InstitutTeknologi Bandung – Indonesia

PREFACE

Infrastructure provides the basic needs of human beings, and sustainable infrastructure systems are essential for the survival, health, and well-being of a society. The civil, environmental, and ocean engineers are at the epicenter in seeking the means to enhance human life through modernization of infrastructure as evidenced by provision of shelter, water, and transport, amongst others.

The current fast rate of urbanization and industrialization has caused a rise in environmental issues, involving environmental mismanagement, which has been associated with unforeseen global catastrophes. The problems are further aggravated by the impacts of environmental degradation such as soil erosion, hurricanes, sea-level rise, depletion of water resources, etc. These issues have become the current focus of attention and studies of the world's academicians and professionals in infrastructure development. Relevant researches include not only hard infrastructure but also soft infrastructure aspects such as regulation, institution, and policy development framework.

To support economic activities and to offer a better quality of life, developing countries need to accelerate sustainable infrastructure provision. In many developing countries, including Indonesia, lack of infrastructure has been the main obstacle of investment and development activities. Besides limited available fund, the acceleration of sustainable infrastructure development still has to face the challenges of, among others, knowledge, human resources management, best practices, and capacity development. On the other hand, developing countries generally possesses abundant local natural resources, sufficient carrying capacity, and local wisdom.

In order to meet these multifaceted challenges, not only proper planning, design, implementation and verification exercises, but also clear policy and strategy direction of sustainable infrastructure development are required, via an integrated, multidisciplinary and holistic approach.

The global momentum for sustainable development must now lead to practical applications of the engineering and science of sustainability – an optimization – which allows an accelerated infrastructure provision with maximum attention on sustainability aspects.

The conference will provide an opportunity for professionals and researchers to learn, share and exchange the latest development and research in civil engineering and environmental engineering. The scope of the conference will be broad, covering all aspects of civil and environmental engineering practices.

Participants of the conference include researches, academic staffs, students, industries, public and local governments. The keynote presentations during the conference are as follows:

Keynote speakers:

- **Ir. Djoko Kirmanto**
  Minister of Public Works, Indonesia
- **Prof. Tamon Ueda**
  Head of International Committee of Faculty of Engineering, Hokkaido University, Japan
- **Dr. Ir. Bambang Susantono, MSCE., MCP**
  Vice Minister of Communication, Indonesia
- **Prof. Shyh-Jian Hwang**
  National Taiwan University, Taiwan
- **Prof. Ir. Suprihanto Notodarmojo, Ph.D.**
  Dean of the Faculty of Civil and Environment Engineering, InstitutTeknologi Bandung, Indonesia
- **Dr. Ir. Achmad Hermanto Dardak, MSc.**
  Vice Minister of Public Works, Indonesia
- **Dr. Ir. Dedy Supriadi Priatna, M.Sc.**
  Deputy Infrastructure of BAPPENAS
- **Dr. Ir. Lucky Eko Wuryanto, M.Sc.**
  Deputy Infrastructure of Coordinator Ministry for Economic Affair

The objectives of the conference are:

1. To provide a platform for exchange of ideas and information among academics, researchers, consultants, engineers, manufacturers and post graduate scholars in civil and environmental engineering
2. To discuss and evaluate the latest approaches, innovative technologies, policies and new directions in infrastructure development, pollution prevention and eco-friendly technologies adapted to developing countries
3. To promote cooperation and networking amongst practitioners and researchers involved in addressing infrastructure and built environment issues

The oral presentations are subdivided into 8 major sctions as following:

1. Structure and materials
2. Transportation system and engineering
3. Water resources engineering and management
4. Water & waste engineering and management
5. Ocean engineering
6. Construction management
7. Geotechnical engineering
8. Environmental protection and management

There are 131 contributors in oral presentation.

Finally, the organizing committee wishes that the conference is able to provide beneficial scientific information to the participants and other concerned readers

Bandung, November 2013

Organizing Committee

LIST OF COMMITTEE

STEERING COMMITTEE

Chair : Prof. Dr. SuprihantoNotodarmodjo (ITB)

Co-Chair : Dr. Puti Farida Marzuki (ITB)

1. Prof. Liang-JenqLeu (NTU, Taiwan)
2. Prof. Naoshi Baba (Hokkaido University, Japan)
3. Prof. Iswandi Imran (ITB)
4. Prof. Syahril B. Kusuma (ITB)
5. Prof. Bambang Sugeng (ITB)
6. Prof. Prayatni Soewondo(ITB)
7. Prof. Arwin Sabar (ITB)
8. Dr. I Wayan Sengara (ITB)
9. Dr. Tri Padmi Damanhuri (ITB)
10. Dr. Muslim Muin (ITB)
11. Prof. Ade Sjafruddin (ITB)
12. Dr. Krisnaldi Idris (ITB)

SCIENTIFIC COMMITTEE

Chair: Prof. EnriDamanhuri (ITB)

Co-Chair: Dr. Krishna S. Pribadi (ITB)

1. Prof. Shyh-Jiann Hwang (NTU, Taiwan)
2. Prof. NaoyukiFunamizu (Hokkaido University, Japan)
3. Prof. TomoyaShibayama (Waseda University, Japan)
4. Prof. Carl Larsen (NTNU, Norway)
5. Prof. Tsunemi Watanabe (Kochi University of Technology, Japan)
6. Prof. Wisjnuprapto (ITB)
7. Prof. Ofyar Z. Tamin (ITB)
8. Prof. Masyhur Irsyam (ITB)
9. Prof. Amrinsyah Nasution (ITB)
10. Prof. Adang Surahman (ITB)
11. Prof. Indratmo Soekarno (ITB)
12. Prof. Ricky Lukman Tawekal (ITB)
13. Dr. Edwan Kardena (ITB)
14. Dr. Saptahari Soegiri (ITB)
15. Dr. Biemo W. Soemardi (ITB)
16. Dr. R. Driejana (ITB)
17. Dr. Iwan Kridasantausa Hadihardaja (ITB)
18. Dr. Mindriany Syafila (ITB)
19. Ir. IdrisMaxdoniKamil, M.Sc., Ph.D.

ORGANIZING COMMITTEE

Chair	: Prof. Dr. Ir. Rizal Z. Tamin
Co-Chair	: Ir. MuhamadAbduh, MT., Ph.D.
Treasurer	: Dr. Ir. Dwina Roosmini
	Dr. Muchammad Chaerul, ST., MT.
	Endra Susila, ST., MT., Ph.D.
General Secretary	: Dr. Nita Yuanita, ST., MT.

		Dr. Benno Rahadyan, ST., MT.
		Rofiq Iqbal, ST., M.Eng., Ph.D.
Publication	:	Ir. Iwan Kridasantausa, M.Sc., Ph.D.,
		Dr. Russ Bona Frazila, ST., MT.
		Dr. Ing. Marisa Handayani, ST., MT.
Exhibition	:	Dhemi Harlan, ST., MT., Ph.D.
		Dr. Paramashanti, ST., MT.
		Ir. R. Driejana, Ph.D.
Sponsorship	:	Ir. Agus Jatnika Effendi, Ph.D.
		Ir. Erza Rismantojo, Ph.D.
		Emenda Sembiring, ST., MT.
Program	:	Dyah Kusumastuti, ST., MT., Ph.D.
		Ir. Yuniati Z. Azzaino, MT., M.Sc., Ph.D.
		Joko Nugroho, ST., MT., Ph.D.
Parallel Session	:	Prof. Dr. Herlien Dwiarti Soemari
		Dr. Kania Dewi, ST., MT.
		Dr. I Made Wahyu Widyarsana, ST., MT.
Social Event	:	Ir. Ima Fatima, M.Eng,
		Dr. Ir. Katharina Oginawati, MS.
		Prof. Dr. Ing. PrayatniSoewondo, MS.
Logistic	:	Dr. Ir. Saptahari M. SoegiriPoetra
		Dr. Sukandar, ST., MT.
		Ir. Rildova, MT., Ph.D.
Proceeding	:	Ir. Indah Rachmatiah S. S., M.Sc., PhD.
		Dr. Irsan Soemantri Brodjonegoro, M.Sc., Ph.D.
		Ivindra Pane, ST., M.SE., Ph.D.
Catering Division	:	Aine Kusumawati, ST., MT., Ph.D.
		Ir. Titi Liliani Soedirdjo, M.Sc.
		Dra.Barti Setiani Muntalif, Ph.D.
Transportation	:	Dr. Ir. Sony SulaksonoWibowo, MT.
		Dr. Ing. Ediansjah, ST., MT.
		HasbullahNawir, St., MT., Ph.D.
Acomodation	:	Dr. Harmein Rahman, ST., MT.
		Suharyanto, ST., M.Sc.
		Hadi Kardhana, ST., MT., Ph.D.

Contents

PREFACE ii

LIST OF COMMITTEE iv

KEYNOTE SPEAKER

Seismic Evaluation and Retrofitting Project of RC School Buildings in Taiwan
Shyh-Jiann HWANG, Lap-Loi CHUNG, Wen-Yu CHIEN, Fu-Pei HSIAO, Hung-Ming CHEN, Wen-Cheng SHEN, Yeong-Kae YEH, &Ching-Pao CHUANG 1

General Strengthening Design Approach for Sustainable Structures
UEDA Tamon& ZHANG Dawe 17

TOPIC 1.STRUCTURE AND MATERIALS

Cyclic Loading Tests for Deep Reinforced Concrete Coupling Beams
Erwin LIM, Ting-Wei WANG&Shyh-Jiann HWANG 41

A Sample Calculation on Seismic Risk of Nuclear Power Plants
Yin-Nan HUANG& Ying-Hsiu SHEN 56

Seismic Evaluation and Retrofitting Project of RC School Buildings in Taiwan
Shyh-Jiann HWANG, Lap-Loi CHUNG, Wen-Yu CHIEN, Fu-Pei HSIAO, Hung-Ming CHEN, Wen-Cheng SHEN, Yeong-Kae YEH, &Ching-Pao CHUANG 70

Experimental Study of Nanomaterial Concrete Durability against Sulfate Infiltration
SALOMA, Amrinsyah NASUTION, Iswandi IMRAN, &Mikrajuddin ABDULLAH 86

Wall Block from Construction Waste Bound with Fat of Waste Cooking Oil
I NyomanAryaTHANAYA ,Ngakan Made Anom WIRYASA , Rambu C.Z.H.E. KAPITA 98

The Chemical Characteristics of Chitosan Extracted from Green Mussels Shell *(Mytilus virdis linneaus)*and Its Potential Application as a Natural Coagulant
SINARDI, Prayatni SOEWONDO, Suprihanto NOTODARMOJO 110

Evaluation Fire Resistance of Reinforced Concrete Slabs Using Analytical Solution and Numerical Modeling
EndahWAHYUNI ,Wahyuniarsih SUTRISNO 118

Study of Residual Stress of Dented Steel Plates
ARIANTA, Ricky L. TAWEKAL, Ahmad TAUFIK, RIDOLVA 129

Fundamental Study on Techniques for Improving Activity of Fly Ash
Toshitsugu INUKAI 137

Comparative Study of Some Sections of Buckling Restrained Braces Due To Axial Loads by Using Finite Element Analysis Program
Gati Annisa HAYU &Budi SUSWANTO 150

Study of Lightweight Concrete with SidoarjoCalcined Mud, Kenaf and Aluminum Powder as Chemical Aerating
M Lutfi MANFALUTHY, Januarti Jaya EKAPUTRI&TRIWULAN 164

Numerical Analysis: Influence of Slab Thickness to the Cyclic Lateral Behavior of Slab-Column Connections with Modified Shear Reinforcement Detail
Riawan GUNADI, Bambang BUDIONO, Iswandi IMRAN, Ananta SOFWAN 172

Economic Potential of Merapi Volcanic Sand as Concrete Block (Batako) Material - case study inKuning River
FitriNUGRAHENI&Adityawan SIGIT 186

Mapping of Indonesian Timber: Potential of Glulam Wooden Beams without Reinforcement and with Reinforcement for Timber Structures
Saptahari SUGIRI, EkaMulyaALAMSYAH&Arie Putra USMAN 197

Behavior of Glulam with Flexural Strengthening
Arie Putra USMAN, Saptahari SUGIRI 205

Study on the Development of Foamed Concrete for Wall Thermal Insulation
Biemo W. SOEMARDI,Ivendar PANE&Eka P. SUSANTO 213

The influence of Elevated Temperature on The Rate of Compressive Strength of Normal Concrete
QOMARIAH &Nova R. ISMAIL 221

On the Accuracy of Shear Wall – Frame Interaction Calculations
Adang SURAHMAN 229

Active Control Application on Cable-Stayed Bridge Structure Using Artificial Neural Network Algorithm
Arka P. REKSOWARDOJO&Herlien D. SETIO 245

Prediction of Fracture Strength in Fine Ceramics under Variable Quasi-Static Loading
Shinya MATSUDA 257

The Study of The Hydrothermal Behaviour of Natural Fibrous Materials Applicable for Insulation in Construction
Jiri ZACH, Jitka HROUDOVA& Jiri BROZOVSKY 270

The Development of Water-ResistantMasonryBlocks
Jiri ZACH, Jitka HROUDOVA, Martin SEDLMAJER& Martina BARTLOVA 289

Development of Low-Damage Earthquake-Resisting Steel Systems Using Sandwiched Buckling-Restrained Braces and Dual-Core Self-Centering Braces
Chung-Che CHOU, Ping-Ting CHUNG, Dinh-Hai PHAM, Ying-Chuan CHEN 299

Structure Modal ParemeterByHilbert - Huang Transform
Mohammad A. RIZAL& Amrinsyah NASUTION 312

Performance Based Specification for Sustainable Concrete Construction
Ivindra Pane 330

TOPIC 7. GEOTECHNICAL ENGINEERING

Effects of Loading Rate on Cyclic Triaxial Tests for Low-Plasticity Silt
Louis GE&Meng-HengCHIANG 351

Mudflow Simulation in Sukaresmi
Budijanto WIDJAJA, S. Hsien Heng LEE, Wahyuning AILA, &Nessiana NOVITA 359

Effect of Cellulose-Degrading Microorganism Treatment in Peat Soil Consolidation
Niken F. GUSMAWATI, Wiwik RAHAYU&Puspita LISDIYANTI 370

Gridded Matrass and Mini-Piles vsTightened Matrass and Mini-Piles vs Top Connected Mini-Piles - Simple and Cheap but Powerful Methods for Soft Soil Reinforcement
EndraSUSILA &Fico Dio AGRENSA 385

Slope Stability Analysis Following Maninjau Landslide 2013
Abdul HAKAM, Febrin A.ISMAIL, Fauzan, BambangISTIJONO & Ricky ARNALDO 400

The Application of Genetic Algorithm in Backcalculating Pavement Moduli of Three-Layered System Structures Using Database Approach
Djunaedi KOSASIH &MirzaNurPRATOMO 409

Gridded Matrass and Mini-Piles vs Tightened Matrass and Mini-Piles vs Top Connected Mini-Piles - Simple and Cheap but Powerful Methods for Soft Soil Reinforcement

Endra Susila
Assistant professor and Head of Soil Mechanics Laboratory
Geotechnical Engineering Research Group
Dept. of Civil Engineering
Faculty of Civil and Environmental Engineering, Bandung Institute of Technology
Email: endrasusila@gmail.com and esusila@si.itb.ac.id

Fico Dio Agrensa
Laboratory assistant of Soil Mechanics Laboratory
Graduate student of Geotechnical Engineering
Dept. of Civil Engineering
Faculty of Civil and Environmental Engineering, Bandung Institute of Technology
Email: fico.agrensa@gmail.com

Abstract: This paper describes, discusses and compares three new breakthrough types of reinforcements for soft soil: a combination of gridded matrass and piles of bamboo, a combination of tightened mattrass and piles of bamboo (Irsyam et. al. 2009), and a group of minipiles connected by small H-beams with a top compacted layer to hold top minipiles. First, illustrations and applications of the three types reinforcement are described from three (3) full scale field works. Next, technical bases for the three types are presented. Technical comparisons will next be discussed. Finally, Conclusions and Potential Future Research are developed. The case studies, analysis results, and the full scale field work verifications show that the three reinforcement systems have their own advantages and disadvantages in terms of construction duration and cost, capability/effectiveness and material availability especially at rural area.

Keywords: soft soil, soil improvement, soil reinforcement, minipile, gridded mattrass, mattrass, simple technology.

1. INTRODUCTION

In recent years, various geotechnical reinforcement systems in problematic soils, particularly soft soils, have been well developed. Through several experiences in embankments on soft soils, efforts have been made to establish new reinforcement systems which could approach these criteria. Also by considering them, three types of soft soil reinforcements have been proposed which offer capability to overcome, or significantly reduce the soft soils problems. In this paper, Gridded Matrass and Mini Piles; Tightened Matrass and Mini-Piles; and Top Connected Mini Piles will be respectively presented and technically discussed.

The major works which are discussed in this paper cover three embankment cases over Indonesia. Prior to the embankment design and analysis, proper geotechnical investigations have been conducted, which found typically large deposit of soft soil at the sites. While the challenging condition cannot be avoided, the reinforcements which have been explained in the previous paragraph came up with better quality, instead, have been technically proved in several field cases. Figure 1 shows the site locations of different reinforcement utilizations.

During the design stage, the embankment stability were analyzed by using a professional finite element software Plaxis 2D v.8.2 (for overal performance) and Terzaghi's 1-D Consolidation Theory (particularly for consolidation settlement). This software accomodates thorough yet simple analysis in order to observe embankment's behaviour which laterly known suffered from bearing capacity problems and excessive settlements for unreinforced embankment. The performances are sensitive to height of embankments that contribute to loading increment due to construction sequences and service life. The reinforced embankment performance analyses were verified by field observations.

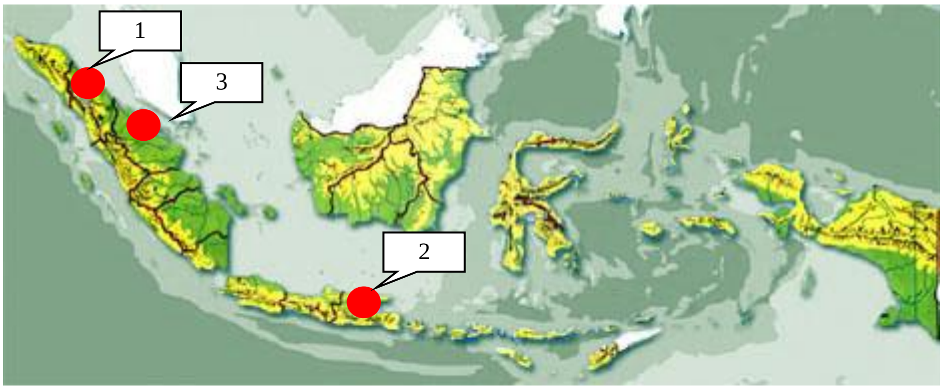


Figure 1. Locations of Field Discussed Cases

2. PROBLEM DEFINITION – SOFT SOIL

A well known problematic soils – soft soil – are generally described as high compressible, low shear strength and low permeability soil. It brings major problems such as low bearing capacity and excessive settlement which lead to unstable structures and deterioration on them. Therefore, the need and use of proper reinforcements are highly recommended.

On the embankment performances over soft soils, height of the embankments that corresponds to the weight of embakment fill directly induce increase in soil stresses, as well as pore water pressures which are continously accumulated and occured in fine-grained soils. As consequences of material properties such as low permeability of fine-grained soil, the dissipation of pore water pressure cannot occur quickly, just like sandy soils which have high permeability. Susila and Apoji (2013) have performed numerical simulations verified by data from field trial for embankment on very soft fined grain material showing the power of numerical simulation as long as soil parameters are appropriate. At this state, the loading is quick relative to excess water pressure dissipation, therefore it is categorized as undrained condition. The mechanism of loaded soil caused by embankment is described as follows: as the soil compressed vertically by the embankment, it expands horizontally until resisted by adjacent soil. Althought the soil is deformed, for undrained conditions, its volume is constant.

Later on, when the excess pore pressure starts dissipating, the volume reduces. Consequently, the consolidation settlement begins to occur. It comprises primary consolidation and secondary consolidation and could cause a serious problem due to the deformation and rate of consolidation. An emphasis should be taken on the stress transfer that sometimes requires considerable time. This condition also influences the failure mechanism (progressive failure). During this process, additional strain often occures when the soil has reached its failure. Because of the low strength of soft soil, the bearing capacity failure usually occurs. The increased stress that cannot be resisted by the soil strength will suppress laterally and develop the slip-circular failure mode in the adjacent area to the embankment toe.

Covering approximately 30 % of Indonesia, this type of soil can easily be found in Indonesia. It is usually described as clay and peat soils. Even so, there are many alternative solutions that have been developed. The decision depends on the criteria, local condition, and material availability.

3. PROPOSED ALTERNATIVES – SIMPLE AND CHEAP BUT POWERFUL METHODS

Proposed alternatives which are discussed in this paper have been applied in the field scale works to overcome the issues related to the embankment stabilities. Compared to the conventional reinforcement or remediation on the same case, these alternatives have been proven to be cheaper and simpler because could often utilize local materials, yet technically considered as powerful as the conventional reinforcement by deeming the embankment performance in the full scale works.

A key point that is taken into consideration on the proposed reinforcement is the stress distribution. On the bearing capacity problems, as elucidated in the previous section, the shear stress induced by the embankment is directly transferred and resisted by the subsurface soil strength. By applying the mattrass (gridded mattrass) reinforcement, the shear stress can be intercepted and distributed to the reinforcement. **Figure 2** describes the mechanism of stress transfer from unreinforced embankment which causes failure to applying reinforcement which can significantly increase its bearing capacity. The resistance of the soil stress by the mattrass involves mechanical properties of the reinforcement material.

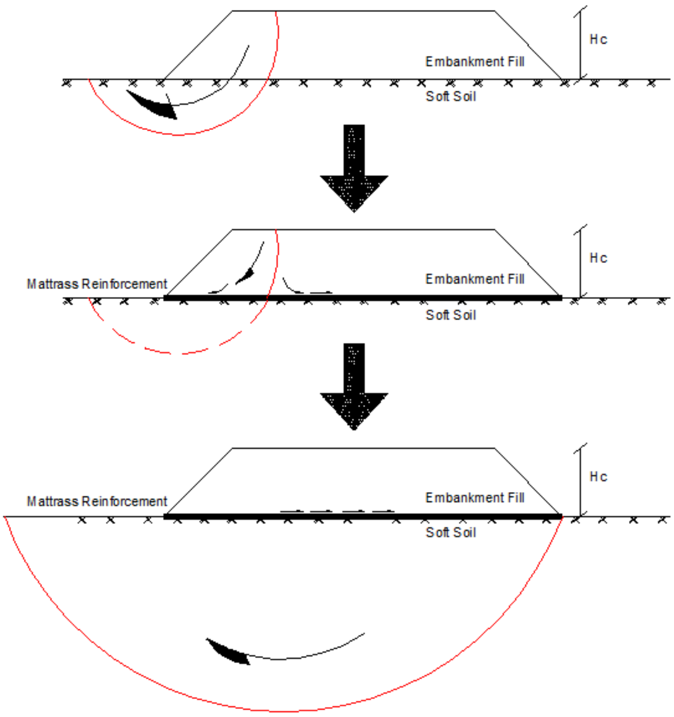


Figure 2. Mechanism of Embankment Failure

Mini-Piles are deemed to provide potential solution to solve stability problems on embankment. As clearly presented by **Figure 3.** Vertical Stress Distribution under Embankment, the differences are increment vertical stress area spread from embankment through the foundation. The large deposit of soft soils will surely cause the embankment more prone to suffering excessive settlement. The vertical stress can be transferred into deeper layer by assuming that the mini-piles have the behaviour as group piles, at least partially. As deeper the vertical stress is transferred, the contact pressure area will be larger and the pressure will be smaller.

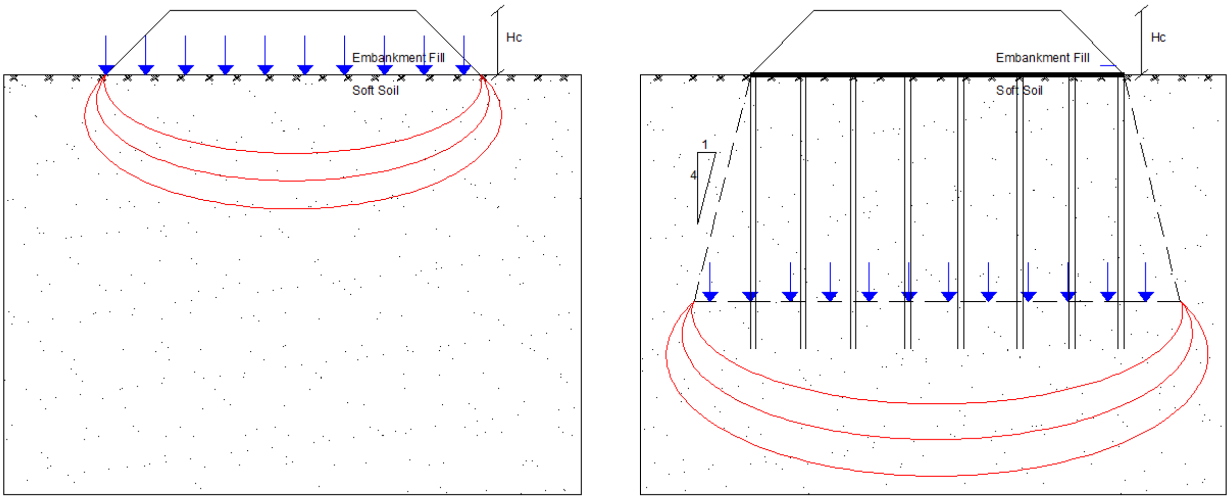


Figure 3. Vertical Stress Distribution under Embankment without amd with Mini-piles Reinforcement

4. CASE STUDIES

4.1. Gridded Mattrass and Mini-piles Application.

In this first case, the discussion is focused on the embankment construction for a causeway in North Sumatra. The planned causeway was designed for 400 meter long and the embankment height was planned to reach ± 6.30 meters. The challenging part during design phase in this case was the geotechnical condition of the site which is dominated by very soft to soft silty clays. However, the most critical condition of embankment case occured at the end of construction. In other words, the embankment will be stable or even more stable because of gain strength as a result of consolidation process as long as there will be no load increment. At the beginning of the construction, prefabricated vertical drain (PVD) was applied as a first response to this condition.

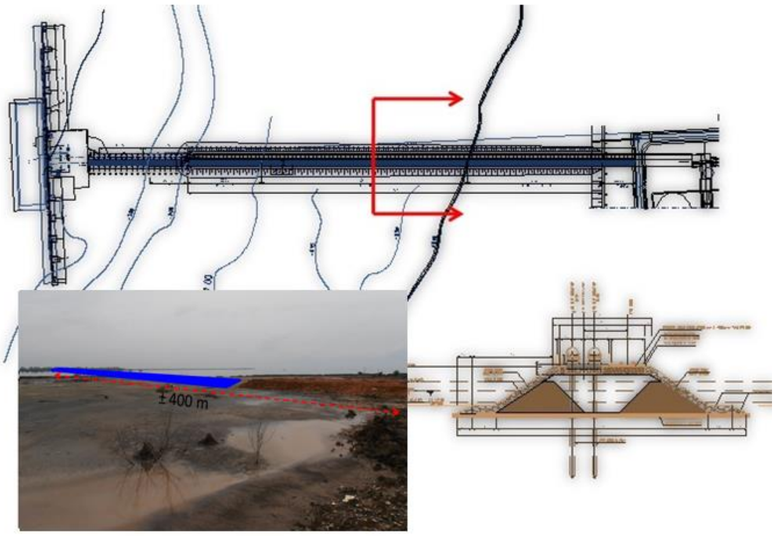


Figure 4. The Planned Causeway and Embankment Cross Section, North Sumatera.

By basing the soil layering presented in **Figure 5**, the subsurface-soil condition was dominated by silty clays, specifically, very soft to soft silty clay to the depths of 22 to 30 meters below the existing surface. The clay layer was followed by medium stiff to very stiff silty clay and hard clay respectively at various depths until the end of boring at a depth of 40 meters below the existing ground surface. On the other hand, for analysis necessity, the undrained strength parameters for each layer was determined based on field vane shear test results, laboratory test results and SPTs. The soil profile and the undrained shear strength profiles are presented in **Figure 5** and **Figure 6**, respectively. Additionally, the laboratory test results indicate that the surface layer was categorized as medium to high compresible clay layer with the compressibility index and void ratio ranged from 0.6 to 1.1 and 1.5 to 2.0, respectively.

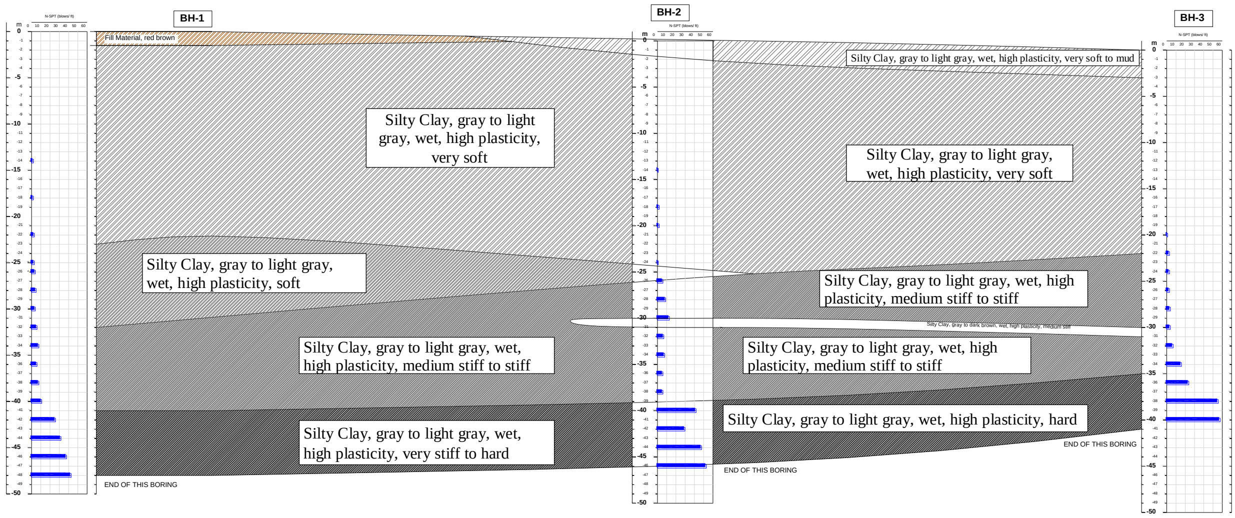


Figure 5. Soil Layering of Pangkalan Susu Case Study Site.

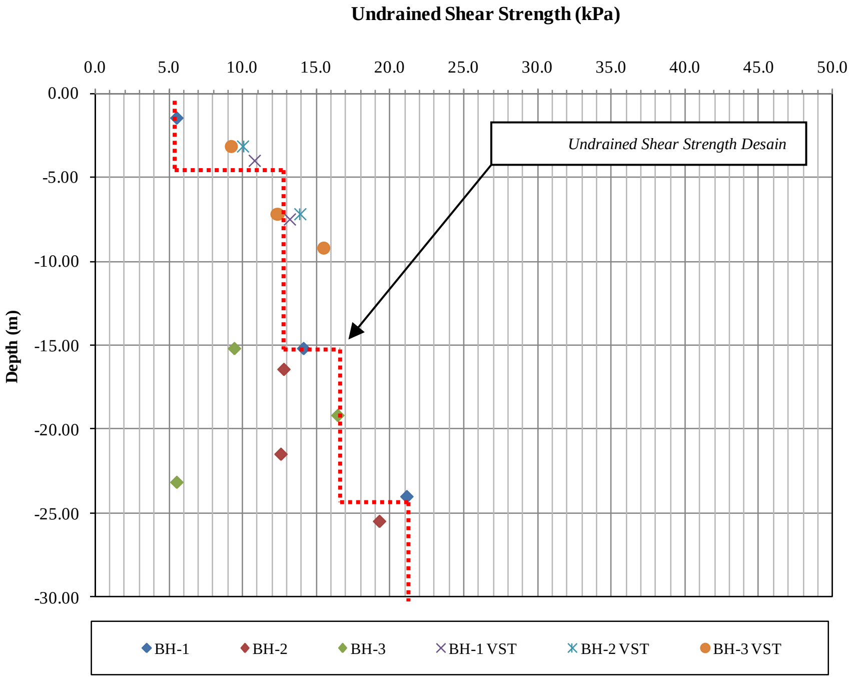
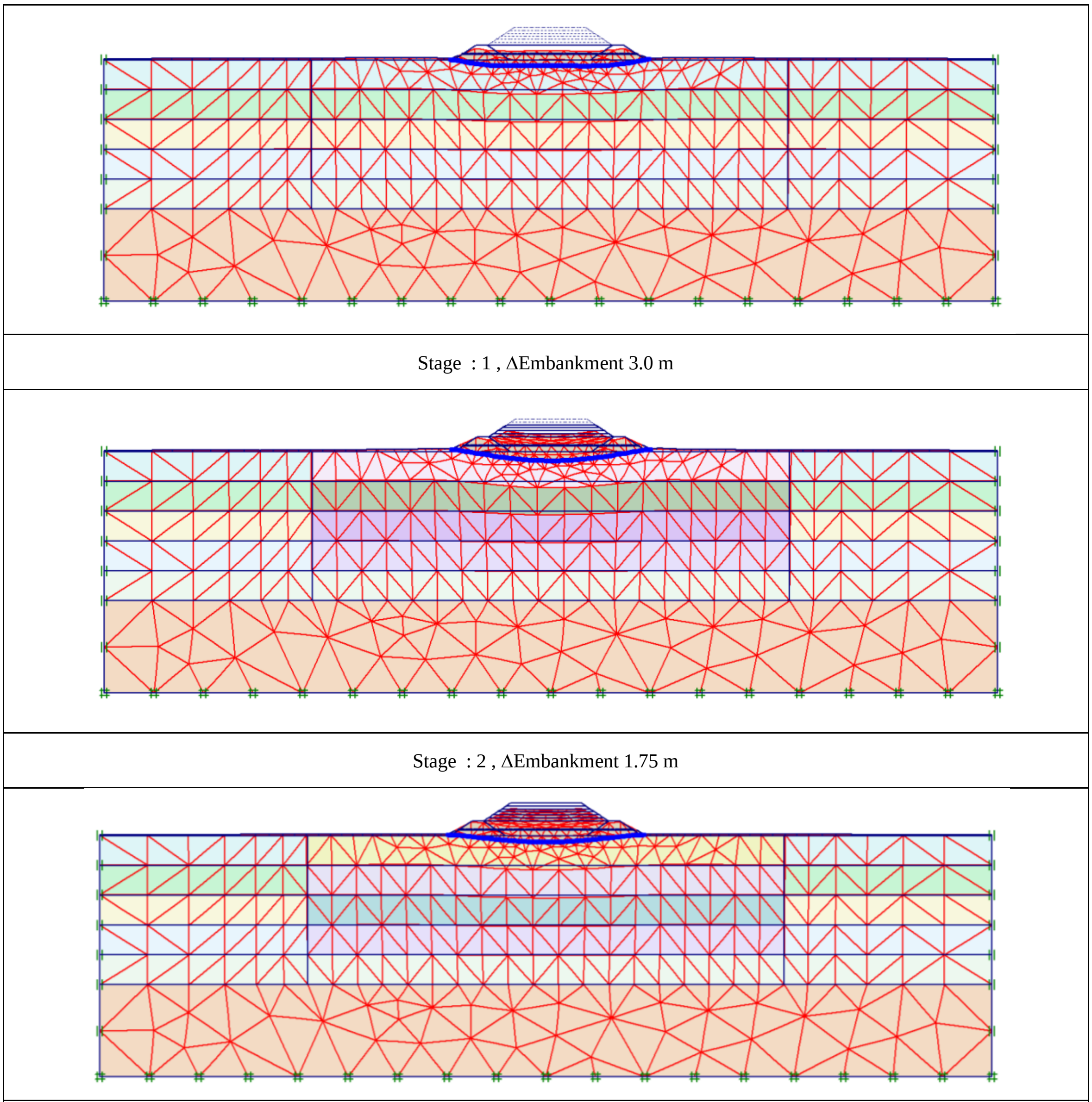


Figure 6. Relationship Between Undrained Shear Strength and Depth

On this case, gridded matrass that used to support the embankment is detailed in **Figure 7**. The reinforcement was consisted of 4 layers of bamboo pile and set in a grid pattern with a space of 1 x 1 m^2. It is placed and considered as an embankment foundation to increase the stability and stiffnes of the subgrade. This type of reinforcement was proven to be effective. Later on, we realize that mini-piles of bamboos will significantly increase their effectiveness of reinforcement.

Figure 7. Gridded Matrass Bamboo for Reinforcement

Stability analysis was performed by using Plaxis 2D v.8.2 package by emphasising on the bearing capacity and excessive settlement. In addition, Terzaghi 1-D Consolidation theory was also included in the analysis to verify the consolidation settlement of the planned embankment. In order to observe the reinforcement performance, the analysis model accounted the embankment with gridded matrass reinforcement and the construction sequence. Besides, the soil replacement from existing surface to depth -3.0 meter was also taken into account in calculation as a better combination with reinforcement. At the first stage, gridded matrass bamboo was applied over the soft soil. Afterwards, the embankment was constructed in three stages: 3.0 meters of, 1.75 meters, and 1.50 meters of thickness. At the end of the calculation, the safety factor that obtained from the reinforced embankment model was 1.29.



Stage : 1 , ΔEmbankment 3.0 m

Stage : 2 , ΔEmbankment 1.75 m

Stage : 3 , ΔEmbankment 1.50 m

Figure 8. Construction Stages of The Embankment Analysis

The results of the settlement analysis are summarized in **Table 1**. Firstly, elastic settlement due to increasing embankment heigh (construction stage) resulted total elastic settlement at the end of construction of 157 cm. Still in the same stage, total consolidation settlement from FEM analysis result shows to approach 172 cm. Verification results of the consolidation settlement by using Terzaghi 1D theory tend to be close to the FEM analysis with the magnitude of consolidation settlement 182 cm. However, the stability performance can still be increased which means by combining the gridded matrass bamboo with piles. Field observation during construction show that the values are comparable to field condition. Unfortunately, field settlement records are still not available.

Table 1. Analysis Results of Settlement Prediction.

No.	Analysis Type	Settlement			Total
		Stage 1	Stage 2	Stage 3	
1	Elastic settlement - FEM	105 cm	34 cm	18 cm	157 cm
2	Consolidation settlement - FEM	85 cm	49 cm	37 cm	172 cm
3	Consolidation settlement – Terzaghi 1D	107 cm	42 cm	33 cm	182 cm

4.2. Matrass and Piles of Bamboo Combination (Taken from publication of Irsyam et. al, 2009)

A highway road embankment was constructed on high deposit of soft soil in Tambak Oso, Surabaya, East Java. According to the soil investigation report (Irsyam, et.al, 2009), very soft to soft soil was discovered with thickness of approximately 30.0 meter. Within this layer, cone resistance (qc) ranged from 1 – 4 kg/cm^2. Illustration of geotechnical condition is shown in **Figure 9**.

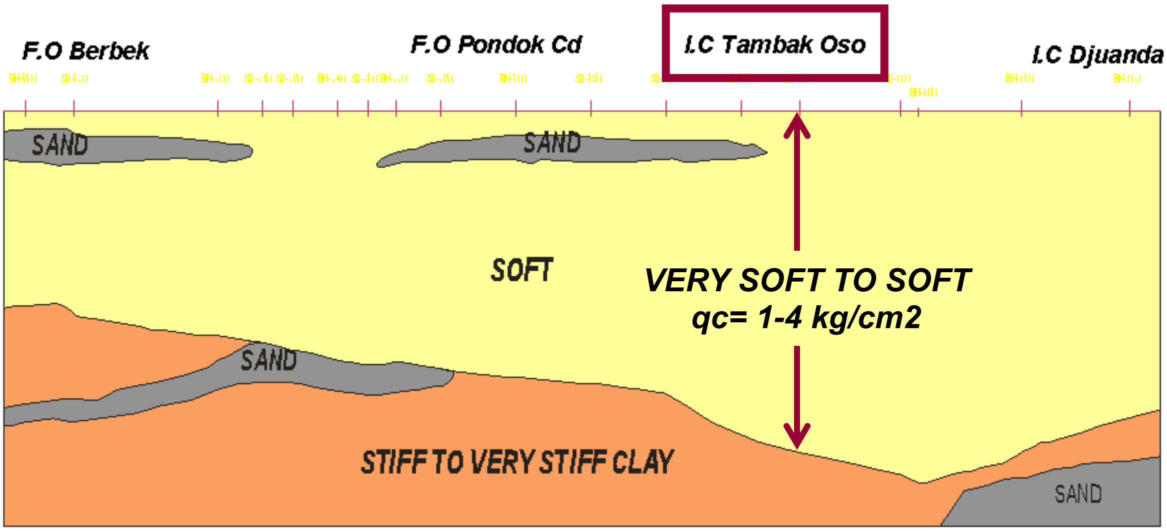


Figure 9. Geotechnical Condition of Tambak Oso Site (Irsyam et. al, 2009)

A reinforcement system which consisted of matrass and piles of bamboo were constructed. Prior to the construction and application of the embankment with reinforcement, a trial embankment experiments had been conducted. The performance was observed by placing instrumentations in which specified to monitor ground settlement and pore water pressure. After the settlement records for 3 months reading had been obtained. It was then compared with finite element analysis and analytical method results.

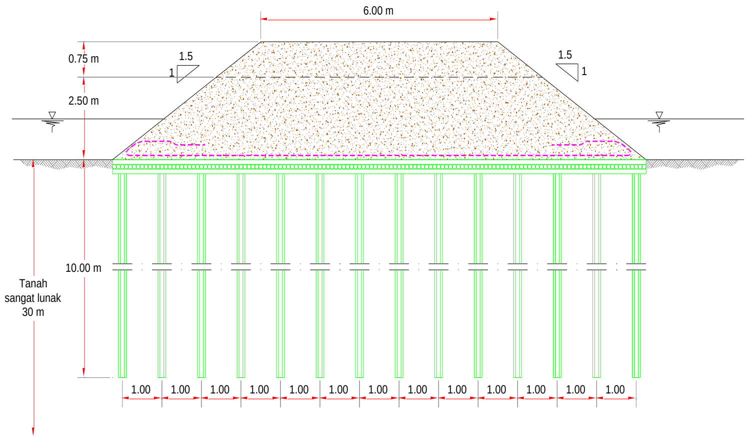


Figure 10. The Full Scale Trial Embankment Model Using Combination of Matrass and Pile of Bamboo (Irsyam et.al., 2009)

As shown in **Figure 10**, the full scale trial embankment was reinforced by matrass and piles of bamboo. The matrass systems were are assembled from four layers of bamboo and intersected each to another for an embankment foundation. It combined with piles consisted of three vertical bamboo with a length of 10 meters and placed with a distance of 1 meter. The total trial embankment height was 3.25 meter which was constructed in two consecutive stages. The first stage was carried out to achieve 2.5 meter height, while the second stage was started after 75 days by adding embankment height until reaching 3.25 meters. During the construction, the instrumentation reading was also conducted.

The results of this experiment to determine whether the reinforcement is reliable or not are presented in **Figure 11**. To verify the settlement reading from the field, two analysis results are included. Based on this experiment, it can be concluded that the embankment with 3.25 meter height was stable in the hight deposit of soft soil with application of matrass and pile of bamboo.

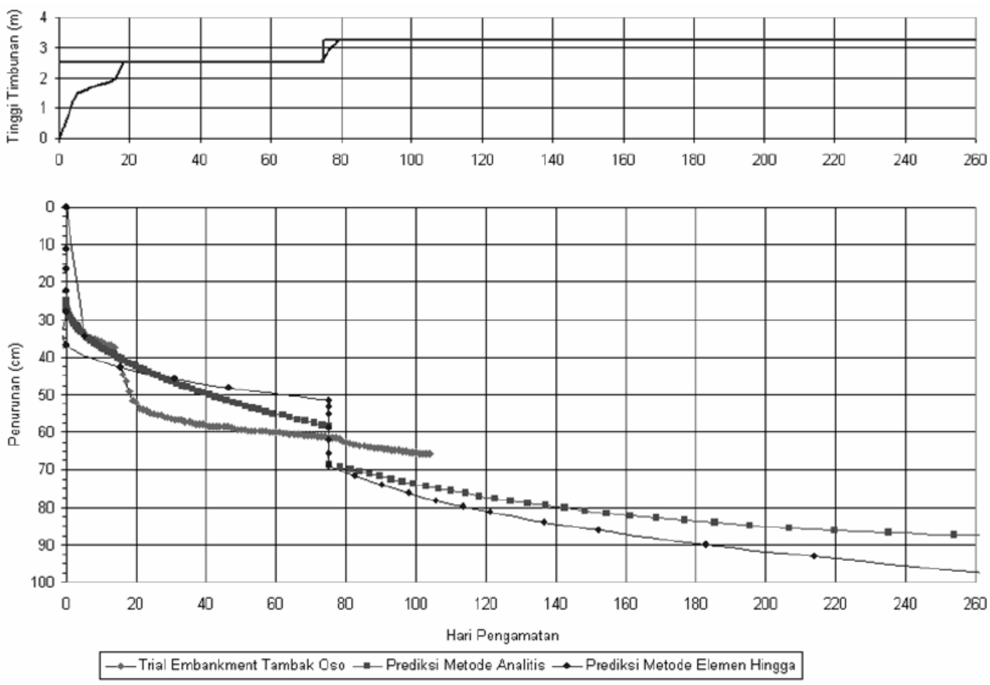


Figure 11. Settlement Comparison of Field Monitoring and Analytical Results (Irsyam et.al., 2009)

4.3. A group of Mini-Piles of Woods and/or Mini Spun Piles Connected by H-beam Application

From the beginning to the middle of 2013, a jetty embankment with an approximate height of 2.8 meters was built on the soft ground in Riau. Special attention should be carried out because it was designed to retain the load of several massive power plant machines which are very expensive. Similar to the previous cases, a large deposit of soft soils was discovered. The condition was worsen due to the location of the embankment itseft which was in the riverside. To avoid bearing capacity failure during both construction phases and service life, several reinforcements had been proposed but no one satisfactorily increase the stability.

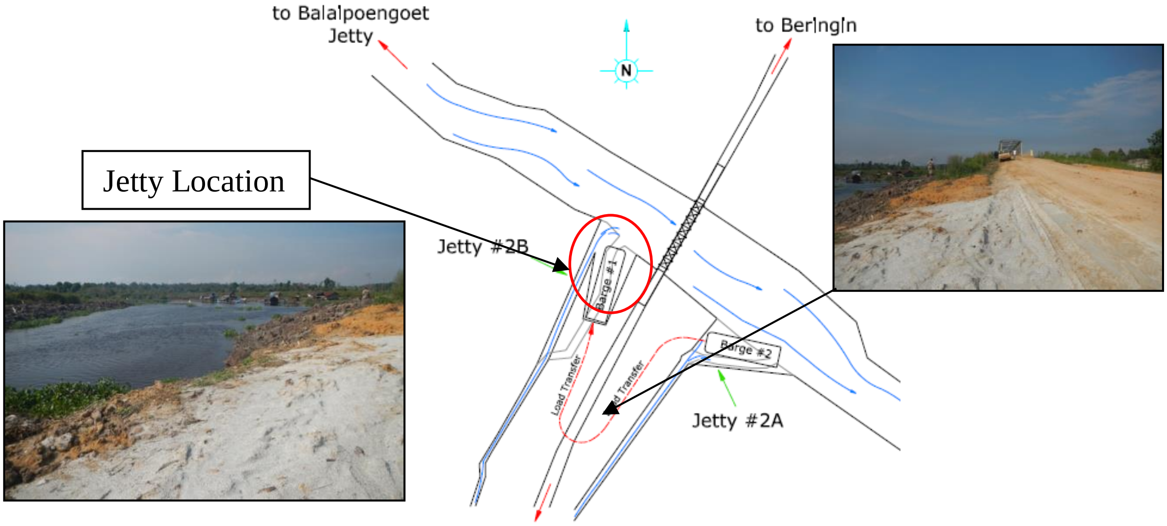


Figure 12. Illustration of Site Location and Condition

A new idea has came up by applying a combination of mini-piles of logs and mini spun piles, wooden block, H-beam, and sand bags. Systematically, the consideration of using those reinforcement elements takes into account the performance and mechanism of load carrying caused by the machine in order to avoid any factor leading to failure. The axial load will be retained by mini-piles which were set to an approximate depth of 6 meters and placed in a grid pattern of 1 x 1 meter^2. To increase mechanism of group and to increase rigidity of pile top, wooden blocks were used by deeming that the composition of mini piles with such pattern plays important role in assuring the stability. The group of mini-piles were then connected by H-beam on the heads of each pile in order to sustain any lateral load induced by the embankment and passing machine load.

Figure 13. Embankment Construction

To investigate the effectiveness and mechanism of the reinforced embankment, an finite element analysis was carried out. The soil data were taken by CPT data of the location as well as the structural parameter regarding to the reinforcement elements. The result of the analysis shows that the embankment was stable represented by SF of 1.28. Field construction and the passing machine has proven the results of analysis and the effectiveness of the reinforcement system.

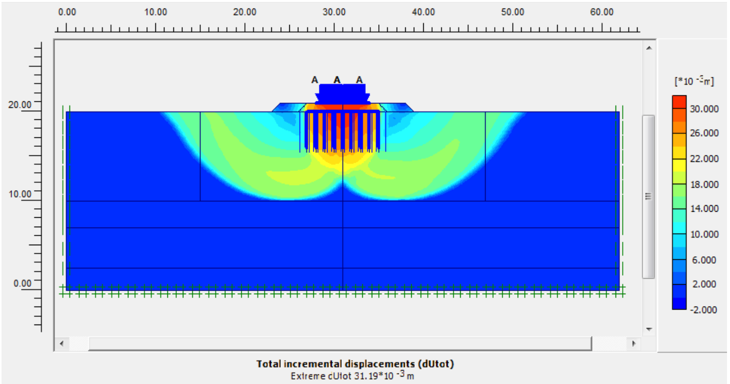


Figure 14. Failure Mode of Finite Element Analysis Model

5. DISCUSSION AND TECHNICAL COMPARISSON

Selection of appropriate reinforcement material does not only depend on technical aspects, but also cost and material provision. For instance at several soft soils cases in particular area, cheaper material is more preferable. Talking about cost aspect, the discussed cases which focus on reinforcement selection are also emphasized on cost-saving criteria, but technically proved in increasing embankment stability.

6. CONCLUSION

Three different embankment cases on soft soil have been elucidated in the previous section. Moreover, the reinforcement of the combination of bamboo piles are proven to provide potential solution to solve soft soils low bearing capacity on embankment construction. The numerical analysis and full scale field test discussed in this paper shows how the three reinforcement systems technically improve the stability and safety of the embankment.

7. References

Irsyam, M and Krisnanto, S. (2008), “Pengujian Skala Penuh dan Analisis Perkuatan Cerucuk Matras Bambu Untuk Timbunan Badan Jalan di Atas Tanah Lunak di Lokasi Tambak Oso Surabaya,” *Forum Teknik Sipil No. XVIII/1-Januari 2008.*

Susila, E. and Apoji, D. (2012), “Settlement of a Full Scale Trial Embankment on Peats in Kalimantan: Field Measurements and Finite Element Simulations”, Journal of Teknik Sipil, Bandung Institute of Technology, Bandung, Indonesia.

Weech, C.N., et. al. (2009), “Highway Embankment Construction Over Soft Soils In The Lower Mainland Of British Columbia,” Annual Conference of the Transportation Association of Canada, Vancouver, British Columbia.