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**Alfred Jonathan Susilo, ST., M.Eng., Ph.D.**

Untuk melaksanakan **Mempresentasikan Hasil Penelitian** dengan data sebagai berikut:

Judul Makalah : **Analysis of Settlement on slab-on-ground in Soil Strengthened With Dolken, Mangrove, and Bamboo Timber**  
Nama Seminar : The 3 rd Tarumanagara International Conference on the Applications of Technology and Engineering (TICATE) 2020  
Penyelenggara : Universitas Tarumanagara  
Peran : Pemakalah (Presenter)  
Waktu Pelaksanaan : 03 - 04 Agustus 2020

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11 Februari 2021

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Analysis of Settlement on Slab-on-Groud in Soil Strengthened with Dolken, Mangrove, and Bamboo Timber

August 3<sup>rd</sup> - 4<sup>th</sup>, 2020 | Universitas Tarumanagara, Jakarta

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## Preface

On behalf of the organizing committee of the 3<sup>rd</sup> TICATE 2020, I would like to welcome all delegates to attend this international conference with great pleasure. In the concern of COVID-19 pandemic, this international conference is being held virtually from August 3<sup>rd</sup> – 4<sup>th</sup>, 2020 from Campus I of Universitas Tarumanagara at Jl. Letjen S. Parman No. 1, Jakarta 11440, Indonesia. The 3<sup>rd</sup> TICATE 2020 is organized by Universitas Tarumanagara and technically sponsored by IOP Publishing. The reason why this conference was changed to virtual format is that due to COVID-19 Pandemic, there are travel restrictions and social distancing ruled by almost all governments in the world, including Indonesian government. We still hold partially the physical presentations regarding the healthy protocols suggested by World Health Organization.

Instead of being postponed, we still hold this international conference virtually using Zoom Meeting because this conference is a forum for engineers, academics, practitioners, and students to exchange their experiences and knowledge. Many innovations and developments are being created from the last event to this one. These need to be shared among stake holders in the field of engineering and technology. Therefore, there is an urgent need to publish the newest results of researches in the conference proceedings.

The 3<sup>rd</sup> TICATE 2020 has attracted many academicians, scientists, engineers, postgraduates and other professionals from many countries. This conference accepted 217 papers from 5 different countries, those are Australia, Taiwan, India, Malaysia, and Indonesia. The aim of the conference is to promote exchange of ideas among engineers, researchers, and scientists active in the related areas of technology and engineering.

Our special thank goes to our Rector, Prof. Dr. Ir. Agustinus Purna Irawan, who has initiate this international conference, to our Plenary Speakers, Prof. Ir. Dr. Lee Sze Wei from Tunku Abdul Rahman University College, Malaysia, and Prof. Dr. Ir. Tresna P. Soemardi, S.E., M.S. from Universitas Indonesia, Indonesia, and to our Invited Speakers, Dr. Ayub Ahmed Janvekar from VIT University, Chennai, India and Prof. Ir. Dr. Mohd Zulkifli Abdullah from Universiti Sains Malaysia, Malaysia. Each keynote speaker will be given 30 minutes to hold his presentation and followed by 15 minutes Q&A session. At the parallel sessions, each presenter is given 15 minutes to present his/her work followed by 10 minutes Q&A session about the related topic. The parallel sessions are opened to all participants. The participants, including presenters at the parallel sessions, are attending this virtual international conference from Indonesia (Jakarta, Bandung, Medan, Yogyakarta, Aceh, Depok, Surabaya, etc.), Kuala Lumpur, Pulau Pinang (Malaysia), Australia, Taiwan, and India.

The virtual format of the 3<sup>rd</sup> TICATE 2020 still provides very satisfying overall technical quality of the conference, e.g. in presenting the articles. Because we used Zoom Meeting as the platform and a good internet connection to hold this virtual conference, the conference can be attended by about 500 participants from 5 countries without any problem.

We would like also to thank our partner international and national Universities in contributing and participating in this international conference. To all individuals and organizations such as the members of international editorial board, the conference organizers, the reviewers and the authors, for their contribution in making the 3<sup>rd</sup> TICATE 2020 as a successful international conference and a memorable gathering event. I am also grateful for the support of publication service of IOP Publishing.



We hope that the conference could present you wonderful memories to bring home in addition to new insights and friendship congregated during the event. We truly value your participation and support for the conference. We hope that you will gather many experiences and benefits from this event.

Dr. Hugeng, S.T., M.T. (SMIEEE)

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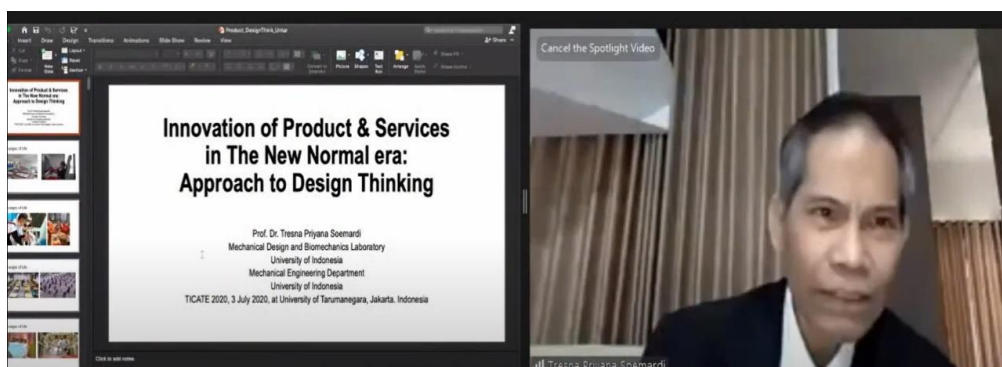
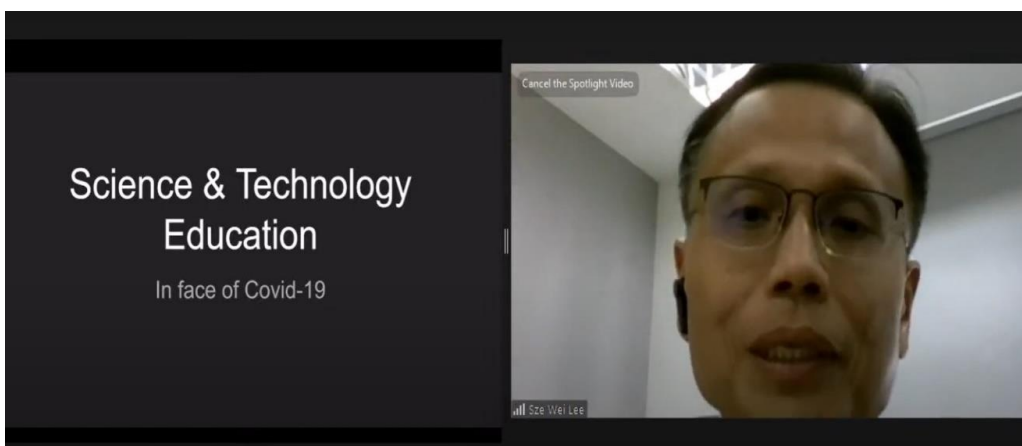
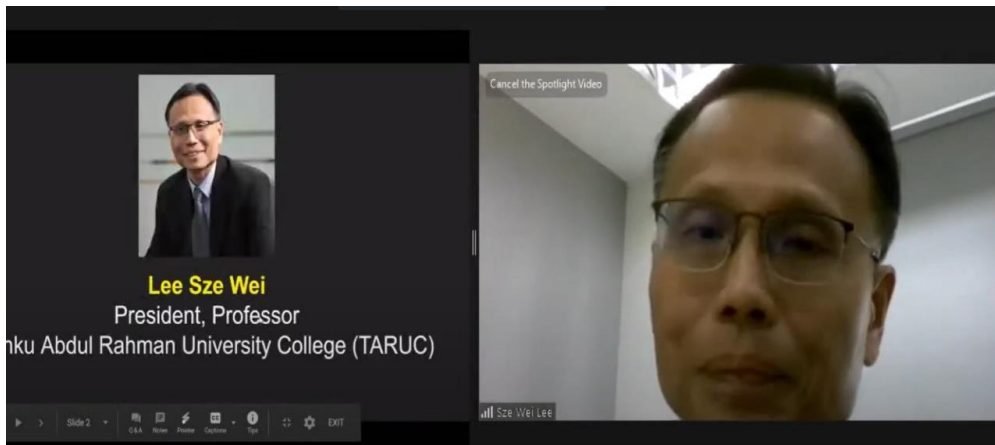
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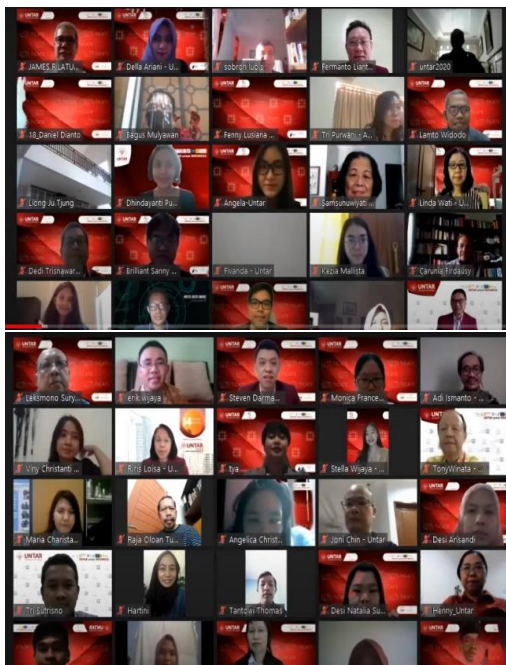
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## Analysis of settlement on slab-on-ground in soil strengthened with dolken, mangrove, and bamboo timber

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## Analysis of settlement on slab-on-ground in soil strengthened with dolken, mangrove, and bamboo timber

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**Abstract.** Shallow foundation and slab on ground that were built on soft clays might have some settlement because of the low bearing capacity. If the settlement that happened was a differential settlement, it can cause damage to the structure. There are many ways to fix the soil by improving the bearing capacity such as using wood pile. Wood pile is often used because it was easy to find, easy to use, and cheaper than using the pile made of concrete. There are many types of wood that can be used, for example dolken wood, mangrove, and bamboo. Those type of woods have different specification that effected the wood strength as a pile to improve the soil bearing capacity. The diameter and length of the wood also influence the pile effectiveness. All this factor can give a different result in reducing the settlement that happened on the soil.

### 1. Background

The increase in population will cause an increase in the number of buildings to support human activities such as houses, schools, hospitals, etc. To be able to build these facilities, it requires a lot of land but not all land has good soil. Many areas have poor surface soil, for example soft surface soil. This soft surface soil has low bearing capacity and shear strength, causing various problems with the structures built on it, such as shallow foundations and slab-on-ground. One such problem is the settlement that occurs in the soil, especially an uneven settlement as shown below.



Figure 1. Settlement that occurs in slab-on-ground. (<https://www.alsplumbing.com/low-priced-slab-leak-repair-no-bargain/foundationrepairhousediabramwithwihoutpiers/>)





Figure 2. Crack on the wall and ceiling. (Located at Sabang)



Figure 3. A gap between the ground and the slab. (Located at Sabang)



Figure 4. Crack on the floor plate. (<https://www.totalfoundationsolutions.com/foundation-repair/foundation-services/floor-symptoms/floor-cracks/>)

An uneven settlement in slab-on-ground can cause the floor to become bumpy, separate wall with ceiling, led to the emergence of a gap between the ground and the slab, and cause the structure to crack as shown on **Error! Reference source not found.**, Figure 3, and Figure 4. To reduce the settlement that occurs, a wood pile is used. Wood pile can increase the soil bearing capacity and reduce the settlement. Because of that, wood pile is often used to improve the soil. In this study, an analysis of settlement on soil reinforced with wood piles will be carried out. The limitation of the problem in this study is that the wood used as wood piles are dolken wood, mangrove wood, and bamboo, the distance between each wood pile and the load are the same for each wood, the price is not taken into account, and the soil used are clay, sand, and landfill.

## 2. Literature review

In building buildings that are not too high on the ground with thick soft surfaces and hard soils far below the surface, pile foundations will result in a very expensive foundation construction cost. Because of this, low rise buildings usually used shallow foundations. If the pressure to the ground is evenly distributed, the settlement can be tolerated if the building can withstand the decline. Settlement is not always a bad characteristic of a building provided that the settlement is uniform and does not cause major damage to the building.

Slabs are thin structural components typically used for floors and roofs in high rise buildings. The slab will take the burden from the top floor or roof and distribute it to the existing support. For slab-on-ground, the support is the soil underneath it. Settlement can cause the slab to lose ground support and suffer damage.

Wood piles are poles made of wood, bamboo, or concrete with a relatively short length that are stuck vertically into the ground and usually used to overcome settlement that can cause the collapse of buildings on soft soil. According to Yudiawati and Marzuki (2018), wood pile is used to increase shear resistance because shear resistance is a major component of soil bearing capacity [1]. Based on Nugroho and Sibarani (2013) research with 8 cm diameter wood piles, the longer the length of wood piles and the closer the space between piles will result in greater shear strength values with a length of 100 cm and 2D space as the size of the pile has the largest shear strength value [2]. The usage of wood piles will increase soil density and reduce void ratio so that according to Muhrozi, the shear strength of the soil will increase and the settlement that occur will decrease [3].

According to Rusdiansyah (2016), the space between piles, length, and diameter affects the soil bearing capacity because [4]:

- The thicker the diameter of wood used; the stiffness of the piles will increase.

- If the space between the piles is denser, then the performance of the group will provide a maximum peg effect.
- The length of the wood affects the size of the work area so that the longer the wood piles used, the greater the work area is.

In using wood piles, one of the main problems that can occur is when the ground water level decreases. When the ground water level drops, the top of the wood piles will meet with air which can cause wood to rot due to mold. According to Lambrechts (2008), the fungus will reduce the amount of wood until finally the remaining wood is not enough to be able to support the structural load [5]. K.W.M. Klaassen and G.M. Creemers (2012) estimated that the speed of fungus to attack wood with saturated water is around 10 mm/year while wood with a moisture content of 25-100% is 100 mm/year [6].

In Indonesia, wood is divided into 5 types of durable classes. Wood with a certain class of durability can last for several years corresponding to the condition of the wood. Dolken gelam wood and mangrove wood are hardwood with durable class III, so according to Peraturan Konstruksi Kayu Indonesia (1961), it can last up to 3 years if it is always in contact with moist soil [7]. However, mangrove wood can no longer be used as wood piles because mangroves are protected trees to prevent sea abrasion therefore, they cannot be cut down. Bamboo does not belong to the classification of wood so it does not have a strong durable class.

Groundwater influences the age of the wood that is planted in the ground. If all wood remains submerged in ground water, the wood can last longer. According to Przewłócki (2005), usually wood starts to rot when there is a decrease in groundwater level [8].

### 3. Data analysis method

Data analysis or data processing is done by calculating the soil bearing capacity and settlement that occurs in each soil and compared with each other to be able to see the difference. Terzaghi method is used to calculate the bearing capacity. According to Terzaghi (1943) in Das (2011), in calculating the bearing capacity of a square foundation the following formula is used [9]:

$$q_{ult} = 1,3 c'N_c + qN_q + 0,4 \gamma B N_\gamma \quad (1)$$

Annotation:

$q_{ult}$	: ultimate bearing capacity [kN/m <sup>2</sup> ]
$c'$	: effective cohesion [kN/m <sup>2</sup> ]
$\gamma$	: soil weight [kN/m <sup>3</sup> ]
$q$	: $\gamma D_f$
$D_f$	: depth of foundation [m]
$B$	: foundation width [m]
$N_c, N_q, N_\gamma$	: Terzaghi's bearing capacity

$N_c, N_q,$  and  $N_\gamma$  values are obtained by using angle of friction. When using a pile, the shear strength of soil will increase where the greater the workload ( $\Delta P$ ) occurs, causing void ratio ( $e$ ) becomes smaller and soil bearing capacity will increase. Based on research conducted by Ladd, et al (1977), soils that undergo normal consolidation will experience an increase in soil shear strength in accordance with the additional load that occurs, which can be determined by using the following formula [10]:

$$\Delta C_u = (0.20-0.30)\Delta\sigma_v' \quad (2)$$

Annotation:

$\Delta C_u$	: additional shear strength [kg/cm <sup>2</sup> ]
$\Delta\sigma_v'$	: additional effective vertical ground tension

If the volume of the pile ( $V_c$ ) is considered as soil grains and inserted into the soil, also the total soil volume ( $V$ ) and grain volume ( $V_s$ ) are considered to have one unit of mass, then the change in void ratio ( $\Delta e$ ) is:

$$\Delta e = 1/(1+V_c)-1 \quad (3)$$

Annotation:

$\Delta e$  : the change in void ratio due to addition of the piles

$V$  : initial total soil volume before using wood piles

$V_s$  : initial grain volume before the wood piles are used

$V_c$  : the volume of wood piles

After obtaining  $e_o$  and  $e_1$ ,  $P_o$  and  $P_1$  values can be found from the consolidation graph so that it will produce  $\Delta P$ . By knowing  $\Delta P$ , the shear strength increase can be found so that the soil bearing capacity can be determined using Equation (1). For  $c'$  used after using wood piles, it should not be greater than the compressive strength of the wood. If  $c'$  is greater than the compressive strength of the wood, the compressive strength will be used in the calculation.

To calculate the settlement in soil, two methods are used namely elastic settlement and consolidation settlement. For elastic settlement, Janbu, et al (1956) in Murthy (2002) propose a formula which is [11]:

$$S_e = \frac{\mu_0 \mu_1 q_n B}{E_s} \quad (4)$$

Annotation:

$\mu_1$  : depends on  $H/B$  and  $L/B$

$\mu_0$  : depends on  $D/B$  and  $L/B$

$q_n = q_o$  : load on foundation

$E_s$  : soil modulus of elasticity

$D$  : the depth of the foundation base [m]

$B$  : the smallest width of foundation base [m]

$L$  : the length of the foundation [m]

$H$  : thickness of the deformed layer [m]

To calculate consolidation settlement, use the equation of Bowles (1988), namely [12]:

If  $P_o + \Delta P (P_1) < P_c$ ,

$$\Delta H = \frac{C_r H}{1 + e_o} \log \frac{P_o + \Delta P}{P_o} \quad (5)$$

Annotation:

$C_r = \frac{\Delta e}{\Delta \log p}$ , on the consolidation chart

$e_o$  : void ratio

$H$  : the thickness of the layer undergoing consolidation [m]

$P_o$  : the overburden stress before being loaded

$\Delta P$  : the increase of the stress

#### 4. Data analysis

For this calculation, wood with a diameter of 10 cm and a length of 4 m is used with the distance between each pile is 400 mm as shown on Figure 5. Wood with that size is used because it is a size that is usually used when going to used wood piles.

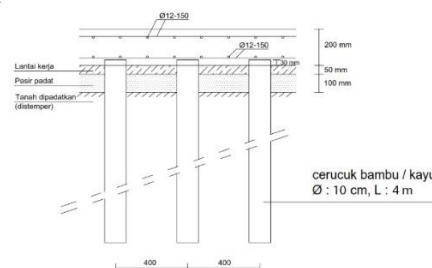


Figure 5. The size of the wood piles.

After calculating the soil bearing capacity, it is known that the void ratio of the soil decreases after the use of wood piles. The decrease in the void ratio can be seen in the Table 1.

**Table 1.** Difference in void ratio before and after using wood piles.

Void ratio	Before using wood piles	After using wood piles
Clay	1.444	0.444
Sand	1.516	0.516
Landfill	1.42	0.42

In addition, the value of soil bearing capacity and the settlement that happened both without and with wood piles can be seen in Table 2 and Table 3 respectively.

**Table 2.** Soil bearing capacity without and with wood piles.

Soil bearing capacity (T/m <sup>2</sup> )	Clay	Sand	Landfill
Without wood piles	19.33	24.09	10.85
With wood piles	85.38	83.29	69.77

**Table 3.** Settlement without and with wood piles.

Settlement (cm)	Clay	Sand	Landfill
Without wood piles	3.65	3.36	11.65
With wood piles	0.27	0.11	5.06

From the results above, it is seen that by using wood piles the soil bearing capacity increases and the settlement decreases. Percentage of differences in soil bearing capacity and settlement between without and with wood piles can be seen in Table 4 and Table 5 respectively.

**Table 4.** Percentage of increased soil bearing capacity.

Soil bearing capacity	Percentage of differences
Clay	341.62%
Sand	245.73%
Landfill	542.80%

**Table 5.** Percentage of decreased settlement.

Settlement	Percentage of differences
Clay	92.53%
Sand	96.75%
Landfill	56.56%

Based on Table 4 and Table 5 above, the difference in soil bearing capacity and settlement when not using wood piles and when using piles is quite large.

## 5. Conclusion

Based on research that has been done, it is known that the soil bearing capacity has increased and settlement more reduced considerably if using wood piles. One of the factors that causes the increase in soil bearing capacity and decrease in settlement is the value of the void ratio which decreases after using



wood piles. Besides that, settlement did not occur at the layer of soil with piles because it is held up by the piles. For the age of wood, dolken and mangrove can be used up to 3 years. The durability of the wood can last longer if the ground water level remains stable and all the wood is always submerged.

The benefit of using wood piles is to reduce the possibility of damage to the building so the building can last longer. In addition, it can open business opportunities for the community such as timber cultivation, wood sellers or distributors, and local contractors who open businesses to install wood piles.

The advantage of using wood piles is that it uses renewable resources that can be obtained by planting trees. In addition, other alternative methods of soil improvement use materials that to obtain them can damage nature such as cement which requires lime obtained from mining. The work to install wood piles is also easier because it does not require heavy equipment. Another advantage is that the prices are lower and wood piles can be used in rural areas and areas that are difficult to reach by transportation.

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