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Lecture Notes in Civil Engineering

Han Ay Lie · Monty Sutrisna ·
Joewono Prasetijo ·
Bonaventura H.W. Hadikusumo ·
Leksmono Suryo Putranto *Editors*

Proceedings of the Second International Conference of Construction, Infrastructure, and Materials

ICCIM 2021, 26 July 2021, Jakarta, Indonesia

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Volume 216

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Preface

This new volume of Lecture Notes in Civil Engineering contains the proceedings of the Second International Conference of Construction, Infrastructure, and Materials (ICCIM 2021). This book presents the latest development in civil engineering on a global scale. It highlights the conference scopes, such as Structural Engineering, Construction Materials, Geotechnical Engineering, Transportation System and Engineering, Constructions Management, Water Resources Engineering, and Infrastructure Development. The 55 articles published in this book went through peer-review processes double-blindly and plagiarism check. Manuscript assessments by the expert reviewers were based on the organizer's technical criteria, including technical criteria, quality criteria, and presentation criteria.

The Second International Conference of Construction, Infrastructure, and Materials (ICCIM 2021) was hosted by the Civil Engineering Undergraduate Study Program of Universitas Tarumanagara, Indonesia, on 26 July 2021. The conference brought together national and international experts to share their researches, knowledge, and experiences. ICCIM 2021 carried the theme "Research and Technology in Civil Engineering to Enhance the Sustainability of the Built Environment".

Due to the global COVID-19 pandemic, which has impacted all activities globally, ICCIM 2021 was held as an online conference. ICCIM 2021 online conference aimed to capture a broader range of participants. The Conference was also expected to facilitate researchers, practitioners, and students in their respective fields of expertise to share information and exchange ideas about the current state of civil engineering development.

ICCIM 2021 was supported by Massey University, New Zealand; Universiti Tun Hussein Onn Malaysia, Malaysia; Nihon University, Japan; fib Indonesia; Diponegoro University, Indonesia; Soegijapranata Catholic University, Indonesia; Universitas Sebelas Maret, Indonesia; and Universitas Atma Jaya Yogyakarta, Indonesia.

ICCIM 2021 has received papers from various countries, such as Indonesia, Japan, Thailand, the United Kingdom, the United States of America, the

Philippines, India, Nigeria, and Bangladesh. More than 600 researchers, practitioners, and students from all over the world registered to attend the Conference.

We are likewise grateful to the keynote speakers for bringing the exciting topics to ICCIM 2021: Prof. Roesdiman Soegiarso (Universitas Tarumanagara, Indonesia); Prof. Monty Sutrisna (Massey University, New Zealand); Dr.-Ing. Joewono Prasetijo (Universiti Tun Hussein Onn Malaysia, Malaysia); and Dr. Tam Chat Tim (National University of Singapore, Singapore).

We would also like to extend our appreciation to the supporting institutions. Secondly, thank you to the sponsors for the utmost support and kind contribution: PT. Waskita Karya (Persero) Tbk, PT. Pamapersada Nusantara, and PT. Bank Negara Indonesia Tbk.

Many people have worked very hard for the organization of this Conference. Special thanks are needed to the Organizing Committee, Steering Committee, Editorial Board, and Scientific Committee. All of whom have generously worked to make this Conference rich in content and pleasant for the attendees. We would also like to thank all the authors who have contributed to the success of this Conference.

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Panchor, Malaysia — Joewono Prasetijo
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Analysis of Diaphragm Wall Stability with Dewatering and Ground Freezing Treatment

Eduard Teja and Aniek Prihatiningsih

Abstract In underground construction, we really need to consider the presence of groundwater. Groundwater can interfere and even endanger the construction and excavation process. Usually, in the tunnel construction process, groundwater needs to be eliminated. So that the tunnel construction process can be carried out as safely as possible. Sometimes the construction of a tunnel in the middle of a city also needs some soil reinforcement to not disturb the surrounding buildings. One method that can be used to eliminate and strengthen excavated walls is ground freezing. Also, we know the dewatering process to eliminate the effects of groundwater by lowering the groundwater level. In this research, the effect of the dewatering and ground freezing processes will be calculated by stabilizing the diaphragm wall. Ground freezing will cause the bonding of soil particles to become stronger. Then the stability of the soil will be much better than dewatering. The result shows that ground freezing has the smallest deflection and moment. So, the stability of the ground freezing excavation has the best value. However, in terms of the price of ground freezing, it is still too high, so studies are needed to minimize the price.

Keywords Ground freezing · Dewatering · Diaphragm wall

1 Introduction

Indonesia is one of the largest countries in Southeast Asia in terms of regional area and population. It is very important for Indonesia to continue to improve its infrastructure development. One of the infrastructures that are being built rapidly is transportation. As we know in Jakarta has just had MRT (Mass Rapid Transit) and LRT (Light Rail Transit). In the construction of MRT and LRT must have high

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work safety. The most crucial thing is the excavation for the tunnels, this is crucial because the excavation of the tunnels is below groundwater level, at a depth of 17–36 m below ground level [1].

In excavation that are under groundwater, the thing that must be prevented is swelling. Swelling of the soil occurs due to the pressure of water trying to get out of the ground. This pressure will later become a disturbance in the installation of the tunnel shield/tunnel wall and can cause failure in excavation stability. If this problem is not addressed, it will be very dangerous and can even cause fatalities, so for this reason, this problem must be prevented. Various precautions can be taken to prevent swelling. The thing that is often applied is dewatering.

Dewatering (Fig. 1) is done by lowering the groundwater level to an adjustable depth. By lowering the groundwater level to minimize swelling. In addition to dewatering abroad, there is also a ground freezing method. The ground freezing method itself is done by freezing the groundwater around the excavation so that a waterproof layer is formed around the excavation. This waterproof layer is useful for protecting excavations. Before determining the dewatering method to be used, the nature of the soil must be considered. Because if we use the wrong dewatering method, it will not only hamper the project but also increase the costs incurred [2].

Ground freezing (Fig. 2) has been carried out since 1862 where this method is used to build mining tunnels [4]. Ground freezing was first time used in North Wales. With the development of the era, this method can be used for tunnel

Fig. 1 Wellpoint system [3]

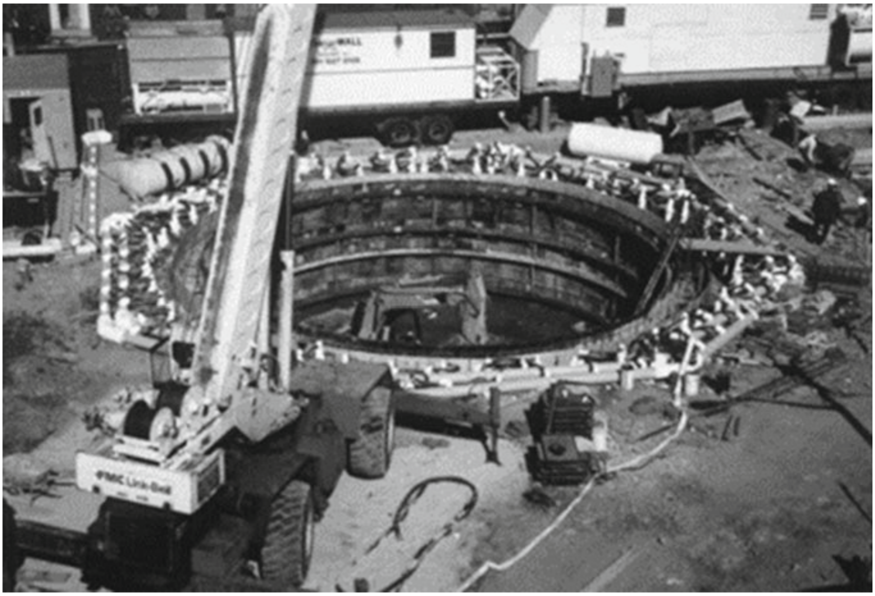


Fig. 2 Ground freezing [5]

construction. Ground freezing is done by inserting a pipe around the excavation. This pipe installation also needs to be considered because pipes with different sizes and different temperatures can affect the area of land that can be frozen. The ground freezing method has not been used in Indonesia, but in Singapore, it was used during the construction of the Thomson East-Coast Line Marina Bay Station.

1.1 Diaphragm Wall

The diaphragm wall or bulkhead wall is an artificial membrane with a certain thickness (according to the thickness of the digging tool called a grabber) and a certain depth [6]. A diaphragm wall is a retaining wall that is installed as a system for further development of the secant pile and contiguous pile system. In calculating the stability of the diaphragm wall, it will be done by calculating the active and passive earth stresses that appear in Eqs. 1–4 [7].

$$P_a = \gamma h k_a \tag{1}$$

$$k_a = tan^2\left(45 - \frac{\emptyset}{2}\right) \tag{2}$$

$$P_p = \gamma h k_p \tag{3}$$

$$k_p = tan^2\left(45 + \frac{\emptyset}{2}\right) \tag{4}$$

The formulas above are used because the soil is considered unable to hold itself (worst condition). For condition 4, a formula will be used where the ability of the soil to hold itself is considered. Because when ground freezing, the water around the soil freezes so that the soil bonds become stronger. In theory, this freezing will increase the compressive strength of the soil to be stronger. As a result, the shear strength of the soil also increases (Fig. 3).

So, to calculate the ability of the soil to hold itself underground freezing conditions, the following formula is shown in Eqs. 5 and 6.

$$P_a = \gamma h k_a - 2c\sqrt[2]{k_a} \tag{5}$$

$$P_p = \gamma h k_p + 2c\sqrt[2]{k_p} \tag{6}$$

for ka and kp, use the same formula as before.

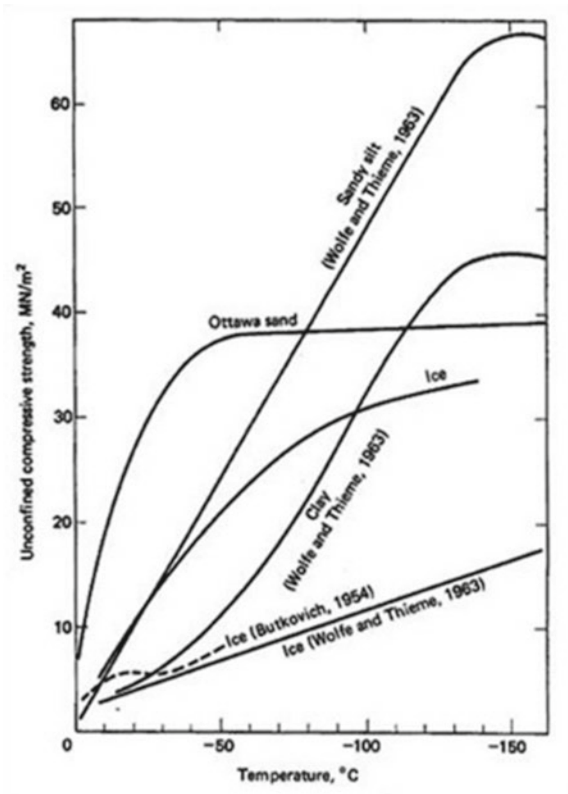


Fig. 3 Relationship between temperature and unconfined compressive strength [8]

2 Research Methods

The research will be carried out in 4 soil conditions with excavations held in place with a diaphragm wall. Excavation with a depth of 20 m and a diaphragm wall with a depth of 40 m. The size of the diaphragm wall used is 1 m with a calculation of every 1 m, so a cross-section of 1 × 1 m is used. The first condition is in-situ soil, where the unit weight of soil used is obtained from correlation and laboratory data. In condition 2, the soil is saturated, then the unit weight of soil is used to use the saturated specific gravity obtained from the correlation. Condition 3 occurs in soil with dewatering treatment where it is considered that in the lower soil (soil under excavation), there is still water flow due to dewatering. So that at a depth of 20–40 m, the unit weight of soil used is the saturation density, and for a depth of 0–20 m, the in-situ unit weight of soil is used. Then for condition 4, namely the ground freezing condition, the in-situ unit weight of soil will be used. The difference with the in-situ condition is the use of soil properties.

2.1 Soil Properties

Unit weight of soil was obtained from correlation and laboratory data. Unit weight is divided into 2, namely the state of the original soil (in-situ) and the state of wet soil. For wet soil conditions, the density with the largest number will be taken in the correlation table. In the original soil condition, the density of laboratory results and correlations will be used. Then soil density will be obtained and tabulated as Table 1.

Cohesion is obtained from laboratory results and correlations which will then be taken the average value of correlations and laboratory data. Then it will be tabulated as Table 2.

The value of undrained shear strength is obtained from the correlation and tabulated in Table 3.

Table 1 Unit weight of soil

Soil layer		Soil classification	γ_{sat} (kN/m^3)	γ (kN/m^3)
Top elev. (m)	Bottom elev. (m)			
0	7	Fine grained	22	15
7	11	Fine grained	22	16
11	20	Coarse grained	20	20
20	23	Fine grained	22	15
23	26	Coarse grained	20	19
26	35	Fine grained	22	19
35	40	Fine grained	22	19

Table 2 Cohesion

Soil layer		Soil classification	Consistency	C′ (kPa)
Top elev. (m)	Bottom elev. (m)			
0	7	Fine grained	Very soft	8
7	11	Fine grained	Stiff	24
11	20	Coarse grained	Dense	–
20	23	Fine grained	Soft	20
23	26	Coarse grained	Dense	–
26	35	Fine grained	Very stiff	30
35	40	Fine grained	Hard	60

Table 3 Shear strength

Soil layer		Soil classification	Consistency	Su (kPa)
Top elev. (m)	Bottom elev. (m)			
0	7	Fine grained	Very soft	9.6
7	11	Fine grained	Stiff	81.439
11	20	Coarse grained	Dense	90
20	23	Fine grained	Soft	28.8
23	26	Coarse grained	Dense	90
26	35	Fine grained	Very stiff	109.867
35	40	Fine grained	Hard	194.133

The value of the internal shear angle is obtained from the correlation and tabulated in Table 4.

The correlation results and lab data will then be processed to obtain the earth stress acting on the wall. Then the deflection will be searched, and the results will be compared. In the calculation of the earth lateral pressure, the following results are obtained. For Fig. 4 shows the earth's stress in in-situ conditions. Figure 5 for earth stress at saturation condition. Figure 6 is an image of the earth's stress for the dewatering condition. The ground freezing conditions are depicted in Fig. 7.

Table 4 Shear angle

Soil layer		Soil classification	Consistency	Φ′ (°)
Top elev. (m)	Bottom elev. (m)			
0	7	Fine grained	Very soft	10
7	11	Fine grained	Stiff	17
11	20	Coarse grained	Dense	35
20	23	Fine grained	Soft	14
23	26	Coarse grained	Dense	35
26	35	Fine grained	Very stiff	17
35	40	Fine grained	Hard	26

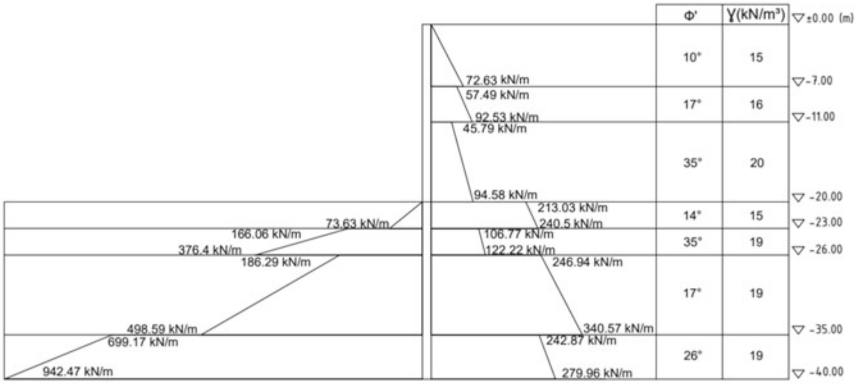


Fig. 4 Earth lateral pressure in-situ conditions

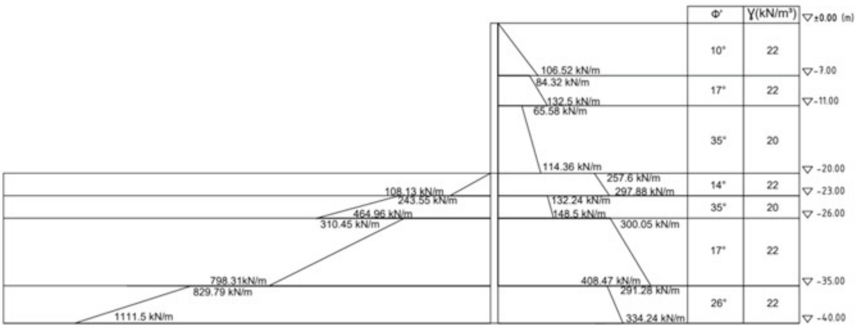


Fig. 5 Earth lateral pressure saturated conditions

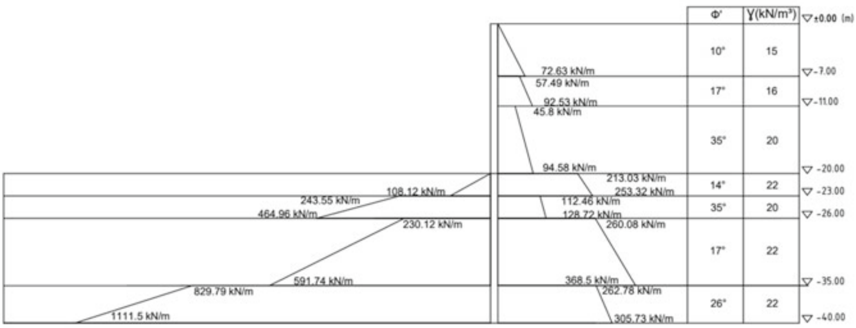


Fig. 6 Earth lateral pressure dewatering conditions

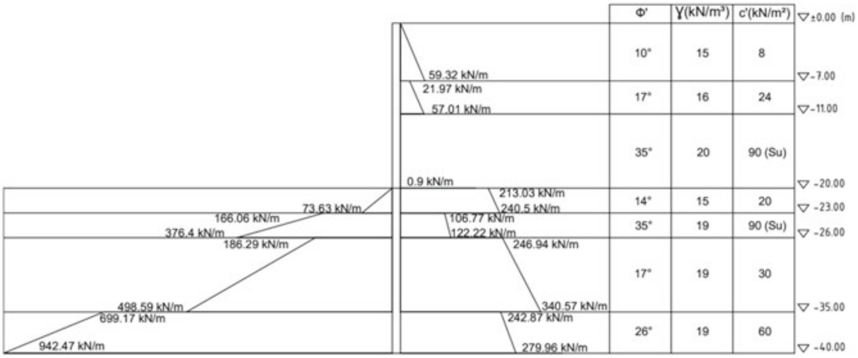


Fig. 7 Earth lateral pressure ground freezing conditions

3 Result

3.1 Deflection and Moment

The results are as shown in Figs. 8 and 9. For in-situ conditions, the maximum deflection is 8.964 m, the saturation condition is maximum deflection 12.154 m, and for dewatering conditions, the maximum deflection is 7.831 m. For ground freezing conditions, if we look at the graph, the maximum is 3.865 m.

4 Conclusions and Suggestions

4.1 Conclusions

1. The greatest deflection occurs when the soil is saturated, which is 12.154 m. Then the second largest deflection is 8.964 m in in-situ conditions. The third-largest deflection is the dewatering condition, which is 7.831 m. The smallest deflection during ground freezing is 3.865 m.
2. From the results of the deflection comparison, it can be concluded that when ground freezing produces the best soil stability.
3. The deflection that occurs in 4 conditions is still more than the permitted limit, namely L/360 or 111 mm.
4. The biggest moment that the wall must hold is during saturation conditions with a moment magnitude of 41,082 kNm/m and the smallest moment is during ground freezing conditions, which is 17,818 kNm/m.
5. Each condition requires reinforcement in the excavation.

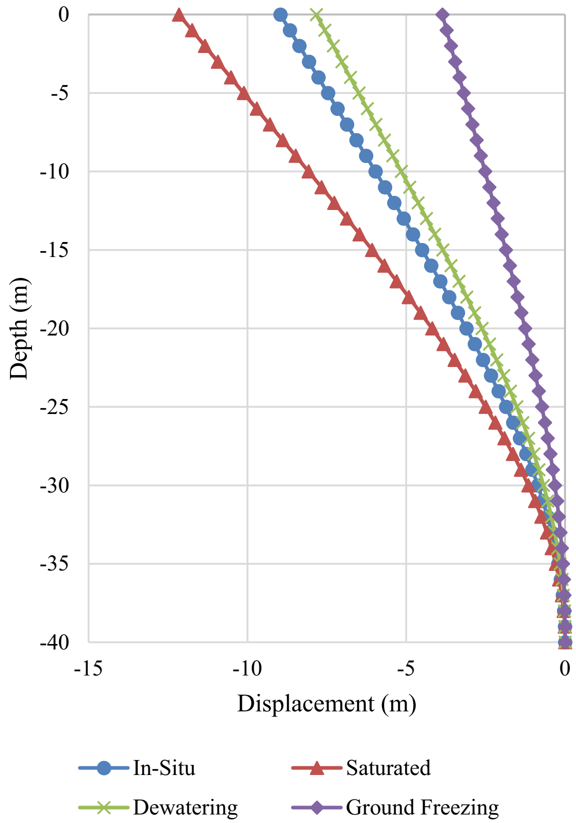
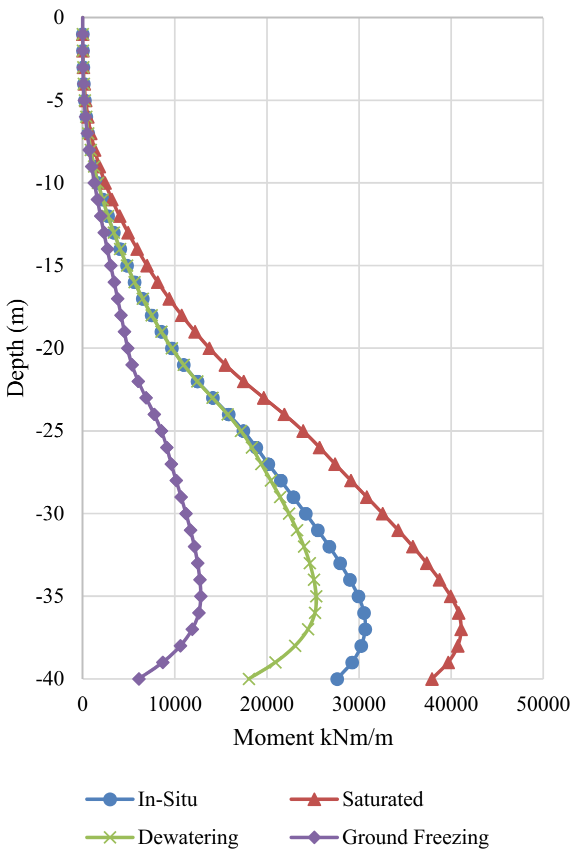


Fig. 8 Deflection results

4.2 *Suggestions*

1. Even though ground freezing is the best method, it is expensive in terms of price. Therefore, it is necessary to conduct further studies or research to reduce and develop this method in Indonesia.
2. The disadvantage of in-situ conditions is that the deflection is too large so that it cannot rely solely on the ability of the retaining wall, and therefore it is necessary to do much more reinforcement compared to dewatering or ground freezing.
3. In the use of ground freezing, because it is only up to a depth of 20 m (equivalent to excavation) and the calculation using the worst cohesion and shear strength (in-situ soil properties), results are obtained that still require reinforcement. If ground freezing is done at different depths and a cooler temperature is used. Then the possibility of ground freezing does not require reinforcement at all so that an open excavation can be done.

Fig. 9 Moment results



4. The use of ground freezing also has additional benefits, one of which is that it does not cause additional settlement due to underground water flow during dewatering which carries fine particles and erodes the soil. Ground freezing should be considered in the future.

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