p–ISSN: 2723 - 6609 e-ISSN: 2745-5254
Vol. 4, No. 10 October 2023 http://jist.publikasiindonesia.id/

STUDY OF VARIOUS TYPES OF PVD AND PH.D. JOINTS ON VERTICAL DRAINAGE PERFORMANCE

Meylani Nurul Hidayah[1*], Hary Christady Hardiyatmo[2], Agus Darmawan Adi[3]
Universitas Gadjah Mada Jogja, Indonesia
Email: hary.christady@ugm.ac.id

*Correspondence

INFO ARTIKEL

Keywords: pvd-phd connection; discharge capacity; hydraulic gradient; overburden pressure.

ABSTRACT

An important factor for increasing the effectiveness of the PVD (Prefabricated Vertical Drains) is the value of sufficient discharge capacity so that the PVD can work optimally. The use of PVD is usually accompanied by the use of PHD (Prefabricated Horizontal Drains) as horizontal drainage and combined with preloading. In the field, the connection is made by winding the PVD to the PHD and then tying it with cable ties. The connection system can cause deformation at the top of the PVD thereby reducing the effectiveness of the PVD discharge capacity. This study aims to find the optimal PVD-PHD connection system for the discharge capacity which is affected by confinement pressure, overburden pressure, and hydraulic gradient with a PVD-PHD connection system discharge capacity tester. The test specimens used were PVD (5mm thick; 100mm wide) and Ph.D. (20 mm thick; wide: 100 mm, 200mm, and 300mm). 4 types of connection systems have been tried, namely connections A1 and A2 where the PHD is connected in a horizontal position, and connections B1 and B2 where the PHD is connected in a vertical position. Of the four connection systems B1, the connection system has the largest discharge capacity value and a significant increase in PHD width from 100 mm to 300 mm with an increase of 7.694% at 50 kPa overburden pressure and 1.0 hydraulic gradient the highest compared to other connection types.

Introduction

Ground improvement is a way to improve the technical properties of soil, such as shear strength, stiffness, and permeability (Nakhe, 2021). The properties of soft soil can disrupt the stability of the infrastructure that stands on it. To prevent damage to infrastructure before development, it is necessary to consolidate the land (Azevedo de Almeida & Mostafavi, 2016) (McFarland, Larsen, Yeshitela, Engida, & Love, 2019). However, the low permeability of soft soils causes the consolidation process to take a long time, so soil improvement that may be carried out is vertical drainage combined with preloading. Vertical drainage that is often used is prefabricated vertical drainage (PVD) which is ribbon-shaped with a rectangular appearance and made of geosynthetics. The function of PVD is to facilitate the radial flow of water from the consolidated soil, transporting it in a vertical direction and discharging it into the drainage layer with the smallest possible hydraulic resistance (Chung, Kweon, & Jang, 2014). Usually pore water in the soil that flows out through PVD is received by the sand blanket as horizontal drainage, and then flowed into the sewer.

The use of PVD has been widely researched and applied worldwide in soft soil improvement projects over the past few decades (Bo, Arulrajah, Horpibulsuk, Chinkulkijniwat, & Leong, 2016) (Jang, Kim, & Lee, 2015)(Nguyen & Kim, 2019) (Lam, Bergado, & Hino, 2015). PVD is considered more effective, efficient, and economical than other types of vertical drainage. In addition to PVD, horizontal drainage is also developed, namely PHD (Prefabricated Horizontal Drains). The use of PHD is more recommended to be used as horizontal drainage in vertical drainage systems to channel to the sewer because it can save costs and be more measurable. The use of PHD in the field is usually used instead of or combined with a sand blanket (PANJAITAN, 2021).

The connection of the PVD and Ph.D. in the field is usually done by hooking the PVD to the Ph.D. or by winding the PVD to the Ph.D. and then tying using cable ties. Regarding the type of PVD-PHD bond, there is no specific standard that can be used as a reference. In Bina Marga (2016) the installation of PHD on PVD has not been explained about the connection procedure. (Chrismaningwang et al., 2022) PVD-PHD connection by tying with cable ties has a large enough reduction in discharge capacity both on clean and dirty sand media due to deformation in the connection so that the connection is not recommended for use in the field due to deformation at the top of PVD, so the connection is not recommended.

PVD deformation due to folding, wrinkling, bending, and twisting due to a large decrease in consolidation can have a considerable influence on the effectiveness of PVD (Chrismaningwang, Hardiyatmo, Adi, & Fathani, 2021). and reduce discharge capacity and significantly or totally (Cao, Zhang, Xu, & Xu, 2021) (Bo et al., 2016). also explain that under clay confinement, PVD discharge capacity can also be significantly reduced, due to channel deformation and blockage. Discharge capacity is one of the factors influencing PVD behavior (Hansbo, Jamiolkowski, & Kok, 1981) (Miura & Chai, 2000).

This study intends to refine/improve PVD and PHD splicing systems to determine the most effective connection to vertical drainage performance of discharge capacity affected by confining pressure, overburden pressure, and hydraulic gradient as well as sand blanket bridle media that present conditions in the field. Studies on PVD-PHD splicing are still very limited, for that it is necessary to conduct more in-depth studies. These studies, it is expected to contribute to and complement previous studies.

Research Methods

Discharge Capacity

Hansbo (1983) describes discharge capacity (qw) as the volume of water per unit of time that can flow along the PVD core in the axial direction under the unit hydraulic gradient (Tran-Nguyen, Edil, & Schneider, 2010). The discharge capacity regulating PVD performance thereby affects the consolidation rate (Lee, Yang, Kang, Park, & Choi, 2022) (Deng, Liu, Lu, & Xie, 2014). Flow capacity or discharge capacity (qw) is a very important parameter in determining PVD design and performance. PVD must have sufficient tensile strength and discharge capacity to be used effectively in the soil improvement process. PVD discharge capacity will decrease when the filter is depressed by lateral ground pressure. The discharge capacity is expressed by the following equation: $q_w=Q/i$ (1)

where Q is the volume of water released by PVD per unit of time (m3/sec) and i is the hydraulic gradient. The qw value will be used to formulate the relationship between qw and restraint pressure and hydraulic gradient, as well as to determine the equivalence value of PHD with a sand blanket.

Test Equipment

PVD and PHD system discharge capacity testing was carried out using a special tool developed by Chrismaningwang 2022 which was designed to refer to ASTM D4716 standards. This test tool aims to determine the effect of the PVD-PHD connection method on its discharge capacity. In this study, the test equipment can present conditions in the field, where PVD experiences restrained pressure in the form of lateral soil pressure, and PHD experiences overbuden pressure in the form of heap soil (Siswanto, Wijaya, & Widawati, 2023) (Aini, Maulana, & Santoso, 2023).

Test Specimen

PVD and PHD are geocomposite materials consisting of an outer casing generally made of non-woven geotextiles to envelop the plastic core and core consisting of plastic folds or knitted plastic threads or other materials (Gries, Raina, Quadflieg, & Stolyarov, 2016). The Directorate General of Highways (2016) also explained that the function of the core is to support the filter layer and allow the passage of water flow along the drainage and the function of the blanket is to separate the core from the surrounding soil and filter to limit the escape of soil to the core. Menon et al. (2021) conducted a study on the process of PHD-induced consolidation in clay deposits investigated with a numerical approach. PHD was found to significantly speed up the consolidation process in soft soils, and its effects were found to be most pronounced in highly plastic soils

Various PVD-PHD Splicing and Test Methods

Discharge capacity testing on various PVD and PHD connection systems is carried out to determine the effectiveness of various PVD and PHD connection systems. Testing the discharge capacity of this connection system using PVD-T5 test specimens wrapped in a latex membrane (as a separator for test specimens with bridle) with a length of 0.50 m mounted on a compression tube with water bridle media with an extension of 0.30 m without a latex membrane then connected with PHD-W100, PHD-W200, and PHD-W300 with a length of 0.30 m in the compression box, The test sketch can be seen in Figure 1

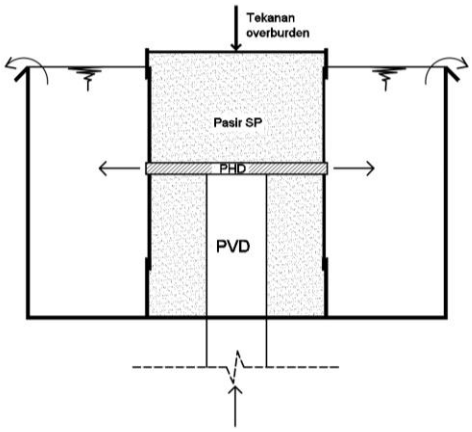

Figure 1. Test sketches

Tests are carried out with variations in specimen dimensions, hydraulic gradient, and overburden pressure. The bridle pressure (σ_c) applied to the fixed / constant compression cylinder is 100 kPa. The overburden pressure (σ_ov) is applied to the PVD-PHD connection system and the sand blanket is applied gradually from 50 kPa to 200 kPa. The hydraulic gradient used is 0.2; 0,5; and 1, Chai and Miura (1999) argue the hydraulic gradient suggested for discharge capacity testing should range between 0.1-1 used to keep the flow in PVD always in a laminar state.

Results and Discussion

1. **Discharge Capacity Test on PVD-PHD Connection**

From the test results of various types of connections, the value of discharge capacity varies even with the same PVD and PHD width. The following graph of the relationship between discharge capacity and PHD width in various connection types is presented in Figure 7 – 10.

2. **Effect of Overburden Pressure, Hydraulic Gradient, and PHD Width on Discharge Capacity in PVD-PHD Connection**

Figure 6-10 shows that all connection types have the largest discharge capacity value at i = 0.2 and PHD width W = 300 mm. The effect of Ph.D. width in general, also has something in common, namely the wider the Ph.D., the greater the discharge produced. The effect of overburden pressure and hydraulic gradient on discharge capacity in PVD-PHD joints. The effect of hydraulic gradients on all variations, in general, has something in common, namely when the value of the hydraulic gradient is small and the discharge capacity is high. For the effect of overburden pressure on discharge capacity, which is when overburden pressure increases, discharge capacity decreases. The following is similar to the statement Bergado 1996 which says discharge capacity decreases at times of high I because energy loss and flow decrease almost linearly as ground pressure increases (Bergado, Manivannan, & Balasubramaniam, 1996).

When viewed from the variation in PHD width, the B1 connection type on average shows a significant increase compared to other connection types in all overload pressures. Increased discharge capacity value at all joints from Ph.D. width 100 mm to 300 mm at overburden pressure 50 kPa and hydraulic gradient 1.0; 0,5; and 0.2 A1 (0.811%; 2.034%; 4.889%), A2 (0.600%; 2.908%; 5.404%), B1 (3.248%; 5.767%; 7.694), and B2 (1.816%; 3.393%; 6.1.01%).

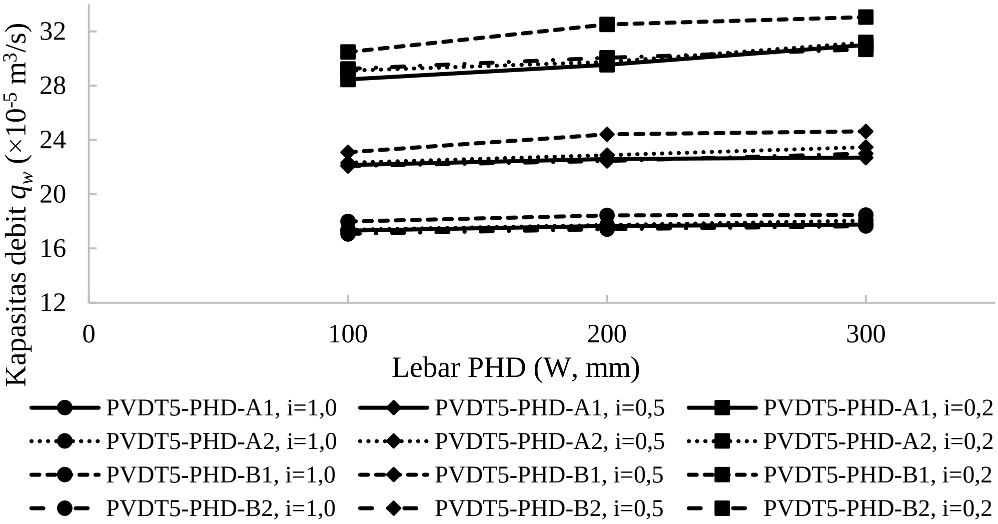

Figure 1

Variation of discharge capacity in various types of PVDT5-PHD connections to PHD width at an overburden pressure of 50 kPa

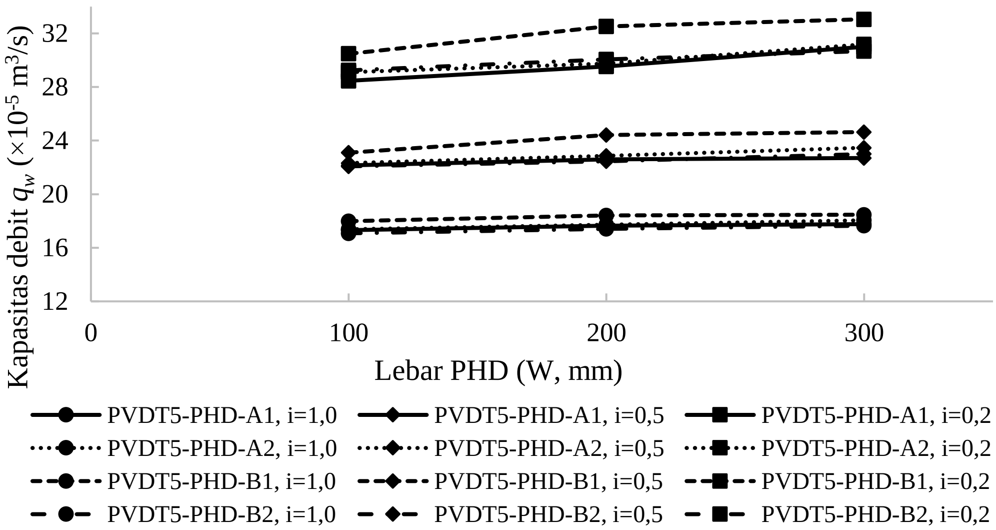

Figure 2

Variation of discharge capacity in various types of PVDT5-PHD connections to PHD width at an overburden pressure of 100 kPa

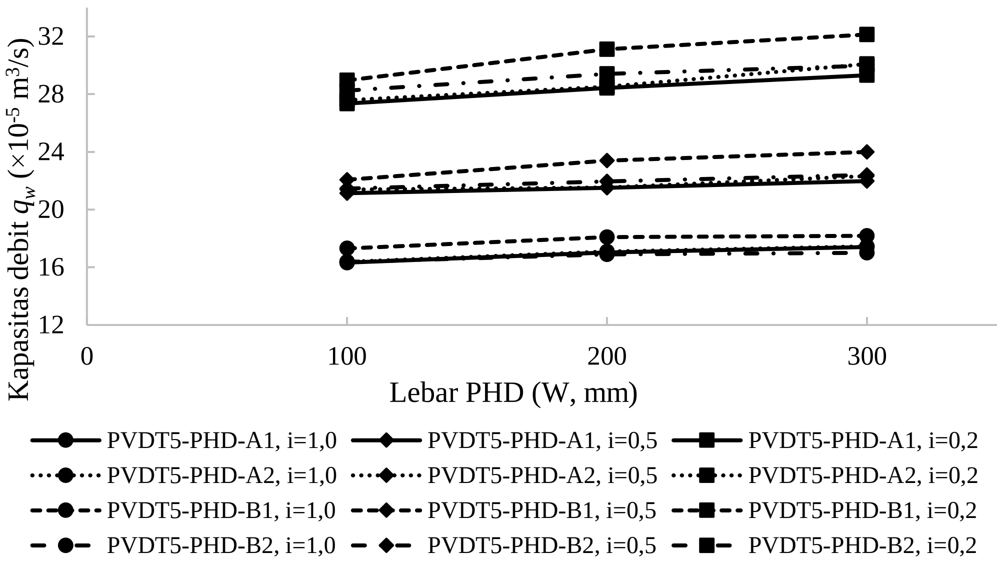

Figure 3

Variation of discharge capacity in various types of PVDT5-PHD connections to PHD width at an overburden pressure of 150 kPa

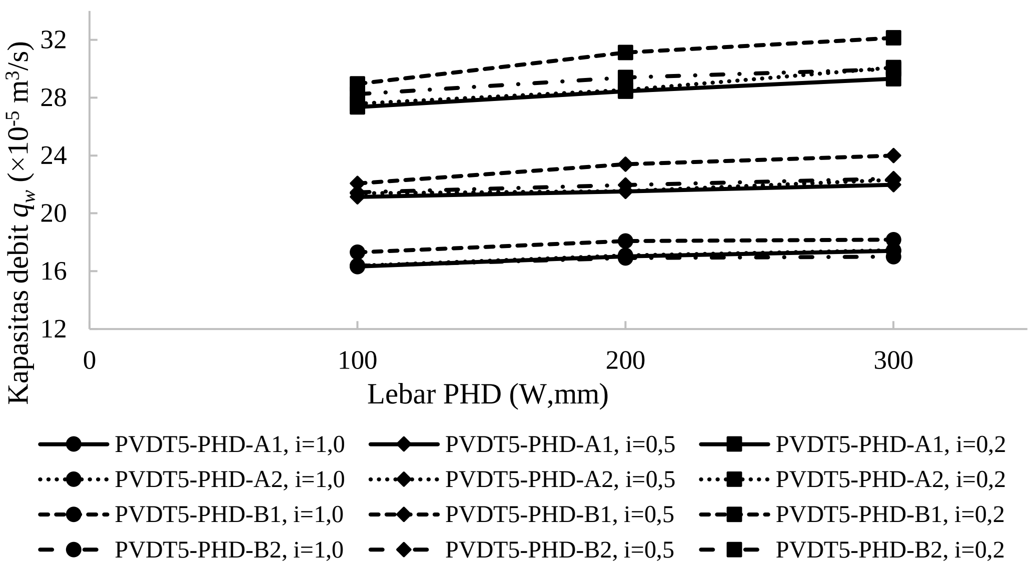

Figure 4

Variation of discharge capacity in various types of PVDT5-PHD connections to PHD width at an overburden pressure of 200 kPa

Conclusion

The effect of overburden pressure and hydraulic gradient on the discharge capacity of PVD-PHD joints is described as follows. The results of the test show that when the overburden pressure increases, the discharge capacity decreases. This is due to the reduction in the cross-sectional area of PHD so that it narrows and disrupts the flow of water. For hydraulic gradients, the results show that when the hydraulic gradient is high, the value of the discharge capacity decreases due to the loss of flow energy. The type of A1 connection and A2 connection have relatively the same discharge quality value, this proves that the connection by attaching the PVD filter with PHD both outside and inside does not have a big effect. Connection B1 and connection B2 have different discharge capacities, connection B1 has a greater value than B2. This proves that the entry of PVD cores into the PHD and flanking them is not effective in increasing the value of discharge capacity, but only by attaching between PVD cores and PHD can produce better discharge capacity.

For PVD-PHD connections horizontally (A) and vertically (B) in each PHD width variation both produce a fairly good discharge capacity, but connections with vertical variations, especially B1 produce the best connection performance. The use of horizontal connections (A) is less recommended because when the horizontal position is wide, the cross-section that affects the pile load or overburden pressure is wider so that if the load is uneven, it will easily deform. This research is still in the early stages because there are still many variations of research that need to be tried. Like testing time, testing is still done with a short-term time (short-term) so it is very necessary to do with long-term testing (long-term). Tests on PVD compression cylinders still use water bridle media that has not described the situation in the field, namely with clay bridle, so the effect of fine grain infiltration on PVD is not yet known. There is no consideration of the effect of soil disturbance (smear zone) on the discharge capacity of the connection.

Bibliography

Aini, Irvita Asri, Maulana, Eggy Ihza, & Santoso, Hinawan Teguh. (2023). Evaluasi Metode Perbaikan Tanah Lunak Dengan Preloading Kombinasi Pvd-Phd Pada Proyek Pembangunan Jalan Tol Semarang-Demak Paket Ii. *Bentang: Jurnal Teoritis Dan Terapan Bidang Rekayasa Sipil*, *11*(1), 21–36.

Azevedo De Almeida, Beatriz, & Mostafavi, Ali. (2016). Resilience Of Infrastructure Systems To Sea-Level Rise In Coastal Areas: Impacts, Adaptation Measures, And Implementation Challenges. *Sustainability*, *8*(11), 1115.

Bergado, D. T., Manivannan, R., & Balasubramaniam, A. S. (1996). Proposed Criteria For Discharge Capacity Of Prefabricated Vertical Drains. *Geotextiles And Geomembranes*, *14*(9), 481–505.

Bo, Myint Win, Arulrajah, Arul, Horpibulsuk, Suksun, Chinkulkijniwat, Avirut, & Leong, Melvyn. (2016). Laboratory Measurements Of Factors Affecting Discharge Capacity Of Prefabricated Vertical Drain Materials. *Soils And Foundations*, *56*(1), 129–137.

Cao, Yupeng, Zhang, Rui, Xu, Guizhong, & Xu, Jianwen. (2021). Axisymmetric Large Strain Consolidation By Vertical Drains Considering Well Resistance Under Vacuum Pressure. *Arabian Journal Of Geosciences*, *14*(19), 2016.

Chrismaningwang, Galuh, Hardiyatmo, Hary Christady, Adi, Agus Darmawan, & Fathani, Teuku Faisal. (2021). Effect Of Well Resistance On Time Factor Ratio Due To Pvd Deformation. *Journal Of The Civil Engineering Forum*, *7*(3), 299–308.

Chung, S. G., Kweon, H. J., & Jang, W. Y. (2014). Observational Method For Field Performance Of Prefabricated Vertical Drains. *Geotextiles And Geomembranes*, *42*(4), 405–416.

Deng, Yue Bao, Liu, Gan Bin, Lu, Meng Meng, & Xie, Kang He. (2014). Consolidation Behavior Of Soft Deposits Considering The Variation Of Prefabricated Vertical Drain Discharge Capacity. *Computers And Geotechnics*, *62*, 310–316.

Gries, T., Raina, M., Quadflieg, T., & Stolyarov, O. (2016). Manufacturing Of Textiles For Civil Engineering Applications. *Textile Fibre Composites In Civil Engineering*, 3–24.

Hansbo, S., Jamiolkowski, M., & Kok, L. (1981). Consolidation By Vertical Drains. *Geotechnique*, *31*(1), 45–66.

Jang, Yeon Soo, Kim, Bumjoo, & Lee, Jin Woong. (2015). Evaluation Of Discharge Capacity Of Geosynthetic Drains For Potential Use In Tunnels. *Geotextiles And Geomembranes*, *43*(3), 228–239.

Lam, Le Gia, Bergado, Dennes T., & Hino, Takenori. (2015). Pvd Improvement Of Soft Bangkok Clay With And Without Vacuum Preloading Using Analytical And

Numerical Analyses. *Geotextiles And Geomembranes*, *43*(6), 547–557.

Lee, Hyobum, Yang, Jeonghun, Kang, Minkyu, Park, Sangwoo, & Choi, Hangseok. (2022). Comparison Of Performance Of Single-And Double-Core Prefabricated Vertical Drains For Thick Reclaimed Ground Improvement. *Marine Georesources & Geotechnology*, *40*(4), 404–414.

Mcfarland, Andrea R., Larsen, Larissa, Yeshitela, Kumelachew, Engida, Agizew Nigussie, & Love, Nancy G. (2019). Guide For Using Green Infrastructure In Urban Environments For Stormwater Management. *Environmental Science: Water Research & Technology*, *5*(4), 643–659.

Miura, N., & Chai, J. C. (2000). Discharge Capacity Of Prefabricated Vertical Drains Confined In Clay. *Geosynthetics International*, *7*(2), 119–135.

Nakhe, Fetra Yahya. (2021). *Analisis Perbaikan Tanah Dengan Metode Prefabricated Vertical Drain (Pvd) Studi Kasus: Pembangunan Jalan Tol Tebing Tinggi-Inderapura*. Universitas Medan Area.

Nguyen, Ba Phu, & Kim, Yun Tae. (2019). Radial Consolidation Of Pvd-Installed Normally Consolidated Soil With Discharge Capacity Reduction Using Large-Strain Theory. *Geotextiles And Geomembranes*, *47*(2), 243–254.

Panjaitan, Maraden. (2021). *Model Preloading Tanah Lunak Dengan Inklusi Induksi Termal Tipe Vertikal Dan Miring= Preloading Model On Soft Soil With Inclusion Thermal Induction Vertical And Incline Types*. Universitas Hasanuddin.

Siswanto, Agus Bambang, Wijaya, Usman, & Widawati, Enny. (2023). Perbaikan Tanah Lunak Untuk Konstruksi Jalan Pada Proyek Jalan Lingkar Utara Brebes Tegal. *Journal Of Civil Engineering And Technology Sciences*, *2*(1), 31–43.

Tran-Nguyen, H. H., Edil, T. B., & Schneider, J. A. (2010). Effect Of Deformation Of Prefabricated Vertical Drains On Discharge Capacity. *Geosynthetics International*, *17*(6), 431–442.